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COP 21 and Economic Theory: Taking Stock

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Henry Tulkens

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Abstract

The texts of the COP 21 *Decision* and its *Annex* are scrutinized from the particular point of view of the extent to which economic theoretic concepts can be considered to inspire them. While this is shown to be partially the case in some of the intentions, the texts themselves contain more diplomatically formulated promises than implementation of mainstream well established economic concepts.

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Keywords: economic and game theory concepts, international climate agreements, voluntary cooperation, greenhouse gas emissions, transfers.

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COP 21 and Economic Theory: Taking Stock

Henry Tulkens

Introduction

COP 21² has been hailed, fairly unanimously, as a landmark. Rightly so for anyone who cares about the environment, and the future of the planet in particular. The reasons for that judgment are many; they have been given and elaborated upon in many places. But a landmark of what?

This paper ambitions to formulate a judgment on the main achievement of the meeting, namely, namely the texts of the *CP.21 Decision*³ and its *Paris Agreement Annex* (referred to henceforth as the "Paris texts") from the point of view our economic science and its occasional game theory partner. Considering the role played by physics, in its climate science branch, in the decades long preparation of what is reached today, all along the UNFCCC process since 1990, it is probably correct to characterize the accord as "science driven policy". Can the same be said about economics?

The paper is addressed to academic economists, with economics considered here in its decision science dimension. The purpose is neither to evaluate the environmental merits of the Paris texts, nor to appreciate the chances that these texts will be effective. The objective is rather internal to the profession: is there a part, if any, of the Paris success that can be attributed to our economic theory?

The question is worth asking. Since the early 70's, problems of transfrontier pollution have been a field of encounter between economic theory and game theory. The emergence of the climate change problem in the late 80's has activated that encounter, due to both the worldwide size of the phenomenon and its very long term dimension. The increased availability of equally worldwide simulation modeling of the economy coupled with climate models from physics, has added occasions to combine theory and factual knowledge in a fascinating way. There is thus an about forty years background of research available to enlighten ideas and policies in this field.

² This is the acronym for the 21st Conference Of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), held in Paris in December 2015. The Convention was signed in 1992 and ratified by all countries members of the United Nations. The Kyoto Protocol, also ratified by all members except the USA, is the Convention's main achievement thus far. It entered into force in 2005 for a first commitment period lasting until December 2012, and was then prolonged until 2020.

³ That part consists of 140 paragraphs, which are the *decisions* taken by the Parties at the meeting. The *Annex* that follows, entitled "Paris Agreement", is a 29 articles document that the Parties decide to submit for ratification to their respective competent authorities. The ratification requirement distinguishes legally the Annex (which is binding for the ratifying country) from the decisions text.

As a precautionary remark, let me say that as an academic not involved in the negotiations, my views are only those of an observing "applied theorist", in search of the internal logic of a collective decision such as the one of COP 21.

In what follows, I begin in sections I (the grand coalition?) and II (on strategies) with game theoretic considerations, given the dominating relevance of the decision science aspects of my purpose. I then pursue in sections III (on outcomes), IV (on dynamics), V (on mitigation, adaptation, loss and damage, and transfers), and VI (on carbon pricing), with more strictly economic issues. The final section summarizes.

I. "Applicable to all Parties": the grand coalition in sight?

When learning about the Durban COP 17 decision taken in 2011 to "launch a process to develop a protocol, another legal instrument, or an agreed outcome with legal force under the (UNFCCC) Convention *applicable to all Parties*⁴", this author could not resist thinking that the economic rationality of public goods theory was going to prevail in international action on climate change. The problem being unanimously recognized in the profession as one of a "global public good", hence requiring an equally global joint decision framework for all countries of the world, the logic was thus confirmed that a full-fledged form of cooperation is called for – the one of the so-called "grand coalition" in game theoretic jargon – and here it was going to be implemented⁵. In fact, more than 185 countries were present at the COP 21 meeting of 2015 in Paris, as many signatures of the document are expected in the coming months prior to April 2017 and ratifications should follow, with entry into force of the Agreement after ratification by 55 countries representing 55% of world CO₂ emissions. For citizens of the planet, all this is very good news. A study of the texts motivated by economic theory is not that rejoicing.

II. On strategies

A fruitful cross fertilization between economics and game theory can only occur if a precise correspondence is established between the components of the economic problem to be handled and what the components of a game are. A game is indeed only a mathematical object, whose contribution to economic thinking and decision making is only possible if the economic issue at stake is couched in terms that the mathematical object can handle. To be

⁴ My italics.

⁵ The feasibility and the virtues of this view had been expounded over several years and with several colleagues in various theoretical and numerical simulation papers as well as in lecturing activities, such as: Chander and Tulkens 1995, 1997, 2006, Eyckmans and Tulkens 2003, Bréchet, Gerard and Tulkens 2011, Tulkens 2012, 2013.

precise, and just as a reminder, a game in strategic form⁶ is a triplet that I shall denote here as (N, Σ, u) where N is the set of players, Σ is the set of strategies (*i.e.* actions) accessible to the players, and u is the vector of payoffs (*i.e.* utilities) of the players that result from the actions taken by the players. Call a "strategy profile", denoted σ , an element of the set Σ , that is, a specification of the actions taken by all players at some moment of time.

With that minimal apparatus, filled with specifications of the economic contents of the strategy sets and of the payoff functions to form what I like to call the "global externality game", I did propose with three colleagues⁷ an economic and game theoretic interpretation of the Kyoto Protocol. It that has lent itself to not only direct applications and extensions of more than one game theoretic solution concepts to the standard economic model of a global public good, but also to their numerical implementation in a so-called "integrated assessment model" of climate change. For the purpose of this comment, the role of this reminder is to bring the reader's attention directly to my first point: what contribution from game theory can one find in the Paris texts?

After a first reading, one is tempted to answer "none", for the simple reason that there is missing one of the three components of a game, namely a specification of the strategies. While players are obviously the parties to the Convention and their payoffs are their individual development levels, there are no environmentally relevant actions to be taken by the players being specified. At variance with the Kyoto Protocol where actions were explicitly stated in great detail, most typically amounts of greenhouse gas (GHG) emission reductions including the specification of units of measurement). The Paris texts contain no quantities, *a fortiori* no units. The game is incompletely defined. I elaborate a bit on this, as exploring this gap may teach us something.

(a) The nature of strategies: emissions and transfers

There are only two figures appearing in the texts under scrutiny (other than administrative ones): "2° C" and "1.5 C", in Art. 2(a). Couldn't these be called the strategies, as suggested by common parlance? In the decision science context we are in here, such vocabulary assimilation would be confusing a *state* variable with a *decision* variable. In the climate change problem, the temperature level – a variable describing the state of the system – cannot be in itself the *direct* object of any human action; it only can *result* from decisions whose direct object is something else, such as and primarily, emission reductions. Thus, the

⁶ As distinct from the extensive form and the coalitional function form. These two alternative forms, complementary to the strategic form, will be briefly evoked below when appropriate.

⁷ In Chander, Tulkens, van Ypersele and Willems 2002 and its update by Chander and Tulkens 2011.

"2° C" and "1.5 C" statements cannot be considered as strategies in an attempt to give a game theoretic interpretation of the outcome of COP 21.

But what should strategies be? Not only emission reductions of course. In the socio-economic context we are in here, other decisions can be candidates for being strategies in a game theoretic approach, such as transfers, be they financial, or materialized in some specific physical resources, or still consisting in elements of information or knowledge, provided they are definable unambiguously and, when quantifiable, expressed in terms of well-defined units. Unlike the Kyoto Protocol⁸, the Paris texts cannot be considered as the outcome of a strategic game, simply because the strategies (= actions bearing on the physical magnitudes of the problem) are not specified.

Yet, the Paris texts are an outcome of something (other than a game), which one may find in a series of *commitments to action*. These can be regrouped in two main categories:

- (1) Commitments by all Parties to adopt in the future some quantitatively defined *emission reductions*, individually determined: individual strategies for most countries, possibly coordinated for groups of countries such as e.g. the EU.
- (2) Commitments by some Parties (called "developed country Parties"), to provide *financial transfers* to other players (called "developing country Parties"), not in lump sum form but in relation with the adaption needs, loss and damage needs, capacity building needs, equity feelings, of the second group, to be determined by future COPs.

In this wider interpretation, fuzziness remains as to which Parties are "developing" and which ones are "developed", a distinction that is clear in the Kyoto Protocol, so one knows who are the players. In the Paris texts the incompleteness in the formulation of the game extends even to the uncertainty on the identity of the players.

Now, and in an attempt not to remain confined within purely classical forms of economic games, one may think of the Paris texts as the outcome of a game where the strategies are not actions, but precisely these announced "commitments", or promises of actions. Not impossible: one may remember the example of games in public goods theory where strategies are not the physical goods, but instead preference revelation (Drèze and de la Vallée Poussin 1969, Roberts 1976, Henry 1979): more precisely announcements of willingness's to pay per unit of the public good. In these games, strategies do not bear on amounts of the public good⁹, but they are nevertheless numerical values. To allow one to exploit the so suggested analogy, the Paris Agreement should provide more precise

⁸ Typically, the Kyoto Protocol mentions three categories of magnitudes, each with well defined units of measurement: Assigned amount unit (AAU) for exchanges through emissions trading, Emission reduction unit (ERU) for emission reductions or emission removals from joint implementation projects, and Certified emission reductions (CER) for emission reductions from CDM project activities.

⁹ In fact, they are formulated in games whose solutions serve as information inputs in a resource allocation processes that determine the physical quantities of the public good.

indications of what the "commitment sets" could be. Otherwise no commitment announcement game can be formulated, no rational behaviors can be characterized, and no game theoretic solution concepts can be called for¹⁰.

A further stretching of the strategies concept could be to consider that the "mechanisms" to which it is repeatedly referred throughout the two Paris texts are in fact the strategies of the Paris COP 21 game. But again, the lack of definition of what a mechanism is makes this attempt illusory.

(b) The source of strategies

In general, the process of *formation* of strategies in a game situation is rather weakly covered in the literature that I know of: where do strategies come from? The history of climatic negotiations since their active beginnings with the Berlin mandate (COP 1, 1995) shows a recurrent debate on where proposals of action should initiate and then percolate until final adoption by the Assembly of Parties. A procedural distinction has often been made between two methods dubbed respectively "top down" vs. "bottom up". Up until the signature of the Kyoto Protocol and its generalized ratification, the former method dominated. The COP 15 in Copenhagen (2009) fundamentally changed this procedure into the latter one, when the US President and Chinese Prime Minister urged state negotiators to proceed by "pledges" voluntarily expressed by the countries¹¹. These eventually became what now appears as Nationally Determined Contributions (ndcs hereafter) in the Paris texts.

For logical arguments able to explain this important procedural evolution I know of no game theoretic explanation. Institutionally, top down methodology can be assimilated with "planning" imposed somehow by an external benevolent umpire, whereas bottom up is often considered to be an expression of autonomous individual decision making.

From a short enquiry on the preparation of past negotiations I learned that even during the top down years, Parties were always invited to submit initial proposals to the UNFCCC Secretariat, with this instance presenting syntheses in various subgroups of negotiators in view of final collective decisions. What is fundamentally changed with the bottom up methodology is at the synthesis stage. Ignoring "technocratic" concessions concocted by experts in subgroups, the Paris texts simply consider that ndcs, when received, will be registered and made publicly known. Period.

This change of procedure should strike any economist familiar with public goods theory, because of the major implication on the outcome of the negotiation that I deal with in Section III.

¹⁰ Filling out all these requests may be seen as formulating the components of the extensive form of the game sketched out to at the outset.

¹¹ Called later and for some time "intended" nationally determined contributions.

(c) The implementation of strategies

Contrary to the Kyoto Protocol there are no sanctions mentioned in neither one of the two Paris texts. The achievement of the announced contributions is thus not mandatory. The ineffectiveness of sanctions is a known drawback in many international agreements in general, and the Kyoto Protocol is no exception, in spite of quite elaborate and innovative attempts made with the Marrakech Accords of 2002. Rather than punitive sanctions, the Paris Agreement introduces in Art. 14 a mechanism sometimes informally dubbed "naming and shaming" that should induce implementation by creating a reputational risk – an essentially political cost – for those parties that would not implement their ndcs. Under the official denomination of "transparency" the main practical instrument of naming and shaming consists in repeated occasions of mandatory reporting on emissions and transfers of many kinds to the future COPS. These are called periodic "global stocktakes", that should start in 2018 and occur every five years thereafter.

There exist "reputation games" in the literature, but I am not aware of any environmental application that might have inspired the negotiators in this direction. Absent such information one may think that they have invented an innovative solution, in a compliance game rarely dealt with¹².

III. On outcomes

(a) Equilibrium with subscription

While the two Paris texts do not specify explicit strategies that would allow for a well grounded game theoretic interpretation, the framework they establish is structured enough to allow one to speculate on the state of the world that could prevail if the kind of strategies these texts announce were to be implemented. Let me go now into a bit of science fiction.

Here, economic and game theories combine nicely. It will not escape to any student of public goods theory that the logical economic outcome at the world level of the "bottom up" procedure of determining future emissions in terms of ndcs exactly corresponds to the concept of *equilibrium with subscription* first introduced by Malinvaud 1969 (pp. 173-176; pp. 213-214 of the 1972 translation). This basically economic concept¹³ is also shown to be of the nature of a Nash equilibrium in a game in which the decision variables (which are the emission strategies in the application below) are "voluntary contributions" of the players, and the sum of these contributions determine the quantity of the public good, *i.e.* a state variable. Being based on voluntary strategies, the concept may be seen as very democratic.

¹² The work of Hovi and Areklett 2003, who deal with the sanctions designed in the Marrakesh Accords is an exception. It might be a useful starting point for a game theoretic study of the name and shame sanction system.

¹³ In the spirit of the Cournot equilibrium in oligopoly theory.

Malinvaud¹⁴ also shows, however, that an equilibrium with subscription is not Pareto efficient: away from it, with cooperation, things can go better for all.¹⁵

Application of that concept to international environmental problems¹⁶ requires a slight modification of the production side of the economic model, so as to allow for multiple producers of the "public good"¹⁷. In that context, the suggestive vocabulary of "environmentally nationalistic equilibrium" was proposed¹⁸, a denomination also adopted by Dasgupta 1982 (p.22), to characterize the non cooperative equilibrium. While that literature developed around "flow" *i.e.* static pollution problems, a further extension of the economic environmental model toward dynamics became necessary later when the accumulation of CO₂ as a stock externality entered the picture. The non cooperative equilibrium concept of the static model has been extended to a dynamic version of it but not, to my knowledge, in the spirit of a dynamic equilibrium with subscription. The focus has been more on the comparison with Pareto efficient trajectories of emissions and states of the system. Corresponding to this dynamic extension of the economic model, dynamic games theory has been brought in, on which I'll have more to say in Section IV.

Turning to the Paris texts of today, I hereby propose to interpret them as establishing a regime of successive equilibria with subscription. I elaborate below on the dynamics and focus now on characteristics of one typical stage in that sequence. First, while being inefficient in the Pareto sense, the world emissions are not reduced to zero at any such equilibrium. This is in contrast with what is called "business as usual" equilibrium, that is, the equilibrium of the economy when no emissions abatement policy at all is in force. The subscription equilibrium concept rests, indeed, on assuming that each country does implement a domestic policy on the basis of its preferences only *vis à vis* the environment. The interpretation proposed above consists in asserting that the ndcs, as currently filed by the countries with the Secretariat of the UNFCCC, are precisely the expression of these national policies. Environmentally, the sum of the ndcs is thus a *juxtaposition* of domestic policies. With this interpretation, this sum should logically not be zero. But it is also not efficient.

¹⁴ As well as followers who dealt with that concept, among which Cornes and Sandler 1986 (chapter 5) and Hirschleifer et al. 2005 (pp. 521-527).

¹⁵ Roberts 1976 later showed that the larger the number of consumers in the economy, the farther the equilibrium with subscription is from Pareto efficiency.

¹⁶ The Malinvaud concept was formulated at least ten years before international environmental problems started being considered in the economic literature.

¹⁷ After this modification, the phenomenon being handled is better designated as the generation of *an externality with public good* – *i.e.* diffuse – *characteristics*.

¹⁸ In Tulkens 1979, pp. 203 and 204.

I am reaching here one of the main points of failure of our discipline. While economic science is conceptually rich enough to characterize the (likely) contents of the Paris texts and lucid enough to point out its efficiency deficit, it obviously has failed to play a role in orienting the design of this contents towards world efficiency. Diplomatic skills succeeded in getting an agreement but it is devoid of part of its desirable contents.

Malinvaud 1969 pointed out that with cooperation, an economic state better than the equilibrium with subscription is reachable. Paradoxically, the Paris texts are full of requirements, expectations, and demands for cooperation between Parties in the determination, the promotion and the facilitation of the ndcs. But these calls are just for the achievement of *their own* (Nash) abatement policies; there is no word in these texts on going beyond these policies. The cooperation that Malinvaud is calling for is instead one towards Pareto efficiency, which essentially consists in emission reduction levels that go beyond the Nash equilibrium levels. In the Paris texts, cooperation is not towards achieving efficiency, it is rather towards ensuring at least a minimal environmental "co-habitation"¹⁹.

(b) Partial agreements Nash equilibria and climate clubs

Over the last two decades, a purely game theoretical controversy has occupied the minds of many economists, bearing on the issue whether the organization of the climate regime worldwide would be effectively a global one, gathering all countries of the world in a joint achievement of an efficient outcome, or a fragmented one with subgroups of countries ("coalitions") each adopting policies of their own. The main reason invoked for doubting of the likeliness of a "grand coalition" is the temptation of free riding on the part of some, possibly many, countries leaving the group and letting the others do the emissions abatement job. Instability of the group would thus characterize any worldwide agreement and make it logically unlikely.

Two responses have been made. One is to conceive of international transfers to stabilize the grand coalition, the other is to consider that groups of other sizes are conceivable. Both have been explored by myself and many colleagues in several joint papers. The former calls on the concept of the core of the game evoked above, taken in its cooperative form, and shows that stability of the grand coalition can be achieved by means of appropriately designed transfers between the countries. The latter is known as the concept of Partial Agreement Nash Equilibrium (PANE) relative to a coalition²⁰, which characterizes

¹⁹ In Bahn and Haurie 2008 an attempt is made to combine the non cooperative equilibrium view with the countries meeting a global constraint, such as 2°. It would be of interest to explore its connection with the outcome implied by the Paris texts.

²⁰ Introduced in Chander and Tulkens 1997, Definitions 6 and 7, and with existence proof 4 on pp. 387-389.

what the members of a single coalition of any size would rationally do, when it forms, letting the other players stick to individually determined strategies.

The Chander and Tulkens 2011 paper presents what is relevant from this stream of literature for the present confrontation between theory and the policy achievements under the UNFCCC process. From the date of entry into force of the Kyoto Protocol (2005) until the end of the first commitment period (2012), it is claimed that a PANE relative to a coalition is prevailing, the coalition consisting of the set of all Parties that have ratified the Kyoto Protocol. Remembering who these are, only one country is outside of that coalition, pursuing its domestically preferred policy namely the USA. From 2012 on, under the extension of the Protocol decided by COP 18 in Doha, the coalition of ratifiers changes: due to some defectors there are by now more numerous non ratifiers adopting their domestically preferred policy instead of complying with their Kyoto commitment. Notice that in making assertions of belonging or not to the stated coalition I refer to the ratification²¹ decisions which are effectively how countries express their strategy: either the cooperative emissions policy mentioned in the Protocol, or their domestically preferred individually decided emissions.

The Paris texts of COP 21 have no relevance for this characterization of the climate regime since they bear only on what will prevail after they will be ratified. For that period, and on the basis of these texts, one may venture that it could be another PANE relative to some coalition. Typically an equilibrium with subscription with some "subscribers" being a coalition – *e.g.* the European Union, abatements occurring both within and outside of that coalition. In any event, on the basis of these texts, it appears very illusory to expect an efficient state of affairs to ever prevail.

In his presidential address to the American Economic Association, Nordhaus 2014 has introduced the nicely chosen nickname of "climate club" for a coalition of the kind just discussed. But his reference to the Buchanan 1965 theory of clubs may be a source of confusion for students of public goods theory: Buchanan's clubs are defined for excludable public goods, thus, clubs of consumers who can deprive some others from access to the good, whereas climate change, a global public good²², is physically non excludable. However, if one ignores that reference, then the Nordhaus clubs are indeed coalitions of producers of the global public good – producers of CO₂ in our case, as the coalition is assumed to do at a PANE.

Art. 4.16-18 allude to the European Union acting as a "climate club" under the overall scheme of the Paris texts. The result will clearly be a PANE relative to the EU coalition. The

²¹ Not to whether or not the country belongs to the subset of those who are assigned abatements specified in Annex I of the Protocol. Non Annex I countries are also ratifiers: only in that capacity can they participate in emission reductions through the clean development mechanism.

²² A public *bad*, for sure! This is why describing the problem as one of "a global externality with public good characteristics" is a better terminology.

texts implicitly allow for possibly more than one such coalition forming in the future. Each coalition doing by definition some abatement, this suggests an equally nice picture drawn by Roger Guesnerie 2015 who advocates "little creeks" eventually forming a large river...

IV. On Dynamics

Compared with the Kyoto Protocol, the Paris texts contain many more provisions concerning the future, and more precisely, on the organization of that future. They are here, to some extent, more explicit on the characterization over time of the strategies than on the content of the strategies²³. Basic in this respect are the provisions of Art. 4.2 and 4.9, according to which *every five years* each Party shall communicate successive ndcs, and be informed of the "global stocktake" referred to in Art. 14. Various modalities accompany this disposition: in Art. 4.3 there is a "ratchet" clause saying that each time, the reported ndc is to represent a *progression* beyond the Party's current ndc. As to the strategies themselves, industrialized countries shall have economy-wide absolute targets of emission reduction (Art. 4.4), whereas developing countries should only "move over time" towards economy-wide reduction or limitation targets (Art. 4.4)²⁴.

Turning now to economics, when dynamics has been introduced in the game theoretically inspired literature on international environmental problems, in the late 90s and early 2000s, the methodology of optimal control has been brought in and dominated the scene, focusing on Pareto efficiency and Nash equilibria of trajectories of emissions, consumptions, investments, etc. that extend over very long periods of time (often centuries). This was the case with both analytical theoretical and simulation models.

Compared with this methodology, one may observe that the time profile of the climate regime proposed and announced by the Paris texts lies ahead of optimal control. Ahead in the sense that the procedure of quinquennial communications and stocktake institutionalizes the necessity of taking into account the state of the system as it is at that point as well as the possibility of rethinking the strategies on that basis. This is not possible with the optimal control models used by, say, Nordhaus and Yang 1996 as well as Yang 2008 in the RICE model, by Bréchet, Gerard and Tulkens 2011 with the CWS model and more recently by Bréchet and Tulkens 2015, or still by Bossetti et al. 2014 with the WICH model.

The alternative methodology of dynamic programming with feedback effects of state variables proposed in Germain et al. 2003 and 2010 lends itself better to a formulation of successive re-negotiations over time. The PANE, efficient and core solution concepts evoked

²³ As stated in the remarkable presentation of the Paris texts by Obergassel et al. (p.3): "The question is (...) not whether the Paris Agreement will deliver the emission reductions necessary, but whether the agreement has the potential to catalyse further changes..."

²⁴ Incidentally, notice that the difference between "shall" and "should" in Art.4.4 is intended, showing again a difference of commitment between developing and developed country Parties.

above find their place in a natural way in that theoretical dynamic structure which is in good agreement with the future proposed by the Paris texts.

V. On mitigation, adaptation, loss and damage, and transfers

Since the early 2000s, adaptation has gained an important place in the overall thinking on the climate change problem and it is given a prominent place in the Paris texts: Art.7 on adaptation now parallels Art. 3 and 4 on mitigation. It appears as an object of major concern and rightly so in general, and from the strict economic point of view in particular. Indeed, that kind of action will mobilize in the future large amounts of resources in many countries, and it is therefore worth considering with as much attention as mitigation. It was surely an error to have it absent from the Kyoto Protocol.

From the economic theoretic point of view, the reasons for international cooperative agreements on adaptation are different from those necessary for mitigation. Mitigation bears at reducing the amount of a public bad that affects all economic agents, whereas adaptation is more of the nature of a private good due to its essentially local character and therefore does not affect all. The former requires cooperation from all because without it an efficient provision cannot be reached. It bears on the total amount of mitigation. By contrast, an efficient level of adaptation essentially depends on who are the beneficiaries of it. Its appropriate level rests on a comparison of local costs and benefits. This does not tell, however, whether or not a country where an adaptation investment is envisaged and justified has the resources to over its cost. A recent paper by Bréchet et al. 2016 deals with this issue in a dynamic general equilibrium setting.

The cooperation called for by the Paris texts on the issue of adaptation is dominated by this last consideration. Knowing that the major part of damages will occur in developing countries, covering the costs of large adaptation expenditures will be impossible for them, even for projects where the efficiency criterion – that benefits exceed the cost – is satisfied. Only transfers can ensure the desirable decision in such cases.

I purposely regrouped above, in section II.(b), in two categories of decisions, the two kinds of strategies listed there: one bearing on magnitudes of physical emissions, the other on transfers of resources. Among the latter, financial transfers linked with emission reductions (e.g. Art. 4.5) do obviously contribute to the financing the public good. The others (Art. 7), when taking a share in the finances of adaptation projects, also contribute to efficiency in achieving the proper balance between the respective roles of adaptation and mitigation²⁵ in the fight against climate change. When they are paid as compensation for loss and damage (as in Art. 8), they are essentially distributional.

²⁵ Roles that are delineated in Tulkens and van Steenberghe 2011 in the benefit-cost perspective.

In the game theoretic literature, transfers are seen as cooperation enhancing and stabilizing instruments whereas in the economic development perspective, which very much dominates the Paris texts, their distributional function is privileged.

VI. On carbon pricing: an instrument relegated to "voluntary cooperation".

As is well known, the marginal abatement costs differ across countries at a Nash equilibrium of the global environmental game – thus at the equilibrium with subscription of the economy. There are thus social efficiency gains to be made through transfers if designed so as to equalize these marginal costs. And the simplest institutional form for this to occur is the one in which the countries transfer to one another emission units against some *numeraire*, through a competitive market. This elementary economics must have been present in the mind of the conceptors of Article 6 of the Paris Agreement annex, because it is all in there – but, strangely enough, in a quite hidden way.

Indeed, under the expression of "voluntary cooperation schemes", Art. 6.2 of the Paris texts mentions the possible "use by the Parties of *internationally transferred mitigation outcomes* towards nationally determined contributions ...", and Art. 6.4 pursues in announcing that "a mechanism (...) is established" to organize that instrument towards the mitigation of GHG emissions by the parties "on a voluntary basis". Commentators (Obergassel et al. 2016) further observe that according to that article all countries can use the announced mechanism, which should combine features of CDM and JI²⁶, and that par. 38(f) of the CP.21 decision "recommends that this mechanism be designed on the basis of (...) experience gained and lessons learned from existing mechanisms and approaches adopted under the Convention and its related legal instruments".²⁷

The good economics of the Kyoto Protocol are thus present – and there is perhaps even more, given the kind of vocabulary used – but in such terms that the words emission units, price of carbon, market are totally absent from the 9 sections of Art. 6 of the Agreement as well as from the entire par. 38-39 of the Decision. How come? Diplomatic language to have it in without saying it, I have been told, due to skeptic opposition to market mechanisms on the part of some delegations²⁸. More constructively, Art. 6.8-9 of the Agreement and par. 40-41 of the Decision announce that a framework is defined to promote *non-market* approaches to sustainable development, "integrated, holistic and balanced", to assist the Parties in the

²⁶ Acronyms of mechanisms established under the Kyoto protocol.

²⁷ These are CDM and JI just mentioned and, last but not least, cap and trade.

²⁸ The carbon price idea regained visibility among officials with the launching in mid April 2016 in Washington DC, just a few days before the signing ceremony of the Paris Agreement in New York, of a "Carbon Pricing Leadership Coalition", with Ms Segolène Royal as vice-chair.

implementation of their NDCs. Unfortunately the content of such framework is not as precisely specified than the mechanisms retained in par. 38(f).

Finally, the kind of emissions trading at a Nash equilibrium that might emerge in the wake of the Paris texts has an early theoretical precedent in the remarkable piece of Helm 2003, where the trading bears on allowances that are themselves a Nash equilibrium outcome of some game. There is probably a close connection to be made between this Helm equilibrium and the equilibrium with subscription that I put forward in an earlier section of this note.

Concluding summary

In terms of both conceptual quality and substance of proposed action, the economics of the Paris texts is a real setback compared to the Kyoto Protocol. Nothing is destroyed, though: for instance, market mechanisms are still present as key instrument. But no progress is gained either. Environmentally speaking, nothing will change for several years, that is, the Kyoto regime will continue prevailing until 2020, admittedly as an inefficient partial agreement equilibrium "club". At its entry into force, the new "bottom up" (subscription) equilibrium prescribed by the Paris Agreement is known to be economically inefficient and environmentally insufficient. But at least better than "business as usual".

Diplomatically, COP 21 is a victory of immediate *savoir faire*. Its outcome, made of credible promises, may be a source of optimism for the planet. But, because of the fuzziness that dominates the texts as they are and the absence of decisions of material action, its economics cannot be characterized as "science driven policy".

References

- Bahn, O. and Haurie, A. 2008, "A class of games with coupled constraints to model international GHG emission agreements", *International Game Theory Review* 10 (04): 337-362
- Bosetti, V., Carraro, C., De Cian, E., Massetti, E., and Tavoni, M. 2013, "Incentives and stability of international climate coalitions: An integrated assessment", *Energy Policy*, 55(44-56).
- Bosetti, V., Carraro, C., Galeotti, M., Massetti, E., and Tavoni, M. 2006, "WITCH: A World Induced Technical Change Hybrid model", *The Energy Journal*, (27):13-38, 2006.
- Bréchet, T., Gerard, F. and Tulkens, H. 2011, "Efficiency vs. stability in climate coalitions: A conceptual and computational appraisal", *The Energy Journal*, 32(1): 49-75. reprinted in Carraro 2015.
- Bréchet, T. and Tulkens, H. 2015, "Climate policies: a burden, or a gain?", *The Energy Journal* 36(3), 155-170.
- Bréchet, T. Hritonenko N. Yatsenko Y. 2016, "Domestic environmental policy and international cooperation for global commons", *Resource and Energy Economics*, 44, 183-205.
- Buchanan J. 1965, "An Economic Theory of Clubs", *Economica* 32: 1-14.
- Carraro, C. ed., *Coalitions and Networks: 12 papers from 20 years of CTN workshops*, The FEEM Series on "Climate Change and Sustainable Development", FEEM Press, Milan.

- Chander, P. and Tulkens, H. 1997, "The Core of An Economy With Multilateral Environmental Externalities", *International Journal of Game Theory* 26, 379-401. Reprinted in Finus and Caparros 2015.
- Chander, P. and Tulkens, H. 2011, "The Kyoto Protocol, the Copenhagen Accord, the Cancun Agreements, and beyond: An economic and game theoretical exploration and interpretation", *CORE Discussion Paper 2011/51* (October)
- Chander, P., Tulkens, H., Van Ypersele, J.-P., and Willems, S. 1998, "The Kyoto Protocol: an economic and game theoretic interpretation", *Economic Theory for the Environment*, Festschrift in honor of Karl Goran Mäler, Eds. P. Dasgupta, B. Kristrom and K.-G. Logfran, Edward Elgar, 98-117.
- Cornes, R. and T. Sandler, 1986, *The theory of externalities, public goods and club goods*, Cambridge University Press, Cambridge.
- Dasgupta, P. 1982, *The Control of Resources*, Basil Blackwell (Oxford) and Harvard University Press (Cambridge, Mass.)
- Drèze, J. and de la Vallée Poussin, D. 1971, "A Tâtonnement Process for Public Goods", *Review of Economic Studies* 38, 133-150.
- Eyckmans, J. and Tulkens, H. 2003, "Simulating coalitionally stable burden sharing agreements for the climate change problem", *Resource and Energy Economics* 25, 299-327.
- Finus, M. and Caparros, A. 2015, eds, *Game Theory and International Environmental Cooperation*, Essential Readings, Elgar, Cheltenham.
- Germain, M., Toint, P.L., Tulkens, H., De Zeeuw, A., 2003, "Transfers to sustain dynamic core-theoretic cooperation in international stock pollutant control", *Journal of Economic Dynamics and Control* 28: 79-99.
- Germain, M., Tulkens, H. and Magnus, A. 2010, "Dynamic core-theoretic cooperation in a two-dimensional international environmental model", *Mathematical Social Sciences* 59: 208-226.
- Guesnerie, R 2015, "Multiplier les 'petits ruisseaux' in *Le dictateur bienveillant et le climat* in *Le Monde* (June 24)
- Helm, C. 2003, "International emissions trading with endogenous allowance choices", *Journal of Public Economics* 87, 2737-2747
- Henry, C., 1979, "On the free rider problem in the M.D.P. procedure", *Review of Economic Studies*, 46(2): 293-303.
- Hirshleifer, J., Glazer, A. and Hirshleifer, D. 2005, *Price theory and applications: decisions, markets and information*, Cambridge University Press, New York.
- Hovi, J. and Areklett, I. 2004, "Enforcing the Climate Regime: Game Theory and the Marrakesh Accords", *International Environmental Agreements: Politics, Law and Economics* 4: 1-26.
- Malinvaud, E. 1969, *Leçons de théorie microéconomique*, Coll. Statistique et programmes économiques n°15, (4e édition : 1974), Dunod, Paris. Translated as *Lectures on Microeconomic Theory*, North-Holland Publ. Co., Amsterdam, 1972.
- Marcu, A. 2016, "Carbon Market Provisions in the Paris Agreement (Article 6)", *CEPS Special Report No. 128*, Brussels, January.
- Nordhaus, W., and Yang, Z. (1996), "A Regional Dynamic General Equilibrium Model of Alternative Climate Change Strategies", *American Economic Review*, 86(4): 741-765.
- Nordhaus, W. 2015, "Climate Clubs: Overcoming Free-Riding in International Climate Policy", *American Economic Review* 105(4): 1339-135.

- Roberts, J. 1976, "Incentives for correct revelation of preferences and the number of consumers", *Journal of Public Economics* 6, 359-374.
- Tulkens, H. 2012, "Climate Dynamics, Economic Dynamics, Negotiations Dynamics", presentation at the *Workshop on the Economics of Climate Change* organized by Ecole polytechnique, Collège de France and Paris School of Economics, held at Collège de France, Paris (October).
- Tulkens, H. 2013. "Le changement climatique au carrefour entre écologie, économie, théorie des jeux et diplomatie", Cours-conférences faits au "Collège Belgique" de l'Académie royale des Sciences, des Lettres et des Beaux-Arts de Belgique", Bruxelles (octobre).
<http://www.academieroyale.be/cgi?lg=fr&pag=919&tab=111&rec=1264&frm=0>
<http://www.academieroyale.be/cgi?lg=fr&pag=919&tab=111&rec=1265&frm=0>
- Tulkens, H. and van Steenberghe, V. 2009, " 'Mitigation, adaptation, suffering': in search of the right mix in the face of climate change", *CORE Discussion Paper* n° 2009/54, *FEEM Nota di Lavoro* n° 79.2009 and *CESifo (Munich) Working Paper* n° 2781 (August).
- Obergassel, W., Arens, C., Hermwille, L., Kreibich, N., Mersmann, F., Ott, H. and Wang-Helmreich, H. 2016, "Phoenix from the Ashes — An Analysis of the Paris Agreement to the United Nations Framework Convention on Climate Change", *Report* issued by the Wuppertal Institute for Climate, Environment and Energy, Wuppertal (January).
- Yang, Z., 2008, *Strategic bargaining and cooperation in greenhouse gas mitigations: an integrated assessment modeling approach*, The MIT Press, Cambridge, MA.