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EDITORIAL

Stern's Review and Adam's fallacy

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Abstract The Stern Review has played an enormous role in making the world of business aware of the challenge of long-term climate change. In order to make real progress on the basis of this awareness, it is important to pay attention to the difference between human suffering and losses of gross domestic product (GDP). The Review has compared climate change to experiences of suffering like World War I. That war, however, hardly affected global GDP. The long-term damages to be expected from business-as-usual greenhouse gas emissions include loss of the coastal cities of the world over the next millennia. This would be an act of unprecedented barbarism, regardless of whether it would slow down economic growth or perhaps even accelerate it. Business leaders worried about climate change need to pay attention to the tensions between ethical and economic concerns. Otherwise, a credibility crisis threatens global climate policy. An important step to establish the credibility needed for effective climate policy will be to gradually move towards a regime where emission permits are auctioned, not handed out as hidden subsidies. The revenues generated by permit auctions should be used to establish a global system of regional climate funds.

1 Climate change and World War I

With his review of the economics of climate change, Lord Nicholas Stern (2007) has produced a landmark document. It has shifted the burden of proof in the climate

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debate. For decades, scientists and environmentalists had warned that anthropogenic climate change was a threat of historic proportions, while industry had lobbied against attempts to implement effective climate policies. In most countries, public debates about climate change were shaped by the tension between images of pending climate catastrophes on one hand, and fears of job losses due to climate policy on the other. The burden of proof that it is economically reasonable to engage in the drastic emissions reductions advocated by those concerned about climate change lied with the latter. With the Stern Review, this has changed.

It has changed because two powerful comparisons proposed by the review have captured the mind of both decision-makers and the general public. First, anthropogenic climate change is put into the same class as three huge experiences of human suffering that have marked the past century: World War I, the Great Depression of the 1930ies, and World War II. Second, the damages from climate change are said to be in the order of up to 20% of global gross domestic product (GDP), while the costs of climate policy are said to be in the order of 1%. Business leaders all over the world have endorsed these comparisons; in his State of the Union address of January 2007 even president G.W.Bush—who had been one of the most determined opponents of any effective climate protection—declared climate policy to be one of the priorities of US policy-making; the fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has become part of a public discourse shaped by the Stern insights.

The congruence of the two comparisons suggests that—at least with regard to climate change—caring about GDP amounts to much the same as caring about human suffering. Is this so? Figure 1 presents data that can be used to check what traces the three paradigmatic events quoted by the Stern Review left in economic growth. Consider World War I first (see Hirschfeld 2003, for data and further sources): about ten million people died from direct military impacts, about 20 million people were seriously wounded, about 30 million died from the pandemic that arose as a consequence of the war. In economic terms, World War I did hit the British economy, and certainly the GDP of Germany and France (not included in the table), but in the US, Canada, Australia, and Japan no interruption, let alone a slow-down of economic growth can be observed. If anything, the *end* of the war was an economic problem, as it triggered a temporary international recession. From the point of view of global GDP, World War I was a negligible event.

The Great Depression, of course, was a huge shock to the world economy that went with massive losses of well-being for millions of people. However, after a few years it was over and long-run economic growth was certainly not slowed down. World War II, including the military buildup in the years before the war, may actually have helped to recover, even if the war led to a brief interruption in economic growth in the Anglo-Saxon countries. In Japan, World War II did wreck the economy; but in the following decades the Japanese economy engaged in a spectacular and successful catch-up race (much as was the case with Germany).

When thinking about climate change in a historical perspective—as is surely appropriate given the time-scales involved—these facts tell an important message. The horrors of the Holocaust, but also the casualties of Iwo Jima and of Hiroshima, and all the suffering that came with the two great wars, are incommensurable with GDP figures. Both human suffering and global GDP are important, and so both

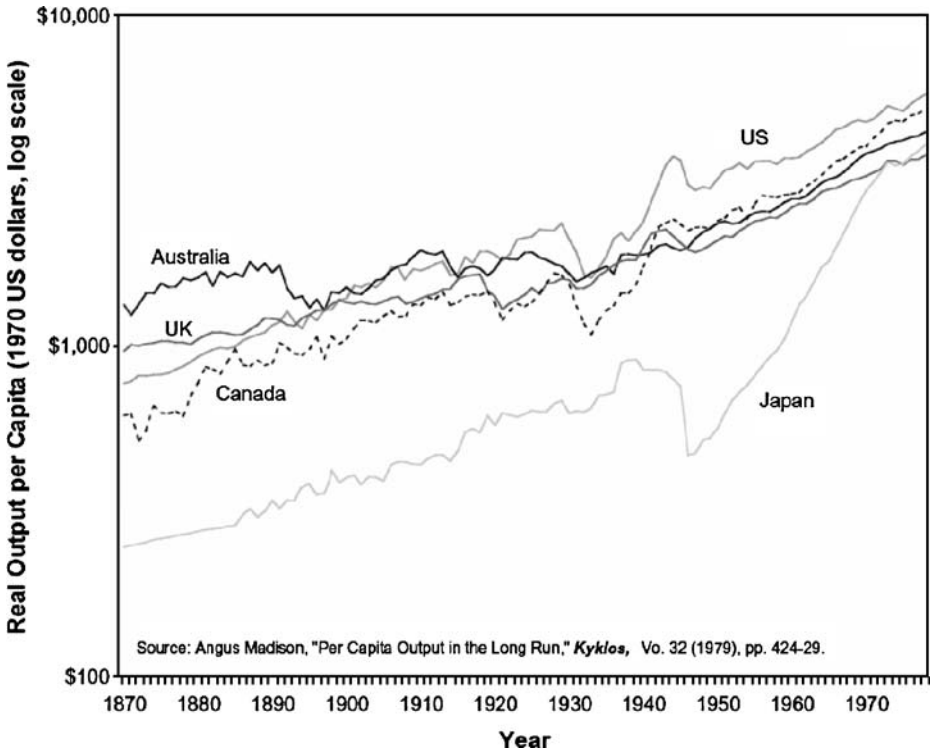

Fig. 1 Real output per capita in five industrialized countries (Madison 1979)

comparisons conveyed by the Stern Review do matter, but their congruence is a fallacy.

These tensions arise in many areas of economics, and so far they are treated mainly with neglect. In the case of climate change, this is hardly appropriate. Foley (2006) argues that this neglect is a problematic part of the paradigm economics has inherited from Adam Smith, hence the "Adam's fallacy" in the title of this essay.

2 What future are we discounting?

One reason the fallacy matters for the debate on climate change is the fact that most voices in this debate still greatly underestimate the time scales involved. It was somewhat unfortunate that doubling of atmospheric CO_2 concentration has been chosen as the benchmark for the bulk of research on climate change, as this shortens the time-horizon considered to a few decades. However, there is enough economically accessible carbon in the Earth's crust for humankind to massively increase greenhouse gas emissions for another 200 years and more (Rogner 1997; Hasselmann et al. 2006; Archer and Brovkin, Millennial atmospheric lifetime of

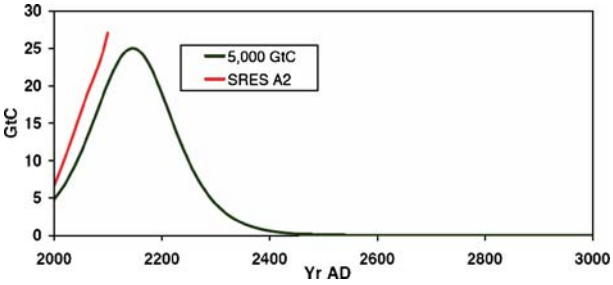

Fig. 2 Feasible emissions with available carbon (Archer and Brovkin Millennium atmospheric lifetime of anthropogenic CO2; submitted to Climatic Change), *black*. IPCC SRES A2 fossil fuel emissions for 21st Century, *red*

anthropogenic CO2 (submitted to Climatic Change); Fig. 2. The IPCC SRES A2 scenario has very fast emissions growth; most likely emissions would have to fall very rapidly after a peak around 2100, with long-term effects similar to the scenario considered here).

As a result, atmospheric CO_2 concentration would increase by a factor of six or more over the next 300 years, and global mean temperature would increase by about 7˚C over the same time horizon. What is even more worrying, global mean temperature would then stay at 5˚C above preindustrial levels for several millennia (Fig. 3).

Paleo-data and modeling studies suggest that global warming will reduce the capacity of continents and oceans to absorb CO_2. For each degree of warming, an additional .05˚ to .3˚ of additional warming may result, perhaps even more (Scheffer et al. 2006; Friedlingstein et al. 2006). Over the next millennia, another positive feedback is to be expected. Methane hydrates storages on oceanic continental slopes embrace several thousand GtC. With warming of the deep ocean, a substantial part of this CH_4 may escape to the atmosphere (mostly in form of CO_2) and further amplify the warming (Archer and Buffett 2005). Given the difficulties of current mechanistic models to explain several important observations, such as lowering of atmospheric CO_2 by 90 ppmv during the last glacial maximum and the recent trend in sea-level rise, semi-empirical approaches based on paleo-data (Scheffer et al. 2006; Rahmstorf 2007) must be taken seriously. For a 3˚C warming over the next 10,000 to 30,000 years from now, they predict sea-level rise of about 50 m (Archer 2006; Fig. 4).

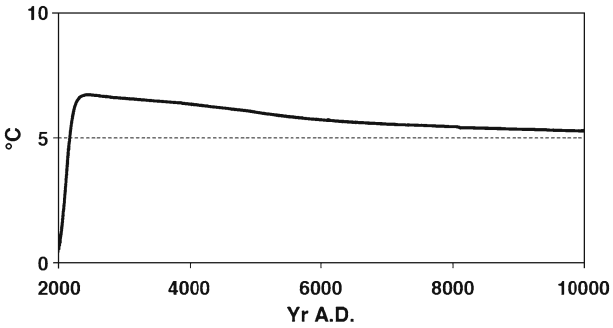

Fig. 3 Temperatures resulting from the emissions of Fig. 2 (Archer and Brovkin, Millennial atmospheric lifetime of anthropogenic CO2; submitted to Climatic Change)

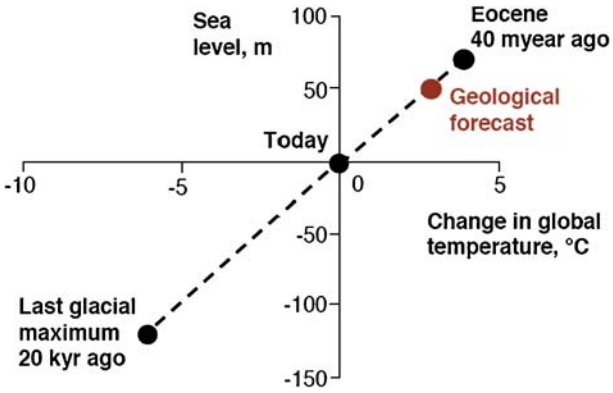

Fig. 4 The relationship between sea level and temperature on geological timescale. Modified from Archer (2006, Fig. 12.7)

These arguments indicate that by burning fossil fuels up to the limits of economic availability, humankind definitely risks sea-level rise of 10 m and more over the next 1,000 years.

Today, we look at the ruins of Ancient Rome and Athens and see 2,000 year old traces of those cities in the midst of contemporary life. Another 1,000 years from now our descendants may have to use submarines to explore the traces of nearly all major cities of the present world: London, New York, Los Angeles, Shanghai, etc.

Will people in those times still use an index of global GDP to assess their well-being? Suppose they will. Will they look at the drowning of all those cities as reductions of past economic growth, just as we look at the Great Depression of the 20th Century? Or will they realize that the end of all those cities meant renewed economic growth thanks to all the new cities that had to be built elsewhere? Nobody can tell, nor do we need to.

In a study of the risk of a 5 m sea-level rise even R. Tol, well-known for his hard-nosed willingness to accept many impacts of climate change, reaches the conclusion that this "is something that should rather be avoided" (Tol et al. 2006, p.478). And the reason we should "rather avoid" drowning the coastal cities of the world is not primarily that this would reduce global GDP, but that drowning those cities would be a dreadful act of global barbarism.

The long-term character of the climate challenge does not mean that there is plenty of time to wait and see before starting to do something about it. This would be irresponsible because the longer we wait, the harder it will be to stop and reverse the dynamics generating unacceptable risks. The difficulties will not always accumulate in slow motion, as the dynamics of climate change is characterized by significant discontinuities or tipping points (Gladwell 2000; Lenton et al. 2004). Sea-level rise, in particular, would not happen simply as a gradual and easily reversible process. A prominent example for relevant discontinuities is the possibility of disintegration of the West-Antarctic ice-sheet, where sea-level rise might accelerate discharge of ice into the Southern polar ocean, leading to rapid sea-level rise of 5–6 m (Oppenheimer 1998). Large sea-level rise may also be induced by melting of the Greenland ice-sheet (Gregory 2004; Oppenheimer and Alley 2005). Nearly all the Greenland ice might melt in the next one to three millennia, contributing about 7 m to global sea level rise. After the melting of its ice cover, the surface of Greenland would be much warmer, as it would reflect less sunlight; therefore the ice might not be regenerated

even if global mean temperature were to return to pre-industrial conditions. These transitions may be uncertain, but if they should happen, they would not be reversible on the time scales at which they would occur.

Another prominent discontinuity is the possibility that large parts of the Amazon rainforest might suddenly break down because of precipitation deficits, and in the transition release huge amounts of carbon, further accelerating climate change (Cox et al. 2006). A further important example is the possibility that the Great Barrier Reef as well as other coral reefs might decay from their current state of treasures of biodiversity into colourless relics where just some particularly robust species survive (Hoegh-Guldberg 1999). The last two examples show that what is at stake here is more than a shift in the parameters of biophysical systems—we might turn the Amazon rainforest and the Great Barrier Reef into historical footprints of global human carelessness. And by accepting this, one may lose not just some percentage points of GDP, but the sense of wonder at the world that lies at the roots of human happiness.

3 Ethics and economics

The fallacy we are faced with is related to one of the most influential breakthroughs of economics: the discovery that sometimes an economy can be described as if all the people involved in it were a single team jointly maximizing a single utility function depending on the aggregate value of all goods consumed. As investment today shapes consumption opportunities tomorrow, the sum of the aggregate a value of all goods consumed and the aggregate value of all goods invested is a key variable for dynamic models of this kind—and this sum is called GDP.

Thanks to the advances of economics, maximizing the long-term growth of GDP under the constraints given by initial resources and technological possibilities has become a powerful mathematical metaphor for the promise made long ago by the founding father of economics, Adam Smith. Embodied in computer models dealing with climate change, as in models dealing with many other issues, this promise addresses "the central anxiety that besets capitalism—the question of how to be a good person and live a good and moral life within the antagonistic, impersonal, and self-regarding social relations that capitalism imposes... [B]y being selfish within the rules of capitalist property relations, Smith promises, we are actually being good to our fellow human beings" (Foley 2006, p.2). Nobody has expressed this promise more succinctly than Milton Friedman (1970) in his justly famous New York Times essay: "The social responsibility of business is to increase its profits". Climate change is one area where the fallacy contained in that statement is particularly relevant.

Neither Smith nor Friedman ever argued that pursuing one's self-interest in business would be sufficient to be a good person. Friedman, e.g., stated explicitly that the pursuit of self-interest had to conform "to the basic rules of the society, both those embodied in law and those embodied in ethical custom." And he was certainly aware of the possibility of external effects that would require appropriate laws to make sure that self-interest really would serve the common good. It is this view that leads to the insight that tackling the challenge of climate change will require putting a price tag on greenhouse gas emissions. Adam's fallacy, as Smith's promise

is called by Foley (2006), is to believe that moral issues have to be dealt with outside the economic sphere only, by developing appropriate laws and respecting ethical custom, while within that sphere the pursuit of self-interest is all it takes to foster the common good (Smythe 2004).

Economics does provide the means to understand why this is a fallacy, because it has clarified the non-trivial circumstances required to model an economy as simply maximizing a single utility function (Arrow 1950; Kirman 2006). A typical set of circumstances implied by contemporary models—although rarely made explicit in their applications—includes the requirement that all agents have the same preferences, that in their preferences the distribution of wealth and income plays no role, that if they entertain some ethical or aesthetical concerns about the environment, these could always be traded for some amount of consumption goods (the beauty of coral reefs can be substituted by a sufficiently large amount of bread, or perhaps virtual coral reefs in cyberspace), that technology has a rather implausible property known as gross substitutability, and that the economy only operates in sufficiently close surroundings of a situation where supply matches demand on all markets. There is nothing to be said against using such models for analysing actual and possible climate policies, but policy advice relying mainly or even exclusively on this kind of models is not built on solid ground (DeCanio 2003). It is a prime example of Adam's fallacy.

Economics also provides some means to start overcoming the fallacy, because the discipline has developed operational notions of second order preferences. Suppose somebody is addicted to some product—an individual to cigarettes, a nation to oil, etc. Then that agent has first order preferences directed at that product. However, the agent may also think that it is not good to have those preferences, he or she may want to get rid of his/her addiction. Those are reflexive ("second order") preferences, directed at other preferences (Nehring 2006). Adam's fallacy is to think that the need for this reflection arises only with regard to government action, not with regard to how to run a business in a given regulatory environment.

Meeting the challenge of climate change will require debates, discourses, conversations about how we, the people involved in today's economy, want to change some of our preferences. An important example is the debate about the use of the discount rate in the Stern Review (Nordhaus 2006; for the relation with second order preferences see O'Donoghue and Rabin 1999). As there is no market for goods a thousand years in the future, there is no empirical discount rate to be found for assessing climate impacts over this time horizon. And as different people have different rates of time preference, and even the same person employs different such rates with regard to different goods, time horizons, and circumstances, there is a need for a debate about what discount rate we want to use when thinking about global change—and how to deal with the fact that in the economy we actually live in, our preferences and distribution of wealth may well imply a very different discount rate. Similar questions arise with regard to preferences directed at unbounded quantitative growth of GDP, or with regard to preferences about various kinds of risks.

Economics can help to think about moral and ethical issues concerning the world of business, it cannot reasonably be used to ignore those issues when thinking about business. "For me the fallacy lies in the idea that it is possible to separate out an economic sphere of life, in which the pursuit of self-interest is guided by objective laws to a socially beneficial outcome, from the rest of social life, in which the pursuit

of self interest is morally problematic and has to be weighed against other ends" (Foley 2006, xiii). Of course, the problem is not the distinction between the world of business and, say, public policy or family life. The problem is the image of the world of business as allowing for a neat separation of facts and values: "the economic way of thinking is just as value-laden as any other way of thinking about society, and can foster dangerous mistakes of judgment" (Foley 2006, xiv).

The traditions of reasoned debate that have evolved in assessing claims to factual knowledge can be used to assess claims to normative insights as well (Putnam 2002). In particular, research on risk management has led to an increased awareness of the possibility, but also necessity of cooperative discourses that accept the intertwinedness of descriptive and normative aspects in managing complex risks (Jaeger et al. 2001). Fortunately, in the world of business the complex risks of climate change are increasingly perceived as a challenge business wants and can help to address, and the Stern Review has played a key role in fostering that sea-change of business mood.

4 Who owns the sky?

The rhetoric of accepting climate change as a major challenge for business and policy will not work as cheap talk, however. A willingness to change some of one's own preferences on the basis of ethical considerations will be required to avoid a credibility crisis that would be fatal for climate policy. We therefore conclude with a practical example for how to ensure the credibility of the emerging business rhetoric on climate change.

So far, the most significant measure of climate policy has been the establishment of the European emissions trading system (EU-ETS). With all its drawbacks (Nordhaus and Boyer 1998; Victor 2001), the EU-ETS is a first step towards the new world order of energy use that will clearly be needed to avoid dangerous climate change (Schellnhuber et al. 2006). A plausible evolution of global policy might involve related, to some extent competing, schemes being established in the U.S., and perhaps China and other world regions, with the different schemes coalescing into some sort of global regime in the course of time (Asheim et al. 2006; Victor et al. 2005; Morgan 2000).

Alternative pathways are conceivable, but one aspect of the EU-ETS experience will require attention in all of them: so far, in the EU-ETS nearly all emission permits have been handed out for free to companies generating emissions, corresponding to a subsidy for industry of about $40 billion per year. In practice, this means that entitlements to use the atmosphere as a sink for greenhouse gases are gradually handed over to industry. If in the wake of the Stern Review climate policy will simply evolve as an effort to maximize GDP and subsidize industry, business support for climate protection will soon be seen as a self-serving rhetoric that has little to do with a sense of responsibility towards future generations—one more example of Adam's fallacy.

There is a natural way of addressing this problem: acknowledging that the atmosphere is a global commons by auctioning an increasing fraction of emissions permits and using the revenues to cover the costs of climate policy. It is precisely this link between the price of carbon and the costs of climate policy that brings about the

internalisation of the external effect that lies at the roots of anthropogenic climate change. Without this link, putting a price on carbon only means generating a rent that will be handed over either to industry—if emissions permits are handed out for free—or to government—if a carbon tax from emissions sales ends up in the generic government budget. And if history is any guide, rent-seeking will make sure that greenhouse gas emissions will work as a source of increasing incomes, rather than being effectively abated (Tullock 1987).

In view of the cumulative damages that anthropogenic climate change will certainly cause for at least some decades, the costs of climate policy will include an increasing share of expenses for adaptation and compensation. These costs will arise stochastically, so there is an insurance component to them (Jaffee and Russell 1997). But even mitigation costs will not arise gradually, as large-scale infrastructures will have to be financed stepwise. Therefore, a sizeable fraction of the revenues from auctioning emissions permits (as from carbon taxes) should be used to build up a system of carbon funds (Bhagwati 2006; Jaeger 2004). The sums involved will be huge. With global emissions of 5 Gt of carbon and a carbon price of $50 per ton, e.g.—both very conservative estimates for the coming decades—annual revenues of $250 billion result. Without financial flows of this magnitude, the climate challenge cannot be addressed. Handling them, however, will involve the imagination and determination needed to develop major financial innovations (Shiller 2006).

As it is unlikely that powerful nations or groups of nations will hand over the bulk of such financial flows to a global authority, a system combining a variety of regional funds seems the most likely outcome. The system as a whole could easily accumulate $1 trillion, and with this amount of money financing effective mitigation and adaptation measures would certainly be possible. Getting there may take some time. A significant first step could be the accumulation of regional carbon funds on the basis of auctioned emissions permits or carbon taxes.

It may be useful to sketch a scenario of how such a system could evolve. Europe is currently committing itself to unconditional emissions reduction in the order of magnitude of 20% until 2020, and is declaring its willingness to engage in further reductions if other nations make similar commitments. In order to realize these ambitious goals, European states as well as the European Union will need climate funds financed by auctioning a growing fraction of emissions permits. At the same time, the permit system will need to be expanded to more industries than the energy sector. Car manufacturers, e.g., may buy permits in proportion to the prospective emissions of the cars they produce. This kind of incentives can trigger the innovation processes required to reach the declared reduction goals. On this basis, Europe may engage in a constructive dialogue—perhaps monitored by Japan, the country of Kyoto and successor of Germany in the G8 presidency—with the US, China, and the other partners in the climate policy arena.

Given the geopolitical realities of our times, it is obvious that the US is crucial for any effective climate regime. After the failure of the Bush Jr. administration to establish a new world order based on unilateralism and on the denial of common tasks like climate policy, it is possible for the US to create its own emissions trading system, generating its own climate fund, and so preparing the resources needed to assume its leadership role as *primum inter pares*, rather than as imperial successor of Ancient Rome. This may take longer than a few years, but there is only one obstacle that can really block this development: a free-riding position of China.

It is obvious by now that China is the only nation with the potential to refute the explicit goal of the American security doctrine: that no nation should be able to effectively challenge the US The "unilateral moment" of the US is likely to come to an end in the face of this potential (Ikenberry 2008). It is no exaggeration to say that the fate of humankind now depends to a large extent on whether China develops its own version of democracy and grows into the role of a constructive partner in the society of nations. There is no doubt that this is the desire of large parts of the Chinese elite and Chinese society, but the obstacles on this road are formidable. There is a serious danger that China will be trapped in autocratic patterns of governance, with scary consequences for China itself and for the rest of the world.

At the juncture of climate and energy security lies a key opportunity to foster a sustainable development of China, a balance between economic, social, and environmental success in which not only China, but actually the whole world has a vital interest. Europe can seize this opportunity by offering China new forms of trading technologies and know-how. Besides traditional forms of scientific cooperation and technology transfer, there is a need for a trade of consulting, engineering, and educational services based not on a static definition of intellectual property rights, but on dynamic rules establishing a continuous process of shared learning. Inviting China to establish its own climate fund based on its own emissions trading system creates the conditions for a booming expansion of the promising beginnings set by current CDM and JI activities.

If a country like Japan would broker such a deal between Europe and China, this would also create the institutional space for the US to grow into its overdue role as a climate policy leader. There would then be a differentiation in initial reduction targets with a broad agreement on global reduction goals in the medium term. Accepting the need for a long and tortuous diplomatic process will not be easy for anybody aware of the urgency of massive global emissions reductions. But patiently working towards true breakthroughs is a more promising strategy than combining a dramatic rhetoric on climate policy with the inability to undertake effective steps like the construction of regional climate funds.

If such steps will be made, however, climate science will be able to shift from assessing the dangers of climate change to helping to avoid them. In this situation, the Platonic philosophy of speaking truth to power will not be very useful anymore. The current set-up for the science policy interface in the climate change area, organized around IPCC, may soon be due for a thorough overhaul. However, so far it is hard to see what could come next. Tackling climate change will take longer than most scholars involved in climate research think appropriate, and it will involve more institutional innovations than most decision-makers involved in climate policy currently envisage.

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References

Archer D (2006) Global warming: understanding the forecast. Blackwell, London
Archer D, Buffett B (2005) Time-dependent response of the global ocean clathrate reservoir to climatic and anthropogenic forcing. Geochem, Geophys, Geosystems 6:Q03002
Arrow K (1950) A difficulty in the concept of social welfare. J Polit Econ 58:328–346
Asheim GB, Froyn CB, Hovi J, Menz F (2006) Regional versus global cooperation for climate control. J Environ Econ Manage 51:93–109
Bhagwati J (2006) A global warming fund could succeed where Kyoto failed. Financ Times, August 15
Cox PM, Huntingford C, Jones CD (2006) Conditions for sink-to-source transitions and runaway feedbacks from the land carbon-cycle. In: Schellnhuber HJ, Cramer W, Nakicenovic N, Wigley T, Yohe G (eds) Avoiding dangerous climate change. Cambridge University Press, Cambridge
DeCanio S (2003) Economic models of climate change, a critique. Macmillan, New York
Foley DK (2006) Adam's fallacy. Harvard University Press, Cambridge
Friedlingstein P, et al (2006) Climate-carbon cycle feedback analysis: results from the C^4MIP model intercomparison. J Climate 19:3337–3353
Friedman M (1970) The social responsibility of business is to increase its profits. New York Times Magazine, September 13
Gladwell M (2000) The tipping point: how little things can make a big difference. Little Brown, Boston
Gregory JM, Huybrechts P, Raper SCB (2004) Climatology: threatened loss of the greenland ice-sheet. Nature 428:616
Hasselmann K, Latif M, Hooss G, Azar C, Edenhofer O, Jaeger CC, Johannessen MO, Kemfert C, Welp M, Wokaun A (2006) The challenge of long-term climate change. In: Kennedy D (ed) Science magazine's state of the planet 2006–2007. Island, Washington, D.C.
Hirschfeld G (ed) (2003) Enzyklopaedie Erster Weltkrieg. Schöningh, Paderborn
Hoegh-Guldberg O (1999) Climate change, coral bleaching and the future of the world's coral reefs. Mar Freshw Res 50:839–866
Ikenberry GJ (2008) The rise of China and the future of the west. Foreign Aff 87:23–37
Jaeger C (2004) Combining mitigation and adaptation. In: Michel D (ed) Climate policy for the 21st Century. Johns Hopkins University, Washington, DC
Jaeger CC, Renn O, Rosa EA, Webler T (2001) Risk, uncertainty, and rational action. Earthscan, London
Jaffee DM, Russell T (1997) Catastrophe insurance, capital markets, and uninsurable risks. J Risk Insur 64:205–230
Kirman A (2006) Demand theory and general equilibrium: from explanation to introspection, a journey down the wrong road. Institute for Advanced Study, Princeton
Lenton TM, et al (2004) Group report: long-term geosphere-biosphere coeveolution and astrobiology. In: Schellnhuber HJ, Crutzen PJ, Clark WC, Claussen M, Held H (eds) Earth system analysis for sustainability: report on the 91st Dahlem Workshop. MIT in cooperation with Dahlem University Press, Cambridge
Madison A (1979) Per capita output in the long run. Kyklos 32:424–429
Morgan MG (2000) Managing carbon from the bottom up. Science 289:2285
Nehring K (2006) Self-control through second-order preferences. University of California, Davis. Accessed at http://emlab.berkeley.edu/users/webfac/szeidl/e208_f06/nehring.pdf
Nordhaus WD (2006) A review of the stern review on the economics of global warming. Yale University, New Haven. Accessed at http://nordhaus.econ.yale.edu/SternReviewD2.pdf
Nordhaus WD, Boyer JG (1998) Requiem for Kyoto: an economic analysis of the Kyoto Protocol, Cowles Foundation Discussion Papers No. 1201. Cowles Foundation, New Haven
O'Donoghue T, Rabin M (1999) Doing it now or doing it later. Am Econ Rev 89:103–124

Oppenheimer M (1998) Global warming and the stability of the West Antarctic Ice Sheet. Nature 393:325–332
Oppenheimer M, Alley RB (2005) Ice sheets, global warming, and Article 2 of the UNFCCC. Clim Change 68:257–267
Putnam H (2002) The collapse of the fact/value dichotomy and other essays. Harvard University Press, Cambridge
Rahmstorf S (2007) A semi-empirical approach to projecting future sea-level rise. Science (Express), doi:10.1126/science.1135456
Rogner HH (1997) An assessment of world hydrocarbon resources. Annu Rev Energy Environ 22:217–262
Scheffer M, Brovkin V, Cox PM (2006) Positive feedback between global warming and atmospheric CO2 concentration inferred from past climate change. Geophys Res Lett 33:L10702
Schellnhuber HJ, Cramer W, Nakicenocic N (2006) Avoiding dangerous climate change. Cambridge University Press, Cambridge
Shiller RJ (2006) Tools for financial innovations: neoclassical versus behavioral finance. Financ Rev 41:1–8
Smythe TW (2004) Problems about corporate moral personhood. J Value Inq 19:327–333
Stern N (2007) The economics of climate change. Cambridge University Press, Cambridge
Tol R, Bohn MT, Downing TE, Guillerminet ML, Hizsnyik E, Kasperson RE, et al (2006) Adaptation to 5 m of sea-level rise. J Risk Res 9:467–482
Tullock G (1987) Rent seeking. In: Eatwell J, Milgate M, Newman P (eds) The New Palgrave, vol. 4. Macmillan, London
Victor DG (2001) The collapse of the Kyoto protocol and the struggle to slow global warming. Princeton University Press, Princeton
Victor DG, House JC, Joy S (2005) A Madisonian approach to climate policy. Science 309:1820–1821