Valuing the loss and damage from climate change: a review of some current issues

Jean-Michel A Salles

CEE-M
CENTER FOR ENVIRONMENTAL ECONOMICS – MONTPELLIER

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Jean-Michel Salles
CEE-M, Univ. Montpellier, CNRS, INRA, SupAgro, Montpellier, France

Abstract

From an economic perspective, damage and loss valuation aims first at justifying climate change mitigation efforts. But the difficulties related to the heterogeneity of the damage and the time horizon of the impacts make the results very contingent of the computation hypotheses. The debate thus focused on the social cost of carbon, driven by the idea of basing climate change policies on emission pricing. But damage assessment could also be used as a basis for compensating victims. Although the idea of climate justice is struggling to establish the basis for this compensation, international negotiations have begun to lay the groundwork for it through the Warsaw Mechanism, which remains however far from this goal.

Key words: Climate change, Compensation, Economic valuation, Loss and damage, Social cost of carbon

Résumé

Dans une perspective économique, l'évaluation des pertes et dommages vise d'abord à justifier les efforts d'atténuation du changement climatique. Mais les difficultés liées à l'hétérogénéité des dommages et l'horizon temporel des impacts rendent les résultats très contingents des hypothèses de calcul. Le débat s'est ainsi focalisé sur le coût social du carbone, porté par l'idée de baser les politiques de lutte contre le changement climatique sur une tarification des émissions. Mais l'évaluation des dommages pourrait aussi servir de base à une compensation des victimes. Même si l'idée d'une justice climatique peine à établir les bases de cette compensation, les négociations internationales ont commencé à en poser des jalons à travers le Mécanisme de Varsovie qui reste cependant loin de cet objectif.

Mots-clés : changement climatique, compensation, évaluation économique, pertes et préjudices, coût social du carbone

Valuing the loss and damage from climate change: where are the issues?

The fact that climate change is already having detrimental effects on human societies and will certainly have more in the future is no longer debated in the scientific community. However, the nature, extent and geographical location of the impacts are not known precisely and are often referred to without further details of climate damage. The evaluation of these damages thus raises many questions that have been the subject of a broad scientific literature. This article could not pretend to make a systematic review; it aims to shed some light on several of the issues that have nourished this literature, and focuses on what appears to be the main current issues.

The terms "loss and damage", as it has been used in the climate negotiations, appear to be more restrictive than the general concept of damage, which is conventionally referred to in economic analyzes; it designates the impacts of climate change that have not been or cannot be avoided by mitigation and adaptation efforts. The idea of taking into account the negative impacts of climate change, particularly in the area of finance and insurance, was already present in the United Nations Framework Convention on Climate Change (Article 4.8). However, the specific terms "loss and damage" appear in the texts of the Convention only since 2007[1].

From the perspective of the standard economic analysis - that is to say in a logic of appreciation of the potential impacts of different alternative options aimed at identifying the best strategies - evaluations take place in a "cost-benefit" framework. The idea is that damage has to be assessed in order to know how far it is economically justified to accept costly constraints to prevent this damage from occurring. The cost-benefit analysis is actually more demanding, since identifying the most desirable situation involves comparing "marginal costs", that is, cost variations related to a "small" change in the intended target. In this conceptual framework, the economic optimum (social efficiency or Pareto efficiency, in the vocabulary of economists) is thus the situation in which any additional effort would entail more costs than benefits and any less effort would mean giving up more benefits than avoiding costs[2]. To clarify the discussions in the climate change context, this marginal effort is often standardized to a unit which is a ton of carbon or more precisely of carbon dioxide[3], hence the fact that the debate is mostly about the "social cost of carbon" (the cost for the whole society of the emission of a ton of carbon dioxide, tCO_2).

A usual criticism of the cost-benefit analysis (and more broadly of the utilitarianism of which it is instrumental) is that it focuses on the totality of gains and losses, but does not artlessly integrate the distribution of these impacts among the concerned populations. Moreover, the

[1] In the *Bali Action Plan*, Roberts, E., & Huq, S. (2015). Coming full circle: the history of loss and damage under the UNFCCC. *International Journal of Global Warming*, *8*(2), 141-157.

[2] Equalizing the marginal costs of damage with the marginal costs of the reduction efforts ensures that the strategy is optimal only if the cost curves are convex; which reflects the notion of diminishing returns.

[3] Technically 1 tC equals 3.67 tCO_2, but 'carbon' is generally used as a shorthand for 'carbon dioxide'.

assessment of impacts is often estimated in terms of income equivalents and measured in monetary units, which tends to give more weight to agents with higher incomes[4].

The economic valuation of damage generally aims at quantifying their cost in order, if it is to choose the target, to confront it with the costs of the policies and measures which will make it possible to avoid or mitigate the damage, or if it is to compensate it, to appreciate the appropriate level of compensation. In any case, it must be ensured that all impacts are taken into account; however, the current or potential impacts of climate change are numerous and heterogeneous[5].

On the first point, the relevance of an ambitious preventive strategy has been the subject of a very lively debate and the implementation of the costly components of the international promises, such as the actual contributions of rich countries to the fund intended to help the adaptation of developing countries, remain significantly lower than the commitments. It is in this perspective that, for example, the Energy Journal published, in 1999, a special issue on the costs of the Kyoto Protocol[6], in which most contributions aimed at demonstrating excessive costs over expected benefits.

At the turn of the century, the question of evaluating climate damage was indeed in a context opposing two visions of the consequences of climate change. For some optimist authors (R. Mendelson, W. Nordhaus, R.S. Tol ...), the damage would be limited because of the capacity of adaptation of the actors and the States. Therefore, they argued that "overly ambitious" prevention policies would have a negative effect on economic growth, considered necessary to create the means to adapt and finance the technological change that would allow the emancipation of fossil fuels. Furthermore, "pessimistic" authors (S. Hallegate, N. Stern, M. Weitzman…), the impacts of climate change are likely to be considerable and amply justify considerable and immediate efforts to limit emissions. N. Stern even pointed out that the margin between the cost of inaction and the cost of an ambitious emission control policy was so large that it was robust to (possible) calculation errors.

The rest of the article is organized into five sections. In section 1, we try to specify what does the concept of "climate loss and damage" refer to. The second section offers a brief review of the issue related to the economic valuation of climate damage. Section 3 tries to clarify the issues of the shift to the "social cost of carbon" and its links with the policies envisaged. The links of damage assessment with the broad debates of climate justice are outlined in section 4. The last section comes back to the possible uses of evaluations in real-life debates.

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[4] The results would probably be different if one knew how to appreciate the effects directly in terms of well-being, happiness or sustainability. But these approaches are even more dependent on the assumptions of the conceptual frameworks and methods than the more classical evaluations used in this text.

[5] Field C.B., & O.F. Canziani, eds. (2014). *Climate Change 2014: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the IPCC*. Cambridge, Cambridge University Press.

[6] Weyant, J. P., & Hill, J. (1999). The costs of the Kyoto Protocol: A multi-model evaluation. *The Energy Journal, 20 (Special Issue)*.

1. Assessing loss and damage: a key issue that is no longer at the core of the climate negotiations

Following the seminal works by W.R. Cline and W.D. Nordhaus[7], climate change has been mostly addressed in the economic literature as a problem of intertemporal consumption tradeoffs. Fighting climate change through costly mitigation measures reduces consumption today, but is expected to increase consumption in the future, as expected losses from climate change are avoided. In this "optimal climate change" framework, the final increase in temperature and the corresponding burden of mitigation efforts result from a cost-benefit analysis. This approach reflects the logic of economic analysis; but it is necessary to be able to specify what these damages are.

Defining "loss and damage"

There is no official definition of "loss and damage" in documents related to UNFCCC whose mandate is to prevent "anthropogenic interference with the climate system", i.e. climate change induced by the man. The concept has been used implicitly since the beginning of the debates, but it has acquired particular importance with the establishment of the *Warsaw International Mechanism* (WIM), in 2013, in response to the requests from a group of developing countries who stressed that they were the entities the most impacted by climate change while their responsibility was very limited. In this context, "*loss and damage*" have been implicitly defined as "*the actual and/or potential manifestation of impacts associated with climate change in developing countries that negatively affect human and natural systems*"; this includes in particular the impacts of extreme events (e.g. heat waves, floods or droughts) or slow-dynamic changes (including sea-level rise and ice retreat). As pointed out by James et al.[8], the most important damages are yet to come, and the mechanism must take into account changes in the risk of damage, present and future, and cannot be limited to dealing with losses already attested. But, faced with territories that are under the influence of multiple factors, a specific difficulty is to identify, as clearly and precisely as possible, the changes and risks that must be attributed to anthropogenic climate change.

The "attribution" issue

The attribution of responsibilities remains a challenge that requires linking losses and damage to the weather and climate events, and relating these weather and climate events to anthropogenic emissions of greenhouse gases. As James et al. (2014) pointed out, decision makers and analysts have documented the former rather well, for example through case studies of extreme weather loss and damage, but it seems more difficult to establish causal links between weather and climate events and anthropogenic forcing, despite a strong development

[7] Cline, W. R. (1992). *The economics of global warming*. Institute for International Economics. Nordhaus, W. D. (1994). *Managing the global commons: the economics of climate change* (Vol. 31). Cambridge, MA: MIT Press.

[8] James, R., Otto, F., Parker, H., Boyd, E., Cornforth, R., Mitchell, D., & Allen, M. (2014). Characterizing loss and damage from climate change. *Nature Climate Change*, *4*(11), 938.

of scientific research addressing this question. Since knowledge appears more advanced in studying impacts than the causes of events has highlighted the information gaps on slow-moving events. It seems easier to define strategies to cope with extreme weather events, since, although their frequency and intensity are increasing, their nature is roughly identified, than to face slow developments that lead us to uncertain situations whose consequences in terms of losses and damage remain poorly understood.

Establishing a causal link between anthropogenic greenhouse gas emissions and loss and damage is therefore a sensitive issue. The links between climate events and damage benefited from some experience related to insurance schemes and specific case studies were conducted for more specific cases, such as sea-level rise. We can mention here a study on the exposure of port cities[9] which results, beside the exposure of the people, to an estimate of the value of the threatened assets of about 5% of the global gross product in 2005, and could reach 9% in 2070.

But the link between climate change and catastrophic events is very difficult to pin down. In practice, it is not possible to establish a link between a given event and the change, other than in statistical form: "with such a change of expected temperatures or precipitations, such extreme event sees its probability increase by so much". Upstream, the link between anthropogenic greenhouse gas emissions and climate change in a given location is also very difficult to establish, given the complexity of the climate system, and here again, the relationship cannot be deterministic but probabilistic. There is therefore a long and insecure way from the attribution a statistical technical responsibility to the establishment of a legal liability.

Evidence of the current and future significance of climate damage appears to have somewhat marginalized the evaluation issue in the recent IPCC reports[10], in favor of in-depth analyzes of mitigation strategies and related transformation pathways. However, losses and damage are real and will increase with the expected future warming[11] and, since the beginning of the debates and negotiations, the question of their economic evaluation has been raised and, in some respects, answered.

[9] Hanson, S., Nicholls, R., Ranger, N., Hallegatte, S., Corfee-Morlot, J., Herweijer, C., & Chateau, J. (2011). A global ranking of port cities with high exposure to climate extremes. *Climatic Change*, *104*(1), 89-111.

[10] Intergovernmental Panel on Climate Change. (2015). *Climate change 2014: Mitigation of climate change* (Vol. 3). Cambridge University Press.

[11] Bindoff, N.L., P.A. Stott, K.M. AchutaRao, M.R. Allen, N. Gillett, D. Gutzler, K. Hansingo, G. Hegerl, Y. Hu, S. Jain, I.I. Mokhov, J. Overland, J. Perlwitz, R. Sebbari and X. Zhang, 2013: Detection and Attribution of Climate Change: from Global to Regional. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the IPCC*. Cambridge University Press, Cambridge, UK, and New York, NY, USA.

2. Valuing loss and damage economically

The valuation of loss and damage is at the heart of the main economic analyzes of climate change[12]. The rationale, explicit or implicit, is always the same: does the magnitude of the expected damage resulting from foreseeable climatic changes justify accepting to support now efforts to avoid or mitigate this damage and what would be the acceptable level of effort?

In order to estimate the costs of climate change, two main methodological approaches can be used[13]. The *enumerative method*[14] consists of estimating the physical effects of the climate change that are obtained from natural science experiments, models, and data; the results are physically realistic and easily interpreted. The economic valuation consists of pricing them one by one and then sum and extrapolates the results. Since it is usually based on a bundle of heterogeneous methods (cost-based, or revealed and stated preferences) the aggregation is indeed challenging [15] and risky (since the impacts are valued separately there is a clear risk of double-counting or omitting the interaction effects in the aggregation).

An alternative approach is the *statistical method*[16], which has the advantage of being based on real-world differences in climate and income, rather than calculated differences. The analyses are therefore based on the processing of past data. For example, data on the value of US

[12] Nordhaus, W. D. (1991). To slow or not to slow: the economics of the greenhouse effect. *The Economic Journal*, *101*(407), 920-937. Schelling, T. C. (1992). Some economics of global warming. *American Economic Review*, 1-14. Tol, R. S. (1995). The damage costs of climate change toward more comprehensive calculations. *Environmental and Resource Economics*, *5*(4), 353-374. Pearce, D. W., Cline, W. R., Achanta, A. N., Fankhauser, S., Pachauri, R. K., Tol, R. S., & Vellinga, P. (1996). The social costs of climate change: greenhouse damage and the benefits of control. *Climate change 1995: Economic and social dimensions of climate change*, 179-224. Stern, N.H., S. Peters, V. Bakhski, A. Bowen, C. Cameron, S. Catovsky, D. Crane, S. Cruickshank, S. Dietz, N. Edmondson, S.L. Garbett, L. Hamid, G. Hoffman, D. Ingram, B. Jones, N. Patmore, H. Radcliffe, R. Sathiyarajah, M. Stock, C. Taylor, T. Vernon, H. Wanjie, & D. Zenghelis (2006). Stern review: The economics of climate change. London, Her Majesty's Treasury. Stern, N. (2008). The economics of climate change. *American Economic Review*, *98*(2), 1-37. Weitzman, M. L. (2010). What Is The "Damages Function" For Global Warming—And What Difference Might It Make?. *Climate Change Economics*, *1*(01), 57-69 Vn den Bergh, J. C., & Botzen, W. J. W. (2015). Monetary valuation of the social cost of CO2 emissions: a critical survey. *Ecological Economics*, *114*, 33-46. Tol, R. S. (2018). The Economic Impacts of Climate Change. *Review of Environmental Economics and Policy*, *12*(1), 4-25.

[13] Tol, R. S. (2009). The economic effects of climate change. *Journal of Economic Perspectives*, *23*(2), 29-51.

[14] Nordhaus, W. D. (1994). *Managing the global commons: the economics of climate change*. Cambridge, MA: MIT press. Tol, R. S. (2002a). Estimates of the damage costs of climate change. Part 1: Benchmark estimates. *Environmental and resource Economics*, *21*(1), 47-73. Tol, R. S. (2002b). Estimates of the damage costs of climate change, Part II. Dynamic estimates. *Environmental and Resource Economics*, *21*(2), 135-160. Fankhauser, S. (2013). *Valuing climate change: the economics of the greenhouse*. Routledge.

[15] Fankhauser, S., Tol, R. S., & Pearce, D. W. (1997). The aggregation of climate change damages: a welfare theoretic approach. *Environmental and Resource Economics*, *10*(3), 249-266.

[16] Mendelsohn, R., Morrison, W., Schlesinger, M. E., & Andronova, N. G. (2000). Country-specific market impacts of climate change. *Climatic change*, *45*(3-4), 553-569.

agricultural crops have been econometrically confronted with meteorological data to estimate the impact of temperature change[17]. Therefore, adaptation behaviors, no matter what they are, are implicitly taken into account. However, the statistical studies rely on uncontrolled experiments and, if the data do not allow precise differences-in-differences analysis, irrelevant variations can be attributed to climate change.

These two approaches have symmetrical advantages and limits, and neither of them makes it possible to obtain really satisfactory results. The main limitation probably lies in the fact that the differences are measured on retrospective data. The most challenging damages will occur in the future and they will likely create new situations that cannot simply be deduced from the extrapolation of the past. To overcome these issues, a wide interest emerged, in the 1990s, for integrated assessment modeling of climate change impacts[18].

The integrated assessment models (IAMs) aim to integrate knowledge from different domains into a single framework to better understand the impacts of climate change on economic dynamics. They do not aim to advance knowledge, but to generate useful information for policy making. In recent work, the focus is on feedback effects, adaptation and mitigation strategies, and uncertainties; which puts the notion of vulnerability at the core of the analyses. Like Moss et al.[19] have pointed out, "*The implications of climate change for the environment and society will depend not only on the response of the Earth system to changes in radiative forcings, but also on how humankind responds through changes in technology, economies, lifestyle and policy. Extensive uncertainties exist in future forcings of and responses to climate change, necessitating the use of scenarios of the future to explore the potential consequences of different response options. To date, such scenarios have not adequately examined crucial possibilities, such as climate change mitigation and adaptation"*. These few sentences summarize the main issues amazingly well.

1. The nature and significance of the impacts of climate forcing remain uncertain and controversial. Most studies conclude that the poorest countries are and will be the most impacted, especially given the importance of agricultural production - a highly exposed sector - and their greater sensitivity to extreme events[20]. But the distribution of these impacts in space

[17] Mendelsohn, R., Nordhaus, W. D., & Shaw, D. (1994). The impact of global warming on agriculture: a Ricardian analysis. *The American Economic Review*, 753-771.

[18] One of the first IAMs and probably the best known is the DICE model (for 'dynamic integrated climate-economy'). These models are not centered on assessing the damage, but on the simulation or optimization of economic development paths that take this damage into account. Nordhaus, W. D. (1993). Rolling the 'DICE': an optimal transition path for controlling greenhouse gases. *Resource and Energy Economics*, *15*(1), 27-50.

[19] Moss, R. H., Edmonds, J. A., Hibbard, K. A., Manning, M. R., Rose, S. K., Van Vuuren, D. P., ... & Meehl, G. A. (2010). The next generation of scenarios for climate change research and assessment. *Nature*, *463*(7282), 747.

[20] Stern, N., Peters, S., Bakhshi, V., Bowen, A., Cameron, C., Catovsky, S., ... & Edmonson, N. (2006). *Stern Review: The economics of climate change* (Vol. 30, p. 2006). London: HM treasury. Mendelsohn, R., Dinar, A., & Williams, L. (2006). The distributional impact of climate change on rich and poor

and time cannot be determined with precision[21]; it is therefore particularly difficult to assess and, a fortiori, to build an economic evaluation of multiple and very heterogeneous damages.

2. The significance of the resulting damage depends both on the Earth's response to radiative forcing, but perhaps more on how human societies will react through their technology, their economies, their way of life and the policies implemented. Damage assessment cannot rely on the assumption that economies will cope with climate change without trying to adapt, the way in which economic dynamics are accounted for and modeled, therefore plays a fundamental role[22].

3. The best way to analyze these complex issues is to develop contrasting scenarios (like the ones from the IPCC). To infer an assessment of the losses and damage of scenarios, it is obviously necessary to define a *business-as-usual* scenario; this cannot be limited to prolonging trends because other considerations than climate change, such as the depletion of accessible natural resources or the evolution of technologies, must be taken into account. And, so far (the Moss et al. article dates from 2010, but recent research and reports have not filled this gap), these exercises have stumbled on the issues raised by an appropriate treatment of mitigation and adaptation efforts[23].

Recently, this approach has led to the development of an integrated model with a flexible architecture for computing damage that integrates climate science, econometric analyzes, and process models[24]. This work allowed to construct spatially explicit, probabilistic, and empirically derived estimates of economic damage from climate change in the United States. The aggregated value for market and non-market damage from the main impacted sectors (agriculture, crime, coastal storms, energy, human mortality, and labor) increases quadratically in global mean temperature, costing roughly 1.2% of the GDP per C degree of average temperature increase. The risk appears unequally distributed in location and increases economic inequalities.

This result, despite the sophistication of the approach, does not contradict the statement of R. Tol (in his 2018 review[25] and in previous publications), according to which, for a 2.5° warming,

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countries. *Environment and Development Economics*, *11*(2), 159-178. Tol, R. S. (2018). The Economic Impacts of Climate Change. *Review of Environmental Economics and Policy*, *12*(1), 4-25.

[21] Bindoff etal., (2013) op.cit..

[22] Hallegatte, S., Hourcade, J. C., & Dumas, P. (2007). Why economic dynamics matter in assessing climate change damages: illustration on extreme events. *Ecological Economics*, *62*(2), 330-340. Hallegatte, S. (2009). Strategies to adapt to an uncertain climate change. *Global Environmental Change*, *19*(2), 240-247.

[23] Stern, N. (2016). Economics: Current climate models are grossly misleading. *Nature News*, *530*(7591), 407.

[24] Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., ... & Larsen, K. (2017). Estimating economic damage from climate change in the United States. *Science*, *356*(6345), 1362-1369.

[25] Tol, R. S. (2018). The Economic Impacts of Climate Change. *Review of Environmental Economics and Policy*, *12*(1), 4-25.

the existing estimates vary significantly (even though its assertion that some net benefits are excessive and based mainly on their own estimates) and are based on different valuation methods, but they remain within an order of magnitude of a few percent of the world gross product, which is equivalent to one year of global economic growth (at its current pace). This leads him to argue that climate change is certainly not the most serious problem facing humanity.

This type of result may reflect the idea that our economies are resilient to the impacts of climate change, but we cannot exclude the possibility that they reflect our inability to build a rigorous and integrated representation of changes that simultaneously impact many sectors of economic activity and their political and social regulations. This is the view advocated by some cautious analysts of the integrated models[26] and even more of N. Stern[27] whose famous *Review* [28] was essentially built on a rejection of the standard modeling approaches in order precisely to be able to provide an analysis of possible disruptions[29].

Despite these very real difficulties, the economic evaluation of damages underlies the apparently less controversial and perhaps more political question of the social cost of carbon.

3. The Social Cost of Carbon: what's in a name?

The social cost of carbon (SCC) is the monetized damage from emitting one unit of CO2 to the atmosphere, often obtained from computational Integrated Assessment Models (IAMs). Reversing the perspective, it is a measure of the benefits of reducing greenhouse gas emissions. It may seem like playing with words, but the shift from aggregate damage to marginal damage emphasizes the fact that, in doing so, we are switching from the question "should we act?" to the question "how to act?", and therefore to concretely define policies for which the SCC can be a more direct reference[30].

Uncertainties remain unresolved[31], but empirical estimates may try to escape the inextricable assessments of long-term damage in evolving economies, to focus on carbon pricing. This is indeed a different perspective. We are no longer trying to justify the level of ambition of a climate strategy, but to estimate the level at which the shadow price of carbon should be set to

[26] Stanton, E. A., Ackerman, F., & Kartha, S. (2009). Inside the integrated assessment models: Four issues in climate economics. *Climate and Development*, *1*(2), 166-184.),

[27] Stern, N. (2016). Economics: current climate models are grossly misleading. *Nature News*, *530*(7591), 407.

[28] Stern, N., Peters, S., Bakhshi, V., Bowen, A., Cameron, C., Catovsky, S., ... & Edmonson, N. (2006). *Stern Review: The economics of climate change* (Vol. 30, p. 2006). London: HM treasury.)

[29] Godard, O. (2008). The Stern Review on the Economics of Climate Change: contents, insights and assessment of the critical debate. *SAPI EN. S. Surveys and Perspectives Integrating Environment and Society*, (1.1).

[30] Pearce, D. W. (2003). The social cost of carbon and its policy implications. *Oxford Review of Eonomic Policy 19* (3), 362-384.

[31] Tol, R. S. (2005). The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties. *Energy Policy*, *33*(16), 2064-2074.

be taken into account in the ex-ante evaluation of projects and policies aiming to reach some political target and, possibly, its pricing. The aim here is to pilot the economy, in particular by directing technical change[32], to achieve a given growth or sustainability goal, or to comply with an international commitment.

Several countries have launched expert processes to develop a range of values representing the SCC. In France, the Quinet Commission[33] resulted in a reference value of €32/tCO_2, for 2008, projected to increase and reach €100 in 2030. In the United States, the central value retained by the government[34] was lower - \$21/tCO_2 - and sensitivity analyzes allowed to test a large variety of values.

The standard economic approach is to estimate the SCC uses a discounted utilitarian social welfare function that simply adds up indicators measuring the well-being of individuals, weighted by a discounting factor. In an authoritative review, R.S. Pindyck[35] concludes severely against any optimism on the performance that can be expected from IAMs with that respect: "*These models have crucial flaws that make them close to useless as tools for policy analysis: certain inputs (e.g., the discount rate) are arbitrary, but have huge effects on the SCC estimates the models produce; the models' descriptions of the impact of climate change are completely ad hoc, with no theoretical or empirical foundation; and the models can tell us nothing about the most important driver of the SCC, the possibility of a catastrophic climate outcome. IAM-based analyses of climate policy create a perception of knowledge and precision, but that perception is illusory and misleading*".

The statement that carbon pricing is an essential element of any policy to fight against climate change is both obvious - setting a price for emissions makes it possible to align the choices of a plurality of heterogeneous actors - and an affirmation somewhat naïve (by authors who are not, however): the price level needed to have a significant effect on emissions, could result in very damaging effects on weakly flexible sectors and, from an international perspective, a single price would tend to impose a uniform pressure on territories that do not have to aim at similar objectives. It is, however, not possible to enter seriously into a complex debate which concerns only indirectly our subject since it is not empirically related to the valuation of damages.

[32] Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. *American Economic Review*, *102*(1), 131-66.

[33] Quinet, A., Baumstark, L., Célestin-Urbain, J., Pouliquen, H., Auverlot, D., & Raynard, C. (2009). La valeur tutélaire du carbone. *Rapport du Conseil d'Analyse Stratégique*, *16*(5), 9305.

[34] Greenstone, M., Kopits, E., & Wolverton, A. (2011). *Estimating the social cost of carbon for use in us federal rulemakings: A summary and interpretation* (No. w16913). National Bureau of Economic Research.

[35] Pindyck, R. S. (2013). Climate change policy: what do the models tell us?, *Journal of Economic Literature*, *51*(3), 860-72.

However, carbon pricing is considered[36] "*an indispensable part of a strategy for reducing emissions in an efficient way. Carbon prices are intended to incentivize the changes needed in investment, production, and consumption patterns, and to induce the kind of technological progress that can bring down future abatement costs*." After these statements, the Stern-Stiglitz Commission develops a series of arguments on the different advantages of a "well-designed carbon price", both to align individual behavior and to guide the economy efficiently. But the conclusions remain nuanced: "*Countries may choose different instruments to implement their climate policies, depending on national and local circumstances and on the support they receive. Based on industry and policy experience, and the literature reviewed, duly considering the respective strengths and limitations of these information sources, this Commission concludes that the explicit carbon-price levels consistent with achieving the Paris temperature target is at least US$40–80/tCO2 by 2020 and US $50–100/tCO2 by 2030, provided a supportive policy environment is in place*".

It can be noted that estimating SCC is a useful element in setting carbon pricing that can both be an indicator for designing policies and measures and for sending a signal to markets. These two functions do not necessarily lead to the same values and, above all, their determination processes are different. The reference values for public policies are directly determined by political discussions informed by analyzes and economic models; the prices that emerge in the carbon markets result from the confrontation of supply and demand for quantities that were previously fixed by the policies in relation to the international negotiations.

Perhaps it can be argued here that carbon pricing, possibly differentiated across territories or sectors, can help to coordinate expectations, behavior and investment choices. But given the importance of networks and technological trajectories in this process, international coordination appears essential. The intense discussions that have accompanied the early stages of this coordination for almost three decades have highlighted the importance of justice issues in this context.

4. The difficulties raised by the notion of climate justice

As O. Godard[37] points out with accuracy, the concept of climate justice refers to a wide variety of problems as well as irreconcilable conceptions of what would be a fair situation. Following the early works analyzing the climate issue as an intertemporal consumption tradeoff, the question was originally addressed in intergenerational terms. This perspective, however authoritative, has been criticized on the ground that, given that climate change was not really likely to hamper economic growth, ambitious and therefore burdensome policies for the current generation could be perceived as asking the "poor" (the current generation) to make efforts to preserve the well-being of the "rich" (the future generations). Are we prepared to consider that

[36] Stiglitz, J., Stern, N., Duan, M., Edenhofer, O., Giraud, G., & Heal, G. (2017). Report of the high-level commission on carbon prices. *Carbon Pricing Leadership Coalition, 29.*

[37] Godard, O. (2015). *La justice climatique mondiale*. La Découverte, 125 p. Godard, O. (2017). *Global Climate Justice. Proposals, arguments and justifications*. Edward Elgard, Cheltenham and Northhamton, 224 p.

the issue may no longer be in these terms if climate change - but also resource depletion and declining biodiversity - undermine economic and social dynamics? In economic analyzes and models, this question leads to a focus on the discount factor.

In his review of the Stern review on the economics of climate change, W.D. Nordhaus[38] pointed out that at the core of its assessment that the damages from climate change are large and that nations should undertake sharp and immediate reductions in greenhouse gas emissions, lies the decisive assumption of a "near-zero" time discount rate. He concluded the "*The Review's unambiguous conclusions about the need for extreme immediate action will not survive the substitution of assumptions that are consistent with today's marketplace real interest rates and savings rates.*" As mentioned above, it is probably not legitimate to model a distant and uncertain future based on the parameters of our current economy, but how to choose alternative parameters. And we do not know how long the so-called environmentalist's paradox will persist[39].

Since the *Stern Review*, both approaches have continued their reflections and their work. On the one hand, the authors defend the idea of limited damage "*at least in the twenty-first century*" (Tol, 2018, op.cit.), assuming that growth will continue and despite issues of concern (sea level rise and coastal protection, agriculture change, malaria extension…) and deep uncertainty that may lead to consider that the expectation of the SCC is "unbounded"[40]. On the other hand, other economists have developed more solid economic bases to justify the relevance of strong policies. Two quite different paths can be mentioned here.

T. Sterner and U. Persson[41] draw attention to the old issue of the evolution of relative prices: if we accept the idea that the services of nature will become scarcer, then, even with a higher discount rate, but applied to assets whose shadow prices increase, the balance leans in favor of ambitious policies.

On the basis of the now well-known criticisms (uncertainties, discounting issues…), but in an ecological economics perspective, J.C. van den Bergh and W.J.W. Botzen conclude their critical survey[42] by recommending to consider alternative approaches to decision-making for climate policy, based on a variety of alternative criteria to the discounted welfare function. They suggest particularly, interpreting the precautionary principle as leading to a maximum level for acceptable greenhouse gas concentration. We know that, somewhat unexpectedly, this

[38] Nordhaus, W.D. (2007). A review of the Stern review on the economics of climate change. *Journal of Economic Literature*, *45*(3), 686-702.

[39] Raudsepp-Hearne, C., Peterson, G. D., Tengö, M., Bennett, E. M., Holland, T., Benessaiah, K., ... & Pfeifer, L. (2010). Untangling the environmentalist's paradox: why is human well-being increasing as ecosystem services degrade?. *BioScience*, *60*(8), 576-589.

[40] Weitzman, M. L. (2011). Fat-tailed uncertainty in the economics of catastrophic climate change. *Review of Environmental Economics and Policy*, *5*(2), 275-292.

[41] Sterner, T., & Persson, U. M. (2008). An even sterner review: Introducing relative prices into the discounting debate. *Review of Environmental Economics and Policy*, *2*(1), 61-76.

[42] van den Bergh, J. C., & Botzen, W. J. W. (2015). Monetary valuation of the social cost of CO2 emissions: a critical survey. *Ecological Economics*, *114*, 33-46.

perspective has been very present for the Paris Agreement, even though concrete commitments have since fallen behind.

M. Adler and colleagues[43] have developed an analytical framework, alternative to the discounted-utilitarian social welfare function, based on a priority given to the worse-off. In this rawlsian perspective, the weight given to the damages depends on the situation of the impacted people and logically leads to substantial difference in SCC estimates.

The question of justice now arises mainly in intra-generational terms: the timeliness or the imminence of certain risks leads to bringing to the fore the question of the distribution of the loss and damages, which we have seen to have a stronger impact on the poorest, both between countries and within the population of some countries.

Again, we cannot present here in a detailed way all the conceptual frameworks and the empirical issues raised by climate justice (for a systematic analysis, see O. Godard (2017) op.cit.). We can mention the irreconcilability of international approaches (the subjects are the countries, and the individuals are treated according to the situation of the country where they reside) and cosmopolitanism (the subjects are the individuals who are entitled to a fair treatment according to their situation individual). But an essential point to consider, is the fact that global climate justice cannot possibly be deduced from the norms conceived for inter-individual relations or for a society endowed with a democratic state (Godard, 2015, op.cit.).

The concept of a historical responsibility of the industrialized countries that appeared in a politicized context of the North-South confrontation seems ill-founded to him (the emissions of greenhouse gases before the problem emerges, can they create a responsibility? And the emerging countries benefit today from less emitting technologies). But nothing prevents developed countries from willing to assume political responsibility. Following this reasoning - shared by other authors -, the fact that climate loss and damage specifically affects the populations of the poorest countries that have contributed the least to the genesis of the climate threat, clearly implicates the international society towards them. "*Duties of assistance, requirement of a compensating justice for the damages due to the emissions after the awareness of the climatic risk, and priority concern to cover the essential needs of each human being converge and should be enough, if they were taken seriously, to satisfy the sense of international political responsibility of the governments of the developed countries*."

In other words, it is difficult to think of climate justice in terms of compensation for the loss and damage, but it can be thought in terms of moral duties[44] and solidarity. Developed countries that have the "ability to pay", should help the developing ones to mitigate (*Clean Development Mechanism*) and adapt (*Warsaw Mechanism*) to climate change that threatens our common future. In this perspective, what are the purposes of assessing climate loss and damage?

[43] Adler, M., Anthoff, D., Bosetti, V., Garner, G., Keller, K., & Treich, N. (2017). Priority for the worse-off and the social cost of carbon. *Nature Climate Change*, *7*(6), 443.

[44] Caney, S. (2010). Climate change and the duties of the advantaged. *Critical Review of International Social and Political Philosophy*, *13*(1), 203-228.

5. Assessing the loss and damage from climate change: for what purpose?

At the 18th UNFCCC meeting in 2012 in Doha, Qatar, it took in-depth negotiations between 195 countries to develop a climate change loss and damage management plan, particularly in the most vulnerable developing countries. Why was it so difficult? Because, on both sides, requests and offers were not aligned at all. The terms of such a debate might seem simple: well-known principles, such as the polluter-pays principle, could guide the discussions. If damages and liabilities were reasonably well identified, the economic question was to find the best balance between avoiding or reducing damage and offsetting losses. And that is more or less what happened, but developing countries were mainly looking for sources of finance justified by a past of dominated economies and rich countries, worried about losing their lead, were anxious not to engage in automatic financing mechanisms.

As we have seen, damage assessment can serve to convince people that there are important issues that imply policy making, to define targets for mitigation policies, to better allocate the effort between mitigation and adaptation, to define and dimension policies, and finally to compensate for damages if we know how to determine what damages are compensable.

In its seminal paper, M. Allen[45] considered the case of a perfectly efficient and well-informed insurance market, on which premium for flood-risk cover should be determined by the risk of flooding, as a property of the climate: "*if insurance premium rise as insurers factors in the increased risk of flooding due to climate change, and house prices consequently fall, some of this loss can straightforwardly be blamed on past greenhouse-gas emissions. But how much?*" The question is in fact whether current greenhouse-gas emitters could ever be held liable for the actual impacts of their emissions. In theory, knowledge of past probability distributions of damaging events and their shift to increased risks could be a source of statistical responsibility. His problem was above all not to block the implementation of an incentive system that would rely on an insurance system to send a signal on the market of the severity of risks related to climate change. But we are clearly not yet in the position to produce such figures for the contribution of greenhouse-gas emissions to the increased risk of most climate events.

However, in-depth studies have been conducted on particularly significant events, such as the heat wave that hit Western Europe in the summer of 2003[46], highlighting that anthropogenic emissions have at least doubled the probability of the heat wave and its consequences, or the flood risks in England and Wales in autumn 2000[47], showing that anthropogenic emissions had significantly altered the probability distribution.

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[45] Allen M. (2003). Liability for climate change. *Nature*, *421*(6926), 891.

[46] Stott, P. A., Stone, D. A., & Allen, M. R. (2004). Human contribution to the European heatwave of 2003. *Nature*, *432*(7017), 610.

[47] Pall, P., Aina, T., Stone, D. A., Stott, P. A., Nozawa, T., Hilberts, A. G., ... & Allen, M. R. (2011). Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000. *Nature*, *470*(7334), 382.

There is obviously a qualitative leap between establishing a causality, even if it is probabilistic, and attributing a legal liability. But it may be wiser to leave the other articles in this issue with the responsibility to explore their potential and limitations. As M. Mace and R. Verheyen[48] have pointed out, the WIM remains "*essentially a mechanism with power 'in progress' and with functions to be elaborated over time*". Although the performativity of the notion of international responsibility has been extensively studied[49], practical details for its possible implementation and political support are still lacking. The central question seems to be which mechanisms are likely to emerge from ongoing negotiation processes. As noted by Gampfer et al.[50]: "*finance mechanisms that focus purely on compensating developing countries, without contributing to the global public good of mitigation, will find it hard to garner public support*."

However, it is to be hoped that loss and damage assessments can better identify the difficulties of some countries or regions to adapt[51]; because, the most serious question is to implement mechanisms that encourage - or engage - all the actors of the planet, public or private, to integrate into their plans and strategies the importance - the need? - of moving towards a carbon neutral economy.

6. As a conclusion

Although the importance of the loss and damage from climate change has sometimes been a central debate in climate negotiations, empirical global valuations have remained scarce and mostly imprecise. For the most part, the problem has been divided into several local debates. The most developed in the discussions of economists is certainly the question of the social cost of carbon as a basis for the implementation of carbon pricing. Outside the community of economists, this issue is recognized, but its practical implementation seems to be viewed primarily as a problem for the long term. In many countries, the reduction or limitation of public taxes is the subject of considerable political debate and public authorities (particularly in France) do not seem ready to engage in such tax reform.

In the long run, if the evidence of costly loss and damage is socially and politically recognized, the most realistic scenario would be to achieve carbon neutrality. This goal, which is part of the Paris Agreement, implies that we have about half a century to completely transform the energy

[48] Mace, M. J., & Verheyen, R. (2016). Loss, Damage and Responsibility after COP 21: All Options Open for the Paris Agreement. *Review of European, Comparative & International Environmental Law*, *25*(2), 197-214.

[49] See, for example, Faure, M. G., & Nollkaemper, A. (2007). International liability as an instrument to prevent and compensate for climate change. *A Stan. Envtl. LJ*, *26*, 123.

[50] Gampfer, R., Bernauer, T., & Kachi, A. (2014). Obtaining public support for North-South climate funding: Evidence from conjoint experiments in donor countries. *Global Environmental Change*, *29*, 118-126.

[51] Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, *16*(3), 282-292. More specifically, Warner, K., van der Geest, K. and Kreft, S. (2013). Pushed to the limit: Evidence of climate change-related loss and damage when people face constraints and limits to adaptation. Report No. 11. Bonn: United Nations University Institute of Environment and Human Security (UNU-EHS), 96 p.

and material base of our economies. The issue of transformation and, more precisely, of transformation pathways has gained growing interest in the last decade[52] and was covered in a comprehensive section dedicated to their assessment[53] in the last report of the IPCC Group III.

We do not really know how to evaluate the social cost of carbon or, more precisely, since they are not based on the same assumptions, the different approaches lead to very heterogeneous results that can hardly serve as a reference for calibrating a carbon pricing policy (Stern, 2016). In this perspective, the proposed prices are most often based on simulations of the effects of pricing on the behavior of economic agents; this opens the debate both on the dynamics of evolution of this shadow price and on the possibility of having differentiated prices by sectors of activity. Conversely, it is also not known how to evaluate the costs and benefits of the transformation pathways, transition to a carbon-neutral economic development.

Regarding the implementation of an autonomous mechanism that would ensure the financing by developed countries of losses and damage from climate change in developing countries, it will be understood that the WIM is, at best, only a preliminary step. To go further, such a mechanism could be based on some form of statistical responsibility, as indicated above. For example, an insurance mechanism compensating for loss and damage related to extreme events could be established and financed by developed countries in a proportion calculated on the basis of contributions to cumulated greenhouse gases emissions and the excess of occurrence of these events related to anthropogenic climate change.

It is understandable that such a mechanism, already difficult to conceive, is particularly difficult to design practically within an international negotiation on a planetary scale. Developed countries are clearly hostile to the idea of an automatic liability that could lead them to finance a significant share of the cost of damage losses, at a time when they perceive their economic advance threatened by growth in developing countries. But it can also be understood that the lack of progress in this area, while actual loss and damage are observed and increasing, creates an unbearable tension that can only block the progress of negotiations on the international strategy to mitigate climate change. As S. Maljean-Dubois (2018) highlights, negotiations are now in the middle of the ford. It can be argued, however, that whatever the difficulties in the way of such a mechanism, it is not conceivable to abandon it altogether.

As N. Stern (2016) points out, neither for loss and damage nor the social cost of carbon, the expected performance of processing trails is not easily amenable to the test of economic valuation. It is tempting to say "by definition", the very notion of transformation, even organized by the optimistic perspective of a governance (or a direction, as for the controversial

[52] See Pelling, M. (2010). *Adaptation to climate change: from resilience to transformation*. Routledge. Kates, R. W., Travis, W. R., & Wilbanks, T. J. (2012). Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences*, 201115521.

[53] Clarke, L., Jiang, K., Akimoto, K., Babiker, M., Blanford, G., Fisher-Vanden, K., ... & McCollum, D. (2014). Assessing transformation pathways. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

"directed technical change"[54]), escapes the meshes of a precise evaluation grid. To go further, the idea of transformation of the economy or society might carry that of the agents and therefore, perhaps, of an evolution of their preferences. However, if the agents' preferences are endogenous[55], this compromises the economic framework for valuing situations. How to compare a situation in which agents give priority to the consumption of goods and services, being insensitive to the consequences in terms of climate impacts, with a situation where the agent's first aim at the use of green techniques because they worry about climate change, when, in both cases, the situation corresponds to the preferences of the agents? There is a significant literature in political sciences and marketing, although little developed in our field, which has studied how cultural context and technical-institutional trajectories shape the preferences of economic agents and citizens[56]. The economic evaluation of the losses and damages related to climate change can only inform the choices at the cost of methodological hypotheses that could compromise its validity as a guide for such structuring choices as climate policies. This observation throws the essential idea that the valuation of loss and damage is in no way an end, it is on the contrary a process whose relevance for informing the choices and strategies imply that data and model adapt continuously to changing and partly unpredictable contexts.

[54] Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. *American Economic Review*, *102*(1), 131-66.

[55] Bowles, S. (1998). Endogenous preferences: The cultural consequences of markets and other economic institutions. *Journal of Economic Literature*, *36*(1), 75-111.

[56] See, for example, Wildavsky, A. (1987). Choosing preferences by constructing institutions: A cultural theory of preference formation. *American Political Science Review*, *81*(1), 3-21.

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