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The "Doomsday" Effect in Climate Policies. Why is the Present Decade so Crucial to Tackling the Climate Challenge?

By **Baptiste Perrissin Fabert**, Centre International de Recherche Agronomique pour le Développement

Etienne Espagne, CIRED

Antonin Pottier, CIRED

Patrice Dumas, Centre International de Recherche Agronomique pour le Développement

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Summary

Despite growing scientific evidence that passing a 2°C temperature increase may trigger tipping points in climate dynamics, most Integrated Assessment Models (IAM) based on Cost Benefit Analysis (CBA) with smooth quadratic damage functions are unable to account for the possibility of strong increase in climate damage. Our IAM RESPONSE makes it possible to bridge this gap by integrating a threshold effect damage function which sets a threshold of temperature increase from which climate damages increase significantly. To fit with on-going climate negotiations, this threshold is set at 2°C. Regardless of the bleak prospect of passing the threshold, it turns out that among a broad set of scenarios accounting for the diversity of worldviews in the climate debate, overshooting the 2°C target and then facing the resulting damage may become an optimal strategy for many economic agents who are struck by what we call a “doomsday effect”. We show that this effect happens for any level of jump in damage and dramatically increases if the beginning of mitigation efforts is postponed till the decade 2010-2020 on. In light of these results, we believe that any further delay in reaching a clear international agreement will close the window of opportunity for meeting the 2°C target with a reasonable chance of diplomatic success.

Keywords Integrated Assessment Model, Non Linear Effect, Doomsday Effect, 2°C Target

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Address for correspondence:

Baptiste Perrissin Fabert
Centre International de Recherche Agronomique pour le Développement
Campus du Jardin Tropical
45 bis, avenue de la Belle Gabrielle
94736 Nogent-sur-Marne Cedex
France
E-mail: perrissin@centre-cired.fr

Corso Magenta, 63, 20123 Milano (I), web site: www.feem.it, e-mail: working.papers@feem.it

The "doomsday" effect in climate policies. Why is the present decade so crucial to tackling the climate challenge?

Baptiste Perrissin Fabert*Etienne Espagne†
Antonin Pottier‡Patrice Dumas§

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Abstract

Despite growing scientific evidence that passing a 2 °C temperature increase may trigger tipping points in climate dynamics, most Integrated Assessment Models (IAM) based on Cost Benefit Analysis (CBA) with smooth quadratic damage functions are unable to account for the possibility of strong increase in climate damage.

Our IAM RESPONSE makes it possible to bridge this gap by integrating a threshold effect damage function which sets a threshold of temperature increase from which climate damages increase significantly. To fit with on-going climate negotiations, this threshold is set at 2 °C. Regardless of the bleak prospect of passing the threshold, it turns out that among a broad set of scenarios accounting for the diversity of worldviews in the climate debate, overshooting the 2 °C target and then facing the resulting damage may become an optimal strategy for many economic agents who are struck by what we call a "doomsday effect". We show that this effect happens for any level of jump in damage and dramatically increases if the beginning of mitigation efforts is postponed till the decade 2010-2020 on.

In light of these results, we believe that any further delay in reaching a clear international agreement will close the window of opportunity for meeting the 2 °C target with a reasonable chance of diplomatic success.

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*Centre International de Recherche sur l'Environnement et le Développement (CIRED) E-mail : perrissin@centre-cired.fr

†(CIRED)

‡(CIRED)

§Centre International de Recherche Agronomique pour le Développement

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Introduction

There is growing scientific evidence for the possible existence of tipping points in climate dynamics, and non-linearity effects in climate damage that may happen when increase in temperature overshoots certain thresholds (Lenton et al., 2008). The collapse of the West-Antarctic Ice Sheet leading to a drastic rise in sea-level of 2 to 7 meters, the shutdown of thermohaline circulation causing a significant cooling of the Northern Hemisphere (Vellinga and Wood, 2008), the permafrost meltdown releasing huge volumes of methane, are some examples of possible mega-catastrophes (Kousky et al., 2009). It is also commonly accepted that beyond a 2 °C increase, uncertainty about climate responses increases drastically and climate changes might become uncontrollable (Hallegatte et al., 2010). Even if neither tipping point, nor irreversability, nor catastrophe happen, last IPCC (2007) report asserts that climate damage should be a major matter of concern. The last UNFCCC conference in Durban has thus confirmed the long term objective to keep temperature increase below 2 °C above pre-industrial levels based on IPCC (2007) findings.

Standard integrated assessment models (IAMs), combining economic and climate modules, usually represent climate damage by a smooth quadratic function incurring costs of a few percentage points of GDP, mostly in a far future. Given this representation of damage, optimal response to climate change is always likely to overshoot the 2 °C target (Stern, 2006; Nordhaus, 2008). Weitzman (2009) states that very few IAMs based on traditional Cost Benefit Analysis (CBA) have been designed to seriously take into account the possibility of a tipping point and thus of a dramatic climate catastrophe. Our model, RESPONSE, aims at bridging this gap building on Gjerde et al. (1999), Keller et al. (2004), and Lempert et al. (2006) who have explored the theoretical and political implications of introducing non-linearities in climate dynamics into usual IAMs. While the two former investigate the effect of uncertain climate thresholds on optimal abatement policy, the latter shows how non-convex models which exhibit multiple solutions with nearly equal welfare resulting nonetheless from very different policy choices, may help policy-makers better understand potential options for hedging against abrupt climatic change.

Following the tradition launched by the seminal DICE model (Nordhaus, 1994), RESPONSE couples a macroeconomic optimal growth model[1] with a simple climate model[2]. Instead of the usual quadratic damage function, RESPONSE uses a threshold effect damage function (or sigmoid function) in order to account for the existence of abrupt changes in climate dynamics by considering thresholds in temperature increase beyond which damage increases significantly although it remains bound (maximum losses range from 0 to 50 percent

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[1] Much like Ramsey-Cass-Koopmans' models (Ramsey, 1928; Koopmans, 1963; Cass, 1965).

[2] A comprehensive presentation of the model RESPONSE is provided in (Dumas et al., 2012)

of GDP). This use of a climate damage function allows us to frame the abatement policy dilemma within a cost-benefit framework which makes an overshoot of the temperature target possible (Ambrosi et al., 2003) and then introduces some degree of flexibility on abatement costs. In contrast, Keller et al. (2007) appraises the potential cost of procrastination in climate policy for different levels of temperature objectives within a cost-effective approach that prevents any overshoot whatever the costs.

In our deterministic runs, depending on the starting date of mitigation policy and the beliefs of economic agents (on economic growth, abatement costs, pure time preference, climate sensitivity, technical progress, the size of the damage once the threshold is exceeded), the optimal strategy is either to overshoot the temperature threshold or on the contrary to struggle against it. This paper focuses on what we call the overshooting, or "doomist," behaviours. Such behaviours result from what we interpret as a "doomsday effect" because it comes to accept that it is too expensive to prevent the rise of climate catastrophes. We point out a significant spreading of these strategies among stakeholders of the climate debate as the beginning of mitigation efforts is delayed. Such spreading of a "resigned" attitude may look contradictory to the ambitious 2 °C target that has been confirmed many times in international climate negotiations as the critical threshold not to overshoot. Still, we argue that it fits rather well with current climate policy orientations which are not likely to be sufficient to meet the precautionary temperature target (Guivarch and Hallegatte, 2011; Davis et al., 2010).

In section 1 we explain what we mean by a "doomist" behaviour. Section 2 presents our methodology to build a population of scenarios that can account for the diversity of views expressed in the climate debate. Section 3 appraises the extent of the "doomsday effect" by distinguishing among scenarios those which do not manage to avoid the overshoot of the 2 °C target. In particular our results show that if no action is taken by the beginning of the decade, then the number of "doomists" will significantly rise between 2010 and 2020.

1 What does "doomist" behaviour look like?

In the optimal control dynamics framework of RESPONSE[3], the damage due to temperature increase exhibits a non-linear effect. The damage function is indeed a sigmoid function: if temperature increase $\theta_{A,t}$ overshoots the threshold θ_D, it triggers a strong increase d in climate damage during a non-linearity phase of size η (see Figure 1). Contrary to the smooth profile of a quadratic function, non-linearity in the sigmoid function implies that a significant jump in damage occurs for relatively low levels of temperature increase. Our damage function is written:

$$D(\theta_{A,t}) = \kappa\theta_{A,t} + \frac{d}{1 + \mathrm{e}^{(\theta_D - \theta_{A,t})/\eta}} \tag{1.1}$$

In our runs, θ_D is set at 2 °C in order to fit with the target commonly referred to in international climate negotiations as the politically acceptable temperature

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[3] A comprehensive description of RESPONSE is provided in (Dumas et al., 2012) which is available at `http://www.centre-cired.fr/IMG/pdf/CIREDWP-201241.pdf`. Several articles (Ambrosi et al., 2003; Perrissin-Fabert et al., 2012) are based on RESPONSE.

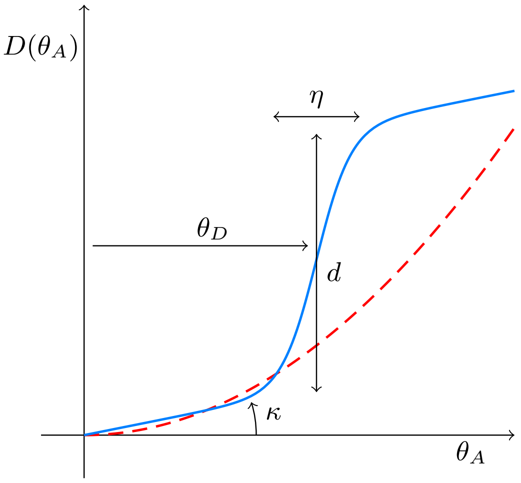

Figure 1: Quadratic vs. sigmoidal forms of the damage function D in RESPONSE. On the x axis, θ_A stands for the atmospheric temperature increase in Kelvin. On the y axis $D(\theta_A)$ represents climate damage in % of GDP. The blue curve represents the sigmoïdal case: θ_D is the temperature threshold where the non-linearity occurs, η is the width of the non-linearity phase, d is the size of the jump in damage, and κ is a linear trend of damage. The red dashed curve represents the quadratic case, where the damage function is written: $D(\theta_A) = \kappa\theta_A^2$

increase beyond which uncontrollable climate change may occur. The range η of the non-linearity phase is calibrated so that the jump in damage d unfolds its potential within the range [1.7 °C; 2.3 °C] of temperature increase. Note that, at θ_D, damage reaches 50% of d.

We call "doomist" behaviour the optimal strategy in which the representative agent overshoots the threshold θ_D. This means that it is optimal for the representative agent to enter the zone where catastrophic damage occurs. As an optimal strategy in a deterministic model, there is no uncertainty, surprise or misexpectations involved in the "doomist" strategy. Hence, with perfect expactations and complete information, it is rational for the representative agent to cross the threshold, *i.e.*, for him, abatement efforts to prevent the overshoot is more costly, in terms of discounted utility, than high losses due to climate damage. The "doomist" behaviour is thus a rational behaviour, as far as cost-benefit analysis is concerned.

2 Accounting for a wide diversity of worldviews in the climate debate

A broad sensitivity analysis over five key parameters of RESPONSE (listed in table 1), namely the rate of long term economic growth, the rate of pure time preference, the rate of technical progress, an index of abatement cost and climate sensitivity, taking four values each, allows us to build a population of $4^5 = 1024$ scenarios. The calibration of these parameters rests basically on "beliefs" because there is no decisive argument to pick one value rather than another, and eventually the calibration results from an irreducible subjective choice within "reasonable" ranges provided by most advanced research (IPCC, 2007). The combination of beliefs in these parameters constitutes what we call a "worldview." All these worldviews are run with the same sigmoid damage function described in section 1, for different levels of damage jumps ranging from 0 to 50% of GDP.

Table 1: Sensitivity analysis over 5 key parameters of RESPONSE taking 4 values within the following ranges

Growth rate	1% - 2.1%
Pure time preference	0.1% - 2.8%
Climate sensitivity	2 °C - 6 °C
Abatement linear cost (ζ)	\$0 /tCO$_2$ - \$101 /tCO$_2$
Technical progress on abatement cost (γ)	0.25% - 5.22% per year

Ranges of the rate of long term economic growth and climate sensitivity are based on estimates provided by the IPCC while ranges of pure time preference and abatement costs are drawn from the emblematic Stern/Nordhaus controversy which has polarized discussions about what to do in order to tackle the climate challenge[4]. Another line of division between the two approaches pointed out in a companion paper (Espagne et al., 2012), though it has remained almost unnoticed in the Stern/Nordhaus controversy, deals with abatement costs. Our abatement cost function is written at date t:

$$C_a(a_t) = \frac{1}{(1+\gamma)^t}\left(a_t\zeta + (BK - \zeta)\frac{(a_t)^\nu}{\nu}\right), \tag{2.1}$$

with γ the rate of technical progress, a_t the fraction of abatement, BK the backstop price, ζ the linear cost of abatement, and ν a power coefficient (set at 4).

While Nordhaus sets the price of the backstop technology (BK) at \$1,200 /tCO$_2$ in 2005 and an annual rate of technical progress of $\gamma = 0.0025\%$ over the next century in order to reach a backstop price of \$950 /tCO$_2$ in 2100, Stern looks much more optimistically on the affect of technical progress on abatement cost. According to Stern, the mean cost of abatement will decrease from \$61 /tCO$_2$ in 2015 for an abatement level of 7.5 percent to \$22 /tCO$_2$ in 2050 for an abatement level of 75 percent. For a backstop price set at \$1,200 /tCO$_2$ in 2005,

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[4] Comments following the Stern (2006) Review (Dasgupta, 2007; Nordhaus, 2007; Weitzman, 2007; Yohe and Tol, 2007) have mainly emphazised the impact of the so-called unusually low rate of pure time preference of 0.1% (which makes the discount rate used in Stern's runs amount to 1.4%) on Stern's recommendation of early and strong mitigation action. In turn, the "policy ramp" promoted by Nordhaus (2008) would be driven by a more conventional level of pure time preference (2.8%) leading to a discount rate of 4.1%.

such a view of mean abatement costs is consistent with a annual rate of technical progress of 0.0522 and an additional linear cost in the abatement cost function of \$101 /tCO$_2$ in 2005.

For each damage jump in the range $0 - 50\%$, we run RESPONSE with 1024 (4^5) scenarios accounting for the wide diversity of worldviews in the climate debate that give as many trajectories of optimal abatement as temperature increase. Among this population of scenarios we then distinguish the worldviews leading to a doomist behaviour for the levels of jump in damage considered and various initial dates for the beginning of mitigation efforts. This allows us to better understand how this effect may spread with time if mitigation efforts are postponed.

3 Appraising the "doomsday effect" across time

This section aims at appraising how the "doomsday effect" evolves with time for different levels of climate catastrophes and different starting dates of mitigation efforts. It allows us to disclose that the current 2010-2020 decade is crucial for climate policy to retain a chance of meeting the 2 °C target.

A static analysis of table 2 shows that the number of doomists decreases with the size of the jump whatever the initial starting date of climate policy. This trend is rather intuitive as the higher the shock in damages the higher the willingness to pay to hedge against the shock and thus to pay for precautionary mitigation efforts. When the jump is null, i.e. climate damages are reduced to their linear part $\kappa\theta_{A,t}$, 94 percent of the scenarios are going to overshoot the temperature threshold. This does not turn however them into genuine doomists as they are not facing any serious threat but rather indicates that the threshold will almost certainly be overshot if only low climate damage is anticipated. The same comment can apply to cases with low jumps in damage which are not "scary" enough to offset the cost of mitigation efforts to meet the 2 °C target.

A dynamic analysis of figure 2 that displays results for only six levels of jump in climate damage reveals that the number of doomists remains almost perfectly constant if mitigation policy is delayed from 1990 to 2010 as there are almost no additional doomists during this period. Then a dramatic increase in additional doomists occurs during the 2010-2020 decade whatever the size of the jump. This increase is all the more striking as it occurs after a three-decade plateau, while one could have expected a steady increase over the whole period. This upward trend of additional doomists is still noticeable during the following two decades.

These results clearly suggest that it becomes more and more difficult to avoid the overshoot of the 2 °C threshold as the beginning of mitigation efforts is postponed. In the extreme case where climate policy would not be implemented by 2040, whatever the jump in damages, table 2 shows that for more than 62 percent of the scenarios it would be too late to prevent temperature increase from passing the 2 °C threshold, and then major climate damage from occuring.

Table 2: Evolution of the total number of “doomists” among the 1024 scenarios depending on the size of the jump in damage and the starting date of mitigation efforts

d	1990	2000	2010	2020	2030	2040
0.50	6	5	8	256	512	640
0.48	11	10	13	258	512	640
0.46	12	12	13	258	512	640
0.44	15	15	15	259	512	640
0.42	17	17	22	263	512	640
0.40	22	23	27	262	512	641
0.38	34	35	36	268	512	642
0.36	35	37	40	271	513	642
0.34	53	54	58	278	516	644
0.32	62	65	70	282	516	646
0.30	77	78	83	293	519	646
0.28	94	97	107	301	524	648
0.26	110	115	118	310	525	653
0.24	130	131	137	315	530	652
0.22	150	153	153	327	536	656
0.20	188	191	194	351	545	664
0.18	202	202	205	361	556	667
0.16	241	242	239	380	563	675
0.14	271	271	272	400	577	683
0.12	334	335	335	430	590	693
0.10	386	388	390	469	605	701
0.08	459	461	457	515	626	713
0.06	529	529	524	564	653	732
0.04	597	598	595	629	690	755
0.02	722	722	732	745	767	812
0.00	963	964	965	965	966	969

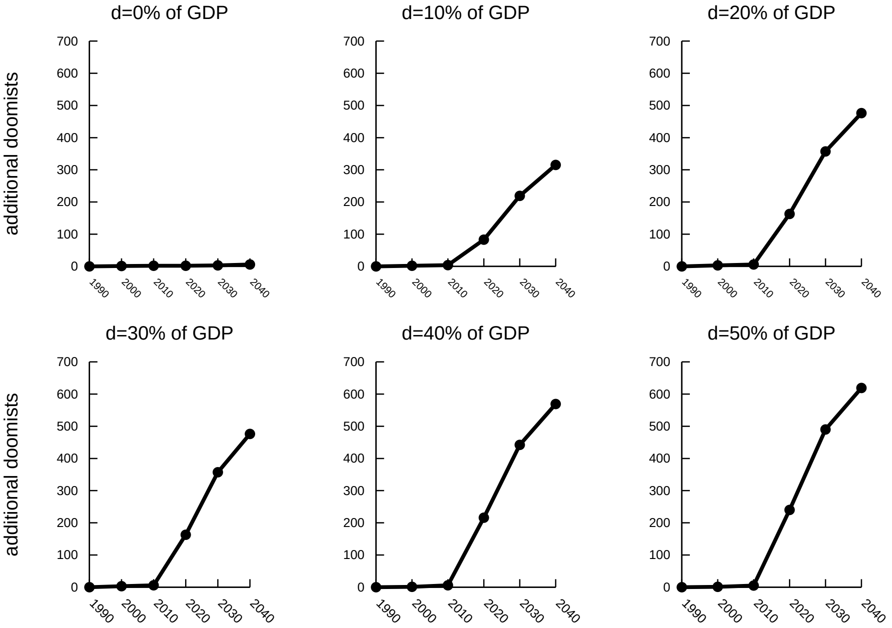

Figure 2: Evolution of the number of additional "doomist" in comparison to 1990 depending on the size of the jump in damage and the starting date of mitigation efforts

Conclusion

In this paper we show that taking into account the possibility of major climate damage by means of a sigmoid damage function may have significant impact on the optimal timing of climate policies and sheds light on the increasing difficulties with time to reach a consensus on mitigating GHG emissions.

Among a broad set of scenarios accounting for the wide diversity of worldviews in the climate debate, we appraise the extent of what we call the "doomsday effect" which makes it optimal for economic agents to resign to overshoot the 2 °C threshold and then face high climate damage. We show that this effect happens for any level of jump in damage and dramatically increases from the 2010-2020 decade on, given that the later the beginning of mitigation efforts the more difficult it becomes to prevent the overshoot.

The vagaries of the diplomatic process since the Rio Conference in 1992 have resulted in "two-lost-decades" for climate action. In light of these results, we believe that any further delay in reaching a clear international agreement will close the window of opportunity for meeting the 2 °C target with any reasonable chance of success. In fact decision-makers may then become reluctant to implement ambitious climate policies as they believe it is too late to act and are struck by the "doomsday effect."

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