Some Simple Economics of Climate Change

Kevin M. Murphy
The University of Chicago
September 7, 2008

Climate Change

- Climate change has emerged as a significant policy issue.
- In the U.S. both Presidential candidates have promised plans to cut greenhouse gas emissions by 50-80% by 2050.
- There is a substantial risk that costly policies to mitigate global warming will be initiated in the near future.
- Is such a response supported by sound economic analysis?

Goals of Today's Talk

- Provide some perspective on and insight into the economics of climate change.
- Analyze some of the key features of the economics of climate change and climate change policy.
- Provide simple and transparent models rather than an integrated analysis.
- Determine some possible focus for policy.

Economic Literature

- Wide range of models
    - Many models are large "black-box" type models with many moving parts.
    - Difficult to asses the key assumptions and interactions.
    - High levels of parameter uncertainty.
- Wide range of implications:
    - Climate ramp (DICE-model) such as Nordhaus – recommends incremental response to climate change.
    - The Stern Review on the Economics of Climate Change calls from "dramatic action" and a carbon tax of $311 per ton.

Important Economic Questions

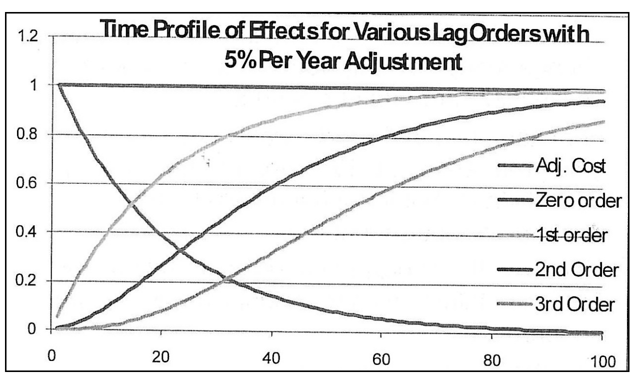
- Discounting — how much should we value costs/benefits in the distant future?
- How large are the costs likely to be?
- How will markets respond to the threat of climate change and climate change policy?
- How does uncertainty about the prospects for climate change affect the analysis?
- What about the dependence on government?

Discounting

What makes discounting important?

- Many actions such as the emissions of GHG may have very long-term consequences (flow effects on the stock of atmospheric GHG concentrations).
- Simple model: current emissions = permanent change GHG concentration.
- If cost = C(GHG concentration) then this would imply the shadow cost of current emissions would be some form of a perpetuity.
- If costs of climate change are largely adjustment costs, that would shorten the horizon.
- When costs accumulate after climate change then the horizon gets longer.
- Many of the effect of GHG concentrations on climate/environment occur with a lag:
    - Rate of sea level rise is affected by the temperature — may take substantial time to equilibrate to its new level
    - Thermal expansion effects are particularly long (centuries)
- Costs that accumulate with the level of environmental change have an upward sloping profile making discounting even more important.
- If costs are convex in climate change then economic impacts are even upward sloping than climate change making discounting even more important.

Examples of Different Orders of Effects



Impact of Discounting with Various Order Effects

Ratio of PV (r = 4.0% normalized to 1.00)

	Discount Rate								
Order	0.10%	0.50%	1.00%	2.00%	3.00%	4.00%	5.00%	6.00%	8.00%
Adj. Costs	1.76	1.64	1.50	1.29	1.13	1.00	0.90	0.82	0.69
Zero Order	40.00	8.00	4.00	2.00	1.33	1.00	0.80	0.67	0.50
First Order	69.24	12.87	5.91	2.55	1.49	1.00	0.72	0.55	0.35
Second	122.15	21.05	8.87	3.27	1.68	1.00	0.65	0.45	0.24
Third Order	215.56	34.44	13.30	4.21	1.89	1.00	0.59	0.37	0.17

The Appropriate Discount Rate

- Given the potential long term impact of climate change many have argued for using a low or essentially zero rate of discount.
- For example, the Stern Review uses a rate of time preference of 0.1 % per year based on an ethical stand that it is indefensible to use a positive social discount rate.
- However, the choice of the discount rate is not fundamentally about the weight we put on future generations.
- It is about opportunity costs.

An Example

- Investment cost in 2008 = $1 B
- Benefit in 2108 = $20B
- r=6.0%
- Do future generations want us to make the investment in climate change mitigation?
- NO! — they would prefer we would invest the $1B in other assets which would yield $339B in 100 years leaving them with the $20B to deal with climate change and $319B left over.
- Alternatively, we could invest just $59M at 6%, give them the $20B in 100 years and have $941 M left for ourselves.

Implications

- We should use the market rate as the discount rate because that is the opportunity cost of climate mitigation.
- Using a lower discount rate unnecessarily harms current and/or future generations.
- With market discount rates the costs of climate change are greatly reduced relative to the claims of Stern and others.

If We set Policy Based on Market Rates Will Future Generations be Impoverished by Climate Change?

- Unlikely based on past experience.
- Should people 100 years ago have adjusted their behavior so we could have more today?
- In fact the Stern model assumes individuals 200 years from now will be more than 10 times as rich as us even without climate change mitigation!
- Should we tax the poor (today's generation) to benefit the rich (future generations)?
- If we are concerned about future generations we should encourage all forms of intergenerational transfers not just transfers of climate wealth.

Is there any justification for a low discount rate?

- One can justify a lower discount rate if climate mitigation has less systematic risk than other capital investments (i.e. a low beta).

β = 0 ➔ risk free rate, β = 1 ➔ return on market

- Can justify a lower long term rate if long term returns are uncertain:
  - For example if the long term returns are equally likely to be 4% and 8%, the appropriate 100 year rate is 4.7% rather than the simple average of 6%.
  - For very long horizons this approaches the minimum possible return of 4%.

The Environment as an Exhaustible Resource

- A simple framework is to think of climate mitigation in terms of limiting GHG concentrations to a particular level (say 650 002 equivalent ppm) in 100 years.
- The difference between the limit 650 and current levels (roughly 380) is then an exhaustible resource.
- To fix ideas, 0 will let c(x(t),t) be the cost of reducing emissions in year t by the amount x(t).

The Economic Problem is Then

$$Min \int_0^{100} e^{-rt} C(x(t),t)dt \;\; s.t. \;\; \int_0^{100} x(t)dt = 650 - 380$$

- The solution to this problem is:

$$c'(x(t),t) = c'(x(0),0)e^{rt}$$

- This implies that the incremental costs of emissions reduction should rise at the interest rate.

Implications

- With a shadow price of carbon of $300 per ton in 100 years and r=6% the prices for carbon would be:
  - $93.54 in 80 years
  - $16.29 in 50 years
  - $2.84 in 20 years
  - $0.88 today
- With r=4% the corresponding prices for carbon would be:
  - $136.92 in 80 years
  - $42.21 in 50 years
  - $13.02 in 20 years
  - $5.94 today
- With productive capital the return to waiting is large.

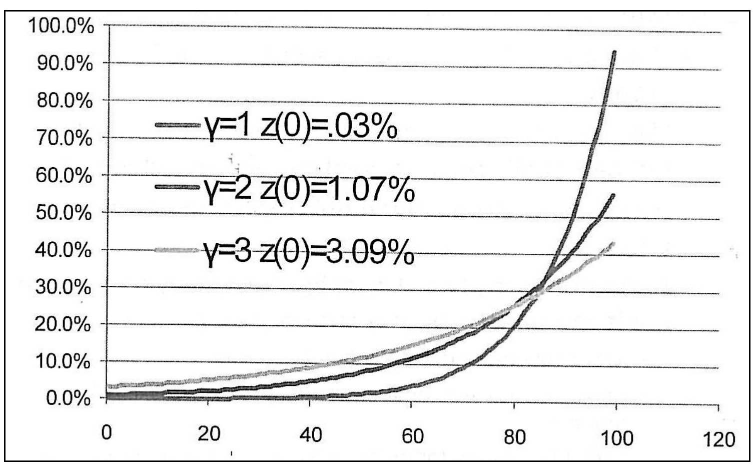
- With a fixed mitigation technology, the amount of mitigation, z(t), will rise over time according to:

$$\frac{dz}{dt} = \frac{r}{\gamma(z)} z(t)$$

- where y(z) is the elasticity of mitigation costs w.r.t. the amount of mitigation (the inverse of the elasticity of supply).
- With technical progress in mitigation at rate a this becomes:

$$\frac{dz}{dt} = \frac{(r+a)}{\gamma(z)} z(t)$$

- Without technical progress the rate of mitigation increase is proportional to the interest rate.
- With technical progress mitigation grows at a rate proportional to the interest rate plus the rate of technical progress.
- Given the technological nature of climate mitigation a is likely to be important making waiting more valuable.
- When marginal costs of mitigation rise slowly, y is low, mitigation is greatly postponed.
- When marginal costs of mitigation increase quickly then it pays to spread mitigation out 99 more mitigation early on.
- Example r=6% a=2%, 20% reduction in emissions over 100 year horizon (baseline growth=1.5%):



Conclusions on Discounting & Timing

- With costs due to climate in the distant future (e.g. 100+ years) and productive capital:
  - It pays to wait for climate mitigation and ramp up policy over time due to discounting.
  - The expectation of technical progress further postpones mitigation.
  - One exception to waiting would be if incremental mitigation costs rise very steeply with the amount of mitigation.

  - With "scalable" technologies, y will tend to be low since costs will then rise slowly with mitigation activity.

What About Estimates of Costs and the Level of Mitigation Needed?

- Estimates of costs will tend to be exaggerated:
  - Substitution tends to reduce costs – perhaps greatly.
  - May be more costly to do what we are doing now but can easily be less costly to do something else.
  - Avenues for substitution not always obvious ex-ante.
  - Economic activity will shift to areas/activities where costs increase less or even decrease:
    - Move toward currently colder locations.
    - Move toward less environmentally sensitive activities – indoors.
    - Shift techniques for given activities – change crops and growing techniques in agriculture.

Evidence from the Marketplace

- GDP is similar in places with very different average temperature (Minnesota & Florida).
- Ability to deal with the environment has grown over time:
- Impact of air conditioning
- Dealing with sea-level rise in the Netherlands
- GDP has become less energy intensive over time (energy usage growing much slower than GDP in the developed world).
- GDP less environmentally dependent over time – agriculture etc. has become a smaller share of GDP over time

What about Uncertainty?

- Uncertainty might matter a lot.
- Several kinds of uncertainty matter:
  - Uncertainty over timing
  - Uncertainty over magnitudes
  - Uncertainty over returns on investment

Example

- A permanent loss of 1 % of GDP that happens 100 years from now
- r=6%, g=1.5%
- PV of loss = 0.25% of current GDP
- WTP is .01 % of GDP per year to avoid the risk
- What if timing is random with same expected time of 100 years (i.e. 1% chance each year)?
- PV = 4.04% of GDP (a 16 fold increase)
- What if the loss is 1% in expectation but it is a small probability of large

catastrophic loss?

- Evidence from the value of life says multiply market loss by a factor of roughly 4-8.
- Using the midpoint of a 6x multiple implies potential loss now valued at 6*4.04% = 24.1 % of GDP (an increase of roughly 100 fold from the certainty case with the same expected loss and expected timing).
- This corresponds to a WTP to eliminate the risk of 1.1% of GDP per year.

Implications

- A small chance of a large loss with very uncertain timing (even if expected waiting time is large) can generate substantial WTP.
- Uncertainty can matter a lot.
- Current action should focus on eliminating the worst case scenarios that could happen quickly (develop a contingency plan).
- Example – this implies high value on a scalable carbon capture/reduction technology.
- Would be highly valuable even if expensive – only used in worst case – truncates the left (worst) tail of outcomes.

Related Economic Issues

- Bad climate outcomes that lower the return to capital may limit our ability to compensate future generations for environmental change making things even worse.
- Mitigation against modest climate change likely to have a positive beta – biggest gains in highest GDP states since costs of climate change likely to rise with GDP.
- Mitigation against very bad climate outcomes likely to have a negative beta (pays off most in the worst states).
- This too says focusing on extreme outcomes makes sense.

Other Economic Issues

- Policy needs to be aware of market responses.
- Example:
    - Unilateral switch to a lower GHG emissions technology
    - Reduces demand for existing fuel sources
    - Lowers price of existing fuel sources
    - Encourages consumption of existing fuels by others
    - Total emissions could go up if the elasticity of supply of fuels is sufficiently low
- Question: can we prevent reserves hydrocarbon fuels from being used by somebody?
- This and other substitution problems create headaches for unilateral policy action.
- May be less substitution problems for GHG capture solutions – no direct substitution – though effects through policy incentives.

- Coordinated government action has its own problems.
- Implementing the climate ramp policy requires commitment to pricing of carbon.
- Governments are not good at long term policy commitments.
- Governments are likely to be particularly bad at creating incentives to mitigate worst case scenarios.
- Mitigating these scenarios requires high payoff in bad states.
- Governments unlikely to honor property rights of private providers in worst states (e.g. nationalization).
- Difficult for governments to plan for low probability events – very difficult to monitor and measure performance – Examples:
    - Pre-war preparedness
    - Disaster management

Conclusions

- Important to use market rates when discounting effects of climate change.
- Optimal response to the threat of modest climate change with future costs should be gradual.
- Technical change enhances the gain to waiting.
- Many estimates of the costs of climate change likely to be too high due to the tendency to understate our ability to substitute in mitigation and adaptation.
- Even catastrophic change that is unlikely and uncertain could be important.
- Governments unlikely to be good at solving these problems – particularly the possibility of extreme change.