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Levity - complementing climate policy strategies

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Abstract When the likelihood of future damages is very small or highly uncertain, decisions are best based on avoidability. Here we present the intuitive and practical measure, *levity*, to account for avoidability in policy strategies - closing the gap between risk assessment and cost-efficiency analysis. *Levity* is applicable to mitigation as well as to adaptation options. It is scale independent and thereby allows to compare global strategies with daily personal decisions. We propose its application to complement climate protection strategies in specific cases that can not be assessed properly by other means.

Keywords Climate policy · Decision making

Hurricane Katrina hit New Orleans practically unprotected. Authorities had clearly underestimated the likelihood of such an event. Had they based their protection strategies on avoidability rather than an estimate of the probability of occurrence, damages would have been much smaller. In the light of a changing climate, not only politicians, also the scientific community is facing a dilemma. Increasingly, stakeholders demand an assessment not only of the most likely future evolution of Earth's climate. More and more information is requested on events which are rather unlikely to occur but imply such drastic humanitarian, economic and ecologic consequences that society might deem the risk as too high to be taken. Examples are the so-called *Tipping Elements* of the climate system [Lenton et al (2008)] which include potentially catastrophic events as the collapse of the West Antarctic Ice Sheet [Oppenheimer and Alley (2004), Bamber et al (2009),Pollard and Deconto(2009)], the Atlantic overturning circulation [Rahmstorf et al (2005)] or Asian monsoon systems [Levermann et al (2009)].

Scientific literature applies the concept of risk as a combination of probability of occurrence of an event and its consequences "with several ways of combining these

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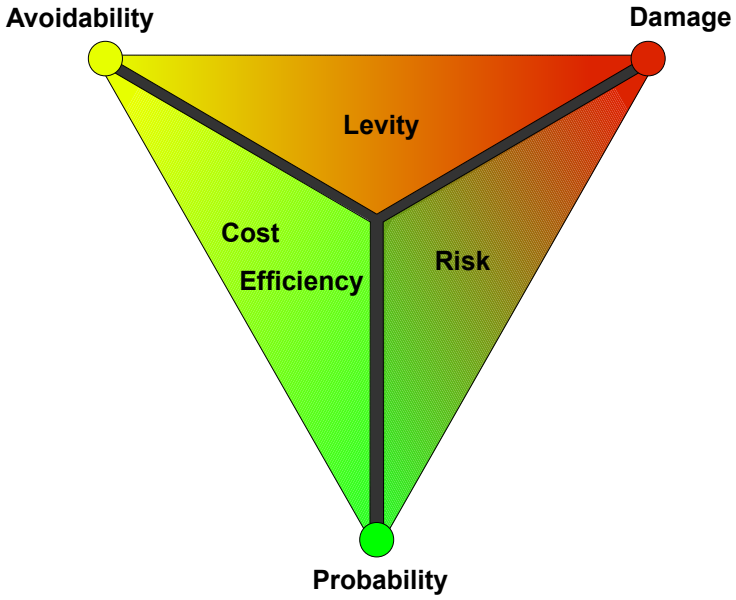

Fig. 1 Assessment triangle for climate policy strategies

two factors being possible"[Carter et al (2007)]. In its simplest form risk is merely the product of the two. However, in the context of societal choices, risk might not always be the best basis for decision making. Whether a negative event can be avoided, does not depend on its likelihood. Often probability even proves to be irrelevant. Most people would, for example, not keep their car unlocked when leaving for a holiday just because they live in a safe neighborhood. The effort of turning the key to lock the car is so small that it does not really matter how unlikely theft would be. However, on a global scale such as relevant for climate change, it is not obvious how avoidance is possible. Here we propose a simple scale-independent measure, complementary to risk, that comprises avoidability of an event and relates it to its damages. We define *levity* in the sense of 'lighthearted carelessness' as

$$\text{Levity} = \text{Damages} \times \text{Avoidability},$$

i.e., as being high for a high-impact event that can easily be avoided.

Taking damages, their probability, and their avoidability as the relevant independent quantities for assessing climate change impacts, different concepts that combine these quantities exist (Fig. 1). While risk weighs damages according to their likelihood, cost-efficiency analysis sets probabilistic climate goals according to their avoidability without specifying damages. *Levity* is the missing link between damages and avoidability. It comprises mitigation and adaptation strategies. Whether damages of an event are avoidable depends on the possibilities of preventing its occurrence or relieving its consequences. These possibilities in turn depend on scientific and economic feasibility as well as on political and economic decisions.

By definition *levity* can be computed for any event without knowledge of its likelihood. For practical purposes this is a strong advantage. While obtaining reliable numbers for the likelihood of a climatic event is very difficult [Betz (2007), Schneider (2004),

Table 1 Examples of *economic levity*

Event	Damages	Costs	*Economic Levity*
Unlocked cheap bike	∼100 €	∼50 €	∼2
Unlocked valuable bike	∼1000 €	∼100 €	∼10
Uninsured car	∼20,000 €	∼2000 €	∼10
Hurricane Katrina [Gaddis et al (2007)]	200-250 bil. US$	14 bil. US$	14 - 16
Climate Change [Stern (2007)]	5-20% GDP	0.18-1.8% GDP	11 - 28

Garthwaite et al (2005),Morgan and Henrion (1990)], it is even more problematic to assess the probability of certain damages to occur. In case of hurricane Katrina not only the landfall probability for New Orleans, but even the severeness of damage caused by hurricanes of different categories was underestimated. Both uncertainties led to an inadequate risk assessment.

In case of climate change the impacts associated with, for example tipping elements of the climate system, such as the collapse of the Atlantic thermohaline circulation, can be tremendous [Vellinga and Wood (2002)], while the corresponding probability might be very small [Zickfeld et al (2007)] or extremely uncertain [Kriegler et al (2009)]. The product of a very large number with a very small and uncertain one is subject to huge uncertainty and renders assessment of climate damages according to risk futile [Weitzmann (2009)]. *Levity* avoids this problem.

A practical way of introducing *levity* into the political debate is through mapping it into the economic world. Quantification is possible when computing avoidability through mitigation and adaptation costs subsumed as avoidability costs. Low avoidability costs are identified with high avoidability. The definition

$$\text{Economic levity} = \text{Damage} \;/\; \text{Avoidability costs}$$

allows to calculate *economic levity* for climate-related events. It is high if avoidability costs for a high-damage event are low. As an example, we estimate *economic levity* of the most severe impacts of the landfall of hurricane 'Katrina' in 2005, from economic damages of the hurricane and estimated costs of sufficient adaptation measures (Table 1). Since avoidability costs and damages both scale with the size of the event, *economic levity* is independent of scale and the value of 14-16 can be compared to every-day situations. Not to lock a cheap bike is a forgivable low-levity misdemeanor, while an expensive bike is generally worth the relatively low investment of a lock.

Using data from the comprehensive economic review of climate change by Sir Nicolas Stern [Stern (2007)], *economic levity* of unmitigated climate change computes to 11-28. That is the value for the so-called "business-as-usual" scenario [Nakicenovic and Swart (2000)] in relation to the mitigation costs of staying below two degrees of global warming. In the insurance industry *economic levity* is already implicitly used for decision making. The cost of a comprehensive car insurance is calculated not only according to the probability of an accident, but naturally increases with the value of the car. Thus avoidability costs are designed to yield high *economic levity*; and people indeed buy policies for new cars. Still, values for hurricane Katrina and unmitigated climate change are even higher.

The examples of Table 1 illustrate the main idea of the concept. *Levity* is proposed as a measure applicable to possible future events to include avoidability in the decision-making process. In contrast to risk, *levity* is independent of scales and thus most suitable as a means for comparison not only within but between categories of damages and their

avoidability. This holds especially for adaptation measures. As the adaptation examples, hurricane Katrina and the bike lock, illustrate, *levity* is a natural quantity that we intuitively use in judging these cases. Mapping *levity* into an economic framework has clear advantages towards a more rational application of avoidability in decision making as it allows for assigning monetary values [Feiler and Soll(2010)] in contrast to the more abstract *levity*. In the framework of cost-benefit analysis the quantifiable *economic levity* corresponds to an expected cost-benefit ratio for uniform probability distributions. Climate protection action with net-benefit [Creyts et al (2007)] are characterized by negative *levity* underlining the measure's intuitive nature.

Nevertheless limiting the concept to the economic sphere excludes a large number of cases which cannot be given a monetary value. As much as the concept of risk is useful without computing actual values for risks, it is useful information whether a certain decision has high *levity*. In general *levity* takes the perspective of the possibility of perfect avoidance in the sense that it asks the question: how much the quasi-certain avoidance of a specific damage requires? This perspective which ignores probability is thereby comparable to that in a risk assessment which neglects avoidability. Consequently, we do not propose to use *levity* as the only means of assessing future actions. It can, however, complement a comprehensive assessment, especially in situations of very high *levity* which make a risk assessment obsolete. In cases of very high and very low probability of occurrence as well as in situation where this probability is highly uncertain, a *levity* assessment can be a useful approach towards rational decision making.

A careful and comprehensive climate policy strategy will be based on the entire assessment triangle (figure 1). *Levity* provides a means to likewise consider mitigation and adaptation measures without explicit use of probability a priori. A posteriori likelihoods can complement the analysis towards an integrated climate policy strategy based on *levity* and risk assessment. Accordingly *levity* permits the combination of two valuable strategies of climate impact assessment. The idea of normative guardrails as in cost-efficiency analysis is combined with the idea of trade-off between costs and risks within cost-benefit analysis. Replacing risk by *economic levity* in an economic analysis provides an alternative for optimizing investment or emission paths. *Levity* is thus a concept to be profitably implemented in formal decision frameworks which are often carried out via optimization over a set of decision variables, e.g. an emission path, and thus trying to minimize economic costs and climatological risks. *Levity* is thus an intuitive and formal measure to assess climate policy strategies.

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References

[Bamber et al (2009)] Bamber JL, Riva REM, Vermeersen BLA, LeBrocq AM (2009) Reassessment of the Potential Sea-Level Rise from a Collapse of the West Antarctic Ice Sheet. Science 324(5929):901–903

[Betz (2007)] Betz G (2007) Probabilities in climate policy advice: a critical comment. Climatic Change 85:1–9

[Carter et al (2007)] Carter TR, Jones RN, Lu X, Bhadwal S, Conde C, Mearns LO, ONeill BC, Rounsevell MDA, Zurek MB (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge,

United Kingdom and New York, NY, USA., chap New Assesment Methods and the Characterisation of Future Conditions

[Creyts et al (2007)] Creyts J, Derkach A, Nyquist S, Ostrowski K, Stephenson J (2007) Reducing u.s. greenhouse gas emissions: How much at what cost? Tech. rep., McKinsey and company, U.S. Greenhouse Gas Abatement Mapping Initiative

[Feiler and Soll(2010)] Feiler DC, Soll JB (2010) A blind spot in driving decisions: how neglecting costs puts us in overdrive. Climatic Change Letters 98:285–290

[Gaddis et al (2007)] Gaddis EB, Miles B, Morse S, Lewis D (2007) Full-cost accounting of coastal disasters in the united states: Implications for planning and preparedness. Ecological Economics 63:307–318

[Garthwaite et al (2005)] Garthwaite PH, Kadane JB, O'Hagan A (2005) Statistical methods for eliciting probability distributions. Journal of the American Statistical Association 100:680–701

[Kriegler et al (2009)] Kriegler E, Hall J, Held H, Dawson R, Schellnhuber HJ (2009) Imprecise probability assessment of tipping points in the climate system. Proceedings of the National Academy of Sciences 106(13):5041–5046

[Lenton et al (2008)] Lenton TM, Held H, Kriegler E, Hall JW, Lucht W, Rahmstorf S, Schellnhuber HJ (2008) Tipping elements in the Earth's climate system. Proceedings of the National Academy of Sciences 105(6):1786–1793

[Levermann et al (2009)] Levermann A, Schewe J, Petoukhov V, Held H (2009) Basic mechanism for abrupt monsoon transitions. Proceedings of the National Academy of Sciences 106(49):20,572–20,577, DOI 10.1073/PNAS.0901414106

[Morgan and Henrion (1990)] Morgan MG, Henrion M (1990) Uncertainty: A guide to dealing with uncertainty in quantitative risk and policy analysis. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[Nakicenovic and Swart (2000)] Nakicenovic N, Swart R (eds) (2000) IPCC Special Report on Emissions Scenarios. Cambridge University Press

[Oppenheimer and Alley (2004)] Oppenheimer M, Alley RB (2004) The West Antarctic ice sheet and long term climate policy. Climatic Change 64:1–10

[Pollard and Deconto(2009)] Pollard D, Deconto RM (2009) Modelling West Antarctic ice sheet growth and collapse through the past five million years. Nature 458:329–332

[Rahmstorf et al (2005)] Rahmstorf S, Crucifix M, Ganopolski A, Goosse H, Kamenkovich I, Knutti R, Lohmann G, Marsh B, Mysak LA, Wang Z, Weaver A (2005) Thermohaline circulation hysteresis: A model intercomparison. Geophysical Research Letters 32:L23,605

[Schneider (2004)] Schneider SH (2004) Can we estimate the likelihood of climatic changes. Climatic Change 52:441–451

[Stern (2007)] Stern NT (2007) The economics of climate change. The Stern Review. Cambridge University Press

[Vellinga and Wood (2002)] Vellinga M, Wood RA (2002) Global climatic impacts of a collapse of the Atlantic thermohaline circulation. Climatic Change 54:251–267

[Weitzmann (2009)] Weitzmann ML (2009) on modeling and interpreting the economics of catastrophic climate change. The Review of Economics and Statistics 91

[Zickfeld et al (2007)] Zickfeld K, Levermann A, Granger HM, Rahmstorf S, Kuhlbrodt T, Keith DW (2007) Expert judgements on the response of the atlantic meridional overturning circulation to climate change. Climatic Change 82:235–265