Towards a representative social cost of carbon

Jinchi Dong[a,1], Richard S.J. Tol[b,c,d,e,f,g,h,*], Fangzhi Wang[i,j]

[a]School of the Environment, Nanjing University, China

[b]Department of Economics, University of Sussex, Falmer, United Kingdom

[c]Institute for Environmental Studies, Vrije Universiteit, Amsterdam, The Netherlands

[d]Department of Spatial Economics, Vrije Universiteit, Amsterdam, The Netherlands

[e]Tinbergen Institute, Amsterdam, The Netherlands

[f]CESifo, Munich, Germany

[g]Payne Institute for Public Policy, Colorado School of Mines, Golden, CO, USA

[h]College of Business, Abu Dhabi University, UAE

[i]School of Management and Economics, Beijing Institute of Technology, Beijing, 100081, China

[j]Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing, 100081, China

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Abstract

The majority of estimates of the social cost of carbon use preference parameters calibrated to data for North America and Europe. We here use representative data for attitudes to time and risk across the world. The social cost of carbon is substantially higher in the global north than in the south. The difference is more pronounced if we count people rather than countries.

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*Jubilee Building, BN1 9SL, UK
Email address: r.tol@sussex.ac.uk (Fangzhi Wang)
URL: http://www.ae-info.org/ae/Member/Tol_Richard (Fangzhi Wang)

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1. Introduction

The social cost of carbon is the damage done, at the margin, by the emission of carbon dioxide. Many assumptions are used to estimate the social cost of carbon. Most of these assumptions are positive; the climate sensitivity is a prime example. Some assumptions are normative; the pure rate of time preference comes to mind. Reasonable people can reasonably disagree about the social welfare function (indeed, Arrow, 1950, shows they cannot agree). An individual's ethical views are partly idiosyncratic and partly cultural. Norms about time and risk have been found to systematically vary between countries. The social cost of carbon, however, is primarily estimated by researchers from North America and Western Europe. In this paper, we recalibrate the social cost of carbon according to the stated preferences of people from 76 countries across the world.

Figure 1 groups 323 papers on the social cost of carbon by the country of a liation of the authors of these papers (data from Tol, 2024a). Papers of mixed nationality are attributed proportionally to the number of authors. The USA contributed most (46%) followed by the UK (20%). Africa and Latin America did not contribute to this literature. Only three non-Western countries are represented, all from East Asia. There is no reason to believe that people from di erent parts of the world would systematically di er in their interpretation of the evidence about climate change and its impact, but they may well hold di erent attitudes to the future. The literature on the social cost of carbon may thus be biased towards Western attitudes.

\Western attitudes" contain a multitude, of course. There has been a lively debate on the pure rate of time preference in the context of climate policy, rst between Nordhaus (1992) and Cline (1992), and later between Stern et al. (2006) and Nordhaus (2007). Arrow et al. (1996) described this as a choice between descriptive and prescriptive discounting. The range of opinions expressed in Drupp et al. (2018) shows that the debate has not abated. In fact, the discussion has become more complicated as alternatives to exponential discounting and its measurement have emerged (Cropper et al., 1991, Weitzman, 2001, Newell and Pizer, 2003, Tol, 2013, Giglio et al., 2014, Iverson and Karp, 2021, Jaakkola and Millner, 2022, Bauer and Rudebusch, 2023, Eden, 2023).

Participants in this debate draw, almost exclusively, from Western cultures. The prescriptive school relies, essentially, on Aristotle's verdict against usury, which was later adopted by St Augustine and the Prophet Muhammad. The descriptive school typically calibrates time and risk preferences with data for the market for U.S. Treasuries. Sohn (2019) is an exception, estimating the social cost of carbon using time and risk preferences based on data from South Korea. In an attempt to re ect a wider range of opinions, Antho et al. (2009) re ect a wider range of opinions, using the 20 OECD countries in Evans (2005). Data for the rest of the world has since improved considerably and this allows us here to cast a wider net and so be more inclusive and representative of the world population.

The paper proceeds as follows. Section 2 presents the data and methods. Section 3 discusses the results. Section 4 concludes.

2. Materials and methods

2.1. Data and calibration

Falk et al. (2018) and Falk et al. (2023) report attitudes towards time and risk for 76 countries,[2] which together constitute 85% of the world population and 93% of the world economy. These preferences are stated in responses to intuitive questions in an unincentivized survey. Falk et al. show that these simple measures correlate well with the results of state-of-the-art preference elicitation in surveys and experiments. They further show that stated preferences do not systematically di er from revealed preferences in incentivized elicitation. Figure A.3 shows the indicators of patience and risk-taking, aggregated to the country level. The two measures are largely uncorrelated, with the possible exception for extreme impatience and risk aversion.

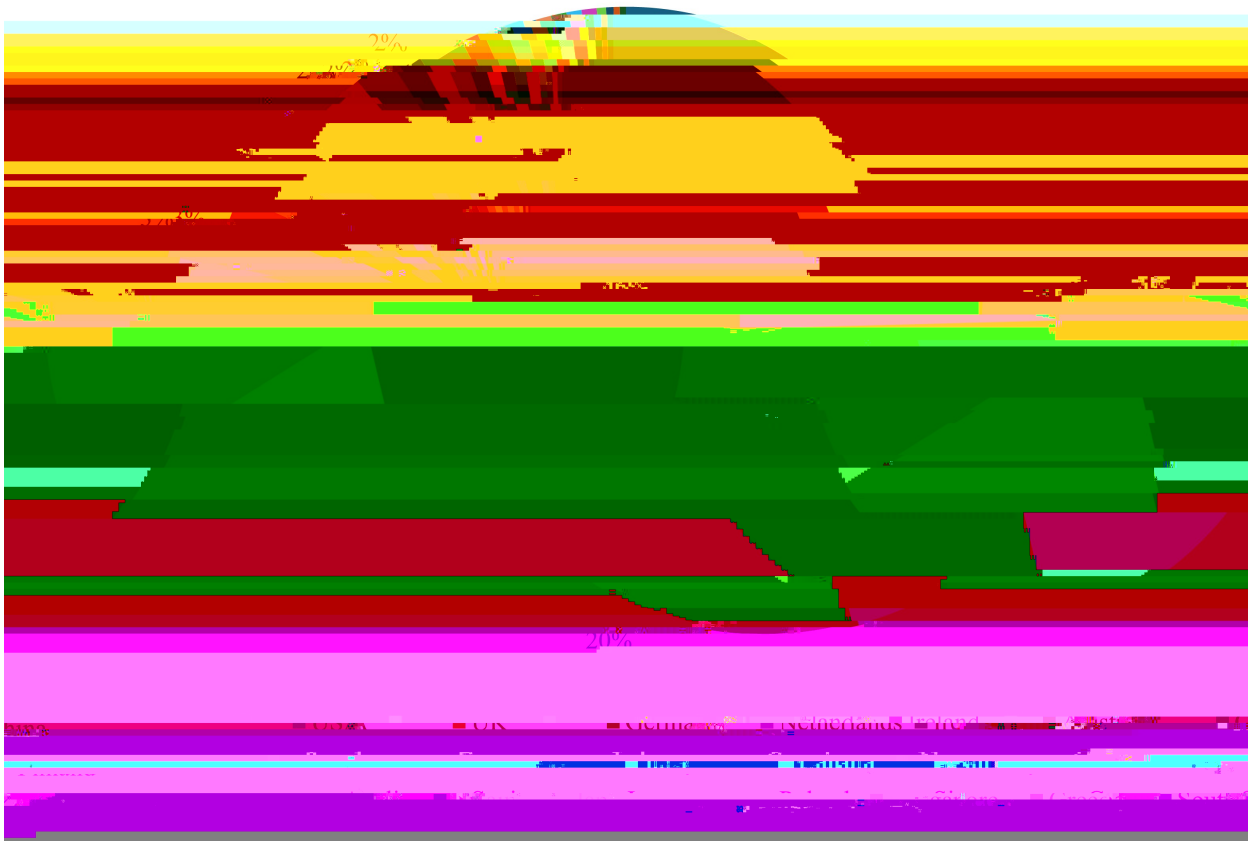
Note that, Falk et al. report indices for, rather than rates of, time preference and risk aversion. Sunde et al. (2022) calibrate rates to indices. We calibrate Falk's data to the results of

3. Results

Figure 2 shows the cumulative frequency of the social cost of carbon for all 76 countries of the

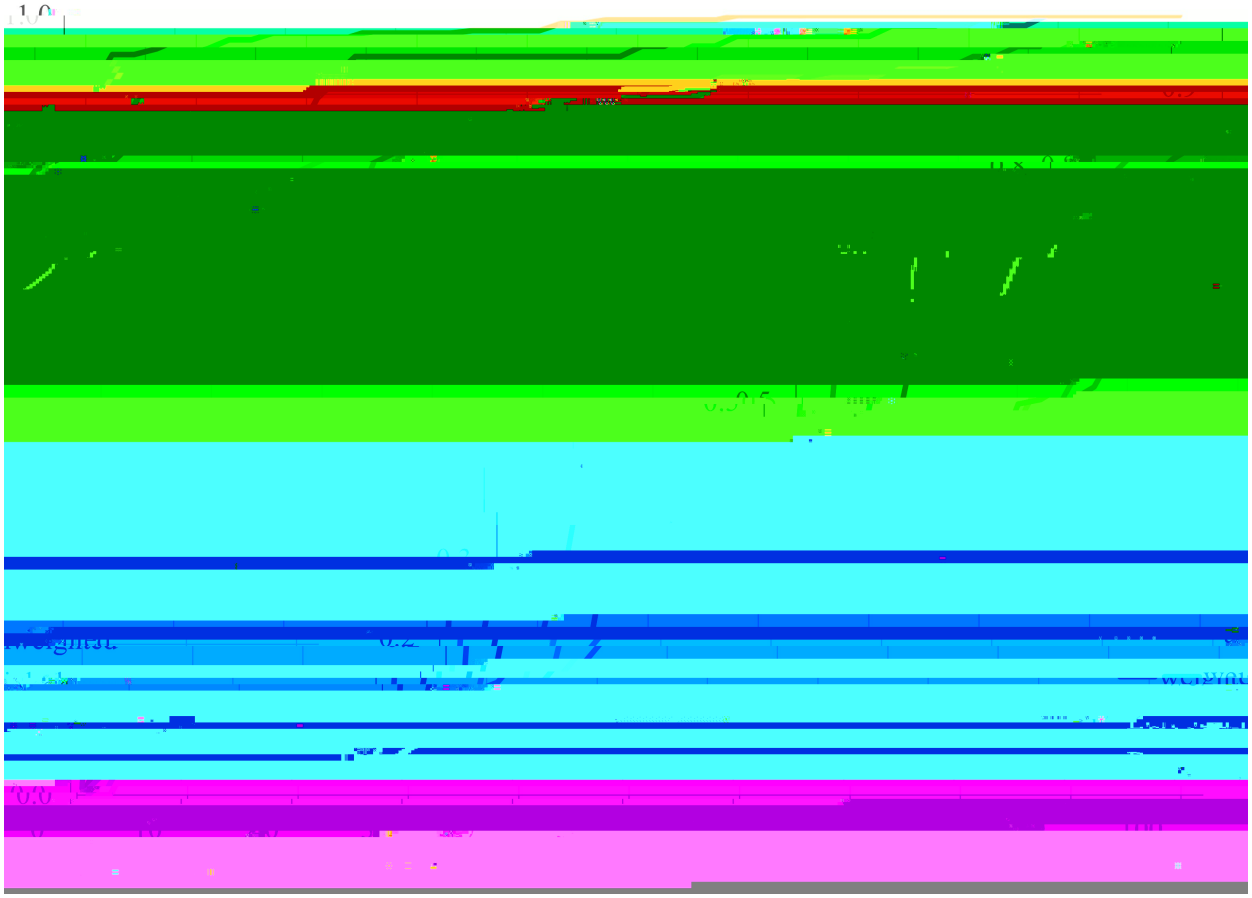
In the appendix, we also nd somewhat di erent results for the Hofstede data and the literature review. The analysis here should therefore be repeated when better data become

Figure 1: Share of papers published on the social cost of carbon by country of a liation.



Papers published between 1980 and 2023. Papers are attributed to country of a liation at the time of publication and inversely proportional to the number of co-authors. Source: Tol (2024a).

Figure 2: Cumulative frequency of the global social cost of carbon with national time and risk preferences.



Three cases are shown: The calibration of the Falk data to the Drupp data, the population-weighted calibration of the Falk data to the population-weighted Drupp data, and Drupp's expert data.

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Appendix A. Calibration

We impose the linear relationship $_c = \quad + \quad r_c$ and $_c = \quad + \quad e_c$ where $\quad$ is the pure rate of time preference, $\quad$ is the Arrow-Pratt rate of relative risk aversion, r is Falk's index of patience, e is Falk's index of risk-taking, $_i$ and $_i$ are calibration parameters, and c denotes country.

In the central calibration, we choose $_i$ and $_i$ such that the $_{(c)} = r_{(c)}$ and $_{(c)} = e_{(c)}$ for $(c) = 0{:}05$ and $(c) = 0{:}95$ of the Drupp and Falk data. We then use the calibrated parameters to derive the welfare parameters for each country. See Table A.2. Note that we impose the restrictions $_c \quad 0$ and $_c \quad 0$. We use the tails to calibrate so that 90% of the imputed data are interpolated and only 10% extrapolated

Drupp's data are unrepresentative: 44% of the surveyed experts are in North America, 49% in Europe, and 7% in the rest of the world. The corresponding numbers for the world population in 2020 are 6%, 8% and 86%. This matters. In Falk's data, the patience (risk-taking) score is 0.80 (0.12) in North America, 0.28 (-0.09) in Europe and 0.051 l14-.12) k-

The Drupp data are for the pure rate of time preference and the intertemporal rate of substitution. Although based on a survey, the respondents are experts who can be expected to understand both these concepts and the implications of their choice. The main disadvantage

Figure A.1: Index of attitudes to time and risk according to Falk et al. (2018), by country.

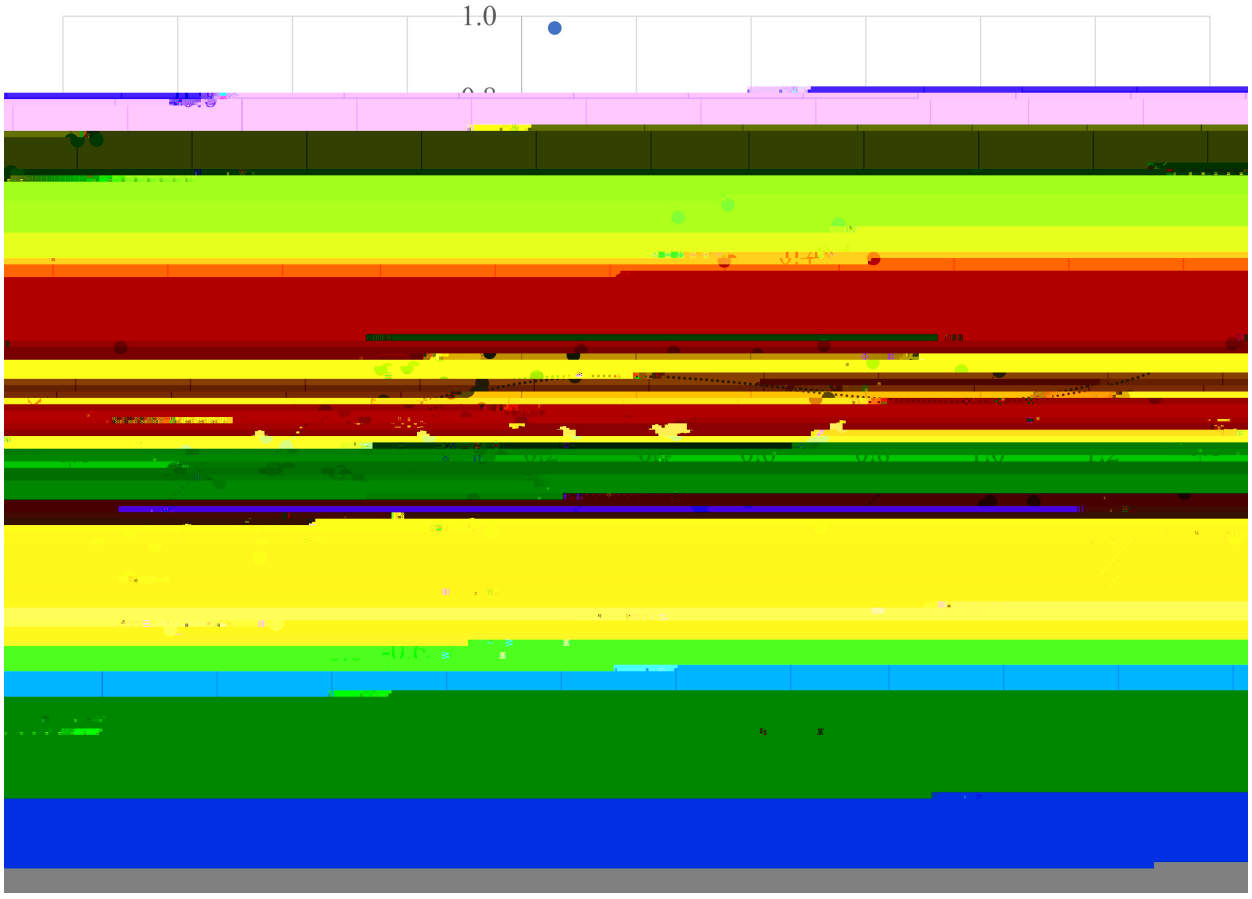

Table A.2: Indicators and rates of time and risk preferences and the corresponding calibrations.

		r	e			constant	slope
Falk	5%ile	-0.43	-0.43	0	0.2	= 2:46	= 3:60
	95%ile	0.68	0.55	4	4	= 1:77	= 2:87
Population weights	5%ile	-0.38	-0.32	0	0.5	= 3:28	= 4:57
	95%ile	0.72	0.39	5	5	= 2:95	= 6:34
N America & Europe	5%ile	-0.35	-0.47	0	0.2	= 2:79	= 3:00
	95%ile	0.93	0.17	3.85	2.05	= 0:70	= 2:88
Table A.1						= 1:07	= 0:03
						= 1:40	= 0:09
Hofstede	5%ile	14.3	29.1	0	0.2	= 4:78	= 0:055
	95%ile	87.0	95.9	4	4	= 1:02	= 0:042

Table A.3: National time and risk preferences for four alternative calibrations.

	Falk						Table A.1			
	unweighted		weighted		Eur & NAm		observed		imputed	
Afghanistan	3.18	1.42	4.20	2.18	3.40	0.35	1.07	1.39	1.07	1.39
Algeria	2.24	0.65	3.01	0.46	2.61	0.00	1.06	1.37	1.06	1.37
Argentina	3.28	1.65	4.33	2.69	3.48	0.58	1.11	1.32	1.07	1.40
Australia	0.09	1.38	0.28	2.08	0.82	0.30	1.50	1.55	1.05	1.39
Austria	0.27	1.95	0.50	3.34	0.97	0.88	1.00	1.60	1.05	1.41
Bangladesh	2.16	2.34	2.91	4.21	2.55	1.27	1.06	1.42	1.06	1.42
Bolivia	2.20	1.47	2.96	2.29	2.58	0.40	1.12	1.16	1.06	1.39
Bosnia Herzegovina	3.35	2.13	4.41	3.75	3.53	1.06	1.07	1.41	1.07	1.41
Botswana	1.61	0.00	2.21	0.00	2.09	0.00	1.06	1.34	1.06	1.34
Brazil	3.39	2.49	4.47	4.54	3.57	1.42	1.11	2.72	1.07	1.42
Cambodia	2.89	2.93	3.83	5.52	3.15	1.87	1.07	1.44	1.07	1.44
Cameroon	4.00	3.31	5.24	6.34	4.07	2.24	1.08	1.45	1.08	1.45
Canada	0.00	1.24	0.00	1.78	0.64	0.17	1.00	1.50	1.05	1.38
Chile	3.02	1.41	3.99	2.15	3.26	0.34	1.12	1.28	1.07	1.39
China	1.02	1.83	1.46	3.07	1.60	0.76	0.67	1.07	1.06	1.40
Colombia	3.70	1.90	4.86	3.24	3.83	0.83	1.15	1.82	1.08	1.41
Costa Rica	3.04	1.77	4.03	2.94	3.28	0.70	1.00	1.11	1.07	1.40
Croatia	2.79	1.57	3.71	2.51	3.07	0.50	1.07	1.40	1.07	1.40
Czech Republic	1.07	1.83	1.53	3.08	1.64	0.76	1.08	1.10	1.06	1.40
Egypt	3.84	2.58	5.03	4.73	3.94	1.51	1.08	1.43	1.08	1.43
Estonia	2.37	2.62	3.17	4.82	2.72	1.55	1.27	0.83	1.07	1.43
Finland	0.30	2.58	0.54	4.74	0.99	1.52	1.00	1.60	1.05	1.43
France	1.17	1.86	1.65	3.14	1.72	0.79	1.05	1.30	1.06	1.40
Georgia	4.21	2.00	5.50	3.46	4.25	0.93	1.08	1.41	1.08	1.41
Germany	0.21	1.90	0.43	3.23	0.92	0.83	0.75	1.50	1.05	1.41
Ghana	2.15	0.00	2.90	0.00	2.54	0.00	1.06	1.35	1.06	1.35
Greece	3.75	2.22	4.93	3.95	3.87	1.15	1.00	1.60	1.08	1.42
Guatemala	3.38	2.40	4.46	4.34	3.56	1.33	1.00	1.04	1.07	1.42
Haiti	3.81	1.72	5.00	2.83	3.92	0.64	1.08	1.40	1.08	1.40
Hungary	4.01	3.20	5.25	6.11	4.08	2.14	1.30	1.10	1.08	1.45
India	2.85	2.56	3.78	4.69	3.12	1.49	1.30	1.64	1.07	1.43
Indonesia	3.76	2.69	4.94	4.99	3.88	1.63	1.08	1.43	1.08	1.43
Iran	3.83	0.80	5.02	0.81	3.93	0.00	0.53	4.27	1.08	1.37
Iraq	3.96	1.29	5.19	1.90	4.04	0.22	1.08	1.39	1.08	1.39
Israel	0.81	1.07	1.20	1.40	1.42	0.00	1.05	1.38	1.05	1.38
Italy	2.07	2.04	2.79	3.54	2.47	0.97	1.00	1.38	1.06	1.41
Japan	2.07	2.79	2.79	5.21	2.47	1.73	1.50	1.40	1.06	1.43
Jordan	3.96	2.13	5.20	3.74	4.05	1.06	1.08	1.41	1.08	1.41
Kazakhstan	3.39	1.07	4.47	1.39	3.57	0.00	1.07	1.38	1.07	1.38
Kenya	2.73	1.07	3.63	1.40	3.02	0.00	1.07	1.38	1.07	1.38
Lithuania	2.68	1.90	3.57	3.24	2.98	0.83	1.37	0.53	1.07	1.41
Malawi	2.62	0.41	3.49	0.00	2.93	0.00	1.07	1.36	1.07	1.36
Mexico	2.85	2.17	3.78	3.83	3.12	1.10	1.00	2.71	1.07	1.41
Moldova	1.75	1.87	2.39	3.17	2.21	0.80	1.06	1.41	1.06	1.41
Morocco	3.58	1.97	4.70	3.39	3.72	0.90	1.07	1.41	1.07	1.41
Netherlands	0.00	1.23	0.00	1.75	0.00	0.15	0.90	1.55	1.04	1.38
Nicaragua	4.66	3.34	6.08	6.42	4.63	2.28	1.00	1.14	1.08	1.45
Nigeria	3.18	0.66	4.20	0.50	3.39	0.00	1.07	1.37	1.07	1.37
Pakistan	2.76	1.71	3.66	2.82	3.04	0.64	1.07	1.40	1.07	1.40
Peru	2.85	1.33	3.78	1.97	3.12	0.25	1.13	1.39	1.07	1.39
Philippines	2.10	0.92	2.83	1.08	2.49	0.00	1.06	1.37	1.06	1.37
Poland	2.20	1.98	2.96	3.42	2.58	0.91	0.98	0.95	1.06	1.41
Portugal	3.58	4.05	4.71	7.98	3.73	2.99	1.00	1.65	1.07	1.47

Table B.5: Welfare parameters and the implied social cost of carbon for four clusters of countries.

cluster	1	2	3	4
Falk & Drupp				
Social cost of carbon ($/tC)	9.76	4.55	45.98	21.72
pure time preference	2.73	3.63	2.48	0.44
risk aversion	1.69	2.54	0.33	1.68
Falk & Drupp, population-weighted				
Social cost of carbon ($/tC)	4.00	1.63	25.97	6.72
pure time preference	3.56	4.14	3.58	1.12
risk aversion	3.04	4.67	0.42	2.89
Falk & Drupp, Europe & North America				
Social cost of carbon ($/tC)	21.52	9.36	47.00	48.62
pure time preference	2.97	3.36	2.99	1.32
risk aversion	0.76	1.48	0.00	0.67
observed and imputed				
Social cost of carbon ($/tC)	21.87	21.96	21.51	21.83
pure time preference	1.06	1.11	1.07	1.03
risk aversion	1.46	1.43	1.35	1.38
imputed				
Social cost of carbon ($/tC)	20.43	19.81	21.51	20.57
pure time preference	1.07	1.08	1.07	1.05
risk aversion	1.40	1.43	1.35	1.40
income (US$/person/year)	16,502	17,034	3,553	42,583
income (Geary-Khamis $/person/year)	9,438	6,257	1,529	34,997
population (millions)	1,449	2,495	590	2,147

The 2015 social cost of carbon (^{2015}/tC) is the average of the global social costs of carbon for national time and risk preferences in the respective clusters. Averages are unweighted unless indicated otherwise. Clusters are found by k-means clustering on time and risk preferences.

Figure B.2: The social cost of carbon plotted against the calibrated pure rate of time preference.

Figure B.3: The social cost of carbon plotted against the calibrated inverse of the intertemporal rate of substitution.

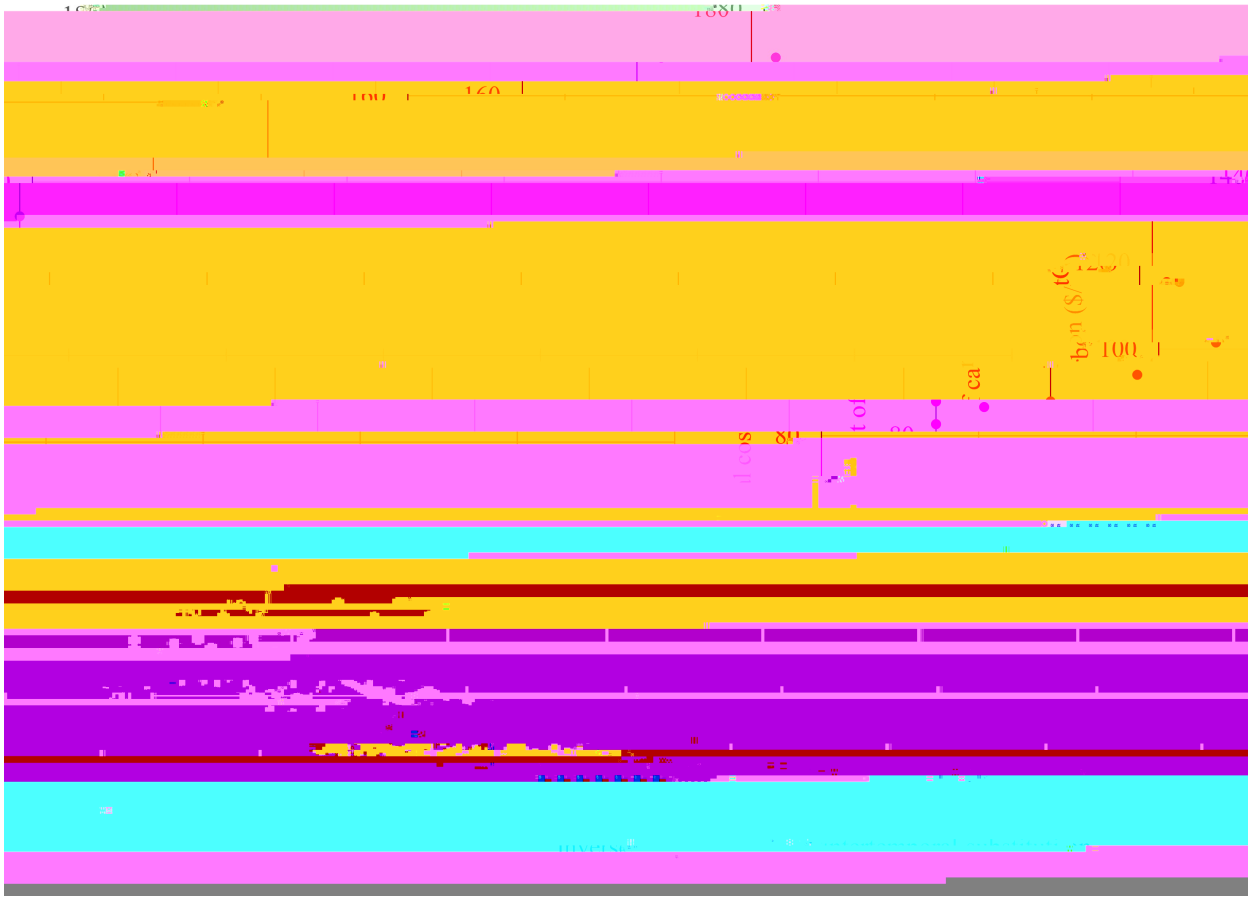

Table B.6: The 2015 global social cost of carbon ($/tC[2015]) per tonne of carbon) for national time and risk preferences according to four alternative calibrations.

		Falk		Table A.1	
	unweighted	weighted	Eur & NAm	observed	imputed
Afghanistan	10.1	4.7	25.7	20.6	20.6
Algeria	29.3	26.4	54.0	21.2	21.2
Argentina	8.2	3.5	19.7	21.9	20.4
Australia	30.9	13.7	86.6	15.1	20.8
Austria	15.6	4.9	38.3	17.1	20.4
Bangladesh	6.5	2.2	13.9	20.0	20.0
Bolivia	12.9	5.6	33.7	26.1	20.6
Bosnia Herzegovina	5.8	2.1	12.3	20.1	20.1
Botswana	87.9	65.2	69.3	21.9	21.9
Brazil	4.6	1.6	9.1	6.4	19.9

Table B.10: Social cost of carbon when preferences are calibrated to Hofstede's cultural dimensions

	LTO	UA	PRTP	RRA	SCC
Argentina	20.40	86.00	3.66	2.59	4.1
Australia	21.16	51.00	3.62	1.12	11.5
Austria	60.45	70.00	1.46	1.91	11.0
Bangladesh	47.10	60.00	2.19	1.50	12.7
Belgium	81.86	94.00	0.28	2.92	6.8
Brazil	43.83	76.00	2.37	2.17	7.0
Bulgaria	69.02	85.00	0.99	2.54	7.5
Canada	36.02	48.00	2.80	0.99	16.6
Chile	30.98	86.00	3.08	2.59	4.6
China	87.41	30.00	0.00	0.24	148.7
Colombia	13.10	80.00	4.06	2.33	4.4
Croatia	58.44	80.00	1.57	2.33	7.6
Czech Republic	70.03	74.00	0.93	2.08	11.1
Denmark	34.76	23.00	2.87	0.00	48.0
El Salvador	19.65	94.00	3.70	2.92	3.4
Estonia	82.12	60.00	0.27	1.50	25.1
Finland	38.29	59.00	2.68	1.45	11.4
France	63.48	86.00	1.29	2.59	6.8
Germany	82.87	65.00	0.22	1.70	20.3
Great Britain	51.13	35.00	1.97	0.45	41.5
Greece	45.34	112.00	2.29	3.67	2.9
Hong Kong	60.96	29.00	1.43	0.20	73.8
Hungary	58.19	82.00	1.58	2.42	7.1
India	50.88	40.00	1.98	0.66	32.2
Indonesia	61.96	48.00	1.37	0.99	28.2
Iran	13.60	59.00	4.04	1.45	7.9
Ireland	24.43	35.00	3.44	0.45	22.9
Israel	37.53	81.00	2.72	2.38	5.6
Italy	61.46	75.00	1.40	2.12	9.4
Japan	87.91	92.00	0.00	2.84	7.8
South Korea	100.00	85.00	0.00	2.54	9.9
Latvia	68.77	63.00	1.00	1.62	16.7
Lithuania	81.86	65.00	0.28	1.70	19.9
Luxembourg	63.98	70.00	1.26	1.91	11.6
Malaysia	40.81	36.00	2.54	0.49	31.0
Malta	47.10	96.00	2.19	3.00	4.3
Mexico	24.18	82.00	3.45	2.42	4.7
Morocco	14.11	68.00	4.01	1.83	6.1
Netherlands	67.00	53.00	1.10	1.20	25.0
New Zealand	32.75	49.00	2.98	1.03	15.0
Norway	34.51	50.00	2.89	1.08	14.9
Pakistan	49.87	70.00	2.04	1.91	9.3
Peru	25.19	87.00	3.40	2.63	4.2
Philippines	27.46	44.00	3.27	0.82	16.6
Poland	37.78	93.00	2.71	2.88	4.2
Portugal	28.21	104.00	3.23	3.34	3.0
Romania	51.89	90.00	1.93	2.75	5.2
Russia	81.36	95.00	0.31	2.96	6.5
Serbia	52.14	92.00	1.92	2.84	5.0
Singapore	71.54	8.00	0.85	0.00	132.1
Slovak Rep	76.57	51.00	0.57	1.12	34.1
Slovenia	48.61	88.00	2.11	2.67	5.3
Spain	47.61	86.00	2.16	2.59	5.5
Sweden	52.90	29.00	1.87	0.20	59.5
Switzerland	73.55	58.00	0.74	1.41	22.9
Taiwan	92.95	69.00	0.00	1.87	18.6
Thailand	31.74	64.00	3.04	1.66	8.7
Trinidad and Tobago	12.59	55.00	4.09	1.29	8.8
Turkey	45.59	85.00	2.28	2.54	5.6
United States	25.69	46.00	3.37	0.91	14.9
Uruguay	26.20	100.00	3.34	3.17	3.2
Venezuela	15.62	76.00	3.93	2.17	5.0
Vietnam	57.18	30.00	1.64	0.24	63.0
Average	49.55	67.17	2.08	1.81	10.0
Weighted average	58.02	50.95	1.61	1.12	22.5
North America	26.75	46.21	3.31	0.92	15.1
Europe	59.27	70.33	1.52	1.93	17.2
Rest of the world	60.23	49.21	1.49	1.04	57.8

The table shows Hofstede's long-term orientation (LTO) and uncertainty avoidance (UA), the calibrated pure rate of time preference (PRTP) and rate of relative risk aversion (RRA), and the resulting estimate of the social cost of carbon (SCC; in dollar per tonne of carbon).

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