Electricity Forecasting

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State Utility Forecasting Group

- Established in 1985 at Purdue
- Initially tasked with developing an electricity forecasting modeling system for the state of Indiana
- Later tasked with annual renewable resource reports

Other SUFG Studies

- Environmental regulations
- Energy efficiency
- Deregulation
- Intermittent resources
- Risk management
- Natural gas

Why Forecast?

- Resource planning
- Resource allocation
- Determining rates

Long-Term vs. Short-Term

- Long-term forecasts typically cover several years and are determined by economic and demographic factors

- Short-term forecasts typically cover several hours and are determined by temporal and weather factors

Using the Past to Predict the Future

- What is the next number in the following sequences?

  0, 2, 4, 6, 8, 10, ….

  0, 1, 4, 9, 16, 25, 36, ...

  0, 1, 2, 3, 5, 7, 11, 13, ...

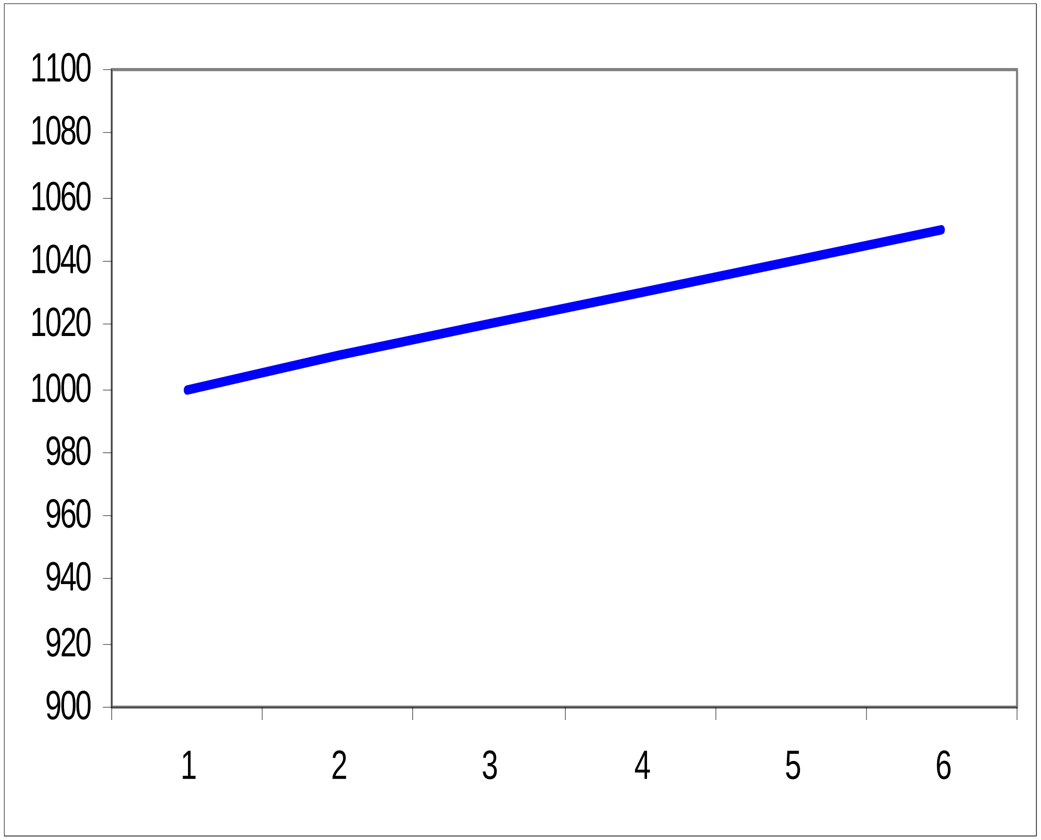
  1, 3, 7, 15, 31, ...

  0, 1, 1, 2, 3, 5, 8, 13, ...

  8, 5, 4, 9, 1, 7, ….

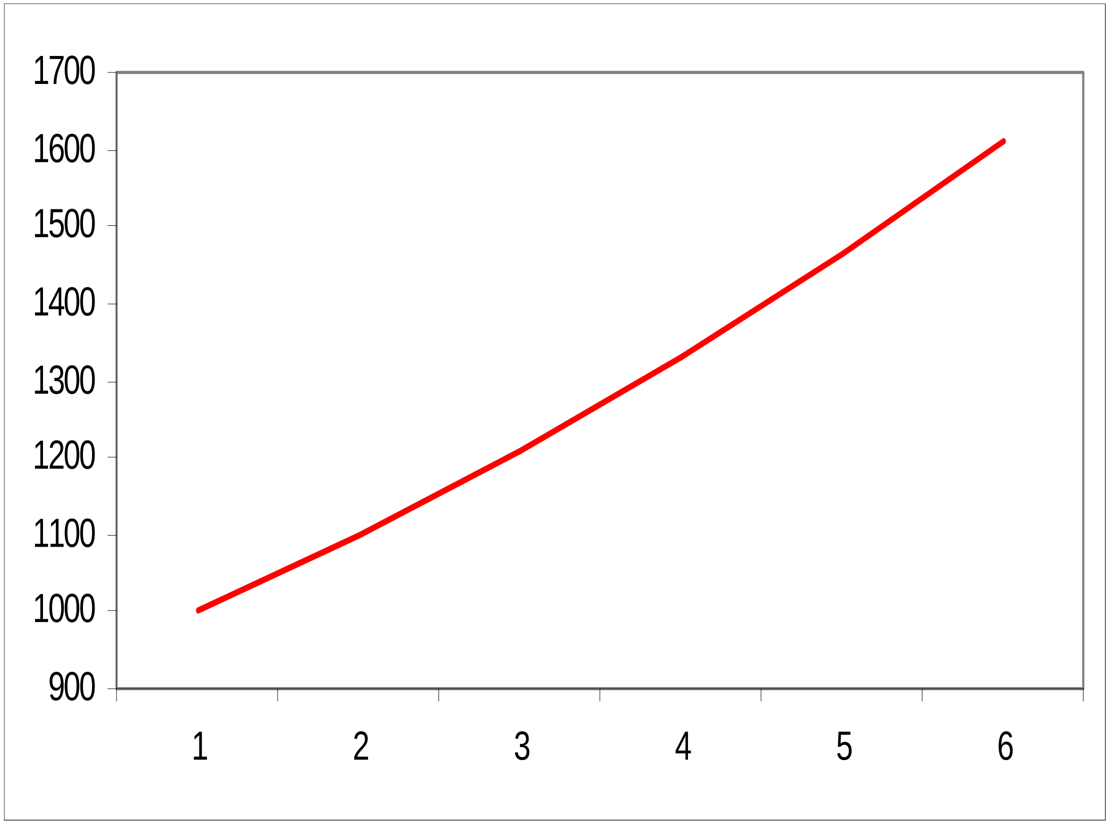
A Simple Example

1000
1010
1020
1030
1040
1050
?
?
?



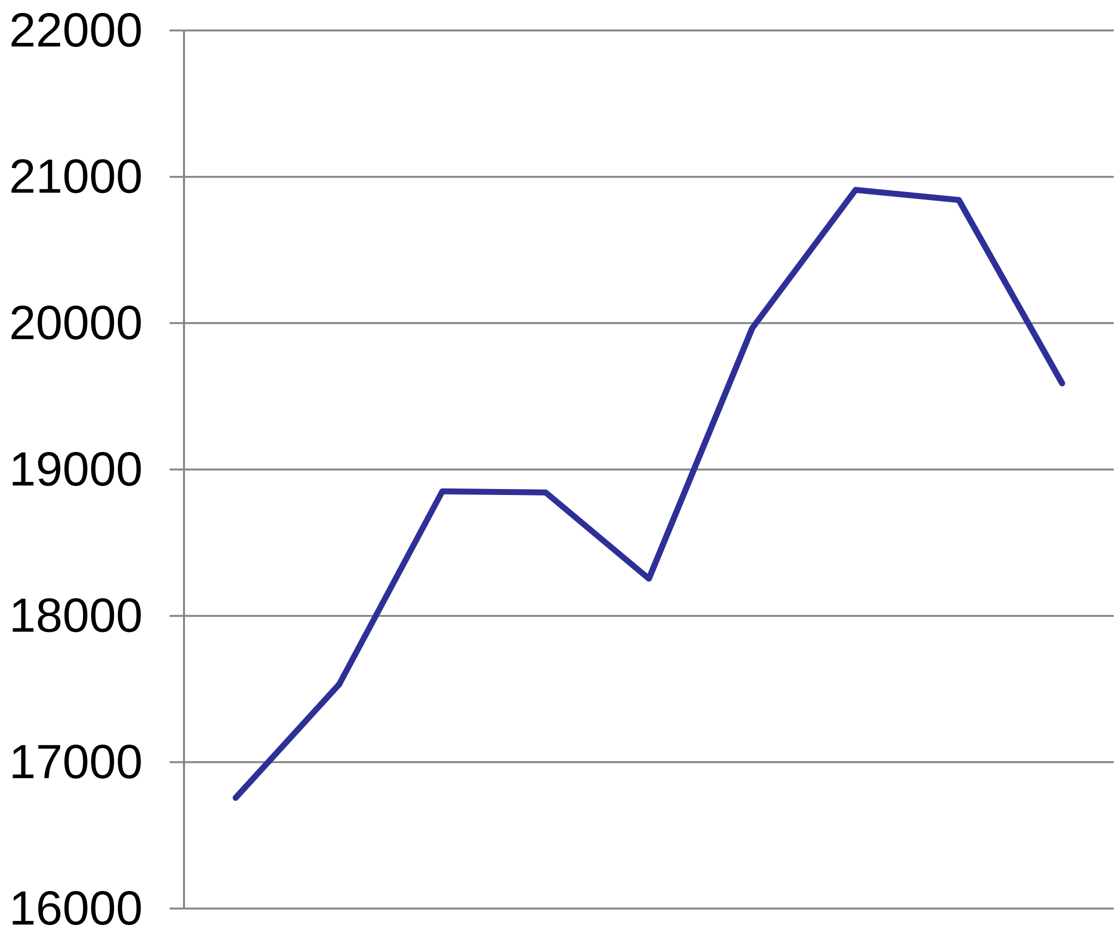
A Little More Difficult

1000
1100
1210
1331
1464
1610
?
?
?



Much More Difficult

16757
17531
18851
18843
18254
19966
20910
20842
19589
?
?

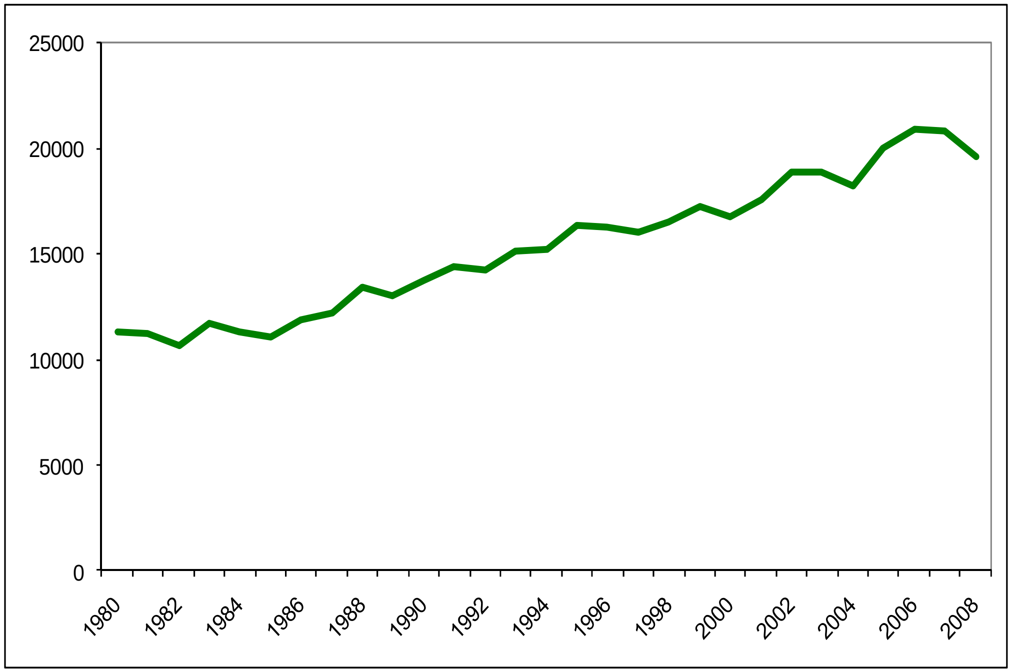


Much More Difficult

- The numbers on the previous slide were the summer peak demands for Indiana from 2000 to 2008
- They are affected by a number of factors
  - Weather
  - Economic activity
  - Price
  - Interruptible customers called upon
  - Price of competing fuels

Question

- How do we find a pattern in these peak demand numbers to predict the future?



Methods of Forecasting

- Time Series
  - trend analysis
- Econometric
  - structural analysis
- End Use
  - engineering analysis

Time Series Forecasting

- Linear Trend
  - Fit the best straight line to the historical data and assume that the future will follow that line
    - works perfectly in the 1st example
  - Many methods exist for finding the best fitting line; the most common is the least squares method

$$Y = \beta + \alpha X$$

Time Series Forecasting

- Polynomial Trend
  - Fit the polynomial curve to the historical data and assume that the future will follow that line
  - Can be done to any order of polynomial (square, cube, etc.) but higher orders are usually needlessly complex

$$Y = \beta + \alpha_1 X + \alpha_2 X^2 + \dots$$

Time Series Forecasting

- Logarithmic Trend
  - Fit an exponential curve to the historical data and assume that the future will follow that line
    - works perfectly for the 2nd example

$$Y = \beta \alpha^X$$

Good News and Bad News

- The statistical functions in most commercial spreadsheet software packages will calculate many of these for you
- These may not work well when there is a lot of variability in the historical data
  - A number of methods exist for dealing with variability, such as modeling by season and using smoothing or filtering techniques
- If the time series curve does not perfectly fit the historical data, there is model error.
  - There is normally model error when trying to forecast a complex system

Econometric Forecasting

- Econometric models attempt to quantify the relationship between the parameter of interest (output variable) and a number of factors that affect the output variable
- Example
  - Output variable
  - Explanatory variable
    - Economic activity
    - Weather (HDD/CDD)
    - Electricity price
    - Natural gas price
    - Fuel oil price

Estimating Relationships

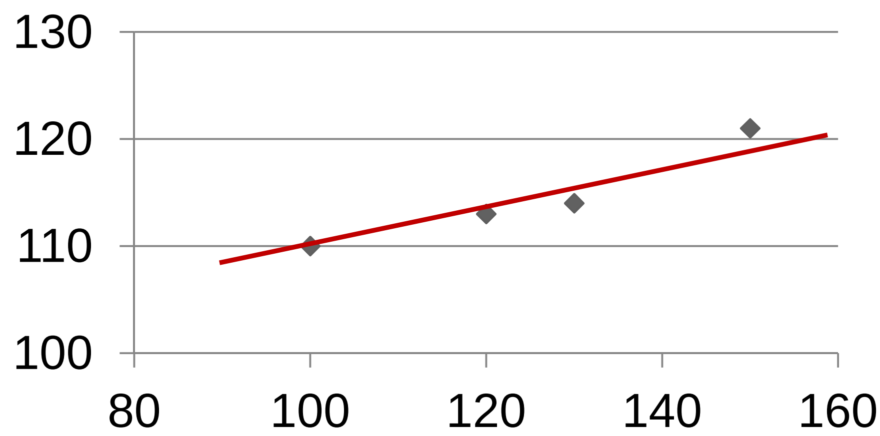
- Each explanatory variable affects the output variable in a different way. The relationships (or sensitivities) can be calculated via any of the methods used in time series forecasting
  - Can be linear, polynomial, logarithmic, moving averages, …

$$Y = \beta + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \ldots$$

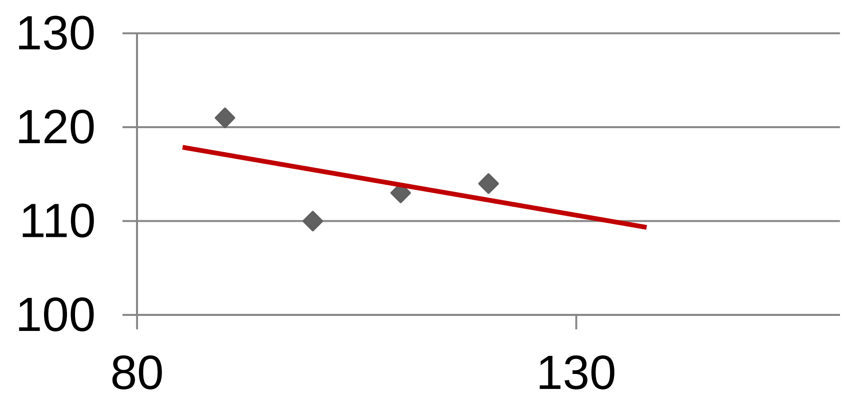
- Relationships are determined simultaneously to find overall best fit

A Simple Example

- Suppose we have 4 sets of observations with 2 possible explanatory variables



Output Y	Variable X_1	Variable X_2
110	100	100
113	120	110
114	130	90
121	150	120



A Simple Example

- Including both variables provides a perfect fit
  - Perfect fits are not usually achievable in complex systems

$$Y = 0.2X_1 – 0.1X_2 + 100$$

End Use Forecasting

- End use forecasting looks at individual devices, aka end uses (e.g., refrigerators)
- How many refrigerators are out there?
- How much electricity does a refrigerator use?
- How will the number of refrigerators change in the future?
- How will the amount of use per refrigerator change in the future?
- Repeat for other end uses

The Good News

- Account for changes in efficiency levels (new refrigerators tend to be more efficient than older ones) both for new uses and for replacement of old equipment
- Allow for impact of competing fuels (natural gas vs. electricity for heating) or for competing technologies (electric resistance heating vs. heat pump)
- Incorporate and evaluate the impact of demand-side management/conservation programs

The Bad News

- Tremendously data intensive
- Primarily limited to forecasting energy usage, unlike other forecasting methods
  - Most long-term planning electricity forecasting models forecast energy and then derive peak demand from the energy forecast

Example

- State Utility Forecasting Group (SUFG) has electrical energy models for each of 8 utilities in Indiana
- Utility energy forecasts are built up from sectoral forecasting models
  - residential
  - commercial
  - industrial

Residential Model Sensitivities

10 Percent Increase In	Causes This Percent Change in Electric Use
Number of Customers	11.1
Electric Rates	-2.4
Natural Gas Price	1.0
Distillate Oil Prices	0.0
Appliance Price	-1.8
Household Income	2.0

Source: SUFG 2009 Forecast

Commercial Model Sensitivities

10 Percent Increase In	Causes This Percent Change in Electric Use
Electric Rates	-2.5
Natural Gas Price	0.2
Distillate Oil Prices	0.0
Coal Prices	0.0
Electric Energy-weighted Floor Space	12.0

Source: SUFG 2009 Forecast

Industrial Model Sensitivities

10 Percent Increase In	Causes This Percent Change in Electric Use
Real Manufacturing Product	10.0
Electric Rates	-4.8
Natural Gas Price	1.4
Oil Prices	0.9
Coal Prices	0.2

Source: SUFG 2009 Forecast

Sources of Uncertainty

- Exogenous assumptions
  - forecast is driven by a number of assumptions (e.g., economic activity) about the future
- Stochastic model error
  - it is usually impossible to perfectly estimate the relationship between all possible factors and the output
- Non-stochastic model error
  - bad input data (measurement/estimation error)

Resource Planning

- Target reserve margin
- Loss of load probability (LOLP)
- Expected unserved energy (EUE)

Reserve Margin

$$RM = \frac{capacity - demand}{demand} x100\%$$

- Reserve margins are relatively easy to use and understand, but may lead to uneconomical planning decisions
  - reserve margins do not account for differences in reliability for different generating units or for diversity of supply

Loss of Load Probability

- A probabilistic method that accounts for the reliability of the various sources of supply
- Given an expected demand for electricity and a given set of supply resources with assumed outage rates, what is the likelihood that the supply will not be able to meet the demand?
- Planner finds the amount of resources needed to keep the LOLP below a target level
  - industry standard is 1 event per 10 years

Expected Unserved Energy

- Similar calculation as for LOLP
- Instead of tracking the expectation that insufficient generation will be available, one tracks the cumulative amount of the shortfall
  - In LOLP, a 1MW shortfall is the same as a 100MW shortfall

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