Symposium on International Climate Negotiations

PETER CRAMTON,[a] AXEL OCKENFELS,[b] and STEVEN STOFT[c]

Once again there is hope that a strong international agreement will emerge from the annual—now the 21st annual—United Nations Conference of the Parties. Before Kyoto, we hoped that the new Protocol would eventually grow into a universal commitment similar to reducing emissions by some percent below 1990 levels, and this would translate into a uniform price on carbon. Instead, repeated negotiation failures led the world to abandon the ideas of having a common commitment and a uniform price after the Copenhagen conference.

In the hope of finding a way to repair these failures, we invited renowned experts on climate policy and the economics of cooperation, not just to present their ideas, but to discuss and debate them as they wrote their papers. The continuing discussion has been lively. All authors agree that what was lost at Copenhagen needs to be rediscovered, and that carbon price coherence is not all that is needed, but it is an essential element.

While all agree that carbon price coherence is central, that is of no value if it cannot be negotiated. And that negotiation failure has been the sticking point for two decades. A better approach to negotiation will be needed, and so we have made "how to negotiate" the focus of this symposium. This focus requires a distinction that is often overlooked. Two things matter most to the success of a negotiation: *what* outcome you aim for and *how* you go about getting there. Everyone knows this, but it is easier to focus on *what* you want than on *how* to structure the negotiations. So the "how" part is usually ignored and almost never analyzed systematically. In fact, the "how" part is so important that all papers in this symposium conclude that the Paris approach to the negotiations, pledge and review, will fail because it fails to inhibit free riding. And three papers conclude that the Kyoto approach, attempting to negotiate commitments to national emission quantities, will doom any negotiation process for the same reason.

The underlying starting point of all papers is that climate change is a tragedy of the commons and hence characterized by the free-rider dilemma. All authors agree that a uniform global price on carbon is what they *want* to solve the climate dilemma (although none insist on perfect uniformity). But by examining *how* to overcome a free-rider dilemma, they all arrive at a critical conclusion: climate change cannot be solved by a patchwork of volunteerism, as Weitzman calls the approach adopted for the Paris conference. And Gollier and Tirole conclude that the "pledge-and-review" approach "will deliver appealing promises and renewed victory statements, only to prolong the waiting game." Again, all authors agree.

As an alternative, all four papers of this symposium propose to negotiate an international commitment. Importantly, international commitments are not national policies. Indeed, the commitments under consideration allow for similar national polices that can range from

[a] University of Maryland, U.S.A.
[b] University of Cologne, Germany
[c] Berkeley, U.S.A.

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universal cap-and-trade to harmonized carbon taxes. This change from the frequent blurring of national and international perspectives has caused much confusion, so let us be clear. If you believe the EU's Emission Trading Scheme has worked well, this is not an argument to commit to international cap-and-trade because, as all symposium authors agree, cap-and-trade policies could be used under an international commitment to a carbon price. And if you favor carbon taxes, this is not an argument for an international price commitment, because a carbon tax could be used under an international commitment to emission quantities. Furthermore, international carbon pricing does not call for "harmonizing" or equalizing taxes between countries. Instead, all countries could rely only on cap-and-trade with a price floor to price carbon or tax different fossil fuels differently. Because any form of carbon pricing can be used under either international scheme, this symposium is about negotiating an international commitment and is not much concerned with national policies.

The first paper, by Gollier and Tirole, should seem most familiar. Its first half sets the stage for the symposium, and explains the need for action and the reason that the "waiting game" continues. Gollier and Tirole then present the two strategies for global price coherence: a global carbon price commitment and a global cap-and-trade mechanism. Both approaches allow "national taxes or cap-and-trade." And both select a key global variable, either the price, P, or the global cap, Q. They review the twenty-year demise of the Kyoto Protocol, the shortcomings of three national cap-and-trade systems, and the relatively high carbon taxes in Sweden and France. Then follows a most powerful critique of the Pledge-and-Review process of negotiations scheduled for the Paris climate conference of 2015. Essentially everything up to this point is agreed upon by all authors.

The second half of their paper begins a debate between the two approaches to setting a global price on carbon. For the reader's convenience, we now outline these two approaches.

Gollier and Tirole's approach specifies that the global cap, Q, should be negotiated first. And then the allocations of tradable carbon permits, $\{A_i\}$, should be negotiated for each country i. As with the Kyoto Protocol, this approach places no restrictions on national climate policies. This potentially allows countries to adopt only non-price climate policies that result in what Gollier and Tirole identify as an inefficient "command-and-control approach"—an approach that has been prevalent under the Kyoto Protocol which takes the same approach towards national policies. So the carbon price referred to by an international cap-and-trade agreement may not lead to any reasonable price on *carbon emissions* in some countries, and it seems unlikely to lead to the hoped-for global price on carbon emissions. Rather, it will price international carbon permits.

A global price commitment, as discussed by the other three papers, specifies that green-fund commitments, $\{G_i\}$, are negotiated first (possibly as a function of the carbon price), and then a global carbon price, P, is chosen. As Weitzman explains, "a price commitment can be met by either permit pricing, fossil fuel taxes, or a tax, a cap-and-trade system, a hybrid system, or whatever else results in an observable price of carbon." So while vastly more flexible regarding national policies than a harmonized carbon tax, a global carbon price cannot be satisfied by inefficient command-and-control policies. The result is that every country must set an average price on their carbon emissions equal to the global carbon price.

Gollier and Tirole consider the dimensionality of the negotiation challenge. Negotiating the global cap, Q, and then n permit allocations, $\{A_i\}$, means $n+1$ parameters must be negotiated. Negotiating n national green-fund parameters $\{G_i\}$ and one global price, P, also gives a total of $n+1$ parameters, although they acknowledge that the paper by Cramton, Ockenfels

and Stoft suggests a simplification of the green-fund negotiation to one dimension. The central point here is that all of the papers agree that dimensionality is a crucial aspect in the design of a workable climate negotiation process. However, dimensionality is not the entire story, and readers may notice that no argument is provided to counter the claims of the other three papers that negotiating the set of permit allocations, $\{A_i\}$, has proven impossible.

The remainder of the Gollier and Tirole paper compares the relative difficulties of implementing international equity transfers under the two proposals and also the relative difficulties of measuring national average carbon prices and national emissions. In both cases they suggest that the cap-and-trade approach will likely have the advantage.

Stiglitz provides an overview of the case for a global carbon price, beginning with a consideration of the ethical issues of developing countries. He then discusses the vulnerability of poor countries, the reluctance of the rich to bear much of the poor countries' burden and the difficulties of negotiating what could be more than a trillion worth of permits. After considering comprehensive approaches to allocating permits, he suggests they could not be negotiated and that we should avoid any such "grand bargain." However, he suggests transferring to poor countries, perhaps, 20% of carbon revenues collected in rich countries. The paper also argues that pricing carbon is actually quite cheap, but that fossil-fuel exporters will need to be brought into the agreement through the threat of trade sanctions.

Weitzman focuses on the theory of negotiating a climate agreement among many parties. He argues that negotiating many permit allocations is likely impossible and suggests that a single price could serve as a focal point since it is widely viewed as desirable and relatively fair, and because it provides a "countervailing force" that acts to prevent free riding. More specifically, he considers the accuracy of the outcome if the price were democratically determined, concluding the global price "can come as close to an optimal price on emissions as the median per-capita marginal benefit is close to the mean per-capita marginal benefit." Recognizing that burden- sharing transfers will also need negotiating, Weitzman suggests these will be considerably smaller and hence easier to negotiate than transfers under cap-and-trade.

Finally, Cramton, Ockenfels and Stoft take a broad view, integrating and extending the other three papers, and they argue in favor of a global carbon price. Their analysis is underpinned by considerations of the behavioral game theory of cooperation. Reciprocal agreements—"I will if you will"—have been found to be the main source of sustained cooperation in laboratory experiments, in natural settings, and in theory. Reciprocity is the glue that stabilizes the small-group solutions to problems of the commons observed by Ostrom (1990). But to obtain such an agreement among many players, a common commitment is needed. They argue for agreeing on a single global carbon price, and agree with Stiglitz and Weitzman that a common quantity commitment is more difficult if not impossible to achieve.

Cramton et al. tackle the problem of negotiating green-fund transfers in a similar manner, by finding a focal formula for green-fund transfers, thereby providing negotiators with a one-dimensional common commitment. They also explain the advantages of negotiating green-fund transfers first and the global price second, and why Q is not a common commitment but rather a common aspiration which fails to simplify the negotiation of permit allocations.

The view of all symposium authors is that much can be gained by building reciprocity into the design of international climate negotiations. We believe the key ingredient is a common commitment and not merely a common aspiration such as a global cap. Reciprocity, not altruism, can make cooperation directly beneficial and thereby change the self-interest of countries to align more closely with the common good. Only then can an effective climate treaty emerge from the negotiations.

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Negotiating Effective Institutions Against Climate Change

CHRISTIAN GOLLIER[a] and JEAN TIROLE[a]

ABSTRACT

In environmental matters, the free riding generated by the lack of collective action is aggravated by concerns about leakages and by the desire to receive compensation in future negotiations. The dominant "pledge and review" approach to mitigation will deliver appealing promises and renewed victory statements, only to prolong the waiting game. The climate change global commons problem will be solved only through coherent carbon pricing. We discuss the roadmap for the negotiation process.

Negotiators must return to the fundamentals: the need for uniform carbon pricing across countries, for verification, and for a governance process to which countries would commit. Each country would enjoy subsidiarity in its allocation of efforts within the country. We suggest an enforcement scheme based on financial and trade penalties to induce all countries to participate and comply with the agreement.

Finally, the choice among economic approaches, whether a carbon price commitment or a cap-and-trade, is subject to trade-offs, on which alternative reasonable views may co-exist. We discuss monitoring reasons for why we personally favor an international cap-and-trade agreement.

Keywords: Pledge-and-review, carbon price, cap-and-trade, climate change, global warming, COP, international public goods, UN climate negotiations, prices versus quantities

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We are faced now with the fact that tomorrow is today. Over the bleached bones and jumbled residues of numerous civilizations are written the pathetic words "Too late".

Martin Luther King, New York, 4 April 1967

1. CLIMATE CHANGE IS A GLOBAL COMMONS PROBLEM

Before discussing efficient institutions against climate change, let us restate the obvious.

1.1. We must put an end to the waiting game

If no strong collective action is undertaken soon, climate change is expected to dramatically deteriorate the well-being of future generations. Although the precise consequences of our inaction are still hard to quantify, there is no question that a business-as-usual scenario would be catastrophic. The 5th Report of the IPCC (IPCC 2014) estimates that the average temperature would increase by somewhere between 2.5°C and 7.8°C by the end of this century, after having already increased by almost 1°C over the last century. Despite the emergence over the last three decades of solid scientific information about the climate impacts of

[a] Toulouse School of Economics

increased CO_2 concentration in the atmosphere, the world's emissions of greenhouse gases (GHGs) have never been larger, rising from 30 $GtCO_2eq$/year in 1970 to 49 $GtCO_2eq$/year in 2010.

According to the IPCC, about half of the anthropogenic CO_2 emissions between 1750 and 2010 occurred during the last 4 decades, due mainly to economic and population growth and to the dearth of actions to fight climate change. Limiting the increase in temperature to 2°C is thus an immense challenge, with a still increasing world population and, hopefully, more countries accessing western standards of living. It will require radical transformations in the way we use energy, we heat and locate our houses, we transport people, and we produce goods and services.

1.2. Two "good" reasons for inaction

Most benefits of mitigation are *global* and *distant*, while costs are local and immediate. The geographic and temporal dimensions of the climate problem account for the current inaction.

Climate change is a global commons problem. In the long run, most countries will benefit from a massive reduction in global emissions of GHGs, but individual incentives to do so are negligible. Most of the benefits of a country's efforts to reduce emissions go to the other countries. In a nutshell, a country bears 100% of the cost of a green policy and receives, say, 1% of the benefits of the policy, if the country has 1% of the population and has an average exposure to climate-related damages. Besides, most of these benefits, however small, do not accrue to current voters, but to future generations. Consequently, countries do not internalize the benefits of their mitigation strategies, emissions are high, and climate changes dramatically. The free-rider problem is well-known to generate the "tragedy of commons" (Hardin 1968), as illustrated by a myriad of case studies in other realms. When herders share a common parcel of land on which their herds graze, overgrazing is a standard outcome, because each herder wants to reap the private benefit of an additional cow without taking account of the fact that what he gains is matched by someone else's loss. Similarly, hunters and fishermen do not internalize the social cost of their catches; overhunting and overfishing led to the extinction of species, from the Dodo of the island of Mauritius to the bears of the Pyrenees and the buffalos of the Great Plains. Diamond (2005) shows how deforestation on Easter Island led to the collapse of an entire civilization. Other illustrations of the tragedy of commons can be found in water and air pollutions, traffic congestion, or international security for example.

Ostrom (1990) showed how small and stable communities are in some circumstances able to manage their local common resource to escape this tragedy, thanks to built-in incentives for responsible use and punishments for overuse. These informal procedures to control the free-rider problem are obviously not applicable to climate change, whose stakeholders include the 7 bn inhabitants currently living on this planet and their unborn descendants. Addressing the global externality problem is complex, as there is no supranational authority that could implement the standard internalization approach suggested by economic theory and often employed at the domestic level.[1]

1. See for example Bosetti et al (2013). According to Nordhaus (2015), the equilibrium average carbon price that would prevail in a simple global non-cooperative game is equal to a fraction h of the first-best price, where h is the Herfindahl index of country sizes (the Herfindahl index h is the sum of the squares of each country's share in global output. For example, if there are ten identical countries, h equals 10%). He concludes that the equilibrium average carbon price in the absence of a coordination mechanism to solve the free-rider problem will be in the order of one-tenth of the efficient level.

A country or region which would contemplate a unilateral mitigation strategy would be further discouraged by the presence of the so-called "carbon leakages". Namely, imposing additional costs to high-emission domestic industries makes them non-competitive. This tends to move production to less responsible countries, yielding an international redistribution of production and wealth with negligible ecological benefit. Similarly, the reduction in demand for fossil energy originating from the virtuous countries tends to reduce their international price, thereby increasing the demand and emissions in non-virtuous countries. This other carbon leakage also reduces the net climate benefit of the effort made by any incomplete club of virtuous countries. Its intertemporal version is called the green paradox. It states that a commitment to be green in the future leads oil producers to increase their production today to cater to today's non-virtuous consumers. Since carbon sequestration is not a mature technology, mitigation is a threat to the oil rent, and its owners should be expected to react to this threat.

1.3. We must accept the fact that climate mitigation is costly in the short run

The good news is that an efficient international climate agreement will generate an important social surplus to be shared among the world's citizens. The political economy of climate change however is unfavorable. The costs of any such agreement are immediate whereas most benefits will occur in the distant future, mainly to people who are not born yet and a fortiori do not vote. In short, climate mitigation is a long-term investment. Many activists and politicians promote climate mitigation policies as an opportunity to boost "economic growth". The fact that only a few countries (Sweden is the best example) come close to doing their share should speak volumes here: why would countries sacrifice the consumption of goods and leisure to be environment-unfriendly? The reality is bleaker, especially for economies in crisis and in the developing world. In reality, fighting climate change will imply reducing consumption in the short run to finance green investments that will generate a better environment only in the distant future. It diverts economic growth from consumption to investment, not good news for the wellbeing of the current poor. Carbon pricing, if implemented, will induce households to invest in photovoltaic panels on their roof or to purchase expensive electric cars, actions that yield no obvious increase in their own wellbeing, to the detriment of spending the corresponding income on other goods.

To be certain, countries may perceive some limited "co-benefits" of climate-friendly policies. For example, green choices may also reduce emissions of other pollutants (coal plants produce both CO_2 and SO_2, a regional pollutant); in a similar spirit, countries may encourage their residents to eat less red meat not so much from a concern about global warming, but because they want to reduce the occurrence of cardiovascular diseases. Substituting dirty lignite by gas and oil as the main source of energy had enormous sanitary and environmental benefits in Western countries after WWII, for example by eliminating smog from London. Therefore some actions are to be expected from countries with an eye on national interest only (not to mention the political benefits of placating domestic and international opinion). But these "zero ambition" actions (to use a phrase coined by Robert Stavins) will be far insufficient to generate what it takes to keep global warming manageable.

Overall, fighting climate change yields short-term collective costs, thereby creating a political problem for benevolent decision-makers who support an ambitious international agreement. To sum up, without a collective incentive mechanism, one's investment in a responsible mode of living will hardly benefit one's wellbeing. Rather, and assuming away leakages, it will

benefit distant generations who mostly will live in other countries. It is collectively efficient to act, but individually optimal to do little.

2. A UNIFORM CARBON PRICE IS NECESSARY

2.1. Economic approach vs. command-and-control

As we have discussed, the core of the climate externality problem is that economic agents do not internalize the damages that they impose on other economic agents when they emit GHGs. The approach[2] that economists have long proposed to solve the free-rider problem consists in inducing economic agents to internalize the negative externalities that they impose when they emit CO_2 ("*polluter pays principle*"). This is done by pricing it at a level corresponding to the present value of the marginal damage associated to the emission, and by forcing all emitters to pay this price. Because GHGs generate the same marginal damage regardless of the identity of the emitter and of the nature and location of the activity that generated the emissions, all tons of CO_2 should be priced equally. By imposing the same price to all economic agents around the world, one would ensure that all actions to abate emissions that cost less than that price will be implemented. This least-cost approach guarantees that the reduction of emissions that is necessary to attain the global concentration objective will be made at the minimum global cost. In contrast with this economic approach, "command-and-control" approaches (source-specific emissions limits, standards and technological requirements,[3] uniform reductions, subsidies/taxes that are not based on actual pollution, vintage-differentiated regulations, industrial policy. . . .) usually create wide discrepancies in the implicit price of carbon put on different emissions. This has been shown empirically to lead to substantial increases in the cost of environmental policies.

Western countries have made some attempts at reducing GHG emissions, notably through direct subsidization of green technologies: generous feed-in electricity tariffs for solar and wind energy, bonus-malus systems favoring low-emission cars, subsidies to the biofuel industry, etc. For each green policy one can estimate its implicit carbon price, i.e., the social cost of the policy per ton of CO_2 saved. A recent OECD study (OECD 2013) showed that these implicit prices vary widely across countries, and also across sectors within each country. In the electricity sector, OECD estimates range from less than 0 to 800 €. In the road transportation sector, the implicit carbon price can be as large as 1,000 €, in particular for biofuels. Given the amount of these subsidies around the world, it is hard to believe that they could be justified by the value of learning in the green technologies sector. The high heterogeneity of implicit carbon prices in actual policymaking is a clear demonstration of the inefficiency of this command-and-control approach. Similarly, any global agreement that would not include all world

2. A liability system would not solve the problem. Because of the diffuse and intertemporal nature of the pollution, it is impossible to link current individual emissions to future individual damages. Therefore, a liability system cannot fix the problem. Besides, even if such a link could be established, one would need an international agreement to prevent free-riding.

3. Let us emphasize that we are not necessarily opposed to standards. For example, one could use an economic instrument to encourage insulation by embodying the carbon price into the price of heating fuel and gas housing. However, insulation standards may overcome an informational problem (consumers may be very poorly informed about the energy efficiency of their dwelling) and, for owners, do not require a complex computation of intertemporal savings on a carbon price. Our point is that standards are often enacted without a clear analysis of whether the goals could have been achieved more efficiently and a computation of the implicit carbon price involved in their design.

regions in the climate coalition would exhibit the same inefficiency by setting a zero carbon price in non-participating countries.

While economists for good reasons are broadly suspicious of command-and-control policies, they also understand that these policies may occasionally be a second-best solution when measurement or informational problems make direct pricing complex and/or when consumers discount the future too much. This is the classic justification for housing insulation standards for instance. But command-and-control is best avoided when feasible.

2.2. Carbon pricing and inequality

Income and wealth inequality at the domestic and international levels is often invoked to dismiss uniform carbon pricing. The problems raised by inequality around the world are ubiquitous in analyses of climate change, as discussed by Posner and Weisbach (2010). On the one hand, if poor people emit proportionally more CO_2, carbon pricing will worsen inequality starting today (Cremer et al 2003). On the other hand, poor people may also be more vulnerable to climate change, so that reducing emissions will reduce inequalities in the future. However, because international and national credit markets are imperfect, poor people may face large discount rates, making them short-termist and focused on their immediate survival to the detriment of the long-term climate risk. This means that the social cost of carbon will be smaller in these countries, even when accounting for future damages abroad.

International inequality raises the question of the allocation of the climate-mitigation burden. For example, the principle of common but differentiated responsibility is redistributive because wealthier countries are typically also those which contributed more to the accumulation of GHGs in the atmosphere. This is certainly an important issue, but its solution should not be found in a Kyoto-Protocol-like manipulation of the law of a single carbon price. The non-Annex 1 parties of the Kyoto Treaty had no binding obligation and their citizens faced no carbon price. This derailed the ratification of the protocol by the U.S. Senate. The Clean Development Mechanism designed in Kyoto was aimed at alleviating the imperfect coverage problem; it met with limited success and anyway was not a satisfactory approach due to yet another leakage problem. For example, Annex 1 countries' paying to protect a forest in a less developed country increases the price of whatever the deforestation would have allowed to sell (beef, soy, palm or wood) and encourages deforestation elsewhere. The CDM mechanism also created the perverse incentive to build, or maintain in operation longer than planned, polluting plants in order to later claim CO_2 credits for their reduction.[4]

The Kyoto Protocol's attempted solution to the equity problem was to exempt non-Annex 1 countries from carbon pricing. But using price distortions to reduce inequalities is always a second-best solution. Policies around the world that manipulate agricultural prices to support farmers' incomes end up generating surpluses and highly inefficient productions. The same hazard affects climate policies if one lets redistributive considerations influence carbon price signals to economic agents. At the national level, one should instead use the income tax system to redistribute income in a transparent way when this is possible. At the international level, one should organize lump-sum transfers to poor countries. This can be done by using the

4. The best example is the hydrofluorocarbon-23 (HFC-23), which has a warming effect 11,000 times greater than CO_2, so that destroying 1 ton of HFC-23 earns 11,000 more CDM certificates than destroying 1 ton of CO_2. From 2005 to June 2012, 46% of all certificates from the CDM were issued for the destruction of HFC-23. Projects for destroying HFC-23 were so profitable that it is believed that coolant manufacturers may have built new factories to produce the coolant gas. As a consequence, the EU banned the use of HFC-23 certificates in the EU ETS from May 1, 2013.

revenues generated by carbon pricing. Given that we emit today approximately 50 $GtCO_2$ yearly, a carbon price at 30 $/t$CO_2$ would generate a rent of $ 1,500 bn per year, or approximately 2% of the world GDP.

2.3. Computing the right price signal

Most infrastructure and R&D investments to reduce GHG emissions have in common that they are irreversible (sunk) costs and yield a delayed reduction of emissions over an extended time span. Energy retrofit programs for residential building reduce emissions for decades, hydroelectric power plans last for centuries. As a consequence, what triggers an investment in these sectors is not the current price of CO_2, but the expectation of high prices in the future. The right price signal is thus given by an entire path of carbon prices. Two factors call for a carbon price that is increasing with time. First, if the damage function is convex, our inability to stabilize the concentration of CO_2 within the next 100 years would imply that the marginal climate damages of each ton of CO_2 will rise in the future. Second, if we impose a cap on GHG concentration in the atmosphere that we should never exceed, the determination of the optimal emission path under this maximum quantity constraint is equivalent to the problem of the optimal extraction path of a non-renewable resource. From Hotelling's rule, the carbon price should then increase at the risk free rate (Chakravorty et al 2006). Any climate policy must also address the various commitment and credibility problems associated with the fixation of the long-term carbon price schedule. This challenge is reinforced by the current uncertainties affecting the marginal damage function, the optimal GHG concentration target, and the speed at which green R&D will produce mature low-carbon energy technologies. This question is addressed in sections 5.3 and 5.4.

Over the last two decades, governments have commissioned estimates of the social cost of carbon (SCC). In France, the Commission Quinet (Quinet 2009) used a real discount rate of 4%, and recommended a price of carbon (/tCO_2) at 32 € in 2010, rising to 100 € in 2030 and between 150 € and 350 € in 2050. In the United States, the US Interagency Working Group (2013) proposed three different discount rates (2.5%, 3% and 5%) to estimate the SCC. Using a 3% real discount rate, their estimation of the SCC is $32 in 2010, rising to $52 and $71 respectively in 2030 and 2050.

2.4. Two economic instruments for price coherence

Two prominent strategies for organizing an efficient, uniform pricing of CO_2 emissions involve a carbon price and a cap-and-trade mechanism, respectively.[5] Both proposals allow subsidiarity, and neither directly concerns national taxes or national cap-and-trade. Both rely on an international agreement that is reasonably encompassing and therefore on an "I will if you will" approach. They both require some strategy for enforcement; in particular, the implementation of credible and transparent mechanisms to measure emissions is a prerequisite to any efficient approach to climate change mitigation, or for that matter to any policy.

5. There are many other variants using an economic instrument. For example, countries could agree on a universal carbon tax (as opposed to a carbon price), leaving no scope for subsidiarity. To do so, a possible strategy would be to set up an international carbon tax collection entity. This however is not discussed in existing proposals, probably because it could be perceived as too large an infringement on sovereignty, or because there are returns to scope in tax collection. Thus, the implementation of the carbon tax would likely be left to individual countries, and the proceeds from the carbon tax would go to the country itself. We will here focus on the two commonly advocated strategies.

a) Carbon price

Under the first strategy, a minimum average price by country on all emissions around the world would be agreed upon and collected by individual countries. All countries would all be using the same price for GHG emissions.[6] The carbon price of a country would be computed as the carbon revenue divided by the country's emissions; the price could correspond to a carbon tax[7] in the special case of a taxation approach; but quite generally it could emerge from a variety of policies (tax, cap and trade, standards etc). Indeed, not all emissions in practice are subject to a carbon tax or ETS price: As Cooper (2015) notes, less than half of the European emissions are subject to EU ETS trading.

An international negotiation on a global carbon price has the advantage of linking each region's mitigation effort to the efforts of the other regions. As explained in Cramton, Ockenfels and Stoft (2015) and Weitzman (2015) for example, each country will internalize in its vote for the level of a uniform price the positive impact of a larger equilibrium price on the global reduction of emissions, thereby raising the potential ambition of the international agreement. Under this scheme, a supra-national supervision of the national carbon-pricing requirement at the internationally agreed level is thus necessary, as we will discuss in Section 5. The compensation issue would be dealt with through a Green Fund.

b) Cap and trade

Under the alternative, cap-and-trade strategy, the agreement would specify a worldwide, predetermined number (the cap) of tradable emission permits. The tradability of these permits would ensure that countries face the same carbon price, emerging from mutually advantageous trades on the market for permits; the cross-country price here would not result from an agreed upon price of carbon, but rather from clearing in this market. To address compensation, permits would be initially allocated to the different countries or regions, with an eye on getting all countries on board (redistribution).

2.5. Failed or unsatisfactory attempts at pushing the economic approach

The cap-and-trade system was adopted, albeit with a failed design, by the Kyoto Protocol. The Kyoto Protocol of 1997 extended the 1992 UNFCCC that committed participating countries to reduce their emissions of GHG. The Treaty entered into effect on February 16, 2005. The Annex-B parties committed to reduce their emissions in 2012 by 5% compared to 1990, and to use a cap-and-trade system. Kyoto participants initially covered more than 65% of global emissions in 1992. But the non-ratification by the US and the withdrawal of Canada, Russia and Japan, combined with the boost of emerging countries emissions reduced the coverage to less than 15% in 2012. The main real attempt to implement a carbon pricing

6. This is naturally the same *absolute* level of a carbon price; adding a common carbon price onto the one already in place in each country would not only be inefficient (carbon prices would differ across the world) but also very unfair to a country like Sweden which has been virtuous prior to the agreement and whose extra contribution relative to other countries would thereby be made perennial.

7. Since Weitzman (1974)'s seminal paper, a sizeable literature has compared the relative merits of the tax and cap approaches, focusing on the economic aspects and often leaving enforcement and political economy aspects aside (the two systems have different implications along these dimensions, as we will discuss in sections 5.2 and 5.3). When the various parameters of the climate change equation (climate science, abatement technologies, demand) are known, a carbon tax and a cap-and-trade system are equivalent because, for a given price target, it is always possible to determine the supply of permits that will support this equilibrium price, and conversely. Not so under uncertainty.

mechanism within the Kyoto agreement emerged in Europe, with the EU Emission Trading Scheme (ETS). In its first trading period of 2005–2007 ("phase 1"), the system was established with a number of allowances (the so-called Assigned Amount Units, AAUs) based on the estimated needs; its design was flawed in many respects, and in any case far inferior to that which had been adopted in the US in 1990 to reduce SO_2 emissions by half. In the second trading period of 2008–2012, the number of allowances was reduced by 12% in order to reduce the emissions of the industrial and electricity sectors of the Union. This crackdown was offset by the possibility given to the capped entities to use Kyoto offsets (mostly from the Clean Development Mechanism described in 2.2) for their compliance. In addition, the deep economic crisis that hit the region during the period reduced the demand for permits. Moreover, large subsidies in the renewable energy sector implemented independently in most countries of the Union reduced further the demand for permits. In the absence of any countervailing reaction on the supply of permits, the carbon price went down from a peak of 30 €/tCO_2 to around 5–7€/tCO_2 today. This recent price level is without any doubt way below the social cost of carbon. It therefore has a limited impact on emissions. It even let electricity producers substitute gas by coal, which emits 100% more carbon (not counting dirty micro particles) per kWh. An additional problem came from the fact that the ETS scheme covered only a fraction of the emissions of the region. Many specific emitters, e.g. the transport and building sectors, faced a zero carbon price. During the third trading period (2013–2020), the EU-wide cap on emissions is reduced by 1.74% each year, and a progressive shift towards auctioning of allowances in substitution of cost-free allocation is implemented.

Over the last three decades, Europeans have sometimes believed that their (limited) commitment to reduce their emissions would motivate other countries to imitate their proactive behavior. That hope never materialized. Canada for example, facing the prospect of the oil sands dividend, quickly realized that their failure to fulfill their commitment would expose them to the need to buy permits,[8] and preferred to withdraw before having to pay them. The US Senate imposed a no-free-rider condition as a prerequisite for ratification, although the motivation for this otherwise reasonable stance may well have been a desire for inaction in view of a somewhat skeptical public opinion. Sadly enough, the Kyoto Protocol was a failure. Its architecture made it doomed to fail. Non-participating countries benefited from the efforts made by the participating ones, both in terms of reduced climate damages (free-rider problem), and in terms of improved competitiveness of their carbon-intensive industries (carbon leakage). The instability of the Kyoto coalition is one plausible explanation for why the EU did not attempt to push the price of permits up on the ETS market after the failure of the Copenhagen Conference in December 2009.

Other cap-and-trade mechanisms have been implemented since Kyoto. A mixture of collateral damages (we mentioned the emissions by coal plants of SO_2, a local pollutant, jointly with that of CO_2), the direct self-impact of CO_2 emissions for large countries like China (which has 20% of the world population and is exposed to serious climate change risk), and the desire to placate domestic opinion and avoid international pressure all lead to *some* carbon control. Outside the Kyoto Protocol, the US, Canada and China established some regional cap-and-trade mechanisms. In the US, where per capita GHG emissions are 2.5 times larger than in Europe and in China, two initiatives are worth mentioning. In the Regional Greenhouse Gas Initiative (RGGI), 9 Northeast and Mid-Atlantic US states created a common cap-

8. Under some estimation, it would have cost Canada $14 billion to buy enough carbon credits to make its target.

and-trade market to limit the emissions of their electricity sector. Here also, the current carbon price is way too low at around \$5 /tCO_2 (up from the price floor level of \$2 /tCO_2 during the period 2010–2012). Over the period 2015–2020, the CO_2 cap will be reduced by 2.5% every year. The system will release extra carbon allowances if the carbon price on the market exceeds \$6 /tCO_2. A similar system exists in California to cover the electricity sector, large industrial plants and more recently fuel distributors, thereby covering more than 85% of the State's emissions of GHGs.[9] In 2014, China has established 7 regional cap-and-trade pilots, officially to prepare for the implementation of a national ETS scheme. The fragmented cap-and-trade systems described above cover almost 10% of worldwide emissions, and observed price levels are low. This is another illustration of the tragedy of commons. These regional or national ETS could be used in the future under any international commitment regime, either a universal carbon price or a cap-and-trade mechanism.

Some countries have implemented a carbon tax. The most aggressive country is Sweden, in which a carbon tax of approximately 100 €/tCO_2 has been implemented in 1991, although with a number of exemptions. France has fixed its own carbon tax at 14.5 €/tCO_2, with exemptions for some categories of users. Both of these taxes are used for various purposes, such as raising revenue (the demand being relatively inelastic) or addressing congestion externalities and road safety. They also now can be used to comply with an international commitment to cap-and-trade or to a carbon price. Outside Europe, some modest carbon taxes exist in Japan and Mexico for example. Except for the Swedish case, these attempts put a carbon price that is far too low compared to the SCC.

3. PLEDGE AND REVIEW: THE WAITING GAME IN THE CURRENT INTERNATIONAL NEGOTIATION

The Copenhagen conference in December 2009 was expected to deliver a new Kyoto Protocol with more participating countries. In reality, the conference delivered a completely different project. The central idea of a unique carbon price induced by international cap-and-trade was completely abandoned, and the secretariat of the UNFCCC became a chamber of registration of non-committal pledges by individual countries. This change of vision was upheld at the Cancun Conference in 2010 and more recently at the COP 20 in Lima in 2014. The new "pledge-and-review" mechanism is likely to be confirmed at the Paris COP 21 conference in December 2015. Voluntary climate actions (or *"intended nationally determined contributions"*) will be registered without any coordination in the method and in the metric of measurement of the ambition of these actions. Although they are crucial to the credibility of the system, the reporting on, and verification of the pledges are not being discussed either.

The pledge-and-review strategy has four main deficiencies, and definitely is an inadequate response to climate change. First, if implemented, the agreement that will come out of this bottom-up process is expected to yield an inefficient allocation of efforts by inducing some economic agents to implement high-cost mitigation actions while others will emit GHGs that would be much cheaper to eliminate. Because the marginal costs of emission reduction are likely to be highly heterogeneous within and across countries, it will be almost impossible to

9. Since early 2014, this market is linked to a similar one established by the Province of Québec. The current price of permits in California is \$12/tCO_2, at the minimum legal price. This fragmented scheme illustrates the strange economics of climate change in the US, where the minimum carbon price in California is larger than the maximum carbon price in RGGI.

measure the ambition of each country's pledge. In fact, individual countries will have a strong incentive to "green wash" their actions by making them complex to measure and to price.

Second, the pledge-and-review promises, even if they were credible, are voluntary; so free-riding is bound to prevail. These pledges are expected to deliver much less effort than what would be collectively desirable. Following Buhr et al (2014), "*pledge-and-review means that climate change is dealt with the lowest possible level of decision making*". As Stiglitz (2015) notes, "in no other area has voluntary action succeeded as a solution to the problem of undersupply of a public good". In a sense, the pledge-and-review process is similar to an income tax system in which each household would be allowed to freely determine its fiscal contribution.

Third, even if the pledges were large enough to put the global emission trajectory back on track, the absence of commitment to the pledges would limit their long-term credibility. This fragility makes it very tempting for countries to deviate from their pledges. The absence of credibility of long-term pledges will reduce the innovators' incentive to perform green R&D, and to implement mature technologies yielding reductions of emissions for a long period of time.

Fourth, the pledge-and-review regime can be analyzed as a waiting game, in which the global negotiation on formal commitments is postponed. Beccherle and Tirole (2011) show that the free riding in this waiting game is magnified by the incentive to achieve a better deal at the bargaining table in the future. Building on both theory and past experiences, countries will realize that staying carbon-intensive will put them in a strong position to demand compensation to join an agreement later: the carbon-intensity of their economy making them less eager to join an agreement, the international community will award them higher transfers (either monetary or in terms of free pollution allowances) so as to bring them on board. Moreover, when the damage function is convex, a country committing to a high emission level before this negotiation raises the marginal damages of all other countries and therefore induces them to reduce their emissions more heavily. All in all, these strategic considerations increase the cost of delay beyond what would be obtained in the traditional free-riding model with no expectation about a future negotiation.

Indeed there has been concern that the current pledges are at a "zero ambition" level, or perhaps even below that level, where "zero ambition" refers to the level that the country would choose simply because of co-damages (local pollutants) and of the direct impact of GHG on the country itself, that is in the absence of any international agreement.[10]

To conclude this section on a more positive note, the pledge-and-review process might be useful in the second half of this year, provided that a) ambitions turned out to be strong enough (a big "if" at this stage) and b) one were to call the countries' bluff and transform or modify their pledges into real commitments. Suppose indeed that the various pledges are in line with a reasonable trajectory for GHG emissions (asserting this requires being able to aggregate/compare the various pledges, as some concern mitigation and others adaptation, and current pledges have rather different time horizons . . .). One could then transform the predicted global trajectory of emissions into an equivalent number of permits; in a second stage, one could allocate permits under the requirement that countries receive the same welfare as they would if their pledge were implemented. A key point is that countries that are sincere about their pledge could only gain from having all countries commited.

10. See the discussion of China's pledge at http://climateparis.org/china-emissions-pledge.

4. NEGOTIATING A PRICE/QUANTITY AND NEGOTIATING TRANSFERS

Let us now turn to the more satisfactory approach of picking an economic instrument together with a measurement and enforcement strategies.

4.1 The one-dimensional negotiation: uniform carbon price or a global emission target

We can imagine two negotiation processes "I will if you will" with only one decision variable. Negotiators could try to agree either on a universal carbon price, or on a global emission target. For the sake of the argument, suppose first that all countries were similar in terms of their exposure to climate change, their degree of development, their endowment in natural resources, their tastes, etc. The free-rider problem inherent to the international negotiation on climate change could then be resolved by negotiating a uniform carbon price.[11] Under this negotiation framework, a "world climate assembly" would vote for a uniform carbon price whose implementation would be left to its individual members. The claimed virtue of this framework is to align the constituents' private interests. Let us illustrate this claim with an example inspired from Cramton, Ockenfels and Stoft (2015). Suppose that the world is composed of 100 countries with the same characteristics (population, economic prosperity, growth expectations, industrial structure . . .). Each ton of CO_2 in the atmosphere generates \$1 of damage in each country. The business-as-usual scenario yields a uniform emission of 10 tCO_2 per capita. Suppose also that 80% of each country's emission can be eliminated at a unit abatement cost of 50 $/tCO_2$. The abatement cost of the remaining 20% is 200 $/tCO_2$. In this context, it is desirable that each country abates its emissions by 80%, since the global damages of 100 $/tCO_2$ exceeds the cheaper marginal abatement cost of 50 $/tCO_2$. But the tragedy of commons would prevail in the absence of a binding international agreement, because the marginal abatement cost is fifty times larger than the local marginal damages. Suppose that the 100 countries accept to join an international coalition in which they cooperate to enforce the domestic imposition of an internationally harmonized carbon price that is voted by a majority rule. Participants are required to impose the common price as long as all signatories do too. The domestic revenues of the scheme are recycled internally. In this framework, all countries will be in favor of a carbon price of, say, 100 $/tCO_2$, which will induce them to abate their emissions by 80%. This dominant strategy yields the first-best solution and makes all countries better off.

As Cramton and Stoft (2012) point out, an equivalent negotiation process exists that is based on quantities. Suppose that all countries in the coalition accept to negotiate a uniform emission per capita that is voted upon by a majority rule. The same subsidiarity rule applies for which green policy should be implemented to attain the national target, and countries are allowed to trade their emissions with others. In this alternative framework, all countries will understand the benefit of imposing an ambitious target for themselves as long as the other countries do the same. It is an optimal for each country to vote for an 80% reduction of emissions. In this example, the two negotiation mechanisms yield the same efficient solution,

11. See Cramton and Soft (2012), Cramton, Ockenfels and Stoft (2015), Weitzman (2013, 2015), and the papers in this symposium. Cramton et al. (2013, 2015) suggest defining a country's carbon price as its carbon revenue divided by its carbon emissions. Others recommend a uniform carbon tax. Still others advocate a global cap and trade system leading to a uniform carbon price. At this stage, there is no need to distinguish between the various approaches.

and have the same simple structure of a one-dimensional negotiation, either on a uniform price or on a uniform per-capita quantity.

Alas, the real world does not look at all like the description above. Indeed, countries differ markedly by their exposure to climate change, their abatement costs, their economic dependence to fossil fuels, their willingness to invest in the future, their emission per capita, and so on. These sources of heterogeneity of costs and benefits make the negotiation dramatically more complex.

Consider for example the case in which only 10 of the 100 countries are responsible for all emissions. The other countries emit nothing. Under the uniform price mechanism as under the quantity mechanism, conditional on all countries ratifying the treaty, the median voter will be in favor of respectively a 200 $/tCO$_2$ and a zero-emission target for all countries. This example illustrates two difficulties with the two simple negotiation mechanism examined in this section. First, in line with Weitzman's result (this issue), there is too much abatement at equilibrium, so that these mechanisms do not guarantee a first-best solution.[12] Second, the 10 high-emission countries are likely to quit the coalition because they bear all the cost of mitigation and receive a tiny fraction of the benefits. In economics parlance, their participation constraint is binding. This is why the economists supporting a price negotiation recognize that due to the heterogeneity among countries, the system is feasible only if some mechanism for side transfers (such as a Green Fund or an allocation of permits) is designed so as to bring on board the reluctant countries. We concur. Observe that the sizes of the transfers from the 90 green countries to the 10 others that would induce the latter to participate are exactly the same for the two negotiation mechanisms. Of course this is an artifact of a static model in which perfect foresight is automatic.

Unfortunately, but unavoidably, the Green Fund (under a carbon price) or the unequal allocation of permits (under cap and trade) destroys the simplicity of a single-dimensional negotiation. The Green Fund must set the net (positive or negative) transfer to the fund for each country and therefore involves dimensionality n + 1 (the number of countries, n, plus 1, the carbon price). In the cap-and-trade mechanism, an unconstrained allocation of permits yields the same dimensionality (n allowances, plus the carbon price). This sharp increase in dimensionality can be avoided by adopting a common formula as the Kyoto negotiators attempted to do. Cramton and Stoft (2010, 2012) propose doing this and argue that by making this the first stage of a two-stage negotiation, countries would find it easier to agree (more on this below).

Summing up, whether the international architecture adopts a uniform carbon price or a cap-and-trade mechanism, cross-country transfers will thus be needed so as to bring reluctant countries on board. As we just discussed, under the carbon pricing approach, the proposed transfer mechanism is to use a fraction of the collected revenue to help developing countries to adopt low-carbon technologies and to adapt to climate change. This is illustrated by the Green Fund which was created at the COP-15 of Copenhagen in 2009. Under a cap-and-trade protocol, transfers operate through the distribution of free permits.

Either way, the design of compensation poses a complex problem: each country will want to pay the smallest possible contribution to the Green Fund or receive the maximum number

12. Weitzman (2015) derives an analytical solution for this majority voting scheme on the carbon price when the damage function and the marginal abatement cost function are linear. In that case, the equilibrium price is efficient if and only if the mean and the median of the distribution of the country-specific marginal damages are the same.

of permits.[13] This negotiation is complex and of course a major impediment to reaching an agreement on a carbon tax or a cap-and-trade. On the other hand, it must be realized that most international negotiations involve give-and-take. And there have been successful negotiations in the past. A case in point is the 1990 Clean Air Act Amendment in 1990. This arrangement was not imposed by a centralized authority, but rather was the outcome of a protracted negotiation, in which the mid-west states, high emitters of SO_2 and NO_x, delayed jumping on board until they received sufficient compensation (in the form of free permits in that case).[14]

4.2. Simplifying the compensation n-dimensional negotiation (Green Fund or allocation of permits)

a) Transparency considerations

A Green Fund may be too transparent to be politically acceptable. The transparency argument requires further thought, but experience here suggests a serious concern; the Green Climate Fund established at COP-16 aims at a *flow* transfer of $100 bn per year by 2020, and four years later had received promises of less than $10 bn in *stock*.[15] As is known from other realms (like humanitarian relief after a natural disaster or LDC health programs), parliaments are known to be reluctant to appropriate vast amounts of money to causes that benefit foreigners. Even successful programs such as the Vaccine Alliance GAVI - which involves a much smaller amount of money - took off only when the Bill & Melinda Gates Foundation brought a substantial financial commitment. Politicians often pledge money at international meetings, only to downsize or renege on their pledge. Substantial free-riding is expected to continue, jeopardizing the build-up of the Green Fund.

We believe that the transparency issue is one of the reasons why many pollution-control programs around the world adopted cap-and-trade and handled the compensation issue through the politically less involved distribution of tradable permits (often in a grandfathered way). The large transfers to the Mid-West implied by the 1990 Clean Air Act Amendment never really made the headlines. To be certain, the transfers made under national cap-and-trade programs are different in their economic and political nature from international payments for international permits; however, in the EU ETS scheme, billions of euros could have been potentially transferred to Eastern European and former Soviet Union countries ("Hot Air") through the allocation of permits in order to convince them to sign the Kyoto Protocol.[16]

The strength of the opaqueness argument in favor of the allocation of permits remains to be tested, and no-one has the answer as to whether it would work for climate change. On the one hand, transfers associated with an allocation of free permits are not that hard to compute and one would imagine that politicians (privately or publicly) opposed to an ambitious climate change agreement would quickly publicize the numbers (if unfavorable to the country) so as to turn their domestic public opinion against the agreement. In fact, the public uproar over

13. In either case, there is also an issue regarding whether the governments will not steal or make use of the transfers for their own wellbeing: they may cash in the Green Fund receipts (or for that matter the carbon tax) or sell permits in the international market to the same effect. This difficulty is inherent to the respect of sovereignty and is not specific to climate policies.

14. See Ellerman et al (2000) for an extensive analysis of these negotiations.

15. However, Cramton and Stoft (2012) claim that a far smaller amount would be needed to support a carbon price of $30/ton, and that donor countries would receive much more for their money than with the current Green Fund.

16. This a priori gave Eastern European countries the choice between making money by selling permits and not exerting any abatement effort; other countries became reluctant to buy the permits and the second option became the leading one.

the sale of Hot-Air AAUs was such that the UN was forced to restrict their sale. On the other hand, some of the cap-and-trade transfers failed to make the headlines in the past. The jury is still out on this question.

Finally, it should be noted that countries routinely transfer sizeable fraction of their GDP to foreign investors in reimbursement of their sovereign debt. It would be useful to have estimates of likely shortfalls/surpluses of permits (which of course depend on the initial distribution) so as to have a better assessment of the sums involved.

b) Reducing the dimensionality of the compensation negotiation

Rich and poor have always had opposite views as to who should compensate the other. Developing countries correctly emphasize ethics and their desire to develop while rich countries were in the past allowed to develop without being hindered by environmental concerns; they demand equal rights per capita or a variant of it. Rich countries invoke Realpolitik and explain that they will not get on board unless permits are grandfathered (like they were in many other instances); or they will contribute only modestly to the Green Fund. The developing countries' being morally right does not mean that they should overstress the equity concern, for their own sake; inducing the rich countries to refuse to get on board will make poor countries much worse off. The politics of negotiations are not always aligned with the ethical view, unfortunately; in the driver's seat lay the countries with a high-projected GDP (they will be the high polluters), those with a high abatement cost, and finally those which will suffer the least -or even slightly gain from- global warming. These countries have low incentives to get on board.

The Green Fund allocation or the formula for the allocation of free permits in the cap-and-trade approach must be acceptable by all.[17] The expectations must also be convergent and unrealistic demands are to be avoided. Rich countries must be much less selfish and accept to bear a large share of the burden (in reality and not through cheap pledges as they sometimes do). Conversely, a common per-capita emission is a complete non-starter for the developed world. This would involve massive wealth transfers to the less-developed world. As Cramton et al. (2013, 2015) stress, it is further unclear on what basis could such transfers be determined; developed countries will argue that while they are responsible for anthropogenic global warming so far, they also have developed numerous technologies (medical, agricultural, communications, etc.) that are benefiting the less-developed countries. Such an acrimonious debate is unlikely to foster a decent solution to climate change. Moreover, the inconsistent expectations that we observe today are, needless to say, very dangerous. Like in the case of an impending war, we hope that the various sides will become more reasonable and come to terms with the huge collective gains from reaching an ambitious agreement.

We agree with the authors of the other papers published in this symposium that free-style negotiations among n countries are exceedingly complex and are very likely to lead to a deadlock, whether the countries negotiate about who will be a contributor or a recipient (and by how much) of the Green Fund or the allocation of free permits among countries under cap and trade. There is here a complex trade-off between a simple rule, which prevents individual countries from demanding a special treatment, and a more complex rule, that better

17. Cramton, Ockenfels and Stoft (2015) make a similar point for the cap-and-trade initial negotiating approach attempted by Kyoto negotiators, who tried to agree on a uniform reduction of x% relative to 1990 emissions; no such x could be found.

accounts for individual willingnesses to get on board, but also make the negotiation captive of specific demands.

To illustrate this, consider the following (simple) rule, which reflects the trade-off described above between ethics and Realpolitik in the case of a common carbon price approach. The transfer scheme in this approach is based on a Green Fund. Cramton, Ockenfels and Stoft (2015), Weitzman (2015) and De Perthuis and Jouvet (2015) propose to finance the Green Fund on the basis of a one-dimensional bonus-malus system where countries whose per-capita emissions lie above a predetermined threshold would transfer funds to countries whose emission is below the threshold. More specifically, let p_i and P denote country i's and the world's populations, and x_i and $X=\sum_{i=1}^{n} x_i$ denote the current emissions of country i and the world. The contribution C_i to the Green Fund by country i would then be determined as follows

$$C_i = g\left(x_i - p_i\frac{X}{P}\right), \qquad [1]$$

where g is a generosity parameter, i.e., how many dollars are transferred per ton of excess emission. Note that the sum of these contributions is equal to 0, as it should.

In a cap-and-trade approach, the transfer is implicit in the allocation of free permits. For conciseness, we state it in terms of intertemporal (total) pollutions. Let q_i denote country i's number of free permits and $Q=\sum_{i=1}^{n} q_i$ denote the total number of permits (as discussed above, Q would be computed so as to contain the temperature increase to 2°C). With grandfathering coefficient $\hat{g}$ in [0, 1], the free permits would be allocated according to formula

$$\frac{q_i}{Q} = \hat{g}\frac{x_i}{X} + (1-\hat{g})\frac{p_i}{P}. \qquad [2]$$

So, the ethical approach prevails if $\hat{g}$ is close to 0, and the Realpolitik concerns are reflected by a large $\hat{g}$ value.

There are many potential criticisms to, and improvements on such formulae. For instance, the formulae need not hold in each year, but only overall. Under cap-and-trade, developing countries' endowment might be backloaded, so as to avoid a situation in which initially they are in expectation big net suppliers of permits in the market for allowances.

But the point we want to make here is that such rules may be a bit too simple. Realpolitik suggests accounting at least somewhat for the exposure to climate change, even if this may be rather unfair. Countries like Canada and Russia may not get on board under formula [1] or [2] while other high-income, high pollution countries would, provided that the generosity coefficient g is not too high or the grandfathering coefficient $\hat{g}$ not too low.

5. PRICE VS. QUANTITY

Given our concern that the pledge and review approach currently favored by policymakers might prevail at the COP 21, it may be premature to enter the intricacies of "prices vs. quantities" (to use Weitzman's 1974 terminology) or "carbon price vs. cap-and-trade" (by cap-and-trade, we mean the setting of a global volume of emissions, not of individual countries' targets, which would be highly inefficient). We feel that either approach clearly dominates the current alternative. Besides, the question is far from being settled among economists. However,

since post-COP 21 negotiations need to be engaged quickly, it is important to discuss these second-stage issues right away.

The choice of instruments has two dimensions: the purely economic question of which system best accommodates scientific and demand uncertainty, a complex question that was treated at a theoretical level in Weitzman's article but on which limited empirical evidence is available;[18] and a political economy dimension on which we now focus.[19]

On the political economy front, of which we developed one dimension (the transparency of transfers) in Section 4.2.a, we would like to make two points. First, like for any other public policy, international commitments must be feasible; that is, its implementation must not be prevented by the lack of information.

Second, and perhaps more controversially,[20] one may want to leave scope for national policies, even though we know that these policies may then deviate from least-cost abatement. Imagine for instance, that some countries with limited tax-collection-and-redistribution capabilities would want to opt for a low carbon price on cement to make housing affordable to the poorest; then they would want to deviate from the single-price rule; to be certain, governments may be weak and grant excessively low carbon prices to some lobbies, but this is by and large a matter of domestic politics (unless the practice is so widespread that it becomes un likely that the country will abide by its overall commitment, whatever the agreement is). The rationale for subsidiarity is two-fold. First, it gives leeway for governments to convince their domestic opinion (or themselves); second, other countries care only about how much CO_2 is emitted by the country, not how the number came about.

5.1 The enforceability problem

a) Enforcement under a carbon price commitment

Lax enforcement. Carbon-pricing proposals allow a large array of regulatory mechanisms that get carbon-pricing credit. In order to fulfill their price commitment, countries could levy a carbon tax or set a cap-and-trade system and value carbon permits at their market price. Some countries' carbon price will also reflect their green standards (with an implicit carbon value) or count their public investments that have an impact on emissions. Under the principle of subsidiarity, we believe that all these actions should indeed be accounted for in

18. Besides, the Weitzman framework does not allow for more complex, but reasonable mechanisms, like dynamic adjustment mechanisms to cope with uncertainty. For instance, the European Commission has recently proposed to create a market stability reserve starting in 2021. The reserve would cope with the current surplus of emission allowances and improve the system's resilience to shocks by adjusting the supply of allowances to be auctioned. It would operate according to pre-defined rules which would leave no discretion to the Commission or Member States.

An economic debate also exists regarding whether price or quantity schemes best insulate countries against uncertainty about climate risk or technology. In theory, hedging instruments should provide an efficient allocation of risk worldwide, but little is known as to the extent to which markets would actually deliver this.

19. We here will not expand on another political economy dimension. Another issue with a carbon tax is the legal process. This obstacle is certainly not insurmountable, but requires specific attention. First, taxes are usually set every year. What is needed for climate change control is a long-term commitment (think about the SO_2 tradable permits in the US, which are issued 30 years ahead). Second, taxes are generally the prerogative of parliaments. For example, in Europe, setting up the ETS cap-and-trade scheme required only a majority vote, while tax harmonization is subject to the unanimity rule, and therefore a carbon tax would have been almost impossible to achieve. So an exception needs to be made to prevent individual parliaments from undoing the international agreement

20. Cramton et al. (2013, 2015) also argue in favor of subsidiarity, although on slightly different grounds.

order to determine the national carbon price, which is the ratio of the carbon revenue over the carbon emission.[21] The net effect is to generate efforts to curb national emissions.

Because most of the climate benefits of this policy accrue abroad, countries currently have no incentive to impose strict carbon usage constraints on their citizens, firms, and administrations; and by and large, except for Sweden, they do not. This will also be the case under any international agreement. Thus, even if enforcement were costless, authorities would still turn a blind eye on certain polluters or underestimate their pollution, thereby economizing on the cost of green policies. This form of moral hazard is particularly hard to avoid in countries which are on the spending side of the compensation scheme (say the Green Fund); but it applies also to countries on the receiving side, which could be threatened by a withholding of transfers in case of non-compliance. To envision the difficulties faced by monitoring of compliance, one can refer to the current debate on poor tax collection in Greece.[22] To sum up, the imposition of a common carbon price faces the standard free-rider problem, with local costs and global benefits. Its management requires a strong international monitoring system.

Undoing. Second, another form of moral hazard consists in undoing the carbon tax through compensating transfers; presumably the countries would do this in an opaque way so as not to attract the attention of the international community.

Multiple grounds for taxation: The case of fossil fuels. Burning fossil fuels generates various local externalities such as the emission of nanoparticles (cardiovascular diseases, asthma . . .), and, in the case of gasoline, road congestion and the deterioration of road infrastructure. This justifies specific Pigovian taxes whose level depends upon the density of population, the value of life, the burning technology or the average atmospheric conditions for example. Countries also take advantage of the relative inelasticity of demand to raise revenue. Proponents of the carbon price approach propose a "zero baseline" in defining the carbon price. That is, they define the carbon price to include all taxes and subsidies on each fossil fuel on each market, implicitly ignoring all other externalities or more generally other motivations for taxing fossil fuels. One problem with this pragmatic strategy is that these other Pigovian prices differ much around the world. Take again gasoline taxation: the distribution of the price of the liter of gasoline at the pump around the world has huge variance: 2 cents in Venezuela, 97 cents in the US and 209 cents in Belgium.[23] Under the above-mentioned definition, imposing the

21. We have not studied and therefore will not discuss the question of aggregation of the various efforts along different dimensions. The choice of weights and their relationship to technological progress has been discussed in the literature on price indices (e.g. Diewert 1993); relevant here is also the very embryonic literature on price caps (here floor): Armstrong-Vickers (2000) and Laffont-Tirole (1999). The optimal response of a country, even in the absence of political economy/favoritism considerations, will not satisfy the law of one price, both within the country (the country-optimal tax depends on good-specific cost and local pollution characteristics) and across countries. We however do not have an educated guess as to whether these deviations from price coherence impose sizable costs; and in comparison with the distortions attached with current pledge-and-review approach, this is without doubt a second-order issue.

22. All symposium authors agree that enforcement should work in two steps (1) monitor, (2) impose trade sanctions if necessary. This of course is not straightforward.

In the last few years, and despite the existence of a program and the presence of the Troika in the country, Greece made very little progress in curbing tax evasion. It is just very difficult for foreigners to impose a tax when the government is reluctant to strengthen it. While in both cases (sovereign debt and climate agreements), the foreigners have a strong vested interest in domestic tax collection, one could even argue that the problem is even more complex in the climate context and that there is no reason to believe that the international community would be much more successful in obtaining compliance of the carbon tax agreement. Indeed some compliance-prone factors are not even present in the case of climate change: there is no troika in each country threatening to cut the flow of lending; countries are not under a program (and therefore carefully monitored); they also derive some benefits from compliance (prospect of no longer being under a program, of not facing international sanctions in case of default), while for most countries almost 100% of the benefits of good behavior are enjoyed by foreigners.

23. http://data.worldbank.org/indicator/EP.PMP.SGAS.CD/countries/1.

same "carbon price" at the world level forces all countries to price local externalities and embody revenue concerns equally, a contradiction with the basic idea of subsidiarity. Monitoring this by the international community is a serious challenge.

Non-price policies. Third, the carbon-price approach requires finding conversion rates for various policies that impact climate change, but are not subject to an explicit price, such as road and housing construction standards, no-till farming or afforestation and reforestation. These conversion rates may need to be country specific: a construction standard will impact GHG emissions differently depending on the country's climate; similarly, afforestation may increase rather than decrease emissions in high latitude areas, in which trees may cover (high-albedo) snow.

b) Enforcement under a cap-and-trade mechanism

Enforcing an international quantity mechanism is relatively straightforward when countries, rather than economic agents, are liable for their national emissions. The anthropogenic emissions of CO_2 by a nation can be derived from a simple carbon accounting by adding extraction and imports and by subtracting exports and the variation of stocks. Carbon sinks from forests and the agricultural sector can already be observable by satellite. Experimental projects from NASA and ESA to measure the global emission of CO_2 at the country level are promising in the long run.[24] We believe that monitoring the country's CO_2 emissions is easier than monitoring emissions at the point source, and, like for existing cap-and-trade mechanisms, agents (here countries) with a shortage of permits at the end of the year would have to buy extra permits, while those with a surplus would sell or bank them.

There is one concern about permit trading among nations: some countries (one has in mind China and the US here) may well enjoy market power due to their share of world emissions. This is a potentially serious issue, which requires oversight and offers some similarity to the control of market power in electricity production or in financial rights over transmission on a power grid.[25] In particular, one would want countries to be as close as possible to zero net supply so as to reduce their incentive to affect the world price for permits by restraining the demand or supply.

5.2 Price volatility under a carbon price and under cap-and-trade

Attention should be paid to the question of how to *accommodate uncertainty*. A cap-and-trade approach would compute and issue a worldwide number of permits consistent with the 2°C target. However, there is scientific uncertainty about the link from emissions to global warming. There is also uncertainty about the abatement technology, consumer demand and so forth. So the number of permits will probably have to be adjusted over time. The market price of permits will be volatile (although presumably less so than under the flawed and unstable attempts at pricing CO_2 so far).[26]

24. For example, the NASA Orbiting Carbon Observatory-2, or OCO-2, is already orbiting the planet. The ESA CarbonSat project is also promising.

25. See e.g. Green-Newbery (1992) and Joskow-Tirole (2000).

26. Even in a well-designed, long-term oriented system such as the acid rain program in the US, SO_2 prices have been volatile. They were stable in the first ten years, but then exhibited substantial volatility from 2005 through 2009 for instance.

The same concern holds for a carbon price. Due to the same sources of uncertainty, there is no guarantee that the price will initially be set at the "right level", consistent with the overall global warming target. Thus, the tax will need to be adjusted over time as well.

More generally still, any proposal must confront the volatility question, as price volatility is likely to be unpopular. One possibility, which a priori does not require public intervention, is to transfer risk through hedging instruments to those who can bear that risk more easily. Another, complementary approach is to intervene in markets to stabilize prices. For example, the European Commission in 2014 has proposed a "Market Stability Reserve", in which the auction volumes will be adjusted in phase 4 of the EU ETS starting in 2021, so as to create a soft target corridor for banking of EU Allowance units (EUAs). The mechanism will reduce the amount of EUAs that are auctioned if an upper threshold of EUAs in circulation is exceeded and releases them if the EUAs in circulation fall short of a lower threshold. This scheme is meant to be automatic, but its efficiency can be questioned.[27] In particular, one can wonder how it can be made responsive to news in a way that guarantees that the 2°C target is reached. This brings us to the question of the trade-off between flexibility and commitment.

5.3 The potential time inconsistency of carbon price and cap-and-trade policies

Whether one opts for a carbon price or for cap-and-trade, one should be concerned by the possibility that, conditional on the accruing news about the climate change process, technology or demand, the ex-post adjustment be too lax (too low a carbon price, too high a number of tradable permits). To understand why, note that the carbon price or tradable rights path is designed so as to incentivize long-term investments: in carbon-light housing, transportation infrastructures or power plants and in green R&D. Ex post the price incentive has served its purpose and now imposes undue sacrifices; put differently, optimal environmental policies are not time-consistent. Furthermore, the possibility of administration turnover or news about other aspects (say, public deficit or indebtedness, economic opportunities) may transform climate policy into an adjustment variable, adding to the overall time inconsistency.

This time inconsistency is studied in Laffont-Tirole (1996 a, b), who look at the optimal mechanism designed by a centralized authority (the world's nations here) when news will accrue that may vindicate a change of course of action. The optimal mechanism must trade off commitment and adaptation. It can for example be implemented through a generalized cap-and-trade mechanism. This mechanism consists in providing authorities with flexibility, provided that the latter commit to compensate permit owners (in cash or Treasury securities). More precisely, authorities must issue a menu of permits with different redeeming values that limit the authority's ability to expropriate their owners by flooding the market with pollution permits. For example, if news led the authority to lower the price of permits (or the carbon tax) from $ 50 to $ 40, some $ 50 and $ 45- strike price put options on the Treasuries (with agreed upon country keys) would become in the money; at $ 35, some other options (with a $ 40 strike price) would also be in the money, and so forth. This approach creates flexibility but constrains it by forcing the authority to partly compensate permit owners. It obviously

27. The precise implementation of this mechanism has been criticized for being asymmetric and failing to have the desired dampening effect (Trotignon et al 2015).

requires a governance mechanism, whose existence is inescapable anyway in any international agreement.

Cap-and-trade mechanisms can obviously accommodate various automatic mechanisms that react to news accrual. We have not studied when the Market Stability Reserve mentioned above or a variant thereof can approximate the optimal adjustment mechanism described in Laffont-Tirole,[28] and we think that economists have not paid enough attention to this aspect, whether they favor carbon pricing or cap-and-trade.

6. ENFORCING A STABLE INTERNATIONAL AGREEMENT: THE CARROT-AND-STICK APPROACH TO PROMOTE INTERNATIONAL COOPERATION

An efficient international agreement should create a grand coalition in which all countries and regions will be induced to set the same carbon price in their jurisdiction. Under the principle of subsidiarity, each country or region would be free to determine its own carbon policy, for instance through a tax, a cap-and-trade, or a hybrid. The free-rider problem raises the question of the stability of this grand coalition.[29] An analogy is sovereign borrowing. Sanctions for defaulting are limited (fortunately gunboat diplomacy has waned!), which raises concerns about countries' commitment to repay creditors. The same applies to climate change. Even if a good agreement is reached, it must still be enforced with limited means. The La La Land of international climate negotiations most often ignores this central question.

Naming and shaming is an approach and should be used; but as we have seen with the Kyoto "commitments", it has limited effects. Countries always find a multitude of excuses (choice of other actions such as R&D, recession, insufficient effort by others, commitment made by a previous government, etc. . . .) not to abide by their pledge.

There is no bullet-proof solution to the enforcement problem, but we think that at a minimum two instruments should be employed. First, countries care about gains from trade; the WTO should view non-compliance with an international agreement as a form of dumping, leading to sanctions. Needless to say, the nature of these sanctions should not be decided by individual countries, as the latter would then gladly take this opportunity to implement protectionist policies.

In the same spirit, one could penalize non-participants through punitive border taxes. This policy would incentivize reluctant countries to jump on board and be conducive to the formation of a stable world climate coalition. Nordhaus (2015) examines the formation of stable climate coalitions when coalitions are able to impose internally a uniform carbon price together with uniform trade sanctions against non-participants. For a carbon price around \$25 per ton of CO_2, a worldwide climate coalition is stable if a uniform tax of 2% is imposed by the coalition for any good or service imported from a non-participating country.

Second, non-compliance with a climate agreement should be treated as committing future administrations and treated as sovereign debt. This policy would involve the IMF as well. For example, in the case of a cap-and-trade approach, a shortfall of permits at the end of the year would add to the public debt; the conversion rate would be the current market price.

28. For instance, suppose that scientists demonstrate that the climate is deteriorating faster than had been thought. Then permits must be withdrawn. The Market Stability Reserve mechanism reacts to an intertemporal use of permits ("is permit use more frontloaded or backloaded than expected?") rather than to the overall target. So it is likely to miss some desirable adjustments.
29. In an asymmetric information framework, Martimort and Sand-Zantman (2015) describe the optimal mechanism for an international climate agreement when states face some local co-benefits and participation is voluntary.

Of course, we are aware of the potential collateral damages associated with such linkages with other successful international institutions. But the real question is that of the alternative. Proponents of non-binding agreements hope that the countries' good will suffice to control GHG emissions. If they are correct, then the incentives provided through institutional linkages will also suffice a fortiori, without any collateral damage on these institutions.

7. PUTTING THE NEGOTIATION BACK ON TRACK

In spite of the mounting evidence about global warming, the international mobilization has been most disappointing. The Kyoto protocol failed to build an international coalition supporting a carbon price in line with its social cost and illustrates the intrinsic instability of any international agreement that does not seriously address the free-rider problem. An international agreement must satisfy three properties: economic efficiency, incentive compatibility, and fairness. Efficiency can be attained only if all countries face the same carbon price. Incentive compatibility can be attained by penalizing free-riders. Fairness, a concept whose definition differs across stakeholders in the absence of a veil of ignorance, can potentially be reached through lump-sum transfers.

There is currently some enthusiasm for the process of letting each country pledge emission reduction efforts in preparation of the Paris COP 21 in December 2015. We believe that this strategy is doomed to fail. It does not address the fundamental free-rider problem of climate change. The pledge-and-review process is another illustration of the waiting game played by key countries, which are postponing their real commitment to reduce emissions. Countries will make sure that their pledge is hard to compare with other pledges, and that it is non-verifiable and non-enforceable. The predicted outcome of this waiting game in terms of emissions of GHGs is potentially worse than the business-as-usual, zero-ambition outcome. We should tackle the climate challenge more seriously.

All contributors to this symposium consider the efficiency objective of a universal carbon price the top priority in the current negotiation process. But this objective can be achieved in many different ways whose relative merits are mostly untested. Several leave scope for subsidiarity of national climate policies, which has drawbacks but nonetheless has our preference.

Given how delayed and confused current negotiations are,[30] there is little hope to come up in Paris with the architecture we propose, or for that matter with any reasonable architecture. So what shall we do?

We should both get the fundamentals right and face the thorny issue of equity. The latter issue is daunting, but any negotiation will have to confront it, and discussing many other topics simultaneously does not facilitate the task. So the roadmap for the COP 21 in Paris would be:

- Agree on a single-carbon-price principle and on the need for the measurement infrastructure to allow for an independent monitoring of countries' overall pollution.
- Agree on a governance and enforcement mechanism (we have proposed that non-participating countries be imposed penalties through punitive border taxes administered by

30. Incidentally, we are not convinced that the Onusian framework is optimal either, as bargaining among 200 nations is incredibly complex. A coalition of the current and future high emitters (say the G20) might prove more effective, both to negotiate and then put pressure on other countries, including through the WTO.

the WTO and that participating countries recognize a "climate debt" accounting for the uncovered emissions of the non-abiding countries and administered by the IMF).

If the choice for a single-price policy is carbon-pricing:

- Find a price that is agreeable to the international community and limits global warming to the 2 °C objective.
- Put in place the monitoring environment, as well as the general principles for conversion of non-price policies into the price realm; and define criteria that limit undoing.

If the choice for a single-price policy is cap and trade (option we favor because we believe that it is easier to monitor):

- Fix a trajectory of emissions that scientists deem consistent with the 2°C objective, and agree on the principle of this worldwide cap trajectory.
- Agree that permits will be allocated to participating countries in line with the aggregate cap.
- Agree on a trading mechanism in which countries will have to match pollution and permits at the end of the year to avoid creating unfulfilled climatic debt.

Under the current circumstances, the implementation of any of these two approaches would constitute a formidable achievement.

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Overcoming the Copenhagen Failure with Flexible Commitments

JOSEPH STIGLITZ[a]

ABSTRACT

The fundamental issues presented by climate change are first, that the global environment is a global public good and second, the question of how to share the burden of providing a better climate. Everyone *would like to "free ride" on the efforts of others, but there is disagreement over who is free riding. The Kyoto approach, based on dividing up emission rights, has an inherent problem in that such rights could easily reach a monetary value of over a trillion dollars a year. The approach suggested here avoids any attempt at a grand solution to the fair allocation of these rights. A low-carbon economy could be achieved through the imposition of a moderate carbon price, which would raise substantial revenue and allow a reduction in other taxes, thereby keeping the deadweight loss small. Countries should be given flexibility in how they meet their obligations—whether through a carbon tax, a system of cap and trade, or even possibly certain regulatory mechanisms. But a fully voluntary agreement likely cannot include countries that export a significant amount of fossil fuel. A green fund financed by allocating say 20% of carbon revenues collected in developed countries could be used to implement "differentiated responsibilities."*

Keywords: Climate change, Global warming, Carbon pricing, UN climate negotiations

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INTRODUCTION

There is by now widespread agreement that climate change represents an existential threat, that only by global action can the accumulation of greenhouse gases in the atmosphere be stymied, and that there has to be some appropriate form of burden sharing (see, in particular, Stiglitz, 2011). There is even broad consensus over the urgency of action; that unless we act soon, there is a serious likelihood of an increase in temperature well above the 2 degrees C that was at the core of the Copenhagen agreement. Yet, in spite of the broad consensus, there has been little progress. There has been some—but the voluntary measures taken by various countries simply don't add up to what is needed. This paper (like others in this symposium) attempts to explain why that may be the case and point to an alternative framework for negotiations which, I believe, is more promising than that on which the world has embarked since the Rio agreement of 1992.

The fundamental issues are simple to state but hard to resolve: the global environment is a global public good—all benefit from a good environment, and all suffer from climate change (Stiglitz 1995, 2006a, 2006b, 2006c). As in the case of any public good, there is a problem of *undersupply; everyone* would like to "free ride" off the efforts of others in supplying the

[a] Columbia University, U.S.A.

public good. In the case of global warming (climate change) there is an additional problem: some suffer more from the consequences of climate change than others; the adjustments some have to make to avoid climate change are greater for some than others; and the ability of some to take the actions to reduce emissions and to adapt to the consequences are greater for some than others. Indeed, it used to be thought that the countries like the United States that were the largest contributors to climate change would be the ones that would suffer the least from it. As we have become more aware of the multiple effects of climate change (including on weather variability), that view is not held so strongly today: rich countries like the United States are vulnerable to more property damage from events like Hurricane Sandy.[1] Moreover, poor countries are today responsible for an increasing share of carbon emissions.

Still, the central issue in reaching a global agreement entails burden sharing—who should pay the price associated with reducing greenhouse gas emissions? Should it be the large developed countries who have so far contributed most to the increase in greenhouse gases over the past two hundred years? Should poorer developing countries be asked to sacrifice their growth potential, so that the advanced countries can continue in their emissions-intensive life style?

Some suggest that it should be easy to arrive at an agreement. Whenever there are large externalities—and greenhouse gases give rise to a huge externality—there are arrangements that are Pareto superior; where all would be better off rather than carrying on in a "business as usual" manner. But the problem in this case is that these Pareto improvements would entail developing countries making significant sacrifices which they view they can ill afford, so that the developed countries can continue in their profligate patterns—or so that developed countries could be compensated for not continuing in their profligate patterns. This is because those in the developing world, disproportionately located in the tropics, are likely to be hurt most by climate change; though there is increasing evidence that some of the extreme weather events associated with climate change will affect even those living in more moderate climates, that many of these countries will be adversely affected by sea level changes, and that all could be affected by disease vectors.

Perhaps, in the end, when developing countries face the bleak alternative of desertification, droughts, flooding, etc. they will be willing to make the sacrifices, as unfair as they may seem. Perhaps, in the end, citizens in the more developed country will feel a stronger moral obligation to bear their fair share of the burden. This paper, however, is written in the hope that there is scope for arriving at a negotiated solution sooner rather than later.

THE FAILURE OF THE CURRENT APPROACH

The Kyoto approach, based on allocating "emission rights" (which could be traded) to different countries, has an inherent problem. It is now widely recognized that emission rights have a monetary value—probably on the order of $80 to $100 a ton in an emissions control scheme achieving the 2 degree goal. Giving a country emission rights is equivalent to giving them money. A global agreement has to decide on how to allocate an asset worth some trillion dollars a year. No wonder that it is hard to reach an agreement.

1. "It is readily apparent that the storm surge and associated damage [from Sandy] was considerably influenced by climate change." From "Attribution of climate extreme events," K. Trenberth et al., *Nature Climate Change*, Perspective, 22 June 2015. www.nature.com/nclimate/journal/vaop/ncurrent/pdf/nclimate2657.pdf.

Inevitably, if there is to be an agreement, the world will have to decide on some principles of allocation—a formula. The debate will focus on the terms of the allocation formula.

Kyoto seemed based on a principle that worked imperfectly among developed countries, but will simply not work when developing countries are brought in: countries were asked to make a given percentage reduction relative to their prior levels of emissions. Negotiations focused on adjustments up or down from the base rate, defended on grounds of particular circumstances facing particular countries. But this principle essentially says that those who emitted more in the past have the right to emit more in the future. No developing country would or should agree to this principle.

There are alternative principles that seem more ethically justifiable. One would divide the world's carbon "space" according to population in 1992, when the problem of global warming was globally recognized. Some countries, like the US, have essentially already used up all of their carbon space. Thus, they either need to move to zero net emissions or purchase emission permits from others.

There are of course more "progressive" allocations. Conventional principles would allocate a global asset such as emission rights in a progressive manner, with poorer countries getting a larger allocation. Many would argue that in allocating carbon space, one should go back in time well before 1992; and since the developed countries were responsible for the overwhelming proportion of the increase in carbon concentration over the past two hundred and fifty years, that would imply that they would have to reduce their carbon emissions going forward even more.

The approach suggested here implies avoiding any attempt at a grand solution to the fair allocation of emission rights, but recasting the problem in ways which minimize the redistributive aspects of the negotiations.

THE COSTS OF ADJUSTMENT

Fair burden sharing requires some notion of the costs of mitigation—the societal costs of lowering emissions. While there have been extensive calculations on the costs to different societies, there is a simple approach that suggests why those costs will be limited. By most accounts, the adjustments to a low carbon economy could be achieved through the imposition of a moderate carbon tax (or an equivalent cap and trade system). Such a carbon charge, say at the rate of $80 to $100 a ton, would, of course, raise substantial revenue and allow a reduction in other taxes. The standard approach for estimating the societal cost of such a carbon charge is the dead weight loss associated with the charge, the sum of the consumer and producer surpluses associated with raising the price of carbon from its current level to $80 or 100 a ton. (These calculations do not include the societal benefit of the reductions in climate change, just the direct economic cost of the "tax" itself.) These numbers are referred to as Harberger triangles, and are typically relatively small (though perhaps they might not be when emission reductions exceed 80%). But the reduction of the other taxes (say on labor or capital) would have a corresponding benefit, an increase in consumer and producer surplus. Thus the *net* societal cost of reducing emissions is the difference between the Harberger triangles; the difference is a number that is likely to be small for most countries, and in many cases will even be positive; and the difference in the differences can be even smaller.

Thus, it is plausible that most would see their own private gains from the reductions in climate change more than offsetting the costs (possibly negative) that they would bear. Though some might see themselves gaining more than others, most would see the agreement as positive.

But *within* many countries, there would be large losers: in the oil producing countries, for instance, oil producers and owners of oil assets would be worse off. While in principle, again, the winners could more than compensate the losers, such compensation is seldom made. Thus, the fact that the country as a whole might be better off does not necessarily mean that the country's government would actually support the agreement: the losers (the oil industry) may have disproportionate voice in many countries. (That is evidently the case, for instance, in the United States.)

Still, the approach we have outlined has even a political economy advantage: an argument that the country as a whole would be better off, even if particular special interests would be worse off, should carry weight. Arguments from the oil industry against an agreement would be seen for what they are: self-serving.

But there is an approach that would provide even more impetus to a global agreement. If those countries without a large fossil fuel lobby could agree to a common level of a carbon price, none would be viewed as having an unfair advantage over the other. In effect, a country which does not charge the full social cost of carbon is *subsidizing* carbon emitting industries, an unfair trade/competitive advantage, not unlike that of a country which subsidizes labor. These countries could impose trade sanctions—a cross border tax—on those who do not implement the common carbon price (Stiglitz 2006a, Helm 2010). (As I explain in Stiglitz (2006b), such a cross border adjustment would likely be WTO legal.) This would be an effective mechanism for ensuring compliance with a global agreement—and would provide a strong argument for those not adopting a carbon tax or an equivalent mechanism to do so. For any country not doing so would in effect be granting the tax revenue associated with its carbon emission to its trading partners.

PARTIAL VS. GENERAL EQUILIBRIUM

At a deeper level, there would be significant distributive consequences—but consequences which would arise no matter what approach was taken to reducing carbon emissions. For the intent of any global agreement is to reduce the demand for fossil fuels, and that *necessarily* must reduce the rents associated with fossil fuels; the recipients of those rents—the owners of the fossil fuels—will be worse off. And that will be the case even taking into account any benefits they directly receive from the reduction in the threat of climate change. That is why one should not expect a fully voluntary global agreement among all countries; in the absence of any sense of a global social responsibility framework, any country which is exporting a significant amount of fossil fuels would likely be worse off (Cramton and Stoft 2012). And even countries which import only a limited amount might not sign on, simply because of the political influence of the fossil industries.

That is why the target should be more limited: an agreement among a "coalition of willing," countries without a large domestic fossil fuel sector, with cross-border adjustments on all other countries. I suspect the combination of social consciousness and self-interest on the part of the citizens of other countries would expand the membership in this coalition, until most, if not all, countries, joined the coalition.

VOLUNTARY VS. ENFORCEABLE AGREEMENTS

The current approach seeks voluntary reductions. Each country would "offer" up actions it would take to reduce carbon emissions. There have been significant reductions on this basis,

and if all countries fulfill their intentions, the results would be impressive; but they would still fall far short of what is needed. Indeed, it would be remarkable if they did not. In no other area has voluntary action succeeded as a solution to the problem of undersupply of a public good. And this is especially so when there are global public goods, the benefits of which are shared by everyone in the world. There is simply insufficient "solidarity" at the global level. Social pressure works to some extent—but only to a limited extent. And that is especially true when there are large groups within our societies for whom the direct cost of taking action (the loss in value of the fossil fuel assets they own) exceeds any direct gain from reduced global warming. It is not a surprise that such groups try to convince others that there is no real danger of climate change.

That is why the *soft* approach advocated in recent years by the US, amongst others, based on voluntary contributions simply will not work. Agreements have to be enforceable. In the absence of a global government able and willing to impose direct fines, the most effective enforcement mechanism are trade sanctions, including the cross-border adjustments described in previous paragraphs.

FLEXIBILITY IN MAKING COMMITMENTS

But countries should be given flexibility in the manner in which they meet their obligations—whether through a carbon tax or through a system of cap and trade (Cooper 2008), which could be complemented with regulatory mechanisms when their results are sufficiently measurable. Systems of auctioned emission rights are equivalent to a carbon tax. In practice, over time there will have to be adjustments in the "caps" and in the price of carbon. The notion that there is less risk to the global environment with a cap and trade is based on the presumption that we have good knowledge of the level of emissions necessary to achieve any objective in terms of changes in temperature.

Some countries seem to believe that the political economy problems posed by climate change can best be solved by compensations provided through the grants of emission rights. Others worry that such systems are themselves subject to unwanted political pressures—and corruption.

Auctioned emission rights or a carbon tax can have large distributive consequences *within* a country, which is why regulatory mechanisms may have some advantages: restrictions on housing, urban design, transportation, and electricity generation can achieve a substantial fraction of what is needed; the requisite changes in carbon prices, with the associated distributive consequences, may be quite large to elicit corresponding changes. It is worth noting that much of the efforts of the international community have been directed at creating such regulatory standards, e.g. in terms of fuel efficiency in cars. But such an approach opens up difficult questions: should an industry that does not pay a carbon charge be viewed as subsidized if it faces a regulatory constraint that forces it to achieve the same level of carbon emissions? It is as if the industry has faced a carbon charge, but with the proceeds reimbursed to those in the industry as a lump sum payment. Clearly, the lump sum payment is a subsidy—even though it is not a carbon subsidy. Firms in countries facing a carbon charge will rightly argue that this is unfair competition. Moreover, there are difficult issues in transparency and comparability: if there were an agreement about a global carbon price of say $80 a ton, and some country were to combine tight regulations with a $70 a ton general price, how would we assess whether it was complying with the regulation? It might argue that it should be given

the flexibility of imposing, in effect, a higher carbon price in some industry (for some technologies) and a lower carbon price for others. Put aside for the moment charges of unfair competition to which such differential pricing might give rise (which arguably would be of limited relevance if the goods in question were non-traded goods). In principle, if we had enough information about the demand and supply curves, we could calculate the reduction in emissions and compare that reduction to what would have happened had there been a uniform $80 a ton carbon price.

COMMON AND DIFFERENTIATED RESPONSIBILITIES

The approach delineated above does not, however, adequately differentiate among the circumstances of different countries. Such differentiation was central to earlier approaches to climate change.

It is inefficient, and likely to be viewed as inequitable for producers in developing countries to face a different carbon price from those confronting firms in developed countries, giving rise to charges of unfair competition. At the same time, those from poor countries struggling to develop rightfully feel that *any* extra costs are taking away funds that could otherwise be used for advancing developmental objectives.

This leads to two suggestions: (a) a global green fund, financed by allocating 20% of the funds from the carbon tax (or the equivalent) imposed in developed countries. Since the magnitude of these revenues would be proportional to emissions of those countries, it would arguably be an appropriate basis for raising funds for a global green fund. And this would be particularly so since current emission levels would be highly correlated with past emissions. (This is not the only basis on which one might raise money for a global green fund. One might, alternatively, impose a charge based on *consumption,* on the carbon associated with the goods that individuals in different countries consume. In a competitive equilibrium, of course, charges on production and on consumption are equivalent. In practice, they may not be. There may, however, be more technical difficulties in levying a charge on consumption than production.)

The revenues from a global green fund would be used to help finance expenditures in developing countries on adaptation and on the *incremental* costs associated with mitigation measures reducing carbon emissions. The funds could also be used to help developing countries pursue objectives of carbon sequestration—paying them to maintain forests (which would have additional global benefits in terms of biodiversity) and even *not* to extract hydrocarbons. The contribution to each of the developing countries from the Green Fund should be large enough to compensate them for accepting the global carbon price. (It may, however, be problematic to ask each country what contribution from the Green Fund would induce them to participate; that would give rise to a bargaining problem where some developing countries might claim that they need large compensation. Equity may require establishing a rule based allocation mechanism.)

(b) Improvements in technology are likely to play an important role in meeting the goals of reductions in carbon emissions. Developing countries rightly worry that, should they sign on to an enforceable agreement concerning reductions in carbon emissions, to meet agreed upon reductions would necessitate their paying developed countries large amounts to use their technology. In effect, a global carbon agreement would be an arrangement to transfer large

amounts from developing countries to the developed. Developing countries understandably are reluctant to sign on to an international conventional that would have that as a result.

In the 1992 Rio agreement, there was a provision for compulsory licenses. And yet, the United States (and other developed countries) continue a stance which entails, in effect, a renegotiation of this provision.

The developed countries are in a better position to finance and conduct research leading to technologies which reduce carbon emissions and which lead to carbon storage at affordable costs. They should provide this technology freely to developing countries (perhaps on a sliding scale, with reduced charges for middle income countries). Some of the costs might be met out of the global green fund: research expenditures to reduce carbon emissions are a double global public good—research itself is a global public good; and climate change is itself a global public good.

CONCLUDING COMMENTS

It is now more than two decades since the world recognized the threat of climate change. And yet there has been little progress—too little progress—beyond a global agreement that we *should* take actions to limit the increase in temperature to 2 degrees C. We are now set on a course in which we will almost surely miss even this modest goal.

We have explained why the approaches of the past—voluntary caps and actions—will almost surely fail, falling far short of what is needed. We have outlined another approach, based on a global agreement around a common carbon price, with flexibility on how each country implements that agreed upon price. With strong border adjustments, this is more likely to result in an agreement. Perhaps the agreement will initially be only among a large number of countries, a coalition of the willing, in which some recalcitrant countries refuse to join in—most likely those in which fossil fuel industries play an important role in the political economy. But we have explained how over time, even many of these will find it desirable to join the coalition. We have explained too how we can incorporate within this approach the recognized principal of "common but differentiated" responsibility.

It is time to give this alternative approach a chance. Climate change is too important to allow the current impasse to continue.

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Internalizing the Climate Externality: Can a Uniform Price Commitment Help?

MARTIN L. WEITZMAN[a]

ABSTRACT

It is difficult to resolve the global warming free-rider externality problem by negotiating many different quantity targets. By contrast, negotiating a single internationally-binding minimum carbon price (the proceeds from which are domestically retained) counters self-interest by incentivizing agents to internalize the externality. In this contribution I attempt to sketch out, mostly with verbal arguments, the sense in which each agent's extra cost from a higher emissions price is counter-balanced by that agent's extra benefit from inducing all other agents to simultaneously lower their emissions in response to the higher price. Some implications are discussed. While the paper could be centered on a more formal model, here the tone of the discussion resembles more that of an exploratory think piece directed to policy-makers and the general public.

Keywords: Climate change, Global Warming, International public goods, Prices versus quantities, UN climate negotiations

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1. INTRODUCTION: GLOBAL WARMING GRIDLOCK

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.

Throughout this paper I use the terms "climate change" and "global warming" interchangeably. The term "climate change" is currently in vogue and is a more apt description overall. But the term "global warming" is more evocative of this paper's main theme. Global warming is a *global* public-goods externality whose resolution requires an unprecedented degree of international cooperation and coordination. This international climate-change externality has frequently been characterized as the most difficult public goods problem that humanity has ever faced. I concentrate in this paper on carbon dioxide emissions, but in principle the discussion could be extended to emissions of all relevant greenhouse gases. Throughout

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

[a] Department of Economics, Harvard University, U.S.A. E-mail: mweitzman@harvard.edu.

the paper I blur the distinction between carbon dioxide and carbon, since the two are linearly related.[2]

My point of departure throughout all of what follows is the critical centrality of the international free-rider problem as a cause (really *the* cause) of negotiating difficulties on climate change emissions. 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.

In this paper I try to argue that a uniform global price on carbon emissions can provide a focal point for a common commitment, while quantity targets, which do not as readily present such a single focal point, have a tendency to rely ultimately on individual commitments. As a consequence, negotiating a global price helps to solve the externality problem while individual caps essentially incorporate it. I will try to explain why negotiating a uniform carbon price embodies what I call a "countervailing force" against narrow self-interest by automatically incentivizing all negotiating parties to (approximately) internalize the externality.

2. NEGOTIATING PRICES VS. NEGOTIATING QUANTITIES

At first, for simplicity of exposition I assume that a commitment to a global price of carbon will be implemented as an internationally harmonized, but nationally retained, carbon tax.

An internationally harmonized but nationally retained carbon tax (or price) has already been proposed as a potential solution to the global warming externality, and has been examined on its merits.[3] In what follows I very briefly summarize some of the possible virtues of an internationally-harmonized but nationally-collected carbon tax (or price) that have already been noted in the literature. My foil here is an internationally harmonized cap-and-trade system. This kind of global-design comparison is complicated and full of subjective judgements about what might or might not work better in practice and why or why not. Cap-and-trade systems are perhaps more widely used throughout the world to control pollution, and in that sense are perhaps more visible or more familiar than pollution taxes (although fossil-fuel taxes and subsidies are ubiquitous, if somewhat hidden, almost everywhere). My purpose here is merely to indicate that the perhaps less-familiar uniform carbon tax already has some significant arguments in its favor—as a prelude to some new arguments for negotiating a uniform price on carbon that I will later develop in this paper.

Both quantity-based and price-based controls are inherently uncertain for the period during which they apply (in between times of periodic review), but the uncertainty takes different forms. With cap-and-trade, total emissions are known but the price or (marginal) cost is uncertain. With a carbon tax, the price or (marginal) cost of carbon emissions is known, but total emissions are uncertain. On the basis of economic models of climate change that include uncertainty, carbon taxes outperform tradable permits, both theoretically and in numerical simulations.[4] In the real world, above and beyond theory and numerical simulations, I think that energy price volatility is very poorly tolerated by the general public. Swings in carbon prices, especially in extreme cases, could sour public opinion and discredit for some time thereafter (decades, generations?) the entire idea of a market-based approach to the

2. One ton of carbon equals 3.67 tons of carbon dioxide. My default unit is carbon dioxide (CO_2).

3. There is actually a fair-sized literature on a carbon-tax (or carbon-price) approach. See, e.g., Metcalf and Weisbach (2009), Cooper (2010), Cramton and Stoft (2012), Nordhaus (2007, 2013), and the many further references cited in these works.

4. See Hoel and Karp (2002), Pizer (1999), and Weitzman (1974).

climate change problem. On the other hand, it is difficult for me to imagine the broad public getting quite so upset because total emissions fluctuate.

It has been argued, I think convincingly, that a carbon tax is more easily administered and is more transparent than a cap-and-trade system. This consideration is especially important in a comprehensive international context that would include all major emitting countries. Under international cap-and-trade, governments will allocate valuable emissions permits to their nation's firms and residents. In some places, under some circumstances, there may be a great temptation for kleptocrats to effectively steal these valuable emissions permits and sell them on the international market.

The collected revenues from an internationally harmonized carbon tax remain within each country, and could be used to offset other taxes or even be redistributed internally as lump sum payments. This, I think, is a desirable property. By contrast the revenues generated from an internationally harmonized cap-and-trade system flow as highly visible external transfer payments across national borders, which might be less easily tolerated by countries required to pay other countries large sums of taxpayer-financed money to buy permits.[5]

This extremely brief, and perhaps somewhat biased, discussion of the advantages of an internationally harmonized carbon tax (compared to cap-and-trade) is not intended to be comprehensive. There are also legitimate arguments in favor of internationally harmonized tradable permits and against a carbon tax.[6]

A point in favor of tradable permits, frequently emphasized by its advocates, is the political appeal of giving free allowance permits to carbon-intensive industry groups (as contrasted with taxing them directly on their carbon emissions). As was pointed out, carbon taxes that are internally-levied and collected by a national government could be used to reduce other, more distortionary, taxes—or they could even be distributed directly to the citizenry as lump-sum payments. But this redistribution aspect of a carbon tax is hidden, behind the scenes as it were. Individual firms will prefer, and typically strongly prefer, what they perceive as the lesser burden of freely allocated permits over the greater perceived burden of pollution taxes. Indeed, studies show that the market value of the free allowances is typically significantly greater than the higher compliance costs of decarbonization that are incurred.[7] Firms and countries in a cap-and-trade regime will therefore struggle hard for a larger share of the total amount of freely distributed emissions allocations. The political appeal of freely distributed tradable permits is a double-edged sword. When negotiating emissions caps, a serious income distortion is introduced because a nation is much more concerned with the revenues from its own free quota allocations than it is concerned with overall international social optimality. Auctioning off the allowances would eliminate this income-effect distortion on the individually desired level of free permit allocations, but then we are effectively back in a tax-like system.

Both approaches (an internationally harmonized but domestically collected carbon price, and freely distributed marketable permits) are subject to immense—sometimes seemingly

5. Of course, persuading nations to commit to negotiating a uniform price of carbon in the first place might well involve some "green-fund" equity transfers. Because the imposed "carbon tax" is internally retained within each nation, then, at least for small changes, the green-fund transfers needed to offset increased costs of compliance for price changes are deadweight-loss second-order Harberger triangles of the relatively modest form $(\Delta P \times \Delta Q)/2$. The corresponding international transfers in a cap-and-trade system (which can be either positive or negative, depending, among other things, on initial cap assignments) are first-order immodest rectangles of the form $P \times \Delta Q$.

6. For a critical review of carbon taxes vs. cap-and-trade, see Goulder and Schein (2013) and the many further references they cite.

7. See Goulder et al (2010) and the further cited references therein.

overwhelming—criticisms. In both cases there are innumerable practical details that must be attended to and worked out. In both cases an effective international treaty needs to be binding, which raises uncomfortable issues of enforcement mechanisms and international sanctions. Additionally, there might be mixed hybrid systems. I merely want to establish a level playing field where the idea of an internationally harmonized carbon tax already commands at least as much intellectual respect as an internationally harmonized cap-and-trade system.

The Kyoto approach to global warming was inspired by the ultimate vision of a top-down worldwide treaty limiting the output of each nation's carbon dioxide emissions. It had been wishfully hoped that the highly incomplete Kyoto quantity assignments might have grown over time into a comprehensive binding system of national emissions caps. If these comprehensive caps were freely traded internationally as emissions permits, and if every country had implemented a comprehensive cap-and-trade system internally, it would have caused there to be one uniform worldwide price of carbon emissions, thereby guaranteeing cost effectiveness.

As events played out, Kyoto did not come close to its inspirational vision of an internationally harmonized binding system of emissions caps. By now, the quantity-based Kyoto-type approach has pretty much broken down, leaving the world with a patchwork of sporadic regional volunteerism that does not address centrally how to efficiently correct the critical international externality of global warming.

Throughout this paper I argue that it is very difficult to resolve the global warming externality problem by directly assigning individual quantity targets. A meaningful comprehensive quantity-based treaty involves specifying as many different binding emissions quotas (whether in the form of tradable permits or not) as there are national entities. Each national entity has a self-interested incentive to negotiate for itself a high cap on carbon emissions—much higher than would be socially optimal. The resulting free-rider problem plagues a quantity-based approach. Even if there were a collective commitment to negotiate or vote on a second-stage worldwide total emissions cap, which I will later assume for the sake of argument, disagreements over the first-stage fractional subdivision formula (for disaggregating the negotiated or majority-voted aggregate worldwide quantity cap into individual quantity caps) would make it difficult to enact such a quantity-based approach.[8]

The inspiration for this paper is the perception of a desperate need for some radical rethinking of international climate policy. As a possibly useful conceptual guide for what negotiations might accomplish, I sometimes ask the reader to temporarily suspend disbelief by considering what might happen in a "World Climate Assembly" (WCA) that votes on global carbon emissions via the basic principle of one-person-one-vote majority rule. In this conceptualization, nations would vote along a single dimension for their desired level of emissions stringency on behalf of their citizen constituents, but the votes are weighted by each nation's population.

Right now, anything like a WCA seems hypothetical and futuristic. It presumes a state of mind where the climate change problem has become sufficiently threatening on a grassroots level that world public opinion is ready to consider novel governance structures which involve relinquishing some national sovereignty in favor of the greater good. What might be the justification for a new international organization like the WCA? The ultimate justification is

8. One could try to argue that binding green-fund equity payments are required to get n countries to agree in the first place to negotiate a uniform carbon price, also representing an n-dimensional problem. However, footnotes 5 and 7 suggest that the required green-fund payments may be smaller than the absolute value of the (positive or negative) transfers involved in a cap-and-trade regime that starts off, say, with equal per-capita permit assignments.

that big new problems may require big new solutions. For a world desperately wanting new solutions to the important externality of climate change, perhaps it is at least worth considering establishing a new organization along the lines of the WCA. After all, it is useful to have some concrete fallback decision mechanism behind vague "negotiations" because even with the focus on a one-dimensional harmonized carbon price (or with the focus on a one-dimensional quantity of total emissions), there are bound to be disagreements whose resolution is unclear. I merely assume that it is in the interest of enough nations to forfeit their rights to pollute in favor of a WCA voting solution of the global warming externality. This is truly a heroic assumption at the present time because the WCA does not correspond to any currently-existing international body. Taken less literally, the thought experiment of a hypothetical WCA can still help us to concentrate our thinking and intuition on what negotiations should be trying to accomplish. In other words, I am hoping that the fiction of a WCA might be useful in indicating what might be the outcome of less-formal international negotiations.

It might be objected that a "consensus" voting rule, not a majority voting rule, is employed in negotiations under the United Nations Framework on Climate Change. This "consensus" voting rule has been widely interpreted as requiring near-unanimity. With such a restrictive voting rule, significant progress on resolving the global warming externality is virtually impossible. Surely, a less restrictive voting-like rule, such as majority rule, would render progress more likely, and is at least worth considering.

One aspect should perhaps be emphasized above all others at the outset. The global warming externality problem cannot be resolved without a binding agreement on some overall formula for dividing emissions responsibilities among nations. Volunteer altruism alone will not solve this international public-goods problem. Of necessity there must be some impingement on national sovereignty in the form of an international mechanism for coordinating targets, verifying fulfillment, and punishing non-compliance. The question then becomes: *Which* collective-commitment frameworks and formulas are more promising than which others?

3. THEORY OF NEGOTIATING A UNIFORM CARBON PRICE

In this paper I examine the theoretical properties of a natural one-dimensional focus on negotiating a single binding price on carbon emissions, the proceeds from which are domestically retained. As was previously mentioned, for expositional simplicity, I identify this single binding price on carbon as if it is a harmonized carbon tax. At a theoretical level of abstraction, I blur the distinction between a carbon price and a carbon tax. However, in actuality the important thing is acquiescence by each nation to a binding minimum price on carbon emissions, not the particular mechanism by which this binding minimum price is attained by a particular nation.

A system of uniform national carbon taxes with revenues kept in the taxing country is a relatively simple and transparent way to achieve harmonized carbon prices. But it is not necessary for the conclusions of this paper. Nations or regions could meet the obligation of a minimum price on carbon emissions by whatever internal mechanism they choose—a tax, a cap-and-trade system, a hybrid system, or whatever else results in an observable price of carbon. I elaborate further on this issue in my concluding remarks.

At a theoretical level, I would suggest that the instruments of negotiation for helping to resolve the global warming externality should ideally possess three desirable properties.

1. *Induce cost effectiveness.*
2. Be of *one dimension centered on a "natural" focal point* to facilitate finding an agreement with relatively low transactions costs.
3. *Embody "countervailing force" against narrow self interest by automatically incentivizing all negotiating parties to internalize the externality.*

Using these three desirable theoretical properties as criteria, I now compare and contrast an idealized binding harmonized price with an idealized binding cap-and-trade system.

On the first desirable property, in principle both a carbon price and tradable permits achieve cost effectiveness (provided agreement can be had in the first place).

The second desirable property (low dimensionality) argues in favor of a one-dimensional harmonized carbon price over an *n*-dimensional harmonized cap-and-trade system among *n* nations. Alas, this argument is elusively difficult to formulate rigorously, or even to articulate coherently. My argument here is necessarily intuitive or behavioral and relies on empirical counter-examples. In this case a primary empirical counter-example is the breakdown of the quantity-based Kyoto approach.

With *n* different national entities, a quantity-based treaty involves assigning *n* different binding emissions quotas (whether tradable or not). Treaty making can be viewed as a coordination game with *n* different players. Such a game can have multiple solutions, often depending delicately on the setup, what is being assumed, and, most relevant here, the choice of negotiating instrument. In the case of Kyoto, the world has in practice arrived at a bad quantity-based solution that has essentially devolved to regional volunteerism.

Thomas Schelling introduced and popularized the notion of a focal point in game theory.[9] Generally speaking, a focal point of an *n*-party coordination game is some salient feature that reduces the dimensionality of the problem and simplifies the negotiations by limiting bargaining to some manageable subset, hopefully of one dimension. The basic idea is that by limiting bargaining to a salient focus, there may be more hope of reaching a good outcome. In a somewhat circular definition, a focal point is anything that provides a focus of convergence. The "naturalness" or "salience" of a focal point is an important aspect of Schelling's argument that is difficult to define rigorously and is ultimately intuitive.

The concept of "transactions cost" is associated with the work of Ronald Coase.[10] The basic idea is that *n* parties to a negotiation can be prevented from attaining a socially desirable outcome by the costs of transacting the agreement among themselves. One could try to argue that, other things being equal, transactions costs increase at least proportionally with the number of parties *n*.

In the case of international negotiations on climate change, I believe that both Schelling's concept of a salient focal point and Coase's concept of transactions costs can be used as informal arguments to support negotiating a single harmonized carbon price whose proceeds are nationally rebated. Put directly, it is easier to negotiate one price than *n* quantities—especially when the one price can be interpreted as "fair" in terms of equality of marginal effort. I cannot defend this claim rigorously. At the end of the day, this is more of a plausible conjecture than a rigorous theorem. Whether justly or not, throughout this paper I basically

9. Schelling (1960). See also the special 2006 issue of the Journal of Economic Psychology devoted to Schelling's psychological decision theory, especially the introduction by Colman (2006). Three of the seven articles in this issue concerned aspects of focal points, testifying to the lasting influence of the concept.

10. Coase himself did not invent or even use the term "transactions cost" but he prominently employed the concept. See Coase (1960). For an application of the transactions cost approach to controlling greenhouse gas emissions, see Libecap (2013).

assume that the essential contrast is between one binding price assignment versus *n* binding quantity assignments—and I then proceed to examine the consequences.

The third desirable property is that the instrument or instruments of negotiation should embody a "countervailing force" against narrow free-riding self-interest by incorporating incentives that automatically internalize the externality. I believe this third property is arguably the most important property of all. This "countervailing force" property is inherently built into a price-based harmonized system of emissions charges, but it is absent from a quantity-based international cap-and-trade system, at least as traditionally formulated.

If I am assigned a cap on emissions, then it is in my own narrow free-riding self-interest to want my cap to be as large as possible (whether or not my cap will be tradable as a permit). The self-interested part of me wants maximal leniency for myself. Other than altruism, there is no countervailing force on the other side encouraging me to lower my desired emissions cap because of the externality benefits I will be bestowing on others.

Within a nation, the government *assigns* binding caps. But *among* sovereign nations, binding caps must be *negotiated*. I believe that this is a crucial distinction for the success or failure of a cap-and-trade regime. A Kyoto-type quantity-based international system fails because no one has an incentive to internalize the externality and everyone has the self-interested incentive to free ride. What remains is essentially an erratic pattern of altruistic individual volunteerism that is far from a socially optimal resolution of the problem.

An internationally-harmonized domestically-collected carbon price is different. If the price were imposed on me alone, I would wish it to be as low as possible so as to limit my abatement costs. But when the price is uniformly imposed, it embodies a countervailing force that internalizes the externality for me. Counterbalancing my desire for the price to be low (in order to limit my abatement costs) is my desire for the price to be high so that other nations will restrict their emissions, thereby increasing my benefit from worldwide total carbon abatement. A binding uniform price of carbon emissions has a built-in self-enforcing mechanism that countervails free riding.[11]

In previous work, I have tried to model formally the role of this third "countervailing force" property of an internationally-harmonized but nationally-collected carbon price.[12] I constructed a basic model indicating an exact sense in which each agent's extra cost from a higher international emissions price is counter-balanced by that agent's extra benefit from inducing all other agents to simultaneously lower their emissions via the higher international price.

With further restrictions, the model showed that population-weighted majority rule for an internationally harmonized carbon price can come as close to an optimal price on emissions as the median per-capita marginal benefit is close to the mean per-capita marginal benefit. The key insight from this way of looking at things is that in voting (or more generally negotiating) a universal carbon price, various nations are, to a greater or lesser degree, internalizing the externality. Loosely speaking, an "average" nation is fully internalizing the exter-

11. Later I discuss negotiating one worldwide aggregate emissions cap (contingent upon a previous-round subdivision formula for n fractional targets, set, for example, by a preceding agreement on various target reductions from various baselines). A system based on negotiating aggregate emissions (given a subdivision formula) could, in principle, embody countervailing force against the global warming externality. But, again, I will conclude that negotiating the extra layer of n first-round Kyoto-like fractional subdivision target reductions will likely founder politically when applied on a worldwide scale.

12. See Weitzman (2014).

nality because its extra cost from a higher emissions price is exactly offset by its extra benefit from inducing all other nations to simultaneously lower their emissions via the higher price.

On the price side, a uniform carbon price automatically has the desirable property that cost effectiveness is guaranteed. I think that the formal voting result of the model might perhaps be interpreted somewhat less formally as indicating that negotiating an internationally harmonized (but nationally collected) carbon price may have an important desirable property on the quantity side as well. If the median marginal benefit (per capita) equals the mean marginal benefit (per capita), then the socially optimal carbon price has the property that, roughly speaking, half of the world's population wants the price to be higher, while the other half of the world's population wants the price to be lower. In this situation, the desirable quantity-side property is that the total worldwide output of all emissions might be "close" to being optimal to the extent that the outcome of negotiations mimics the outcome of majority voting. Although the real world is a far more complicated and nuanced place than the restrictive theoretical model that was constructed, I think this voting result is trying to indicate something positive (even if only at an abstract level) about how a negotiated uniform carbon price might possess some overall potential to counteract via internalization the externality of global warming.

4. MIGHT A MODIFIED CAP-AND-TRADE WORK AS WELL?

Previously I listed three desirable features that instruments for negotiating climate change should ideally possess: (1) cost effectiveness; (2) a natural one-dimensional focal point; (3) a built-in self-enforcement mechanism that internalizes the externality. I then explained that an internationally-harmonized but nationally-retained carbon price possesses all three properties, whereas an n-dimensional quantity-based cap-and-trade system at best (if it can be negotiated in the first place) possesses only the first property of cost effectiveness. With n different nations, there will be difficult bargaining over n different caps with no force other than altruism countervailing each nation's selfish desire to be a free rider and secure for itself a large cap on emissions.

But maybe I am being unfair to tradable permits. Suppose we imagine trying to convert the n-dimensional problem of allocating carbon emissions permits into some one-dimensional quantity analogue of a uniform price on carbon emissions. We might imagine a thought experiment where the cap-and-trade negotiators are sitting around a negotiating table and limiting themselves to simple linear formulas for allocating individual emissions caps as a fraction of total world emissions.[13]

Suppose the cap-and-trade negotiators must decide the total amount of emissions E, given a sub-allocation formula for deciding the fraction of emissions permits allotted to each nation. A standard way of conceptualizing this allocation problem for each country is in terms of an assigned fractional emissions reduction from an assigned baseline level. Here I think it is most instructive to view the essence of such an assignment process in terms of a simple linear reduced form that allots emissions permits $E_i(E) = a_i + b_i E$ to nation i (where $\sum a_i = 0$, $b_i > 0$, and $\sum b_i = 1$).

If each nation i would accept as *given* the assigned distributional coefficients (a_i, b_i) and

13. This approach is spelled out in more mathematical detail in Weitzman (2014).

the above sub-allocation formula $E_i(E) = a_i + b_i E$, one might then imagine negotiating over (or even voting for) the total emissions E. *Contingent* upon the distribution of coefficients being accepted as given, this system would seemingly possesses the desirable property of having a one-dimensional locus of negotiations (here the level of total worldwide emissions E). And there is also countervailing force against negotiating for a higher value of worldwide total emissions E. Although each nation i's automatic assignment of a higher individual emissions cap E_i when total emissions E are higher helps directly by lowering its emissions costs, this domestic effect is counteracted by the benefits that each nation would lose from a higher total worldwide emissions level, because then everyone else would also emit more. It appears that such a cap-and-trade system might in principle have desirable focal-point and countervailing-force properties *if* the assigned distribution coefficients were accepted and bargaining were restricted to negotiating total emissions.

But now follow the thought experiment further by asking: Where do the distributional sub-allocation coefficients (a_i, b_i) come from in the first place? They are presumably the result of an n-party negotiating process where there is no countervailing force to the selfish desire of each country to make its own fractional allocation coefficients as high as possible. With n different nations, there will be the usual difficult bargaining over n different distributional coefficients, with no externality-internalizing incentive countervailing each nation's desire to secure for itself a high fraction of emissions—again presumably resulting in a Kyoto-like breakdown.

When a cap-and-trade system is used to control pollution *within* a nation, the government of that nation *assigns* the caps (or the fractions of emissions).[14] In this intra-national case there is a natural symmetry between a one-dimensional price p and a one-dimensional total quantity of emissions E. But there is no international government that has the unilateral power to assign caps or fractions. These caps or fractions must be *negotiated* among sovereign nations. This breaks the one-dimensional symmetry because now one price p is contrasted with the asymmetry of n vested sovereign interests jockeying for the n initial fractional distributions. There is thus a critical distinction between intra-national and inter-national cap-and-trade systems. In the international case the initial distribution of caps is explicitly distributive, resulting in a war of words about who caused the global-warming problem and who should bear the burden of remedying it, who is rich and who is poor, what is fair and what is unfair, and so forth and so on. There could also be a war of words about the green-fund transfers required to induce participation in a uniform-price treaty, but, for reasons elaborated in footnotes 5 and 8 having to do with the difference between first-order and second-order transfers, I think that an internally-retained price treaty takes a lot of pressure off the green-fund payments.

But perhaps a formulation of this generality is biased against cap-and-trade. We might try to imbue the distribution coefficients with dimensionality-reducing salient qualities by imagining "naturally symmetric" focal allocations of the fractional coefficients. One such seemingly symmetric formula might be that each country is assigned the same fractional reduction of emissions from some agreed-upon baseline year. The Kyoto Protocol of 1997 adopted just a little of the spirit of this idea for developed countries alone, with the hope that some variant of it might later be extended to developing countries. The high-income industrialized countries (Annex I) agreed to "binding" commitments (but without any enforcement

14. Admittedly, this is often done in a way that eases special-interest acceptance, such as being allocated for free or almost for free based on something like a uniform reduction of previous pollution levels.

mechanism!) to reduce greenhouse gas emissions in 2012 by an average of 5% relative to 1990 levels (although allowing some individually-negotiated variations around that 5% average). Developing countries were exempt from any "binding" commitments. Overall, the Kyoto Protocol did not come close to fulfilling its initial aspirations. The U.S. and Australia did not ratify, Canada and Japan eventually dropped out, and individual compliance was at best spotty.[15] Furthermore, and perhaps most distressingly, non-Annex I countries have not formally agreed to any actual future "binding" commitments going forward from 2012. The Kyoto experience is subject to multiple interpretations. For me, it largely testifies to the great difficulty of negotiating binding international quantity caps on the major emitters. In the language that I have employed here, it has been overwhelmingly problematic to assign binding quantity-like distributional coefficients on a worldwide basis.

Other seemingly symmetric quantity formulas might also be examined. For example, one might entertain the idea of assigning the same worldwide emissions level per capita. This is a symmetric formula that embodies a certain concept of worldwide fairness, but a cap-and-trade system based on such an initial distribution of caps would involve massive transfers from the developed to the developing countries, which would likely prove politically unacceptable. Besides, even this formula does not address concerns regarding historical responsibility for the cumulative stock of emissions, which would surely be raised. Alternatively, one might imagine negotiating (or even voting on) an identical percentage reduction from some base case of emissions. In this situation, I think, everyone would first argue about the fairness of the baseline emissions that they were initially assigned.

I abstain from further speculation. My point is that no matter what quantity-like initial allocation mechanism I can imagine, an attempt to modify an international cap-and-trade system by making it one dimensional seems likely to founder for essentially the same reasons that an unmodified international cap-and-trade system founders. In a quantity-based system with n different sovereign nations I fear there will be intractable negotiations for n different distributional assignments (a_i, b_i), with no force countervailing each nation's free-riding desire to secure for itself a selfishly lenient emissions fraction of the total emissions E.[16]

Here is what I think is the essence of the one-price vs. n-quantities negotiation problem as elaborated in this section. A quantity-type system based on a formula like $E_i(E) = a_i + b_i E$ involves *two* layers of negotiations. First, the n parties must agree on the quantity-like distributional coefficients (a_i, b_i). Then, second, the parties must agree on the single worldwide aggregate level of emissions E. By contrast, a price-based system involves only *one* layer of negotiation, focused on agreeing to a single one-dimensional uniform price p. This latter is not an easy task, but it would seem generally easier to negotiate one price layer than two quantity layers (whose first layer involves assigning n quantity-like distributional coefficients). Admittedly this argument depends upon a particular way of framing the issue, but it seems to me that, in international negotiations among n sovereign nations, there may be an irreducible asymmetry between one price instrument vs. n quantity instruments.

15. The one bright spot might be considered the European Union, whose emissions trading system could perhaps be interpreted as evolving towards an EU-wide cap (declining annually) with member-state shares increasingly being determined by auctioning permits. I am unsure and somewhat skeptical about the extent to which this EU model might be extended to the world as a whole. For a generally favorable assessment of this possibility, see Ellerman (2010).

16. Bosetti and Frankel (2012) propose a constructive and imaginative allocation formula for emissions permits, but it still looks complicated and contentious to me.

Even while acknowledging that it only involves one layer of negotiations (as opposed to two on the quantity side), one could ask on the price side what might induce *n* countries to agree to a single harmonized charge for carbon emissions. We have been over this ground before. It all begins with the recognition that any resolution of the global warming free-rider problem requires a collective commitment to some binding restriction on the sovereign right of nations to freely emit as much carbon dioxide as they wish. Why might nations restrict their own sovereignty by collectively committing to a common price regime for resolving the global warming externality? Perhaps because enough of them come to realize (or are made to realize) that the international climate-change public good is sufficiently important to outweigh national rights to pollute the global commons—and that a radical collective problem may call for a radical collective solution. Without such a realization and the will to act upon it, progress on resolving the global warming externality will be limited to voluntary altruism, which seems not nearly enough to overcome the free rider problem.

5. CONCLUDING REMARKS

At the end of the day, there is no airtight logic in favor of a negotiated price over negotiated quantities, only a series of partial arguments. One argument is that the revenues from a carbon price are nationally collected, so that the contentious distributional side is somewhat hidden and there is at least the appearance of fairness as measured by equality of marginal effort. A second desirable feature, I have argued, is the natural salience and relatively low transaction costs of negotiating one price as against negotiating *n* quantities, which, while somewhat imprecise, is in my opinion an important distinction. A third argument is the self-enforcement mechanism that constitutes the main theme of this paper, namely the built-in countervailing force of an imposed uniform price of carbon, which tends to internalize the externality and gives national negotiators an incentive to offset their natural impulse to otherwise bargain for a low price.

Of necessity, my argument has been sprinkled with subjective judgements. This, unfortunately, is the nature of the subject. To repeat yet again, this time after examining somewhat more carefully the alternatives, I judge it difficult to escape the conclusion that, in the context of an international treaty that covers all major emitters, it is more politically acceptable and it comes closer to a social optimum to negotiate one binding price than *n* binding quantities or quantity-like distributional coefficients.

My argument here is sufficiently abstract that it is open to enormous amounts of criticism on many different levels. There are so many potential complaints that it would be incongruous to list them all and attempt to address them one by one. These many potential criticisms notwithstanding, I believe the argument here is exposing a fundamental countervailing-force argument that deserves to be highlighted.

Because the formulation is at such a high level of abstraction, it has blurred the distinction between a carbon price and a carbon tax. As was previously noted, the important thing is acquiescence by each nation to a *binding minimum price* on carbon emissions, not the particular internal mechanism by which this obligation is met. A system of national carbon taxes with revenues kept in the taxing country is a relatively simple and transparent way to achieve harmonized carbon prices. But it is not necessary for the conclusions of this paper. Nations or regions could meet the obligation of a minimum price on carbon emissions by whatever internal mechanism they choose—a tax, a cap-and-trade system, a hybrid system, or whatever

else results in an observable price of carbon.[17] And any nation or region could choose to impose a carbon price above the international minimum. The hope is that even a low positive initial value of a universal minimum carbon price could be useful for gaining confidence and building trust in this price-based international architecture.

The purpose of this paper is primarily expository and exploratory. *Any* proposal to resolve the global warming externality will face a seemingly overwhelming array of practical administrative obstacles and will need to overcome powerful vested interests. That is the nature of the global warming externality problem. The theory of this paper seems to indicate that negotiating a uniform minimum price on carbon can have several desirable properties, including, especially, helping to internalize the global warming externality. To fully defend the relative "practicality" of what I am proposing would probably require a book, not an article. In any event, *this* article is not primarily about practical considerations of international negotiations. I leave that important task mostly to others.[18] However, I do want to mention just a few real-world considerations that have been left out of my mental model yet seem especially pertinent.

An example of a relatively small practical issue that I am waving aside is just where in the production chain a carbon price should be collected. I think the presumption would be that the carbon price should be collected by the country in which the carbon dioxide is actually released into the atmosphere. One might try to argue that a carbon price should be collected downstream as close as possible to the point where the carbon is burned. But this would involve an impractically large number of collection points. It is much easier to collect the price upstream, at various chokepoints where the carbon is first introduced into the carbon-burning economy.[19]

A truly critical issue is that a binding international agreement on a uniform minimum carbon price requires some serious compliance mechanism. To begin with, the carbon price must be observable. For enforcement, perhaps there is no practical alternative to using the international trading system for applying tariff-based penalties on imports from non-complying nations. Nordhaus (2015) advocates such an approach with uniform border tariffs on imports from non-member countries imposed by a "climate club" of member nations who agree to impose on themselves a harmonized carbon price. Cooper (2010) has argued for an expansive interpretation whereby the internationally agreed charge on carbon emissions would be considered a cost of doing business, such that failure to pay the charge would be treated as a subsidy that is subject to countervailing duties under existing provisions of the World Trade Organization.[20]

An efficient carbon price naturally produces more winners than losers (by the metric of the modified Pareto criterion). In the case of the global warming externality, which has been characterized as the greatest public goods problem of all time, it seems reasonable to suppose that there might be many times more winners than losers from imposing a uniform carbon price. Because countries here get to keep their own carbon-price-generated revenues, then welfare-compensating transfers, to the extent they are made at all, ought, at least for small

17. A minimum carbon price could be attained in a cap-and-trade system by setting it as a floor, which could be enforced, e.g., by making it a reserve price on the auctioning of permits.

18. See, e.g., Bodansky (2010) or Barrett (2005).

19. This set of issues and its distributional consequences (including references to other literature) is discussed extensively in Asheim (2012).

20. See also the discussion of the legality of such sanctions under WTO provisions in Metcalf and Weisbach (2009).

changes, to be relatively modest second-order deadweight-loss triangles instead of the relatively immodest first-order rectangle transfers associated with tradable permits from, say, an initial assignment of caps that are equal per-capita.[21]

I close by noting again that global warming is an extremely serious as-yet-unresolved international public goods problem. With the failure of a Kyoto-style quantity-based approach, the world has seemingly given up on a comprehensive global design, settling instead for sporadic national, sub-national, and regional measures. These partial measures seem far from constituting a socially efficient response to the global warming externality. Perhaps, as was previously suggested, the Kyoto-style quantity-based focus on negotiating emissions caps embodies a bad design flaw. The arguments of this paper indicate a way in which negotiating a binding internationally-harmonized nationally-collected minimum price on carbon emissions might help to internalize the global warming externality.

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21. Cramton, Ockenfels, and Stoft (2015) make an analogous argument in the form of a numerical example indicating that committing to a price tends to be less risky than quantity targets. Thus, according to this reasoning, equity transfers under cap-and-trade would have to be larger than equity transfers under a uniform price because of the increased risk imposed by caps. In a separate argument, they also indicate that choosing a particular green-fund equity-payment formula to encourage participation in a uniform price regime can itself be reduced from a seemingly n-dimensional problem to a one-dimensional focal problem.

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An International Carbon-Price Commitment Promotes Cooperation

PETER CRAMTON,[a] AXEL OCKENFELS,[b] and STEVEN STOFT[c]

ABSTRACT

To promote cooperation in international climate negotiations, negotiators should focus on a common commitment. Such commitments have the advantage of facilitating reciprocal "I will if you will" agreements in a group. Reciprocity is the basis for cooperation in repeated public goods games, and a uniform price would provide a natural focal point for a common international commitment. Such a price is also essential for efficient abatement. Countries would retain flexibility in how to implement the price—with cap-and-trade, a carbon tax, or a hybrid approach. Country risk is reduced relative to risk under international cap-and-trade since carbon revenues stay within the country. Price commitments also tend to equalize effort intensity and can facilitate enforcement. To encourage participation by less-developed countries, a green fund is needed to transfer money from richer to poorer countries. Transfers are smaller and more predictable with a uniform price commitment than with international cap and trade.

Keywords: Climate change, global warming, carbon pricing, international public goods, UN climate negotiations, prices versus quantities

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HOW A COMMON COMMITMENT PROMOTES INTERNATIONAL AGREEMENT

For twenty years, climate negotiators have been stymied by the most challenging tragedy of the commons ever encountered. The central problem is well understood. All countries can use the atmospheric commons for free, but only a small fraction of the benefits of investing in CO_2 reductions accrue to the country that incurs the cost of such an investment. As a result, self-interested countries rationally invest too little in CO_2 abatement, and instead attempt to free-ride on the hoped-for investments of others. Indeed, "climate change is a public good (bad) par excellence" (Arrow 2007).

The Kyoto process started with a natural approach to breaking the free-rider deadlock: agree on a *common commitment*. A common commitment helps realign self-interest with the common good by assuring all parties that they will only be required to contribute to the common good if all are required to follow the same commitment rule. This "I will if you will" feature is critical for solving problems of the commons.[1]

1. We will return to this later. For the moment, observe that democracies habitually solve national public-goods problems by voting on a common commitment. Usually this is a commitment to pay a uniform tax with revenues used for public goods, such as parks, highways, education, defense, or cleaning up toxic waste. Voting for a tax is an organized approach to saying "I will adhere to the common commitment if you will."

[a] University of Maryland, U.S.A.
[b] University of Cologne, Germany
[c] Berkeley, U.S.A.

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A common commitment needs to be enforced like any other commitment. Yet the fairness that comes with protection from exploitation offered by a reciprocal common commitment removes one reason to defect. Also, since defecting will weaken the common commitment and hence jeopardize the contributions of others, a well-structured common commitment automatically embodies some enforcement.[2] Moreover, as we show below, a price commitment reduces risks compared to quantity commitments, and thus reduces the needed size of the enforcement penalty.

In a nutshell, a common commitment facilitates the collective reciprocity which is the only known way of overcoming free riding—the central problem of climate negotiations (Weitzman 2015a). Moreover it is likely a necessary precursor to the implementation of effective enforcement. Yet Kyoto failed to find such a commitment. This failure was no accident. The quantity commitments needed for international cap-and-trade preclude a common commitment. This paper suggests this deficiency of quantity commitments is the motivation underlying the proposals for an international price commitment by Cooper (2004), Nordhaus (2013), Stiglitz (2015), Weitzman (2015a) and ourselves.

WHY KYOTO FAILED

Initially, many countries supported a common commitment by all to reduce their emissions by an equal, agreed percentage below their 1990 emission levels. Such a general percentage-reduction rule—as opposed to individually pledged percentages—would constitute a common commitment. But many disagreed, and at least ten other formulas were developed and considered. After many failed attempts, the resolve to forge a common commitment was broken and replaced with a resignation to accept *individual* commitments. Indeed, even before concluding the negotiations, Chairman Estrada allowed parties "to negotiate their own targets," and finally "invited Annex I Parties to submit their revised, final, numbers to the podium" without any restrictions (Depledge 2000, ¶192, 214).

The EU offered a 15% emission cut with a common commitment, but accepted only 8% when that failed.[3] Russia accepted 0%, Australia and Iceland accepted 8% and 10% increases respectively, and the US, a 7% cut which was not serious. Of course the developing countries accepted nothing, and the EU's 8% reduction masked cuts that ranged from 30 percent to an increase of 40%. The 95 to 0 rejection by the US Senate was explicitly linked to the fear of free riding although there were other motives as well. The lack of an acceptable common commitment meant there was little check on free riding, but if any common commitment had been forced on the parties, the outcome would have been worse, which is why none was agreed to.

The Kyoto negotiations were right to focus on the search for a common commitment, but what they proved, after more than a year of searching, was that no common *quantity* commitment can be found. The result was a weak and fragile international cap and the mistaken conclusion that a common commitment is impossible. The mistake was accepting the international-cap-and-trade straight jacket as inevitable.

Interestingly, the Kyoto Protocol also failed to achieve its second goal, equalized prices. International permits were implemented in the form of Assigned Amount Units (AAUs). The

2. In other words, a treaty based on a common commitment is a partially self-enforcing treaty.

3. Kyoto Chairman Estrada personally suggested the target of "8% below 1990 emissions" for many countries, and many adopted his suggestion when submitting their final pledges.

Soviet Bloc's AAUs are referred to as "hot air" in the popular press and, in fact, some AAU trades that took place simply enriched those in Eastern Europe who faced no burden from the Kyoto Protocol. Because trading was seen as inappropriately redistributional and evasive of climate commitments, AAU trading became so controversial that Japan had to publicly deny purchasing AAUs from countries previously in the Soviet Bloc.[4] And now the U.N. has restricted AAU trading.[5] As a result, and because of political uncertainties (Edenhofer et al. 2014) and various regulatory interventions (Marcantonini and Ellerman 2014), quantity commitments did not lead to anything like the hoped-for equalization of carbon prices.

Stiglitz (2006b, 2015) has explained why there is no reason to believe anyone will ever come up with a quantity-based emissions rule. The history of the Kyoto negotiations strongly confirms that requiring quantity targets will block any hope of a broad common commitment even without including the developing countries. The US government has now come to the same conclusion.[6] Without a common commitment, any agreement, if one could be reached, would again be weak and fragile. And it would not produce anything like a uniform price on carbon. Kyoto was a useful experiment, but the world learned the wrong lesson.

KYOTO'S LEGACY FOR PARIS

In response to Kyoto's dramatic failure, and then Copenhagen's, the idea of striving for a common global commitment has been abandoned on the way to Paris. Rather, it is hoped now that individually-selected quantity targets will cover the bulk of global emissions with sufficient stringency. Indeed, the plan for Paris is to let every country simply pledge to do whatever it wants. There will be reviews without consequences for hundreds of incomparable proposals (Gollier and Tirole 2015). And if countries fall short of their pledges, there still will be no consequences.

This pledge-and-review approach for Paris is unlikely to work. As the Kyoto Protocol demonstrates, individually adopted targets do not change self-interest, at least not by enough to notice. The reason is that such agreements are not of the "I will if you will" type. In fact, under the Kyoto Protocol, several countries, including the US, Canada, New Zealand, Japan and Russian, have said "We won't" while the others continue to say "We will." So the Protocol is an "I will, even if you won't" agreement. This is an agreement of nations acting altruistically—a coalition of the politically willing. But, as explained by Gollier and Tirole (2015), there is no reason to suppose that altruism can solve the tragedy of the commons. Conditional cooperation in the vein of "I will if you will," on the other hand, provides a strong source of cooperation, as explained by Weitzman (2015a). Indeed, conditional cooperation is the most robust pattern of cooperation seen in laboratory, field and theoretical studies of free-rider situations, and is—unlike unilateral altruism—consistently found to stabilize higher cooperation levels. Numerous studies show that conditionally cooperative strategies can promote

4. "Japan is defending itself against criticism that it's exploiting a surplus of Kyoto assigned credits and using 'hot air' to meet emission targets." Bloomberg, 23 July 2009. The importance of high-profile political ramifications caused by unpredictable public transfers between rival countries was anticipated by Cooper (2004), "*What US Senator, once s/he understands the full implications of a trading regime, can vote for a procedure which could result in the unconditional transfer of billions of dollars, even tens of billions, to the government of communist China, or to Castro's Cuba, or even to Putin's Russia?*"

5. "After tense negotiations, countries decided to restrict how much of this [AAU] surplus can be used for compliance with emission reduction targets." Doha, March 2013, carbonmarketwatch.org/doha-on-aaus-the-future-of-the-phantom-menace.

6. In its 11 March 2013 submission, the US stated, "It is hard to imagine agreement on any formula or criteria for imposition of contributions, as this would get into the most controversial issues."

cooperation levels among selfish players well beyond what is theoretically sustainable. One reason is that conditional cooperation—unlike unilateral altruism—is considered fair (see Bolton and Ockenfels 2000, Cramton et al. 2015, Hauser et al. 2015, Kraft-Todd et al. 2015, and the references therein).

This is why we advocate that negotiations again focus on a common commitment. While a common *quantity* commitment proved infeasible, we argue that a common *price* commitment can substantially mitigate many of the problems associated with quantity commitments (see also Stiglitz 2015, Weitzman 2015a). One reason is that there is near-unanimous agreement that each country should commit to the same price, which thus constitutes what Schelling (1960) calls a focal point. Such a common commitment makes possible the type of agreement that changes self-interests for the better: "I will commit to the common price if you will."

The difference between the two commitments, price and quantity, has been overlooked in part because the two can be economically equivalent in a world without uncertainty. A global cap induces a carbon price, and taxing carbon at that price would limit emissions to that cap. But for reaching agreements, the two targets are substantially different. Before exploring that in more depth, it is useful to review why international commitments do not automatically induce specific national policies.

INTERNATIONAL COMMITMENTS ARE NOT NATIONAL POLICIES

Economists sometimes imagine that caps or taxes could be implemented by an international tax-collection agency or by an international cap-and-trade market covering a large majority of each-country's carbon emissions. Such plans assume a dose of top-down regulation that is presently infeasible.

However, a different pair of alternatives requires no such top-down apparatus and would allow countries tremendous flexibility. Under these alternatives, countries simply commit to a set of quantity commitments (regarding carbon permits) or to a price. Either type of commitment could be met by national or regional cap-and-trade markets, fossil-fuel taxes, or any mixture of these along with bonus-malus systems applied to, for example, auto emissions estimated at the time of sale. An example of a mixture is the EU's reliance on a weak cap-and-trade market and a strong tax on carbon in the form of a tax on oil. Another possibility is cap-and-trade with a floor price. This flexibility should minimize the acrimonious debate over caps and taxes to the extent possible, since all countries could adopt linked cap-and-trade markets under either a global price commitment or a global quantity commitment. And countries also comply with either commitment by using fossil-fuel taxes.

DEFINING A GLOBAL PRICE COMMITMENT

A country that commits to the global price only needs to meet the commitment on average. The average carbon price is simply the country's carbon revenues divided by its emissions. The revenue can, of course, come from selling permits under cap-and-trade, from fossil fuel taxes, or from calculations on other pricing-compatible regulation.

There should be some restrictions on how unevenly a country prices its carbon. For example exports should face a price rather close to the global price. (And the same is true under an international cap.) But we will not get into such details.

Also, our definition leaves a question of how to count pre-existing taxes. There are at least two views on this. For accounting simplicity, all carbon charges would be counted towards compliance. This is the approach that we would prefer for pragmatic reasons. Another view is that this would be true after some base year, say 2015, and the fossil-fuel tax rate in that base year (excluding any taxes imposed for climate reasons) would be subtracted from all future carbon-price measurements. Both approaches are quite simple, and from an implementation point of view, the only difference is that the second approach requires a one-time accounting of fossil-fuel tax revenues at the start. There is no need to untangle taxes by purpose after the initial accounting and even that may be unnecessary. So there is no possibility of gaming the commitment by saying a non-climate tax is for the climate. Going forward all taxes count.

Of course, it is inefficient to credit a new tax to pay for highways as if it were a carbon tax for the climate (Gollier and Tirole 2015). But this is simply the minor inefficiency of not having a perfectly uniform tax—which seems even more out-of-reach with an international cap-and-trade scheme, as we will explain below.

PRICE VERSUS QUANTITY COMMITMENTS: A COMPARISON

This paper argues for correcting the flaw that derailed the Kyoto process and for returning to Kyoto's sound fundamental principle: agree on a common commitment that leads to (fairly) uniform carbon pricing. And it proposes to do so in the most straightforward way—by using a global price commitment. Similar views have been expressed by Cooper (2004, 2008), Nordhaus (2013), Weitzman (2014, 2015a), and Cramton and Stoft (2012a, b).

While a single price commitment would be effective and is within reach, as we discuss throughout this paper, it appears impossible to agree on n national quantity commitments. Stiglitz (2015) has made the case that there is no way to achieve a compromise between rich and poor countries regarding quantity commitments, and Weitzman (2015a) too argues that quantities cannot be successfully negotiated. We add that history confirms this. The hope of finding a common quantity commitment was high at the start of the Kyoto treaty but has declined steadily ever since to the point where no one any longer mentions the possibility. Neither is there any discussion of how individual quantity commitments might be negotiated, even in this symposium which raise this as the central topic for discussion. This explains why we will not attempt to refute any arguments that quantity commitments, common or individual, could be successfully negotiated. Rather, we will focus on comparing the two negotiation processes in terms of reciprocity and common commitments.

Importantly, cap-and-trade advocates and tax proponents nearly always agree that a uniform global price is the desired outcome. So unlike quantity, for which there is little if any agreement on the appropriate common commitment rule, there is nearly universal agreement that a common price commitment should be a uniform price commitment (or more precisely a uniform price floor). That is, a uniform price is a natural focal point. This facilitates negotiations about the price commitment (Weitzman 2015a, Schelling 1960).

There is an apparent, but not actual, symmetry between the global cap of Gollier and Tirole (2015) and the global price of our approach. Gollier and Tirole suggest a cap corresponding to 2°C, which is likely a focal point. Also, as they point out, negotiating a cap avoids the free-rider problem much like negotiating a price. However, there is an important difference. While a global price is a common commitment, a global quantity is only a common

aspiration. Individual countries can implement the global price, and their commitment to the price is in principle enforceable. But no country can implement the global cap. And an aspiration cannot be enforced.

The practical benefit of a price commitment is that it takes us most of the way to the set of final commitments. It resolves who will do how much for the climate, and of course it can also strive to reach the 2°C goal or any other focal climate goal. It leaves only the question of equity transfers to be resolved. This is still a crucial and difficult question (and we will get to it below) but focusing on price helps to disentangle it from the larger question of climate efforts.

Another advantage is that price is an inherently more fair measure of effort intensity than is a Kyoto-style quantity measure. The US has tried to persuade India to commit to a cap in the vicinity of its emissions level, which would have been lower than the per-capita emission of the US in 1880. Not surprisingly, India rejected this idea. Accepting a carbon price would not limit India to any lower emission rate or "intensity rate" than the US, and would even allow India to emit as much or even more per-capita than the United States. A price treats India more equitably and it is at least as efficient as a cap that induces the same carbon emissions.

Monitoring and corruption

For the two global commitments (as opposed to national policies) there are two main questions that will determine which is best. The first concerns reaching an agreement (discussed above), and the second concerns whether compliance can be verified. Here we discuss verification.

Local monitoring and corruption. Under a commitment to either price or quantity, it is possible for emitters to bribe the carbon-tax collector or the carbon-permit collector (Victor 2001, Tirole 2012). Such corruption will impose an inefficiency on the country but will not disrupt the enforcement of the international commitment, which only requires information of a more aggregate nature. If a power plant dodges its carbon charge, national carbon revenues are reduced. So the country must charge other emitters more to meet its average-price commitment, but the national commitment is still verifiable.

National monitoring and corruption. Emissions should be measured by monitoring the inflow of fossil fuel from extraction and from net imports. Even so, with over 500 coal mines in India and over 18,000 in China, emissions monitoring could be poorly enforced or deliberately distorted. Similarly, under a price commitment, national carbon-pricing revenues could be falsely reported. Although this could be a serious problem in a number of countries, there are several ways to mitigate such problems. There could be monitoring by the IMF, World Bank, IEA or WTO, all of which do some similar monitoring already. Countries receiving green funds could be required to open their national accounting books in order to receive such funds.

Finally, most real carbon pricing will be reflected in visible prices at gas stations, in home heating bills and in retail electricity prices. These prices could be easily monitored. So verification is possible under either commitment, but in a few countries it may require a significant effort. Both commitments would include a requirement to allow verification, and any country that did not cooperate would be considered to be out of compliance and would be sanctioned just as if it had not met its price or quantity commitment.

International monitoring and corruption. On a global level, the corruption problem is asymmetric. Suppose a local official, on behalf of a kleptocratic ruler, allows a company to under-report emission so that it needs fewer carbon permits. The kleptocrat then sells supposedly-surplus international carbon permits to a perfectly honest country. As Nordhaus (2008) explained, both the government and private company benefit, because this shifts money from honest to corrupt countries. It also crowds out the honest country's abatements.

Conclusion on monitoring. Proponents of international cap-and-trade claim a carbon price cannot be monitored. Yet they claim that cap-and-trade will solve the export-import problem that results from international carbon-price differentials. But as we saw above, equality of nationally-traded permit prices says nothing about the price of carbon emissions from exporters or from anyone else. So the export-import problem can only be solved by monitoring the carbon prices paid by exporters. In other words, a crucial claim of cap-and-trade proponents relies on the assumption that carbon prices can be monitored accurately under the worst of conditions—at the local level, in industries where (unlike at gas stations) the price can be camouflaged, and where there is, perhaps, the strongest incentive for corruption.

Overall, looking at the various arguments in favor and against each commitment type with respect to monitoring and corruption, we tend to agree with Nordhaus (2008) who concludes, "quantity-type systems are much more susceptible to corruption than price-type regimes," and with Cooper (2008) who concludes that a global cap-and-trade system "will unavoidably foster rampant corruption."

Will carbon emission actually be priced?

The point of international cap-and-trade is usually viewed a*s imposing on "all* CO_2 emitters the cost of their damage to the climate."[7] The result of this would be an *economically* efficient reduction in emissions. This efficiency is a central goal of the policy, partly because cost reduction is a great help in making a strong policy sustainable. Environmentalists, however, generally have quite a different goal for cap-and-trade. Their view is that the price doesn't matter but that the cap is a good old-fashioned command-and-control mechanism.

So the question is, will *international cap-and-trade* induce a uniform and efficient carbon price as economists would like, or will it produced an inefficient mix of national command-and-control policies? Let us look at the Kyoto protocol, which priced international permits and allowed any national policy. This is also specified by Gollier and Tirole, who note that within the OECD countries, there were direct subsidies to green technologies which resulted in implicit carbon prices that range from "less than 0" to "as large as 1,000 €." It is likely that most of this range was spanned within countries that were under the Kyoto Protocol. Gollier and Tirole conclude that such policies demonstrate "the inefficiency of this command-and-control approach."

In other words, in the only test case, the outcome was, by and large, not what economists hoped for but rather the inefficient command-and-control policies. Two conclusions seem evident. International cap-and-trade need not induce much if anything in way of actual carbon pricing, and it may leave the current command-and-control approaches untouched. In other words, international cap-and-trade may not achieve the central objective of its proponents, but rather, the opposite.

7. From sites.google.com/a/chaireeconomieduclimat.org/tse-cec-joint-initiative/some-economic-perspectives, accessed 14 July 2015.

Committing to a price is less risky

Quantity targets are favored because they supposedly remove the risk of emission and climate uncertainty and shift that risk to nations in the form of price and cost uncertainty. While their success at limiting climate risk has been dismal, in part due to the uncertainty of the resulting quantity agreements and disagreements, quantity targets do impose risks on the countries that adopt them.

More specifically, accepting a quantity commitment entails risk, because future business-as-usual (BAU) emissions and abatement costs are both highly uncertain. Suppose that a country expects BAU emissions of 100 Mt and considers two commitments: (1) a quantity reduction to 90 Mt and (2) a price of $20/t. Assume these are equivalent (they both cause the same price and same emission quantity). Furthermore, assume that the global carbon price will be $20/t.

Now suppose, that the country's BAU emissions turn out to be 110 Mt (10 Mt higher than expected). Under the quantity commitment, the $20/t global price will reduce emissions 10% to 99 Mt. But the country will only have been issued 90 Mt of permits, so it will need to buy 9 Mt of permits on the world market for a cost of $180 M. Under a price commitment, the country simply sets its carbon price to $20/t as if nothing had changed.

Even though the price-commitment policy specifies that countries keep all of the carbon revenues from pricing carbon, there is still a social cost. To find that cost, note that the more that is abated, the greater the cost per ton abated, with the per-unit cost starting at $0/ton and reaching a maximum of $P/ton. So the standard estimate of the cost of abatement, A, under carbon price, P, is $A \times P/2$, or in this case 11 Mt $\times$ ($20/t)/2, which equals $110 M. This cost occurs under either policy because the global price of $20 causes 11 Mt of abatement in both cases.

Hence the total cost under the quantity commitment is $180 M + $110 M = $290 M. That's 2.6 times as much as the $110 M cost under the price commitment. But some cost was expected to occur under the expected BAU emission of 100 Mt. That expected cost was 10M $\times$ $20 / 2, or $100 M. So the unexpected cost under the quantity policy is $290 M − $100 M = $190 M, while the unexpected cost under the price commitment is $110 M − $100 M = $10 M. The financial risk from a possible 10% shock to BAU emissions in this example is 19 times greater with caps than under a price commitment.[8]

This example does not exaggerate the risks of quantity commitments. In 2000, the US DOE's International Energy Outlook predicted China's 2010 emissions would be 1.5 Gt, but in the event, emissions were over 7 Gt—nearly a 400% error rather than the 10% error assumed in the above example. And quantity targets generally have been set 10 to 15 years in advance. Moreover quantity errors can have a high political sensitivity. If China had committed to a cap in 2000 equal to its expected BAU emissions (not reduced by any cooperative climate efforts) it would have been purchasing over 5 billion tons of permits annually by 2010 from, perhaps the US and the EU. This would have likely cause a dramatic permit shortage and high carbon prices, but even at $20/ton this comes to $100 billion per year in highly visible transfers to foreign countries. If China had made anything like the quantity commitments desired of it by cap-and-trade advocates at that time, quantity risks would have likely destroyed

8. Based on our example, Weitzman (2015b) has recently shown in a rigorous and general model, that under uncertainty, internationally-tradable permits expose a country to unambiguously greater risk than the imposition of a uniform carbon price whose tax proceeds are domestically retained.

that international quantity commitment and any associated cap-and-trade treaty. China was right to reject such quantity commitments.

Enforcement

A major advantage of monitoring and enforcement of a price commitment is that it is an annual rather than a once-in-15-year event, like the Kyoto Protocol or like China's recent commitment to cap emissions in 2030. This creates free-riding incentives and diffuses responsibilities among successive governments within countries, and makes it difficult to repair non-compliance. Annual price commitments have the advantage that cheating can be quickly detected, and can be quickly corrected, because full compliance can be achieved simply by increasing the carbon charge. Indeed, frequent monitoring is known to be one of the most critical aspects of self-enforcing cooperation (Ostrom 1990).

Gollier and Tirole (2015) propose a fix for this problem: "countries will have to match pollution and permits at the end of the year to avoid creating unfulfilled climatic debt." Unfortunately, this proposal blocks banking and borrowing of permits, the standard method of mitigating the volatility of permit prices. Such price volatility is likely to be unpopular with investors and the public.[9]

Successful enforcement is one key to successful cooperation (Nordhaus 2015). We have argued before that cooperation based on a common commitment is relatively easy to enforce, because the common commitment enables a reciprocal relationship, which is known to promote cooperation. Here we argue that a common price commitment facilitates enforcement compared to a quantity commitment. One reason is that a price commitment is continuously monitored and thus more easily enforceable (see above). Another reason is that it reduces risks (as discussed above). Risks can produce strong incentives to leave or avoid a quantity commitment. Without such strong negative incentives, the needed size of the enforcement penalty is reduced. Finally, price commitments reduce the required size of equity transfers (as we describe below), which also reduces the needed size of the enforcement penalty.

There are various complementary mechanisms that can further ease the enforcement of price commitments. For instance, efficient performance, which we borrow from modern electricity markets where deviations from plans are settled at the market price for carbon revenues. In other words a country that exceeds its commitment can sell its excess performance to a country that falls short. This guarantees that plans are met in aggregate and yet gives countries the flexibility to easily and efficiently react in an uncertain environment. Efficient resolution of deviations from plans greatly reduces risks, facilitates performance, and encourages participation.

The waiting game

Gollier and Tirole (2015) explain that negotiations that are currently ineffective but are likely to eventually result in individual pledges contribute to what they call the "waiting game." The result of this game is that present behavior, while waiting for an agreement on individual commitments, can be even worse than the outcome of the non-cooperative Nash equilibrium of the public goods game—worse than without any thought of cooperation.

9. In that respect, the first trading period in the context of the EU-ETS provides a good lesson of undesired price effects when banking and borrowing is not allowed.

The problem does not arise if a *common* commitment is expected to be the eventual outcome. Yet if individual climate commitments are expected, it pays countries to jockey now for position in the final round of commitments. For example, if it is expected that commitments will be made relative to 2020 emissions or some future BAU emissions, then it pays to not take easy actions to reduce emissions before 2020.

But if the eventual commitment will be a common price, then having higher emissions in 2020 will simply mean more emissions will be taxed at the global price. This confers no advantage on the recalcitrant country. That is, deciding now to agree on a common price ends the waiting game now, even though there is still a wait for the actual agreement.

THE ROLE OF THE GREEN FUND AND EQUITY TRANSFERS

Equity transfers are less expensive with price commitments

Agreeing on price as the indicator of global action opens the door to a common commitment. But poorer countries like India will feel that they should receive significant help with it. Fortunately, this is relatively inexpensive. Since India's carbon-pricing revenues would stay in India, pricing India's two billion tons of emissions at $20 per ton will have a *net* cost to India of only about $2 B if emissions were reduced 10%—far less than the planned $100 B per year Green Climate Fund. This is not to suggest that India should be given an exception to the common commitment. Rather, the common commitment should include a green-fund formula for providing assistance from richer, high-emission countries to poorer, low-emission countries. In this way, the common pricing commitment would respect the UN's principle of "common but differentiated responsibilities."

Equity transfers need not be as high with price commitments, because risk is lower. As seen in the above example of price and quantity risk, if a country expects a $100 M cost of abatement, but there is a risk that its BAU emissions will be unexpectedly high by 10%, this would add $190 M in the case of a quantity commitment and only $10 M in the case of a price commitment. If the country demands that this risk be covered by equity transfers, these will need to be $180 M larger in the case of a quantity commitment. Politically it seems difficult for a poor country to risk having its equity transfer obliterated by a miscalculation of future BAU emissions.

Choosing a green fund formula

By committing to a uniform global price, we have confined the differentiated-responsibilities problem to the green-fund formula. This makes possible a natural, and less-divisive, principle for national differentiation. The new design principle is to choose the green-fund formula that maximizes global emissions abatement.

This suggests a two-step design: first select the green-fund formula, then choose the common price. This is similar to many political processes in which it is common to specify the payment and benefit structure before deciding how much to spend on a program, say a school system. If voters are pleased with the payment-benefit structure they will be generous in voting for a strong program. If they are displeased they will be less generous. This arrangement gives those designing the payment-benefit structure, in this case the green-fund structure, a strong incentive to design the structure to please all of those whose support is needed. It also allows the funders to have peace of mind when the funders delegate authority to those

negotiating the structure—first because they know that they can reject or minimize the proposed structure if it is not to their liking, and second because they know the negotiator/designers will be well aware of this.

Compare this to the cap-and-trade alternative, which is also a two-step approach. First the global cap Q is selected and then the permit allocations $\{A_i\}$ are negotiated. But, as noted above, Q is an aspiration and not a commitment, so all of the work of solving both the climate-effort problem and the equity-transfer problem are bundled into the single step of negotiating $\{A_i\}$. In contrast the two-step approach of pricing breaks the problem in two—choosing climate effort (P) and negotiating equity transfers $\{G_i\}$—this simplifies both negotiations. Then it links the two halves so that the availability of the step-two price decision provides good incentives for, and confidence in, the green-fund design process. And the green-fund design is properly focussed on making the price negotiation successful. This is why the "$\{G_i\}$ then P" negotiation process can outperform the "Q then $\{A_i\}$" process.

We now describe, for the sake of concreteness, a possible pair of negotiating procedures, beginning with the step-two price negotiation. To set the price, countries pledge their highest acceptable global price target, taking the step-one green-fund formula into account. Then the highest price target acceptable to, say, 70% of the countries (emissions-weighted), determines the global price commitment.[10] Only countries that have pledged at least that price would sign the global-pricing agreement and participate in the green fund.[11] (This "club" could then implement enforcement that could induce additional members to join; see Stiglitz 2015.)

Before describing step-one, the green-fund negotiation, we note that, as pointed out by Gollier and Tirole (2015), it is an n-dimensional negotiation and hence difficult. As with the climate-effort negotiations, a common formula is needed, but here we are not lucky enough to have something as simple and well-agreed-upon as a uniform price. Nonetheless, it pays to look for an equity formula that is focal and has a single parameter that can differentiate responsibilities to the extent required. Of course in reality no simple formula will be sufficient. However, this example will serve to illustrate the value of looking for a common-commitment formula, even if the actual one needs to weight multiple relevant variables.

The formula that we propose as most simple and focal for green-fund transfers is to make transfers proportional to a country's excess emissions. These are defined as emissions that are in excess of what the country would emit if it had world-average per-capita emissions. Countries pay into the green fund in proportion their excess emissions and receive payments from the green fund in proportion to their negative excess emissions.

There seems little doubt that this formula would work if accepted, because perfection is not required. But it would likely not achieve as high a price as a more detailed and thoughtfully designed formula. The formula should be judged by how high a price results from its use in the stage-two voting process.

The excess-emissions formula must also include a generosity parameter, G, that determines its strength—how many dollars per ton of excess emissions will be transferred. If the green-fund formula is too generous, rich countries will hold down the global price to reduce green-fund payments. And if the formula is too miserly, poor countries will hold down the carbon price to reduce the burden of carbon pricing. Only a compromise on generosity will lead to

10. The higher the coverage of global emissions, the lower the price that will be agreed to by all the countries that must be included to achieve that coverage.

11. Countries may also agree on a price path. In any case, this initial agreement would be updated periodically with the intention of increasing its coverage and strength, and of reflecting the improving estimates of costs and benefits of climate change.

the highest agreed global carbon price and maximize abatement ambition. Hence, the objective of maximizing ambition leads naturally to a reasonably fair compromise on differentiation of responsibilities.

To assure that the generosity of the green-fund formula is set objectively to maximize climate ambition, it will be best to rely on countries that have the least stake in green-fund payments. Such countries will base their recommendations on climate considerations rather than on green-fund considerations. Within such a group, the median (not the average) opinion should determine the outcome. This prevents any one country from having too much influence (Cramton and Stoft 2012a, b).

When proposing individual commitments, the US argues (2013) that it is "hard to imagine that Parties would be willing to have other Parties dictate their contributions." But the above illustrative agreement shows the US argument is irrelevant. Under such an agreement no country will ever be asked to commit to a price higher than it nominates voluntarily with full knowledge of the generosity of the green fund. Nothing is "dictated" by other Parties. But in spite of the completely voluntary nature of this treaty, the resulting agreement captures the "I will if you will" effect of a common commitment that modifies self-interest within the agreeing group. Hence, each country's self-interest in naming a high price will be increased dramatically relative to the individual commitments the US is proposing.

Why opaqueness is not an argument for quantity commitments

Some observers argue that a green fund is too transparent to be politically acceptable, and that a supposed lack of transparency is a major advantage of cap-and-trade. However, the cap-and-trade programs often referred to are domestic, and are opaque for a different reason. Their transfers are not in the form of traceable money. Companies get paid mainly by raising commodity prices by an amount that is hard to measure and that most people cannot comprehend. On the other hand, international purchases of AAU's—the real standard of comparison—have been extremely controversial, as we described in our introduction. Indeed, we find it difficult to believe that large cross-border money transfers through perfectly transparent markets would not catch the public's attention. It seems even more likely that the transfer will become obvious at an earlier stage. To give India a large transfer, India must receive a cap that is far above its BAU emissions level. This part of the transfer will be highly visible and past comments have shown that environmentalists will find this highly objectionable. It will also make it impossible to explain to the US public why the US is giving a multibillion dollar climate transfer to a country that is required to do less than nothing.

That said, even if the supposed opaqueness of permit transfers is something worth taking advantage of, this might be possible under a price commitment without incurring the political risk premiums associated with quantity commitments. For example, instead of the US government paying India $100 M, it could allow US businesses to purchase offsets from the Indian government at the global price of carbon, and India could be issued a package of say 5 million one ton permits. While these would be just as visible as permits under cap-and-trade, they would not cause the financial risks of cap-and-trade.

CONCLUSIONS

Despite much rhetoric, there is almost no hope that the Paris negotiations, if based on individual pledges, can solve the climate dilemma. Rather, to address the dilemma, we agree with

all experts in this symposium that a common commitment is necessary. In this piece, we reiterate Weitzman's plea that price and quantity commitments be compared on a level playing field. This seems eminently reasonable since quantity commitments have had the field to themselves for over 20 years, and failed repeatedly. Quantity commitments have been favored partly because of the misperception that caps provide stronger incentives and more certainty than a price, together with an incorrect analogy between an easily-enforced domestic cap and unenforced international caps. Yet, for reasons that we and other contributors to this symposium explain, a price commitment is likely a much more promising basis for a common commitment; it is a fair focal point, reduces risks, is easier to enforce, and is consistent with climate policies already in place. Indeed, one beauty of a carbon price commitment is that it will not interfere with the current, dispersed cap-and-trade experiments, thereby leaving the door open to a future rehabilitation of caps, while keeping alive the fundamental idea of using price.

Promoting cooperation in international climate negotiations is *the* crux of the climate problem. We hope our paper, along with the other contributions in the symposium, will provide guidance to those negotiating the necessary global agreements. After over 20 years of failure, surely it is worth attempting a fresh approach, one that is guided by insights from the science of cooperation.

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