The Economic Value Of Weather Forecasts

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## Economic Value of Weather Forecasts

<table>
<thead>
<tr>
<th>Action</th>
<th>Forecast</th>
<th>Frost</th>
<th>No Frost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protect</td>
<td>-C (lost cost)</td>
<td>-C (lost cost)</td>
<td></td>
</tr>
<tr>
<td>Don’t Protect</td>
<td>-L (lost crop)</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Nelson and Winter *QJE*

## Objectives

- Ensure that “economic value” is valid economics
- Look at broader approach to economic valuation
Outline

• Economics and neoclassical value theory
• Risk and uncertainty
• Value of information
• Public goods
• Valuation methods
Economics

• “Study of the allocation of scarce resources to satisfy unlimited wants”
  – scarce resources
  – unlimited wants
  – allocation

• Why Econ 101 (Econ 601)?
Neoclassical Value Theory

• Economic agents
  – Consumers
  – Producers
  – Government

• Assumptions
  1. People have rational preferences
  2. Individuals maximize utility
  3. Firms maximize profits
  4. Agents act independently using full information

• Neoclassical Theory includes or extends to
  – Competitive equilibrium
  – Social welfare theory
  – Benefit-cost analysis
Utility is a function of consumption of two commodities: $X_1, X_2$.

Utility is also dependent on the weather, $w$.

“Indifference Curve”
Individual constrained by
(1) income: $Y$
(2) prices: $P_1, P_2$

**Budget Constraint**

$$Y - PX_1 - PX_2 \geq 0$$

$$X_2 = \frac{Y}{P_2} - \frac{P_1}{P_2} X_1$$
Constrained Utility Maximization

Chooses $X_1$ and $X_2$
- subject to prices
- subject to income
- to reach the highest level of utility
Solution to Utility Maximization Problem

Max \( L_{X_1, X_2} = U(X_1, X_2, w) + \lambda(Y - PX_1 - PX_2) \)

\[
\frac{\partial L}{\partial X_1} = \frac{\partial U}{\partial X_1} - \lambda P_1 \equiv 0 \\
\frac{\partial L}{\partial X_2} = \frac{\partial U}{\partial X_2} - \lambda P_2 \equiv 0 \\
\frac{\partial L}{\partial \lambda} = Y - PX_1 - PX_2 \equiv 0
\]

\[
\frac{\partial U}{\partial X_1} / \frac{\partial U}{\partial X_2} = P_1 / P_2
\]
Economics of Production

• Profit maximization
  – Revenues minus costs

• Production constraint
  – Technology
  – Wages and input price

• Subjective decision making

• How does avoided costs relate to Economic Value?
  – Translates to increased income (Y)
Value of Increased Income

$$\text{Max } L_{x_1, x_2} = U(X_1, X_2) + \lambda(Y - PX_1 - PX_2)$$

$$\frac{\partial L}{\partial Y} = \lambda$$
Lessons Learned So Far

• Neoclassical value theory asserts that economic value is determined by consumers’ marginal utility

• “Value” is based on individuals’ preferences
  – Value is subjective
  – Value does not mean “dollars”
    ▪ Dollars serve only as a unit of measurement
  – Value does mean “utility”

• Prices convey information
  – To “consumers” for making decisions
  – To “observers” about relative preferences

• Cost savings translates to “Income” and thus “Value”
Where’s the weather?
Weather and State Dependent Utility

Utility is dependent on the weather, $w$.

**Weather** $w_2$ favors activity that uses $X_2$

Have to give up a lot of $X_1$ to get some more $X_2$ to keep utility constant.

\[
U = U(X_1, X_2, w)
\]
Weather and State Dependent Utility

Weather $w_1$ favors activity that uses $X_1$

Have to give up a lot of $X_2$ to get some more $X_1$ to keep utility constant

How to choose when unknown whether weather is $w_1$ or $w_2$?
Risk and Uncertainty

Three approaches to risk and uncertainty:

1. Games of chance
2. Behavioral uncertainty
3. Incomplete information
   • Prices
   • Income
   • Commodity quality
   • Outcome probabilities?

How to formulate “weather uncertainty” and forecast information?
Expected Utility (EU) Theory

\[
\begin{align*}
\text{Max } EU_{x_1, x_2} &= \sum_{i=1}^{n} p_i \left[ U \left( X_1, X_2, w_i \right) \right] \\
\text{Assuming two states of world: } p_1 + p_2 &= 1 \\
\text{Max } EU_{x_1, x_2} &= p_1 \left[ U \left( X_1, X_2, w_1 \right) \right] + (1-p_1) \left[ U \left( X_1, X_2, w_2 \right) \right] \\
\text{Being explicit about the income constraint: } \\
\text{Max } L_{x_1, x_2} &= p_1 \left[ U \left( X_1, X_2, w_1 \right) + \lambda (Y - PX_1 - PX_2) \right] + \\
&(1-p_1) \left[ U \left( X_1, X_2, w_2 \right) + \lambda (Y - PX_1 - PX_2) \right] = \\
&= p_1 \left[ U \left( X_1, X_2, w_1 \right) \right] + (1-p_1) \left[ U \left( X_1, X_2, w_2 \right) \right] + \lambda (Y - PX_1 - PX_2) \\
\text{income constraint not affected by risk or uncertainty}
\end{align*}
\]
Expected Utility (EU) Theory

\[
Max_{x_1, x_2} L = p_1 [U(x_1, x_2, w_1) + \lambda(y \{w_1\} - P \{w_1\} x_1 - P \{w_1\} x_2)] + (1-p_1) [U(x_1, x_2, w_2) + \lambda(y \{w_2\} - P \{w_2\} x_1 - P \{w_2\} x_2)]
\]
Subjective probability values $p$ are a function of forecast, $f$.

$$p = p(f)$$

$$\text{Max } EU = \sum_{i=1}^{n} p_i(f)[U(X_1, X_2, w_i)]$$

$$p = p(f \sim \{f, \sigma, \ldots, \ldots\})$$

$$\text{Max } EU = \sum_{i=1}^{n} p(f \sim \{f, \sigma, \ldots, \ldots\})[U(X_1, X_2, w_i)]$$
Value of Information

Max $EU_{X_1, X_2} = \sum_{i=1}^{n} p(f \sim \{f, \sigma, \ldots, \ldots\}) U(X_1, X_2, w_i)$

$p = p(f \sim \{f, \sigma, skew, kurtosis\})$

“Improving” forecast means:
- improving some measure the distribution of the forecast
- Improving how forecast information translates to “p”
  - i.e., education and communication

Forecast has value if it increases Expected Utility
- this depends on how f relates to p
- does not require a behavioral change
Public Goods

What is the price (i.e., value) of weather forecasts?

Weather forecast characteristics
  • Non-rival
  • Non-exclusive

Problems of public goods
  • No observable price information
  • No provision by private markets

Weather forecasts as “quasi-public goods”? 
Valuation Methods

Market Methods
• how much is the information bought and sold for

Prescriptive Models
• “optimal” decision making by an economic agent

Non-Market Methods
• Indirect
  – Hedonic pricing
  – Value of statistical life
• Direct
  – Willingness-to-pay (WTP) studies
Valuation Methods

Value of Statistical Life (VSL)

- 1,000,000 people each willing to pay $50 a year for a program to reduce the chance of death by 1 in 100,000 per year (say from 20 in 100,000 to 19 in 100,000 each year)

- Means that the group is WTP $50,000,000 to prevent 10 deaths

- VSL = $50,000,000/10 deaths = $5,000,000
Valuation Methods

Non-Market Methods
• Direct
  – Willingness-to-pay (WTP)
    ➢ Value for improvements not yet realized

\[ U = U(X_1, X_2, w) \implies U = V(Y, P, w) \]

\[ U^1 = V(Y^1, P^1, w_1) \]

\[ U^1 = V(Y^1, P^1, w_1) = V(Y^1 \ - \ WTP, P^1, w_2) \]

\[ w_2 \succ w_1 \text{ where } \succ \text{ implies "preferred"} \]
Making Connections

Weather

Observations

Forecasts

Communicate

Perceive

Value

Integrate social science research on weather forecasting

- Risk communication
- Psychology
- Sociology

- Risk perception
- Anthropology
- Geography
Conclusion

• Economic value means “utility”

• How does “improved” forecast accuracy relate to value?
  – depends on what “improved forecast accuracy” means
  – depends on the utility function

• Economics can add to understanding complex relationships between
  – weather events
  – weather forecasts
  – users and values

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Fin

Merci Beaucoup