Climate change: the global public good

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Abstract

Climate change is the exemplary global public good, because each country's emissions of greenhouse gases contribute cumulatively to the increase of the overall concentration, and each country's abatements entail higher cost than benefit, unless effective concerted collective actions take place.
Unfortunately there are weak political and economic instruments for entering a climate agreement and for attaining and maintaining its goals. Moreover there are strong free-riding incentives since it is quite difficult - and indeed very unpopular - for Governments to convince people to give up part of their current wealth for the sake of uncertain gains in the future, maybe accruing to population in remote distance. In this paper I deal with the main issues put forward by the global public good nature of climate change. Namely, I firstly shed some light on the economics of global warming in order to point out a benefit-cost framework suitable for quantifying its impacts. Then, I analyse the determinants of the provision of climate stability and the international collective action that should be undertaken to compel sovereign countries to enter into a climate agreement. Hence, after outlining the most important approach to international cooperation, I consider the possibility of a coalition formation according to the game theoretic perspective, the interests determining the participation in international agreements, and the possible sanctions imposable to countries that refuse to comply with an international climate agreement.

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Introduction

Global climate change results from the accumulation of greenhouse gases (GHGs) in the atmosphere. GHGs, some naturally produced and others resulting from human activities[1], absorb infrared radiation and return it back to the earth surface, raising world temperature. There are two undisputed facts: GHGs are accumulating at a faster rate in the atmosphere mainly as a result of human activity[2], and air and sea temperatures are rising. Beyond these points many controversies arise.
Over the latest years an increasing body of observations, analysis and studies has led to a better understanding of climate change. A widespread consensus about the potential threats that climate change poses over human well-being does exist. Carbon dioxide concentration in the atmosphere has in fact augmented by 31% since 1750[3] (International Panel on Climate Change - IPCC, 2001

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[1] Naturally GHGs include carbon dioxide, methane, nitrous oxide, ozone, and water vapor. The first three gases (carbon dioxide, methane, nitrous oxide) are also naturally produced, while hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride, are solely human responsibility.

[2] «There is new and stronger evidence that most of the warming observed in the last 50 years is attributable to human activities» (IPCC, 2001 (a): 10).

[3] Similarly, methane and nitrous oxide concentrations have increased respectively by 151%, and the by 17% since 1750 (IPCC, 2001 (a): 7).

(a): 7) and its rate of increase has been about 1.5 ppm (0.4%) per year over the past twenty years, while during the 1990s it has increased from 0.9 ppm (0.2%) to 2.8 ppm (0.8%) (IPCC, 2001 (a): 7). According to IPCC global average surface temperature has augmented over the last century between 0.4° C and 0.8° C, and is likely that the increase in temperature in the northern hemisphere has been the largest of any century during the past millennium (IPCC, 2001 (a): 2). Moreover, snow cover has decreased of about 10% since the late '60s, and there has been a remarkable shrinking of mountain glaciers in non polar regions, and an increase between 0.1 and 0.2 meters of average sea level during the 20th century (IPCC, 2001 (a): 4). Most of this observed warming is due to the increase in GHGs concentration (IPCC, 2001 (a): 10) and the emissions of carbon dioxide deriving from the burning of fossil fuel are «virtually certain» the determinant of the trends in CO_2 concentration in 21st century (IPCC, 2001 (a): 12). Climate change simulations for the period 1990-2100 depict a globally averaged surface temperature increase by the end of the period of 1.4° to 5.8° C (IPCC, 2001 (a): 13).

Even another important expert assessment of climate change, the U.S. National Research Council response to the White House, points out in the Summary that air and ocean temperatures are rising due to the higher concentrations of GHGs which «are accumulating in Earth's atmosphere as a result of human activities». Moreover «human-induced warming and associated sea level rise are expected to continue through the 21st century».

Climate variations, which are basically irreversible, are expected besides to generate an array of effects on our planet and on our ecosystems. According to Kolstad and Toman (2001) examples include: reduced productivity of resources, damage to human-built environments, risk to health and life, damage to "less managed resources" (such as wilderness and biodiversity). The chances that these adverse effects will take place are rather poorly understood and the ensuing socioeconomic outcomes are even less foreseeable.

At the same time there is a substantial disagreement on many substantive issues related to climate dynamics[4] and thus the understanding of the undisputable impact of human activities on global warming is still poor in its dynamics. In a word, even if higher concentrations of GHGs trap energy and make the atmosphere warmer and warmer, it is unclear which is the precise role played by human beings on global climate patterns.

In spite of the fact that the most important attribute of climate change, at least as a policy issue, is uncertainty, policy-makers, at different level, have proposed various policies to reduce GHGs emissions. The ongoing best known – and highly questioned – attempt to address global climate change is the Kyoto Protocol. This document was negotiated in 1997 during the Third Conference of the Parties (COP 3) to the United Nations Framework Convention on Climate Change (UNFCCC), a treaty adopted by the Rio de Janeiro 1992 UN Earth Summit, in order to stabilize GHGs concentrations in the atmosphere. The Kyoto Protocol imposes legally binding GHGs emission reduction limits for 38 industrialized countries (Annex B countries). The countries' limits are expressed as percentage of their emissions in 1990, ranging from 92 to 110 percent, and they must be attained during the commitment period 2008-2012. The Protocol will become effective when at least 55 countries, accounting for at least 55 percent of Annex B emission, will ratify it[5].

Unfortunately the Kyoto recipe to climate change policy is far from being widely accepted by policy makers around the world. The scientific community too shows perplexity: even many climatologists, economists and political scientists point out that the Kyoto Protocol is a fragile agreement, whose enforcement is unlikely and whose potential outcomes are limited.

Nonetheless, there is a widespread consensus that we cannot continue to release increasing quantities of GHGs into the atmosphere without any adverse consequences. But the most efficient way to limit these emission has not yet been marked out, since a number of issues, other then the solely physical uncertainties (IPCC, 2001 (b)), makes it thorny to define the real dimension of the threats posed by global warming to mankind.

[4] From a physical point of view the most important are the understanding of the link between temperature change and atmospheric water vapor, the role of aerosol in the atmosphere, sea-ice dynamics, ocean heat transport. For a complete analysis of the physical impact of climate change on ecosystems see IPCC, 2001 (b).

[5] The average emission limit is 95%: if all Annex B Countries ratified the Protocol, the overall reduction for industrialized countries would be 5% below the value of 1990. For a thorough analysis of the Kyoto Protocol, see Kopp, Tatcher, (Eds.) 2000.

Global climate change is a major international policy issue, which presents at least three important questions that must be resolved in order to address the problem effectively.
The first topic is related to the uncertainties of the economics of climate change. In fact the estimates of the costs to of reducing GHGs emissions – i.e. the costs that individuals, firms, and Governments have to face to modify their behaviour in order to abate emissions – are highly ambiguous. For instance, according to the Stanford University Energy Modeling Forum (Weyant and Hill, 1999) the estimated marginal costs to reduce GHGs emissions to the levels required by the Kyoto Protocol for European OECD countries vary between US$ 25 and US$ 825 (in 2000 US$). The volatility of the estimates depends greatly on variables difficult to predict in the long run, such as population, productivity growth, technological improvement, patterns of consumption. Unfortunately the knowledge of the distribution of benefits and costs of actions needed to mitigate the adverse effects of raising temperatures is essential for effectively addressing climate change. The removal of such an uncertainty is itself a public good which fosters the efficient provision of a global public good such as climate change.
Climate change is a global public good – and this is the second question and the focus of this paper – because effective controls of GHGs emissions must involve all actual and potential emitters. Therefore (collective) actions concerned with global climate change should be taken at supranational level. In this framework each country has to determine the optimal level of emissions in order to deal correctly with the issue at stake, but unfortunately there are weak political and economic instruments for attaining and maintaining these goals. In fact, countries tend to decide non-cooperatively, according to their own cost-benefit ratio. In other words, it is far from clear how the international community defines the framework for the needed inter-governmental collective decision-making process, and the political economy of climate change often seems to prove ineffective in fostering the necessary cut back of GHGs emissions. A particularly tricky point lies in the fact that GHGs concentrations depend on long-term profile of emissions, because GHGs remain in the atmosphere as long as two hundred years, making the estimates of the benefits deriving from curbing the emissions both highly unpredictable and distant in the future[6]. This circumstance generates strong free-riding incentives since it is quite difficult - and indeed very unpopular - for Governments to convince people to give up part of their current wealth for the sake of uncertain gains in the future, maybe accruing to population in remote distance.
Finally, the definition of an equitable commitment[7] is still an unresolved question in the climate change debate: which countries are responsible for climate change, who should act in response, how to fairly allocate the burden between countries, and how to undertake a just international approach, capable at the same time to prove fair at national level?

1 Measuring global public goods: some economics

Climate change cannot be properly addressed without a deep understanding of its economics. Global warming in fact produces diverse economic effects: from reduced productivity of natural resources (e.g. agriculture), to damage to non-managed natural resources (e.g. biodiversity, landscapes, wilderness), from damage to human-built environment (e.g. coastal flooding from sea level rising), to risks to humans due to extreme weather variations. Ultimately, excessive anthropogenic emissions of GHGs are an economic problem, namely externalities, a well-known category of market failures which affect climate stability, a (global) public good with no market nor price, and that do not offer proper incentives against overexploitation of the atmosphere.
The perspective of economics makes possible estimating and comparing people's valuations of different uses of climate resources in different moments. In general, the most effective policy is the one that maximizes the net present value of using the atmosphere, and that distributes fairly related benefits and costs. Mitigation policies (i.e. policies that cut GHGs emissions), relenting or halting the raise of temperatures, provide benefits and involve large costs. Actually, both the odds of adverse events and of advantages deriving from avoiding them are not well understood. Therefore, benefits and costs are highly uncertain. Nonetheless climate change risks are real and

[6] While the costs occur in the present.

[7] The question of equity (justice, fairness) is a major point in the current international debate on climate change, both in mitigation and adaptation issues. It is however beyond the scope of this paper.

in order to address them effectively it is necessary to weigh the potential benefits and costs of the various actions (or of the inaction).
An environmental benefit in economic theory derives from the flow of services that natural assets provide to human beings[8], thus benefits from reducing global warming by controlling emissions stem from the lessening of the risks that the increase of the temperature could induce to a number of ecosystem's services. The notion of cost is more straightforward: it is the opportunity cost – what must be given up in order to obtain something – of GHGs mitigation or adaptation, i.e. what society must give up to carry out a sound climate policy.
In general, in a *n* countries world, where e_i is the GHGs cutback of country *i*, the global abatement is $E = \Sigma_i e_i$. Each country's benefits depend on the global abatement: $B_i = B_i (E)$, while costs depend on the cutback level that the country itself choose: $C_i = C_i(e_i)$. To optimise this framework each country would choose a situation where marginal abatement cost equates marginal benefit from abatement. Consequently an assessment of benefits and costs provides policy-makers with the information they need to make more educated decisions. Therefore, I hereafter briefly introduce the main economic issues of climate change in a benefit-cost dichotomy.

1.1 Benefits

In principle, to value benefits of GHGs emissions reduction is necessary to foretell the different climate impacts with and without controls, and to aggregate such differences over the time. This is quite a problematic process: climate in fact influences almost every aspect of human life, with great regional variations. Furthermore, its impacts depend more on concentration than on emissions, due to the extraordinary long persistence of GHGs in the atmosphere. Hence the valuation process outcomes, requiring the knowledge of economic and biophysical systems and of their interactions, are tricky and arguable.
The usual way to see benefits of protection against the adverse effects of climate change is to refer to reductions in the losses, in term of GDP, posed by the augmenting GHGs concentrations[9]. These losses derive from a number of impact categories, depicted in the ensuing table.

Table 1 – Environmental impacts in economic models

Environmental impact	Description
Agriculture	Impacts on the level of productivity of different crops
Forestry	Impacts on the level of productivity of commercial forests
See-level rise	Impacts of rising sea levels on coastal development
Ecosystems	Impacts on ecosystem function and vegetation patterns
Human health	Impacts on the incidence of induced diseases
Wildlife	Impacts on animal life
Biodiversity	Impacts on plant and animal species diversity
Fisheries	Impact on commercial fisheries
Amenity values	Values individuals place on recreational opportunities

Source: Weyant (2000: 25)

There is an ample variety of studies incorporating countries specifics and diversities of targeted policies which provide different results in term of benefits. According, for instance, to the IPCC Second Assessment Report - SAR (IPCC, 1996) the harming effects of a doubling of GHGs in the atmosphere cost between 1.0% and 1.5% of GDP for developed countries, and between 2.0% and 9.0% for developing countries. Alternatively, other estimates of the direct benefits of reducing GHGs emission are offered: Weyant, (2000: 42) suggests that they range between $ 5 and $ 125 (1990 US $) per metric ton of curbed emissions, reflecting variations in model assumption and a high sensitivity to the choice of the discount rate.
Anyway, a major factor affecting the dimension of benefits is their definition. The literature in fact uses a number of terms to represent the benefits of GHGs control. The IPCC Third Assessment

[8] Economics is matter-of-factly anthropocentric: the objective of any economic analysis is to measure the change in human welfare generated by a change in the use of resources.

[9] Specifically the welfare loss, i.e. the reduction in the flow of ecosystem services, caused by climate change is given by the damages from a lack of control that allows unrestricted emissions, leading ultimately to variations in climate patterns. Hence such damages, which in case of control would not have occurred, can be read as benefits.

Report - TAR (IPCC, 2001(d): 460) defines co-benefits «the non-climate benefits of GHG mitigation policies that are explicitly incorporated into the initial creation of mitigation policies», while the term ancillary benefits «connotes those secondary or side effects of climate change mitigation policies on problems that arise subsequent to any proposed GHG mitigation policies». The ancillary benefits, according to Weyant (2000: 43), range from $ 0 to $ 20 per metric ton of carbon (1990 US $).

1.2 Costs

The debate on the costs of climate change policies is very harsh, polarized between the ones who hold the control of GHGs emissions, for instance by means of the Kyoto Protocol, disastrously expensive – most of the US voices, for example –, and the ones who claim – as many radical environmentalists do – that the problem can be addressed with no economic costs, or even with some savings.

Economics suggests that the true is somehow in between. A number of studies estimate such costs: according to an IPCC guess, focusing on a doubling of GHGs concentrations in 2100 as to pre-industrial level, they would range between 1.5% and 2% of global economic output.

A landmark study conducted by the Energy Modeling Forum at Stanford University[10] compared the estimated costs of controlling GHGs according to eleven global energy-economic models which provide estimates of the costs of a carbon dioxide tax or tradable permits scheme. For example, in case of a 15% carbon abatement relative to baseline, the median marginal control costs (in 2000 US $ per ton of carbon emissions) range from approximately 300 $ for Europe, to 190 $ for Japan, 180 $ for the group Canada, Australia, New Zealand, and 110 $ for the US. Furthermore, these costs increase with greater abatement at a fester rate in Europe and Japan, than North-America and Oceania. Other important conclusions of this study suggest that abatement costs in the OECD countries exceed $ 100 per ton for stabilization within 1990 levels, and that policies that shift abatement to lower costs region through trading diminish the overall cost of controlling carbon emissions.

The economic rationale for the costs is, as usual, the value of scarce resources to individuals, based on their preferences. Specifically, costs are intended as opportunity costs of GHGs mitigation or adaptation: in other words what a society must forgo in order to undertake climate change policies. Therefore costs are the foregone social benefits of employing scarce resources on climate change control instead on other issues[11].

It is worth to develop a taxonomy of these costs. Kolstad and Toman (2001) identify four categories, from the most intuitive to the least direct one. First, *direct outlays* of monitoring and enforcing environmental laws and regulations and their cost. Then *partial equilibrium costs to consumers and producers,* associated to GHGs emissions reduction compliance, such as utility losses due to foregone more costly activities for consumers and faster depreciation of fixed capital for producers: a raise in gasoline price will diminish the use of cars (effect on consumers) and will crowd out the production of fuel-inefficient cars (effect on producers). These can be considered piecemeal effects since their consequences do not spread to the entire economy. The next level costs are the *general equilibrium* ones. They refer to the overall impact on the economic system of GHGs emission control. At the very hearth of this category of costs is the degree to which consumers and producers can substitute goods and services after a change in relative prices. Finally, there are non-market costs of climate change reflecting the costs of GHGs emissions cutbacks not comprised in the markets, for example the human toll of displaced workers. There still are considerable ambiguities and uncertainties concerning these costs, both in the short and in the long term. According to Aldy et al. (2001) the main reasons for this are the followings:

- difficulties in the business-as-usual emissions forecasts, even growing as time horizon extends. Lacking a sure reference, the whole costs estimation process can be undermined.

[10] Weyant and Hill 1999, Kyoto Special Issue of the Energy Journal (1999).

[11] Benefits and cost can thus be considered the two sides of a same coin. An environmental measure implies some benefits and, at the same time, the renunciation of others. Thus the cost of that measure is given by these foregone benefits, and may be defined as the gross decrease in benefits and with any resulting price and/or income changes.

- problems for consumers and producers to substitute carbon intensive activities with carbon efficient ones. Actually, the cost of GHGs abatements depend largely on this shift.
- unpredictability of the rate of technological change in the long term, which can in fact substantially alter long run costs of abatement.
- scarce policy instrument effectiveness, especially at international level, mostly due to difficulties in establishing an effective international emissions trading regime, at least in a few years.
- unpredictability of the potentiality of emissions reductions across countries, both in terms of costs and of quantities, in case of rapid adoption of best practices, due to the marked differences in energy and emission efficiency.

Furthermore, estimates of GHGs control costs may prove very variable not only for technical differences in economic assumptions, but mainly for the focus of the estimators and for their basic beliefs about climate change itself and its predictable development. In other words, the adoption of a particular perspective influences the degree of priority of climate change issues and eventually the cost analysis. Basically, it is possible to identify three different lenses – none of which more "right" than the others - through which read the problem of global warming: the technological, the economical and the ecological:

- the technological approach focuses on the development of new technologies which are expected to eliminate energy inefficiencies at little or no cost – viewed according a bottom-up perspective - for the economy.
- the economic line moves in a cost-benefit framework, generally assuming the *status quo* as the baseline against which costs and benefits are to be measured. The costs are framed in a top-down perspective.
- the ecological point of view refers to ethical values in analysing the threats posed by climate change to the ecosystem and the human beings. Costs are broadly defined and non-easily quantifiable by means of economic analysis.

1.3 Economic analysis and public goods

The assessment of benefits and costs of proposed climate policies is intended to supply decision-makers with useful information about the way to deal with a global public good. For this purpose the usual benefit-cost framework offers the overall characterization of a policy in terms of its likely benefits and costs, and hence determines whether a society is made better or worse off as a result of such a policy. The main critics objected to the benefit-cost approach concentrate on the incapability of dealing with the large-scale, irreversible effects of climate change and the uncertainty in the determination of mitigation costs, especially when referred to firm emission control policies[12]. Nevertheless, benefit-cost analysis can address both irreversibility and uncertainty, and ultimately can prove a powerful tool for better educated decisions.

More specifically, economic analysis indicates people's preferences for (or against) the streams of services involved by global warming. This process is based on people's preferences and what is actually being measured is not global warming itself, but people's preferences towards quality and/or quantity changes of the resources affected by climate change, which cause variations in the streams of received services[13]. Omitting for the sake of simplicity ethical questions, the problem is about the coincidence between individuals' Willingness To Pay (*WTP*) and the value of environmental impacts produced by climate change. Many observers think natural resources have an "absolute" value[14], independent of people's preferences. The economic value, the *WTP*, would be scarcely significant. Instead I think that these two points of view are not necessarily opposite. There is no reason to refuse the notion of "absolute" value just because the preference measurement process is used. Simply, the two work on different levels: the latter provides the economic value of people's preferences towards (or against) the environment impact of global

[12] Another major concern, deals with equity issues (i.e. the distribution of benefits and costs across relevant populations). As aforementioned this point is not dealt in this paper.

[13] It seems reasonable enough to think that people have preferences about environmental changes, and that they would pay to foster or to prevent them.

[14] Here, the notion of value is wider than the notion of existence value, one of the elements of the total economic value of natural resources. This is because it would like to be equal to the "true" value of the environmental resource.

warming; the former looks at the effects of variations of temperatures on ecosystem itself, in terms of quality and characteristics. Ultimately, economic analysis indicates the demand curve of services provided by public goods such as natural resources. Opportunity reasons justify monetary measures, as money is one of the very few means that highlight people's preferences. Once the existence of those two value dimensions is accepted, the problem is choosing which one should inform and help decision-makers. The answer, in my opinion, is that since they are both plausible, both should be used. A decision made considering only economic value cannot satisfy all the different needs of the decision-maker. But while economic value can generally be measured, "absolute" value cannot. If the decision-maker does not need to know the amount of the costs and benefits involved by her choice, the absence of measure is not important. But if she does need to know it, choosing between alternative climate actions with different environmental impacts becomes difficult. The practical problem of economic value is to find measures that can be reliable even when the market is absent or malfunctioning. If, in doing so, we find measures based on people's widest expression of the value of natural resources, it is possible that the measure based on people's preferences (economic value) captures, at least partly, the true value of the natural resource.
In a democratic society, the more attentive public decision-makers are to choice problems, the more they need information to improve the decisional process: monetary valuations certainly increase the available information. Their usefulness consists in their comprehensible methodologies and generally accepted rules to simplify all complex effects and activities to a one-dimensional measure, money. Thus, the ability of organizing and simplifying all information into a quantity, money, which is measurable and as univocal as possible, is the main point of the cost benefit approach, which I maintain as a background reference throughout the paper.

2 Climate stability: the global public good

Climate change can be seen as an economic activity whose effects concern, in principle, everybody around the world. According to the standpoint of economics the compliance cost that a country is willing to accept to address climate change is close to zero, because cutbacks undertaken today will affect climate stability only in the far future. Therefore, benefits will accrue to future generations, while costs are shouldered only by the current one. In formal terms, since $B_i(E) \cong 0$, hence $C_i(e_i) = 0$ and no country will enter an international agreement to enhance climate stability.
The reason for this outcome lies in the fact that climate stabilization is a global[15] public good[16] (GPG): «In many ways, global warming is the quintessential global pure public good, because each country's release of GHGs augments the world's atmospheric stock in an additive fashion and each country's cutback results in a greater cost than benefit for that country unless assurances can be given that a sufficient number of action will act» (Sandler, 1998: 225).

2.1 Determinants of the provision of global public goods

The classical economics' definition of a public good is Samuelson's: «[a public good is a good] which all enjoy in common in the sense that each individual's consumption of such a good leads to no subtraction from any other individual's consumption of that good» (Samuelson, 1954: 387). From this definition emerge the two main characteristics of public goods: non-excludability (i.e. it is impossible to prevent everyone from enjoying the benefits deriving from the consumption of the good) and non-rivalry (i.e. the consumption of the good from one person does not undermine another's consumption). GPG, has pointed out above, have a third dimension: they provide globally available benefits unconstrained by national boundaries. These elements may eventually provoke a policy failure, inducing some country not to participate (or to participate in a limited way) to the provision of the GPG itself. This failure is ascribable to a series of problems in public behaviour, the most prominent probably being the prisoner's dilemma and free riding. According to

[15] Sometimes it is referred as an international public good: the two are basically synonymous. Global (or international) public goods distinguish from local (national and sub-national) public goods because the former have cross-borders effects.

[16] To be more specific global climate stability is a GPG, and global warming is the corresponding global public "bad".

the former, the provision of a GPG, though in everyone's interest, remains unsatisfactory because it is unclear both how the associated collective action should take place, and who should coordinate it. Therefore, without shared information and cooperation, is very unlikely to reach an efficient and fair allocation of the impacts of the GPG. The latter problem of free-riding occurs when some parties benefit from the GPG (because of its non-excludability) without participating in its provision. Actually there is a strong incentive for everyone to escape the burden of her provision quota, waiting for others to take initiative.
There is a variety of mechanism to deal with policy failures in the provision of GPGs, spanning from doing nothing to establishing international governance bodies. According to Nordhaus (2002: 3) a partial list includes:

- non-cooperative approach or *laissez-faire*,
- aspirational agreement (the UNFCCC), and non-binding voluntary agreement,
- specific and binding treaties (as should be the Kyoto Protocol),
- agreements embedded in broader arrangement,
- limited delegations of regulatory or fiscal authority to supranational bodies

The choice of the type of mechanism for climate change depends on the identification of the factors that favour collective action at transnational level.
Probably the single most important determinant of the provision of a GPG is the individual contribution to the total quantity, known as the aggregation technology of public goods. In short when the contribution of every agent (i.e. nation) is a perfect substitute for every other's, the provision of a public good is often associated with a prisoner's dilemma. In fact when the benefit per unit derived from the provision of the public good b_i is smaller then the cost of provision per unit c_i, every agent, which in case of contribution loses $c_i - b_i$ independently from the actions of the others, has a dominant strategy favouring an under-provision of the public good. This is exactly the case of global warming, where the aggregation technology is basically a summation process, implying that every action against growing temperatures will sum up to any other similar effort, thus increasing the overall provision. Moreover, empirical analyses suggest that the costs of contributing perfectly substitutable quantities of the GPG global climate stability are in general greater then benefits, even when there is a sufficiently large number of participating countries. These benefits, further, do not distribute equally between the participants: some countries, especially in the northern hemisphere, may experiment positive effects from global warming, such as milder winters or longer growing seasons. Here is one more nuisance of this particular GPG: its unequal distribution that weakens the incentive of the collective action, because some countries, besides non-participating, would even hinder the efforts of the others to increase their gain.
Another important factor conditioning the collective provision of a GPG is the income distribution among countries. In general, if the subsequent income distribution were to become more equal, then the provision of the GPG would rise. Since the distribution of costs of climate change mostly affects developing countries, by and large located in climatic-sensitive regions[17] (ODS, 2002: 43), the income distribution after the provision of the global warming-related GPG is expected to become fairer. Therefore the smallest level of provision of climate stability is expected to increase (Sandler, 1998: 23).
A major problem is the range of spillovers, which makes necessary to locate the decisional process at that political level able to internalise spillovers themselves. In other words, as the share of nation/region-specific benefits to total benefit increases, that nation's/region's action becomes more likely, thus upholding the provision of the GPG. This in turn makes essential to choose the right level of (environmental) federalism to encompass the largest amount of spillovers.
An additional factor fostering transnational collective action is the presence of a powerful driving nation, whose action can be usefully followed by the others. If only small island states lead the battle against GHGs emissions, there is no incentive for the international community to join, since their effort is of little use for halting global warming. But if a major GHGs emitter (the US, or China,

[17] Basically because their economies are more dependent on agriculture. Matter-of-factly, according to Richards (2003: 5, note 1) «Between 1990 and 1998, 94% of 568 major natural disaster, and 97% of all disaster-related deaths have taken place in developing countries. Another study has found that 35-40% of the worst catastrophes have been climate change related»

or the EU) assumes a leading role, the problem would be addressed much more effectively by the international community.
It is eventually worth to point out the importance of knowing in depth the terms of the GPG, since uncertainty must be worked out to favour collective action. In the case of climate change the distribution of costs and benefits must therefore be identified, and such a knowledge is a GPG itself, whose provision may require another kind of collective action aiming expressly at knowledge, like the one provided for instance by the IPCC.
Summing up, the less the substitutability among the contributions, the more the fairness of the distribution of benefits and of income, the wider the level of federalism, the stronger the leading nation(s) and the more comprehensive the knowledge, the more likely is the probability for collective action to address effectively climate change.
Climate change is a problematic GPG: according to Nordhaus (2002: 4) it involves «huge numbers of economic agents in a large number of countries and….the costs and benefits of action do not indicate any obvious fiscal policy or technological fix». These difficulties are actually determined in various degrees by all the above mentioned factors characterizing GPGs.

2.2 International collective action and global public goods

There is no legally binding mechanism by which disinterested sovereign nations can be forced to enter into any agreement for the provision of GPGs[18]. After outlining the most important approach to international cooperation, I focus on the possibility of a coalition formation through the game theoretic perspective, the interests determining the participation in international agreements, and the possible sanctions imposable to countries that refuse to comply with the framework defined by the international community.

2.2.1 Approach to international cooperation

Three major theoretical approaches dominated the debate about international relations in the latest decades[19]: realism, neoliberal institutionalism and cognitivism. The main characteristics of these approaches related to global climate change are summarized in the following table.

Table 2 – Characteristics of theoretical approach and global climate change (GCC)

Approach	Key concept	Hypothesis on international cooperation on GCC	Evaluation of GCC policy
Realism	Power and interests	Major powers determine the international rules of GCC regulation	Major powers successfully blocked GHG rules
Neoliberal institutionalism	Institutional factors	International regime on GCC will emerge and assist the strengthening of international rules of GCC regulations	No univocal effects of international institutions on strengthening GHG reduction rules
Cognitivism	Epistemic community	Experts with access to decision-makers strongly influence international rules	Hypothesis supported at the stage of agenda setting, not at the stage of concluding international rules of GHG reduction

Source: adaptation from Sprinz, Luterbacher (1996: 33)

Realism depicts a world dominated by interests of national states to maximize their own power and security, where international cooperation takes usually the form of temporary, power-balancing, alliances. In climate change issues the notion of power is partly unclear, nonetheless major players (e.g. the USA) may to some regards have sufficient resources to influence unilaterally the outcomes of negotiation processes according to their particular interests. Unfortunately major

[18] Nordhaus addresses this situation as the "Westphalian dilemma": «Under international law as it developed out of the 1648 treaty of Westphalia and evolved in the West, obligation may be imposed on a sovereign state only with its consent» (Nordhaus, 2002: 3).

[19] Usually the major approaches considered are four. I omit the Marxist or historical materialism one, because in the climate change arena it does not seem very helpful. Actually, according to it, the rules of international policy-making simply reflect the interest of the rich North at the expense of the poorer South.

powers' interests do not seem to get along with international cooperation on climate change. Rather, they resist efforts to reach an international agreement to effectively curb GHG emissions.
Neoliberal institutionalism suggests that the international arena is not only the battlefield of national interests. Actually, international institutions too play a crucial role either by driving national powers and interests toward certain behaviours, or being themselves a source of supranational powers and interests. Therefore, according to this approach, an international regime on climate change will very likely emerge, and this circumstance will improve the probability for setting international rules against global warming.
Cognitivism points out the importance of knowledge and information in supporting decision-making processes. Consequently transnational networks of experts and educated policymakers play a crucial role in shaping international rules. Matter-of-factly the influence of epistemic community has been important in raising the consciousness of the climate change risk and in setting the political agenda. Less significant has been the experts' opinions at the stage of defining international rules against GHGs emissions.
Besides the three classical theoretical approaches to international cooperation, is emerging in the realm of environmental agreements – especially with regard to climate change – the so called interest-based one which, in a sense, may also be seen as an extension of realism.
In brief, it puts forward the centrality for each country to weigh benefits and costs of entering any international agreement. Two orders of considerations hence drive the willingness to enter an international environmental regulation: on the one hand the ecological vulnerability, on the other hand the cost of the enforcement of the rules set by the international agreement. In general, the higher the ecological vulnerability and the lower the cost, the more will be the favour to regulations. According to Sprinz and Vaahtoranta (2002), countries with high ecological vulnerability and low abatement cost should act as *pushers* in the international arena, while countries with the opposite characteristics as *draggers*. Moreover, countries with low vulnerability and low cost are supposed to be *bystander*, and countries with high vulnerability and high cost *intermediates*.

Table 3 – The interest-based approach

		Ecological vulnerability	
		Low	High
Abatement cost	Low	*Bystanders*	*Pushers*
	High	*Draggers*	*Intermediates*

Source: Sprinz, Vaahtoranta (2002: 324)

This four-fold classification proves helpful in foreseeing the behaviour of countries. Actually being the benefit cost ratio the most favourable for pushers and the least convenient for draggers, the former are expected to strongly support international agreements, while draggers are supposed to be the most adverse, and both intermediates and bystanders move between the two extremes.
The above-illustrated attitudes towards international cooperation in dealing with climate change are ultimately shaped by political processes, and thus can be usefully interpreted in the light of the framework offered by political science theory. In fact, states are not unitary actors; rather they are complex players whose behaviour is a function of three main determinants: the internal distribution of interests, the internal distribution of power, and the nature of institutions. Moreover climate change is not the only political issue, and thus its relevance depends also on the urgency of other concurrent concerns. In this perspective the international approach to cooperation cannot be one of maximization in terms of avoided damages and diminished abatement costs. The "policy game" causes government actions to deviate from the main road indicated by the maximization of national interests. Furthermore, an international environmental agreement is a social institution that promotes "social roles" rooted in considerations of legitimacy and authority that in some cases could overwhelm benefit-cost calculations.

2.2.2 The game theoretic perspective

Game theory has been quite widely used to explore international environmental cooperation, especially in order to understand the emerging international regime and the possibility of coalition formation. Regrettably the very problems posed by dealing with a GPG such as climate change has not yet been thoroughly analysed in this perspective, in spite of the fact that game theory

would provide helpful insights on the potentiality of climate agreements in curbing GHGs emissions[20].

Some early contributions used to see cooperation against global warming inevitably as a prisoners' dilemma giving rise to the tragedy of the common. Instead the logical rigor of game theoretic perspective, as same recent literature pointed out, can help bringing into focus the outcomes of international cooperation and the effectiveness of compliance systems even in presence of spillovers, a main feature of climate-related decision processes. These innovative approaches usually rely on a non-cooperative game-theory framework.

In the case countries negotiate on a single worldwide agreement the main conclusion are the following (IPCC 2001(d): 621): global self-enforcing agreements are unlikely due to asymmetries across countries and incentives to free-ride; when such an agreement exists, it is signed only by a few countries, while when a large number of countries the difference between the co-operative behaviour and the non-cooperative one is very small. These results suggest that this route cannot lead to a stable coalition formed by all major polluters. At the same time most recent empirical literature concentrates on partial agreements, especially with regards to the strengths and pitfalls of the Kyoto Protocol[21] in terms of the number of countries that commit themselves to emissions limits. By and large, this family of studies indicates that the Kyoto mechanisms greatly reduce the cost of compliance for any type of coalition. Moreover according to these evidences partial coalitions are effective when there are not spillovers, when the baseline scenario is characterized by high pollution level, and when signatory countries emit a large share of the total GHGs released. Finally, they prove that to broaden a climate coalition it is very important linking climate agreement with other international agreements (for instance on technological co-operation or on trade).

More specifically a study of Helland (2002) uses two open horizon games - the Barret model and the Green-Porter model - to investigate the results of climate change agreements. The former predicts that in a group of countries behaving rationally only minor agreements will be implemented by all the members, while more important climate agreements will be implemented only by a few countries, thus making the agreement itself of little use for the group. In the Green-Porter model countries have imperfect public information, i.e. they cannot observe other's action directly, but the conclusion is similar to the one of the previous model: large groups are less cooperative since their marginal impact of non-compliance is smaller. According to this point of view the number of parties to international agreements is decisive, and wide treaties, as the ones required by climate change, are unlikely to have relevant outcomes.

Turning to the issue of climate agreements compliance, non-cooperative game theory suggests, according to Hovi (2002), that establishing a system for hard enforcement (i.e. through political or financial penalties) is a tough task. A stable equilibrium situation requires in fact rigorous and more then proportionate consequences to discourage non-compliance. Moreover, to be credible in case a transgression takes place, these punishments ought to be individually and collectively rational and thus need to operate on the Pareto frontier, rather than on other sub-optimal states.

In general game-theoretic perspectives envision "win-loose" scenario, where a number of countries or regions benefit from global warming, while others are damaged[22]. Sandler (1996) examining non-cooperative games points out that preferences over global warming are not consistent with the pure public good model since they are regional-specific; hence no neutrality results, i.e. income redistributions alter the equilibrium quantity of the public good.

The game-theoretic perspective puts therefore forward some reasons for pessimism about the success of collective action in relation to global climate change. In fact the number of players is very high (much higher than in the case of the stratospheric ozone depletion problem, when the Montreal Protocol succeeded in enforcing a treaty to ban CFCs). Furthermore parties are very different with respect to causes, impacts and costs of climate

[20] In fact the problem of the provision of public goods are often analyzed as strategic interaction between different players who are stimulated to free-ride. In the climate arena the maximum abatement that each player can achieve has small impact on global warming, and since emission cutback are expensive free-riding incentives are quite strong.

[21] In the end, in fact, the Kyoto Protocol can be seen as a tentative partial agreement.

[22] Notwithstanding other interpretations consider global warming as an asymmetric transboundary externality generating "lose-lose" scenario, in which every country is damaged.

change, and thus they have, due to the lack of related sanctions, strong incentives to free-ride. Unfortunately there is no sound game-theoretic reason to assume that every party would eventually take part. Nonetheless game theory demonstrates that the number of the actors involved is crucial for the success of whatever agreement: the larger the number of participating countries, the larger the reduction of abatement costs gained via flexible mechanisms. Hence even a partial "sub-optimal" agreement – as the Kyoto Protocol – is not necessary ineffective: it is effectiveness relies mainly on the number of participants, and thus the correct size could transform it in an in an "optimal" one.

2.2.3 A public choice view

Another important aspect of the public good nature of climate stability gives rise to ineffective or questionable choice of instruments, and to inefficient attainments of set goals. As far as these issues are concerned, the theory of interest groups, or public choice, can prove a promising point of view.

According to this perspective, the policy process is an output of the political market, a market whose demand side consists of interest groups, and whose supply side of politicians and bureaucrats. The essential idea of public choice theory is that every agent acts in her own interest, both in the private and in the public sphere. This condition can result not suitable in addressing GPGs issues, insofar political participation is presumed to be centred on the calculation of personal advantages and benefits of the political process usually accrue to politicians, bureaucrats and other interest groups, while costs are spread by and large among the public. The key actors in the climate change arena are basically the industry, environmental organizations and decision-makers (politicians and bureaucrats).

The industry

Apparently the preferred strategy for the industry – the main polluter – or for business lobbies is to oppose every restriction of emissions. Their goal is to keep costs of coping with climate change the lowest possible. But companies, at least responsible ones, have also less narrow economic and social roles, in which environmental friendliness can play an important part. According to Boom and Svendsen (2000) the business community prefers voluntary agreements at national level, since they are flexible and economically and environmentally effective, and refuses taxes considered too burdensome, and emissions caps deemed too tight.

Environmental organizations

The agenda of all involved environmental organizations is to reduce global warming. Their attention is on the level of emissions, with scarce or no consideration to the cost of achieving that level. They usually agree on the demand of limits on trading, because they fear that trading pollution permits could prevent the domestic effort to curb emissions. Moreover they had scarce impact on policy because they have rather showed any preferences for the different instruments to address global warming. At the same time environmental groups tend to be poorly accountable to their members and their claims could sometimes provide misleading information if the end justifies the mean. Their main focus is at international level, where the rent-seeking activities of environmental interests resulted more important than the industry's one at the Kyoto COP, while they became less well represented in the following COPs.

Decision-makers

Decision-makers', the supply side of the political process, influence on climate change negotiations is quite difficult to verify since, compared to industry and environmental organizations, they apparently keep a lower profile. Anyway, since the Berlin Mandate (Berlin COP 1 – 1995) the climate change bureaucracy is growing. By all means, politicians and bureaucrats have strong incentives to support evidences and actions of the necessity to firmly address climate change, since this can extend their responsibilities and their influence. They tend to promote policies promoting discretionary decision in order to increase the manageable budget. Furthermore they have their own interests and preferences for climate instruments. For instance, their experience and familiarity can favour particular instruments, they can prefer high visibility instruments and policies, with hidden (and larger) costs to those with evident (and probably smaller) ones, and privilege distributional issues over efficiency.

The others
Among the others, the major role is played by the scientific community, especially the international one such as the IPCC. Science needs funding, but the competition for the scarce resources is harsh. High importance and policy relevance of the issue at stake are essential elements in the chase of funding: climate change has both. The scientific community is likely to be influenced by these incentives and thus it is not surprising its inclination to present global warming as a major danger.

In summary, the two most important pressure groups in the climate change debate are the industry and environmental organizations. The industry is active at national level, while only energy intensive sectors are present at international level. On the other side environmental interests are less organized at national level and more aggressive at international level, where in the absence of industry they may have considerable force. However climate change remains essentially a matter of governments, for the roles of the above mentioned groups of actors is limited to their capability of influencing and shaping policies.

2.2.4 Sticks and carrots

Any international effort to address GPGs relies on a credible enforcement and implies the treatment of non-compliers or free-raiders. In fact the success of an international agreement depends largely on how it is implemented in the single countries. Given the circumstance that every party is a sovereign nation and thus any obligation needs its consent, the issue arising deals with monitoring and enforcing that commitments are fully respected. The general nature of the commitments of a global agreement on climate change makes anyway difficult the enforcement process. Actually, the complexity of setting such an agreement depends basically on four factors. First of all, the heterogeneity of countries with respect to causes, impacts, mitigation and adaptation costs. Secondly there is no environmental leadership, and thus no possibility of achieving a global agreement in a sequential process. Thirdly, being the political focus only on a single international agreement there's no room for negotiation among bloc of different countries. Finally, as put forward above, there are strong incentives to free-ride, especially where no sanctions exist. However, almost every recent international agreement includes formal mechanisms for implementation review; furthermore there are a number of concurrent informal mechanisms to manage the cases of non-compliance. Nonetheless the verification and enforcement system can be made more effective by the use of coercive measures. For instance the world community can impose sanctions on a country which refuses to observe international agreements and norms. Sanctions, though rarely used, have proved to be effective, especially the economic ones[23]. They have been used, for instance, against the non-signatories and non-compliers of the Montreal Protocol for the protection of the stratospheric ozone layer, in the form of trade restrictions. In that case the trade restrictions dealt only with CFCs and did not encompass other goods and services[24]. Unfortunately international agreements cannot largely rely on sanctions, which in many cases are counter-productive.
Therefore, where cooperation fails, an additional and possibly complementary approach consists in providing positive incentives for compliance. Such carrots, in the form of financial help or technology transfer, may for instance induce developing countries to improve their energy efficiency. Or, besides, the enforcement of higher efficiency standards correlated with GHGs emissions can crowd out the exportations of less efficient countries, inducing them to improve the level of their offer: for example high fuel efficiency standards could force industries to produce more efficient goods.
Finally, it is worth to point out that market-based mechanisms, like the system of internationally tradable emission permits envisioned by the Kyoto Protocol, lowering the cost of participating in the international agreement (i.e. in the case of the KP reducing the GHGs abatement costs), favours the compliance. Nonetheless, the KP itself and its legally binding quantified commitments raise

23 There is also the possibility of using social sanctions (e.g. precluding the country form participating in international events or impeding its access to international bodies) and fines, like the ones contemplated by the European Union for violations of the Stability Pact. Both the instruments are less effective then economic sanctions. The former seem nowadays to prove too weak, the latter on the contrary are unpopular and scarcely acceptable demonstration of strength.

24 Here we would face the problem of the potential conflict with the World Trade Organization obligations (Adly, Orszag and Stiglitz, 2001).

compliance difficulties. The literature offers some legally binding consequence proposals for the non-respects of these commitments, such as payment into a (national or international) compliance fund that would invest in quotas, issue of warnings and reports to trigger off public pressure, suspension of treaty privilege. Alternatively the focus can be on the policy tools that prevent non-compliance. Here the most effective instrument is that emission trading and emission data be highly transparent and publicly available, in order to expose signatories to public judgement. Ultimately, with no global governance, the way to induce voluntary observance to an international climate agreement is based on a multiplicity of strategies. Probably the most effective factors are a commitment to the agreement objectives by the signatories and a high degree of transparency in their actions.

Conclusions

Usually, environmental issues can be settled by means of local solutions. Climate change is different, insofar it is the emissions of all sources in all nations that cause the concentration of GHGs in the atmosphere. Therefore, climate change problem is essentially a public good problem. That is, the climate is the result of everyone's behaviour. No single entity, neither individuals nor nations, can determine the concentration of GHGs in the atmosphere. Any independent action to address the climate change issue has almost trivial effects. As a consequence, individuals' and nations' autonomous actions will prove, together, less effective than concerted actions. This characteristic, which is a specific trait of global public goods, would apparently offer strong incentives for collective, global action from a theoretical standpoint. In reality public goods have particularly crucial features: non-excludability and non-rivalry. Furthermore, GPGs, have a third dimension since they provide globally available benefits unconstrained by national boundaries. These elements may eventually provoke a policy failure that limits collective actions. The very nature of GPGs also implies that all social structures are covered. This in turn entails that an array of policy responses is needed. Unfortunately, responses that are effective and proper in one social context could be completely improper in others. Another major problem due to the global public good nature of climate change concerns the diversity of emissions and impacts among countries. Both emissions and the capability to control them are unequally distributed among countries. Actually, countries can be positioned in a spectrum ranging from high emitters to low emitters and high impacts to low impacts. High emitters with low expected impacts have a high potential to control concentrations, but little incentive. On the contrary, countries with low emissions and high impacts have great incentive to control emissions, but little capability.
To put it sharply, global warming owes most of its intractability to its quintessential global public good nature.

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