Damage from a Change in the Climate

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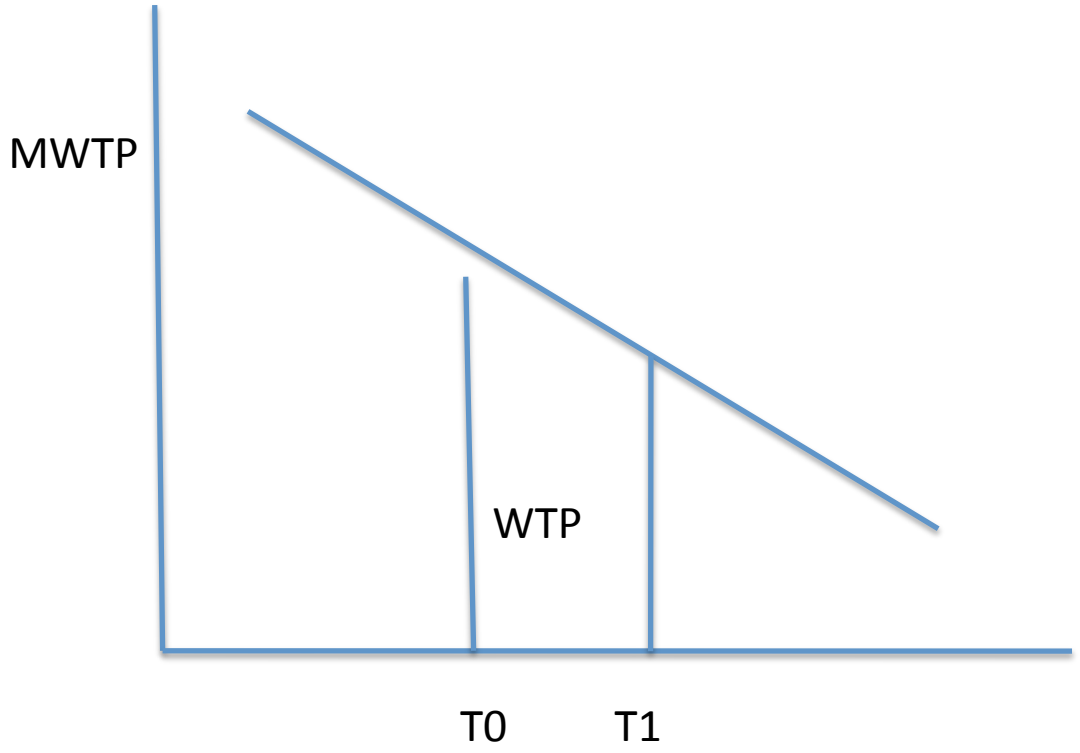
What is damage from climate change?

- An Individual: the harm (positive or negative) caused by a change in climate relative to a baseline (not absolute), expressed in terms of a numeraire good. Equivalently, WTP to avoid change in climate.
- Society: aggregate damage, summed over individuals, space and time, also from a relative change in climate, expressed in terms of a numeraire good

Damage equivalent to WTP to avoid change



Metrics and Adaptation

- Climate change has many relevant dimensions
  - Mean weather
  - Variance of weather
  - Precipitation vs temperature
  - Sea level
  - Catastrophic change
  - Transient – time path of the change
- Implicit is that individuals, firms, governments take steps to autonomously adapt to the change in the climate
- Along a path of change, firms may adjust and incur losses – example of sea level rise.

Some Categories of damage

- MARKET IMPACTS
  - Energy consumption
  - Agriculture
  - Water resources
  - Infrastructure
  - Tourism
  - Real Estate
- NONMARKET IMPACTS
  - Health
  - Aesthetics
  - Ecosystem services

See OECD, 2009

Why do we need aggregate measures of damage?

- Determining the right amount of mitigation
- Understanding to consequences of not taking action
- Use in IAMs, which in turn may be used in policy analysis.
- Use in computing Social Cost of Carbon for use in decentralizing carbon regulations

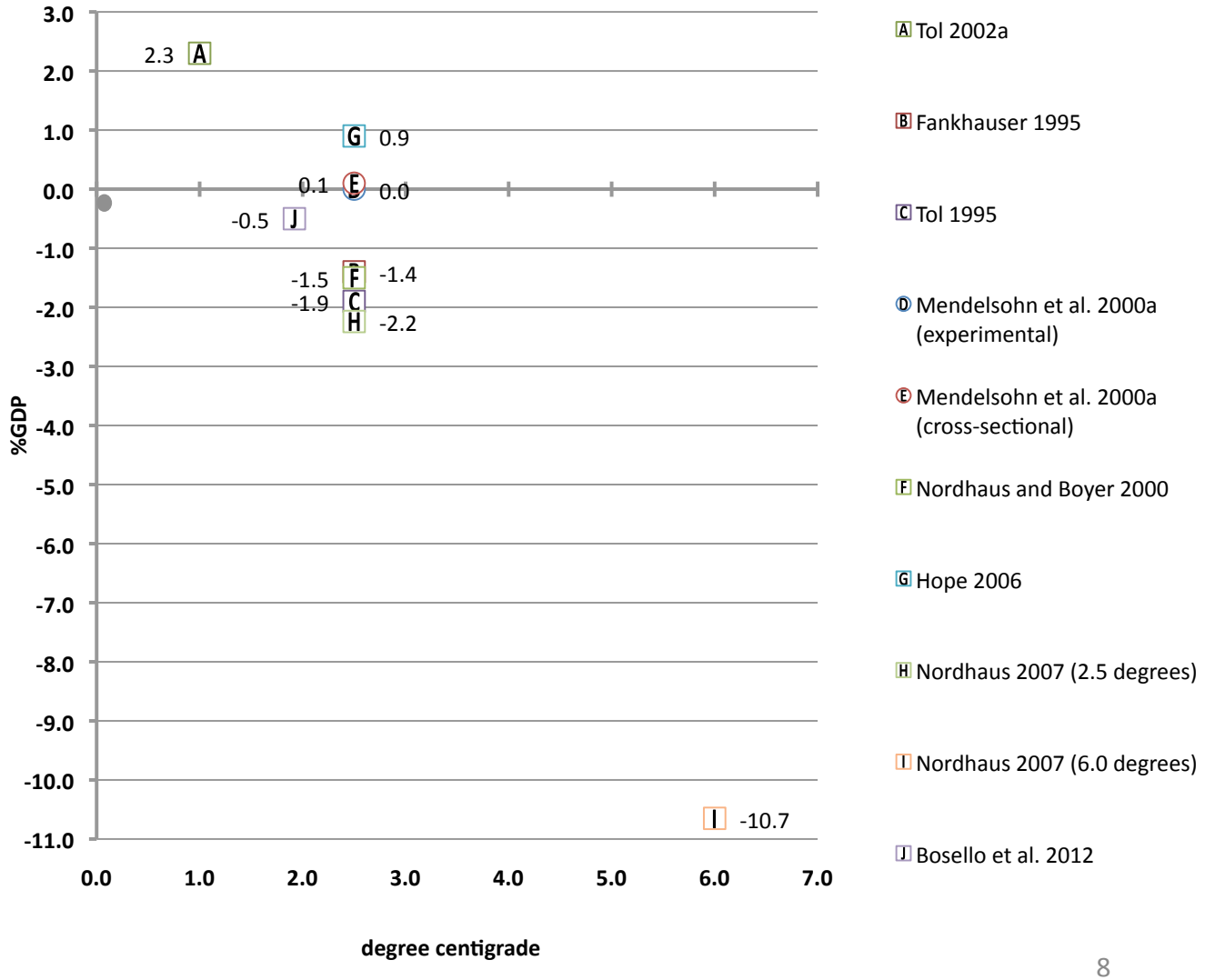
Estimates of the Welfare Impact of Climate Change

(expressed as an equivalent income gain or loss in percent GDP)

			Worst-off region		*Best-off region*	
Study	*Warming (°C)*	*Impact (% of GDP)*	*(% of GDP)*	*(Name)*	*(% of GDP)*	*(Name)*
Nordhaus (1994a)	3.0	−1.3				
Nordhaus (1994b)	3.0	−4.8 (−30.0 to 0.0)				
Fankhauser (1995)	2.5	−1.4	−4.7	China	−0.7	Eastern Europe and the former Soviet Union
Tol (1995)	2.5	−1.9	−8.7	Africa	−0.3	Eastern Europe and the former Soviet Union
Nordhaus and Yang (1996)[a]	2.5	−1.7	−2.1	Developing countries	0.9	Former Soviet Union
Plambeck and Hope (1996)[a]	2.5	2.5 (−0.5 to −11.4)	−8.6 (−0.6 to −39.5)	Asia (w/o China)	0.0 (−0.2 to 1.5)	Eastern Europe and the former Soviet Union
Mendelsohn, Schlesinger, and Williams (2000)[a,b,c]	2.5	0.0[b] 0.1[b]	−3.6[b] −0.5[b]	Africa	4.0[b] 1.7[b]	Eastern Europe and the former Soviet Union
Nordhaus and Boyer (2000)	2.5	−1.5	−3.9	Africa	0.7	Russia
Tol (2002)	1.0	2.3 (1.0)	−4.1 (2.2)	Africa	3.7 (2.2)	Western Europe
Maddison (2003)[a,d,e]	2.5	−0.1	−14.6	South America	2.5	Western Europe
Rehdanz and Maddison (2005)[a,c]	1.0	−0.4	−23.5	Sub-Saharan Africa	12.9	South Asia
Hope (2006)[a,f]	2.5	0.9 (−0.2 to 2.7)	−2.6 (−0.4 to 10.0)	Asia (w/o China)	0.3 (−2.5 to 0.5)	Eastern Europe and the former Soviet Union
Nordhaus (2006)	2.5	−0.9 (0.1)				

Tol, 2009

Aggregate Measures of Damages from CC



Source: adapted from Tol (2013)

Issues of Aggregation I

- Across Impacts
  - Need a common metric so that a variety of different damages may be aggregated.
- Across space
  - Aggregation of losses in Bangladesh with losses in US can lead to US swamping Bangladesh. Need prioritarian perspective in aggregation (weights)
  - Differences in VSL provide possible insights into welfare weights

Table 3 – Descriptive statistics for the studies included in the meta-analysis

Paper	Biblio. Ref.	No. Obs.	Publication year	Country	Mean VSL (in 2005 dollars)	Range (*10^6 2005 dollars)	Per capita VSL/GDP ratio
ADB	[6]	4	2005	Malaysia	**1 194 228**	0.7 – 1.7	104
Alberini & Chiabai	[1]	7	2006	Italy	**2 701 947**	1 – 5.6	97
Alberini & Kahn	[8]	12	2006	United States	**1 266 037**	0.2 – 6.4	30
Alberini et al.	[3]	11	2006	Czech Republic	**2 965 895**	0.7 – 5.4	146
Alberini et al.	[2]	2	2004	United States	**1 421 025**	1.1 – 1.7	34
Alberini et al.	[4]	3	2007	Italy	**3 598 485**	1.4 – 6.3	130
Alberini et al.	[5]	2	2006	Canada - United States	**1 036 062**	0.8 – 1.2	27
Buzby, Ready & Skees	[7]	2	1995	United States	**6 521 801**	5.4 – 7.6	156
Chestnut et al.	[9]	12	2009	Canada - United States	**5 142 629**	2.5 – 9.4	134
Desaigues et al.	[12] [31]	20	2004-2007	France	**2 943 355**	0.9 – 9.1	99
Ghani & Faudzi	[14]	8	2003	Malaysia	**1 269 214**	0.7 – 1.9	111
Gibson et al.	[15]	1	2007	Thailand	**659 955**	##	96
Giergiczny	[16]	3	2006	Poland	**795 082**	0.2 – 1.7	59
Guo, Haab & Hammitt	[17]	1	2006	China	**24 427**	##	6
Hakes & Viscusi	[19]	2	2004	United States	**6 247 816**	6.1 – 6.4	150
Hammitt & Zhou	[20]	12	2006	China	**115 515**	0.02 – 0.4	28
Itaoka et al.	[21]	19	2007	Japan	**1 280 220**	0.5 – 2.8	42
Johannesson, Johansson & Löfgren	[22]	14	1997	Sweden	**4 509 711**	2.8 – 5.5	141
Johannesson, Johansson & O'Conor	[23]	4	1996	Sweden	**4 652 973**	2 – 7.1	145
Jones-Lee, Hammerton & Philips	[24]	4	1985	United Kingdom	**5 226 967**	3.9 – 7.2	166
Krupnick et al.	[25]	8	2002	Canada	**1 758 343**	1.1 – 3.6	50
Krupnick et al.	[26]	110	2006	China	**562 225**	0.1 – 1.7	137
Leiter & Pruckner	[27]	24	2008-2009	Austria	**3 021 948**	1.9 – 5.2	89
Leiter & Pruckner	[28]	4	2008	Austria	**2 445 736**	2.1 – 2.8	72
Liu et al.	[29]	24	2005	Chinese Taipei	**12 300 000**	5.8 – 22.1	472
Mahmud	[30]	4	2006	Bangladesh	**5 248**	0.04 – 0.07	4
Leung et al.	[18]	8	2009	New Zealand	**2 870 491**	1.8 – 4.4	117
Persson et al.	[32]	7	2001	Sweden	**3 107 326**	1.6 – 4.2	97
Rheinberger	[33]	2	2009	Switzerland	**4 362 827**	4.2 – 4.5	123
Schwab Christe & Soguel	[34]	4	1995	France	**1 094 639**	0.3 – 2.2	37
Schwab Christe & Soguel	[34]	6	1995	Denmark	**13 600 000**	9 – 17.5	404
Svensson	[35]	14	2009	Sweden	**7 693 884**	3 – 9.6	240
Tsuge, Kishimoto & Takeuchi	[36]	1	2005	Japan	**2 695 444**	##	89
Vassanadumrondgee & Matsuoka	[37]	4	2005	Thailand	**1 555 256**	1.3 – 1.8	226
duVair & Loomis	[13]	3	1993	United States	**352 962**	0.2 – 0.5	8

Source: OECD

Issues of Aggregation II

- Across time
  - Market discount rate is the rate at which individuals tade off time
  - Social discount rate is what governments use in making intertemporal decisions
    - r= d + e g, where d is rate of pure time preference for well-being, g is growth rate of consumption and e represents aversion to inequality
    - d is typically close to zero; e is typically 1-2; g is typically 2-3 (but can be negative). Implies r 1-2 time the growth rate.
    - d is purely normative but some reality checking with how willing one is to transfer resources to poorer people at same point in time.

Social Discount Rate from Ramsey Rule

Author	Impatience	Inequality aversion	Growth rate	Implied social discount rate
Cline (1992)	0%	1.5	1%	1.5%
Arrow (1996)	0%	2	2%	4%
UK: Green Book (HM Treasury, 2003)	1.5%	1	2%	3.5%*
France: Rapport Lebègue (2005)	0%	2	2%	4%*
Stern (2007)	0.1%	1	1.3%	1.4%
Weitzman (2007a)	2%	2	2%	6%
Nordhaus (2008)	1%	2	2%	5%

*Decreasing with the time horizon.

From: Gollier, 2012

Real Market Rates

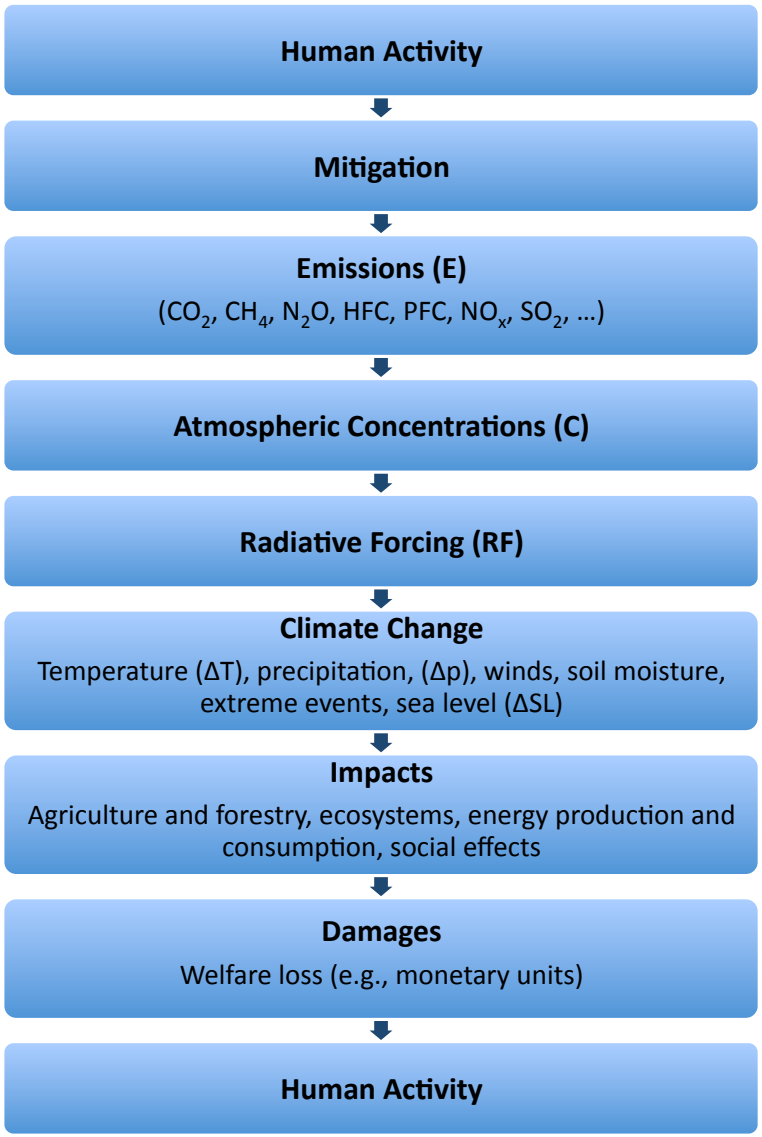
	Bills		Bonds		Equity	
	1900-2006	1971-2006	1900-2006	1971-2006	1900-2006	1971-2006
Australia	0.6%	2.5%	1.3%	2.8%	7.8%	6.3%
Canada	1.6%	2.7%	2.0%	4.5%	6.3%	5.8%
Denmark	2.3%	3.5%	3.0%	7.0%	5.4%	9.0%
France	-2.9%	1.2%	-0.3%	6.6%	3.7%	7.8%
Italy	-3.8%	-0.3%	-1.8%	2.8%	2.6%	3.0%
Japan	-2.0%	0.4%	-1.3%	3.9%	4.5%	5.0%
Netherland	0.7%	1.8%	1.3%	3.9%	5.4%	8.5%
United Kingdom	1.0%	1.9%	1.3%	3.9%	5.6%	7.1%
Sweden	1.9%	2.4%	2.4%	4.2%	7.9%	11.0%
Switzerland	0.8%	0.4%	2.1%	2.8%	5.3%	6.1%
USA	1.0%	1.3%	1.9%	4.0%	6.6%	6.6%

Source: Gollier, 2012

Measuring Damage

- Requires knowledge of the quantitative biological and physical impacts of a particular climate change
- Often the natural science is insufficiently precise to be able to generate a meaningful estimate of damage

Chain of Causation



Methods for Measuring Damage

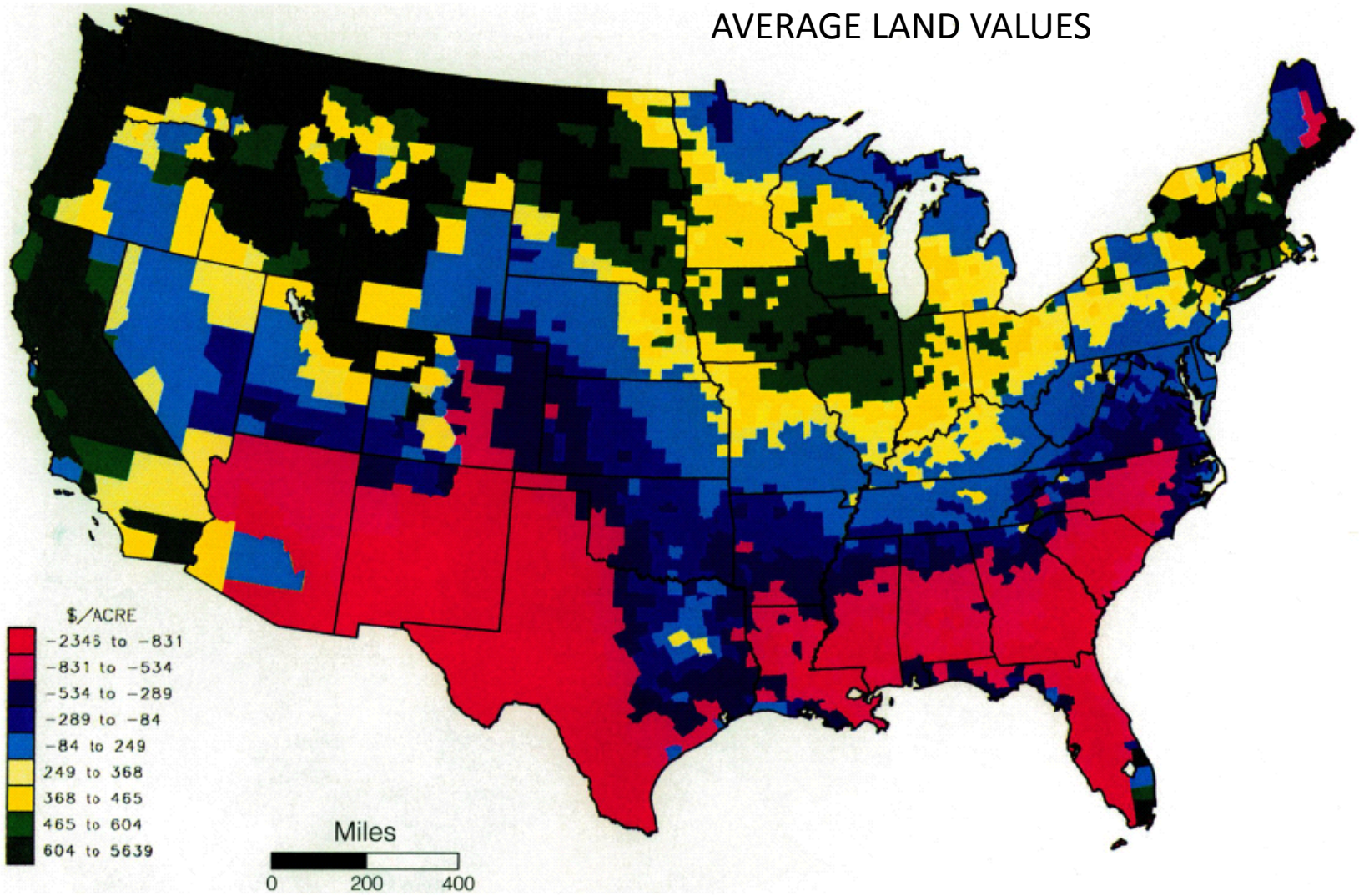
- Revealed Preference Methods
  - Economist always suspicious of what people SAY they will do vs what they ACTUALLY do – actions speak louder than words.
  - Best to try to look at historic analogues rather than speculate about future
  - Look at behavior in markets related to environmental harm
  - Eg, how much to house prices change when air quality gets better
  - Typically preferred since real economic decisions are involved
- Stated preferences
  - Contingent valuation – respondents are asked their WTP
  - Referenda – respondents vote on expenditure issue with associated environmental benefits
    - Eg, Kahn and Matsusaka—California voting on environmental propositions

Revealed Preference Methods

- Hedonic
  - Look at how price of market good varies with different levels of associated environmental good
- Household production
  - Look at expenditures made to adapt to different levels of the environmental good – defensive expenditures
  - Travel cost is an example which is widely used for recreation deman

Example: Market Impacts on Agriculture

Classic Analysis of Medelsohn, Nordhaus and Shaw (1994)

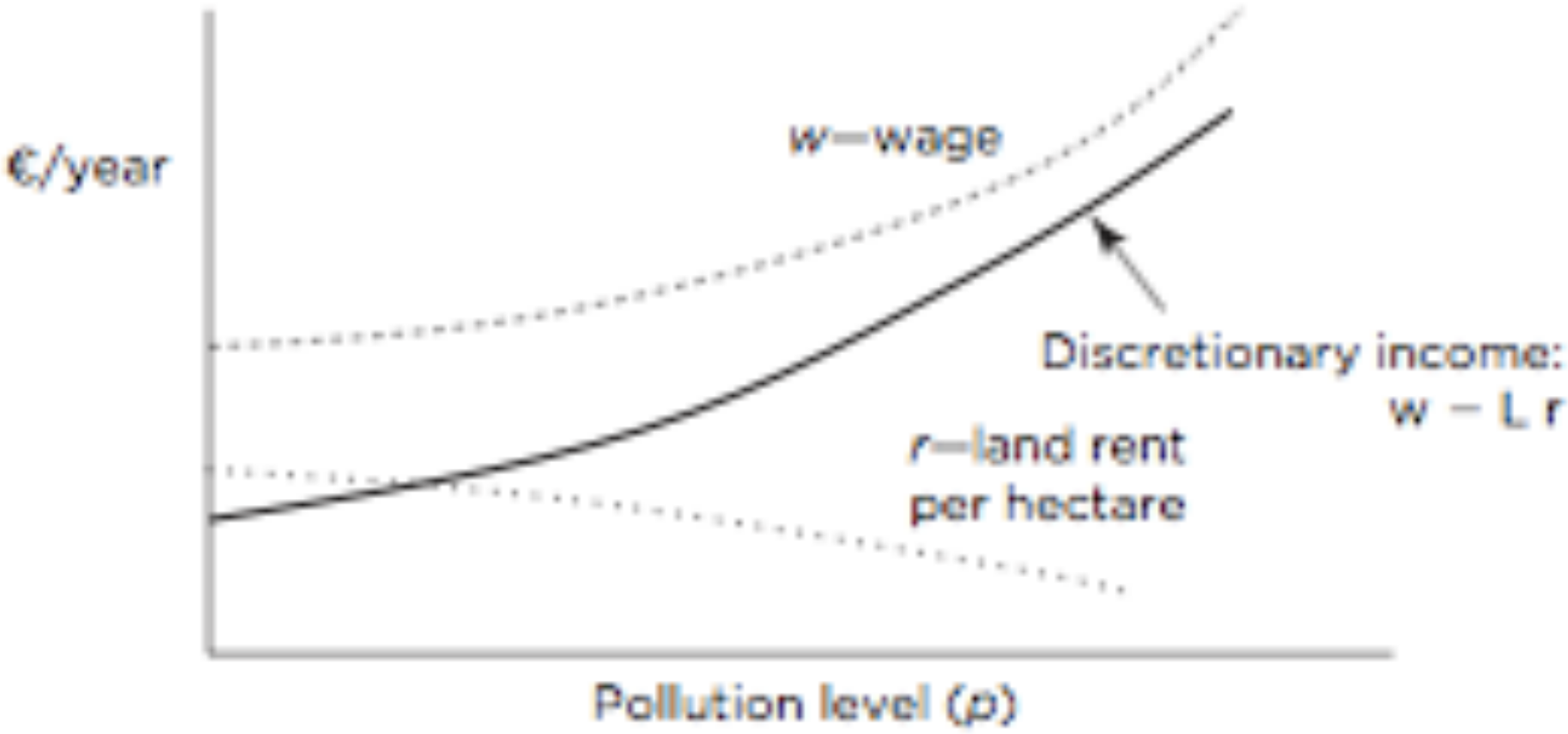


Source: Mendelsohn et al, 1994

Extensions of simple cross-section analysis

- Panel – pooled time series, cross section.
- Look at ag profits rather than land prices; look at weather anomalies as well as climate (Kelly et al, 2005)
- Applied to other countries (Series of papers by Mendelsohn et al and others)
- Improve metrics of climate change (Deschenes and Greenstone, 2009)
  - Difficult to find summary statistics for weather/climate
- One problem is that factor prices are held constant
- Result is a good understanding of the effect of climate change on agriculture

Nonmarket Impact: Amenity Values of Climate (Maddison and Bigano, 2005)



Source: Kolstad, 2010

Details

- Data from 95 Italian Provinces
- 1991-95
- Measure discretionary income
- Jan, July temperature, precip and cloudcover
- Conclude:
  - 1 degree increase in July temp causes household loss of 350 euros per year
  - 1 mm increase in Jan precip generates loss of 15 euros per year

Methods for Ecosystem Services

- Use value has generated low estimates of value (eg, pharmaceutical value of tropical biodiversity)
- Ecosystem services are generally detached from markets – revealed preference methods inadequate (so far)
- CV one of the only methods – fraught with problems.

Social Cost of Carbon

- Important and controversial
- Useful for decentralizing carbon regulation domestically
- Defined as the net present value of marginal damages with respect to carbon emissions, conditional on a baseline regulatory policy
- NOT the marginal net benefits, as incorrectly used by US Government (though concepts are the same absent any sort of carbon regulation)

Co-benefits

- Example: If carbon regulations are tightened, sulfur emissions may decline
- Incorrect to value those co-benefits based on the averted damage from sulfur
- Correct to look at the marginal net welfare implications of decreasing carbon by one ton, conditional on a trajectory of emissions
- Note: Envelope theorem tells us if the sulfur is optimally regulated, there will be no welfare consequences on one less ton of sulfur

Benefits Transfer

- Benefits transfer involves using a study done in one location to infer the damage from pollution in a different location.
- Carefully done, it can be useful
- Will be very important to do significant amounts of benefit transfer in the climate area, particularly for nonmarket damages. World is too big.

Conclusions

- Significant need for a research program to catalog the monetary impacts of a change in the climate
- Better estimates of aggregate damage from climate change are long overdue
- Will we ever be able to get something comprehensive (like the “Cost of Clean”)?