Observations on the Economics of Adaptation: Uncertainty and Timing

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Topics

- Adaptation: what are the questions
- Adaptation in agriculture
- Timing of adaptation
- Katrina: A Vignette of Adaptation
- Extremes, adaptation and risk aversion
- Adaptation and distribution
- Short- versus long-run adaptation costs
- Adaptation and institutional reform

Significance of adaptation

- Adaptation is deliberate action intended to lessen the adverse consequences of climate change.
- The notion that there will be no adaptation is inconceivable. Humans are always likely to respond in some manner to perceived opportunities for advantageous change in the face of adverse circumstances, and there is no reason why climate change should be an exception.
- The issue is the cost and efficacy of the adaptation.

Cost and efficacy of adaptation

- When the adaptive action occurs. Does it occur instantaneously as soon as it is first needed, or with some delay?
- The cost of the adaptation itself.
- The adequacy of the adaptation. How perfect will it be in its ability to lessen the adverse climate impacts: will it offset them completely, or only partially?

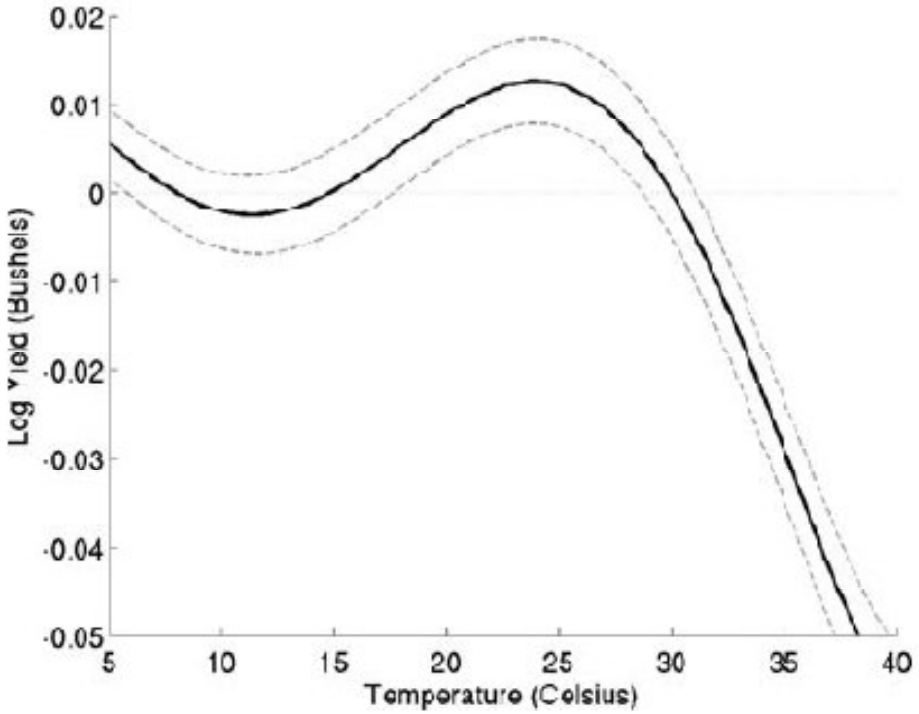
- These are empirical questions.
- They are not questions that can be answered simply by recourse to economic theory.
- The answers are likely to vary by location and by time, as well as by type of impact and by actor. The answers are contingent and context-dependent.
- Adaptation is local. There cannot be a single answer that applies globally.

Adaptation in agriculture

- From an agronomic perspective, there are many potential adaptations
    - Change planting/harvest dates
    - Change cropping pattern
    - New seed varieties
    - Change land use
- The question is whether these will be actually be implemented, and whether this will occur sufficiently quickly to avoid damages.
- This is complicated by the significance of extreme events in crop damage

The shape of the damage function matters: it is not likely to be symmetrical (Schlenker & Roberts 2006)

Figure 2. Nonlinear relationship between temperature and corn yields



Notes: Figure displays the impact of a given temperature for a twenty-four-hour period of the growing season on yearly log yields. The curve is relative to a temperature of 8°C. The 95% confidence interval after adjusting for spatial correlation is added as dashed lines.

- There is a similar pattern in the relationship between temperature and energy demand, and between temperature and mortality.
- With energy, it has been well known since Engle et al. (1986) that the relationship with temperature is asymmetric: the increase in demand at high temperatures is much steeper than the decrease at low temperatures.
- Where this is not found, it is due to aggregation that masks effect of very high temperatures (e.g., 90 vs 100 vs 110^{o}F; this is a problem for Deschenes Greenstone 2007b).

- What all this suggests is that a disproportionate share of the damages from climate change arises from extreme events – it comes when key thresholds are crossed.
- A similar conclusion emerges from the analysis of climate change impacts on water supply in California by Hanemann et al. (2006). Most of the economic losses from reduced availability to urban and agricultural water users occur in the extreme years.

- Under the A1Fi scenario as downscaled to California as compared to without climate change, by the end of the century (around 2085, say), in an average year there is only a 9% loss of net revenue for Central Valley agriculture.
- But, in the lowest 15% of years, the annual revenue loss averages 26%.
- For urban water users, without climate change in 2070-2099, it is estimated that there would be a need for some rationing of urban users in Southern California in about 18% of the years.
- With climate change, this increases to 34% of the years. Moreover, when they occur, the droughts are typically more severe and the rationing creates, on average, a 32% greater loss of consumer's surplus than without climate change.
- Most of the economic loss occurs in drought years.

Adaptation & the Ricardian model

- One set of approaches combines crop yield model with some model of economic market behavior.
  - Leads to estimates of loss to US agriculture ranging from $1.1 billion to $17.5 billion.
- Ricardian Approach (Mendelsohn, Nordhaus and Shaw, 1994) [MNS]. Regress farmland value directly on climate variables. In theory, allows for adaptation to a greater extent.
  - Gain of $2.5 billion, $24 billion.

- The difference was widely attributed to the economic effect of adaptation.
- In fact, it arises from some flaws in MNS's statistical analysis of their data involving their failure to control adequately for irrigation (Schlenker, Hanemann and Fisher 2005).
- Irrigation breaks the link between precipitation where crop is grown and the amount of plant growth. Therefore, need to analyze irrigated areas separately from rainfed areas.

- When MNS analysis is repeated just for rain fed areas of US, instead of a gain for these areas of $2.3 billion, there is a loss of $11 billion.
- Irrigated areas need individual analysis based on a measure of their water supply; but there clearly is a net loss in those areas, too:
  - Increased crop demand for water
  - Reduced supply of water
- There is no evidence that, when correctly implemented, Ricardian approach yields substantially different estimates of loss from models of agricultural market models.

Economics of adaptive response

- What distinguishes the real world from the simple economic theory of adaptation is:
  - There is not a single actor but multiple actors. Most adaptation is local.
  - Adaptive action is mediated by institutions which govern the allocation of costs and benefits and the pace of decision making.
  - The facts of climate change and potential adaptations are not know with certainty, nor are they agreed to by the parties involved.
- These influence both the timing and the nature of the actions that occur.

The timing of adaptation

- Before an action can occur, an agent has to perceive a reason for undertaking the action.
- This underscores two potential obstacles to timely or effective adaptation: the lack of perception of a need for action, and the lack of perception of a benefit from the action.
- Whether and when a problem is perceived by a decision maker is likely to vary.
- The result is that errors in the timing of action – judged with hindsight – are likely to occur. The errors can be in either direction: too hasty or too tardy.

Sea level rise

- It is sometimes assumed that sea walls will be constructed at the point in time when the level of the sea rises to that of the coastal land, and that this avoids all damage from sea level rise.
- This relies on two assumptions that are implausible:
  - (i) the rate of sea level rise is known in advance with certainty,
  - (ii) there are no storms.
- Given uncertainty regarding sea level rise, it is unlikely that sea walls will be constructed just in time – neither too soon nor too late.
- It is incorrect to assume that no inundation can occur before the level of the sea rises to that of the coastal land. This is because of the occurrence of storms which cause inundation well before the level of the sea reaches that of the coastal land.

- The occurrence of storms will lead to efforts to construct sea walls well before the mean sea level reaches the elevation of the coastal land.
- If so, this raises the discounted present value of the cost of the adaptation.
- In their study of sea-level rise in California Neumann and Hudgens (2006) note that, with a 3% interest rate, the discounted capital cost would be increased by 35% if sea walls were constructed 10 years before the level of the sea rises to that of the land, and by 81% if they were constructed 20 years sooner. With a 5% interest rate, the cost increases are 63% and 165%, respectively.

- There are also reasons why adaptation can come too late.
- There are many examples from history where problems were recognized too late; for example, where preventive action against wildfire was undertaken only after a serious wildfire had occurred (San Diego County, California).
- Similar examples exist for both flood and drought prevention.

How quickly is adaptation implemented? Hurricane Katrina

- In 1955, USACE starts planning for flood protection in New Orleans.
- In 1962, USACE completes comprehensive flood protection plan. No action is taken.
- 7 weeks after Hurricane Betsy in 1965, Congress authorizes construction of New Orleans Flood Defense System at cost of $80 million and with completion date of 1978.
- When Katrina hit in 2005, the cost was over $700 million and the projected completion date was 2013, with likelihood of further postponement.
- The two portions of the flood defense system that failed most comprehensively when Katrina hit were officially rated as 90% and 98% complete.

What are the lessons of Katrina?

- Katrina is not at all unrepresentative as an example of flood defense by the federal government through the USACE.
- Clearly, though, it is not necessarily representative of efforts by all organizations, private and public, everywhere in the world, to deal with sea level rise.
- Nevertheless there are some features of the New Orleans/ Katrina experience which may have some general applicability.

- What is involved here is infrastructure that is generally supplied by governments.
- The costs of this type of infrastructure are mainly fixed costs, not variable costs.
- The infrastructure has to be built all at once – you can't finance it incrementally as more is used.
- Moreover, this type of infrastructure is (or is intended to be) relatively long-lived. Once built, the levees were expected to last for decades, even perhaps a century or more.
- Much of their lifetime benefit will go to future generations, but it is not possible to make those generations contribute to the up-front cost of building the levees now.
- Therefore, one naturally turns to the government to finance this infrastructure in the public interest.

- In short, this is very capital-intensive and long-lived infrastructure, heavily reliant on the public sector for its provision, and involving multi-jurisdictional participation and multi-jurisdictional conflicts.
- Wherever this constellation of factors occurs, it is likely to delay the implementation of adaptation and, perhaps also, impair its efficacy.
  - Lack of funds causes government to stretch out project completion
  - Inter-jurisdictional conflict slows project down

- Katrina is at least a salutary reminder not to assume that adaptation is instantaneous, costless, and perfectly effective.
- With this in mind, when one looks at the figures in the literature for the costs of sea wall protection and other adaptations, how should we think of those costs? Are those costs comparable to
  - (a) the $87 million that Congress thought this would cost;
  - (b) the $700+ million that it might have cost if had actually been completed in 2013 without anything untoward occurring;
  - (c) what has already been spend (<$700 million) plus what will be needed now (~$1.5billion) to fix the system?

Extreme events and risk aversion

- The prominence of extreme events has two important implications for both the assessment of economic impacts and the analysis of adaptation.
- First, it means that an analysis based on average conditions understates the true loss: the loss function is convex and the reduction in damage when conditions are milder than average is far smaller than the increase in damage when they are severer than average.
- Second, it raises the question of risk aversion.

- In most of the existing damage literature (for example, Nordhaus and Boyer, 2002), risk aversion is invoked only for the purpose of valuing economic damages for truly extreme events such as the disruption of the thermohaline circulation or the melting of the Greenland ice sheet.
- However, the other, more "normal," market impacts -- a sharp increase in the risk and severity of drought or wildfires or energy shortages -- may *also* elicit a positive risk premium from the communities confronted with these risks.
- These are mostly not risks that can be well hedged by risk pooling across the whole country. There is considerable empirical evidence that communities and individual decision makers are risk averse about these types of event, at least some of the time.

- Bringing risk aversion into the picture for the “normal” impacts of climate change has two consequences.
  - It is likely to raise the estimated cost of these adverse impacts of climate change (measured in terms of the WTP to avoid them).
  - It is likely to raise the value of adaptation, because adaptation serves as an insurance against the worse impacts. When this is taken into account, ceteris paribus it increases the likelihood that adaptation will take place.

Adaptation and insurance

- Insurance is a general metaphor for adaptation (and mitigation): incur costs now to lessen unpleasant risks in future.
- The insurance sector itself can be a key actor in inducing the adaptation that is needed.
- But this is not unproblematic.
  - Flood insurance in the US is a disaster.
  - Insurance coverage for Katrina has hardly been satisfactory.
  - Private insurance firms withdrew from US areas (California, Florida) after wildfires occurred.
  - California state government is terrified to discover that it is the insurer of last resort for private levees in state.

Distribution and adaptation

- Distributional issues associated with adaptation, create difficulties for its financing.
- The question is whether affairs can be arranged so that the people who benefit from the adaptation are the ones who pay for it, and conversely. This may not happen automatically.
- Adaptation is often likely to involve significant distributional issues partly because climate change itself is often a major agent of re-distribution (some areas, sectors, occupations lose, while others gain).

- When defending against sea level rise, because of the high cost it is likely that a decision will be made to abandon *some* of the land threatened by inundation rather protect every last inch. But this imposes a loss on the owners of the unprotected land and they will oppose the defense system unless they are compensated.
- Poor people often may be more vulnerable to climate impacts than the rich; will they therefore be expected to pay more?

- In the real world distributional issues are highly important factors determining which actions are undertaken and which policies actually get implemented. Ignoring the distributional implications of adaptation is likely to lead to an over-optimistic assessment of how much adaptation occurs, and how quickly.

Adaptation in the short- & long-run

- It is commonly assumed that cost of a given adaptation will be lower in the long run than the short run. This is based on the Le Chatelier principle: more inputs are variable in the long run than in the short run; hence, long-run elasticities are larger (in absolute value) than short-run elasticities, and long-run costs are lower.
- Fisher, Hanemann, Roberts and Schlenker (2007) have identified a class of cases in agriculture where the long-run adaptation is likely to be smaller and *more* expensive than the short-run adaptation.
- These are all cases where there is a limited *stock of adaptation potential* which is depleted as time passes.

- Pumping more groundwater is a short-run adaptive response to a reduction in the availability of surface water.
- But, to the extent that there is a fixed stock of groundwater, the cost of using pumped groundwater rises over time as the water table declines and groundwater has to be pumped from an increasing depth.
- Groundwater pumping becomes more costly as an adaptive response in the long-run than the short-run.

- Storage is widely used for storable agricultural commodities (e.g., grains, but *not* fruits and vegetables).
- When prices are low (or yields high), farmers put some fraction of their crop into storage rather than selling it immediately on harvest; conversely, when prices are high (or yields low), farmers boost this year's income by taking some previous years' production that they had put into storage and selling it.
- Selling crop from storage is an effective short-run adaptive response to a decline in yield induced, say, by a heat wave.
- This is not going to be effective over the long run, if the occurrence of heat waves persists for a long time. With persistent heat waves and yield declines, storage will be significantly depleted and withdrawal from storage will become less available as an adaptive responses.

- These examples were introduced by Fisher et al. to explain why an analysis of the impact of weather on current year profit from farming would not necessarily provide an upper bound on the effect of climate change, as claimed by Deschenes and Greenstone (2007).
- More generally, this point may apply to adaptation in a number of non-agricultural contexts, wherever there is a depletable and non-renewable stock of adaptive capacity.

Adaptation & institutional reform

- There certainly will be autonomous, private efforts at adaptation.
- But there are some key issues:
  - Co-ordination of adaptation
  - Dealing with public infrastructure
  - Providing of insurance
- Governments are likely to have a key role here: by themselves markets may not be adequate.

- Dysfunctional institutional structure – fragmentation, incoherence, conflict – is an impediment to adaptation.
  - In the US, we don't do land use planning.
  - Land use, water supply, fire control, public health, etc are highly decentralized
- All the more reason to highlight Institutional reform – getting our house in order – as a precondition for effective adaptation.
- There are not necessarily grounds for optimism.

In summary

- Adaptation involves some particular individuals or organizations taking some particular actions at some particular point in time.
- A generic analysis which identifies some action that could be undertaken to reduce the adverse impacts of climate change is not by itself adequate – or informative – as an assessment of what can be expected from adaptation.
- The mere existence of an adaptive action is a necessary but not a sufficient condition for assuming that it will be undertaken. It is essential to identify who is expected to undertake the action, what motivates them, how the adaptation will be paid for if undertaken, and when and under what circumstances the parties are likely to decide to undertake it.
- This type of “thick analysis” is largely absent from the existing economic literature on adaptation.

Thank you!

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