Overall US Sector Sensitivity Assessment

Evaluation of the Sensitivity of U.S. Economic Sectors to Weather Variability

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University of New Mexico – May 5, 206

Outline

- Motivation
- Concept
- What is Economic Sensitivity?
- Data and Modeling
- Results
- Conclusions

Dutton – BAMS – September 2002

"**. . . one-third of the private industry activities, representing annual revenues of some $3 trillion, have some degree of weather and climate risk.**

This represents a large market for atmospheric information . . . "

TABLE 2. Weather and climate sensitive components of the gross domestic product (GDP; $ billion). The first two columns are from the Bureau of Economic Analysis industry accounts data for 2000; the third column lists the contribution to the GDP of industries with a (subjectively determined) weather sensitivity on operations, demand, or price.

Industries (1987 standard industrial classification)	GDP components ($ billion)	Weather sensitive components ($ billion)
Agriculture, forestry, and fishing	**135.8**	**135.8**
Farms	79.0	79.0
Agricultural services, forestry, and fishing	56.7	56.7
Mining	**127.1**	**109.6**
Coal mining	10.1	10.1
Oil and gas extraction	99.5	99.5
Other mining	17.5	0.0
Construction	**463.6**	**463.6**
Manufacturing	**1,566.6**	—
Transportation and public utilities	**825.0**	**786.5**
Transportation		
Railroad transportation	22.9	22.9
Local and interurban passenger transit	18.7	18.7
Trucking and warehousing	126.0	126.0
Water transportation	14.8	14.8
Transportation by air	93.0	93.0
Other transportation	38.5	0.0
Communications	281.1	281.1
Electric, gas, and sanitary services	230.0	230.0
Wholesale trade	**674.1**	—
Retail trade	**893.9**	**893.9**
Finance, insurance, and real estate	**1,936.2**	**379.1**
Security and commodity brokers	144.2	144.2
Insurance carriers	167.7	167.7
Insurance agents, brokers, and service	67.3	67.3
Other finance, insurance, real estate	1,557.1	—
Services	**2,164.6**	**261.2**
Hotels and other lodging places	86.5	86.5
Auto repair, services, and parking	93.9	93.9
Amusement and recreation services	80.8	80.8

Industries (1987 standard industrial classification)	GDP components ($ billion)	Weather sensitive components ($ billion)
TOTAL GROSS DOMESTIC PRODUCT	9,872.9	3,859.1

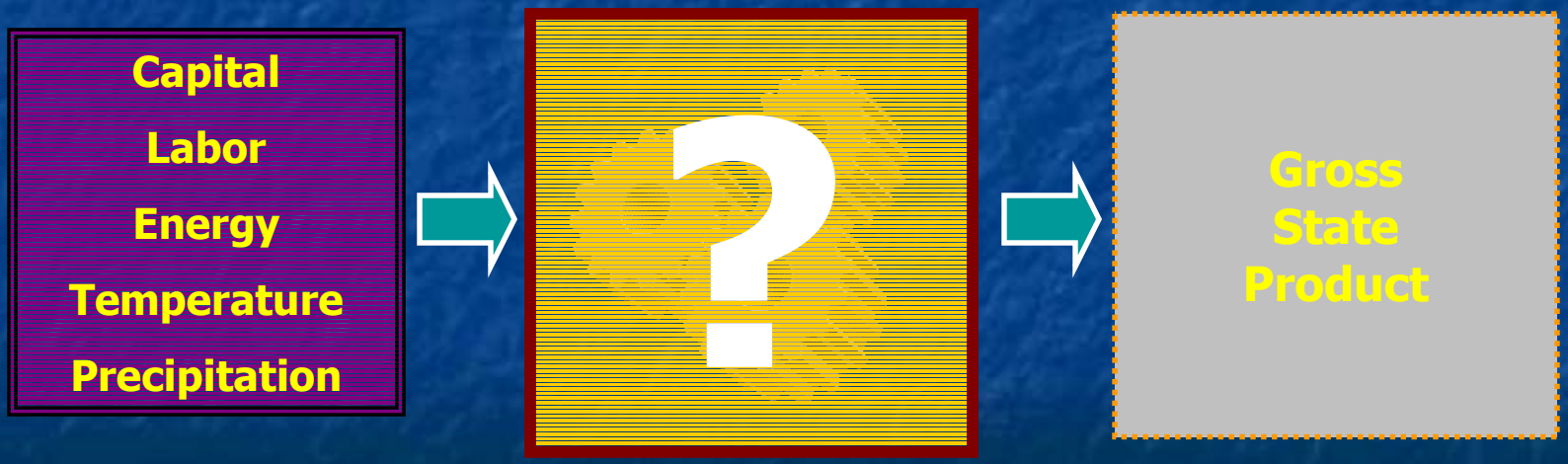
1307

Background

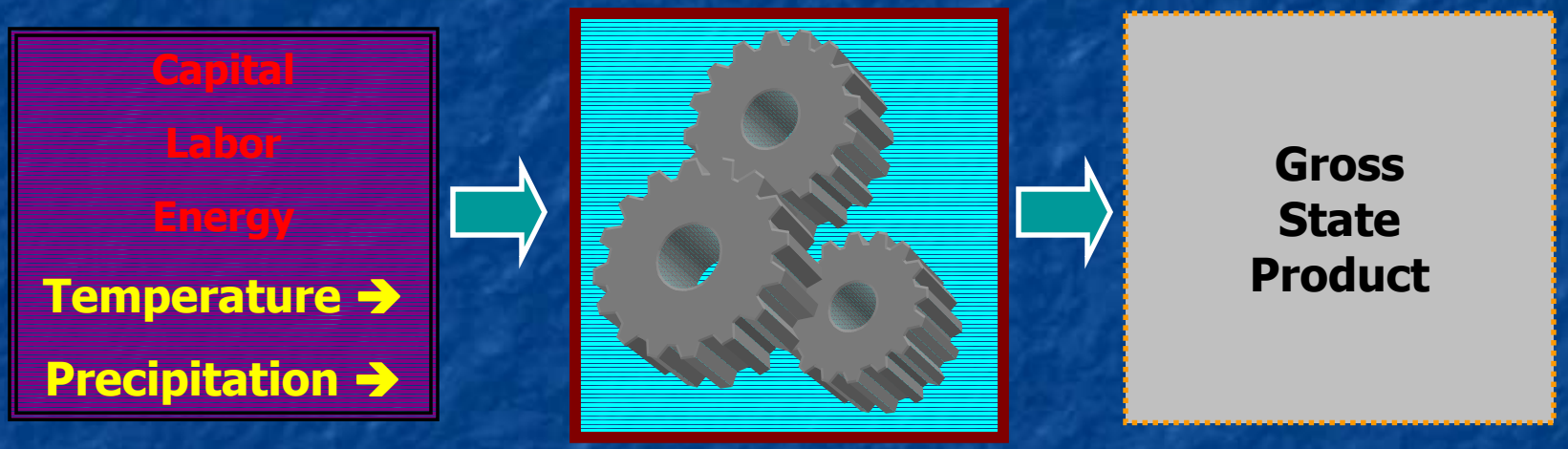
- Studies analyze the economic effects of climate change on sectors of the U.S. economy.
  - Nordhaus (1994, 1996), Cline (1992), Fankhauser (1995), Tol (1995), and Titus (1992).
- Models calculating long-term sectoral sensitivity to climate change
- Studies quantifying sensitivity of economic sectors to weather in the United States.

Conceptual Approach

Model Building: using historical economic and weather data, we model the relationship between economic output in 11 sectors, economic inputs, and weather and weather variability



Conceptual Approach



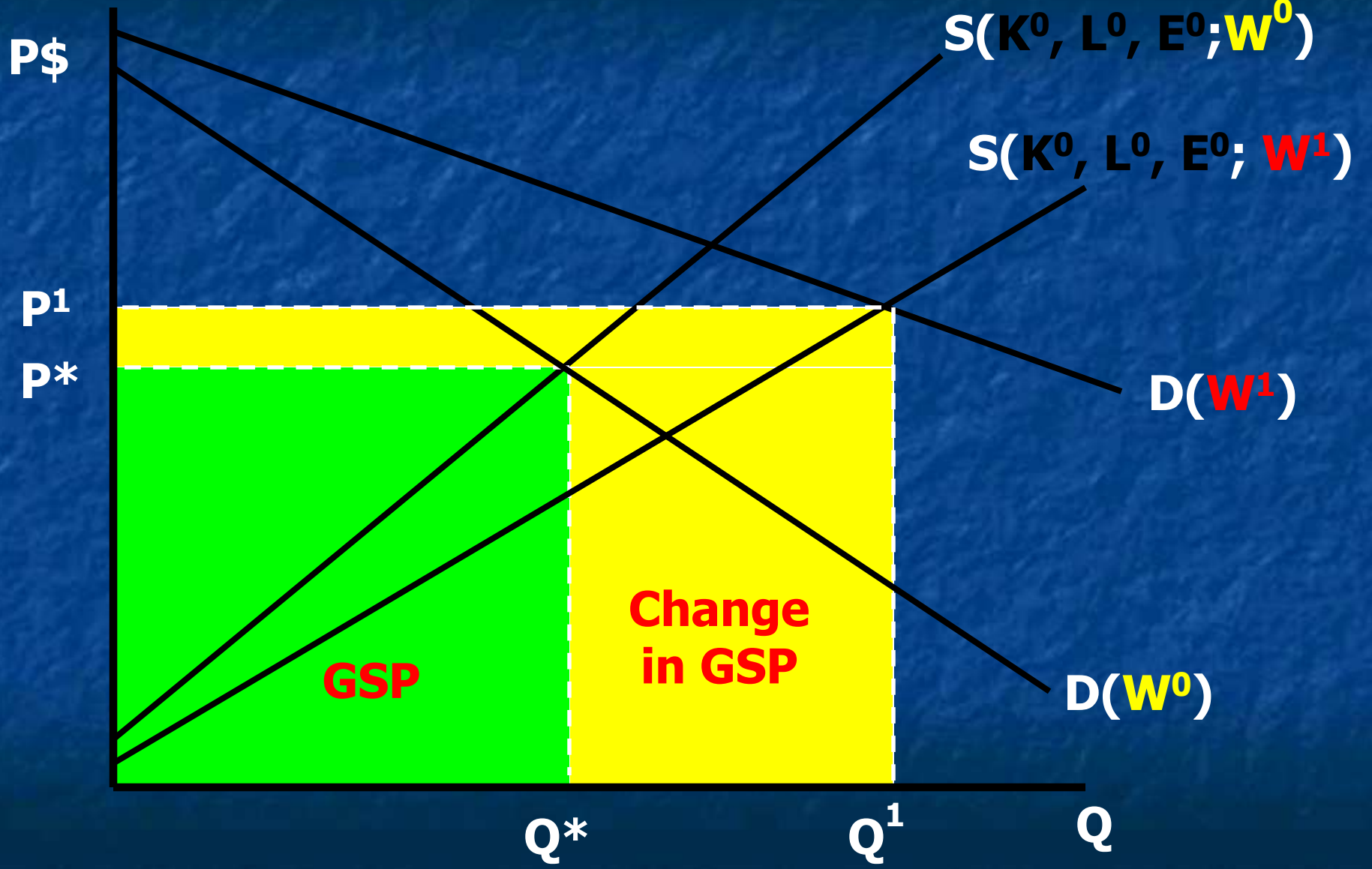
Sensitivity Analysis: Using these models, we then hold the economic inputs constant, and use 70 years of weather data to see how economic output varies as a result of variation in weather

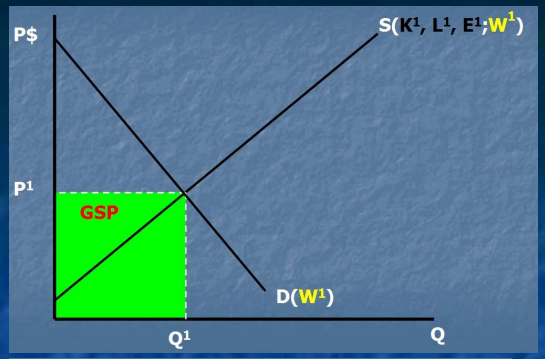
Define "Sensitive"

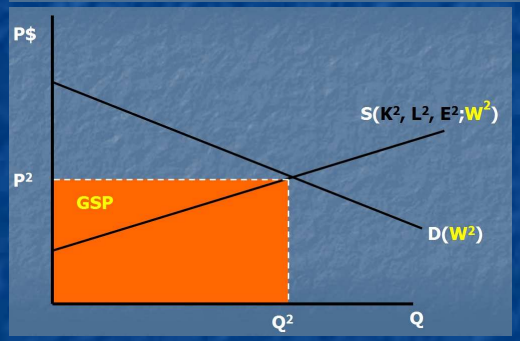
- **No single correct definition**

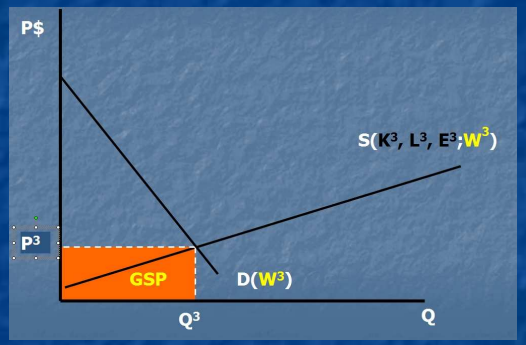
- **Characteristics of a meaningful approach**
  - **consistent with economic theory**
  - **amenable to empirical examination**
  - **provide meaningful information about economic impacts of Wx**

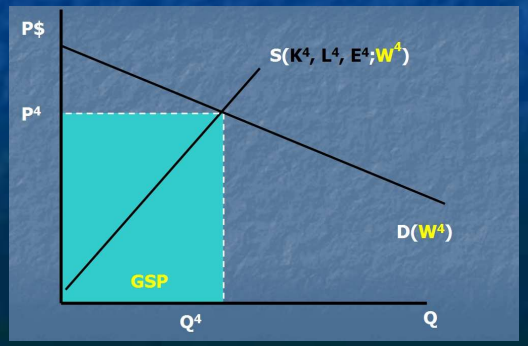
What is Weather Sensitivity?





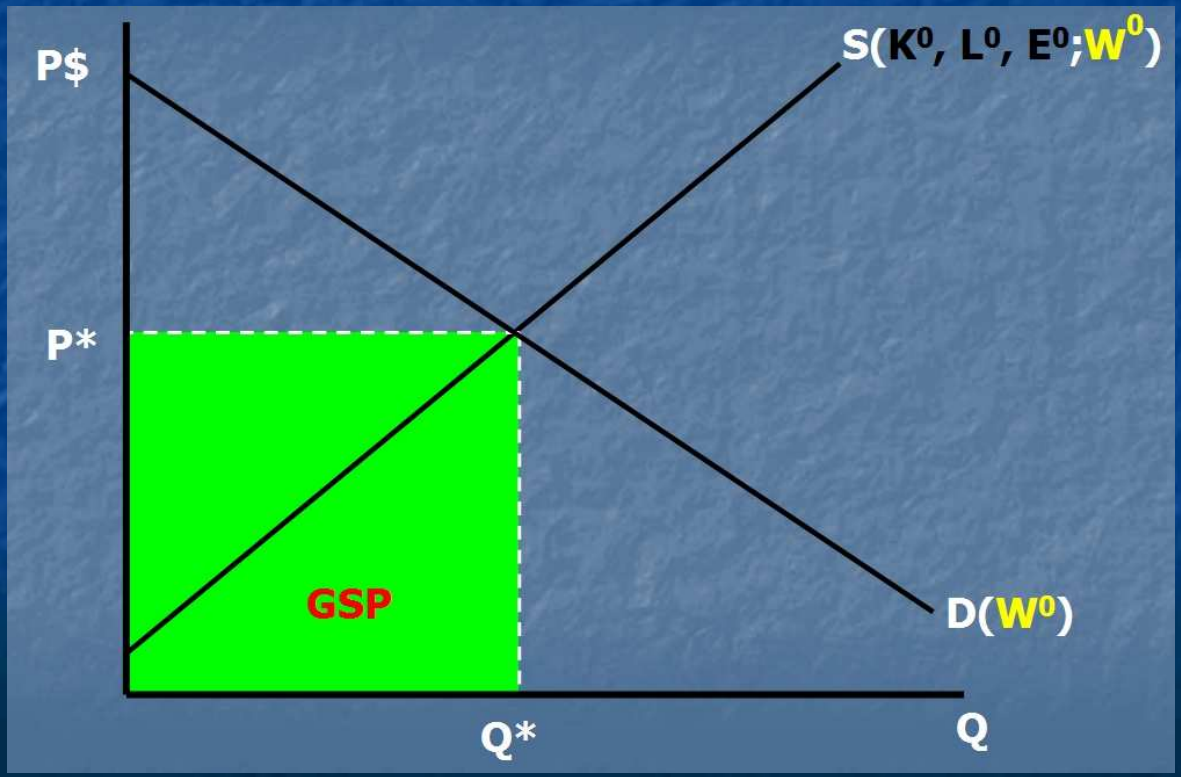






Issues?

- Weather or climate?
- Sensitivity or something else?



Super Sectors

Sector	Billions (2000$)
Wholesale Trade	592
Retail Trade	662
Transportation	302
Utilities	189
Communications	458
Agriculture	98
FIRE	1,931
Manufacturing	1,426
Construction	436
Mining	121
Services	675
Total Private Sector	6,890
Government	1,135
Total	8,026

Economic Modeling

$$Q = f(L, K, E)$$

$$Q_{ijt} = A_{ijt} e^{r_{ij} t} L_{ijt}^{\beta_L} K_{ijt}^{\beta_K} E_{ijt}^{\beta_E} \bar{W}_{it}^{\beta_{\bar{W}}}$$

Translog Function

$$\ln(Q_{ijt}) = \ln(A_{ijt}) + \delta t + \beta_L \ln(L_{ijt}) + \beta_K \ln(K_{ijt}) + \beta_E \ln(E_{ijt}) +$$

$$\beta_{\bar{W}} \ln(\bar{W}_{it}) + \frac{1}{2}\beta_{\bar{W}\bar{W}} \ln(\bar{W}_{it}) \ln(\bar{W}_{it}) + \frac{1}{2}\beta_{LL} \ln(L_{ijt}) \ln(L_{ijt}) +$$

$$\beta_{LK} \ln(L_{ijt}) \ln(K_{ijt}) + \beta_{LE} \ln(L_{ijt}) \ln(E_{ijt}) + \beta_{L\bar{W}} \ln(L_{ijt}) \ln(\bar{W}_{it}) +$$

$$\frac{1}{2}\beta_{KK} \ln(K_{ijt}) \ln(K_{ijt}) + \beta_{KE} \ln(K_{ijt}) \ln(E_{ijt}) +$$

$$\beta_{K\bar{W}} \ln(K_{ijt}) \ln(\bar{W}_{it}) + \frac{1}{2}\beta_{EE} \ln(E_{ijt}) \ln(E_{ijt}) + \beta_{E\bar{W}} \ln(E_{ijt}) \ln(\bar{W}_{it}) + \varepsilon_{ijt}$$

Weather "Sensitivity"

$$\ln Q = \ln A + rt + \beta_L \ln L + \mathrm{L} + \beta_W \ln W + \varepsilon$$

$$\partial \ln Q / \partial \ln W = \beta_W$$

$$\ln Q = \mathrm{L} + \beta_L \ln L\left(\bar{L}, \sigma_L\right) + \mathrm{L} + \beta_W \ln W\left(\bar{W}, \sigma_W\right) \mathrm{L}$$

$Q\left(Q, \sigma_Q\right)$ caused by σ_W

Economic Data

Economic Data - state x year x sector

Gross State Product (dependent variable)

Production Inputs

- Capital (K) - dollars
- Labor (L) - hours
- Energy (E) – BTUs

Weather Data - state x year

Temperature Variability

- CDD : Cooling Degree Days: (T - 65) on a given day
- HDD : Heating Degree Days: (65 - T) on a given day

Precipitation

- P_Tot: Precipitation Total (per square mile)
- P_Std: Precipitation Standard Deviation

i = state 48
j = sector 11
t = year 1977-2000 = 24 years
48 x 11 x 24 = 12,672 "observations"

Temperature Weather Inputs

- **CDD: Defined as (T - 65) = daily CDD, where T is daily Average Temperature (F). If T is less than 65 degrees F, CDD=0.**
- **HDD: Defined as (65 - T) = daily HDD, where T is daily Average Temperature (F). If T is greater than 65 degrees F, HDD=0.**
- **Average (Mean) Temperature of the day : (High Temperature + Low Temperature) / 2 ; High and Low Temperature are whole integer values.**

http://www.weather2000.com/dd_glossary.html

Econometric Methods

- Level data versus per capita
- Panel data – time series – AR(1)
- Heteroskedasticity
- Fixed Effects
- Covariance calculations for marginal effects

Econometric Results

Sector: Agriculture

Parameter	Estimate	Sig.
Intercept	-12.089	***
YEAR	0.003	**
Capital	0.672	***
Labor	0.798	***
Energy	0.086	**
Heating Degree Days	-0.035	ns
Cooling Degree Days	-0.068	***
P_Tot	-0.187	***
P_Std	0.185	***

ns = not significant at 10%
* 10%, ** 5%, *** 1%

Parameter Estimates from Full Model Regressions

Significance (* = 10%, ** = 5%, *** = 1%, ns = not signficant)
DF=1068 for all models

	Agric.	Wholes	Retail	FIRE	Comm.	Utilities	Transp.	Manf.	Constr.	Mining	Svcs
Inter	50.46 ns	-1.65 ns	-2.08 ns	39.98 ns	27.08 ns	-25.26 ns	-28.44 ns	-24.78 ns	-6.13 ns	153.57 **	55.72 ***
YEAR	-0.01 ***	0.02 ***	-0.01 ***	0.004 **	-0.01 ***	0.01 **	0.01 ***	0.03 ***	0.00 ns	-0.03 ***	0.003 ***
ln KAP	-2.10 **	-0.12 ns	-0.75 ns	7.70 ***	2.98 ***	9.21 ***	4.78 ***	0.51 ns	-9.55 ***	-5.93 ***	-2.66 ***
CDD	2.56 *	-0.24 ns	0.24 ns	-3.10 **	-0.97 ns	2.79 ns	-3.52 ***	1.49 ns	-1.43 ns	2.50 ns	-1.05 *
KAP^2	0.14 ***	0.05 ***	0.08 ***	0.02 ns	0.02 ns	-0.23 ***	0.07 ***	0.04 ns	0.06 ***	0.19 ***	-0.03 ns
KAP x HDD	-0.06 ns	0.04 **	0.09 ***	-0.07 **	0.06 **	-0.31 ***	-0.06 ns	0.05 ns	0.24 ***	0.57 ***	0.15 ***

State Fixed Effects

Marginal Responses

	Capital		Labor		Energy	
Sector	Marg Eff	T-Stat	Marg Eff	T-Stat	Marg Eff	T-Stat
Agriculture	1.10	35.02	0.44	8.55	-0.01	-0.14
Communications	1.12	30.08	0.31	12.57	-0.14	-6.23
Construction	0.48	12.40	1.14	52.35	0.12	4.60
FIRE	0.98	32.49	0.39	9.82	-0.20	-6.84
Manufacturing	0.48	5.76	0.62	6.98	0.09	1.71
Mining	1.20	11.86	0.60	9.20	0.10	1.51
Retail Trade	0.91	31.15	0.54	15.94	-0.04	-2.02
Services	0.94	35.85	0.64	18.57	-0.07	-5.53
Transportation	0.94	28.84	0.33	12.21	0.07	1.90
Utilities	1.11	22.57	-0.31	-4.94	-0.03	-0.73
Wholesale Trade	0.50	19.99	0.78	33.01	-0.02	-1.15

Marginal Responses

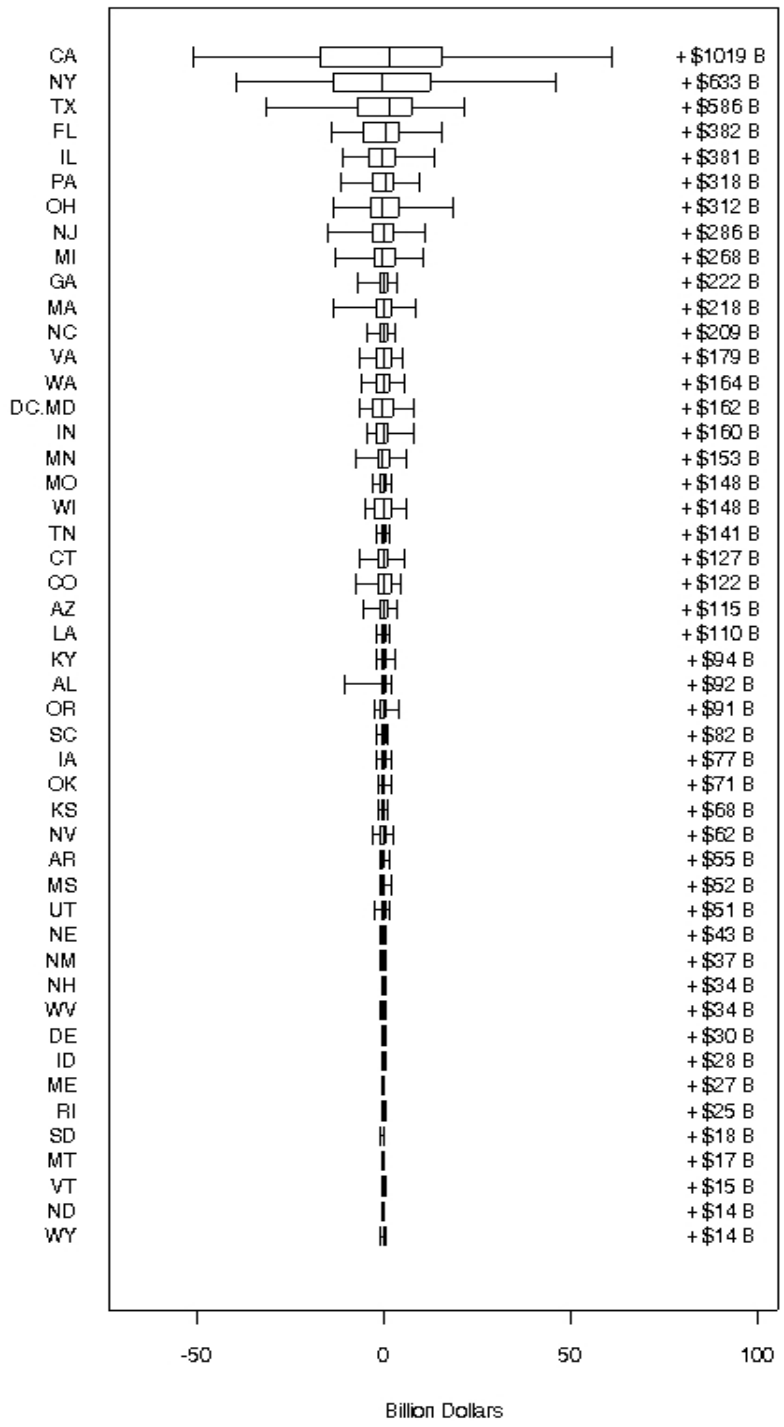
	HDD		CDD		Total Precip		Precip Variance	
Sector	Marg Eff	T-Stat	Marg Eff	T-Stat	Marg Eff	T-Stat	Marg Eff	T-Stat
Agriculture	0.00	-0.05	-0.19	-6.11	0.28	1.89	-0.12	-6.75
Communic.	0.13	3.96	0.06	3.31	0.06	0.36	0.17	16.15
Construct.	-0.01	-0.38	0.06	2.85	-0.01	-0.05	0.26	20.84
FIRE	0.15	3.52	0.06	2.70	0.54	3.19	-0.08	-5.60
Manufact.	0.18	1.85	0.02	0.36	0.49	2.34	-0.22	-6.60
Mining	0.25	1.97	0.04	0.57	-3.52	-9.54	1.10	27.44
RetailTrade	0.04	1.75	0.03	2.88	-0.13	-1.32	0.13	18.20
Services	0.04	2.07	0.00	0.29	0.33	4.01	-0.05	-7.72
Transport.	-0.03	-0.91	0.01	0.44	-0.15	-0.74	0.15	12.18
Utilities	0.00	0.04	0.08	1.91	-0.59	-1.42	-0.28	-11.59
Wholesale	0.10	4.63	0.02	1.65	-0.19	-1.93	0.02	3.03

Wx Sensitivity Analysis

11 Sector Models:

$$Q = f(K, L, E, W; \text{Year}, \text{State})$$

- Average K, L, E 1996-2000
- Set Year to 2000
- Historical weather data 1931-2000
- Fitted GSP values by sector by state by year
  - 11 sectors
  - 48 states
  - 70 "years" fit to 2000 "economic structure"


CA +$1019 B
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FL +$382 B
IL +$381 B
PA +$318 B
OH +$312 B
NJ +$286 B
MI +$268 B
GA +$222 B
MA +$218 B
NC +$209 B
VA +$179 B
WA +$164 B
DC.MD +$162 B
IN +$160 B
MN +$153 B
MO +$148 B
WI +$148 B
TN +$141 B
CT +$127 B
CO +$122 B
AZ +$115 B
LA +$110 B
KY +$94 B
AL +$92 B
OR +$91 B
SC +$82 B
IA +$77 B
OK +$71 B
KS +$68 B
NV +$62 B
AR +$55 B
MS +$52 B
UT +$51 B
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NM +$37 B
NH +$34 B
WV +$34 B
DE +$30 B
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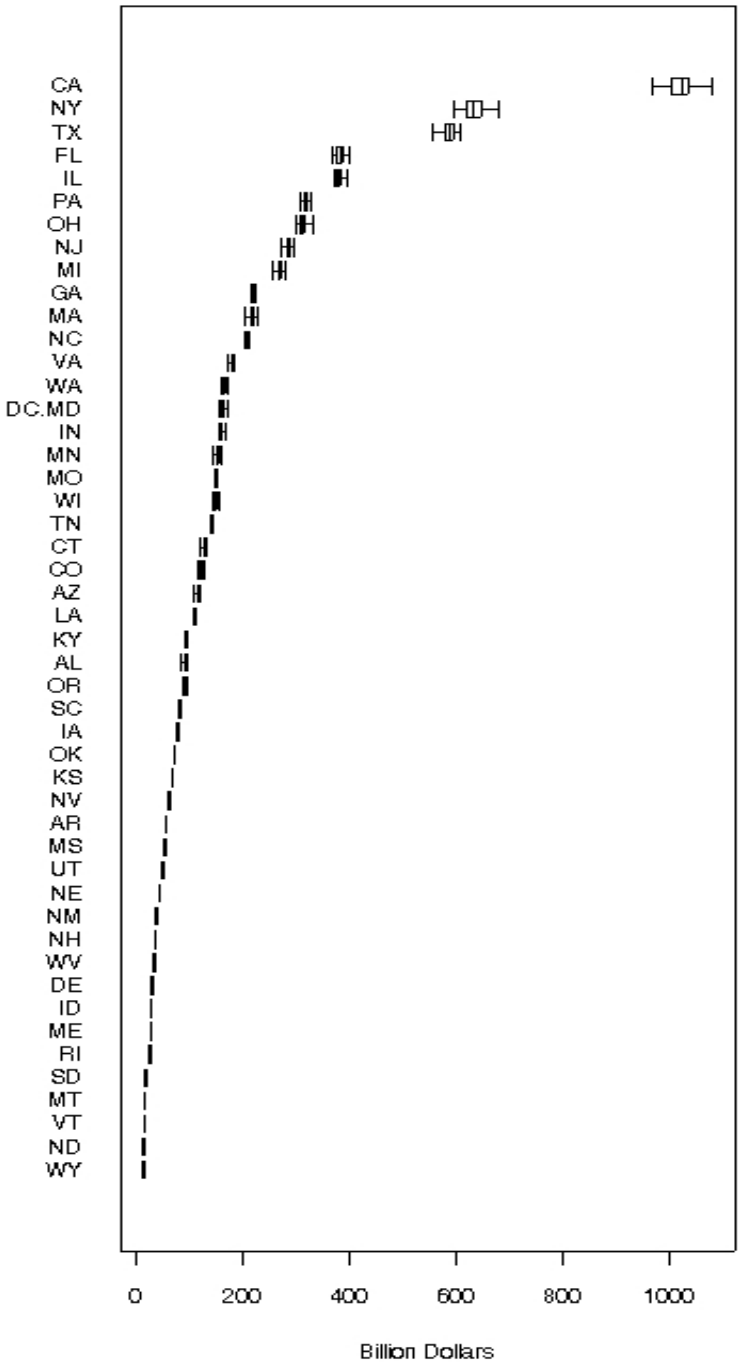
Billion Dollars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800
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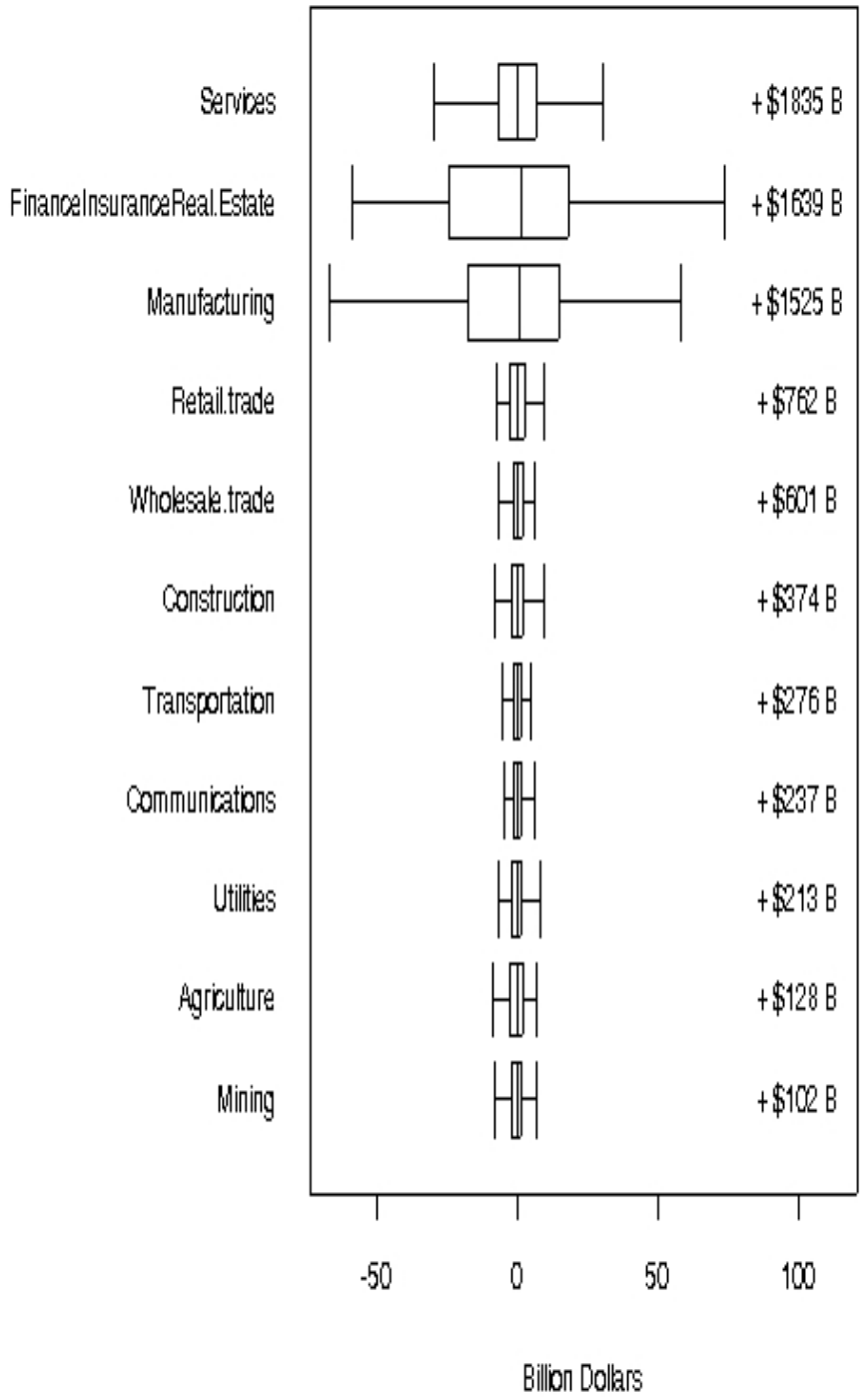
Billion Dollars

State Sensitivity
(Billions $2000)

State	Mean	Max	Min	Range	% Range	Rank
New York	633.3	679.6	594.0	85.6	13.5%	1
Alabama	92.0	93.9	81.7	12.2	13.3%	2
California	1019.4	1080.5	968.6	111.9	11.0%	3
Wyoming	13.7	14.3	12.8	1.4	10.5%	4
Ohio	312.0	330.6	298.4	32.2	10.3%	5
⋮	⋮	⋮	⋮	⋮	⋮	⋮
Delaware	30.2	30.6	29.6	1.0	3.3%	44
Maine	27.0	27.4	26.5	0.9	3.3%	45
Montana	17.2	17.4	16.9	0.6	3.3%	46
Louisiana	109.5	111.2	107.6	3.6	3.3%	47
Tennessee	141.1	142.8	139.3	3.5	2.5%	48


Services
FinanceInsuranceReal.Estate
Manufacturing
Retail.trade
Wholesale.trade
Construction
Transportation
Communications
Utilities
Agriculture
Mining
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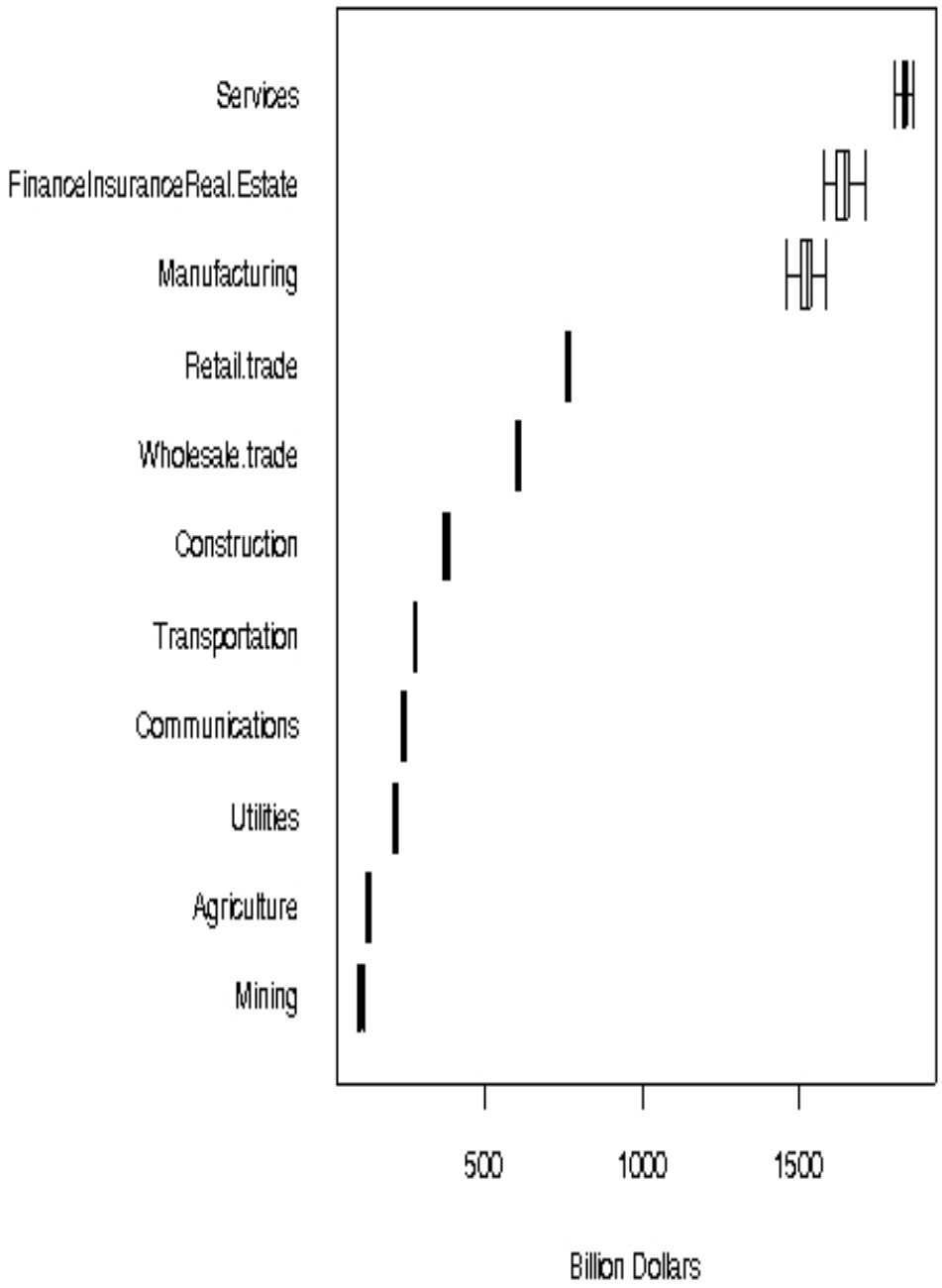
+$1639 B
+$1525 B
+$762 B
+$601 B
+$374 B
+$276 B
+$237 B
+$213 B
+$128 B
+$102 B
-50
0
50
100
Billion Dollars


Services
FinanceInsuranceReal.Estate
Manufacturing
Retail.trade
Wholesale.trade
Construction
Transportation
Communications
Utilities
Agriculture
Mining
500
1000
1500
Billion Dollars

Sector Sensitivity

(Billions $2000)

Sector	Mean	Max	Min	Range	%Range
Agriculture	127.6	134.4	119.0	15.4	12.09%
Wholesale trade	601.5	607.8	594.5	13.3	2.20%
Retail trade	761.5	771.2	753.9	17.3	2.27%
FIRE	1,639.3	1,713.1	1,580.6	132.5	8.08%
Communications	237.3	243.4	232.3	11.1	4.68%
Utilities	212.9	220.8	206.0	14.9	6.98%
Transportation	276.1	280.7	271.0	9.8	3.53%
Manufacturing	1,524.8	1,583.2	1,458.2	125.1	8.20%
Construction	374.5	384.0	366.4	17.7	4.71%
Mining	102.0	108.9	94.2	14.7	14.38%
Services	1,834.9	1,865.4	1,804.9	60.5	3.30%

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National Sensitivity

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Services	1,834.9	1,865.4	1,804.9	60.5	3.30%
Total National	**7,692.4**	**7,554.6**	**7,813.4**	**258.7**	**3.36%**

Future Research (1)

- extend data past 2000
- better capital and energy data
- include “storms” data
- include forecast skill measure
  - value of weather forecasts?
- split supply and demand
- model uncertainty

Future Research (2)

- finer spatial scales
  - county level data for a state
- finer temporal scales
  - quarterly / monthly economic data
- finer sectoral scales
  - 2, 3, or 4 digit sector study
- other regions / countries

Conclusions

- Economically valid analysis
- Significant impact of weather
  - significant regression coefficients
  - significant marginal effects
- Interpretation of weather sensitivity
  - upper-bound weather risk measure?
  - upper-bound measure of value of weather information?
- 3.4% of annual US economic variability
- $260B US economic variability related to weather variability