Non-Market Valuation: Environmental Externalities, Part III - Hedonics

Reed Walker
UC Berkeley

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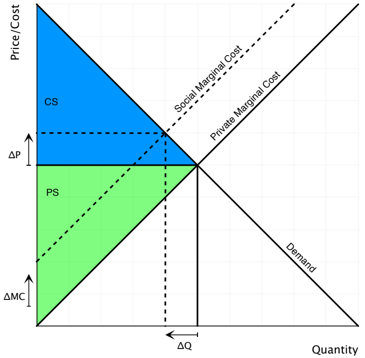
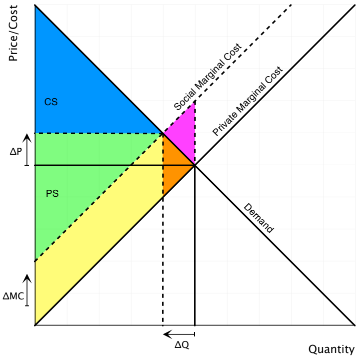
Quick Recap: Welfare Analysis





Externalities: Empirical Measurement

- Three primary approaches
  - Bottom-up damage aggregation **[DONE]**
  - Revealed preference, market-based methods [Today/Thursday]
  - Contingent valuation [Thursday or Next Week]

Revealed Preference, Motivating Example #1: Value of a Statistical Life

Intuition: People make tradeoffs that risk their lives often

- Look for cases where people make trade-offs
  - Deciding whether to take dangerous work (e.g., mining)
  - Deciding to wear a seat belt or purchase safe/unsafe car
- Price difference measures willingness to pay of...
  - Marginal person just indifferent between two choices
- Assumes everyone cares same amount as marginal person

Empirical VSL Examples:

- Ashenfelter & Greenstone: faster highway speeds, time saved vs. accident risk
- Viscusi et al. - compensating wage differentials in labor market

Revealed Preference, Motivating Example #2: School Quality

School Quality: Black 1999

- How do parents value schools that are provided for "free"?
- Could look at housing prices in districts and compare to school quality
- Problem: excludability - lots of things are changing in neighborhood that are correlated with school quality

Solution: Border analysis

- Within a neighborhood, some houses are on one side of school attendance boundary versus the other
- Compare housing values on either side of the border within the same neighborhood.

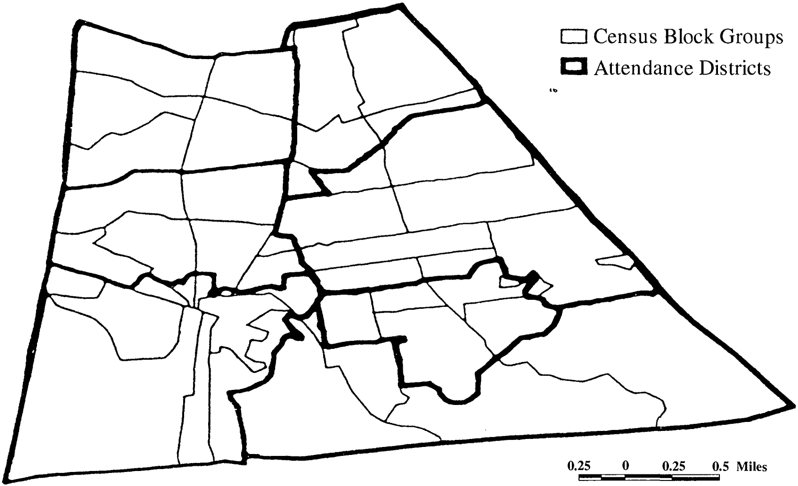


FIGURE II
Example of Data Collection for One City: Melrose
Census Block Groups and Attendance District Boundaries

TABLE II
REGRESSION RESULTS[a]
(ADJUSTED STANDARD ERRORS ARE IN PARENTHESES[b])
DEPENDENT VARIABLE = ln (HOUSE PRICE)

Distance from boundary:	(1) All houses[d]	(2) 0.35 mile from boundary (616 yards)	(3) 0.20 mile from boundary (350 yards)	(4) 0.15 mile from boundary (260 yards)	(5) 0.15 mile from boundary (260 yards)
Elementary school test score[c]	.035 (.004)	.016 (.007)	.013 (.0065)	.015 (.007)	.031 (.006)
Boundary fixed effects	NO	YES	YES	YES	NO
Census variables	Yes	No	No	No	Yes
N	22,679	10,657	6,824	4,594	4,589
Number of boundaries	N/A	175	174	172	N/A
Adjusted R^2	0.6417	0.6745	0.6719	0.6784	.6564

Hedonic Valuation - Overview

Hedonic model: key tool for evaluating consequences of policies that target supply of local public goods, environmental services, and urban amenities. e.g.,

- An explicit market for a clean local environment does not exist.
- Hedonic regression: commonly used to infer value of nonmarket amenities.

Appeal: simple relationship between hedonic prices and consumer demand

- Derivative of a hedonic price function with respect to a characteristic, at a point in time, is equal to a household's MWTP for the characteristic.
- Price functions can feasibly be estimated... also have a clear welfare interpretation.

Hedonic - Theory Overview (Rosen 1974)

A differentiated good can be described by a vector of its characteristics,

$$C = (c_1, c_2, ..., c_n)$$

In the case of a house, characteristics may include

- structural elements: # of bedrooms
- neighborhood public services: local school quality
- local amenities: (e.g., air quality).

Housing prices can be written as

$$P = P(c_1, c_2, ..., c_n)$$

The partial derivative of $P(\cdot)$ with respect to the nth characteristic, $\partial P / \partial c_n$, is referred to as the marginal implicit price.

Hedonic - Theory Overview, Consumer Side

Utility a function of characteristics C and numeraire X (price normalized to 1)

$$u = u(X, \mathbf{C})$$

with budget constraint $I - P - X = 0$

Maximizing subject to budget constraint reveals

$$\frac{\partial U / \partial c_j}{\partial U / \partial x} = \frac{\partial P}{\partial c_j}$$

In equilibrium, MWTP $=$ marginal cost of provision

Hedonic - Theory Overview, Consumer Side

WTP for characteristic c_j obtained by substituting budget constraint, inverting, and solving for c_j

$$B_j = \underbrace{B_j(I - P, c_j, \mathbf{C}^*_{-J}, u^*)}_{\text{Bid/indifference curve}}$$

where u^* is highest level of utility attainable given budget constraint and $\mathbf{C}^*_{-J}$ is optimal quantities of other characteristics.

Bid (or indifference) curve: reveals amount that individual would pay for different values of c_j, holding utility constant.

Hedonic Price Schedule, Consumer Side

Hedonic Price Schedule: heterogeneity in individuals' bid functions leads to differences in the chosen quantities of a characteristic

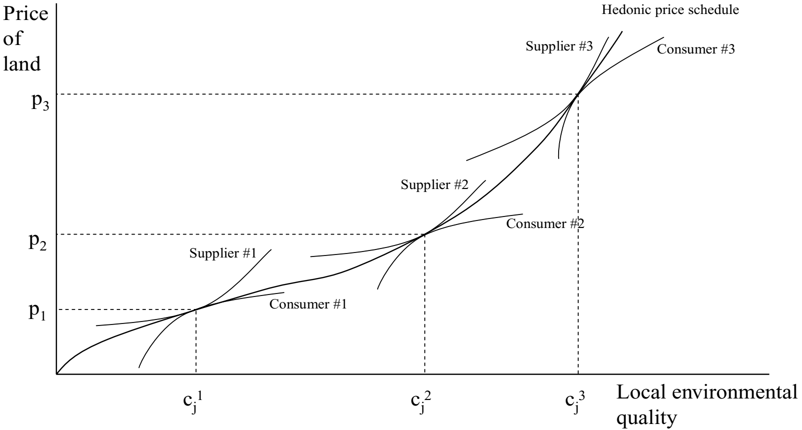


FIGURE Ia
Bid Curves, Offer Curves, and the Equilibrium Hedonic Price Schedule in a Hedonic Market for Local Environmental Quality

Hedonic - Theory Overview, Producer Side

Suppliers of housing services:

- suppliers are heterogeneous because of differences in their cost functions
- e.g. could be costly to provide clean air next steel plant

Invert supplier's profit function: offer/isoprofit curve for the characteristic c_j

$$O_j = O_j(c_j, \mathbf{C}^*_{-j}, \pi^*)$$

HPS: formed by tangencies between consumer bid and supplier offer functions

- At each point, marginal price of characteristic is equal to an individual's MWTP and supplier's marginal cost of producing it

Hedonic Price Schedule, Equilibrium

HPS can be used to infer welfare effects of a marginal change in characteristic

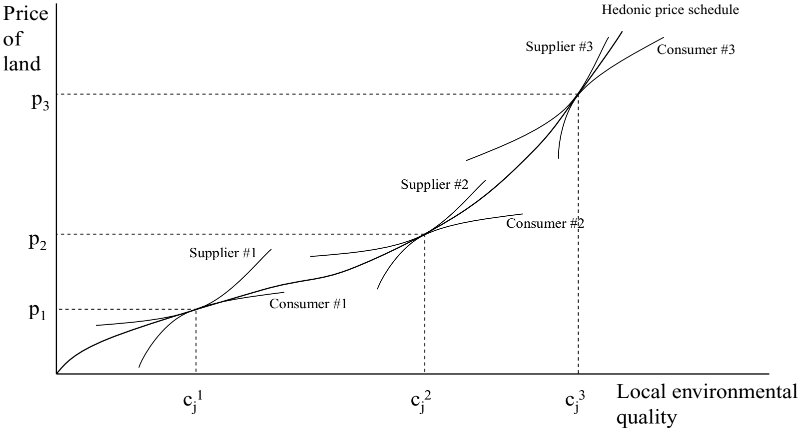


FIGURE Ia
Bid Curves, Offer Curves, and the Equilibrium Hedonic Price Schedule in a Hedonic Market for Local Environmental Quality

Hedonic Price Schedule: Non-Marginal Changes

What about non-marginal changes? Policy counterfactuals, etc...

- Starts to get a bit murky empirically
- What if HPS shifts (i.e. due to re-sorting of consumers/producers)?

Two-Step Approach: Rosen (1974)

- In theory, hedonic method can recover entire demand function.
- Step 1: Identify marginal implicit prices for different quantities of characteristic
- Step 2: See how these vary as a function of demand shifters
    - Challenge: demand shifters correlated with both price and quantity

Hedonic - From Theory to Empirics

Consistent estimation of a single marginal implicit price is difficult

- Much less entire hedonic price schedule
- Much less MWTP function / demand curve

A brief walk-through some of the empirical challenges WRT:

- Identification challenges
- Interpretation challenges

Empirical Challenges in Practice #1

Spatially Correlated Unobservables: Cross-sectional hedonic methods may be severely biased

Example: Lots of reasons why houses in areas with low air quality are priced lower (observed and unobserved)

Solution:

- Take correlated unobservables seriously
- Location fixed effects, difference in differences, RD, IV, etc...

Still faces some additional challenges... and may raise a few more...

Empirical Challenges in Practice #2

Treatment Effect Heterogeneity: What does OLS/IV give us in the presence of treatment effect heterogeneity?

- IV: LATE for compliers
- OLS: Weighted average where weights proportional to conditional variance of outcome with respect to amenity

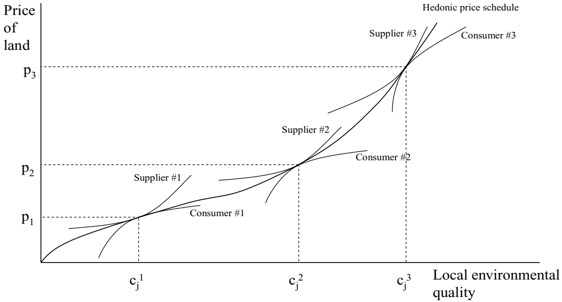


FIGURE Ia
Bid Curves, Offer Curves, and the Equilibrium Hedonic Price Schedule in a Hedonic Market for Local Environmental Quality

Empirical Challenges in Practice #3

Marginal versus Non-marginal Changes

- Theory suggests that marginal changes will give us marginal WTP based on gradient of hedonic pricing function, but what about non-marginal changes?
- Need to know inverse demand functions and supply functions for all consumers + suppliers...

Solutions in Literature

1. Make assumptions about preferences and distribution of preference heterogeneity [thursday, maybe?]
    - Delivers households' WTP ***functions*** for amenities
    - Costs of imposing additional structure...
    - Kind of give up on spatially correlated unobservables...
2. Handwave + additional assumptions (e.g. localized externalities, no shifting in hedonic pricing function, etc...)

Empirical Challenges in Practice #3

Two Views in the Literature About Valuing Non-Marginal Changes

1. Impossible Empirically: but let's sketch out some assumptions for which we can use first stage estimates to say something about Δ welfare

2. Maybe Possible Empirically: need strong assumptions for identification
   - Ekeland, Heckman, and Nesheim (2004) outline assumptions needed to identify demand (and supply) in hedonic model with data from a single market.
   - Heckman, Matzkin, and Nesheim (2005, 2010a) + Bishop and Timmins (2015) discuss strategies for imposing functional form restrictions to map quantities of characteristics demanded into demands.

To do welfare analysis, either approach requires strong assumptions:

- Recent work by Banzhaf (2015) highlights these tradeoffs/assumptions

Empirical Challenges in Practice #4

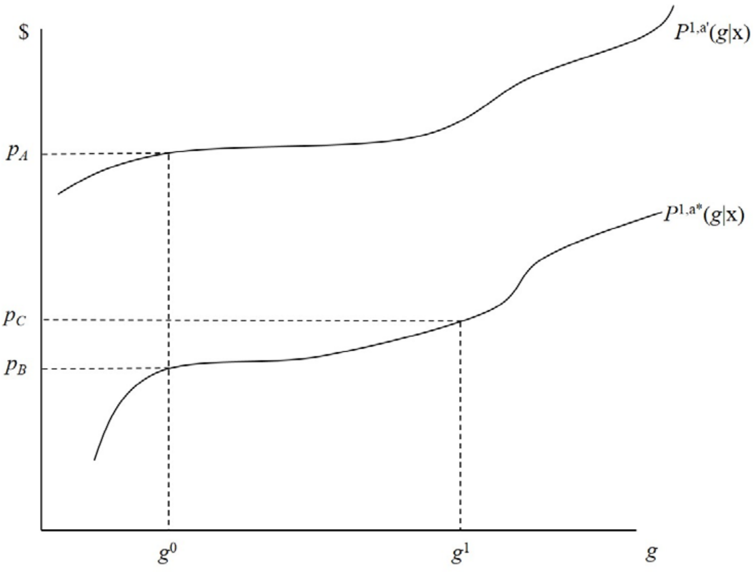
Shifts in the Hedonic Pricing Schedule

- Large changes in amenities can lead to shifts in the hedonic pricing schedule reflecting different individual preferences, income, amenities, etc...
- Large change in the supply of an amenity will shift the price of the amenity as well as of substitutes, thus shifting the hedonic price function.
- How to interpret empirical estimates?

<u>This is particular salient in the case of:</u>

- Large, non-marginal changes in amenities
- Quasi-experiments that use changes *over time* for identification
    - Especially long differences

Policy Change with Shifting Hedonic Pricing Schedule



What do Quasi-Experimental Hedonic Estimates Deliver?

A body of recent work that seeks to explain what quasi-experimental hedonic estimates are actually estimating

- Hint: may not always be MWTP

Representative Papers:

- Kuminoff and Pope (2014)
- Banzhaf (2015)
- Klaiber and Smith (2013)

Might be able to bound MWTP using some more reasonable assumptions

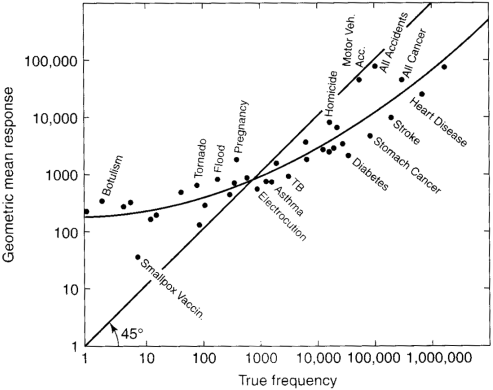
- e.g. Banzhaf (2015)

Other Assumptions Underlying Revealed Preference Approach

Benefits may be improperly valued by revealed preference methods if...

- Imperfect information (Gao, Song, Timmins, 2021)
- Credit constraints (Berkouwer 2022)
- Other constraints (e.g., discrimination; Christensen and Timmins 2021)

These are frontier issues that are just now being explored rigorously.



Back to Heterogeneity: What Does it Mean in Hedonics?

Frontier Questions:

We have a fairly rudimentary understanding of non-market valuation via hedonics

- Heterogeneity in WTP (e.g. by income)
- Credit constraints, information, etc...

Similar to adaptation literature – can cut the data one way or another, but...

- without explicit manipulation of underlying drivers of effect heterogeneity (e.g. income, amenities), evidence is speculative.

Empirical Example: Greenstone and Gallagher (2008)

What is the question and why is it interesting?

- We spend lots of money cleaning up Superfund sites without a good understanding of benefits

Why is the existing literature crappy, non-existent, and/or unresolved?

- Existing literature is not well identified and/or comprehensive (i.e. examines 30 out of 1200 sites)

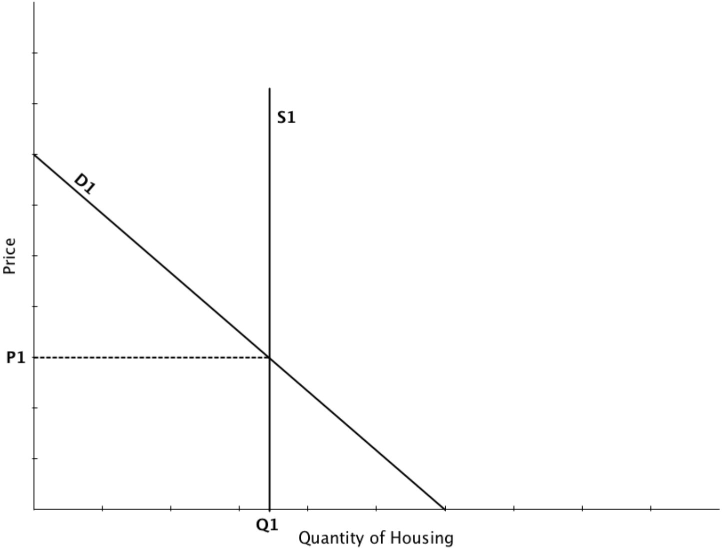
What is this paper going to do to solve it?

- New research design exploiting discontinuities in treatment assignment
- Comprehensive data on all Superfund sites

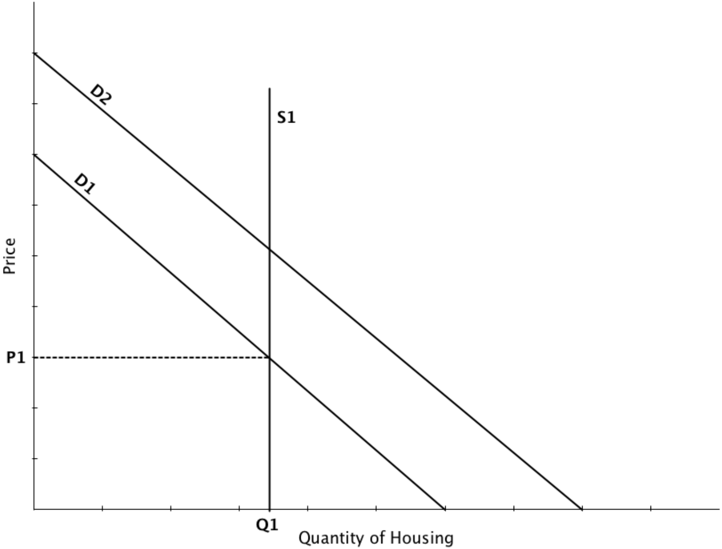
Study Background

- Idea of paper
  - EPA was allocated funding for 400 cleanups
  - EPA initially reduced list from 15000 to 690 sites
    - List of worst sites that need clean-up
  - Implemented Hazardous Ranking System (HRS) for each site
  - Cleanup of sites with highest score
- Cutoff not known a priori
  - Ended up being 28.5
- Compare sites
  - Scores below 28.5
  - Scores above 28.5

Effect on Price: Perfectly Inelastic Supply



Effect on Price: Perfectly Inelastic Supply



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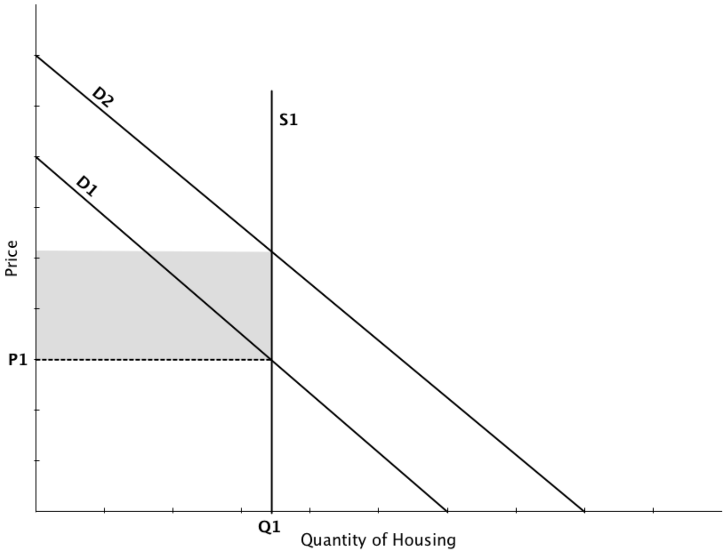

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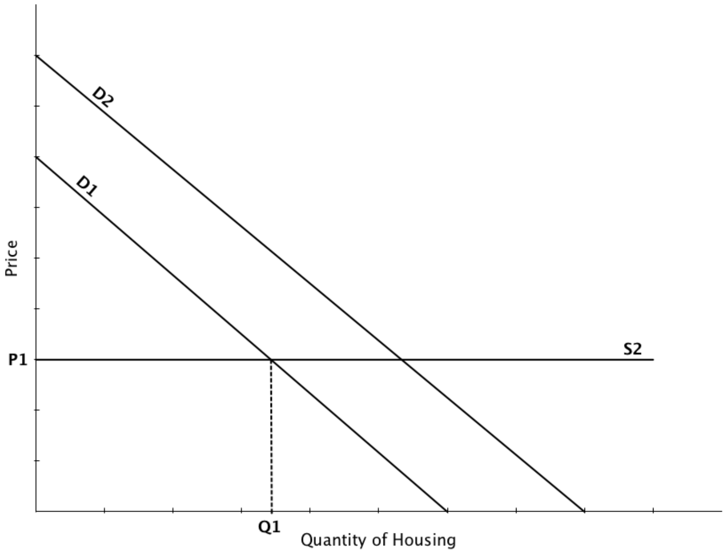

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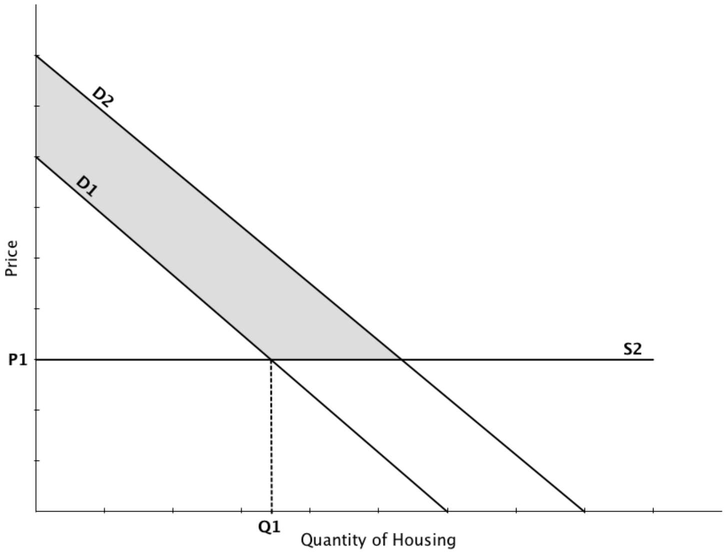


Empirical Takeaways

Focusing just on price changes in a market might be misleading:

- In the limiting case of perfectly elastic supply, price doesn't change but welfare increases!
- Need to explore changes in both price and quantity

Transitional dynamics:

1. Short run remediation costs (e.g. noisy trucks)
2. Longer run benefits

Decadal nature of data precludes them from estimating/understanding #1

Data

- Census tract estimates of *median* housing values
  - Use 2000 tract boundaries
  - Recalculate 1980 and 1990 Census
    - Match 2000 boundaries
  - Problem: only available for urban areas
    - Some areas are missing in earlier years
- Other socio-economic variables
- Questions?
  - Are Superfund cites randomly allocated
  - Are subset of sites for which Superfund data is available representative?

Data

TABLE II
MEAN CENSUS TRACT CHARACTERISTICS BY CATEGORIES OF THE 1982 HRS SCORE

	NPL site by 2000 (1)	No NPL site by 2000 (2)	HRS < 28.5 (3)	HRS > 28.5 (4)	HRS > 16.5 & < 28.5 (5)	HRS > 28.5 & < 40.5 (6)	*p*-Value (1) vs. (2) (7)	*p*-Value (3) vs. (4) (8)	*p*-Value (5) vs. (6) (9)
No. of Census tracts	985	41,989	181	306	90	137	—	—	—
Superfund cleanup activities									
Ever NPL by 1990	0.7574	—	0.1271	0.9902	0.2222	0.9854	—	**.000**	**.000**
Ever NPL by 2000	1.0000	—	0.1602	0.9902	0.2667	0.9854	—	**.000**	**.000**
1980 mean housing prices									
Site's Census tract	58,045	69,904	45,027	52,137	46,135	50,648	**.000**	**.000**	.084
2-mile-radius circle around site	56,020	—	48,243	53,081	48,595	52,497	—	.016	.179
3-mile-radius circle around site	56,839	—	51,543	54,458	49,434	53,868	—	.257	.126
1980 housing characteristics									
Total housing units	1,392	1,350	1,357	1,353	1,367	1,319	.039	.951	.575
Mobile homes (%)	0.0862	0.0473	0.0813	0.0785	0.0944	0.0787	**.000**	.792	.285
Occupied (%)	0.9408	0.9330	0.9408	0.9411	0.9412	0.9411	**.000**	.940	.989
Owner occupied (%)	0.6818	0.6125	0.6792	0.6800	0.6942	0.6730	**.000**	.959	.344
0–2 bedrooms (%)	0.4484	0.4722	0.4691	0.4443	0.4671	0.4496	**.000**	.107	.417
3–4 bedrooms (%)	0.5245	0.5016	0.5099	0.5288	0.5089	0.5199	**.000**	.202	.586
Built last 5 years (%)	0.1434	0.1543	0.1185	0.1404	0.1366	0.1397	**.006**	.050	.844
Built last 10 years (%)	0.2834	0.2874	0.2370	0.2814	0.2673	0.2758	.506	.012	.723
No air-conditioning (%)	0.4903	0.4220	0.5058	0.4801	0.5157	0.5103	**.000**	.253	.870
Units attached (%)	0.0374	0.0754	0.0603	0.0307	0.0511	0.0317	**.000**	.040	.297

Data

TABLE II
MEAN CENSUS TRACT CHARACTERISTICS BY CATEGORIES OF THE 1982 HRS SCORE

	NPL site by 2000 (1)	No NPL site by 2000 (2)	HRS < 28.5 (3)	HRS > 28.5 (4)	HRS > 16.5 & < 28.5 (5)	HRS > 28.5 & < 40.5 (6)	*p*-Value (1) vs. (2) (7)	*p*-Value (3) vs. (4) (8)	*p*-Value (5) vs. (6) (9)
1980 demographics & economic characteristics									
Population density	1,407	5,786	1,670	1,157	1,361	1,151	**.000**	.067	.570
Black (%)	0.0914	0.1207	0.1126	0.0713	0.0819	0.0844	**.000**	.037	.926
Hispanic (%)	0.0515	0.0739	0.0443	0.0424	0.0309	0.0300	**.000**	.841	.928
Under 18 (%)	0.2939	0.2780	0.2932	0.2936	0.2885	0.2934	**.000**	.958	.568
Female head HH (%)	0.1616	0.1934	0.1879	0.1576	0.1639	0.1664	**.000**	.017	.862
Same house 5 yrs ago (%)	0.5442	0.5127	0.6025	0.5623	0.5854	0.5655	**.000**	**.001**	.244
> 25 no HS diploma (%)	0.3427	0.3144	0.4053	0.3429	0.3881	0.3533	**.000**	**.000**	.060
> 25 B.A. or better (%)	0.1389	0.1767	0.1003	0.1377	0.1092	0.1343	**.000**	**.000**	.036
< Poverty line (%)	0.1056	0.1141	0.1139	0.1005	0.1072	0.1115	**.003**	.109	.716
Public assistance (%)	0.0736	0.0773	0.0885	0.0745	0.0805	0.0755	.084	.041	.578
Household income	20,340	21,526	19,635	20,869	19,812	20,301	**.000**	.013	.486
1980 geographic distribution across Census regions									
Northeast (%)	0.3797	0.2116	0.3315	0.4771	0.3889	0.4234	**.000**	**.001**	.6063
Midwest (%)	0.2183	0.2320	0.3481	0.2255	0.3222	0.2847	.302	**.004**	.5507
South (%)	0.2355	0.3227	0.2155	0.1928	0.1889	0.2044	**.000**	.552	.7744
West (%)	0.1665	0.2337	0.1050	0.1046	0.1000	0.0876	**.000**	.989	.7565

Notes: Columns (1)–(6) report the means of the variables listed in the row headings across the groups of Census tracts listed at the top of the columns. In all of these columns, the sample restriction that the Census tract must have nonmissing house price data in 1980, 1990, and 2000 is added. Columns (7)–(9) report the *p*-values from tests that the means in different sets of the subsamples are equal. The 1980 mean housing price in the two-mile- and three-mile-radius circles are calculated as the weighted mean across Census tracts that fall within the circle, where the weight is the fraction of the tract's land area inside the circle multiplied by the tract's 1980 population. All other entries in the table refer to characteristics of the tracts where the sites are located (except the column (2) entries, which report the means in tracts without a site). The *p*-values less than .01 are denoted in bold. For the air-conditioning and bath questions, the numerator is year-round housing units and the denominator is all housing units. For all other variables in the "housing characteristics" category, the denominator is all housing units. In contrast to the remainder of the paper, the dollar figures are not adjusted for inflation.

Conventional OLS Research Design

- Traditional "cross-sectional" estimates

$$y_{c,2000} = \theta 1_{NPL,c,2000} + \mathbf{X}_{c,1980}\beta + \epsilon_{c,2000}$$

- Controls for 1980 characteristics (including mean housing values)
- Identifying assumption?

Conventional OLS Research Design

	(1)	(2)	(3)
A. All NPL sample, own Census tract observation			
1(NPL status by 2000)	0.040	0.046	0.067
	(0.012)	(0.011)	(0.009)
R^2	0.579	0.654	0.779
B. All NPL sample, 3-mile-radius circle sample observation			
1(NPL status by 2000)	0.030	0.060	0.106
	(0.011)	(0.013)	(0.011)
Ho: $>$ 0.046, p-value	.061	.862	.999
R^2	0.580	0.652	0.776
1980 ln house price	Yes	Yes	Yes
1980 housing characteristics	No	Yes	Yes
1980 economic and demographic variables	No	No	Yes
State fixed effects	No	No	Yes

Conventional OLS Research Design

	(1)	(2)	(3)
C. Restrict NPL sites to those in 1982 HRS sample, own Census tract observation			
1(NPL status by 2000)	0.071	0.076	0.057
	(0.016)	(0.015)	(0.013)
R^2	0.581	0.655	0.780
D. Restrict NPL sites to those in 1982 HRS sample, 3-mile-radius circle sample observation			
1(NPL status by 2000)	0.046	0.143	0.191
	(0.015)	(0.021)	(0.021)
Ho: $>$ 0.058, p-value	.215	.999	.999
R^2	0.580	0.653	0.777
1980 ln house price	Yes	Yes	Yes
1980 housing characteristics	No	Yes	Yes
1980 economic and demographic variables	No	No	Yes
State fixed effects	No	No	Yes

Conventional OLS Research Design

Empirical Takeaways from Naive Approach

- Authors suggest that results are sensitive and unstable
- Why would larger radius around plant have larger effects?
- Point estimates are quite heterogeneous (4.6% to 19.1%)

IV and RD Estimates

- IV and RD estimates

$$1_{NPL,c,2000} = \mathbf{X}_{c,1980}\Pi + \delta 1_{HRS,c,1982} + \eta_{c,2000}$$

- Use indicator (above 28.5) as an IV for NPL list placement, either...
  - Controlling for HRS quadratic, or
  - Using narrow bandwidth sample (i.e. $16.5 < HRS < 40.5$)

IV and RD Estimates

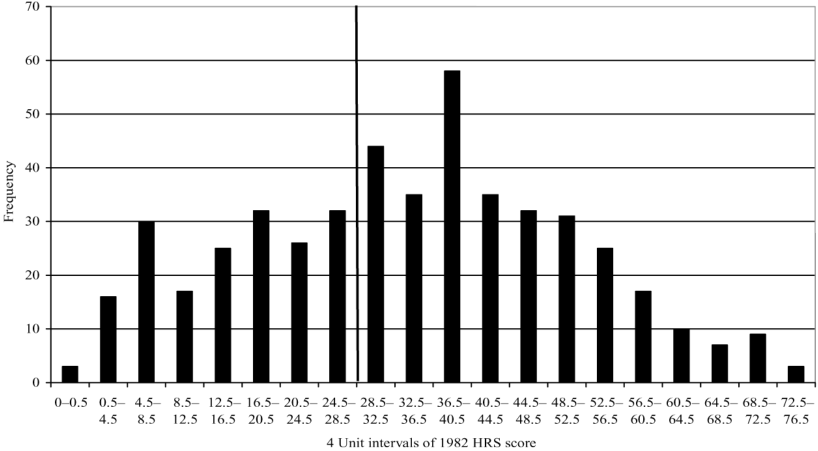


FIGURE III
Distribution of 1982 HRS Scores in the 1982 HRS Sample

IV and RD Estimates: Instrument Relevance

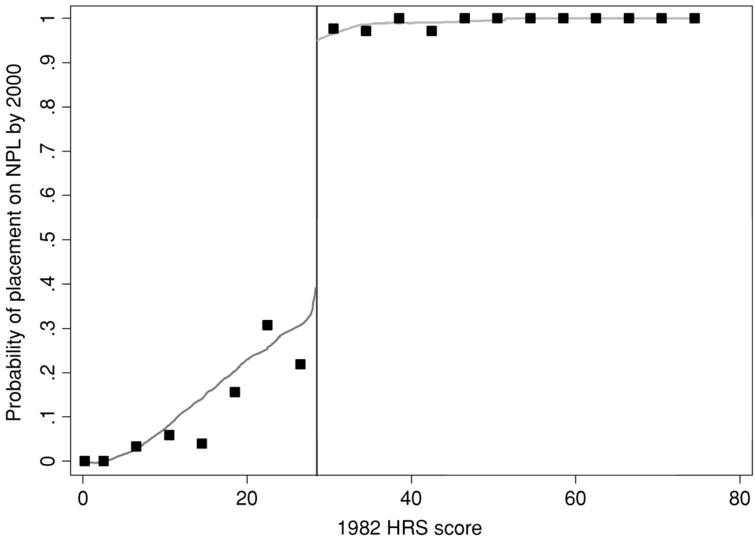


FIGURE IV
Probability of Placement on the NPL by 1982 HRS Score in the 1982 HRS Sample

IV and RD Estimates

					RD-style estimators		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			A. Own Census tract				
1(NPL status by 2000)	0.035	0.037	0.043	0.047	0.007	0.022	0.027
	(0.031)	(0.035)	(0.031)	(0.027)	(0.063)	(0.042)	(0.038)
1980 ln house price	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instrument for 1 (NPL 2000)	No	Yes	Yes	Yes	Yes	Yes	Yes
1980 housing charasteristics	No	No	Yes	Yes	Yes	Yes	Yes
1980 economic and demographic variables	No	No	No	Yes	Yes	Yes	Yes
State fixed effects	No	No	No	Yes	Yes	Yes	Yes
Quadratic in 1982 HRS score	No	No	No	No	Yes	No	No
Control for pathway scores	No	No	No	No	No	Yes	No
RD sample	No	No	No	No	No	No	Yes

IV and RD Estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
					RD-style estimators		
	B. Adjacent Census tracts						
1(NPL status by 2000)	0.071	0.066	0.012	0.015	−0.006	−0.002	0.001
	(0.031)	(0.035)	(0.029)	(0.022)	(0.056)	(0.035)	(0.035)
1980 ln house price	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instrument for 1 (NPL 2000)	No	Yes	Yes	Yes	Yes	Yes	Yes
1980 housing charasteristics	No	No	Yes	Yes	Yes	Yes	Yes
1980 economic and demographic variables	No	No	No	Yes	Yes	Yes	Yes
State fixed effects	No	No	No	Yes	Yes	Yes	Yes
Quadratic in 1982 HRS score	No	No	No	No	Yes	No	No
Control for pathway scores	No	No	No	No	No	Yes	No
RD sample	No	No	No	No	No	No	Yes

IV and RD Estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
					RD-style estimators		
C. Two-mile radius from hazardous waste sites							
1(NPL status by 2000)	0.021	0.019	0.011	0.001	0.023	–0.018	–0.007
	(0.028)	(0.032)	(0.029)	(0.023)	(0.054)	(0.035)	(0.034)
Ho: > 0.138, *p*-value	.000	.000	.000	.000	.018	.000	.000
1980 ln house price	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instrument for 1 (NPL 2000)	No	Yes	Yes	Yes	Yes	Yes	Yes
1980 housing charasteristics	No	No	Yes	Yes	Yes	Yes	Yes
1980 economic and demographic variables	No	No	No	Yes	Yes	Yes	Yes
State fixed effects	No	No	No	Yes	Yes	Yes	Yes
Quadratic in 1982 HRS score	No	No	No	No	Yes	No	No
Control for pathway scores	No	No	No	No	No	Yes	No
RD sample	No	No	No	No	No	No	Yes

IV and RD Estimates

	(1)	(2)	(3)	(4)	RD-style estimators (5)	(6)	(7)
D. Three-mile radius from hazardous waste sites							
1(NPL status by 2000)	0.059	0.055	0.035	–0.004	–0.027	–0.024	–0.006
	(0.033)	(0.038)	(0.031)	(0.022)	(0.051)	(0.034)	(0.034)
Ho: > 0.058, p-value	.483	.467	.236	.003	.048	.007	.031
1980 ln house price	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instrument for 1 (NPL 2000)	No	Yes	Yes	Yes	Yes	Yes	Yes
1980 housing charasteristics	No	No	Yes	Yes	Yes	Yes	Yes
1980 economic and demographic variables	No	No	No	Yes	Yes	Yes	Yes
State fixed effects	No	No	No	Yes	Yes	Yes	Yes
Quadratic in 1982 HRS score	No	No	No	No	Yes	No	No
Control for pathway scores	No	No	No	No	No	Yes	No
RD sample	No	No	No	No	No	No	Yes

IV and RD Estimates

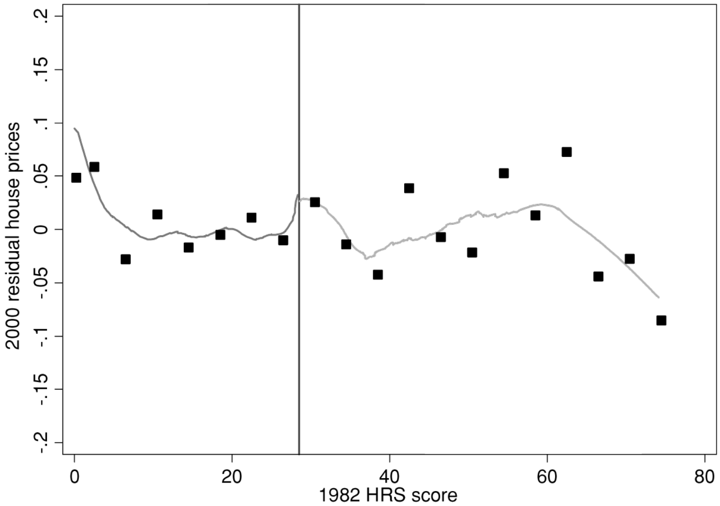


FIGURE V
Year-2000 Residual House Prices by 1982 HRS Score, Sample of Two-Mile-Radius Circles around 1982 HRS Sites

Sorting

			RD-style estimators		
	(1)	(2)	(3)	(4)	(5)
		A. Income and wealth			
Household income	2,698	1,431	−1,232	123	−593
[1980 mean: 42,506;	(1237)	(1302)	(3130)	(1900)	(2227)
2000–1980 mean: 14,301]					
Public assistance (%)	−0.007	−0.005	0.008	0.003	0.004
[1980 mean: 0.078;	(0.003)	(0.003)	(0.007)	(0.004)	(0.005)
2000–1980 mean: 0.000]					
College graduates (%)	0.001	−0.001	−0.009	−0.005	−0.010
[1980 mean: 0.134;	(0.007)	(0.007)	(0.019)	(0.011)	(0.013)
2000–1980 mean: 0.082]					
1980 dependent variable	Yes	Yes	Yes	Yes	Yes
State fixed effects	No	Yes	Yes	Yes	Yes
Quadratic in 1982 HRS score	No	No	Yes	No	No
Control for pathway scores	No	No	No	Yes	No
RD sample	No	No	No	No	Yes

Sorting

	(1)	(2)	(3)	(4)	(5)
			RD-style estimators		
B. Demographics demand shifters					
Population under age 6 (%)	0.000	−0.000	0.002	0.000	0.001
[1980 mean: 0.086;	(0.001)	(0.001)	(0.003)	(0.002)	(0.002)
2000–1980 mean: –0.019]					
Population over age 65 (%)	−0.000	−0.003	−0.014	−0.007	−0.005
[1980 mean: 0.106;	(0.004)	(0.004)	(0.009)	(0.005)	(0.005)
2000–1980 mean: 0.019]					
Black (%)	−0.015	−0.016	−0.007	−0.012	−0.008
[1980 mean: 0.088;	(0.008)	(0.007)	(0.018)	(0.010)	(0.009)
2000–1980 mean: 0.026]					
1980 dependent variable	Yes	Yes	Yes	Yes	Yes
State fixed effects	No	Yes	Yes	Yes	Yes
Quadratic in 1982 HRS score	No	No	Yes	No	No
Control for pathway scores	No	No	No	Yes	No
RD sample	No	No	No	No	Yes

Sorting

	(1)	(2)	(3)	(4)	(5)
			RD-style estimators		
	C. Total population				
Total population	1,864	514	−2,342	−23	−289
[1980 mean: 18,038; 2000–1980 mean: 1,226]	(526)	(522)	(1,556)	(809)	(811)
1980 dependent variable	Yes	Yes	Yes	Yes	Yes
State fixed effects	No	Yes	Yes	Yes	Yes
Quadratic in 1982 HRS score	No	No	Yes	No	No
Control for pathway scores	No	No	No	Yes	No
RD sample	No	No	No	No	Yes

Supply Effects

			RD-style estimators		
	(1)	(2)	(3)	(4)	(5)
Total housing units					
Two-mile radius from hazardous waste sites	332	94	−829	−208	−255
[1980 mean: 6,835; 2000–1980 mean: 853]	(139)	(147)	(349)	(210)	(187)
Three-mile radius from hazardous waste sites	1,046	292	−903	61	−77
[1980 mean: 15,657; 2000–1980 mean: 1,960]	(317)	(278)	(669)	(408)	(356)
1980 dependent variable and ln house price	Yes	Yes	Yes	Yes	Yes
1980 housing characteristics	No	Yes	Yes	Yes	Yes
1980 economic and demographic variables	No	Yes	Yes	Yes	Yes
State fixed effects	No	Yes	Yes	Yes	Yes
Quadratic in 1982 HRS score	No	No	Yes	No	No
Control for pathway scores	No	No	No	Yes	No
RD sample	No	No	No	No	Yes

Conclusion

- Cross-sectional studies found benefit of Superfund Cleanup
    - Concern of omitted variable bias
- New clever idea
    - Only 400 of 690 sites were put on NPL
    - Sites ranked by hazard risk (0-100)
    - Cutoff value of 28.5
- No effect of Superfund clean-up on
    - Housing prices
    - Neighborhood composition
    - Housing supply
- Other explanations for lack of observed effects?

Follow-Up: Gamper-Rabindran and Timmins (2013)

- Revisit Greenstone and Gallagher
  - Perhaps focusing on median housing values obscures a lot of heterogeneity
- Data: Dataquick
  - Housing-level data, geocoded
  - Can look at quartiles and areas closer to Superfund site
- Results
  - Significant 19% increase within 1km of site
  - Housing prices of lower quartiles increase the most
- Lessons
  - Micro-data can be useful
  - Look at distribution, not just median
  - Better to be first than best

Hedonic Valuation of Climate Impacts

First: brief introduction to agriculture / climate

Second: climate impact literature re: agriculture

- How did we get to hedonics?
- How/why have we stepped back from hedonics?
- Where is the literature now?

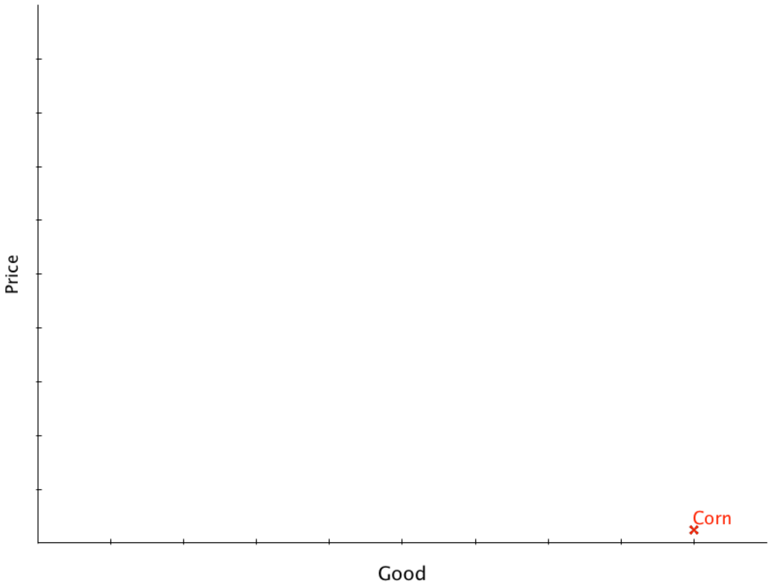
Agriculture and Welfare

Why Impacts on US Agriculture Might be Economically Meaningful

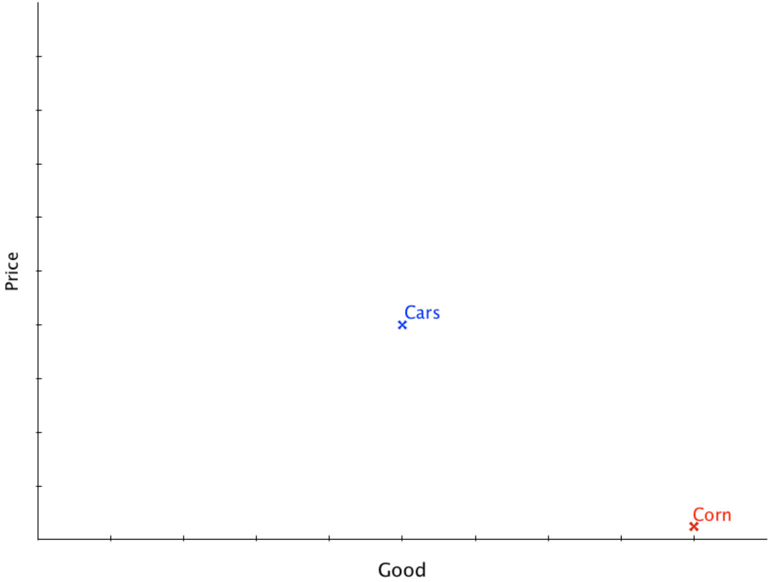
- Agriculture accounts for small share of US GDP
  - 2-3% of GDP
  - Does that mean any possible impacts are negligible?

- Adam Smith: Paradox of value / price
  - Why is the price of diamonds (nonessential good) so high, while the price of water (essential good) is low?
    - Price of a good depends on scarcity!

Agriculture and Welfare



Agriculture and Welfare



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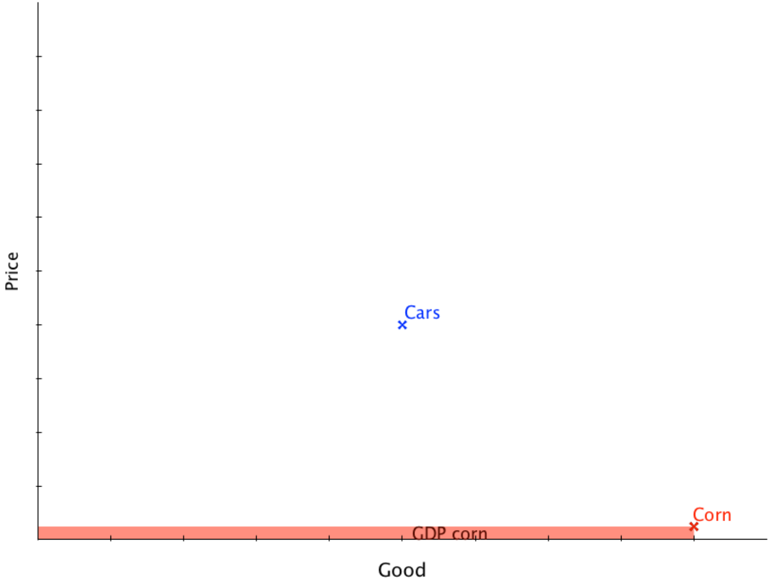

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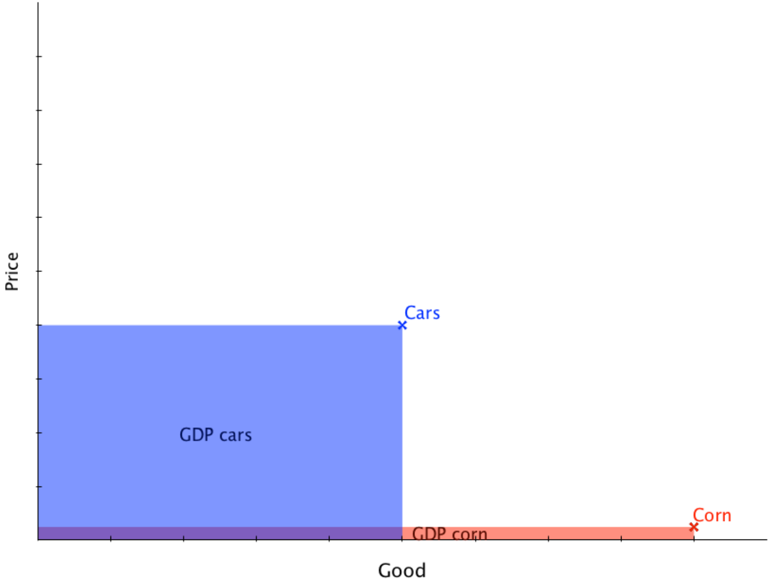

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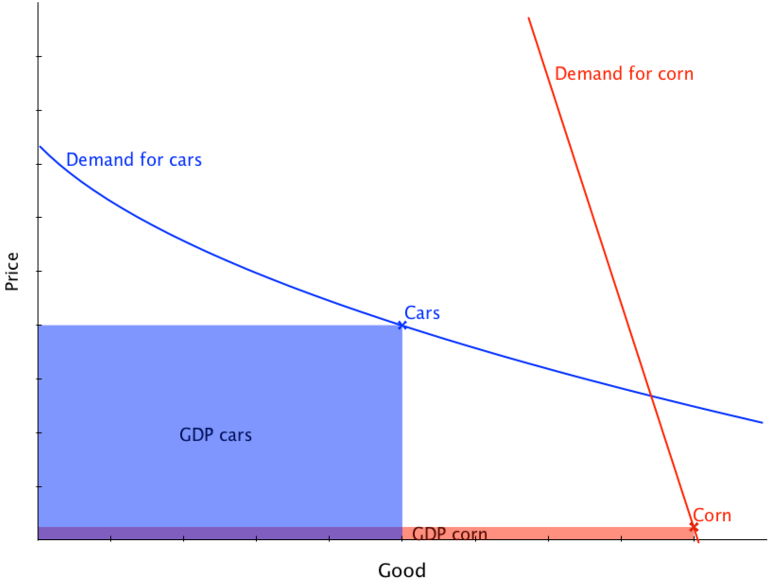
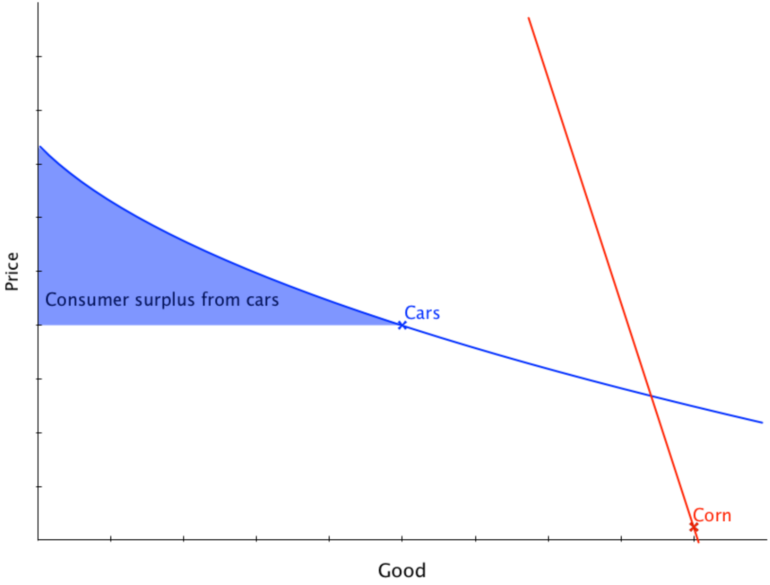
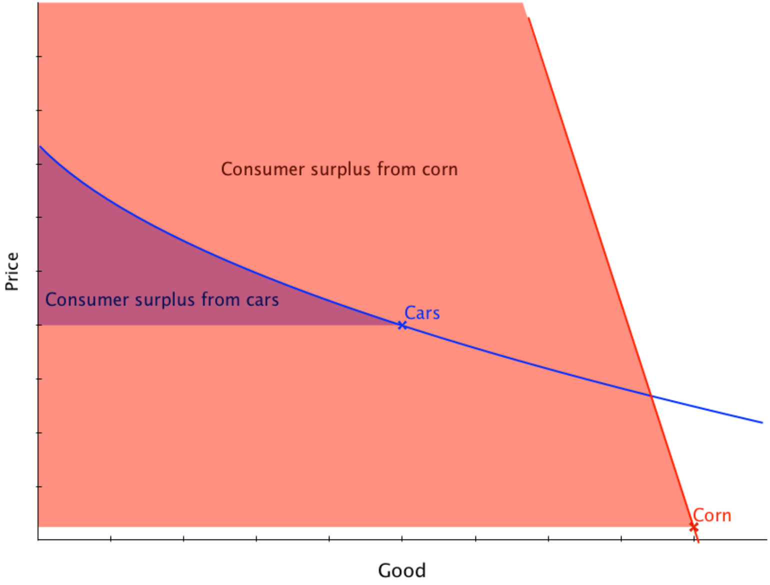


Agriculture and Welfare



Agriculture and Welfare



Agriculture and Welfare

- GDP is not a welfare measure
  - Agricultural demand is highly inelastic ($\sim$0.05)
  - Low price, but large consumer surplus
- Climate impacts
  - Small reduction in production result in
  - Large price changes (inelastic demand)
  - Potential for large welfare losses (consumer surplus)
- Four basic staple commodities
  - Corn, rice, soybeans, and wheat
  - 75% of calories humans consume worldwide
  - Recent tripling of prices: 1.25 trillion dollar surplus loss per year

Modeling Link Between Weather and Yields: Contrasting Approaches

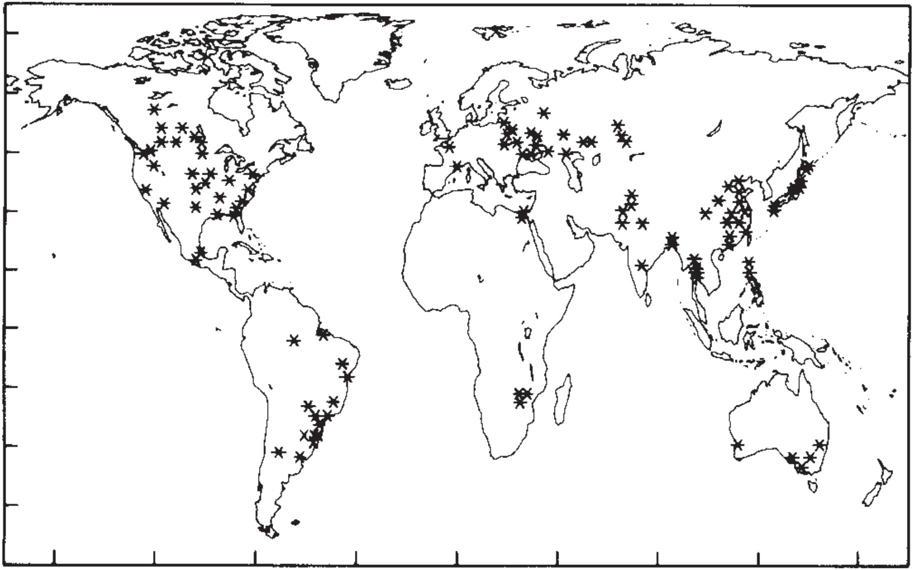
- Agronomic approach (crop-models)
  - Calibrated using laboratory / field trials
  - Allow for complex interactions
    - Temperature, precipitation, soil moisture, fertilizer, CO_2, etc
  - Estimated impacts of climate change
    - Predicted changes in yields
    - Modeling of crop switching (solve optimization problem)

- Statistical studies
  - Estimated using real-world data (Aggregate or field-level data)
  - Limited number of variables
    - Usually precipitation and temperature (degree days)
  - Estimated impacts of climate change
    - Predicted changes in yields/profits from panel
    - Estimating adaptation using cross-section

Rosenzweig and Parry (1994): Agronomic Model

- Field trials where crop models are calibrated
  - Models based on bio-physical characteristics
  - Many parameters, can't be estimated, but are calibrated
  - Different models (tend to be black-boxes)
    - Start of AGMIP
- Ask scientists to predict changes in yields for each site
  - Look at three GCM models
  - Aggregate model prediction to country
    - Use existing growing areas as weights
  - Predicted yield impacts
    - Without CO_2 fertilization
    - With CO_2 fertilization: Often changes sign of impact

Study Sites



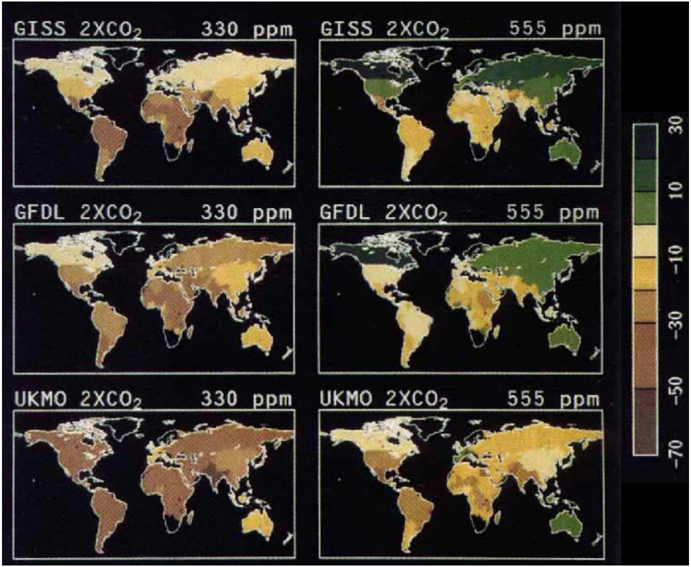
Climate Change Scenarios

TABLE 1 GCM doubled-CO_2 climate change scenarios

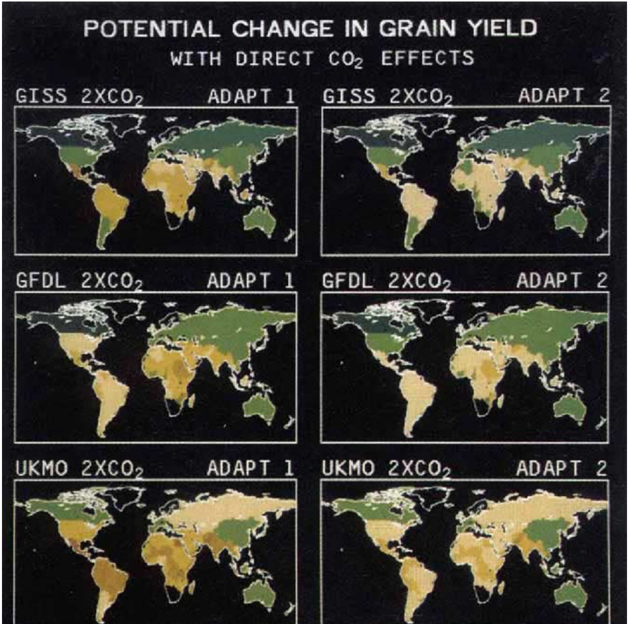
GCM	Year*	Resolution (lat. × long.)	CO_2 (p.p.m.)	Change in average global temperature (°C)	Change in average global precipitation (%)
GISS†	1982	7.83° × 10°	630	4.2	11
GFDL‡	1988	4.4° × 7.5°	600	4.0	8
UKMO§	1986	5.0° × 7.5°	640	5.2	15

* When calculated.
† Goddard Institute for Space Studies[20].
‡ Geophysical Fluid Dynamics Laboratory[21].
§ United Kingdom Meteorological Office[22].

Predicted Yield Impact - No CO_2 Fertilization



Predicted Yield Impact - w/ CO_2 Fertilization



Rosenzweig and Parry (1994): Agronomic Model

Criticisms of Crop Model Approach

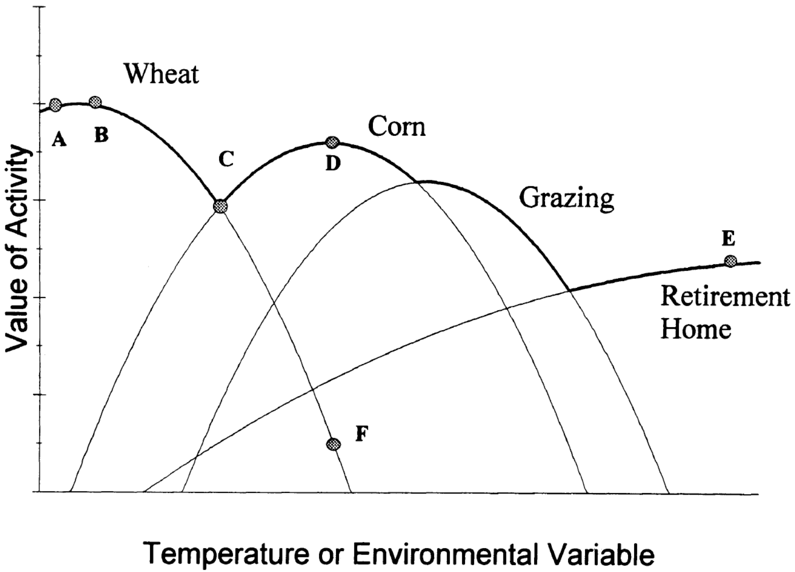
- Very ad hoc and black box
- Ability to understand adaptation seemingly limited
  - e.g. what would happen if switch planting dates by 1 month or use existing crop variety?
- Model output not seemingly robust (e.g. very sensitive to CO2 fertilization)

Agriculture, Climate Impacts, and Hedonics

- Agronomic crop models
  - Often keep crop choices fixed
    - Or model crop switch ad-hoc
    - Also a black box / not super transparent
  - Understate adaptation possibility

- New idea: estimate outer envelope of optimal crop/use choice
  - Reduced form regression
  - Dependent variables
    - Farmland prices (forward-looking)
    - Farm revenues (current profitability)
  - Independent variables
    - Climate variables (quadratic in temperature and precipitation)
    - Soil and socio-economic controls

Outer Envelope of Adaptation



Hedonic Valuation of Climate Impacts

In early, pathbreaking paper Mendelsohn, Nordhaus, and Shaw (1994) demonstrated how to use hedonic methods to value climate impacts

- Cross-sectional approach comparing farm values in hot versus cooler place

They use what they call a **"Ricardian" approach:**

- Basically the distinction of studying land rents rather than ag production

Data:

- 1982 Census of Agriculture: county level data on land prices and revenues
- National Resource Inventory: Soil quality
- National Climatic Data Center: 5500 stations, Interpolate (30-year station averages)

Data Construction

- Agricultural Census
  - Farmland prices in each county
    - Land and Building
  - Farm revenue
- Matched with socio-economic data
  - City and County Data Book
- Matched with weather data
  - For each county and weather variables, fit a surface
    - Regression weather variable on monitors within 500km
    - Control for longitude / latitude / altitude / distance to centroid
    - Interpolate variable to county centroid
- Weighted regression
  - Cropland: fraction of county that is cropland
  - Crop revenue: crop sales in county

Regression Results - Farmland Values

TABLE 3—REGRESSION MODELS EXPLAINING FARM VALUES

Independent variables	Cropland weights 1982 (i)	Cropland weights 1982 (ii)	Cropland weights 1978 (iii)	Crop-revenue weights 1982 (iv)	Crop-revenue weights 1978 (v)
Constant	1,490	1,329	1,173	1,451	1,307
	(71.20)	(60.18)	(57.95)	(46.36)	(52.82)
January temperature	−57.0	−88.6	−103	−160	−138
	(6.22)	(9.94)	(12.55)	(12.97)	(13.83)
January temperature squared	−0.33	−1.34	−2.11	−2.68	−3.00
	(1.43)	(6.39)	(11.03)	(9.86)	(14.11)
April temperature	−137	−18.0	23.6	13.6	31.8
	(10.81)	(1.56)	(2.23)	(1.00)	(2.92)
April temperature squared	−7.32	−4.90	−4.31	−6.69	−6.63
	(9.42)	(7.43)	(7.11)	(9.44)	(11.59)
July temperature	−167	−155	−177	−87.7	−132
	(13.10)	(14.50)	(18.07)	(6.80)	(12.55)
July temperature squared	−3.81	−2.95	−3.87	−0.30	−1.27
	(5.08)	(4.68)	(6.69)	(0.53)	(2.82)
October temperature	351.9	192	175	217	198
	(19.37)	(11.08)	(11.01)	(8.89)	(9.94)
October temperature squared	6.91	6.62	7.65	12.4	12.4
Adjusted R^2:	0.671	0.782	0.784	0.836	0.835
Number of observations:	2,938	2,938	2,941	2,941	2,941

Notes: The dependent variable is the value of land and buildings per acre. All regressions are weighted. Values in parenthesis are t statistics.

Temperature variables demeaned for interpretation. How to interpret?

Explaining Current Values: Cropland Weights

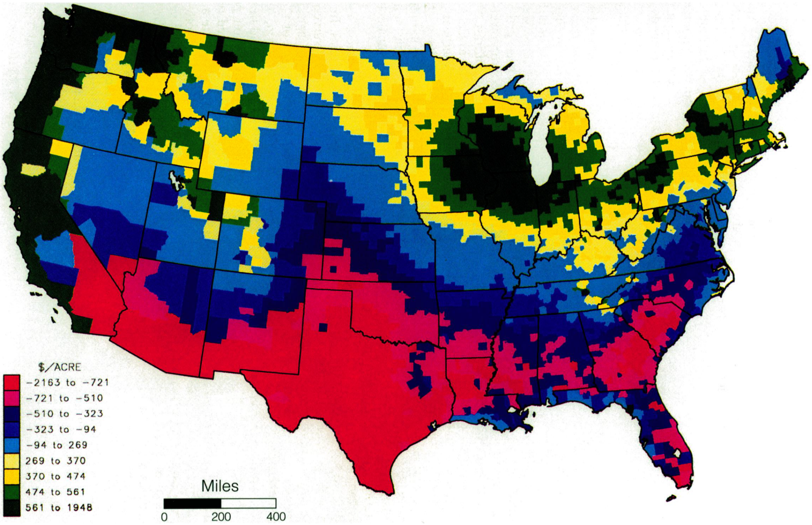


FIGURE 2. INFLUENCE OF CURRENT CLIMATE ON FARM VALUES: CROPLAND WEIGHTS
Note: Farm value is measured as the difference in dollars per acre from the sample average, 1982 prices.

Explaining Current Values: Crop-revenue Weights

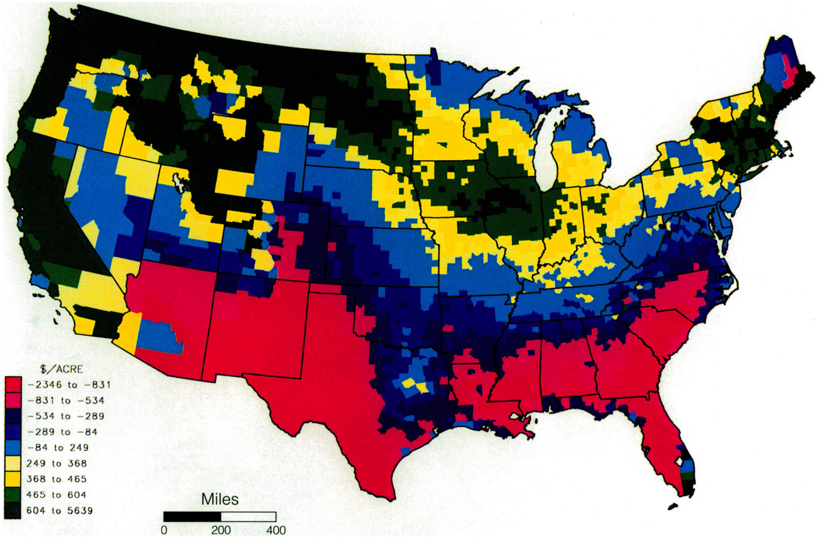


FIGURE 3. INFLUENCE OF CURRENT CLIMATE ON FARM VALUES: CROP-REVENUE WEIGHTS
Note: Farm value is measured as the difference in dollars per acre from the sample average, 1982 prices.

+5F Warming, +8% Precipitation: Cropland Weights

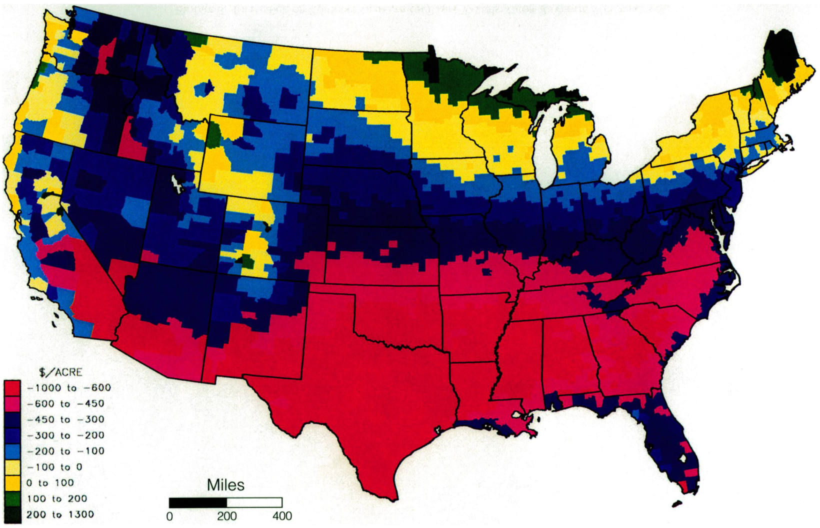


FIGURE 4. CHANGE IN FARM VALUE FROM GLOBAL WARMING: CROPLAND WEIGHTS
Note: The map shows the change in terms of dollars per acre for a 5°F uniform warming and an 8-percent increase in precipitation, 1982 prices.

+5F Warming, +8% Precipitation: Crop-revenue Weights

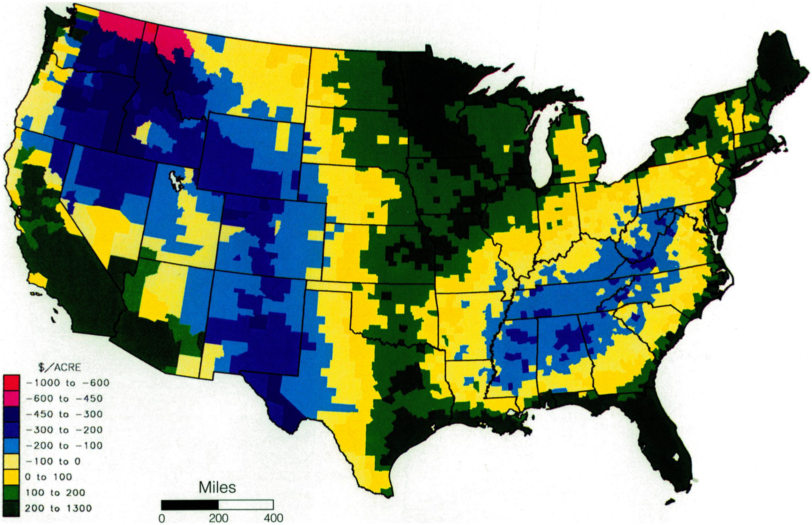


FIGURE 5. CHANGE IN FARM VALUE FROM GLOBAL WARMING: CROP-REVENUE WEIGHTS
Notes: The map shows the change in terms of dollars per acre for a 5°F uniform warming and an 8-percent increase in precipitation, 1982 prices.

Predicted Impact: +5F Warming, +8% Precipitation

TABLE 5—PREDICTED IMPACT OF GLOBAL WARMING ON FARMLAND VALUES AND FARM RENTS

		Change in farmland values (billions of dollars, 1982 prices)		Change in farmland rents (percentage of 1982 farm marketings)	
Year	Weight	Impact	Truncated impact	Impact	Truncated impact
1982	Cropland	−$125.2	−$118.8	−4.4	−4.2
1978	Cropland	−$162.8	−$141.4	−5.7	−4.9
1982	Crop revenue	$34.5	$34.8	1.2	1.2
1978	Crop revenue	−$14.0	$21.0	−0.5	0.7

Notes: The global-warming scenario is a uniform 5°F increase with a uniform 8-percent precipitation increase. The "impact" column shows the estimated loss; the "truncated impact" columns show the impact when the loss in farmland value in each county is limited to the original value of the land. The last two columns are annualized impacts, as explained in the text, as a percentage of 1982 farm marketings.

Hedonic Model II: Treatment Effect Heterogeneity + OVB

Results of Mendelsohn, Nordhaus, and Shaw

- Differ greatly between weights
- Authors estimate one model for the entire US

Schlenker, Hanemann, Fisher (2005)

- Irrigated areas have different relationship [effect heterogeneity]
  - Spatial link: It's not weather in county that necessarily matters
  - Temporal link: Can be stored in reservoirs
- Irrigation is highly subsidized [OVB]
  - Studies argue it is around 84 cents for each dollar
  - Beneficial to users, paid by society: capitalized into land values
  - Hotter temperatures correlated with subsidy
  - Temperature is beneficial?
- Crop-revenue weights exaggerate problem [Misspecification?]
  - Higher weight on counties with higher subsidies (California)

Can Counties be Pooled?

TABLE 1—CHOW TESTS WHETHER DRYLAND NON-URBAN AND IRRIGATED AND/OR URBAN COUNTIES CAN BE POOLED

	Crop revenue weights	Cropland weights	White's estimator
p-value for the test that all 31 coefficients are the same	$<10^{-16}$	$<10^{-16}$	$<10^{-16}$
p-value for the test that the 16 climatic variables are the same	$<10^{-16}$	$<10^{-16}$	$4.58 * 10^{-8}$
Number of climatic variables that are individually different at the 5-percent level	6	5	4

Notes: All tests examine whether the coefficients are the same for the 2,197 dryland non-urban counties and the 514 irrigated non-urban counties. Both the crop revenue and cropland models are weighted regressions. White's estimator is an unweighted regression that utilizes White's heteroskedasticity-consistent estimate of the variance-covariance matrix.

Selected Regression Coefficients

Variable	Crop revenue weights	Cropland weights	White's estimator
All observations in the estimation			
July precipitation	−116	−36.1	−24.9
t-statistic	(6.06)	(2.75)	(1.27)
July precipitation squared	57.0	52.4	25.8
t-statistic	(8.20)	(9.50)	(3.66)
Slope length	54.0	17.8	23.3
t-statistic	(6.24)	(2.99)	(2.38)
Dryland non-urban counties			
July precipitation	49.0	0.449	10.5
t-statistic	(2.93)	(0.03)	(0.66)
July precipitation squared	18.4	17.8	14.8
t-statistic	(2.88)	(2.55)	(2.38)
Slope length	−32.7	−20.4	−11.0
t-statistic	(4.77)	(3.02)	(1.48)

Notes: Both the crop revenue and cropland model are weighted regressions. White's estimator is an unweighted regression that utilizes White's heteroskedasticity-consistent estimate of the variance-covariance matrix.

Revised Impacts: Dryland Nonurban Counties

TABLE 4—CHANGE IN ANNUAL PROFITS IN DRYLAND NON-URBAN COUNTIES FROM GLOBAL WARMING, USING ONLY DRYLAND NON-URBAN COUNTIES IN THE ESTIMATION
(*$ billion, 1982*)

Model	Point estimate	95-percent bootstrap confidence interval	95-percent OLS confidence interval
Cropland weights	−5.32	(−6.79; −3.78)	(−6.52; −3.98)
Crop revenue weights	−4.97	(−7.01; −2.87)	(−6.33; −3.46)

Hedonic Model III: Functional Form

Agronomic Crop Models

- Nonlinear temperature effects can be highly nonlinear
  - Hotter temperatures good up until some point
  - Then become detrimental
- Perhaps not realistically characterized by quadratic

Schlenker, Hanemann, and Fisher (2006)

- Measure nonlinearity with piecewise linear function (above threshold)
  - Threshold of 34°C: count degrees above 34C
  - Temperature of 35C: 1 degree day
  - Temperature of 36C: 2 degree days
  - Sum over days of the year
- Extremely hot temperatures drive everything
  - Model becomes very robust to controls / Census year

Regression Results

TABLE 3.—REGRESSION RESULTS EXPLAINING LOG OF FARMLAND VALUE PER ACRE USING ONLY COUNTIES EAST OF THE 100TH MERIDIAN

Variable	82–97 Census	82–97 Census	1982 Census	1987 Census	1992 Census	1997 Census
Constant	320 (4.04)	337 (4.69)	295 (3.49)	329 (4.08)	375 (4.52)	328 (4.06)
Degree days (8–32°C)	165 (5.94)	127 (5.37)	161 (6.10)	134 (4.62)	167 (5.24)	226 (7.53)
Degree days (8–32°C) squared	−34.3 (5.34)	−24.9 (4.58)	−31.3 (5.09)	−26.9 (4.04)	−37.4 (5.04)	−51.4 (7.56)
Square root of degree days (34°C)	−14.4 (4.80)	−25.2 (9.76)	−13.1 (4.70)	−15.5 (4.91)	−15.0 (4.34)	−14.2 (4.31)
Precipitation	4.47 (3.88)	5.49 (4.89)	4.84 (3.92)	4.90 (4.29)	3.84 (3.26)	4.41 (3.90)
Precipitation squared	−0.0281 (3.04)	−0.0373 (4.14)	−0.0318 (3.16)	−0.0326 (3.55)	−0.0227 (2.40)	−0.0270 (3.00)
Latitude	−0.582 (0.44)	0.0224 (0.02)	−0.403 (0.28)	−0.473 (0.35)	−1.33 (0.91)	−1.62 (1.16)
Income per capita	3.66 (13.64)	3.85 (13.86)	3.83 (10.92)	3.70 (11.01)	3.47 (11.50)	2.87 (14.34)
Population density	4.80 (11.74)	4.80 (11.57)	5.00 (11.18)	5.76 (12.26)	5.67 (10.64)	4.54 (9.26)
Population density squared	−0.0639 (5.72)	−0.063 (5.68)	−0.0685 (5.04)	−0.0786 (6.09)	−0.0738 (4.58)	−0.0791 (4.63)
Average water capacity	0.696 (1.28)	0.790 (1.45)	1.24 (2.07)	0.543 (0.98)	0.464 (0.73)	0.689 (1.15)
Percent clay	0.0905 (0.83)	0.0137 (0.12)	0.222 (1.92)	0.0968 (0.80)	0.0567 (0.44)	−0.0484 (0.39)
Minimum permeability	2.37 (2.52)	2.50 (2.28)	3.26 (3.41)	2.22 (2.32)	1.39 (1.18)	2.32 (2.24)
K-factor of topsoil	−29.0 (1.84)	−16.6 (1.08)	−38.1 (2.14)	−20.9 (1.17)	−39.9 (2.10)	−26.8 (1.45)
Best soil class	0.298 (6.51)	0.289 (6.05)	0.417 (7.82)	0.255 (5.28)	0.294 (5.64)	0.269 (5.64)
State fixed effects	Yes	No	Yes	Yes	Yes	Yes
Number of observations	2,398	2,398	2,398	2,398	2,398	2,398
Spatial correlation	0.71	0.74	0.65	0.67	0.68	0.64

Table lists coefficient estimates and *t*-values in parenthesis. For expositional purposes, the coefficients have been multiplied by 100. Variables in the first two columns are averages of the variables in each census year. Climate variables are constructed from the 30-year climate history preceding each census.

Predicted Climate Change

TABLE 4.—PREDICTED CHANGES IN CLIMATIC VARIABLES FOR COUNTIES EAST OF THE 100TH MERIDIAN UNDER DIFFERENT EMISSION SCENARIOS FOR THE HADLEY HADCM3 MODEL

Variable	2020–2049 Average				2070–2099 Average			
	Mean	Min.	Max.	σ	Mean	Min.	Max.	σ
Hadley HadCM3—Scenario B1								
Average temperature (°C)	1.98	1.01	2.49	0.26	3.58	2.03	4.24	0.36
Degree days (8–32°C)	0.34	0.18	0.43	0.05	0.61	0.36	0.71	0.05
Degree days (34°C)	4.94	−0.62	40.60	4.51	15.98	0.44	108.91	13.31
Precipitation (cm)	2.45	−9.39	10.19	3.94	2.72	−10.61	18.28	4.37
Hadley HadCM3—Scenario B2								
Average temperature (°C)	2.22	1.00	3.07	0.36	4.17	2.26	4.84	0.42
Degree days (8–32°C)	0.38	0.18	0.50	0.06	0.70	0.40	0.81	0.06
Degree days (34°C)	11.12	0.23	56.36	8.78	22.11	1.23	188.23	22.46
Precipitation (cm)	0.29	−15.28	10.73	4.44	2.21	−18.84	11.14	4.58
Hadley HadCM3—Scenario A2								
Average temperature (°C)	2.41	0.99	3.00	0.34	5.98	3.02	6.98	0.63
Degree days (8–32°C)	0.41	0.17	0.51	0.06	0.95	0.52	1.11	0.10
Degree days (34°C)	11.93	0.45	75.67	8.92	67.56	5.89	319.81	42.16
Precipitation (cm)	0.16	−14.24	6.52	2.73	−0.45	−21.00	11.10	6.21
Hadley HadCM3—Scenario A1FI								
Average temperature (°C)	2.28	1.05	2.97	0.31	7.44	3.83	8.70	0.74
Degree days (8–32°C)	0.38	0.19	0.47	0.05	1.15	0.61	1.34	0.14
Degree days (34°C)	15.76	−0.13	69.34	12.63	97.27	7.02	468.96	69.16
Precipitation (cm)	1.10	−7.27	9.92	3.76	2.34	−21.89	20.73	7.67

Table lists changes in degree days and precipitation during the major growing season, April through September, as well as changes in average temperature for the months April–September. The above emissions scenarios are taken out of the Special Report on Emissions Scenarios (SRES) for the IPCC 3rd Assessment Report (Nakicenovic, 2000). The chosen scenarios span the range from the slowest increase in greenhouse gas concentrations (B1), which would imply a little less than a doubling of the preindustrial level by the end of the century, to the fastest (A1FI), associated with more than a tripling, as well as two intermediate scenarios (A2 and B2).

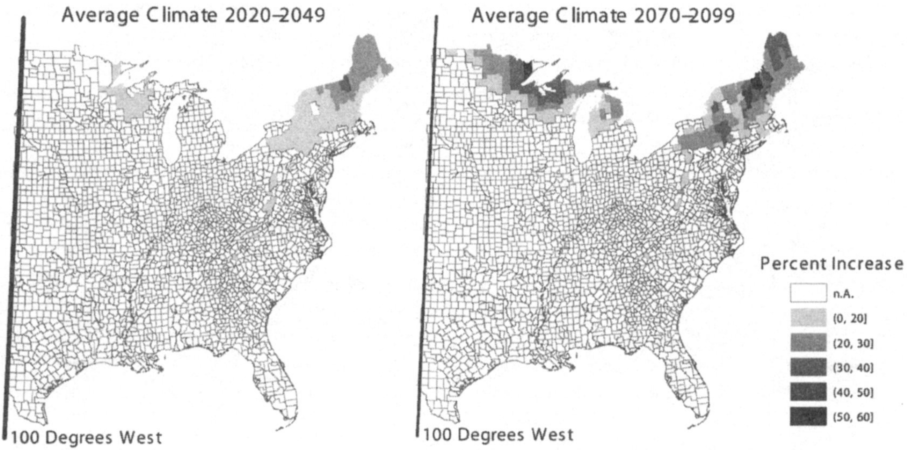
Effects of Predicted Climate Change

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

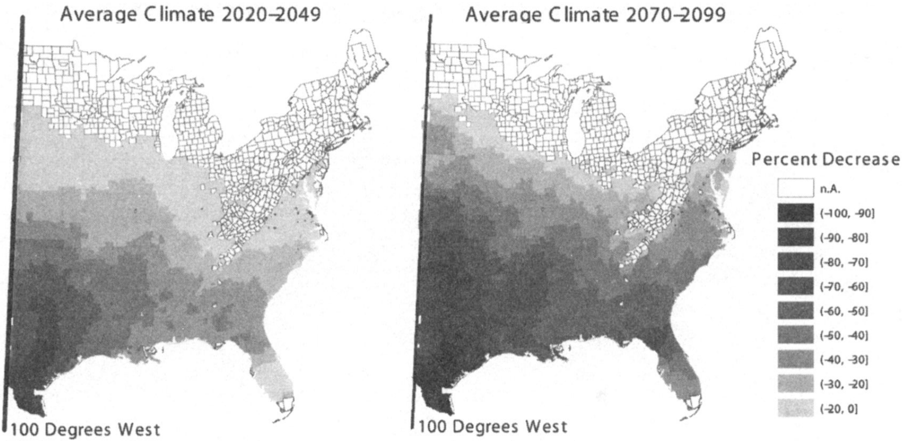
Variable	2020–2049 Average (%)				2070–2099 Average (%)			
	Mean	Min.	Max.	σ	Mean	Min.	Max.	σ
Hadley HadCM3—Scenario B1								
Degree days (8–32°C)	−0.96	−26.83	24.33	12.11	−4.44	−41.73	49.83	20.13
Degree days (34°C)	−11.17	−33.66	2.75	4.82	−26.21	−59.01	−1.86	9.57
Precipitation	1.02	−19.51	13.26	4.99	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)	

Table decomposes total impacts into contribution of each of the three climatic variables for four emission scenarios. The last line for each scenario reports the standard error for the mean, minimum, and maximum of the total impact.

Distribution of Impacts: Winners under HCM3-B2



Distribution of Impacts: Losers under HCM3-B2



Hedonic Model: Omitted Variable Bias (Redux)

Wait, I thought cross-sectional estimates were suspect due to spatially correlated unobservables?

- No border discontinuity (Black) / RD (Greenstone/Gallagher) design here.

Enter, Deschenes and Greenstone (2007)...

- Cross-sectional estimates biased/sensitive
- Do, next best thing: county fixed effects models and look at relationship between annual weather variation and firm profits.

Deschenes and Greenstone (2007)

Adopt degree day specification of Schlenker, Hanemann, and Fisher (2006)

- County-year agricultural profits + <u>county FE</u> + <u>state-year FE</u>
- Use model to predict future change in profits and discount back to present to calculate predicted change in land values
  - i.e. present discounted stream of rental rates

Deschenes and Greenstone (2007): Main Finding

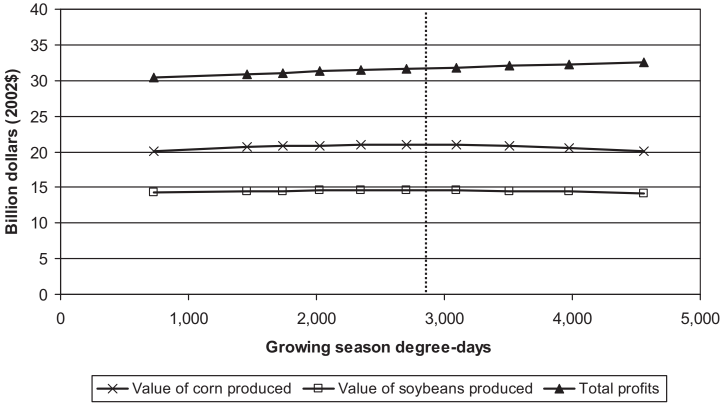


FIGURE 1A. FITTED RELATIONSHIP BETWEEN AGGREGATE PROFITS (TOTAL VALUE OF CROPS PRODUCED) AND GROWING SEASON DEGREE-DAYS

Fisher, Hanemann, Roberts, Schlenker (2012)

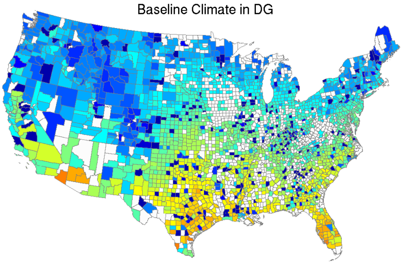
American Economic Review 2012, 102(7): 3749–3760
http://dx.doi.org/10.1257/aer.102.7.3749

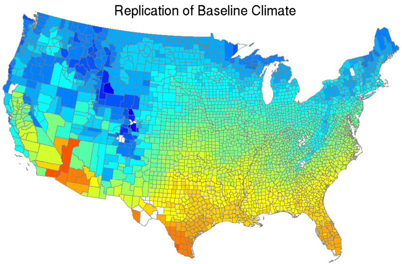
The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather: Comment†

By Anthony C. Fisher, W. Michael Hanemann, Michael J. Roberts, and Wolfram Schlenker*

Fisher, Hanemann, Roberts, Schlenker (2012)

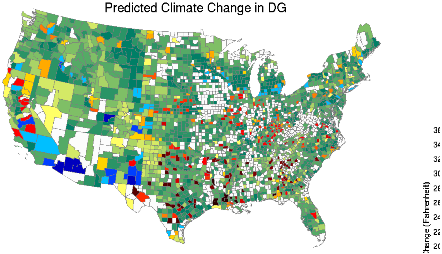
Figure 1: Baseline Climate in Deschenes and Greenstone

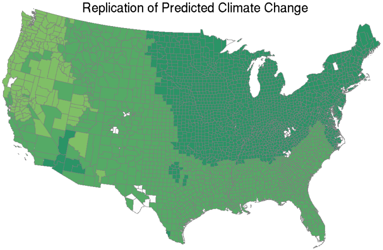




Fisher, Hanemann, Roberts, Schlenker (2012)

Figure 2: Climate Change Predictions in Deschenes and Greenstone





Fisher, Hanemann, Roberts, Schlenker (2012)

Table 1: Comparison of Various Data Sources in Yield Regressions

	Corn			Soybeans		
	(1a)	**(1b)**	**(1c)**	**(2a)**	**(2b)**	**(2c)**
Regression diagnostics						
Variance explained by weather	12.6%	21.3%	26.3%	15.3%	31.0%	38.1%
Model comparison tests (J-test)						
DG against other weather (t-value)		15.97	21.08		19.98	25.80
Other weather against DG (t-value)		1.85	1.66		1.59	1.16
Climate change impact (Percent)						
Hadley II-IS92a scenario	-0.98	-11.50	-14.03	-3.01	-16.49	-18.36
(s.e.)	(1.23)	(1.71)	(1.66)	(1.38)	(1.73)	(1.64)
[s.e. Conley]	[2.12]	[5.57]	[5.18]	[1.96]	[4.93]	[4.39]
Hadley III-B2 scenario		-44.46	-65.64		-53.90	-75.71
(s.e.)		(3.69)	(3.97)		(3.87)	(3.92)
[s.e. Conley]		[13.09]	[11.76]		[11.94]	[10.60]
Observations	6862	6862	6862	5141	5141	5141
Soil controls	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

More Recent Work in This Area

Burke and Emerick (2015):

- Panel fixed effects but over long time horizons
- Several advantages:
  1. Deal with (fixed) spatially correlated unobservables
  2. Better approximate climate experiment (i.e. gradual changes)
  3. Long run horizons allow for adaptation effects

Ricardian Approach: What happens if land prices already reflect future projections of climate impacts?

- Depends on correlation between current climate and predicted climate (and access to information). See e.g., Severen, Costello, and Deschenes (2016)

Remote Sensing / Satellite Data + Global Weather Data

- Revisit the Rosenzweig and Perry (1994) paper with modern tools (e.g. recent work by David Lobell)

Non-Market Valuation - Limitations of Hedonic Approach

1. Marginal Willingness to Pay $\neq$ Average Willingness to Pay
2. For some outcomes, it is impossible to have a revealed preference measure
    - Existence value
    - Ex: protecting endangered species

Common solution: “contingent valuation” surveys

- How much would you be willing to pay to avoid extinction of whales?

Use versus Existence Values

- Sometimes we even don't have observed indirect tradeoffs
  - Existence values!
  - People derive utility from existence of good
    - Willingness to contribute to Nature Conservancy
    - Use money to set aside land, most people will not actually visit
  - Since people never directly visit ("use") these goods
    - No way of constructing indirect revealed choice
- Contingent valuation method
  - Use surveys to construct estimates
    - Give people "hypothetical" choices
    - Record their answers
- When are existence values important?
  - Exxon Valdez oil spill in Alaska
    - Contaminated Prince Williams Sound
    - Very few vistors, so direct use values are limited
    - Many people very concerned, so existence value might be much higher

Travel Cost Method

- Method to elicit use values
  - Like hedonic method, can only look at use values
  - Mostly willingness to pay for recreational sites

- Tradeoff between price and number of visits
  - Model how often people visit a recreational site
  - People with higher cost visit less frequently

- Travel cost include
  (i) Cost of getting to the site (transportation)
  (ii) Entry fees
  (iii) Opportunity cost of not working and earning income

- Data for study
  - Usually comes from personal interviews
  - Ask respondents how often they visit, income, etc

Contingent Valuation Method: Arguments in Favor

- Economists readily rely on other survey data
  - E.g., the Consumer Expenditure Survey, Monthly Labor Survey, and Panel Study on Income Dynamics
  - Require people to "state" what they did (recall data)

- Contingent valuation does not rely on recall data, but requires respondents to evaluate a hypothetical example
  - The same is true for voting behavior
    - California system of propositions
  - People are forced to make decisions with limited knowledge

- Framework of questions is important
  - Easy to "misguide" people if wanted
    - Same is true of regressions
  - Can be informative if done correctly
    - Focus groups: check that respondents understand questions
    - Used extensively in marketing and politics

Arguments in Favor - Part II

- “Good” cv studies
  - Provide context
  - For example: study to preserve Mono Lake
    - Use computer animations for different scenarios
  - Quiet expensive to conduct

Contingent Valuation - Example - Specificity Matters

> If the majority of households vote in favor of the South Platte River restoration fund, the 45 miles of river would look like (*in-person interviewer points to a figure showing increased water quality and fish and wildlife*). If a majority votes against, these 45 miles of the South Platte River would remain as they are today, as illustrated by (*in-person interviewer points to a figure showing current management*). If the South Platte River restoration fund was on the ballot in the next election and it cost your household \$B each month in a higher water bill, would you vote in favor or against?

The dollar amount \$B was randomly filled in with one of twelve values (\$1, 2, 3, 5, 8, 10, 12, 20, 30, 40, 50, 100). Based on survey responses from 100 local respondents, Loomis et al. estimated an average willingness to pay of \$21 per month or over \$250 annually per household for the proposal.

Contingent Valuation: Traditional Criticism

Such surveys are in low repute among economists; why?

1. People don't take these seriously
   - How would you take a question like this?
2. People answer the wrong question: overall valuation
   - What we want is harm/WTP of that *individual personally*
   - Most people make casual, overall social evaluation
3. People don't have any idea, information, experience
   - Takes a lot of reflection to determine value for things
4. People's answers motivated by "warm glow"
   - Many feel good about thinking they value these things
   - This may be a main cause of their answers
5. Responses highly inconsistent, apparently irrational
   - Depend on order, grouping, etc.: how to interpret?
6. No incentive to get things right...

Contingent Valuation: Why CV can't work in practice

Actually, much worse than this; what are incentives?

- Depends on what survey is used for
  1. What if no one takes survey seriously
     - Then no incentives, but why take survey in first place?
  2. Survey has major impact on public policy?
     - In this case, large incentives!
     - If you want preservation, report huge number
     - If you want no preservation, report $0
- Never a real incentive to report truthfully
- Example from Haiti in *The Economist*
  - After quake, reporter asked if people got supplies
  - Everyone said no, but later saw people had!
  - Only way to make sure aid keeps flowing is to lie

NOAA Panel

- Panel of economists discussed pros and cons
  - Similar to court trial
  - Economists argued pros and cons
    - Pro: Hanemann
    - Con: Hausman
- Findings
  - Found that it can be a valuable exercise
  - Studies have to follow guidelines

NOAA Panel - Guidelines

- CV should use in-person interviews rather than telephone surveys and telephone surveys $>>$ mail surveys
- CV should elicit WTP to prevent future incident rather than minimum compensation required for an incident that has already occurred.

NOAA Panel - Guidelines

- CV should utilize referendum format
  - e.g. respondents asked how they would vote if faced with a program that would produce some kind of environmental benefit in exchange for higher taxes or product prices.
  - Seemingly better than open-ended questions eliciting maximum WTP for the program
- CV must begin with scenario that accurately and understandably describes expected effects of the program under consideration.

NOAA Panel - Guidelines

- Must contain reminders to respondents that WTP for program would reduce the amount they would have available to spend on other things.
- Must include reminders of substitutes for the “commodity” in question.
    - e.g. respondents asked how they would vote on a measure to protect a wilderness area, they should be reminded of the other areas that already exist or are being created independent of the one in question.
- Should include one or more follow-up questions to ensure that respondents understood choice and to discover the reasons for their answer.

Carson, Flores, Martin and Wright (1996): Comparing CV and RV

- Do contingent valuation studies overstate "true" preferences?
  - Compare cv estimates to revealed preference (RP) estimates
  - Are they higher, i.e., is ratio CV/RP >1?

- Authors examine 1600 contingent valuation studies
- Looked for studies that estimated both
  - Contingent valuation
  - Revealed preference

- Ended up with 83 studies that had both
  - 616 comparisons
  - Some studies had more than one

Data - RP Comparison Method

	Revealed Preference Techniques	Number
1)	Single-site travel cost models (TC1)	295
2)	Multiple-site travel cost models (TC2)	183
3)	Hedonic pricing (HP)	62
4)	Averting behavior (AVERT) which includes expenditure and household production function models not already included in TC2	28
5)	Simulated or actual markets (ACTUAL)	48

Data - Good being evaluated

	Amenity Being Evaluated	Number
1)	Recreation (REC) includes studies that valued outdoor recreation, e.g. sport fishing, hunting, and camping	432
2)	Environmental amenities (ENVAM) includes studies that valued changes in goods, e.g., air and water quality	163
3)	Health risk (HEALTH) includes studies that valued small reductions in environmental or work-related health risks	21

Summary Statistics of CV/RP Ratios

TABLE 2
CV/RP ESTIMATES FOR THREE SAMPLE TREATMENTS

Statistic	Complete Sample	Trimmed Sample	Weighted Sample
Mean	0.886	0.774	0.922
Standard Error	0.038	0.019	0.057
Maximum	10.269	2.071	3.512
99%	5.584	1.948	3.512
95%	2.071	1.593	1.780
90%	1.524	1.345	1.447
80%	1.201	1.144	1.153
75%	1.122	1.090	1.111
70%	1.037	1.007	1.066
60%	0.908	0.886	0.990
50%	0.747	0.747	0.936
40%	0.610	0.624	0.809
30%	0.467	0.502	0.640
25%	0.376	0.432	0.585
20%	0.294	0.358	0.568
10%	0.094	0.132	0.349
5%	0.043	0.092	0.201
1%	0.011	0.063	0.079
Minimum	0.005	0.054	0.079
N	616	555	83

Graphical Summary of CV/RP Ratios

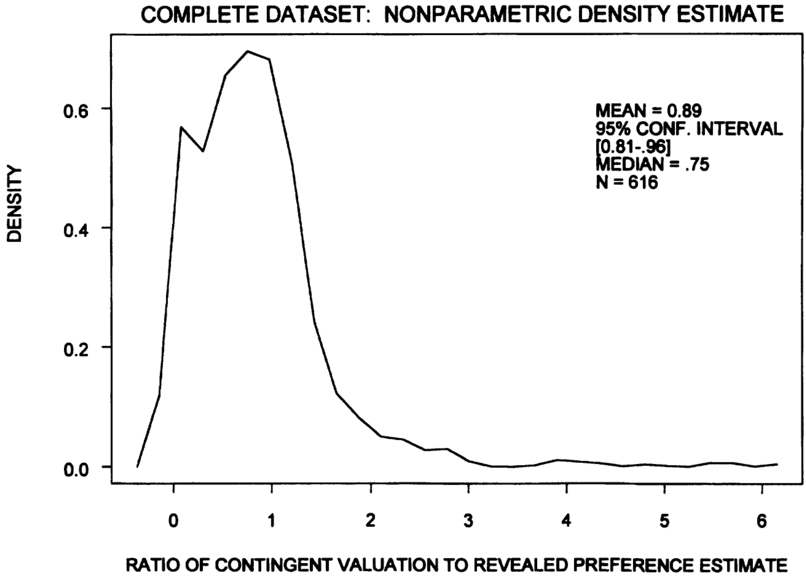


FIGURE 1

Graphical Summary of CV/RP Ratios: Trimmed Data

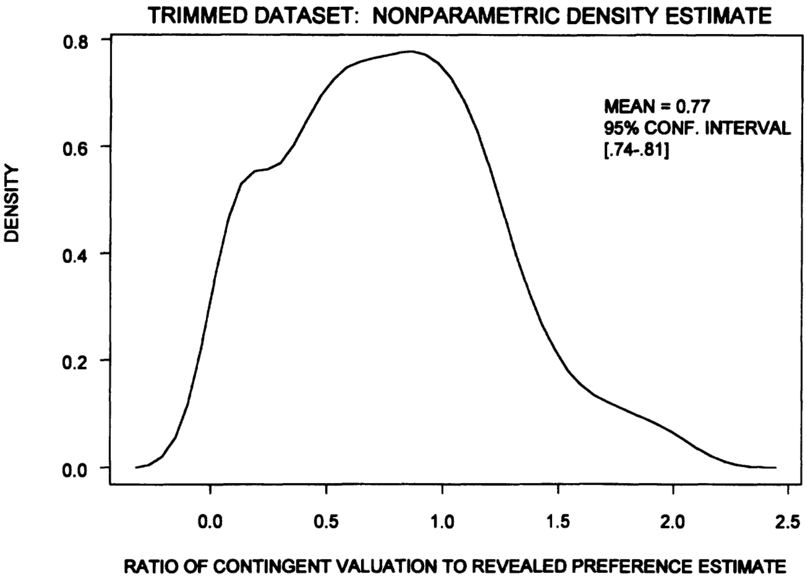


FIGURE 2

Graphical Summary of CV/RP Ratios: Weighted Data

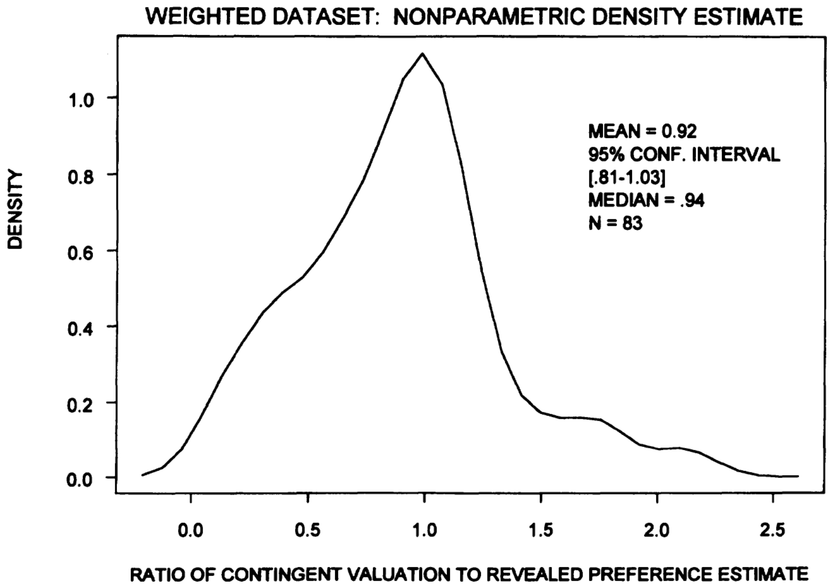


FIGURE 3

Heterogeneity by RP Method

TABLE 3
REGRESSION OF CV / RP ON RP TECHNIQUE USED

Parameter	Estimate	t-Statistic
Intercept	0.8014	28.55
TC2	−0.1039	−2.21
HP	−0.1813	−3.18
AVERT	0.0335	0.51
ACTUAL	0.2348	3.91
	$N = 555$	$R^2 = .051$

Heterogeneity by Good Valued

TABLE 4
REGRESSION OF CV / RP ON TYPE OF GOOD VALUED

Parameter	Estimate	t-Statistic
Intercept	0.7706	34.06
ENVAM	−0.0107	−0.23
HEALTH	0.1450	1.64
	$N = 555$	$R^2 = .004$

Conclusions

- Compares 83 studies that provide both
  - CV and RP estimates
- Ratio CV/RP is usually less than one
  - CV estimates not systematically higher

Thoughts

- Can only test this for use values!
  - Doesn't imply that CV will be good measure for existence values
- Papers with both CV + RP, RP might have anchoring bias associated with researcher's DoF

Diamond and Hausman 1994

- Describe problems with contingent valuation using surveys
- No resource cost to respondents
- Lack of consistency in responses
  - Framing Effects: whales then seals vs. seals then whales
  - WTP to clean one lake = WTP to clean 5 lakes
- Diamond and Hausman: let experts decide based on a budget voted on by individuals for the environment instead of relying on valuation

Contingent Valuation

Journal of Economic Perspectives

Vol. 26 No. 4 Fall 2012

SYMPOSIUM: CONTINGENT VALUATION

Contingent Valuation

Consensus: Not sure / definitely polarizing

- A lot of smart people have devoted a lot of effort to improving methods
- Some, but not tremendous progress
- Plagued with problems that make some economists cringe

Seems to work ok in places where a market could/would exist (e.g. marketing)

- Nonuse/existence values seem a bit shakier
- Some experimental papers use stated preference as measures of valuation (e.g. Kremer, Miguel, Null, and Zwane (2011); Lee, Miguel, Wolfram (2016))

Research Idea: One interesting possibility would be to "adjust" CV estimates using revealed preference estimates in spirit of empirical Bayes literature

- Hull (2017): Improve "naive" hospital risk adjustment quality measures using a narrower set of experimental estimates
- Angrist, Hull, Pathak, and Walters (QJE, 2017): Improve "naive" school value added measures using a narrower set of experimental lottery estimates

Subjective valuation with incentives

Survey experiments / Information Provisions experiments

- Increasingly common in other fields and often incentivized

Handful of different methods

- Becker–Degroot–Marshack: incentive-compatible procedure used in experimental econ to measure willingness to pay (WTP)
- Vickrey–Clarke–Groves: 2nd price auction mechanism designed to illicit true valuations
- "List response" or "unmatched count" techniques
  (more for sensitive preference illicitation).
  - See Cantoni, Yang, Yuchtman, and Zhang (2017) or Bursztyn, Callen, Ferman, Gulzar, Hasanain, and Yuchtman (2016)