LECTURE 1

Introduction to Econometrics

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What is econometrics?

To beginning students, it may seem as if econometrics is an overly complex obstacle to an otherwise useful education. (...) To professionals in the field, econometric is a fascinating set of techniques that allows the measurement and analysis of economic phenomena and the prediction of future economic trends.

Studenmund (*Using Econometrics: A Practical Guide*)

What is econometrics?

- Econometrics is a set of statistical tools and techniques for quantitative measurement of actual economic and business phenomena
- It attempts to
  - quantify economic reality
  - bridge the gap between the abstract world of economic theory and the real world of human activity
- It has three major uses:
  1. describing economic reality
  2. testing hypotheses about economic theory
  3. forecasting future economic activity

"Are you just pissing and moaning, or can you verify what you're saying with data?"

Example

- Consumer demand for a particular commodity can be thought of as a relationship between
  - quantity demanded (Q)
  - commodity's price (P)
  - price of substitute good (P_s)
  - disposable income (Y)
- Theoretical functional relationship:

$$Q = f(P, P_s, Y)$$

- Econometrics allows us to specify:

$$Q = 31.50 - 0.73P + 0.11P_s + 0.23Y$$

Introductory econometrics course

- **Lecturer:** Ján Palguta (CERGE-EI, Prague)
  171922@mail.muni.cz
- **Lectures:** Tuesday, 10:15-11:00 a.m., room VT 203
  Tuesday, 11:05-12:45 a.m., room VT 203
- **Web:** `https://is.muni.cz/auth/el/1456/podzim2016/BPE_INEC/`

Introductory econometrics course

- **Course requirements:**
  - 4 home assignments (account for $4 \times 10 = 40$ points)
  - written final exam (accounts for 60 points)
  - to pass the course, student has to achieve at least 30 points in the exam and 50 points in total
- **Recommended literature:**
  - Studenmund, A. H., *Using Econometrics: A Practical Guide*
  - Adkins, L., *Using gretl for Principles of Econometrics*
  - Wooldridge, J. M., *Introductory Econometrics: A Modern Approach*

Course content

- **Lectures:**
  - Lecture 1: Introduction, repetition of statistical background
  - Lectures 2 - 5: Linear regression models
  - Lectures 6 - 12: Violations of standard assumptions
  - Lecture 13: Final exam
- **In-class exercises:**
  - Will serve to clarify and apply concepts presented on lectures
  - We will use statistical software (Gretl) to solve the exercises

Lecture 1.

- **Introduction, repetition of statistical background**
  - probability theory
  - statistical inference
- Readings:
  - Studenmund, A. H., Using Econometrics: A Practical Guide, Chapter 17
  - Wooldridge, J. M., Introductory Econometrics: A Modern Approach, Appendix B and C

Random variables

- A **random variable** X is a variable whose numerical value is determined by chance. It is a quantification of the outcome of a random phenomenon.
- **Discrete random variable**: has a countable number of possible values
  - Example: the number of times that a coin will be flipped before a heads is obtained
- **Continuous random variable**: can take on any value in an interval
  - Example: time until the first goal is shot in a football match between FC Barcelona and Real Madrid

Discrete random variables

- Described by listing the possible values and the associated probability that it takes on each value
- **Probability distribution** of a variable X that can take values $x_1, x_2, x_3, \ldots$:

$$\begin{aligned} P(X = x_1) &= p_1 \\ P(X = x_2) &= p_2 \\ P(X = x_3) &= p_3 \\ &\vdots \end{aligned}$$

- **Cumulative distribution function** (CDF) :

$$F_X(x) = P(X \leq x) = \sum_{i=1, x_i \leq x} P(X = x_i)$$

Six-sided die: probability density function

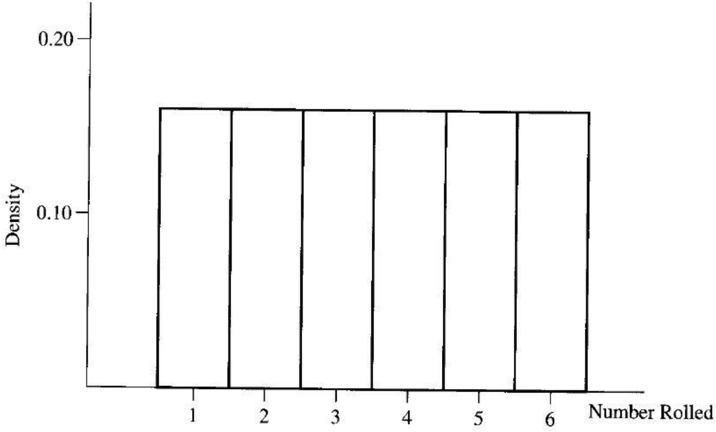
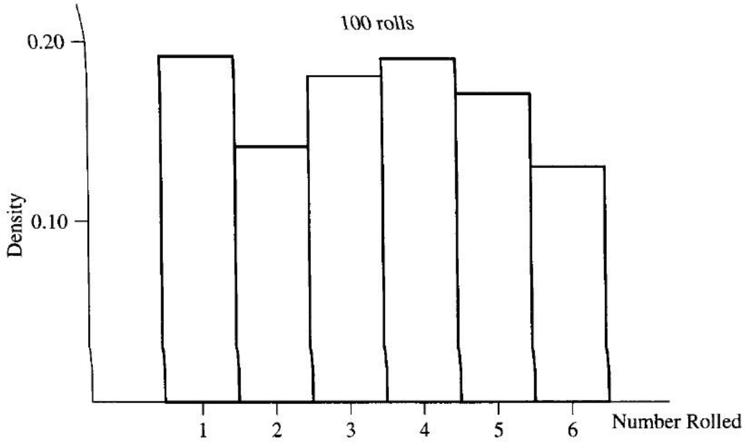
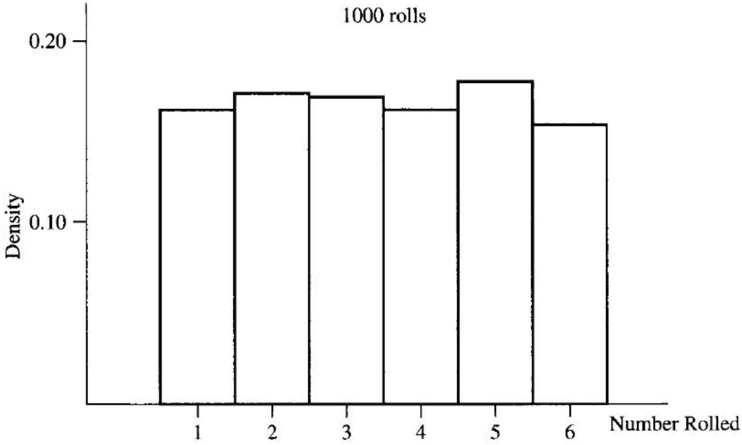


Figure 16.3 Probability Distribution for a Six-Sided Die

SIX-SIDED DIE: HISTOGRAM OF DATA (100 ROLLS)



SIX-SIDED DIE: HISTOGRAM OF DATA (1000 ROLLS)



Continuous random variables

- **Probability density function** $f_X(x)$ (PDF) describes the relative likelihood for the random variable X to take on a particular value x

- **Cumulative distribution function** (CDF) :

$$F_X(x) = P(X \leq x) = \int_{-\infty}^{x} f_X(t)\mathrm{d}t$$

- **Computational rule:**

$$P(X \geq x) = 1 - P(X \leq x)$$

Expected value and median

- **Expected value (mean)** :
  - Mean is the (long-run) average value of random variable

Discrete variable

$$E[X] = \sum_{i=1} x_i P(X = x_i)$$

Continuous variable

$$E[X] = \int_{-\infty}^{+\infty} x f_X(x) \mathrm{d}x$$

  - Example: calculating mean of six-sided die

- **Median** : "the value in the middle"

EXERCISE 1

- A researcher is analyzing data on financial wealth of 100 professors at a small liberal arts college. The values of their wealth range from $400 to $400,000, with a mean of $40,000, and a median of $25,000.
- However, when entering these data into a statistical software package, the researcher mistakenly enters $4,000,000 for the person with $400,000 wealth.
- How much does this error affect the mean and median?

Variance and standard deviation

- **Variance** :
  - Measures the extent to which the values of a random variable are dispersed from the mean.
  - If values (outcomes) are far away from the mean, variance is high. If they are close to the mean, variance is low.

$$Var[X] = E\left[(X - E[X])^2\right]$$

- **Standard deviation** : $\sigma_X = \sqrt{Var[X]}$

Dancing statistics

Watch the video "Dancing statistics: Explaining the statistical concept of variance through dance":

- https://www.youtube.com/watch?v=pGfwj4GrUlA&list=PLEzw67WWDg82xKriFiOoixGpNLXK2GNs9&index=4

Use the 'dancing' terminology to answer these questions:

1. How do we define variance?
2. How can we tell if variance is large or small?
3. What does it mean to evaluate variance within a set?
4. What does it mean to evaluate variance between sets?
5. What is the homogeneity of variance?
6. What is the heterogeneity of variance?

Covariance, correlation, independence

- **Covariance** :
  - How, on average, two random variables vary with one another.
  - Do the two variables move in the same or opposite direction?
  - Measures the amount of linear dependence between two variables.

$$Cov(X, Y) = E\left[(X - E[X])\,(Y - E[Y])\right] = E\left[XY\right] - E[X]E[Y]$$

- **Correlation** :
  - Similar concept to covariance, but easier to interpret.
  - It has values between -1 and 1.

$$Corr(X, Y) = \frac{Cov(X, Y)}{\sigma_X \sigma_Y}$$

Independence of variables

- **Independence** : X and Y are independent if the conditional probability distribution of X given the observed value of Y is the same as if the value of Y had not been observed.
- If X and Y are independent, then $Cov(X, Y) = 0$ (not the other way round in general)
- Dancing statistics: explaining the statistical concept of correlation through dance
  - https://www.youtube.com/watch?v=VFjaBh12C6s&index=3&list=PLEzw67WWDg82xKriFiOoixGpNLXK2GNs9

Random vectors

- Sometimes, we deal with vectors of random variables
- Example: $\mathbf{X} = \begin{pmatrix} X_1 \\ X_2 \\ X_3 \end{pmatrix}$
- Expected value: $E[\mathbf{X}] = \begin{pmatrix} E[X_1] \\ E[X_2] \\ E[X_3] \end{pmatrix}$
- Variance/covariance matrix:

$$Var[\mathbf{X}] = \begin{pmatrix} Var[X_1] & Cov(X_1, X_2) & Cov(X_1, X_3) \\ Cov(X_2, X_1) & Var[X_2] & Cov(X_2, X_3) \\ Cov(X_3, X_1) & Cov(X_3, X_2) & Var[X_3] \end{pmatrix}$$

Standardized random variables

- Standardization is used for better comparison of different variables
- Define Z to be the standardized variable of X:

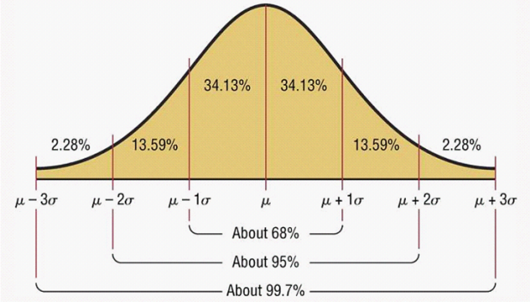
$$Z = \frac{X - \mu_X}{\sigma_X}$$

- The standardized variable Z measures how many standard deviations X is below or above its mean
- No matter what are the expected value and variance of X, it always holds that

$$E[Z] = 0 \quad \text{and} \quad Var[Z] = \sigma_Z = 1$$

Normal (Gaussian) distribution

- Notation : $X \sim N(\mu, \sigma^2)$
- $E[X] = \mu$
- $Var[X] = \sigma^2$



- Dancing statistics
  - `https://www.youtube.com/watch?v=dr1DynUzjq0&index=2&list=PLEzw67WWDg82xKriFiOoixGpNLXK2GNs9`

EXERCISE 2

- A woman wrote to Dear Abby, saying that she had been pregnant for 310 days before giving birth.
- Completed pregnancies are normally distributed with a mean of 266 days and a standard deviation of 16 days.
- Use statistical tables to determine the probability that a completed pregnancy lasts
  - at least 270 days
  - at least 310 days

Chi squared distribution

- **Chi-squared distribution** with k degrees of freedom : χ_k^2

- Let $Z_i \sim N(0, 1)$ for each i and independent, then

$$X = \sum_{i=1}^{k} Z_i^2 \quad \longrightarrow \quad X \sim \chi_k^2$$

t AND F DISTRIBUTIONS

- Student's **t distribution** with n degrees of freedom: t_n
- Fisher-Snedecor **F distribution** with m and n degrees of freedom: $F_{m,n}$
- Let $Z \sim N(0,1)$, $X \sim \chi^2_m$ and $Y \sim \chi^2_n$, independent:

$$\frac{Z}{\sqrt{Y/n}} \sim t_n \qquad \text{and} \qquad \frac{X/m}{Y/n} \sim F_{m,n}$$

- Note that as n grows, t distribution approaches $N(0,1)$
- Why do we care? $\longrightarrow$ Construction of confidence intervals, hypothesis testing

SUMMARY

- Today, we revised some concepts from statistics that we will use throughout our econometrics classes
- It was a very brief overview, serving only for information what students are expected to know already
- The focus was on properties of statistical distributions and on work with normal distribution tables

Next lecture

- We will go through terminology of sampling and estimation
- We will start with regression analysis and introduce the Ordinary Least Squares estimator