

Introduction to Econometrics

**AECN 896-002**

# Outline

1. Logistics
2. What is econometrics about?
3. Causality and Association
4. Endogeneity

# Logistics

---

## Instructors

- **Instructor** : Taro Mieno (Office: 209, E-mail: [tmieno2@unl.edu](mailto:tmieno2@unl.edu))
- **Teaching Assistant** :
  - Aakanksha Melkani: [amelkani@unl.edu](mailto:amelkani@unl.edu)
  - Sagar Dahal: [sdahal3@huskers.unl.edu](mailto:sdahal3@huskers.unl.edu)

## Goals of the course

- Learn modern introductory econometric theory
- Apply econometric theories to real economic problems
- Learn how to use statistical software (R) so you can conduct research independently (without technical help from your advisor)
  - manage data
  - visualize data
  - run regressions
  - interpret results

## Text Books

### Recommended:

Wooldridge, Jeffrey M. 2006. "Introductory Econometrics: A Modern Approach (5th edition)." Mason, OH: Thomson/South-Western.

## Course Schedule

- Lectures (MW): 3:00-4:30pm
- Lab sessions (F): 1:00-2:30pm

## Course Website

### Course Website

- Lecture Slides
- Assignments and submission links
- Final paper samples and submission link



## Grading

- Problem sets (4 assignments): 40%
- Small-size midterms (2): 20%
- Paper: 40%

# Assignments

## Problem sets

- Most questions are from the required text book
- Some questions come from what we cover in lab sessions

## Rmarkdown to do and submit your problem sets

- You are required to present your R codes
- You learn how to compile your assignment with your R code written in a document using **Rmarkdown** , which will be covered in the second lab session

## Assignments

### Caution

- 2nd year students have answers to all the questions I will assign (I will use exactly the same problems because they are really good to learn econometrics)
- You are free to copy and paste (or rephrase) the answers for your assignment. I won't bother to try to tell if you have copied and pasted answers.
- However, you are simply doing dis-service to yourself by depriving yourself of learning opportunities
- Moreover, your lack of understanding of the material will be clearly manifested on your performance at midterms and final paper

## Midterms

In-class open-book midterm

- Midterm 1: Oct, 10 (M)
- Midterm 2: Nov, 21 (M)

## Paper

In this assignment,

- you write a paper with a particular emphasis on econometric analysis using a real world data set
- you are encouraged to use the data set you are using for your masters thesis (talk with your advisor)
- you need to ensure that you use a **panel** dataset
- No presentation of your final paper

## Paper

Here is the time line of the paper assignment:

- **Oct, 17** : identify a research topic and the data set you will be using, and get an approval from the instructor
- **Oct, 24** : paper proposal
- **Dec, 16** : final paper

# Paper Proposal

## Introduction

- clear identification of what you are trying to find out (research question)
- why the research question is worthwhile answering

## Simple Model

- dependent variable (the variable to be explained)
- explanatory variable (variables to be explain)

## Data Source

- where you get data

# Final Paper

## Introduction

- clear identification of what you are trying to find out (research question) [1 point]
- why the research question is worthwhile answering [1 point]

## Data description

- the nature of the data with summary statistics table [1 point]
- visualize a few key variables in a meaningful way [3 points]



# Final Paper

## Econometric Methods:

the **process** of how you end up with the final econometric models and methods. [40 points ( **or more** )]

- justification of your choice of independent variables
- potential endogeneity problems
- what did you do to address the endogeneity problems?
- justification of econometric model(s) and method(s)
- identify appropriate standard error estimation methods

## Results, Discussions, and Conclusions:

- interpret and describe the results [2 points]
- implications of the results [1 point]
- conclusions [1 point]

**What is econometrics about?**

---

# What econometrics is about

## **Econometrics**:

Estimate quantitative relationships between variables

## **Examples**:

- the impact of fertilizer on crop yield
- the impact of political campaign expenditure on voting outcomes
- the impact of education on wage

## Steps in Econometric Analysis

- formulation of the question of interest (what are you trying to find out?)
- develop an economic model of the phenomenon you are interested in understanding (identify variables that matter)
- turn the economic model into an econometric model
- collect data
- estimate the model using econometrics
- test hypotheses

## Step 2: Develop an economic model

### Example: Job training and worker productivity

$$wage = f(educ, exper, training)$$

- *wage*: hourly wage
- *educ*: years of formal education
- *exper*: years of workforce experience
- *training*: weeks spent in job training

**Note**: Depending on questions you would like to answer, the economic model can (and should) be much more involved

### Step 3: Develop an econometric model

$$wage = f(educ, exper, training)$$

The form of the function  $f(\cdot)$  must be specified (almost always) before we can undertake an econometric analysis

$$wage = \beta_0 + \beta_1 educ + \beta_2 exper + \beta_3 training + u$$

$\beta_0, \beta_1, \beta_2, \beta_3$

- are the **parameters** of the econometric model.
- describe the directions and strengths of the relationship between *wage* and the factors used to determine *wage* in the model

$u$

- is called error term
- includes **ALL** the other factors that can affect wage other than the included variables (like innate ability)

## Step 4: Collect data

- survey
- websites
- experiment

# Data types

## Cross-sectional Data

- a sample of individuals, households, firms, cities, states, countries, or a variety of other units, taken at a given point in time
- the data on all units do not correspond to precisely the same time period
  - some families surveyed during different weeks within a year



# Cross-sectional Data

```
here("Data/wage1.rds") %>%  
  readRDS() %>%  
  data.table() %>%  
  .[, .(wage, educ, exper, female, married)]
```

```
##      wage educ exper female married  
## 1:  3.10   11    2      1        0  
## 2:  3.24   12   22      1        1  
## 3:  3.00   11    2      0        0  
## 4:  6.00    8   44      0        1  
## 5:  5.30   12    7      0        1  
## ---  
## 522: 15.00   16   14      1        1  
## 523:  2.27   10    2      1        0  
## 524:  4.67   15   13      0        1  
## 525: 11.56   16    5      0        1  
## 526:  3.50   14    5      1        0
```

## Data types: Time-series Data

**Time-series Data** Observations on a variable or several variables over time

- corn price
- oil price

### **Note**:

- The econometric frameworks necessary to analyze time series data are quite different from those for cross-sectional data
- We do **NOT** learn time-series econometric methods

## Data types: Panel (Longitudinal) Data

**Panel (Longitudinal) Data** time series data for each cross-sectional member in the data set ( **same** cross-sectional units are tracked over a given period of time)

### Example

- wage data for individuals collected every five years over the past 30 years
- yearly GDP data for 60 countries over the past 10 years

### Notes

- Panel data are much more common than they used to be
- Panel data econometric methods take advantage of the panel data structure

## Data types: Panel (Longitudinal) Data

```
here("Data/crime4.rds") %>%  
  readRDS() %>%  
  .[, .(county, year, crmrte, prbarr, prbpris)]
```

```
##      county year   crmrte  prbarr  prbpris  
## 1:         1   81 0.0398849 0.289696 0.472222  
## 2:         1   82 0.0383449 0.338111 0.506993  
## 3:         1   83 0.0303048 0.330449 0.479705  
## 4:         1   84 0.0347259 0.362525 0.520104  
## 5:         1   85 0.0365730 0.325395 0.497059  
## ---  
## 626:      197   83 0.0155747 0.226667 0.428571  
## 627:      197   84 0.0136619 0.204188 0.372727  
## 628:      197   85 0.0130857 0.180556 0.333333  
## 629:      197   86 0.0128740 0.112676 0.244444  
## 630:      197   87 0.0141928 0.207595 0.360825
```

## Steps 5 and 6

This is what you learn for the next few months!!

- estimate the model using econometrics
- test hypothesis

# Causality and Association

---

# Causality and Association

## Association

An association of two variables arise because **either of or both** variables affect the other variable

$$A \longleftrightarrow B$$

$$A \longrightarrow B$$

$$A \longleftarrow B$$

Association does **NOT** concern which affects which. Under all the three cases above, A and B are **associated**. Or, we say there is an association between A and B. This is what **correlation coefficient** measures.

# Causality and Association

## Association

An association of two variables arise because **either of or both** variables affect the other variable

$$A \longleftrightarrow B$$

$$A \longrightarrow B$$

$$A \longleftarrow B$$

Association does **NOT** concern which affects which. Under all the three cases above, A and B are **associated**. Or, we say there is an association between A and B. This is what **correlation coefficient** measures.

## Causality

When A has a causal impact on B,

$$A \longrightarrow B$$

Here, changes in  $A$  cause changes in  $B$ , not the other way around



Let's watch this interesting CM.

### Claims made in the video

People who wear glasses are

- much smarter than those who don't
- more likely to pursue higher education
- 200% more likely to graduate college

### Claims made in the video

People who wear glasses are

- much smarter than those who don't
- more likely to pursue higher education
- 200% more likely to graduate college

For you to be convinced to buy glasses, these claims need to be causal, not association:

- Does wearing glasses make you much smarter?
- Does wearing glasses make it more likely for you to pursue higher education?
- Does wearing glasses make it 200% more likely for you to graduate college?

However, this seems to be a more likely explanation of the association:

- One spends more time studying academic subjects
  - smarter (or knowledgeable) → pursue higher education and graduate college
  - worsened eyesight  $\Rightarrow$  wear glasses

### **Important:**

- We care about isolating causal effects, but not association
- Identifying association is super easy
- Identifying causal effects is extremely hard (this is what we tackle)

## Endogeneity: Your Nemesis

---

## Causality and Association

It is super easy to find an association of multiple variables, but it is incredibly hard to find a causal effect (at least in Economics)!!

## Endogeneity

You are interested in the causal impact of fire fighters on the number of death tolls in fire events

fire event	death toll	# of firefighters deployed
1	10	20
2	0	3
3	5	10
4	3	5
5	50	50

### Questions

- How are they associated?
- Can you say anything about the causal effect of fire fighters deployment on the number of death tolls?



## What happened?

You ignored an important variable!!

fire event	death toll	# of firefighters deployed	scale of fire
1	10	20	20
2	0	3	5
3	5	10	20
4	3	5	10
5	50	50	100

## Endogeneity Problem

### Endogeneity (Definition):

Variables of interest are correlated with some unobservables (variables that cannot be observed or are missing) that have non-zero impacts on the variable that you want to explain

In the above example,

- **variable of interest** : the number of firefighters
- **unobservables** : the scale of fire events (and other factors)
- **variable to explain** : death toll

In the above example,

- **variable of interest** : the number of firefighters
- **unobservables** : the scale of fire events (and other factors)
- **variable to explain** : death toll

**The model** :

$$\text{death toll} = \alpha + \beta \# \text{ of fire fighters} + (\gamma \text{ scale} + v)$$

**Endogeneity Problem** :

# of fire fighters is correlated with scale, which we ignored

### Another example: education on wage

$$wage = \beta_0 + \beta_1 educ + \beta_2 exper + \beta_3 training + u$$

What are unobservables in  $u$  that are likely to be correlated with  $educ$ ?

### An important unobservable

- innate ability  $\rightarrow$  wage
- innate ability  $\rightarrow$  education

Most of the time, you will be faced with endogeneity problems caused by at least one of the followings,

- omitted variables (the scale of fire events, innate ability)
- self-selection
- simultaneity
- measurement error

Most of the time, you will be faced with endogeneity problems caused by at least one of the followings,

- omitted variables (the scale of fire events, innate ability)
- self-selection
- simultaneity
- measurement error

### Central Question

How can we avoid or solve endogeneity problems?

## How to deal with endogeneity?

- You have two opportunities to deal with endogeneity problems
  - at the design stage
  - at the regression stage (what you will learn in this course)
- Econometrics has evolved to address endogeneity problems at the regression stage because randomized experiments are infeasible most of the time
- How about econometrics and other fields of statistics: Statistics, Psychometrics, and Biometrics?



## How to deal with endogeneity?

Field	Design	Estimation Method
Econometrics	not feasible (often)	intricate
Many other fields	feasible	relatively simple

## Deal with endogeneity at the design stage

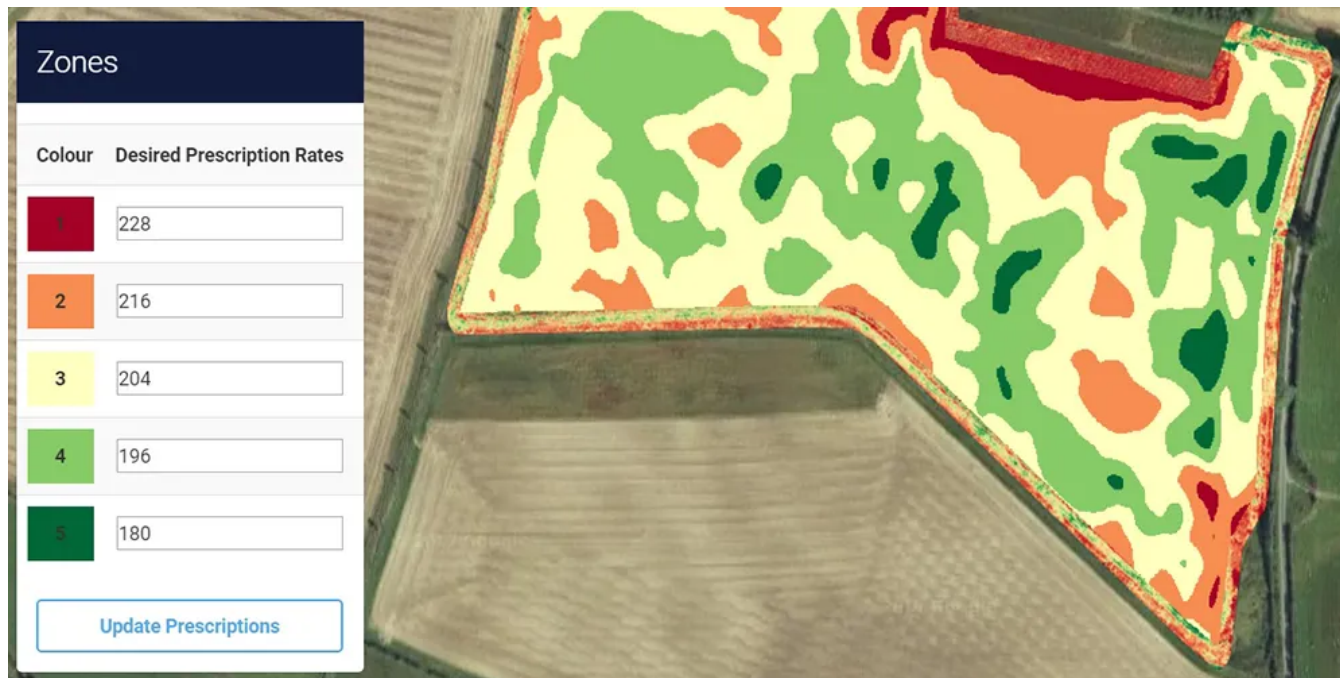
### Randomized Experiments

- you have a liberty to determine the level of the variable of interest
- by randomizing the value of the variable of interest, you can effectively break the link (association) with whatever is included in the error term

## The impact of fertilizer on corn yield (Non-Randomized)

### Data :

Yield and nitrogen rate data obtained from a field that is managed by a farmer



## The impact of fertilizer on corn yield (Non-Randomized)

### Farmer

- decide nitrogen rate based on soil characteristics

### Researcher

- soil characteristics is not observable, so it is in the error term

$$yield = \beta_0 + \beta_1 N + (\gamma SC + \mu)$$

- N (nitrogen rate) and SC (soil characteristics) are correlated



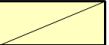
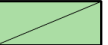

## The impact of fertilizer on corn yield (Non-Randomized)

Suppose the farmer applied more nitrogen to the area where its soil characteristics lead to higher corn yield

**Question** If the researcher estimate the model (which ignores soil characteristics), do you over- or under-estimate the impact of nitrogen rate on corn yield?

# Randomized Experiments



Randomized N rate (lb/acre)  111  134  156  178  201

**Important** Soil quality (in error term) is no longer correlated with N!!

## Randomized Experiments on Education?

### Randomized Experiment? :

Researchers determine randomly how much education subjects (people) can get?

## Endogeneity Problem in Economics

- Economics is about understanding human behavior



## Endogeneity Problem in Economics

- Economics is about understanding human behavior
- Almost always, you need to deal with endogeneity problem because people are **smart**: we make decisions based on available information (not just randomly) so that our decisions lead to good outcomes (**whether our decisions turn out to be good or not is irrelevant**)
  - how much education one get is determined based on their judgment of their own ability (not by rolling a dice)
  - how many fire fighters to be deployed was determined based on the scale of fire (not by rolling a dice)
  - how much nitrogen to apply based on soil characteristics (not by rolling a dice)

# Endogeneity Problem in Economics

- Economics is about understanding human behavior
- Almost always, you need to deal with endogeneity problem because people are **smart**: we make decisions based on available information (not just randomly) so that our decisions lead to good outcomes (**whether our decisions turn out to be good or not is irrelevant**)
  - how much education one get is determined based on their judgment of their own ability (not by rolling a dice)
  - how many fire fighters to be deployed was determined based on the scale of fire (not by rolling a dice)
  - how much nitrogen to apply based on soil characteristics (not by rolling a dice)
- If people are not smart and just roll a dice for their decision making, we would have much easier time identifying causal effects