The Economic Value Of Weather Forecasts

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NCAR - RAP/ESIG

International Verification Methods Workshop
September 17, 2004

Economic Value of Weather Forecasts

		Forecast	
		Frost	No Frost
Action	Protect	-C (lost cost)	-C (lost cost)
	Don’t Protect	-L (lost crop)	0

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

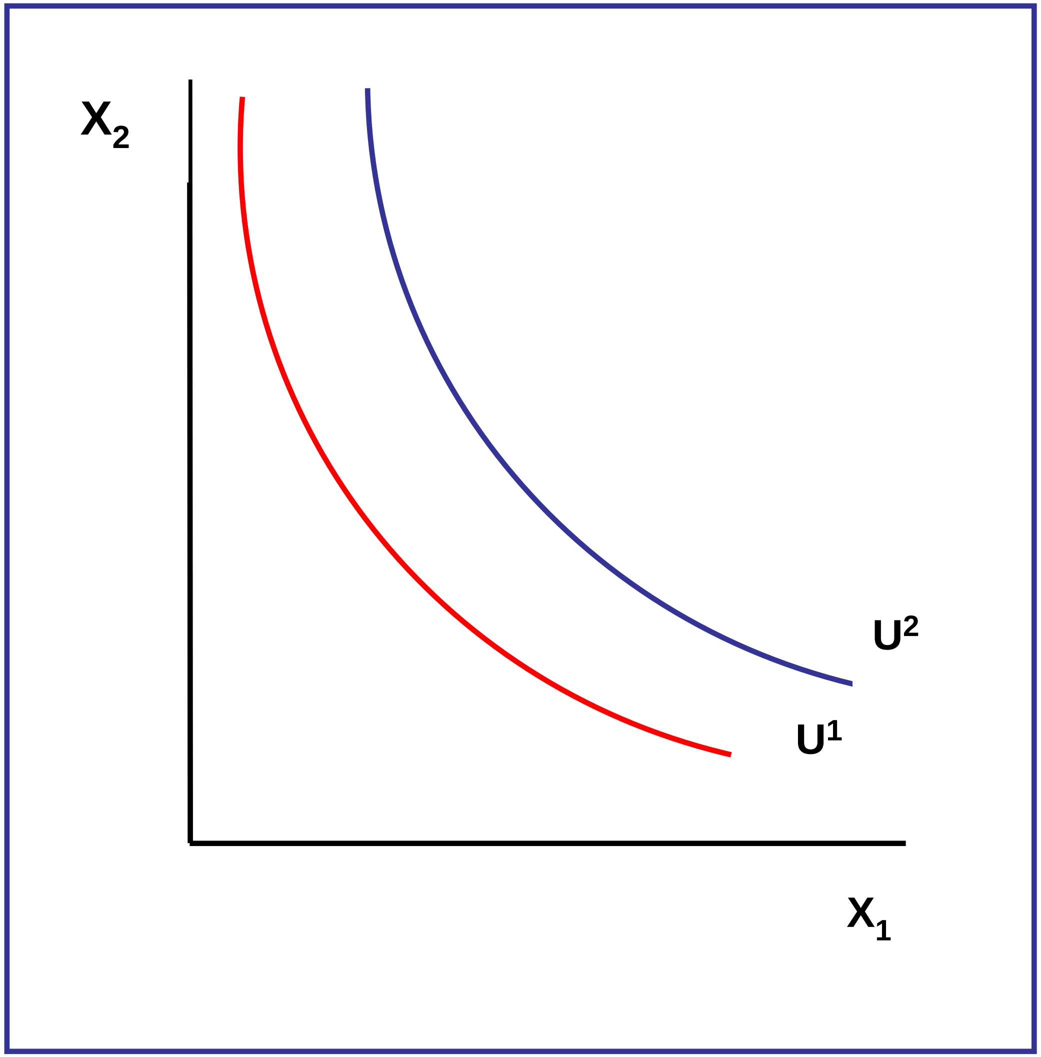
Consumer Utility Theory

$$U = U\left(X_1, X_2, w\right)$$

Utility is a function of consumption of two commodities: X_1 , X_2.

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

"Indifference Curve"



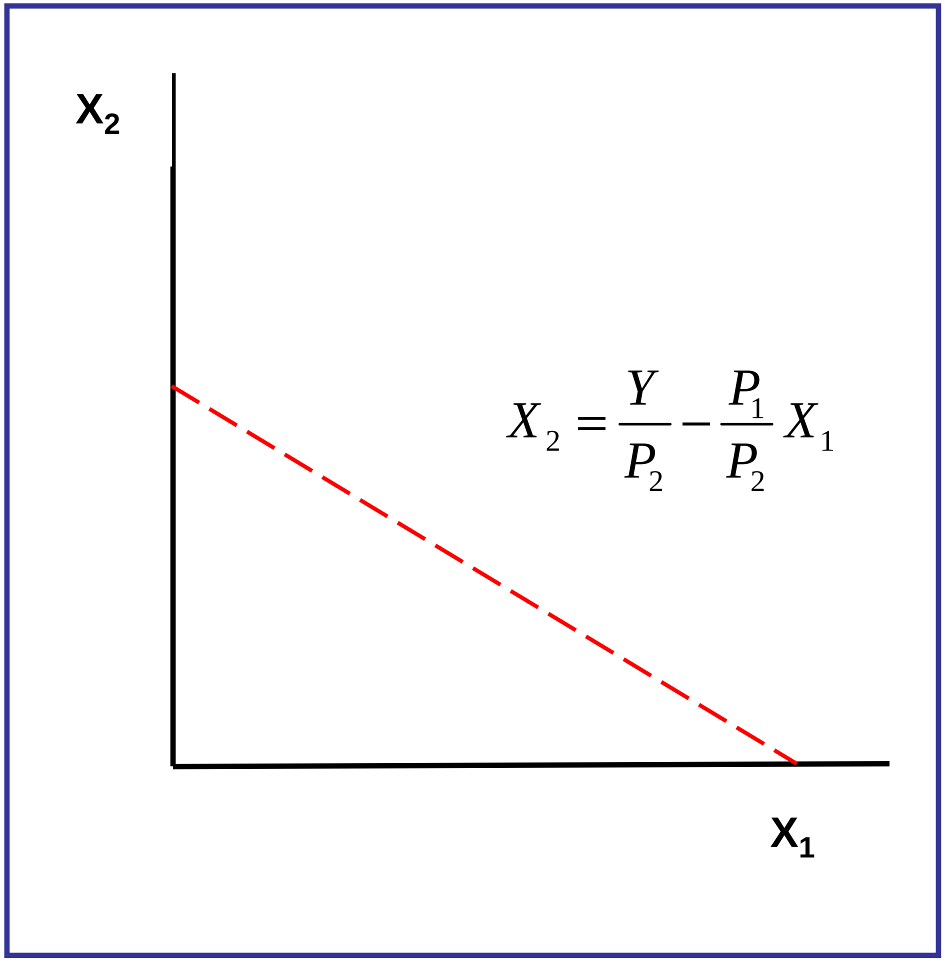
Budget Constraint

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

Individual constrained by

(1) income: Y

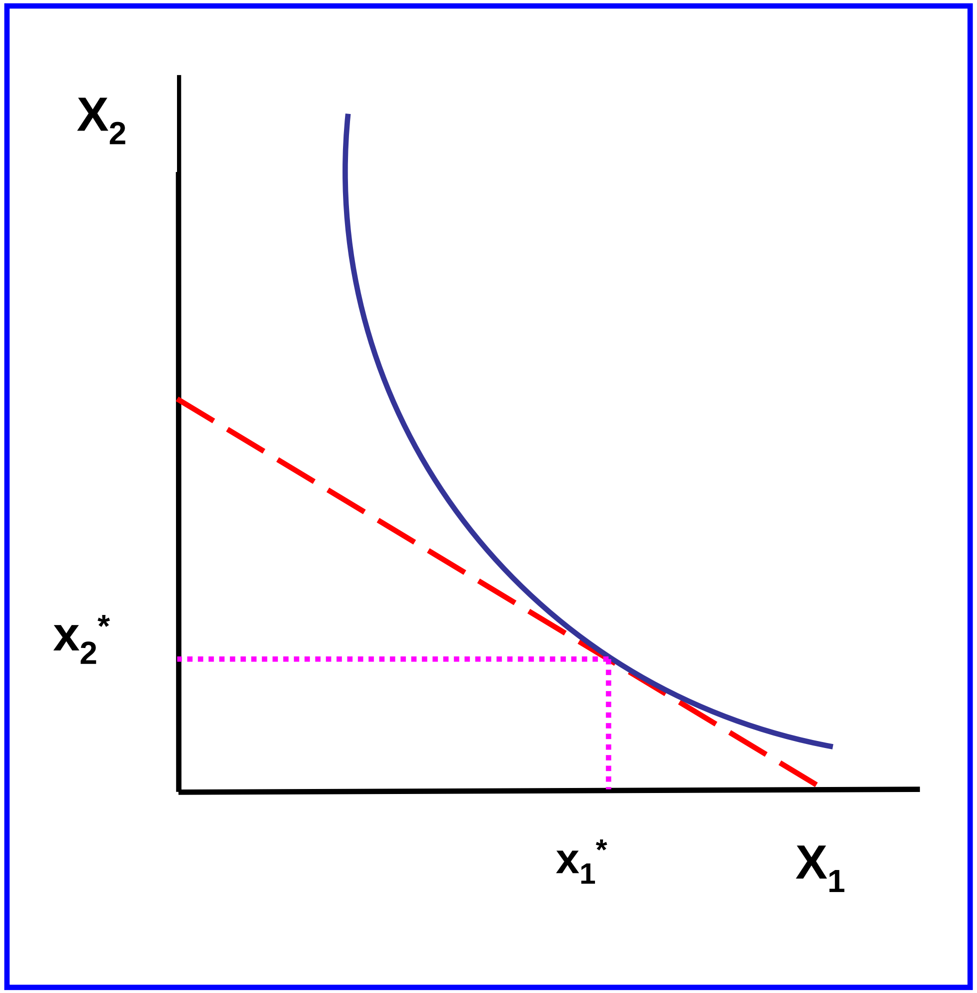
(2) prices: P_1 , P_2



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

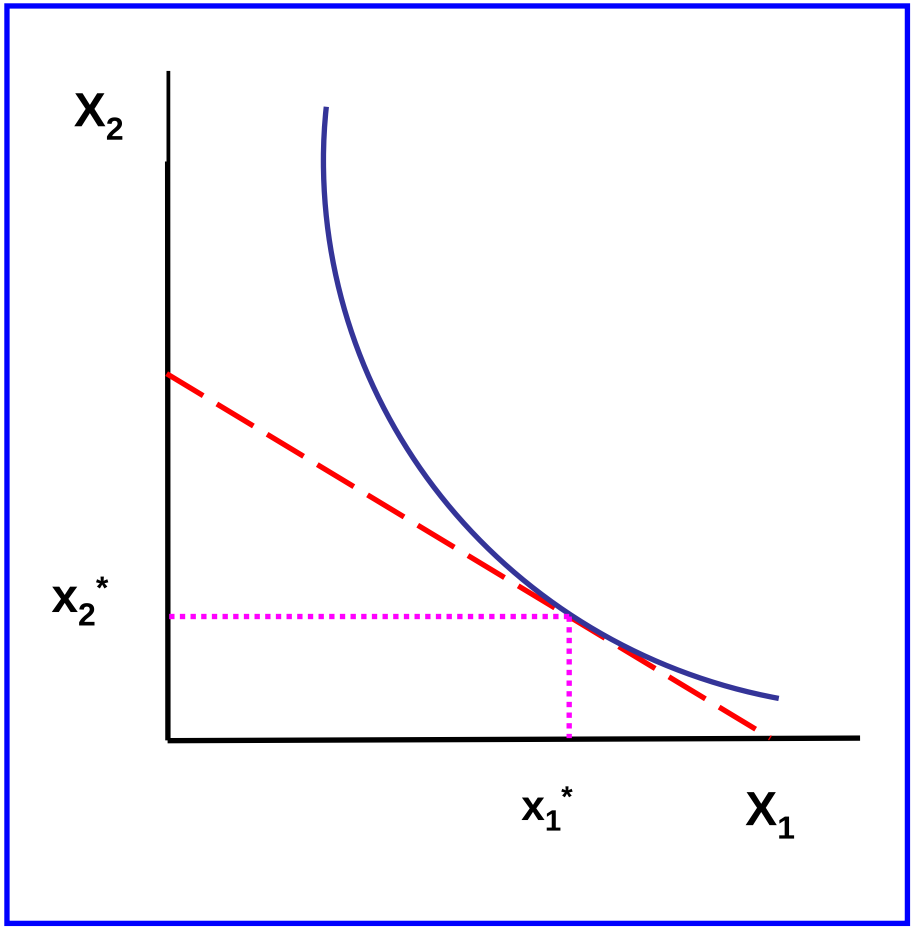
$$\underset{X_1, X_2}{Max} \; L = U\left(X_1, X_2, w\right) + \lambda(Y - PX_1 - PX_2)$$

$$\frac{\partial L}{\partial X_1} = \frac{\partial U}{\partial X_1} - \lambda P_1 \equiv 0$$

$$\frac{\partial L}{\partial X_2} = \frac{\partial U}{\partial X_2} - \lambda P_2 \equiv 0$$

$$\frac{\partial L}{\partial \lambda} = Y - PX_1 - PX_2 \equiv 0$$

$$\frac{\partial U}{\partial X_1} \bigg/ \frac{\partial U}{\partial X_2} = P_1 / P_2$$



Economics of Production

- Profit maximization
  - Revenues minus costs

- Production constraint
  - Technology
  - Wages and input price

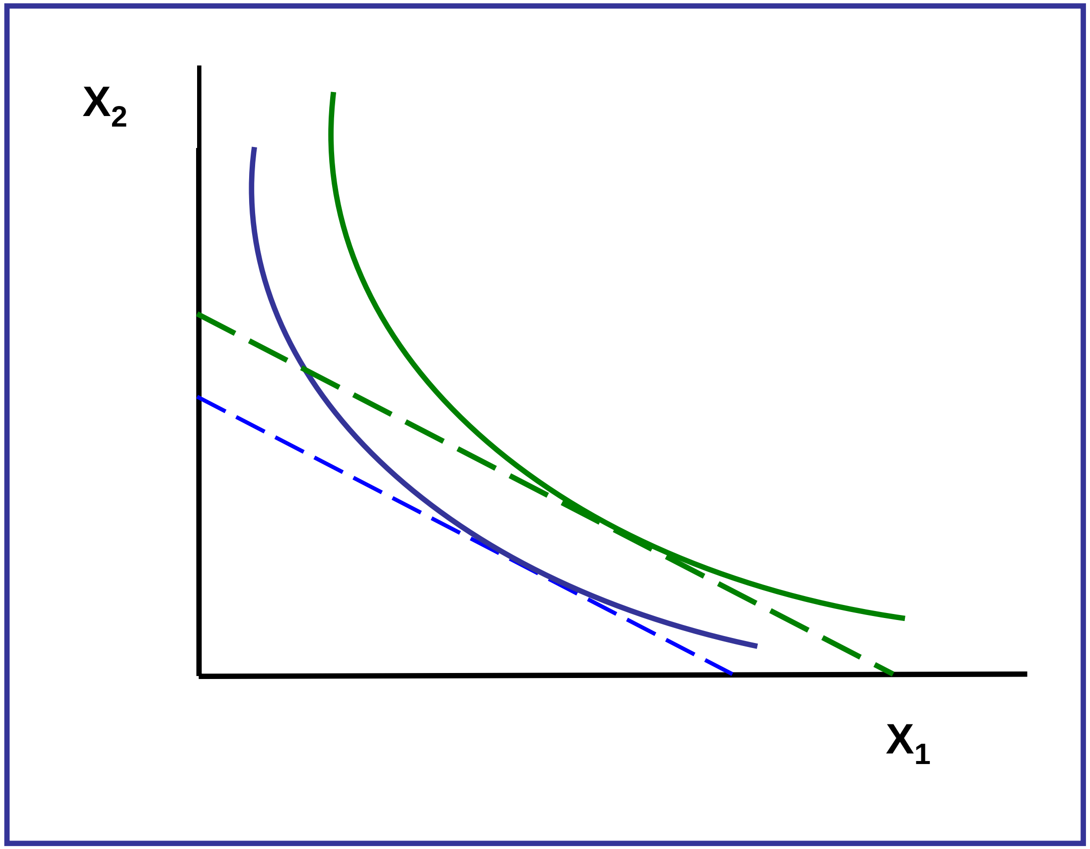
- Subjective decision making

- How does avoided costs relate to Economic Value?
  - Translates to increased income (Y)

Value of Increased Income

$$\underset{X_1, X_2}{Max} \; L = U\left(X_1, X_2\right) + \lambda(Y - PX_1 - PX_2)$$

$$\frac{\partial L}{\partial Y} = \lambda$$



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?

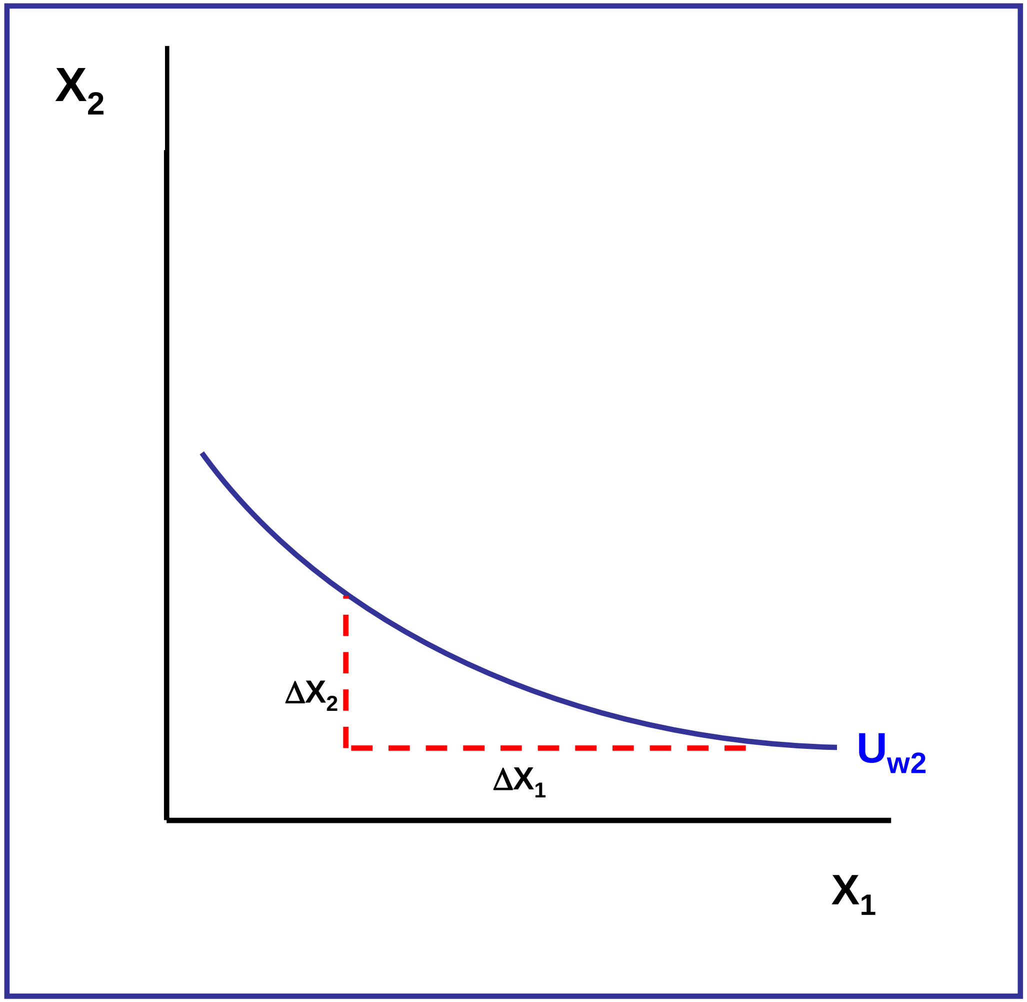
Weather and State Dependent Utility

$$U = U(X_1, X_2, w)$$

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

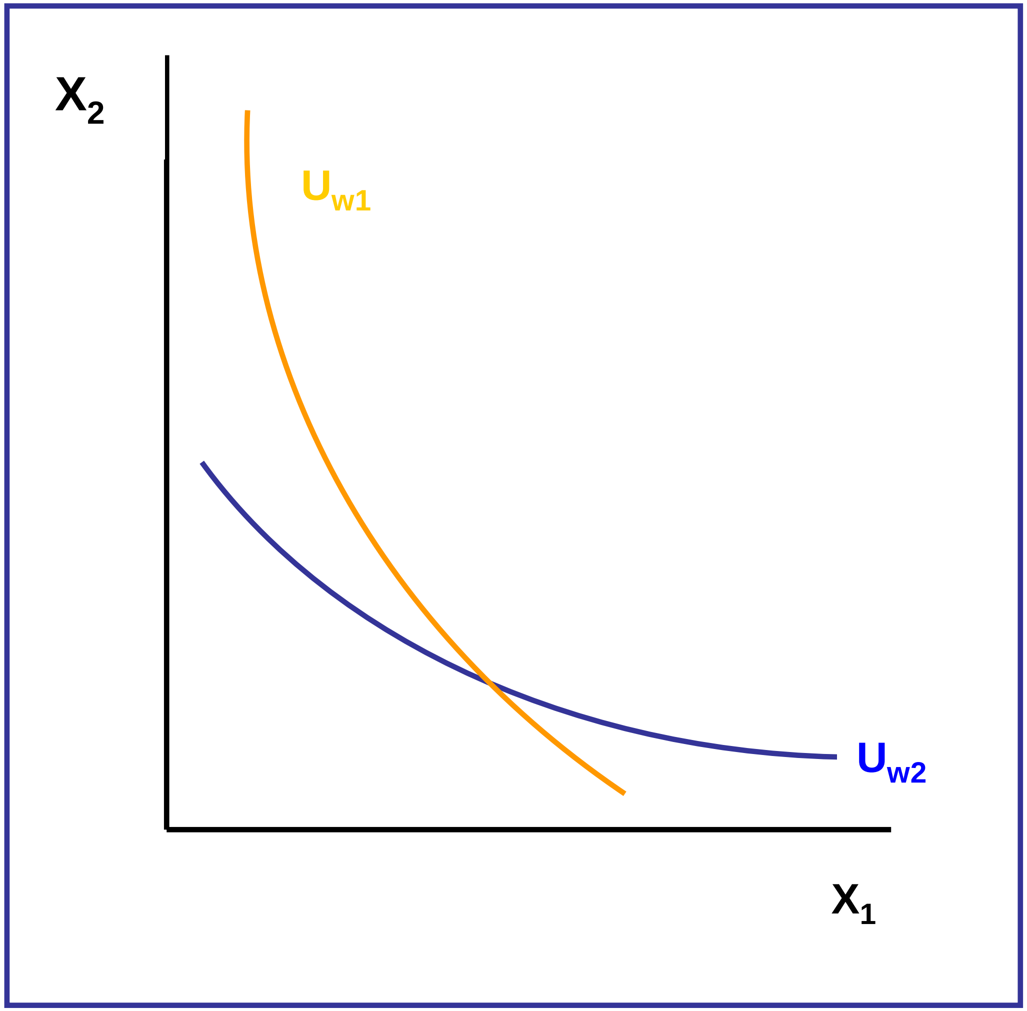


Weather and State Dependent Utility

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

$$\underset{X_1,X_2}{Max\,EU} = \sum_{i=1}^{n} \boldsymbol{p_i}\left[U\left(X_1,X_2,\boldsymbol{w_i}\right)\right]$$

Assuming two states of world: $p_1 + p_2 = 1$

$$\underset{X_1,X_2}{Max\,EU} = p_1\left[U\left(X_1,X_2,w_1\right)\right]+\left(1\text{-}p_1\right)\left[U\left(X_1,X_2,w_2\right)\right]$$

Being explicit about the income constraint:

$$\underset{X_1,X_2}{Max\,L} = p_1\left[U\left(X_1,X_2,w_1\right)+\lambda(Y-PX_1-PX_2)\right]+$$

$$\left(1\text{-}p_1\right)\left[U\left(X_1,X_2,w_2\right)+\lambda(Y-PX_1-PX_2)\right]=$$

$$p_1\left[U\left(X_1,X_2,w_1\right)\right]+\left(1\text{-}p_1\right)\left[U\left(X_1,X_2,w_2\right)\right]+\lambda(Y-PX_1-PX_2)$$

income constraint not affected by risk or uncertainty

Expected Utility (EU) Theory

$$\underset{X_1, X_2}{Max}\, L = p_1\left[U\left(X_1, X_2, w_1\right) + \lambda(Y\{w_1\} - P\{w_1\}X_1 - P\{w_1\}X_2)\right] +$$
$$\left(1\text{-}p_1\right)\left[U\left(X_1, X_2, w_2\right) + \lambda(Y\{w_2\} - P\{w_2\}X_1 - P\{w_2\}X_2)\right]$$

Expected Utility and Forecast Information

Subjective probability values p are a function of forecast, f.

$$p = p(f)$$

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

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

$$\underset{X_1, X_2}{Max\ EU} = \sum_{i=1}^{n} p\left(f \sim \left\{\overline{f}, \sigma, \ldots, \ldots\right\}\right)\left[U(X_1, X_2, w_i)\right]$$

Value of Information

$$\underset{X_1,X_2}{Max\ EU} = \sum_{i=1}^{n} p\left(f \sim \left\{ \overline{f}, \sigma,\ ...,\ ... \right\} \right) \left[U\left(X_1, X_2, w_i \right) \right]$$

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

- “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

$$U = U\left(X_1, X_2, w\right) \quad \Rightarrow \quad U = V\left(Y, P, w\right)$$

$$U^1 = V\left(Y^1, P^1, w_1\right)$$

$$U^1 = V\left(Y^1, P^1, w_1\right) = V\left(Y^1 - \boldsymbol{WTP}, P^1, \boldsymbol{w_2}\right)$$

$$w_2 \succ w_1 \quad \text{where } \succ \text{ implies "preferred"}$$

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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Merci Beaucoup