Effective institutions against climate change

Christian Gollier and Jean Tirole[1]

Toulouse School of Economics

April 6, 2015

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. With political economy reasons in mind, we favor an international cap-and-trade agreement in which equity and acceptability considerations would be treated through the allocation of emission permits across countries, and in which each country could sovereignly choose the allocation of its efforts. We suggest an enforcement scheme based on financial and trade penalties to induce all countries to participate and comply with the agreement.

[1] Revised version to be published in *Economics of Energy & Environmental Policy*. We are grateful to Dominique Bureau and Christian de Perthuis for helpful comments.

We are faced now with the fact that tomorrow is today. Over the bleached bones and jumble 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 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. As a direct consequence, the concentration crossed the 430 ppm bar in 2011 and keeps increasing by over 2 ppm per year. 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. In order to limit the increase in average temperature to 2°C, the concentration of GHGs needs to be contained to around 530 ppm CO_2eq. Limiting the increase in temperature to 2°C is thus an immense challenge, with a still increasing worldwide 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. At equilibrium, 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. 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 fishers 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 of 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 descendants yet to be borne. Addressing this 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 (see for example Bosetti et al 2013). According to Nordhaus (2015), the equilibrium averaged 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[2] index of country sizes. He concludes that the equilibrium averaged 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

[2] The Herfindahl index h is the sum of the square of each country share in global output. For example, if there are ten identical countries, h equals 10%.

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 pledged 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. The current drop in oil price illustrates the fact that a collective action with a strong commitment of all parties is necessary to leave most of the fossil fuels underground in the long 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 are quick to sell climate mitigation policies as an opportunity to boost "economic growth". The fact that no country comes remotely close to doing its share should speak volumes here: Why would countries sacrifice the consumption of goods and leisure to be environment-unfriendly? The reality is bleaker, in particular 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.

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

If a carbon tax is implemented for example, the associated price distortion will induce households to invest in photovoltaic panels on their roof or to purchase expensive electric cars, yielding no noticeable increase in their current wellbeing, to the detriment of spending their income on leisure goods or vacation for example. To be certain, countries may perceive some limited short-term "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). 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 fog from London. But 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, our sacrifices 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. Two economic approaches have been proposed to solve the free-rider problem: A liability system, and a Pigovian price mechanism. Because of the diffuse and intertemporal nature of the pollution, it is not possible to link current individual emissions to future individual damages. Therefore, a liability system is unlikely to fix the problem. Even if such a link could be established, one would need an international agreement to prevent free-riding.

The alternative solution 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 the 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 emission, all tons of CO_2 should be priced equally. By imposing the same price to all economic agents around the world, one makes sure 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. By contrast with this economic approach, "command-and-control" approaches (source-specific emissions limits, standards and technological requirements, uniform reductions, subsidies/taxes that are not based on actual pollution, vintage-differentiated regulations, industrial policy….) usually imply 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. Intuitively, if agent A faces a price of 30 $/tCO_2$ whereas agent B faces a price of 10 $/tCO_2$, agent A will invest in a pollution-abating project that costs 29 $/tCO_2$

whereas agent B will not invest in a pollution-abating project that costs 11 $/tCO$_2$. This is clearly a misallocation of mitigation efforts.

Western countries have made some attempts at reducing GHG emissions, notably through direct subsidies 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. The high heterogeneity of observed implicit carbon prices is a clear demonstration of the inefficiency of this command-and-control approach. Similarly, any global agreement that would not include all world regions in the climate coalition will exhibit the same inefficiency by setting a zero carbon price in non-participating countries.

2.2. Carbon pricing and inequality

Wealth inequalities at the domestic and international levels are often invoked to dismiss uniform carbon pricing. The problems raised by wealth inequalities 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.

International wealth inequalities raise the question of the allocation of the burden of the global climate policy. For example, the principle of common but differentiated responsibility is redistributive because wealthier countries are also typically those which contributed more to the accumulation of GHG 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 I 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 a limited success and anyway was not a

satisfactory approach due to yet another leakage problem. For example, Annex I 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 afterward claim CO_2 credits for their reduction.[3]

Using price distortions to reduce inequalities is 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 could use the revenues generated by carbon pricing to subsidize low-income countries. Given that we emit today approximately 50 $GtCO_2$, a carbon tax at 30 $\$/tCO_2$ would generate a revenue of $ 1,500 bn per year. The same revenue would be obtained through the auctioning of carbon permits in the cap-and-trade mechanism. If wisely redistributed, this large global revenue must make all countries better off. One could alternatively alleviate international inequalities by offering free permits to countries from the South while preserving the benefits of a single carbon price around the world.

2.3. Computing the right price signals

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 matters to trigger 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 from today to potentially the next century. There are strong arguments for recommending a carbon price schedule 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. However, if we believe

[3] 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 could be building new factories to produce the coolant gas. As a consequence, the EU banned the use of HFC-23 certificates in the EU ETS from 1 May 2013.

that the climate policy will be strong enough to reduce concentration after a peak, the carbon price path should be hump-shaped. Second, if we impose a cap on GHGs 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 Section 3.2.

Although the fifth report of the IPCC (IPCC 2014) does not contain much information about it, there is now a sizeable literature about the social cost of carbon (SCC). In order to send the right signal to economic agents, the carbon price must be equal to the present value of the marginal damages generated by the emission of one more ton of CO_2. Estimating the SCC is complex because most of these damages will materialize only in the distant future and are uncertain. The time and risk dimensions raise the problem of the choice of the discount rate. If future climate damages were statistically independent of world GDP growth, a relatively low real discount rate of 1% should be used to discount these damages to the present (Weitzman 1998 and 2001, Gollier 2012). However, most standard integrated assessment models such as the DICE model are such that climate damages are positively linked to consumption growth (Dietz et al 2015). Indeed, a stronger consumption growth raises emissions in the business-as-usual scenario. If the damage function is convex, the increased concentration of GHGs in the atmosphere implies a larger marginal damage, hence the positive correlation. Using technical terms from finance theory, this implies that the climate consumption-based CAPM beta is positive, and that the relevant climate discount rate is closer to the mean return of equity than to the risk-free rate (Gollier 2014).

Over the last two decades, governments have commissioned estimates of the 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

There are two alternative strategies for organizing an efficient, uniform pricing of CO_2 emissions: carbon tax and cap-and-trade. Under the first strategy, a uniform tax on all emissions around the world would be agreed upon and collected by individual countries. The carbon price would then be equal to this tax. Under the alternative, cap-and-trade strategy, a multilateral organization would either auction off or allocate a predetermined number (cap) of tradable emission permits to the different countries or regions. A market for these permits would ensure that a single carbon price emerges from mutually advantageous trades of permits around the world. The cap-and-trade solution is simple and straightforward to implement as long as emissions are verifiable and penalties can be imposed for uncovered emissions. The implementation of credible and transparent mechanisms to measure emissions is of course a prerequisite to any efficient approach (tax or cap-and-trade) to climate change mitigation, or for that matter to any policy.

Since Weitzman (1974)'s seminal paper, a sizeable literature has compared the relative merits of the two economic approaches. 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. Furthermore, the two systems have quite different political economy implications, as we will discuss in Section 3.1.

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 mechanism within the Kyoto agreement emerged in Europe, with the EU Emission Trading Scheme (EU ETS). In its first trading period of 2005-2007 ("phase 1"), the system was established with a number of allowances 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 need of 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. This price signal therefore has a limited impact on emissions. It even let electricity producers to substitute gas by coal, which emits 100% more carbon (not counting dirty micro particles). 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 allowance 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 the high penalties to which their failure to fulfill their commitment exposed them, 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 emission of SO_2, a local pollutant, jointly with that of CO_2 by coal plants), the direct self-impact of CO_2 emissions for large countries like China, 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 examining. In

the Regional Greenhouse Gas Initiative (RGGI), 9 Northeast and Mid-Atlantic US states created a common cap-and-trade market to limit the emissions of their electricity sector. Here also, the current carbon price is too low at around \$5 /tCO_2 (up from the minimum price floor 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. 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. 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.

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. France has fixed its own carbon tax at 14.5 €/tCO_2. Outside Europe, some modest carbon tax exists 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. Carbon tax or cap-and-trade?

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 tax vs. cap-and-trade[4]". Furthermore, the question is far from being settled among economists. It 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; and a political economy dimension on which wefocus in Sections 3.1 and 3.2[5].

[4] By cap-and-trade, we of course mean the setting of a global volume of emissions, not of individual countries' targets, which would be highly inefficient.

[5] 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

3.1. Enforceability

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. However, a global carbon price commitment faces a number of obstacles.

The first and most fundamental one is *enforcement*. 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. Under this scheme, a supra-national supervision of the national tax collection at the internationally agreed level is necessary. Indeed, countries as we have seen individually prefer to free-ride to reduce or even not to collect the tax even if they receive its proceeds- otherwise they would already collect one. Moral hazard is not going to disappear because of the existence of an international agreement.

Individual countries will have strong incentives for lax enforcement: they can turn a blind eye on certain polluters or underestimate their pollution, thereby saving on enforcement resources and especially on the cost of green policies.[6] 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. For example, when a product is subject to a specific excise tax or VAT, as is often the case for heating oil or gasoline, it is impossible to disentangle the carbon tax from other taxes justified by local pollutants, use of public road infrastructures, and congestion. The outcome would nonetheless be a reduction in the incentives of the country's economic agents to emit

---

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

[6] To envision the difficulties faced by the tax collection approach, one can refer to the current sovereign-debt difficulties faced by Greece. 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 very difficult for foreigners to impose tax collection when the government is reluctant to strengthen it.
While in both cases 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: In the sovereign-debt context , countries not only are under a program (and therefore carefully monitored); they also derive some benefits from compliance (prospect of no longer being under 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.

less CO_2. Mitigation efforts are costly, and letting countries keep the proceeds of the tax does not suffice to incentivize them to collect the tax (incidentally, they can already collect and keep carbon taxes today, and predictably do not do so, at least at a decent level). And even if the tax is perfectly collected, there is no other way of measuring the country's CO_2 effort than through emissions.

By contrast, enforcing an international cap-and-trade mechanism is relatively straightforward when countries, rather than economic agents, are liable for their national emissions. Under this subsidiarity principle[7], it suffices to monitor the country's CO_2 emissions 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.

3.2 Compensation and the dimensionality of negotiations

The second obstacle to a carbon tax in our view is *compensation*. Whether the international architecture adopts a carbon tax or a cap-and-trade mechanism, cross-country transfers will be needed so as to bring reluctant countries on board. Under a carbon tax, 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 Climate Fund which was decided at the COP-15 of Copenhagen in 2009. Under a cap-and-trade protocol, transfers operate through the distribution of permits across countries.

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 of permits.[8] 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,

[7] That is, countries are free to choose their domestic carbon policy. While we would of course recommend a uniform carbon price within the country, the only thing that matters for foreigners is how many tons of CO_2 the country emits, so subsidiarity can prevail.

[8] 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.

delayed jumping on board until they received sufficient compensation (in the form of free permits in that case).[9]

De Perthuis and Jouvet (2015) propose to finance the green fund on the basis of a bonus-malus system where high emission-per-capita countries would finance green projects to be implemented in low emission-per-capita countries, and to pay for the implementation of the common supervising institutions of the international agreement. In our view, a green fund is 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. 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 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.

Like it or not, the transparency issue is one of the reasons why pollution-control programs around the world have often adopted cap-and-trade and handled the compensation issue through the politically less involved distribution of tradable permits (often in a grandfathered way). In the EU ETS scheme for example, billions of euros have been 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. No such transfers would have been possible through the vote of direct financial subsidies by Western European countries.

An attractive aspect of a stand-alone carbon tax is that it does not lead to transfers among countries, and therefore perhaps generates less resistance in countries that would suffer a permit deficit in a cap-and-trade approach. It facilitates negotiations by focusing it on a single variable. This comparative benefit however disappears if, as is understandably conceived, the carbon tax is complemented with a green fund, which sets the net (positive or negative) transfer to the fund for each country and therefore involves the same dimensionality (the number of countries, n, plus 1, the carbon tax) as a cap-and-trade mechanism with an allocation of permits. Another way to see the equivalence between a carbon tax and

[9] See Ellerman et al (2000) for an extensive treatment of these negotiations.

cap-and-trade along the dimensionality problem is that if transfers are ruled out, the cap-and-trade mechanism becomes single dimensional: countries only need to agree on the overall emission cap and then permits can be auctioned off.

Also, 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.

3.2. Price volatility under a carbon tax and cap-and-trade

Returning to the economic dimension of the carbon tax vs. cap-and-trade debate, we should also note that 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-degree Celsius 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 may need 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)[10].

The same concern holds for a carbon tax. Due to the same sources of uncertainty, there is no guarantee that the tax 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. In the absence of further investigation, it is hard to ascertain which of cap-and-trade and carbon tax will deliver the highest price volatility.

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 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

[10] 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.

automatic, but its efficiency can be questioned. In particular, one can wonder how it can be made responsive to news in a way that guarantees that the 2C target is reached. This brings us to the question of the trade-off between flexibility and commitment.

3.3. The potential time inconsistency of carbon taxes and cap-and-trade

Whether one opts for a carbon tax 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 tax, too high a number of tradable permits). To understand why, note that the carbon tax 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. The optimal policy 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 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. For example, in January 2014, the European Commission proposed to amend the EU ETS system, starting in 2021, by appending a "Market Stability Reserve", which is a "an objective and rule-based mechanism on the basis of which the auction volumes are adjusted in an "automatic manner". The mechanism reduces the amount of EU Allowance units 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. Thus a target corridor for banking of allowance units is introduced to the EU ETS. The precise implementation of this mechanism has been criticized for being asymmetric and failing to have the desired dampening effect.[11] We have not studied when the MSR or a variant thereof can approximate the optimal adjustment mechanism described in Laffont-Tirole[12], and we think that economists have not paid enough attention to this aspect, whether they favor taxes or cap-and-trade.

4. 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 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, and verification of the pledges are not being discussed.

The pledge-and-review strategy has three 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 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 absence of commitment to the pledge limits its long-term

[11] Trotignon et al (2015).

[12] For instance, suppose that scientists demonstate that the climate is deteriorating faster than had been thought. Then permits must be withdrawn. The MSR 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.

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 reduction of emissions for a long period of time. Third and relatedly, the pledge-and-review process does not address the free-rider problem. Free-riding remains individually optimal in this game, so that 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*". Pledge-and-review will only magnify the free-rider problem.

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) 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.

To conclude this section on a more positive note, the pledge-and-review process could be useful if in the second half of this year, 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 so 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 commit.

5. Enforcing an international agreement

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. 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 Lalaland 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.

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.

6. Conclusion

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 economic agents 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 about 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 in the business-as-usual. We should tackle the climate challenge more seriously.

Our proposal is to implement an international cap-and-trade scheme, in which each country must purchase additional permits when their nationals emit more than the allowance allocated to the country, and can sell surplus permits when they over-perform environmentally. Participating countries will also commit to impose penalties on non-participating countries, through punitive border taxes administered by the WTO and through the recognition of a "climate debt" accounting for the uncovered emissions of the non-abiding countries valued at the price of carbon prevailing within the coalition. Finally, the allocation of country-specific allowances can be organized in such a way to transfer revenue to

developing countries, with an eye on alleviating the fairness and acceptability concerns. Allocating free permits to a country is likely to be politically easier to arrange for donor countries than a lump-sum transfer, as illustrated by the failure of the Green Fund set up at the 2009 Copenhagen Conference.

Bibliography

Beccherle, J. and J. Tirole, (2011), Regional Initiatives and the Cost of Delaying Binding Climate Change Agreements, *Journal of Public Economics*, 95(11/12): 1339-1348.

Bosetti, V., C. Carraro, E. De Cian, E. Massetti and M. Tavoni, (2013), Incentives and stability of international climate coalitions : An integrated assessment, *Energy Policy* 55, 44-56.

Buhr, K., S. Roth, and P. Stigson, (2014), Climate change politics through a global pledge-and-review regime: Positions among negotiators and stakeholders, *Sustainability* 6, 794-811.

Chakravorty, U., B. Magne, and M. Moreaux, (2006), A Hotelling model with a ceiling on the stock of pollution, *Journal of Economic Dynamics and Control* 30(12), 2875-2904.

Cremer, H., F. Gahvari, and N. Ladoux, (2003), Environmental Taxes with Heterogeneous Consumers: An Application to Energy Consumption in France, *Journal of Public Economics* 87 (12), 2791–2815.

De Perthuis, C., and L.-A. Jouvet, (2015), Les voies d'un accord climatique ambitieux en 2015, Institut Louis Bachelier, Opinions et Débats.

Dietz, S., C. Gollier, and L. Kessler, (2015), The climate beta, mimeo, London School of Economics.

Ellerman, A.D., P.L. Joskow, R. Schmalensee, J.P. Montero, and E.M. Bailey, (2000), *Markets for Clean Air: The U.S. Acid Rain Program.* Cambridge: Cambridge University Press.

Gollier, C., (2012), *Pricing the planet's future: The economics of discounting in an uncertain world*, Princeton University Press.

Gollier, C., (2014), Evaluation of long-dated investments under uncertain growth trend, volatility and catastrophes, mimeo, Toulouse School of Economics.

Hardin, G., (1968), The tragedy of commons, *Science* 162 (3859), 1243–1248.

IPCC, (2014), *Climate Change 2014: Mitigation of Climate Change*, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B.

Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Laffont, J.J. and J. Tirole, (1996a) Pollution Permits and Compliance Strategies, *Journal of Public Economics*, 62: 85-125.

Laffont, J.J. and J. Tirole, (1996b) Pollution Permits and Environmental Innovation, *Journal of Public Economics*, 62: 127-140.

Nordhaus, W., (2015), Climate clubs: Overcoming free-riding in international climate policy, *American Economic Review* 105(4), 1-32.

OECD, (2013), Climate and carbon: Aligning prices and policies, OECD Environment Policy Paper 1, OECD Publishing, Paris.

Ostrom, E., (1990), *Governing the commons: the evolution of institutions for collective action*, Cambridge University Press.

Posner, E., and D. Weisbach, (2010), *Climate change justice*, Princeton University Press.

Quinet, A., (2009), *La valeur tutélaire du carbone*, La Documentation Française, Rapports et Documents 16, Paris.

Tirole, J. (2012) "Some Political Economy of Global Warming," *Economics of Energy and Environmental Policy*, 1(1): 121-132.

Trotignon, R., Jouvet, P.A, Soliera, B. , Quemina, S., and J. Elbezea (2015) “European Carbon Market: Lessons on the Impact of a “Market Stability Reserve” using the Zephyr Model”, mimeo, chaire économie du climat, University Paris Dauphine.

US Interagency Working Group, (2013), Technical update of the social cost of carbon for regulatory impact analysis under executive order 128666.

Weitzman, M.L., (1974), Prices vs. quantities, *Review of Economic Studies*, 477-491.