Complex model to complex data
— the statistical approach

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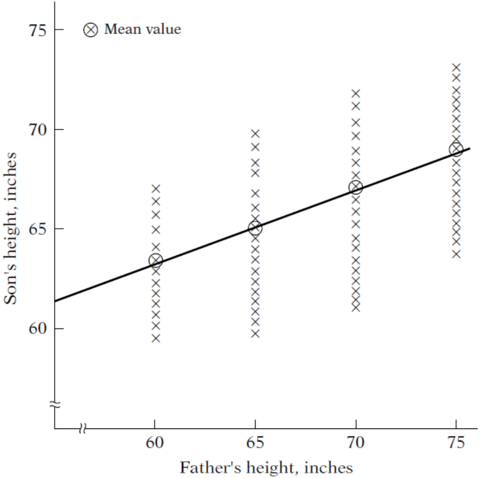
Have you ever thought about...

- Why the weather forecast is not accurate sometimes?
  (rain or not ⇔ cloudy, humidity, historical data)
- How does the email filter know whether a mail is a spam or not?
  (spam or not ⇔ sender, keywords)
- Can we predict the next financial crisis?
  (Next crisis time ⇔ when was last time, stock prices, exchange rate, unemployment rate)
- ...

Statistical modeling is trying to formalize (**model**) the relationships among the variables (**data**).

Toy examples

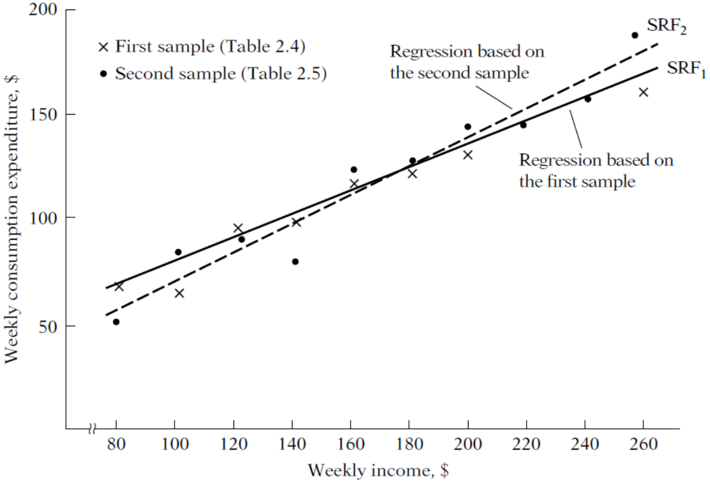
↬ Father's height vs son's height



Gujarati, D. N. (2003). Basic Econometrics. 4th.

Toy examples

↛ Family income and consumption

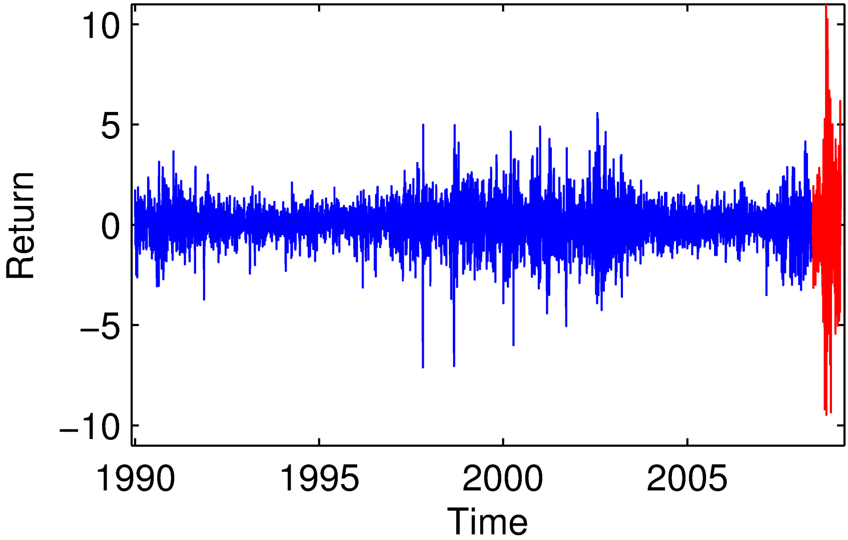


Gujarati, D. N. (2003). Basic Econometrics. 4th.

- Models are simple.
- Works well at most situations.
- Easy to imagine and implement.
- It takes less than 1 second to have the result with a laptop.

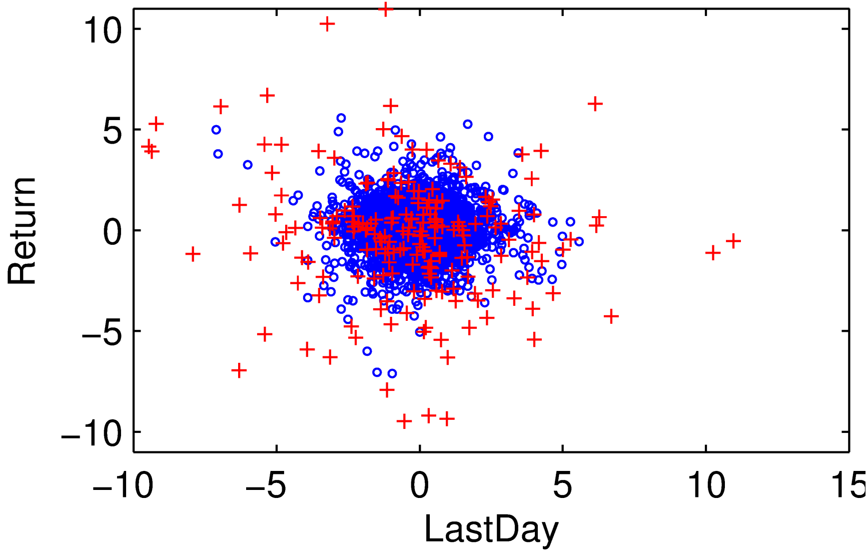
The typical data in finance

↪ Daily stock market returns



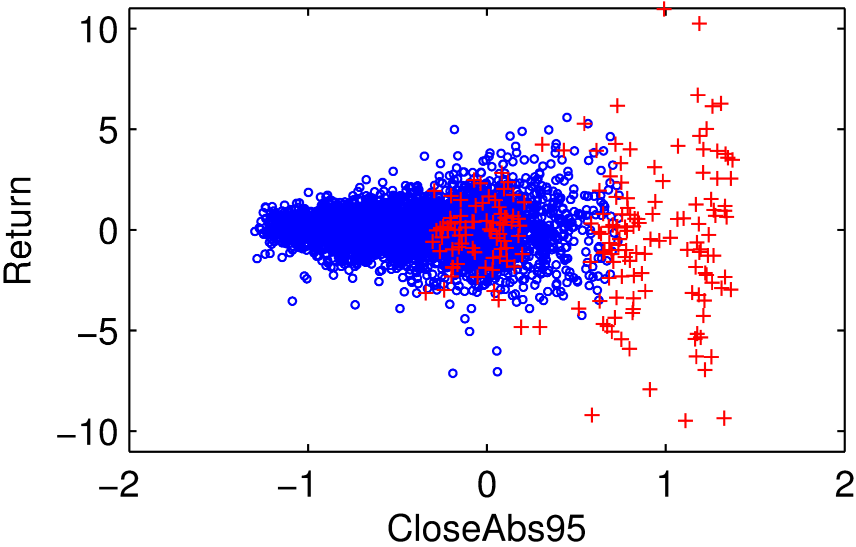
The typical data in finance

↛ Daily stock market returns, a closer look



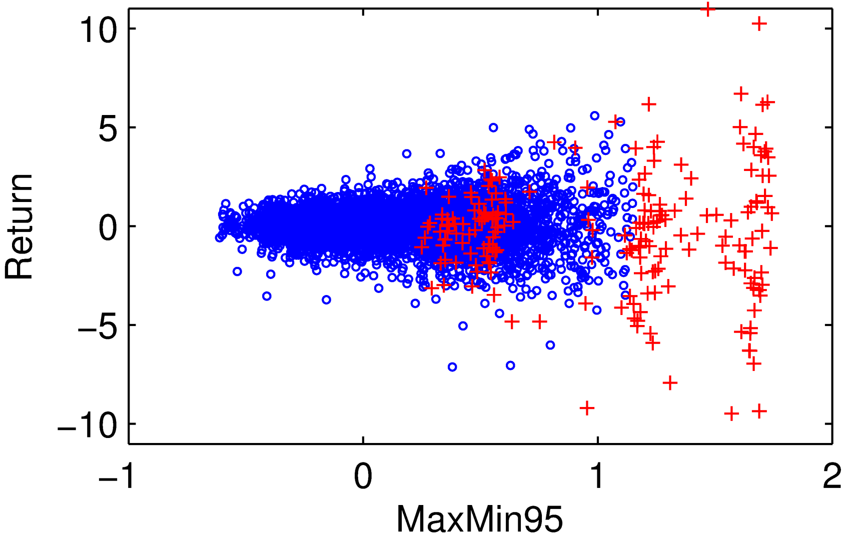
The typical data in finance

↬ Daily stock market returns, a closer look



The typical data in finance

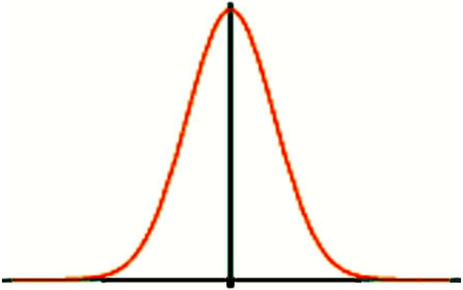
↪ Daily stock market returns, a closer look



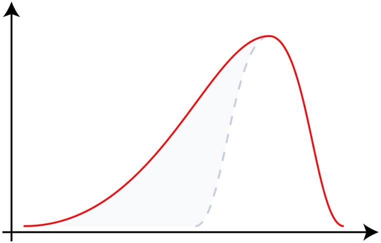
What can we find?

- This does not look like as **normal** (think about the mean and variation)!
- How do we describe it in the language of statistics?
  - We use **mean** and **variance** (*standard deviation*) to describe normality.
  - We use **skewness**, and **kurtosis** (*degrees of freedom*) to detect the abnormal events.

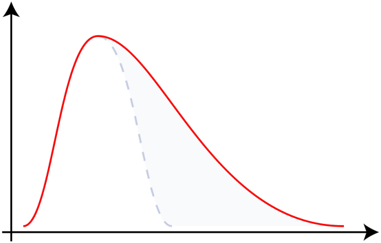
Normal and not normal



Normal

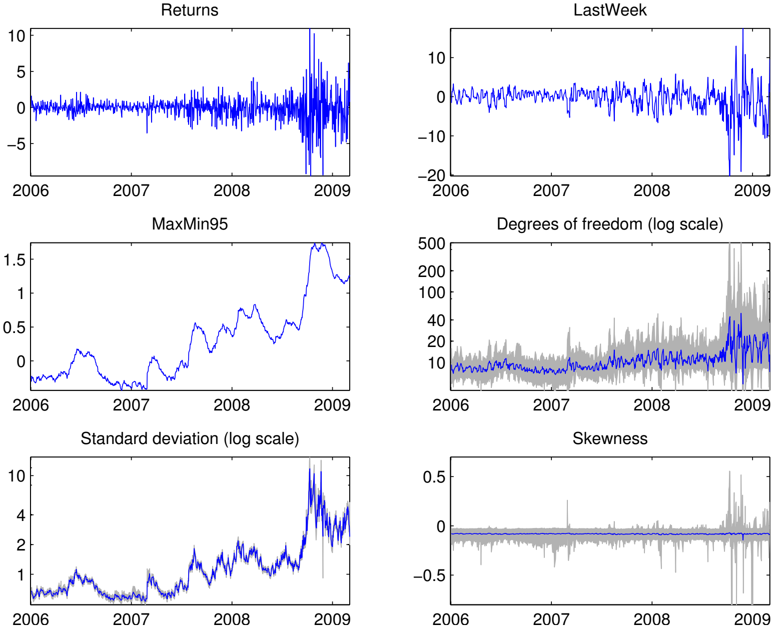


Negative Skew



Positive Skew

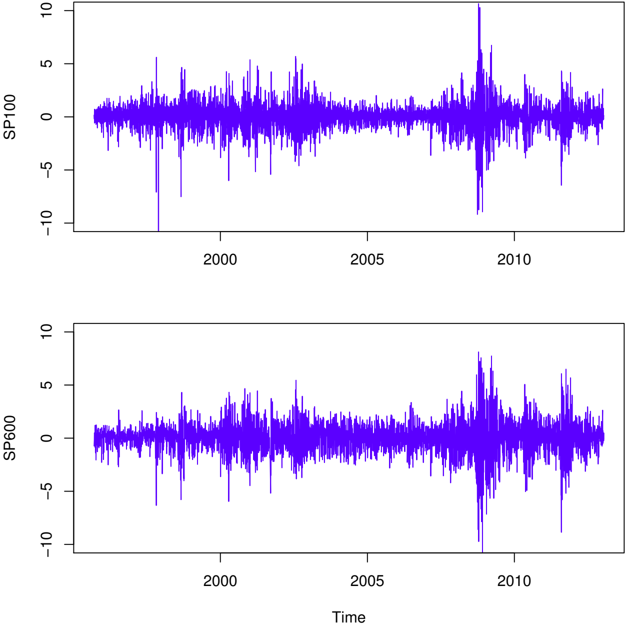
Detecting the financial crisis



What if we insist using the normal model?

- The model will be misspecified.
- The conclusion based on that model can lead to a wrong decision.
- But people still do it anyway!
    - The normal model is simpler anyway.
    - We eventually do not know that we are wrong.
    - The computational tools are still feasible for everyone to use.
        - There was no ready-to-use computer software to use for this model.
        - The model takes a night to estimate with a cluster.

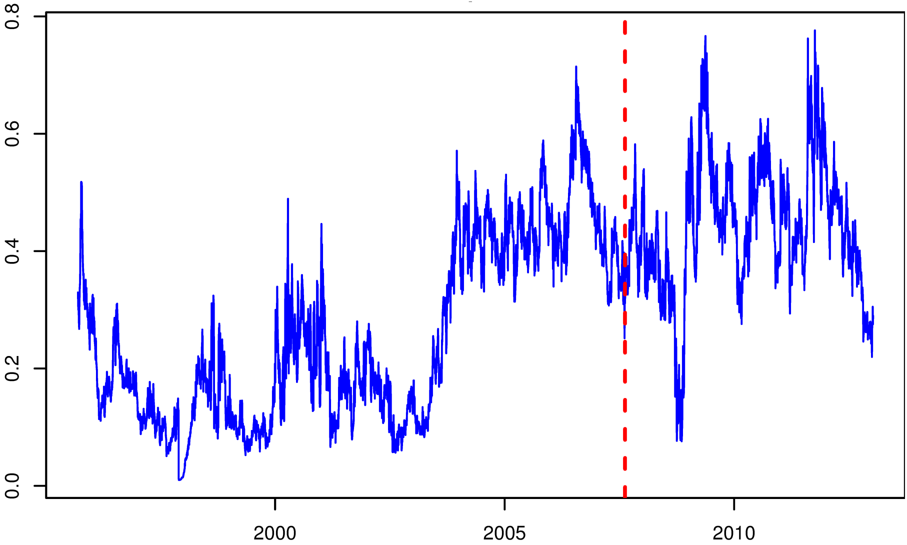
A more complicated situation



Our interests

- The S&P100 index includes the largest and most established companies in the U.S.
- The S&P600 index covers the small capitalization companies which present the possibility of greater capital appreciation, but at greater risk
- We are not only interested to detect the extreme events of a single stock, but also the co-movement of a two or more stocks.
  - What will happen to S&P100 if S&P600 collapses?
  - We call this as **tail-dependence**—the dependence only happens when extreme events happen.
  - What are the underlying factors that are connected to this dependence?

The dependence on the tail



Knowing the elephant

↪ The trend of statistical modeling

- In the 1950s, linear regression model was considered as very advanced which is now the standard course content for university students.
- The data are much more complicated nowadays we meet.
  - Numerical, categorical, brain image...
  - A few observations to millions by millions.
  - Very high-dimensional data are not rare anymore.

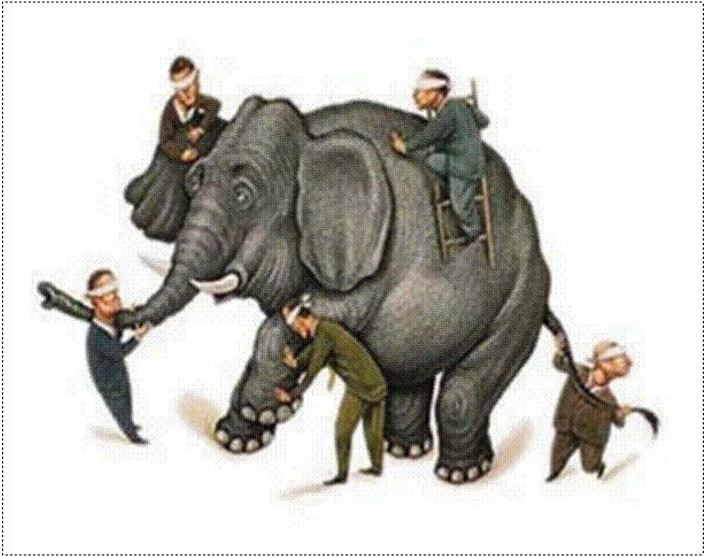
Knowing the elephant

↪ The common procedure statistical modeling

- Data collection
- Model estimation
- Model evaluation
- Model comparison
- Prediction (if needed)

Knowing the elephant

↛ Can we have a model that is big like an elephant?



Knowing the elephant

- Sophisticated models are essential for such situations.
- In principle, the complicated model should be able to capture more complicated data features.
- Estimating such model is not easy.
- There is huge space to explore.
  - The computer is still not fast enough.
  - Techniques like parallel computing should be used to speed up the computation.
  - Statistics with big data is the new challenge.

...essentially, all models are wrong, but some are useful

— George E. P. Box

Thank you!