Overview [1]

Jasmine(Yu) Hao

Faculty of Business and Economics
Hong Kong University

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Introduction I

Ask a half dozen econometricians what econometrics is, and you could get a half dozen different answers.

- the science of testing economic theories
- the set of tools used for forecasting future values of economic variables, such as a firm's sales, the overall growth of the economy, or stock prices
- process of fitting mathematical economic models to real-world data
- it is the science and art of using historical data to make numerical, or quantitative, policy recommendations in government and business.

In fact, all these answers are right.

Introduction II

At a broad level, econometrics is the science and art of using economic theory and statistical techniques to analyze economic data.

- Econometric methods are used in many branches of economics, including finance, labor economics, macroeconomics, microeconomics, marketing, and economic policy.
- Econometric methods are also commonly used in other social sciences, including political science and sociology.
- This course introduces you to the core set of methods used by econometricians.
- We will use these methods to answer a variety of specific, quantitative questions from the worlds of business and government policy.

Economic Questions I

Many decisions in economics, business, and government hinge on understanding relationships among variables in the world around us. These decisions require quantitative answers to quantitative questions.

This text examines several quantitative questions taken from current issues in economics. Four of these questions concern education policy, racial bias in mortgage lending, cigarette consumption, and macroeconomic forecasting.

1. **Question #1: Does Reducing Class Size Improve Elementary School Education?**
   Debate for reform of the U.S. public education system: reduce class sizes at elementary schools increase students grades?
   - Reducing class size **costs money**: It requires hiring more teachers and, if the school is already at capacity, building more classrooms.
   - A decision maker contemplating hiring more teachers must weigh these costs against the benefits.

Economic Questions II

- ◇ To weigh costs and benefits, however, the decision maker must have a **precise quantitative understanding** of the likely benefits.
- ◇ How beneficial is the effect on basic learning of smaller classes? Is it possible that smaller class size actually has no effect on basic learning?

Common sense: more learning occurs when there are fewer students. common sense cannot provide a quantitative answer to the question of what exactly is the effect on basic learning of reducing class size.

- ◇ Examine empirical evidence—that is, evidence based on data—relating class size to basic learning in elementary schools.
- ◇ Dataset: 420 California school districts in 1999.
- ◇ Data suggests: Students in districts with small class sizes tend to perform better on standardized tests than students in districts with larger classes.

Economic Questions III

Causal relationship? While this fact is consistent with the idea that smaller classes produce better test scores, it might simply reflect many other advantages that students in districts with small classes have over their counterparts in districts with large classes.

- ◇ districts with small class sizes tend to have wealthier residents, could have more opportunities for learning outside the classroom.
- ◇ It could be **these extra learning opportunities** that lead to higher test scores, not smaller class sizes.

2. **Question #2: Is There Racial Discrimination in the Market for Home Loans?**
    - ◇ Most people buy their homes with a mortgage, a large loan secured by the value of the home.
    - ◇ By law, U.S. lending institutions **cannot take race into account** when deciding to grant or deny a request for a mortgage:
        - Applicants who are identical in all ways except their race should be equally likely to have their mortgage applications approved.
    - ◇ In theory, then, there should be no racial bias in mortgage lending.

Economic Questions IV

- Researchers at the Federal Reserve Bank of Boston found (using data from the early 1990s)
  - that 28% of black applicants are denied mortgages,
  - while only 9% of white applicants are denied.
- Do these data indicate that, in practice, there is **racial bias** in mortgage lending? If so, how large is it?
- The fact that more black than white applicants are denied in the Boston Fed data does not by itself provide evidence of discrimination by mortgage lenders because the black and white applicants **differ in many ways other than their race**.
- Before concluding that there is bias in the mortgage market, these data must be examined more closely to see if there is a difference in the probability of being denied for **otherwise identical applicants** and,
- if so, how big is this difference?
- Method to quantify the effect of race on the chance of obtaining a mortgage, holding constant other applicant characteristics, notably their ability to repay the loan.

Economic Questions V

3. **Question #3: Does Healthcare Spending Improve Health Outcomes?**
    - ◇ Avoidable deaths can be reduced and survival can be extended through the provision of healthcare.
    - ◇ Healthcare has other beneficial effects too, like the improvement of the health-related quality of life of individuals.
    - ◇ To these ends and more, a vast quantity of resources is devoted to the provision of healthcare worldwide.
    - ◇ Which part of healthcare do we spend most money?
        - across countries both in absolute and per capita terms, as well as variations in health outcomes across countries, for example measured by life expectancy at birth.
    - ◇ Putting aside concerns about iatrogenesis (the idea that healthcare is bad for your health), basic economics says that **more expenditure on healthcare should generally reduce avoidable mortality**.

Economic Questions VI

- But by how much? If the amount spent on healthcare increases by 1%, by what percentage will avoidable mortality decrease? The percentage change in avoidable mortality resulting from a 1% increase in healthcare expenditure is the spending elasticity for mortality.
- If we want to reduce avoidable mortality, say, 20% by increasing healthcare expenditure, then we need to know the spending elasticity for mortality to calculate the healthcare expenditure increase necessary to achieve this reduction in avoidable mortality.
- A number of policy objectives are based on meeting targets based on avoidable mortality;
  - for example, one of the United Nations Development Programme's sustainable development goals is that all countries should aim to reduce "under-5 mortality to at least as low as 25 per 1,000 live births."
- But how should the goal be met: from expanding healthcare services or other services?
- And if increasing healthcare spending is to form part of the mix of policies, by how much will it need to increase?

Economic Questions VII

The answers to these can be obtained with estimates of the spending elasticity for mortality.

To estimate the value, we must examine empirical evidence about the returns to healthcare spending—either based on variations in spending across countries or within countries over time.

Two of the biggest challenges concern the **extensive heterogeneity** across countries.

- The first challenge is **observable heterogeneity**, which concerns factors that affect countries' mortality rates that may also be associated with healthcare expenditure,
  - for example, the income per capita of each country. This can be controlled for using **multiple regression analysis**.
- The second and more troublesome challenge is the presence of **unobservable heterogeneity**.
  - Unobserved factors may be important in the underlying processes determining both how decisions are made on how much money is spent on healthcare, and how the overall level of health outcome that is attained.

Economic Questions VIII

- **Simultaneously causality**: factors result in causality running in both directions—healthcare reduces mortality, but higher healthcare expenditure might be a response to unobserved factors.

Quantitative Questions, Quantitative Answers I

Each of these questions requires a **numerical answer**. Economic theory provides clues about that answer—for example, cigarette consumption ought to go down when the price goes up—but the actual value of the number must be learned empirically, that is, by analyzing data.

Uncertainties in the answers:

- A different set of data would produce a different numerical answer.
- Conceptual framework to measure of how precise the answer is.
- multiple regression: quantify how a change in one variable affects another variable, holding other things constant.

Quantitative Questions, Quantitative Answers II

- For example, what effect does a change in class size have on test scores, holding constant or controlling for student characteristics (such as family income) that a school district administrator cannot control?
- What effect does your race have on your chances of having a mortgage application granted, holding constant other factors such as your ability to repay the loan? What effect does a 1% increase in the price of cigarettes have on cigarette consumption, holding constant the income of smokers and potential smokers?

Causal Effects and Idealized Experiments I

- The questions concern causal relationships among variables. In common usage,
  - an action is said to cause an outcome if the outcome is the direct result, or consequence, of that action.
  - eg. Touching a hot stove causes you to get burned, drinking water causes you to be less thirsty, putting air in your tires causes them to inflate, putting fertilizer on your tomato plants causes them to produce more tomatoes.
- Causality means that a specific action (applying fertilizer) leads to a specific, measurable consequence (more tomatoes).

Estimation of Causal Effects I

- How best might we measure the causal effect on tomato yield (measured in kilograms) of applying a certain amount of fertilizer, say, 100 grams of fertilizer per square meter?
- One way to measure this causal effect is to conduct an experiment.
- In that experiment, a horticultural researcher plants many plots of tomatoes.
- Each plot is tended identically, with one exception: Some plots get 100 grams of fertilizer per square meter, while the rest get none.
- Whether or not a plot is fertilized is determined randomly by a computer, ensuring that any other differences between the plots are unrelated to whether they receive fertilizer.
- At the end of the growing season, the horticulturalist weighs the harvest from each plot.

Estimation of Causal Effects II

- The difference between the average yield per square meter of the treated and untreated plots is the effect on tomato production of the fertilizer treatment.
- This is an example of a **randomized controlled experiment**.
  - a **control group** that receives no treatment (no fertilizer)
  - a **treatment group** that receives the treatment (100 g/m^2 of fertilizer). It is **randomized** in the sense that the treatment is assigned randomly.
- This random assignment eliminates the possibility of a systematic relationship between, for example, how sunny the plot is and whether it receives fertilizer so that the only systematic difference between the treatment and control groups is the treatment.
- If this experiment is properly implemented on a large enough scale, then it will yield an estimate of the **causal effect** on the outcome of interest (tomato production) of the treatment (applying 100 g/m^2 of fertilizer).

Estimation of Causal Effects III

The **causal effect** is defined to be the effect on an outcome of a given action or treatment, as measured in an ideal randomized controlled experiment. In such an experiment, the only systematic reason for differences in outcomes between the treatment and control groups is the treatment itself.

Experiments are used increasingly widely in econometrics. In many applications, however, they are not an option because they are unethical, impossible to execute satisfactorily, too time-consuming, or prohibitively expensive. Even with nonexperimental data, the concept of an ideal randomized controlled experiment is important because it provides a definition of a causal effect.

Experimental versus Observational Data I

Experimental data come from experiments designed to evaluate a treatment or policy or to investigate a causal effect.
For example, the state of Tennessee financed a large randomized controlled experiment examining class size in the 1980s.

- In that experiment, which we examine in Chapter 13, thousands of students were randomly assigned to classes of different sizes for several years and were given standardized tests annually.
- The Tennessee class size experiment cost millions of dollars and required the ongoing cooperation of many administrators, parents, and teachers over several years.
- Because real-world experiments with human subjects are difficult to administer and to control, they have flaws relative to ideal randomized controlled experiments. Moreover, in some circumstances, experiments are not only expensive and difficult to administer but also unethical. (Would it be ethical to offer randomly selected teenagers inexpensive cigarettes to see how many they buy?)

Experimental versus Observational Data II

- Because of these financial, practical, and ethical problems, experiments in economics are relatively rare. Instead, most economic data are obtained by observing real-world behavior.
- Data obtained by observing actual behavior outside an experimental setting are called observational data. Observational data are collected using surveys, such as telephone surveys of consumers, and administrative records, such as historical records on mortgage applications maintained by lending institutions.

Observational data pose major challenges to econometric attempts to estimate causal effects, and the tools of econometrics are designed to tackle these challenges.

- In the real world, levels of “treatment” (the amount of fertilizer in the tomato example, the student–teacher ratio in the class size example) are not assigned at random, so it is difficult to sort out the effect of the “treatment” from other relevant factors.

Experimental versus Observational Data III

- Much of econometrics, and much of this text, is devoted to methods for meeting the challenges encountered when real-world data are used to estimate causal effects.
- Whether the data are experimental or observational, data sets come in three main types: cross-sectional data, time series data, and panel data. In this text, you will encounter all three types.

Cross-Sectional Data I

Data on different entities—workers, consumers, firms, governmental units, and so forth— for a single time period are called cross-sectional data. For example, the data on test scores in California school districts are cross sectional. Those data are for 420 entities (school districts) for a single time period (1999).
In general, the number of entities on which we have observations is denoted n; so, for example, in the California data set, $n = 420$.

- The California test score data set contains measurements of several different variables for each district. Some of these data are tabulated in Table 1.1.
- Each row lists data for a different district. For example, the average test score for the first district ("district 1") is 690.8; this is the average of the math and science test scores for all fifth-graders in that district in 1999 on a standardized test (the Stanford Achievement Test).

Cross-Sectional Data II

- The average student–teacher ratio in that district is 17.89; that is, the number of students in district 1 divided by the number of classroom teachers in district 1 is 17.89.
- Average expenditure per pupil in district 1 is $6385. The percentage of students in that district still learning English—that is, the percentage of students for whom English is a second language and who are not yet proficient in English—is 0%.
- The remaining rows present data for other districts. The order of the rows is arbitrary, and the number of the district, which is called the **observation number**, is an arbitrarily assigned number that organizes the data. As you can see in the table, all the variables listed vary considerably.

Cross-Sectional Data III

TABLE 1.1 Selected Observations on Test Scores and Other Variables for California School Districts in 1999

Observation (District) Number	District Average Test Score (fifth grade)	Student–Teacher Ratio	Expenditure per Pupil ($)	Percentage of Students Learning English
1	690.8	17.89	$6385	0.0%
2	661.2	21.52	5099	4.6
3	643.6	18.70	5502	30.0
4	647.7	17.36	7102	0.0
5	640.8	18.67	5236	13.9
⋮	⋮	⋮	⋮	⋮
418	645.0	21.89	4403	24.3
419	672.2	20.20	4776	3.0
420	655.8	19.04	5993	5.0

Note: The California test score data set is described in Appendix 4.1.

Link to download the data:`http://fmwww.bc.edu/ec-p/data/stockwatson/caschool.des`.

Time Series Data I

Time series data are data for a single entity (person, firm, country) collected at multiple time periods.

- Our data set on the growth rate of GDP and the term spread in the United States is an example of a time series data set.
- The data set contains observations on two variables (the growth rate of GDP and the term spread) for a single entity (the United States) for 232 time periods.
- Each time period in this data set is a quarter of a year (the first quarter is January, February, and March; the second quarter is April, May, and June; and so forth).
- The observations in this data set begin in the first quarter of 1960, which is denoted 1960:Q1, and end in the fourth quarter of 2017 (2017:Q4).
- The number of observations (that is, time periods) in a time series data set is denoted T. Because there are 232 quarters from 1960:Q1 to 2017:Q4, this data set contains T $=$ 232 observations.

Time Series Data II

TABLE 1.2 Selected Observations on the Growth Rate of GDP and the Term Spread in the United States: Quarterly Data, 1960:Q1–2017:Q4

Observation Number	Date (year: quarter)	GDP Growth Rate (% at an annual rate)	Term Spread (percentage points)
1	1960:Q1	8.8%	0.6
2	1960:Q2	−1.5	1.3
3	1960:Q3	1.0	1.5
4	1960:Q4	−4.9	1.6
5	1961:Q1	2.7	1.4
⋮	⋮	⋮	⋮
230	2017:Q2	3.0	1.4
231	2017:Q3	3.1	1.2
232	2017:Q4	2.5	1.2

Note: The United States GDP and term spread data set is described in Appendix 15.1.

Panel Data I

Panel data, also called **longitudinal data**, are data for multiple entities in which each entity is observed at two or more time periods. Our data on cigarette consumption and prices are an example of a panel data set, and selected variables and observations in that data set are listed in Table 1.3.

TABLE 1.3 Selected Observations on Cigarette Sales, Prices, and Taxes, by State and Year for U.S. States, 1985–1995

Observation Number	State	Year	Cigarette Sales (packs per capita)	Average Price per Pack (including taxes)	Total Taxes (cigarette excise tax + sales tax)
1	Alabama	1985	116.5	$1.022	$0.333
2	Arkansas	1985	128.5	1.015	0.370
3	Arizona	1985	104.5	1.086	0.362
⋮	⋮	⋮	⋮	⋮	⋮
47	West Virginia	1985	112.8	1.089	0.382
48	Wyoming	1985	129.4	0.935	0.240
49	Alabama	1986	117.2	1.080	0.334
⋮	⋮	⋮	⋮	⋮	⋮
96	Wyoming	1986	127.8	1.007	0.240
97	Alabama	1987	115.8	1.135	0.335
⋮	⋮	⋮	⋮	⋮	⋮
528	Wyoming	1995	112.2	1.585	0.360

Note: The cigarette consumption data set is described in Appendix 12.1.

Panel Data II

- The **number of entities** in a panel data set is denoted n,
- and the **number of time periods** is denoted T.
- In the cigarette data set, we have observations on $n = 48$ continental U.S. states (entities) for $T = 11$ years (time periods) from 1985 to 1995.
- Thus, there is a total of $n * T = 48 * 11 = 528$ observations.

References I

Stock, J. H. and Watson, M. W. (2020). *Introduction to econometrics*, volume 4. Pearson New York.