BEFORE THE OFFICE OF ADMINISTRATIVE HEARINGS
FOR THE MINNESOTA PUBLIC UTILITIES COMMISSION
STATE OF MINNESOTA

In the Matter of the Further Investigation into
Environmental and Socioeconomic Costs
Under Minnesota Statute 216B.2422, Subdivision 3

OAH Docket No. 80-2500-31888

MPUC Docket No. E-999-CI-14-643

Exhibit ______

Rebuttal Testimony and Exhibits of

Dr. Richard S.J. Tol

August 12, 2015

Q. Please state your name, address, and occupation.

A. Richard S.J. Tol.

Apple House, Hamsey Road, Barcombe, BN8 5TG, United Kingdom

Professor of economics

Q. **Please describe your educational background and professional experience.**

MSc (econometrics, Vrije Universiteit Amsterdam, 1992)

PhD (economics, Vrije Universiteit Amsterdam, 1997)

1992-2007, researcher, Vrije Universiteit Amsterdam

1998-2008, Adjunct professor, Carnegie Mellon University

2000-2006, Michael Otto Professor of Sustainability and Global Change, Hamburg University

2005-2006, Visiting professor, Princeton University

2006-2011, Research professor, Economic and Social Research Institute, Dublin

2010-2011, Adjunct professor, Trinity College, Dublin

2008-, Professor of the economics of climate change, Vrije Universiteit Amsterdam

2012-, Professor of economics, University of Sussex

I have served on the Intergovernmental Panel on Climate Change (IPCC) since 1994. I regularly participate in studies of the Energy Modeling Forum, and I am an editor of Energy Economics. Additional biographical background is provided in Tol Rebuttal Exhibit 1.

Q. Did you previously submit testimony in this proceeding?

A. No.

Q. Have you reviewed other pre-filed testimony?

A. Yes. I reviewed written testimony by Michael Hanemann and Stephen Polasky.

Q. Have you prepared a rebuttal report that responds to this pre-filed testimony?

A. Yes, I have prepared a report, which is attached as Tol Rebuttal Exhibit 2.

Q. Have you responded to discovery requests in this proceeding?

A. No.

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Exhibit 1

To

Rebuttal Testimony of

Dr. Richard S.J. Tol

August 12, 2015

Richard S.J. Tol - Biography

Richard S.J. Tol is a Professor of Economics at the University of Sussex and the Professor of the Economics of Climate Change, Institute for Environmental Studies and Department of Spatial Economics, Vrije Universiteit, Amsterdam, the Netherlands. Formerly, he was a Research Professor at the Economic and Social Research Institute, Dublin, an Adjunct Professor, Department of Economics, Trinity College, Dublin, the Michael Otto Professor of Sustainability and Global Change at Hamburg University and an Adjunct Professor, Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA, USA.

He has had visiting appointments at the Canadian Centre for Climate Research, University of Victoria, British Colombia, at the Centre for Social and Economic Research on the Global Environment, University College London, and at the Princeton Environmental Institute and the Department of Economics, Princeton University.

He received an M.Sc. in econometrics (1992) and a Ph.D. in economics (1997) from the Vrije Universiteit Amsterdam. He is ranked among the top 200 economists in the world, and has 170 publications in learned journals (with 108 co-authors), 3 books, 5 major reports, 37 book chapters, and many minor publications.

He specialises in the economics of energy, environment, and climate, and is interested in integrated assessment modelling. He is an editor for Energy Economics, and an associate editor of economics the e-journal.

He is advisor and referee of national and international policy and research. He is an author (contributing, lead, principal and convening) of Working Groups I, II and III of the Intergovernmental Panel on Climate Change, shared winner of the Nobel Peace Prize for 2007; an author and editor of the UNEP Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies; a GTAP Research Fellow; and a member of the Academia Europaea. He is actively involved in the European Climate Forum, the European Forum on Integrated Environmental Assessment, and the Energy Modeling Forum.

Books

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Hertel, T.W., S. Rose and R.S.J. Tol (eds.) (2009), Economic Analysis of Land Use in Global Climate Change Policy, Routledge, London.

Von Storch, H., R.S.J. Tol and G. Floeser (eds.) (2008), Environmental Crises: Science and Policy, Springer, Berlin, 146 pp.

Downing, T.E., A.A. Olsthoorn and R.S.J. Tol (eds.) (1998), Climate, Change and Risk, Routledge, London, 407 pp.

Journal articles

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  - Bias in IPCC AR4 WG3? (part VI), 15 Mar 2010
  - Bias in IPCC AR4 WG3 (part V), 11 Mar 2010
  - Bias in IPCC AR4 WG3? (part IV), 10 Mar 2010
  - Bias in IPCC AR4 WG3? (part III), 8 Mar 2010
  - Bias in IPCC AR4 WG3? (part II), 4 Mar 2010
  - Bias in IPCC AR4 WG3? (part I), 3 Mar 2010
- Klimazwiebel
  - Feasibility of Two Degrees
  - Working Group 3 of the IPCC, 28 Feb 2010
  - More on WG3
- Gumbusters
  - An fliuch mor

Contributions to televised media

- Tonight with Vincent Browne (on water charges)
- Ireland AM (on household charges again)
- Ireland AM (on household charges)
- Prime Time (on wind energy)
- Prime Time (on electric vehicles)

Contributions to broadcast media

- Morning Ireland (on ESB privatizaton)
- Morning Ireland (on carbon taxes)

- Tonight with Vincent Browne (on environmental issue)

BEFORE THE OFFICE OF ADMINISTRATIVE HEARINGS FOR
THE MINNESOTA PUBLIC UTILITIES COMMISSION
STATE OF MINNESOTA

In the Matter of the Further Investigation in to Environmental and Socioeconomic Costs Under Minnesota Statute 216B.2422, Subdivision 3

OAH Docket No. 80-2500-31888
MPUC Docket No. E-999-CI-14-643

Exhibit 2

To

Rebuttal Testimony of

Professor Dr. Richard S.J. Tol

August 12, 2015

Rebuttal Report of Dr. Richard S.J. Tol

INTRODUCTION

My name is Dr. Richard S.J. Tol. I am a Professor of the Economics of Climate Change at Vrije Universiteit Amsterdam and a Professor of Economics at the University of Sussex. I am a Member of the Academia Europaea. I have served on the Intergovernmental Panel on Climate Change (IPCC) since 1994. I regularly participate in studies of the Energy Modeling Forum, and I am an editor of Energy Economics. I am the primary author of the FUND model.

I have direct experience estimating the social cost of carbon. The Interagency Working Group on the Social Cost of Carbon relies on three integrated assessment models – DICE, PAGE, and FUND. I started building the FUND model in 1993. On the strength of this research, I was invited to be a Principal Lead Author of the Second Assessment Report of Working Group III of the Intergovernmental Panel on Climate Change, and I have participated in several rounds of the Energy Modeling Forum of Stanford University. Until 2004, I was the sole developer of the model. Since then, the model has been co-developed by Dr David Anthoff. On the strength of the later research, Dr Anthoff was appointed on a tenure-track position at the University of California at Berkeley. I have published over 30 papers in learned journals based on results from the FUND model; these papers have been cited over 800 times. Besides the research with FUND, I have published three literature reviews and meta-analyses on the social cost of carbon (in 2005, 2009 and 2011; a fourth one was submitted earlier this year). IDEAS/RePEc ranks me 124th out of 44,647 economists; and 5th in environmental economics and energy economics.

I have been asked to opine as to the testimonies of Dr. W. Michael Hanemann, who is testifying in this proceeding on behalf of the Division of Energy Resources of the Minnesota Department of Commerce, in consultation with the Minnesota Pollution Control Agency, and Dr. Stephen Polasky, who is testifying on behalf of Clean Energy Organizations. Both of them rely on the estimate of the federal social cost of carbon developed by the U.S. government's Interagency Working Group ("IWG").

1. <u>Dr. Hanemann's Testimony</u>

It appears to me as though the parties retaining Dr. W. Michael Hanemann have requested him to provide testimony outside his area of prior experience and expertise. To the best of my knowledge, he has never published an estimate of the social cost of carbon. Dr. Hanemann's relative unfamiliarity with this field shows in several aspects of his testimony:

i. Dr Hanemann claims that the first estimate of the impact of climate change was published in 1992. (Hanemann Direct at 30:15-16.) But it was in 1979 by Dr. Ralph C. d'Arge, while the first estimate of the social cost of carbon was published in 1982 by Dr. William D. Nordhaus.

ii. Dr. Hanemann's Figure 1 (Hanemann Direct at 25:1-2) is accurate for PAGE but not for DICE and FUND. In DICE, the impacts of climate change (7) affect economic growth (1). In FUND, climate change (4, 5) affects emissions (2) and the impacts of climate change (7) affect population and economic growth (1).

iii. Dr. Hanemann's further confuses "equilibrium warming" (shown in his Equation (2), Hanemann Direct at 28:13) and "transient warming" (used in DICE, PAGE and FUND). This is a basic error. "Equilibrium warming" refers to equilibrated warming – i.e., the ultimate temperature increase after the full effects of warming have expressed themselves through the "inertia" of ocean heat uptake and otherwise. "Transient warming" refers to the temperature response over a given period of time, such as 20 years, or by a certain date, such as 2100.

iv. Dr. Hanemann claims that FUND is not "readily available." (Hanemann Direct at 65:1-8.) This is false. FUND has been in the public domain since 1999; at the moment, it can be freely downloaded from GitHub.

Dr. Hanemann defends the discount rates used by the IWG. I disagree. The Ramsey rule is a more appropriate choice. The Ramsey rule is named after a 1928 publication in the

Economic Journal by Frank Ramsey. (F.P. Ramsey, "A Mathematical Theory of Saving," 38 Econ. J. 543 (Dec. 1928), available at http://piketty.pse.ens.fr/files/Ramsey1928.pdf.) According to the Ramsey rule, the discount rate should vary with economic growth. The Ramsey rule makes sense because it relates the money discount rate to parameters underlying the "time value" of money – i.e., the reasons that receiving money today is preferred over receiving it in the future.

The "time value" of money reflects several considerations. We discount future pay-outs because we are impatient and because we expect to be richer in the future. The rate of impatience is often referred to as the "pure rate of time preference" or the "utility discount rate." The pure rate of time preference measures how much we prefer to get good things now rather than later.

Furthermore, because we expect our income to grow, a dollar gain today is worth more than a dollar gain in a year from now, because the relative gain in income is greater now than later. This component of the Ramsey rule has two parameters, viz. the rate of income growth and the rate at which an extra dollar loses incremental value as we grow richer: A dollar means more to a homeless person than to Bill Gates.

The Ramsey rule relates to the reasons that receiving money today is preferred over receiving it in the future. As noted, under the Ramsey rule, the discount rate varies with economic growth. As economic growth is unlikely to be constant over long periods of time, a constant discount rate is likely to equal the appropriate discount rate. Similarly, the Ramsey rule dictates that the discount rate should differ between different scenarios of future economic growth, and between countries growing at different rates.

The IWG used real discount rates of 2.5%, 3.0% and 5.0% and did not use the Ramsey rule, which had an effect on its analysis. Table 1 shows the social cost of carbon for alternative discount rates. The Office of Management and Budget recommends real rates of 3.0% and 7.0%, but the IWG used 2.5%, 3.0% and 5.0%. Table 1 shows the full range. The social cost of carbon rises sharply for higher discount rates. Because the initial impacts of climate change are positive, due to carbon dioxide fertilization, reduced winter heating, and few cold-related deaths, the social cost of carbon is negative for the highest discount rates, that is, carbon dioxide emissions should be subsidized rather than taxed.

The IWG used a consumption rate of discount that is constant over time, rather than the more appropriate Ramsey discount rate (Ramsey, 1928, Arrow et al., 2013). Table 1 shows the implications. The parameters of the Ramsey rule – the pure rate of time preference and the rate of risk aversion – are chosen such that the net present value of a stream of $1 gains for a century is the same for the economic growth rate assumed for the USA. However, because many other regions are assumed to grow faster than the USA, applying the Ramsey rule leads, as shown in Table 1, to lower estimates of the social cost of carbon. Because the Ramsey discount rate and the constant discount rate diverge as we peer further into the future, the difference is particularly pronounced for lower discount rates.

Table 1. Estimates of the social cost of carbon ($/tC) for alternative discount rates.*

R	*P*	*H*	*SCC*
7.0%			-1.75
	5.5%	1.0	-1.89
	4.8%	1.5	-1.89
	4.0%	2.0	-1.84
5.0%			1.14
	3.6%	1.0	-0.31
	2.9%	1.5	-0.59
	2.1%	2.0	-0.55
3.0%			20.05
	1.6%	1.0	11.15
	0.9%	1.5	9.83
	0.2%	2.0	10.02
2.5%			35.29
	1.1%	1.0	21.09
	0.5%	1.5	17.22
	-0.2%	2.0	19.28

* The utility discount rate (ρ) and the rate of risk aversion (η) are chosen to be equivalent to the consumption discount rate (r) for the Ramsey rule ($r=\rho+\eta g$) and projected US growth (g) for the 21st century.

The social cost of carbon, as estimated by the IWG, reflects the marginal damage to the whole world. The majority of the impacts of climate change will fall outside the jurisdiction of the US government. The IWG discounted future impacts with the same discount rate, regardless of the location of those impacts. This is equivalent to using region-specific weights. According to the Ramsey rule, the consumption rate of discount equals the utility rate of discount plus the population growth rate plus the growth rate of per capita consumption times the rate of risk aversion. The Ramsey rule implies that future impacts are more heavily discounted in more rapidly growing economies. By using the same discount rate regardless of the prospects for economic growth, the IWG puts a premium on the impacts in countries that grow faster than the USA. The effect can be substantial. For instance, using the FUND scenario as used by the IWG, impacts in China are weighted 46% to 87% higher than impacts in the USA. In other words, a $1.00 loss in the USA is counted as $1.00; but a $1.00 loss in China is counted as $1.46 to $1.87. The result of this approach is that the IWG effectively places more value on the circumstances in China than on those in the USA.

Dr. Hanemann accepts that the IWG increased the social cost of carbon between 2010 and 2013. I am surprised by that. Table 2 shows the estimates of the 2020 social cost of carbon as recommended by the IWG on the Social Cost of Carbon in 2010 and 2013 (IAWGSCC, 2013, IAWGSCC, 2010). Table 4 also shows the estimates by the three models used by the IWG on the Social Cost of Carbon. All models show an increase in their estimates. This is most pronounced for PAGE and least pronounced for DICE, with FUND somewhere in the middle. PAGE's modeller, Dr. Chris W. Hope, has not published comparable estimates around 2010 and 2013. The FUND team has (Waldhoff et al., 2014, Waldhoff et al., 2011). The estimates of the social cost of carbon by the FUND team are not directly comparable to those by the IWG, but they are comparable to one another. In 2011, FUND estimated a social cost of carbon of $8.0/tC; in 2014, was $6.6/tC. In other words, FUND as used by the FUND team shows a *lower* social cost of carbon, whereas FUND as used by US Federal Government shows a *higher* social cost of carbon. I have not tried to reconstruct the IWG estimates, so I do not know what they did to find a stark increase in their estimate of the social cost of carbon.

Table 2. Estimates of the social cost of carbon (^{2007}\$/tCO_2) for emissions in 2020.

	2010			2013		
Model\Discount rate	5.0%	3.0%	2.5%	5.0%	3.0%	2.5%

DICE	13.0	34.7	50.2	12.2	37.8	56.6
PAGE	9.4	36.7	58.7	21.6	70.6	101.4
FUND	-0.9	7.3	16.2	2.6	21.0	36.0
IAWGSCC	6.8	26.3	41.7	12.0	43.0	65.0

As the author of FUND, my assessment is the IWG may not have correctly operated FUND in generating its estimates. Because the IWG process and the calculations themselves are not immediately transparent, it is has not been possible for me to ascertain exactly how the IWG generated its estimates or whether they are economically and scientifically valid. However, the inconsistency between the numbers that my operation of the FUND model generates and those produced by the IWG raises serious questions as to whether the IWG's estimates lack economic and scientific reliability.

2. **Dr. Polasky's Testimony**

It appears to me as though the parties retaining Dr. Stephen Polasky have requested him to provide testimony outside his area of prior experience and expertise. To the best of my knowledge, he has never published an estimate of the social cost of carbon.

Dr. Polasky simultaneously argues that the IWG's estimate of the social cost of carbon is too low and about right. He gives four reasons why the estimate would be too low. First, he argues that the federal estimate does not give adequate weight to catastrophic damages. Earlier, Dr. Polasky discusses the representation of catastrophic impacts in DICE and PAGE. Dr. Polasky refers to Weitzman (2009) but omits that that paper was anticipated by Tol (2003), which is based on results from the FUND model. Dr. Polasky cites a speculative estimate by Weitzman that a 6˚C warming would cost 50% of GDP, but omits other estimates that put the number closer to 7% of GDP (Nordhaus, 1994, Roson and van der Mensbrugghe, 2012).

Dr. Polasky argues that the IWG used relatively high discount rates. The IWG used discount rates of 2.5%, 3.0% and 5.0%. The Office of Management and Budget recommends real discount rates of 3.0% and 7.0%.

Dr. Polasky argues that integrated assessment models do not account for the impact of climate change on economic growth. This is true for the PAGE model, but not true for DICE and FUND. Dr. Polasky omits reference to Pizer (1999) and Fankhauser and Tol (2005), who find that the growth effect is small. He does refer to Dietz and Stern (2015) and Moore and Diaz (2015), who find large effects but only under the assumption that climate change would affect total factor productivity. While Dietz and Stern (2015) offer no evidence in support of that assumption, Moore and Diaz (2015) refer to Dell et al. (2012). However, as emphasized by (Dell et al., 2014), the Dell 2012 paper is about the effects of weather and it should not be interpreted as evidence that climate (change) affects productivity.

Dr. Polasky argues that estimates of the impacts of climate change are incomplete and underestimates. Impact estimates are indeed incomplete. However, the models that are used to estimate the social cost of carbon include all impacts for which a global impact estimate is available. Therefore, the size and indeed the sign of the missing impacts is unknown. Dr. Polasky's assertion that the missing impacts are sizable and negative, is pure speculation.

3. <u>The FUND Model</u>

As I mentioned previously, both Dr. Hanemann and Dr. Polasky rely on the estimate of the federal social cost of carbon developed by the IWG, which in turn relied on three Integrated Assessment Models, known as DICE, FUND, and PAGE. I understand that Robert Mendelsohn of Yale has already provided testimony in this proceeding using the DICE model. I have been asked to show the results of the FUND model under the same parameters as Professor Mendelsohn used (which he derived from the testimony of Professors Lindzen, Happer and Spencer).

Professor Mendelsohn's testimony in this case used discount rates between 3% and 7%, and climate sensitivity values between 1.0 and 3.0. My Table 1 above shows the results of the FUND model using various discount rates. The results of the FUND model using the same assumptions regarding climate sensitivity values as Professor Mendelsohn is as follows:

Table 3. Estimates of the social cost of carbon ($/tC) for the alternative climate sensitivities (CS) used by Professor Mendelsohn.

CS	1.0	1.5	2.0	2.5	3.0
SCC	-17.97	-12.06	-4.05	7.06	20.05

4. Disaggregating the Effects Of Human-Induced And Natural Climate Variability

Current estimates of the social cost of carbon are based on the assumptions that short-term natural climate variability is irrelevant in that it averages out, and that there is no long-term natural climate variability. There are a few papers (Estrada and Tol, 2013a, Estrada and Tol, 2013b), yet to be published in peer-reviewed journals, that test these assumption, but it is too early to draw any conclusion. Accordingly, current models do not disaggregate the effects of human-induced warming and natural variability, and work on that issue is just in its infancy.

5. The 97% Figure Is Flawed

It is often said that 97% of climate scientists agree that climate change is real, human-made, and dangerous. There are many things wrong with this assertion, as I have previously noted. (*See* Richard S.J. Tol, "Quantifying the Consensus on Anthropogenic Global Warming in the Literature: A Re-Analysis," 73 Energy Policy 701 (2014); Richard S.J. Tol, "Quantifying the Consensus on Anthropogenic Global Warming in the Literature: Rejoinder," 73 Energy Policy 709 (2014).) The 97% number is taken from Cook et al. (2013). The paper is silent about whether climate change is dangerous or not. In this context, "human-made" means that at least half of the observed warming is due to human activity, which includes but is not limited to anthropogenic greenhouse gas emissions. And the 97% refers to the number of papers rather than the number of researchers.

The 97% pertains to a sample of the literature, rather than the whole literature, and the sample is unrepresentative. The sample is dominated by papers that are not about climate change and its causes, but rather about the impacts of climate change and climate policy. Cook and colleagues report two tests for data quality, and fail both.

Cook and colleagues have claimed that abstracts were rated by two independent raters, even though these raters freely interacted with each other. They have claimed that the raters did not know journal and author, even though they did. They have claimed that data could not be inspected by independent experts because that would violate a confidentiality agreement, even though such an agreement never existed. They have climate data that could not be inspected because it was never collected, even though it was.

Cook and colleagues collected data, inspected the results, collected more data, inspected the results again, changed the way the data was classified, collected yet more data, inspected the results, and changed the data classification again before the final results were presented. The same team collected and analyzed the data. Cook and colleagues thus broke all rules about scientific data gathering.

The journal editors and publishers are aware of the paper's problems, but have chosen not to act.

Cook's paper illustrates everything that is wrong with climate research. Studies are praised because the results are politically expedient rather than scientifically valid. Research scandals are covered up. Whistleblowers are vilified.

6. <u>Differences Between Social Cost of Carbon and Traditional Damages Cost Methodologies.</u>

The causal chain for the social cost of carbon is rather long, complex and contingent. In this way it is different from the traditional damages cost methodology for a pollutant like mercury or lead. Let us consider two particular impacts, malaria and coastal flooding.

In either case, the emission of a tonne of carbon dioxide leads to a change in the atmospheric concentration of carbon dioxide. However, the precise relationship between emission and concentration is mediated by the terrestrial biosphere, which is influenced by such things as the climate, land and water use, and the deposition of fertilizers such as nitrogen.

A change in the atmospheric concentration of carbon dioxide leads to a change in radiative forcing of the atmosphere. However, the change in radiative forcing depends on radiative forcing itself.

A change in radiative forcing leads to a change in climate. This change in climate sets in motion a number of feedback effects, each of which lead to further climate change and many of which vary with climate itself.

This makes it rather difficult to estimate the climate effect of carbon dioxide emissions, and indeed that effect varies over time and is contingent on human choices within the domain of climate policy (e.g., emissions, land use) as well as outside that domain (e.g., fertilization).

Now let us turn to malaria. The parasite develops faster in warmer climates; and the vector thrives in warm and wet conditions. Climate change is likely to lead to an increase in potential malaria. However, there is a difference between potential and actual malaria. Malaria used to be endemic in the southern USA and southern Europe. Malaria outbreaks have been reported as far north as Murmansk. Malaria is now rare in the rich world because mosquito habitat was destroyed, mosquitoes were exterminated, and medicine created herd immunity. Malaria is now largely limited to poor countries.

As vulnerability to malaria depends on development, future vulnerability will be different than today’s. The impact of climate change is thus contingent on the state of roofs and pavements, on the availability of pesticide-impregnated bed nets, and on the affordability of malaria medicine. Resistance to anti-malarial drugs and the development of new malaria medicine or even vaccines further complicate the matter. As climate change plays out over centuries, major developments can be expected.

The social cost of carbon is expressed in money. Estimates of the social cost of carbon therefore do not only estimate the number of climate-change-induced malaria deaths, but also attach a monetary value to these fatalities. So, as a final complication, the willingness to pay to reduce the risk of premature mortality has to be projected over a century or more.

Let us consider the impact of coastal flooding in a country like Bangladesh next. Where malaria is driven by temperature and rainfall, coastal flooding are further driven by sea level rise and wind speed and direction. But the impact of a possible increase in coastal flooding is also determined by the quality of flood protection. Flood protection is typically provided by the public sector. Estimates of the social cost of carbon thus require not only projections of future floods and the number and value of properties in the coastal zone, but also projections of decisions made by future politicians.

This is rather complicated. Like Bangladesh, the Netherlands is a densely populated delta facing the risks of storms and floods from sea and river. The Netherlands started its modern dike building program in 1850. At the time, the Netherlands was not much richer than Bangladesh is now, and technology was more primitive. In 1850, the Netherlands had long been vulnerable to floods. Dike building started in response to political events. In response to the European Spring of 1848, a new constitution was introduced in 1849 that gave the Netherlands a strong central government that was broadly representative of the population. The new government promptly invested in one of the electorate's main concerns: flood protection.

Bangladesh is among the worst-governed countries in the world. As long as that is the case, it cannot muster the large-scale infrastructure projects needed to protect its population against floods. A competent and caring government can. Estimates of the social cost of carbon are thus contingent on assumptions about the future governance of countries such as Bangladesh.

Malaria and coastal protection are two examples. Similar issues arise in the other impact of climate change, be it in agriculture, health, energy use, biodiversity, floods or storms.

In sum, the causal chain from carbon dioxide emission to social cost of carbon is long, complex and contingent on human decisions that are at least partly unrelated to climate policy. The social cost of carbon is, at least in part, also the social cost of underinvestment in infectious disease, the social cost of institutional failure in coastal countries, and so on.

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