Econometrics

Anna Donina

Lecture 1

INTRODUCTORY ECONOMETRICS COURSE

- **Lecturer:** Anna Donina (Junior Researcher, CERGE-EI, Prague)
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- **Lectures / Seminars:** Friday, 14:00 – 15:50 / 16:00 – 17:50 (VT203)

Grading

- *Quizzes/Home assignment: 40 %*
- *Midterm exam: 30 %*
- *Final Exam/Project: 30 %*

to pass the course, student has to get at least 20 points in the final exam and 50 points in total

Introductory econometrics course

Recommended literature:

- Studenmund, A. H., *Using Econometrics: A Practical Guide*
- Wooldridge, J. M., *Introductory Econometrics: A Modern Approach*
- Adkins, L., *Using gretl for Principles of Econometrics*

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, econometrics 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
  1. quantify economic reality
  2. 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

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:

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

LECTURE 1

Introduction, repetition of statistical background

- probability theory
- statistical inference

Readings:

- Studenmund, A. H., Using Econometrics: A Practical Guide, Chapter 16
- Wooldridge, J. M., Introductory Econometrics: A Modern Approach, Appendix B and C

RANDOM VARIABLES

- **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 scored in a football match

Discrete random variables

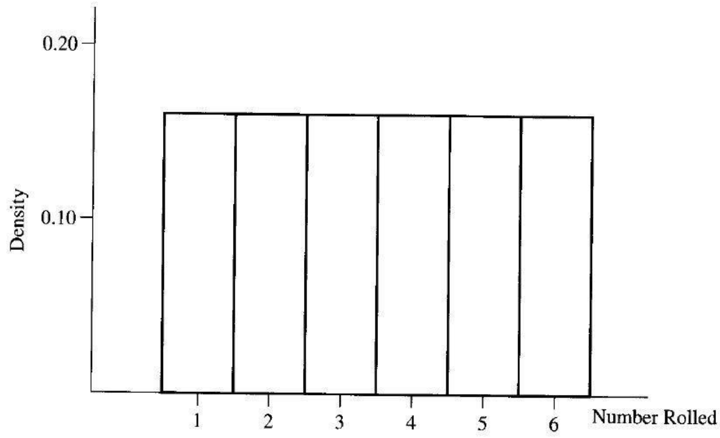
- Described by listing the possible values and the associated probability that it takes on each value
- **Probability distribution** of a variable X that can take values $x_1, x_2, x_3, \ldots$:

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

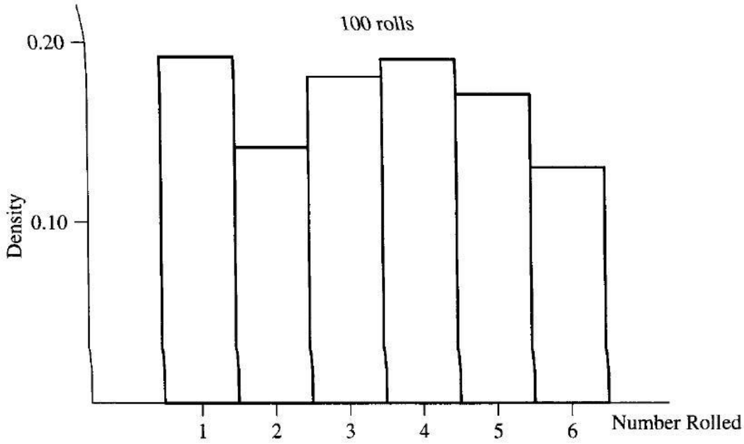
- **Cumulative distribution function** (CDF):

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

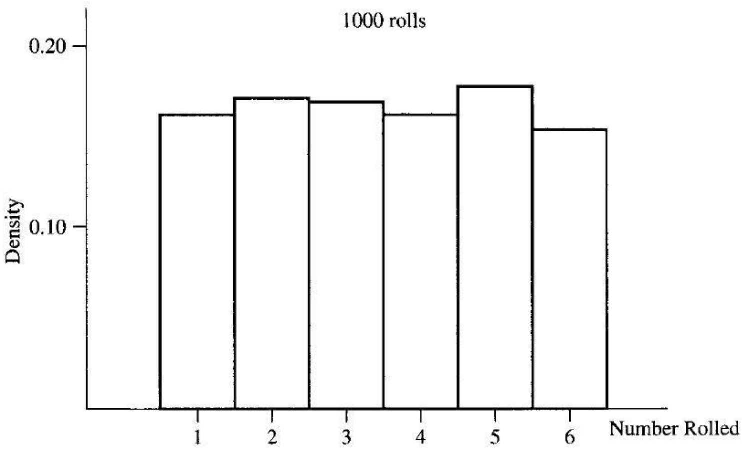
SIX-SIDED DIE: PROBABILITY DISTRIBUTION FUNCTION



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.

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

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

Note: Outliers influence on variance/sd.

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?

Exercise 2

- Which has a higher expected value and which has a higher standard deviation:
  - a standard six-sided die or
  - a four-sided die with the numbers 1 through 4 printed on the sides?
- Explain your reasoning, without doing any calculations, then verify, doing the calculations.

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

Computational rules

$$
\begin{aligned}
E(aX+b) &= aE(X)+b \\
Var(aX+b) &= a^2Var(X) \\
Var(X+Y) &= Var(X)+Var(Y)+2Cov(X,Y) \\
Cov(aX,bY) &= Cov(bY,aX) = abCov(X,Y) \\
Cov(X+Z,Y) &= Cov(X,Y)+Cov(Z,Y) \\
Cov(X,X) &= Var[X]
\end{aligned}
$$

Random vectors

Sometimes, we deal with vectors of randomvariables

Example: $$\mathbf{X} = \begin{pmatrix} X_1 \\ X_2 \\ X_3 \end{pmatrix}$$

Expected value: $$E\left[\mathbf{X}\right] = \begin{pmatrix} E[X_1] \\ E[X_2] \\ E[X_3] \end{pmatrix}$$

Variance/covariancematrix:

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

Standardized random variables

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

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

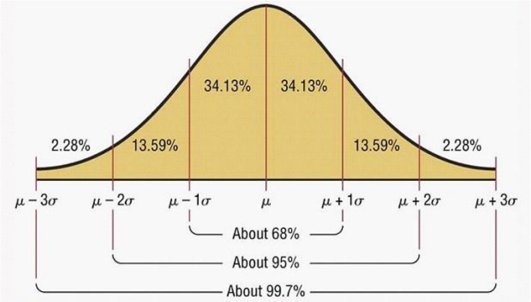
- The standardized variable Z measures how many standard deviations X is below or above its mean
- No matter what are the expected value and variance of X, it always holds that

$$E[Z] = 0 \quad \text{and} \quad Var[Z] = {\sigma_Z}^2 = 1$$

NORMAL (GAUSSIAN) DISTRIBUTION

Notation : $X \sim N(\mu, \sigma^2)$

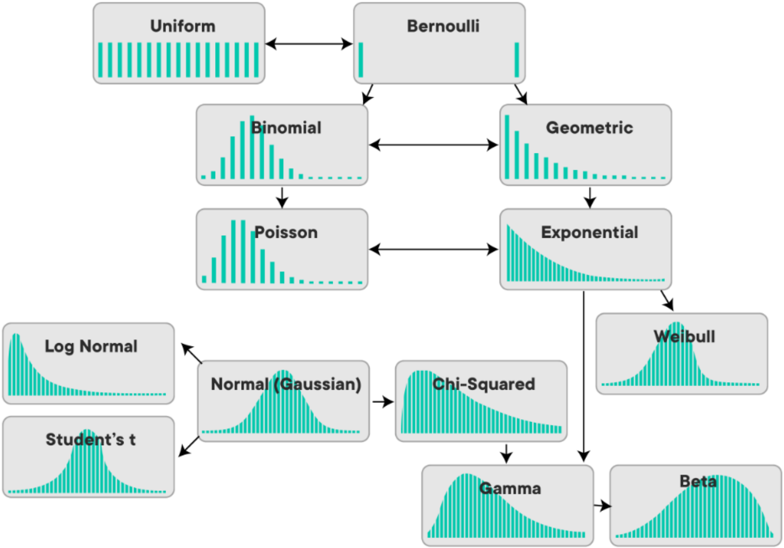
- $E[X] = \mu$
- $Var[X] = \sigma^2$



Dancingstatistics

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

OTHER DISTRIBUTIONS



Exercise 3

- The heights of U.S. females between age 25 and 34 are approximately normally distributed with a mean of 66 inches and a standard deviation of 2.5 inches.
- What fraction of U.S. female population in this age bracket is taller than 70 inches, the height of average adult U.S. male of this age?

Exercise 4

- 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

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