Some comments on “Macroeconomic costs and benefits”

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Tensions

- Climate change stretches to the limit (and beyond it) how we usually do economic analysis.
- Temporal scale – effects play out over decades and centuries, with significant temporal interdependence
- Spatial scale – while a global focus may be appropriate for mitigation, impacts and adaptation require a local focus.
- Sectoral scale – the use of energy pervades the modern economy; affects all economic sectors, but differentially, with different costs and potential for mitigation and adaptation.

Why we need to pay attention to climate damages

- The standard practice in CGE and some other macroeconomic modeling is to assume separability in the utility function between market and non-market commodities.
- This is done for mathematical tractability.
- Hence, non-market impacts of climate change have no impact on the economy.
- Carbone & Smith (2010, 2013) have shown how to calibrate a small, non-separable CGE model, and have demonstrated that this has significant market effects.
- Starting a collaboration with EU-JRC to introduce this into PESETA modeling exercise.

- An implication is that the conventional distinction between macro-economic and micro-economic analysis may be less relevant.
  - Need to be able to model on different spatial and temporal scales, and to accommodate different degrees of sectoral disaggregation.
  - Requires a different computational strategy.
- Another distinction involves methods of empirical calibration
  - Modeling levels (calibration to one or two years of data)
  - Modeling change (Calibrating to multiple-year series of data)

The curse of aggregation

- Given the burden of the temporal and spatial scales associated with climate impacts, many economic modelers resort to high levels of aggregation.
- Aggregation massively distorts – understates – the prospective damages from climate change.

Two problems with high degree of spatial aggregation

- Global average annual temperature – or the change therein – is a poor summary statistics for impacts on human wellbeing.
  - Majority of world population lives on land (not ocean) and at higher latitudes where warming is above average.
  - Need population weighted ΔT.
- With convex damage function, use of change in average temperature understates damages.

- Much of the existing economic literature focuses on the change in *global average* temperature when assessing impacts. That can be very misleading. In California, for example, local summer time temperature is key to many of the impacts. This is more than twice the global average ΔT.

HOW TO CHARACTERIZE THE CHANGE IN TEMPERATURE, 2070-2099, USING HADCM3			
		EMISSION SCENARIO**	
		A1fi	B1
Change in global average annual temperature		4.1	2
Change in statewide average annual temperature in California*		5.8	3.3
Change in statewide average winter temperature in California*		4	2.3
Change in statewide average summer temperature in California*		8.3	4.6
Change in LA/Sacramento average summer temperature		~10	~5
*Change relative to 1990-1999. Units are ˚C			

Using the global annual average ΔT understates the impact.

Aggregation systematically biases down the damage estimate

- With convex damage function (increasing marginal damage), aggregation understates damages:

$$E\{D(\Delta T)\} > D(E\{\Delta T\}).$$

- A local approximation:

$$E\{D(\Delta T)\} = D(E\{\Delta T\}) + \sigma_\Delta^2 D''(E\{\Delta T\})$$

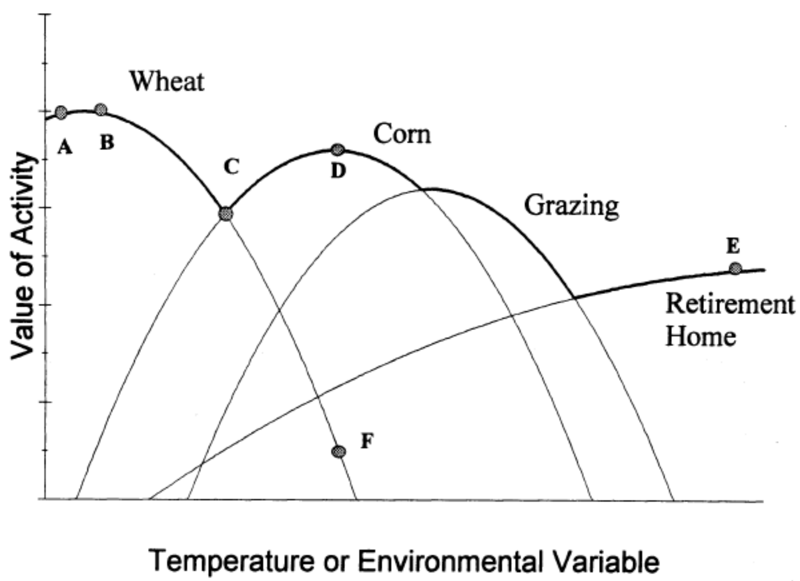
- The larger σ_Δ^2 and the larger $D''(\circ)$, the more $D(E\{\Delta T\})$ understates the aggregate damage $E\{D(\Delta T)\}$.

The importance of extreme events

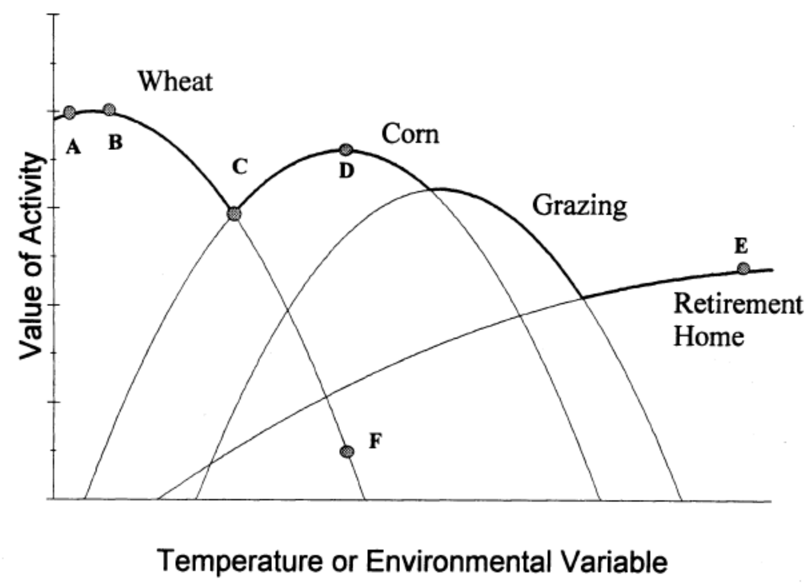
- For the next 40-50 or more, the economic damages from climate change will be dominated by extreme events.
  - These are not well reflected in climate projections (too coarse a temporal scale to be visible)
  - Require some form of spatial downscaling to become visible

The standard paradigm

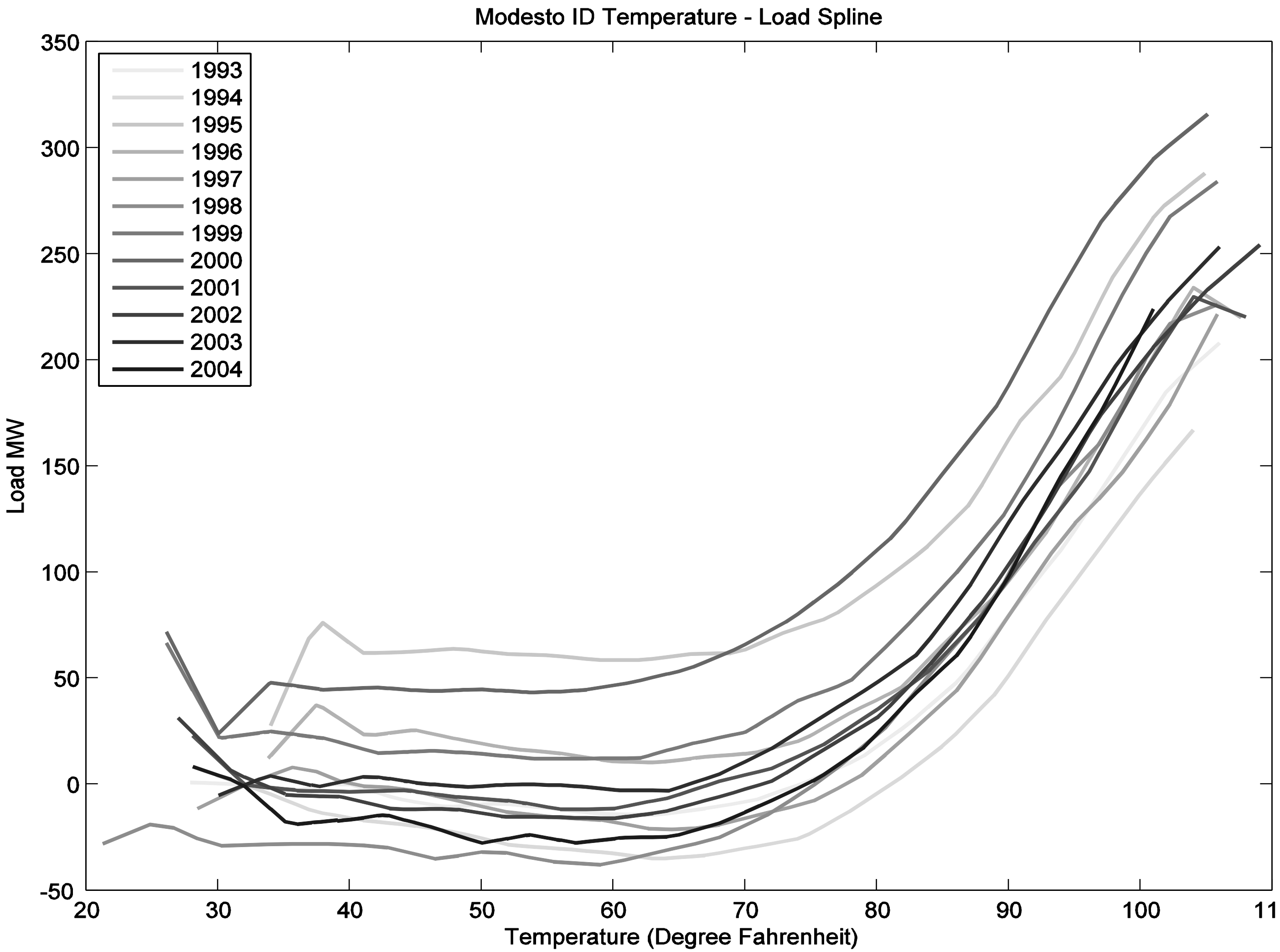
- Climate change brings benefits for small temperature increases, though damages for large increases.
- To allow for this, the practice developed of using quadratic functions to represent economic impacts.



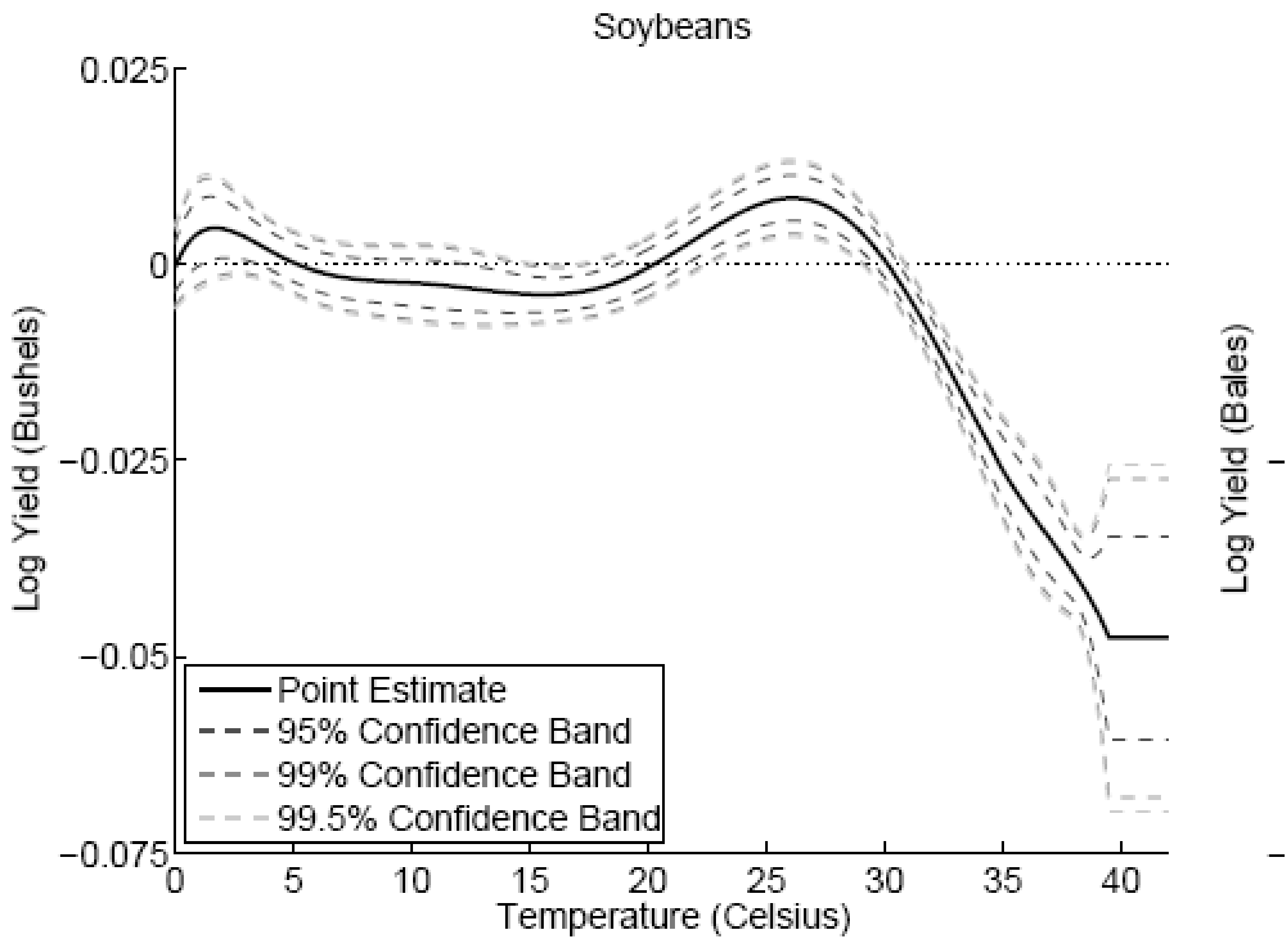
- The quadratic function implies symmetry between benefits and harms as temperature rises.
- The quadratic form is just an assumption. Not based on empirical evidence.
- The empirical evidence suggests otherwise.



Modesto Hourly Load/Temp (Aufhammer) This is not symmetric.



Asymmetric Relation of Temperature and Crop Yield Schlenker & Roberts (PNAS, 2009)



- The asymmetric form implies that large damages are associated with extreme heat.

- What proportion of the expected total damage is attributable to
  - Change in temperature within the normal range (8-32C)
  - Change in precipitation
  - Change in temperature above 34C

Schlenker, Hanemann, Smith (2006)

TABLE 5—DECOMPOSITION OF RELATIVE CHANGES IN FARMLAND VALUE DUE TO EACH INDIVIDUAL CLIMATIC VARIABLE

Variable	2020–2049 Average (%)				2070–2099 Average (%)			
	Mean	Min.	Max.	σ	Mean	Min.	Max.	σ
Hadley HadCM3—Scenario B1								
Degree days (8–32°C)	−0.96	−26.83	24.33	12.11	−4.44	−41.73	49.83	20.13
Degree days (34°C)	−11.17	−33.66	2.75	4.82	−26.21	−59.01	−1.86	9.57
Precipitation	1.02	−19.51	13.26	4.99	1.11	−21.31	11.33	4.35
Total impact	−10.46	−58.58	28.02	16.21	−27.37	−78.77	44.15	22.58
Std. error, total impact	(2.89)	(4.85)	(4.51)		(4.90)	(4.83)	(8.93)	
Hadley HadCM3—Scenario B2								
Degree days (8–32°C)	−1.38	−31.50	30.37	14.02	−6.79	−45.71	60.91	22.40
Degree days (34°C)	−19.77	−42.84	−2.09	7.35	−29.79	−73.26	−8.20	12.73
Precipitation	−1.22	−30.61	13.42	5.44	0.18	−37.45	13.70	5.84
Total impact	−20.57	−67.67	34.41	18.66	−31.61	−88.28	52.37	26.57
Std. error, total impact	(3.44)	(4.75)	(5.70)		(5.17)	(3.66)	(11.20)	
Hadley HadCM3—Scenario A2								
Degree days (8–32°C)	−1.44	−30.12	30.11	14.19	−14.90	−52.76	80.70	26.54
Degree days (34°C)	−20.12	−49.19	−3.96	8.12	−56.53	−84.78	−23.59	10.85
Precipitation	−0.32	−28.56	8.94	3.83	−2.70	−41.48	15.83	7.62
Total impact	−20.21	−69.31	29.70	19.72	−61.64	−94.72	27.87	20.25
Std. error, total impact	(3.58)	(4.86)	(5.22)		(6.01)	(2.44)	(11.48)	
Hadley HadCM3—Scenario A1FI								
Degree days (8–32°C)	−0.54	−28.82	31.07	13.28	−23.29	−56.83	91.38	27.10
Degree days (34°C)	−24.99	−50.49	1.04	9.42	−63.16	−90.97	−20.08	13.39
Precipitation	−0.22	−15.15	13.28	4.39	−0.80	−41.66	18.74	9.20
Total impact	−24.50	−60.38	23.83	18.68	−68.54	−96.95	39.61	21.79
Std. error, total impact	(4.00)	(5.61)	(4.65)		(5.90)	(1.86)	(13.85)	

- Most of the damages to US agriculture from climate change are associated with extreme events.
  - 80-90% of the damage to US agriculture -- earlier in the century (2020-2049) is estimated to be associated with the increase in extreme heat events (degree days over 34C) rather than with the change over the normal weather range (degree days within the range 8-32C) and the change in precipitation.
  - 60% of the projected economic damage to US agriculture at the end of the century is associated with extreme heat.
- This is probably true for many other types of impact as well. They occur when a threshold is passed. They result in a probability distribution of damages with a long right tail.
- Weitzman has emphasized the issue of fat tails in context of updating a prior. There are also physical reasons – thresholds – why a fat tail may arise.

- Extreme events occur infrequently and, often, on fine spatial scale. Averaged on an annual scale for a country, they may hardly show up.
- A major component of the impact from extreme weather events is associated with the destruction of capital. Yet, many economic models don't track capital stocks. They annualize capital costs and combine capital and operating costs, hiding that destruction.
  - Issues of (i) financing, and (ii) timing of capital investment. Also, capacity constraints on replacing damaged capital stocks.
- Accounting effectively for extreme events in economic models is a challenge.

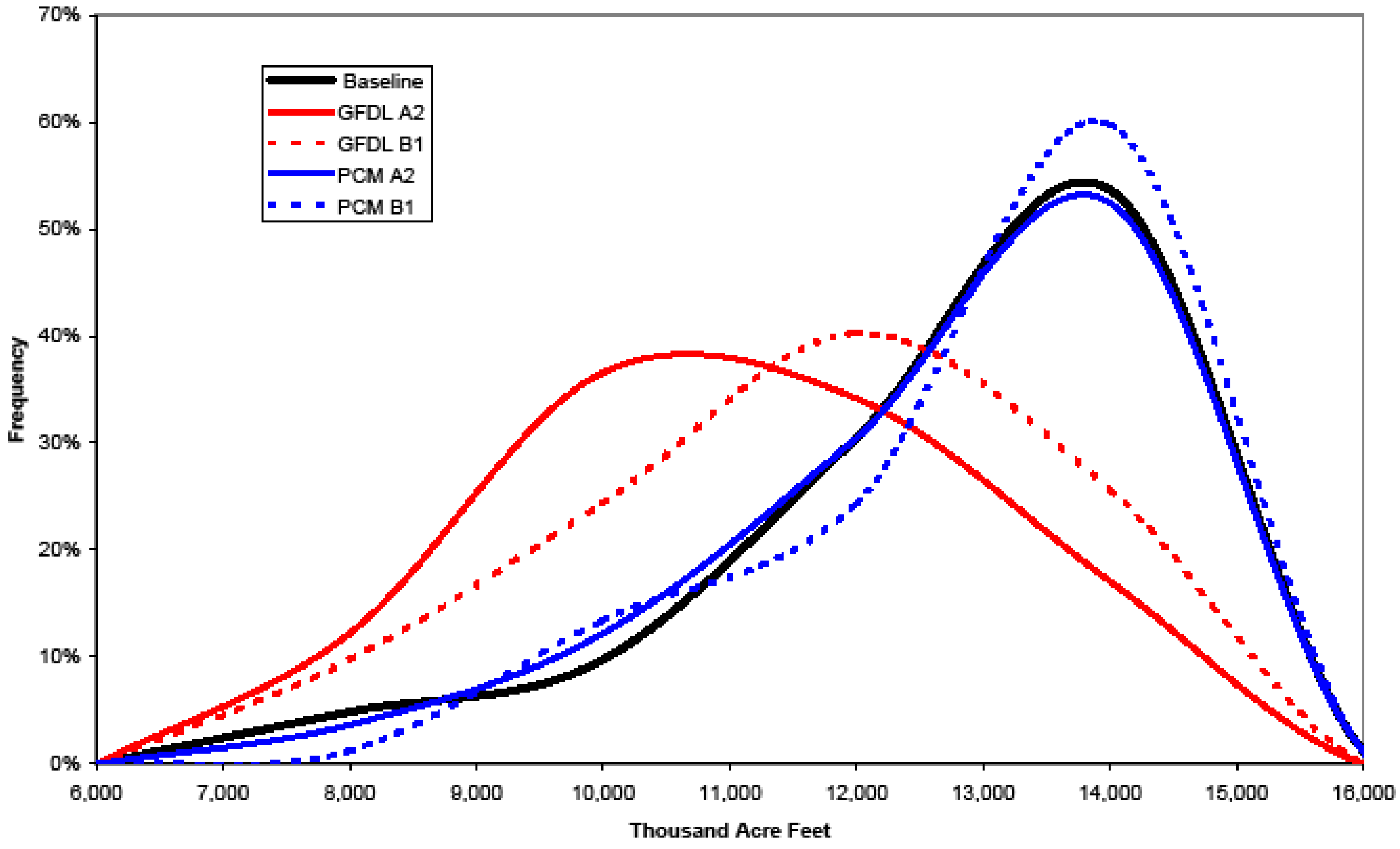
Downside risk

- This is a modification of the conventional theory of risk aversion.
- It is based on the notion that there is some asymmetry in risk attitudes towards outcomes.
- Downside outcomes (defined relative to some point) are weighed more heavily than upside outcomes.
- The concept was first applied in the financial literature in the 1970s – going broke is viewed differently than making a profit.
- It is likely to apply to many physical outcomes of climate change – e.g., asymmetry between having too little water and having too much.

Example of downside risk analysis
(Hanemann et al. 2009)

- Under the downscaled projections from the GDFL model (a medium-sensitivity GCM), but not the PCM model (a low-sensitivity GCM), there is a significant increase in downside risk with respect to water deliveries for agriculture in California's Central Valley.
- With downside risk aversion there is a significant risk premium associated with that change.

Annual deliveries to Central Valley agriculture, 2085



The static view of energy efficiency

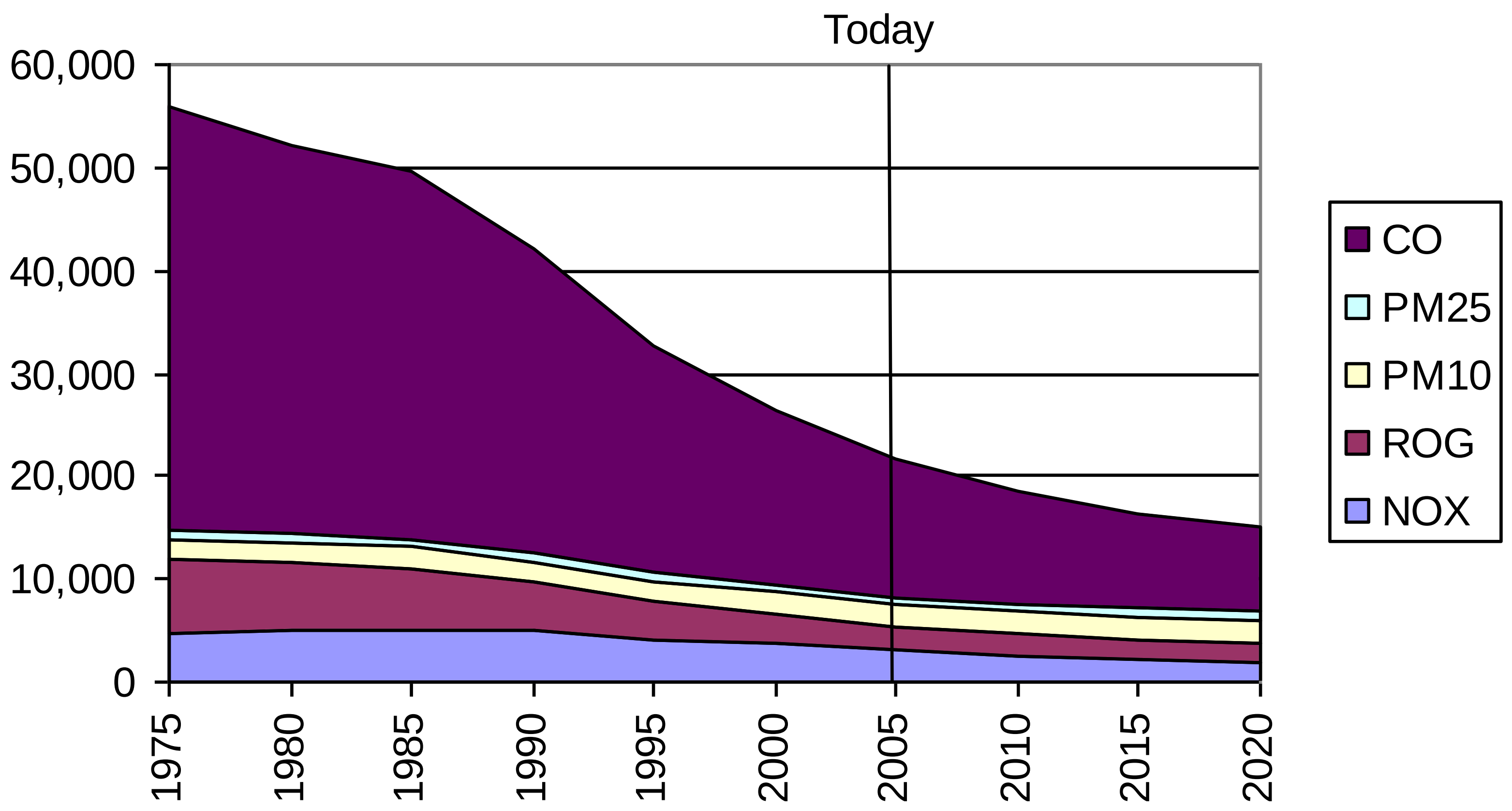
- Conventional economic analysis views energy efficiency in static terms, with reference to a given set of technologies.
- These technologies can be represented via a production function.
- In general, the production function allows for some degree of substituion among inputs, including energy and other inputs.
- The ratio of energy use per unit of output can be lowered by substituting other inputs for energy.
- Since other inputs also cost money, whether lowering the ratio of energy use per unit of output is cost-effective or profitable depends in part on the ratio of energy to tother input prices, and in part on the degree of substitutability allowed by the technology.

- In this analysis, whether or not raising energy efficiency is meritorious depends entirely depends on prices and the elasticity of substitution among energy and non-energy inputs.
- Also, the only way to accomplish a reduction in energy use per unit of output is to raise the price of energy relative to that of other inputs.
- And the way to reduce total energy use is either to lower output, or to raise energy efficiency by in turn raising the relative price of energy.

- While these observation as correct in theory, they are actually contradicted by some real-world experience.

- Especially California‘s experience in regulating air pollution since the 1950s and energy efficiency since 1974.

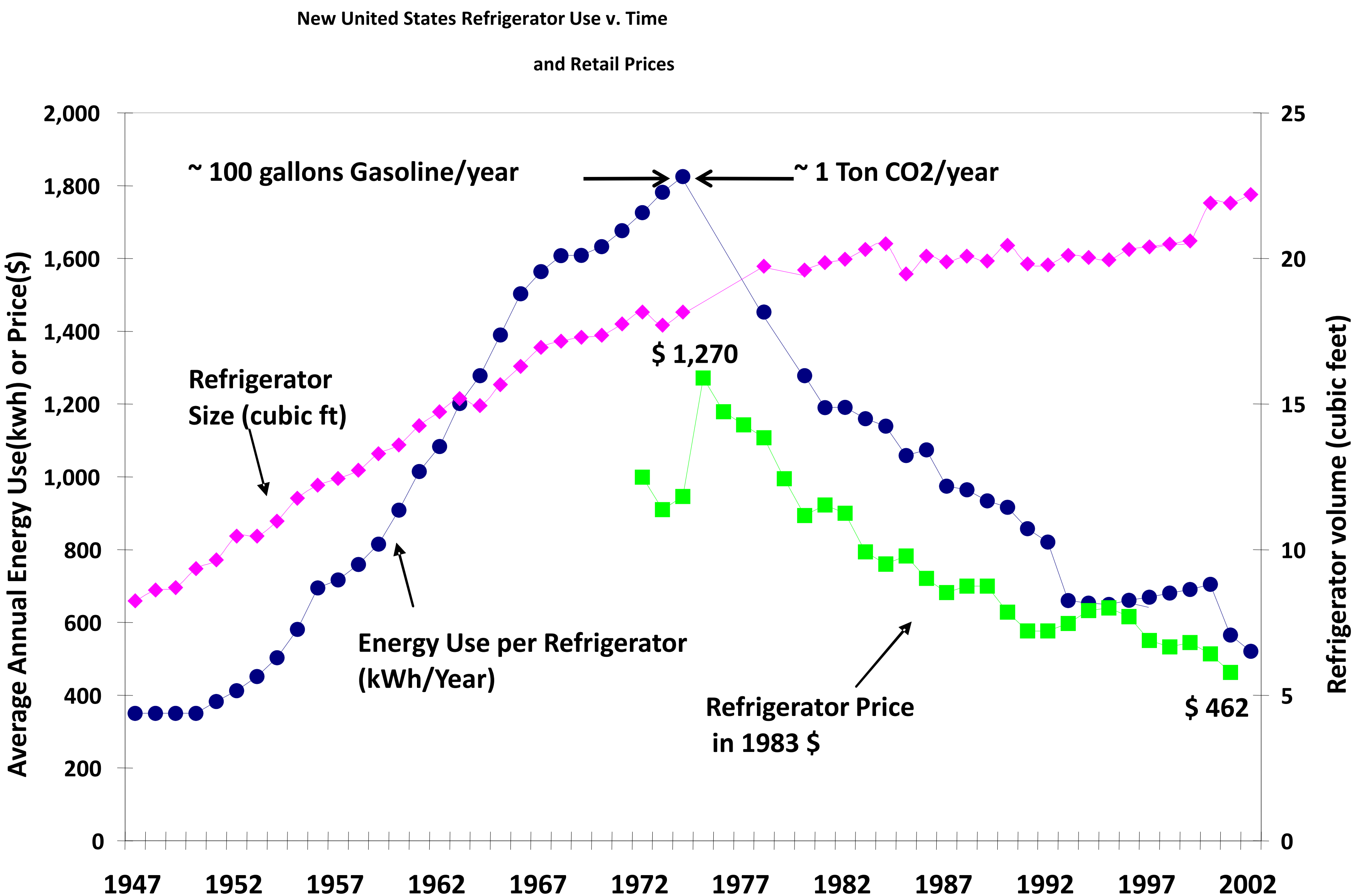
CARB Impact on Air Pollution Emissions in California (tons/day, annual average)



Source: California Air Resources Board 2005 Almanac (web)

- The point is that there was a massive reduction in air pollutants, while the amount of transportation services grew rather than being reduced.
- The population grew, and the number of cars per capita grew, but emisisons declined. And air pollution remained unpriced – there was no price signal guiding consumers‘ choices regarding transportation services.

- What happened, of course, was technological innovation in the design of motor vehicles – a shift in theproduction function.



Source: David Goldstein

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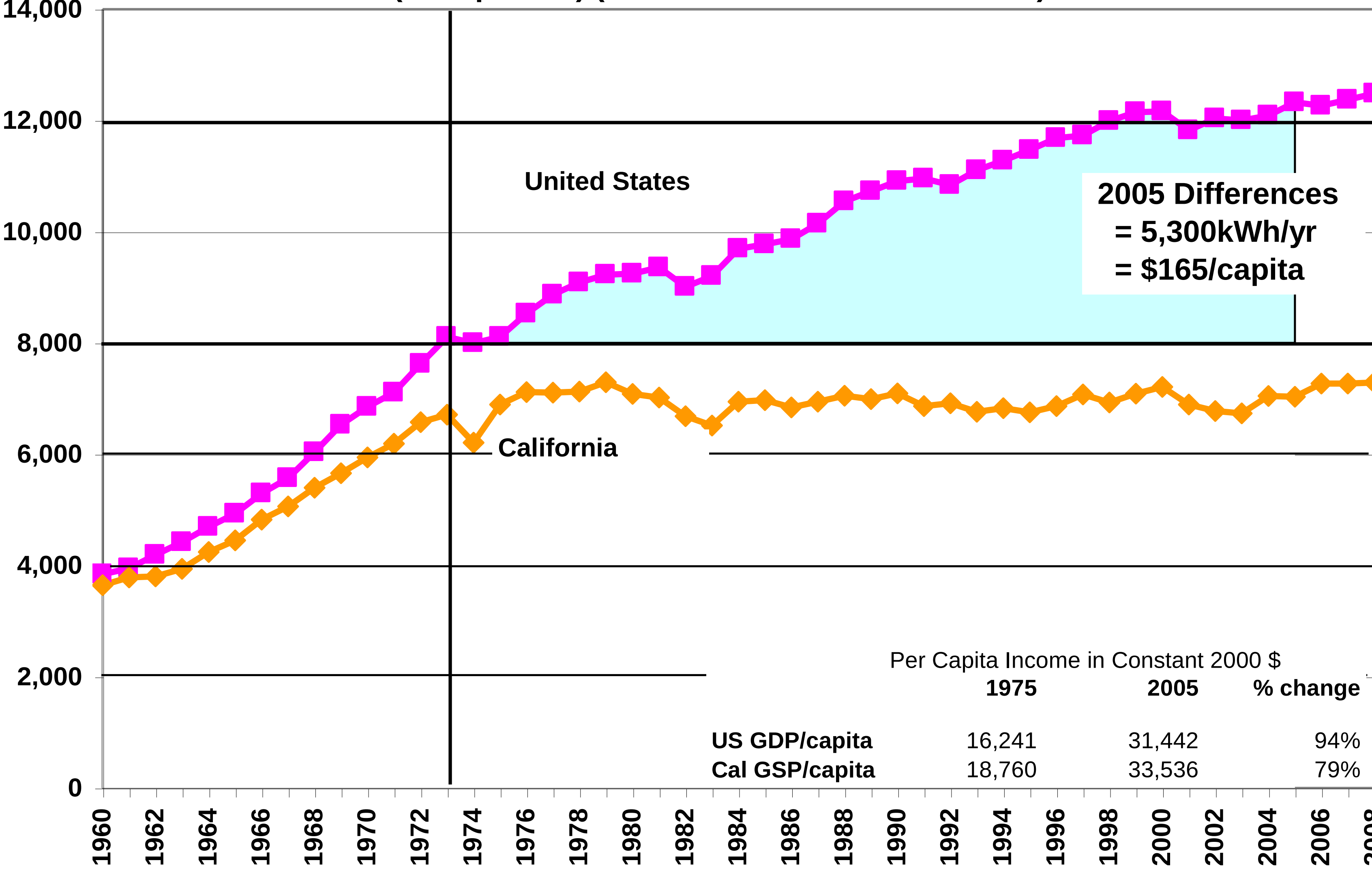
Per Capita Electricity Sales (not including self-generation) (kWh/person) (2006 to 2008 are forecast data)



Per Capita Income in Constant 2000 $

	1975	2005	% change
US GDP/capita	16,241	31,442	94%
Cal GSP/capita	18,760	33,536	79%

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- While income per capita has grown substantially in California over the past 35 years, and the number of electricity-using products has increased, per capita consumption of electricity has not increased.
- Part of this has been due to a price effect – the relative price of electricity has risen in Californiy – but not all is due to a price effect. It is due to regulation induced changes in technology (e.g., refrigerators) and regulation induced changes in consumer behavior.
- The result has been an inward shift in the demand function for electricity – not just a movement along a static demand function.

California has higher energy prices than other states, but a lower energy *bill.*

ELECTRICITY PRICES AND BILLS (INFLATION ADJUSTED) BY SECTOR

CALIFORNIA, U.S. WITHOUT CALIFORNIA, FLORIDA, TEXAS

		PRICE (CENTS PER kwh)	AVERAGE MONTHLY BILL		
		2007	1990	2007	% CHANGE 1990-2007
RESIDENTIAL	CALIFORNIA	$0.15	$86	$86	-0.2%
	REST OF THE U.S.	$0.11	$98	$98	0.4%
INDUSTRIAL	CALIFORNIA	$0.13	$740	$761	3%
	REST OF THE U.S.	$0.10	$573	$634	11%
COMMERCIAL	CALIFORNIA	$0.10	$14,603	$5,496	-62%
	REST OF THE U.S.	$0.07	$14,925	$13,971	-6%

- Economic analysis focuses typically on adjustments within a given structure.
- Climate change is more about changing the structure.

Components of California Program 2006 -

- Appliance standards & building energy codes
- Utility energy efficiency programs
- Rate decoupling
- Public goods charge
- Energy conservation incorporated in Integrated Resource Plan
- State energy conservation goal
- Renewable resource mandate
- Time of use pricing & advanced metering
- Carbon adder imposed by CPUC
- AB 32 sets cap on utility emissions
- Authorization of municipal energy finance districts
- Cap and trade (started January 2013)

The limits to price signals

- Economics focuses on price signals as motivators of behavior.
- The empirical experience with SO_2, lead and NOx is that emission price signal played little role in emission reduction. The individual caps on firms may have been more influential (Hanemann 2009, 2010).
- Non-price attributes can have a larger influence on behavior than prices.
- Changing the perceptions of attributes can be influential.
- So can changing the consideration set.
- A signal needs to be perceived and salient to have an effect.

Conceptualizing technological change

- Schumpeter's three stages
  - Invention [The first development of a scientifically or technically new product or process, which may involve both basic and applied research.]
  - Innovation [Accomplished when the new product or process is commercialized, i.e., made available on the market.]
  - Diffusion [The product or process comes to be widely used through adoption by many firms or individuals.]
- SO2 emission control involved diffusion.
- For climate change, the key is invention and innovation – development & commercialization of technologies that do not exist yet or, at best, are still highly experimental (e.g., CCS).

Invention/innovation coordination problem

- Economists focus mainly on knowledge externality as the market failure hampering invention/innovation.
- This overlooks the coordination problem in going from a raw idea to full-scale production and commercialization.
  - Actions by multiple agents have to occur in synchrony and in the right sequence over time
  - Uncertainty is an inherent barrier to coordinated decision-making
  - Policy goal is to promote coordination

Importance of complementary inputs

- Economists have overlooked the significance of complementary inputs as drivers of change.
- For containerized shipping, the complementary inputs included having a new type of crane, standardized containers, and docks with parking space for trucks.
- Having the right business model is a key complementary input to innovation
  – For energy conservation, it is financial intermediation by Energy Service Companies.
  – For CCS, it may be necessary for the coal companies to provide CCS services.