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NEEDS

New Energy Externalities Developments for Sustainability

INTEGRATED PROJECT

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Sub-priority 6.1.3.2.5: Socio-economic tools and concepts for energy strategy.

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"Report on marginal external costs inventory of greenhouse gas emissions
/
Report on the analysis on average and marginal avoidance costs of greenhouse gas emissions"

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Authors: Richard S.J. Tol

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THE COSTS OF G
REENHOUSE GAS EMISSIONS

Richard S.J. Tol

Research unit Sustainability and Global Change, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg, Germany

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1. Introduction

The costs of greenhouse gas emissions have been the subject of much debate and study. Tol (2005b) reviews the marginal damage costs of carbon dioxide emissions. Section 2 presents new estimates, also of three other greenhouse gases: methane, nitrous oxide, and sulfur hexafluoride. Damage cost estimates are controversial because of the many value-laden assumption behind them, for example on discounting, valuation of the risks of mortality, and aggregating impacts across countries with very different standards of living; because of the vast uncertainty; and because the use of marginal damage reflects weak sustainability. Therefore, in Section 3, avoidance costs are presented. Weyant (2004) and van Vuuren *et al.* (2006) review the literature on this.

Both damage and avoidance costs are estimated with the latest version (2.9) of the *Climate Framework for Uncertainty, Negotiation and Distribution* (*FUND*). The *FUND* model has been frequently used for exercises like this (Guo *et al.*, 2006; Link and Tol, 2004; Tol, 1997, 1999a,b, 2002a,b, 2005a, forthcoming a; Tol *et al.*, 2003). A full technical description, the model code and a publications list can be found at:

http://www.uni-hamburg.de/Wiss/FB/15/Sustainability/fund.html

2. Marginal damage costs

Marginal damage costs are defined as the net present value of the difference in monetized impacts caused by a small increase in emissions, normalized by the emissions increase. Marginal damage costs are here presented for carbon dioxide, methane, nitrous oxide, and sulfur hexafluoride, the four greenhouse gases included in *FUND*2.9. Results can be found in Tables 1-4.

Marginal damage costs estimates are obviously sensitive to the discount rate. Here we use Ramsey discounting (also known as neo-classical, conventional, geometric, and exponential discounting), with three alternative pure rates of time preference. As the utility function is logarithmic, the consumption discount rate equals the growth rate of per capita income plus the pure rate of time preference.

We also report results for Weitzman discounting (also known as hyperbolic or γ discounting), with an initial pure rate of time preference of 3%, falling to 1% after 25 years.

We report results for a simple summation of monetary impacts per region, and for equity-weighting, in which regional impacts are weighted (by the world average income over the regional average income). Equity weighting reflects the fact that a dollar to a poor person is not the same as a dollar to a rich person. The specific equity weighting chosen assumes a global social planner.

3. Marginal abatement costs

Marginal abatement costs are reported in Table 5, for carbon dioxide, methane and nitrous oxide. Sulfur hexafluoride is not subject to emission control in *FUND*2.9. Emission reduction is implemented with full where, when and what flexibility. That is, the marginal abatement costs are equal between regions and between gases – corrected for the global warming potentials of methane (21) and nitrous oxide (310) – and rise over time with the discount rate (5%). We use a range of targets for the maximum radiative forcing. The EU target of keeping temperature below 2ºC above pre-industrial (cf. Tol, forthcoming b) is infeasible in *FUND*.

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Table 1. The marginal costs of carbon dioxide emissions ($/tC) per decade, for Ramsey discounting with three alternative pure rates of time preference and for Weitzman discounting, with equity-weighted (EW) impacts or regional values (SS).

	0%		1%		3%		Weitzman	
Decade	SS	EW	SS	EW	SS	EW	SS	EW
2005	54.3	62.1	15.2	19.8	1.4	2.1	21.7	25.5
2015	52.9	58.0	14.5	17.6	1.6	2.1	21.1	23.8
2025	51.1	54.1	13.4	15.4	1.6	1.9	20.3	21.9
2035	49.0	50.2	12.2	13.5	1.4	1.6	19.2	20.0
2045	46.6	46.5	11.0	11.6	1.1	1.2	18.0	18.2
2055	43.9	42.9	9.7	9.9	0.9	0.9	16.7	16.5
2065	41.2	39.5	8.5	8.4	0.7	0.7	15.4	14.9
2075	38.5	36.2	7.3	7.1	0.5	0.5	14.2	13.4
2085	35.8	33.2	6.3	6.0	0.4	0.4	13.0	12.1
2095	33.3	30.5	5.4	5.1	0.3	0.2	11.9	11.0

Table 2. The marginal costs of methane emissions ($/tCH4) per decade, for Ramsey discounting with three alternative pure rates of time preference and for Weitzman discounting, with equity-weighted (EW) impacts or regional values (SS).

	0%		1%		3%		Weitzman	
Decade	SS	EW	SS	EW	SS	EW	SS	EW
2005	185.8	344.1	115.6	230.0	57.4	123.8	107.8	208.3
2015	197.3	322.8	112.8	195.9	46.8	87.2	107.0	180.7
2025	205.4	301.7	107.4	165.8	37.1	60.9	105.4	158.5
2035	211.9	283.3	100.9	140.7	29.0	42.6	103.6	141.1
2045	216.9	267.7	93.9	120.0	22.4	29.9	101.7	127.3
2055	220.3	254.2	86.6	102.9	17.2	21.1	99.4	116.0
2065	221.9	241.3	79.2	88.1	13.0	14.9	96.8	106.1
2075	222.5	230.0	72.0	75.6	9.8	10.5	94.0	97.7
2085	222.7	221.5	65.4	65.6	7.4	7.4	91.4	91.2
2095	222.2	214.7	59.3	57.5	5.5	5.4	88.9	86.0

Table 3. The marginal costs of nitrous emissions ($/tN2O) per decade, for Ramsey discounting with three alternative pure rates of time preference and for Weitzman discounting, with equity-weighted (EW) impacts or regional values (SS).

	0%		1%		3%		Weitzman	
decade	SS	EW	SS	EW	SS	EW	SS	EW
2005	13737.1	16046.4	4718.1	6485.2	1239.3	2111.2	5993.5	7466.5
2015	13877.3	15411.4	4452.4	5656.3	995.7	1515.6	5889.3	6862.3
2025	13937.1	14811.8	4163.9	4939.8	788.9	1088.9	5767.9	6355.5
2035	13917.9	14239.8	3862.8	4319.4	617.6	782.7	5627.8	5916.6
2045	13822.6	13690.5	3558.3	3782.7	478.8	563.7	5470.0	5529.5
2055	13654.5	13155.3	3256.7	3316.2	368.1	406.7	5295.7	5180.7
2065	13416.4	12624.7	2962.5	2907.2	280.7	293.0	5105.9	4859.2
2075	13115.0	12102.7	2680.5	2551.8	212.6	211.5	4903.4	4562.9
2085	12757.1	11588.9	2414.3	2244.2	160.3	153.6	4691.1	4288.5
2095	12347.6	11073.7	2165.2	1975.1	120.4	112.1	4470.5	4029.0

Table 4. The marginal costs of sulfur hexafluoride emissions ($/kg SF6) per decade, for Ramsey discounting with three alternative pure rates of time preference and for Weitzman discounting, with equity-weighted (EW) impacts or regional values (SS).

	0%		1%		3%		Weitzman	
decade	SS	EW	SS	EW	SS	EW	SS	EW
2005	1196.8	1218.8	292.4	352.0	54.9	87.0	469.3	503.2
2015	1168.0	1160.2	272.5	310.3	44.3	63.4	451.5	466.2
2025	1135.7	1103.2	252.3	273.6	35.3	46.3	433.1	433.2
2035	1100.1	1047.6	232.1	241.2	27.8	33.7	414.1	403.2
2045	1061.5	993.4	212.2	212.6	21.7	24.6	394.5	375.5
2055	1020.0	940.2	192.9	187.4	16.8	18.0	374.5	349.6
2065	976.0	887.7	174.4	164.9	12.9	13.2	354.2	325.1
2075	929.7	836.1	156.9	145.1	9.9	9.6	333.6	302.0
2085	881.7	785.5	140.4	127.6	7.5	7.1	312.9	280.2
2095	832.1	735.5	125.1	112.0	5.7	5.2	292.3	259.3

Table 5. The marginal abatement costs in 2050 for carbon dioxide, methane and nitrous oxide for four alternative targets (in CO2 equivalent and radiative forcing). For comparison, the global mean surface air temperature in 2100 is given too, as is the reference scenario.

Target		Carbon dioxide		Methane	Nitrous oxide	Temperature
ppm	Wm^{-2}	\$/tC	\$/tCO_2	\$/tCH_4	\$/tN_2O	ºC
500	3.2	95.2	349	7330	108211	2.2
550	3.7	49.7	182	3827	56492	2.4
650	4.6	20.3	74	1563	23074	2.9
750	5.4	10.3	38	793	11708	3.2
-	-	0	0	0	0	3.7