Overall U.S. Economic Sensitivity to Weather

Jeffrey K. Lazo

Societal Impacts Program
NCAR - Boulder, CO

lazo@ucar.edu
www.sip.ucar.edu

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Societal Impacts Program

Objective: become a focal point of social science research and information on societal impacts and benefits of weather information

- NOAA & NCAR Funded Program

- Create and Support the Community
  - Social Science Research Agenda on Hurricanes
  - THORPEX Societal and Economic Applications

- Provide Outreach and Education
  - WAS*IS – Weather and Society
  - Digital Library

- Conduct and Facilitate Research
  - Sector Weather Sensitivity
    - baseline for understanding weather and society
Outline

- Motivation
- Our Approach
- What is Economic Sensitivity?
- Data and Modeling
- Results
- Next Steps and Future Research
- Conclusions
Motivation

Why Does It Matter?

- value of weather information
- value of weather risk
- question of increasing weather vulnerability
- weather and climate issues
### Motivation

**CONTRIBUTIONS OF THE ATMOSPHERIC SCIENCES TO THE NATIONAL WELL-BEING**

**TABLE I.2.5 Categories of U.S. Activities That Display Sensitivity to Weather and Climate**

<table>
<thead>
<tr>
<th>Industry</th>
<th>Contribution to Gross Domestic Product, 1996 ($ billion)</th>
<th>Percent of Gross Domestic Product</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industries Sensitive to Weather and Climate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture, Forestry, and Fisheries</td>
<td>115.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Construction</td>
<td>222.1</td>
<td>3.7</td>
</tr>
<tr>
<td>Transportation and Public Utilities</td>
<td>529.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>557.5</td>
<td>9.3</td>
</tr>
<tr>
<td>Finance, Insurance, and Real Estate</td>
<td>1106.1</td>
<td>18.4</td>
</tr>
<tr>
<td>Subtotal</td>
<td>2530.5</td>
<td>42.1</td>
</tr>
<tr>
<td><strong>Industries Generally Not Sensitive to Weather and Climate</strong></td>
<td>85.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Mining</td>
<td>1063.0</td>
<td>17.7</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>394.4</td>
<td>6.5</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>1182.7</td>
<td>19.7</td>
</tr>
<tr>
<td>Services</td>
<td>755.7</td>
<td>12.6</td>
</tr>
<tr>
<td>Government</td>
<td>3481.0</td>
<td>57.9</td>
</tr>
<tr>
<td>Subtotal</td>
<td>6011.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**SOURCE:** Bureau of Economic Analysis, Department of Commerce.
Opportunities And Priorities In A New Era For Weather And Climate Services - John Dutton – BAMS – September 2002

“... some 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 ...”
Opportunities And Priorities In A New Era For Weather And Climate Services - John Dutton – BAMS – September 2002

“The third [column of Table 2] indicates those [sectors] that (in the author’s opinion) are, to some extent, sensitive to weather and climate events and variations.”
Our Approach

1. Define Sensitivity
2. Data — Economic and Weather
3. Analyze Economic Productivity Measures In Relation to Wx Data
4. Look at How Economic Productivity Varies as Weather Varies (holding everything else constant)
What Does Sensitive Mean?

- No single correct definition
- First step therefore is to develop a meaningful definition
  - Understand the sources of Wx impact
  - Consistent with economic theory and methods
  - Amenable to empirical examination
  - Will provide meaningful information about economic impacts of Wx
Sources of Weather Impact

- Consumer – demands good and services
  - direct – “consume” sunshine for recreation
  - indirect – more snow impacts demand for skiing

- Producer – use capital, labor, energy to produce goods and service
  - direct – rain as input to crop production
  - indirect – temperature impacts efficiency of machinery
Supply and Demand

Consumers maximize utility by buying quantities at different prices.

Equilibrium price ($P^*$) and quantity ($Q^*$) determined by interaction of Supply and Demand given $w^0$

Producers maximize profits by offering quantities for sale at different prices.
What is Gross State Product?

GSP = Price x Quantity
   = total revenues
   = total expenditures
What is Weather Sensitivity?

Change in GSP
Our Approach

We have data on GSP, K, L, E, and \( W^0 \) at a point in time for a given sector in a specific state.
Economic Data

Gross State Product
by state by year by sector

Production Inputs
- Capital (K) - dollars
- Labor (L) - hours
- Energy (E) – BTUs
  by state by year by sector

i = state  48
j = sector  11
t = year  1977-2000 = 24 years
48 x 11 x 24 = 12,672 “observations”
Weather Data

Proxy for Temperature Variability

- CDD: Defined as (T - 65) on a given day
  - If T is less than 65 degrees F, CDD=0
- HDD: Defined as (65 - T) on a given day
  - If T is greater than 65 degrees F, HDD=0
  - \( T = \text{Average Temperature of the day} \)
  - \( (\text{High Temperature} + \text{Low Temperature}) / 2 \)

Precipitation Measures

- Precipitation Total (per square mile)
- Precipitation Variance

Measured by **state** by **year**

- \( i = \text{state} \quad 48 \)
- \( t = \text{year} \quad 1977-2000 = 24 \text{ years} \)
# Super Sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Billions (2000$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholesale Trade</td>
<td>592</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>662</td>
</tr>
<tr>
<td>Transportation</td>
<td>302</td>
</tr>
<tr>
<td>Utilities</td>
<td>189</td>
</tr>
<tr>
<td>Communications</td>
<td>458</td>
</tr>
<tr>
<td>Agriculture</td>
<td>98</td>
</tr>
<tr>
<td>FIRE</td>
<td>1,931</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1,426</td>
</tr>
<tr>
<td>Construction</td>
<td>436</td>
</tr>
<tr>
<td>Mining</td>
<td>121</td>
</tr>
<tr>
<td>Services</td>
<td>675</td>
</tr>
<tr>
<td>Government</td>
<td>1,135</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8,026</strong></td>
</tr>
</tbody>
</table>
# Econometric Results

**Sector: Agriculture**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-12.0893</td>
<td>***</td>
</tr>
<tr>
<td>YEAR</td>
<td>0.0032</td>
<td>**</td>
</tr>
<tr>
<td>Capital</td>
<td>0.6721</td>
<td>***</td>
</tr>
<tr>
<td>Labor</td>
<td>0.7978</td>
<td>***</td>
</tr>
<tr>
<td>Energy</td>
<td>0.0858</td>
<td>**</td>
</tr>
<tr>
<td>Precip Variation</td>
<td>0.1853</td>
<td>***</td>
</tr>
<tr>
<td>Heating Degree Days</td>
<td>-0.0351</td>
<td>ns</td>
</tr>
<tr>
<td>Cooling Degree Days</td>
<td>-0.0682</td>
<td>***</td>
</tr>
<tr>
<td>Precip Total</td>
<td>-0.1871</td>
<td>***</td>
</tr>
</tbody>
</table>

*ns = not significant at 10%*

* 10%, ** 5%, *** 1%*
Fitted Values

Predicted Real $ vs. Actual Real $

Transportation

MEST Region: NY, NJ, DE, MD/DC, PA

Date

$10,000,000,000

$20,000,000,000

$30,000,000,000

$40,000,000,000

$50,000,000,000

PLOT

Model 10: Translog
Real Sector Output

Model 10: Translog with Wx
Wx Sensitivity Analysis

11 Sector Models of $Q=f(K,L,E,W;Year,State)$

- take average of physical inputs (K,L,E)
- set year to 2000
- use historical wx data 1931-2000
- fitted GSP values by sector by state by year
  - 11 sectors
  - 48 states
  - 70 “years” fit to 2000 “economic structure”

- aggregation
  - by sector
  - by state
  - nationally
## Aggregation

<table>
<thead>
<tr>
<th>Measure</th>
<th>Agriculture</th>
<th>Mining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millions (2000$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000 GSP</td>
<td>98,000</td>
<td>121,000</td>
</tr>
<tr>
<td>Average Fitted Value</td>
<td>104,653</td>
<td>121,232</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>10,977</td>
<td>24,184</td>
</tr>
<tr>
<td>Coefficient of Variation</td>
<td>10.59%</td>
<td>19.95%</td>
</tr>
</tbody>
</table>

Next Steps

1. to resolve this for all 11 sectors
2. show CoV by state (rank states)
3. show CoV by sector (rank sectors)
4. show national CoV – National Sensitivity to Wx
Future Research

- Extend data set to most recent years
- Improve weather data
  - Storm data
  - adjust HDD/CDD to state level measures
- Statistical methods
  - Monte Carlo analysis with model uncertainty
- Specific sectors or states for detailed analysis
- Include measures of forecast accuracy
- Look at changes in sensitivity over time
Conclusion

- Economically valid analysis of weather-sensitivity of US economic sectors
- Significant impacts of weather on economic output
- Upper-bound measure of weather risk?
- Upper-bound measure of value of weather information?