Getting fit for the Midterm!

Econon 140, Section 4

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Roadmap

1. Recap
2. Interaction terms (Q6)
3. Logs (Q4)
4. Topics we've glossed over so far

Any questions?

... Some comments on the evaluations asked for more space to answer left-over questions from the lecture: Now is the time!

Recap

Recap: OVB (Very important!)

We can summarize everything of OVB in three equations. Let Y_i be the outcome variable, X_i our regressor of interest, and Z_i the "omitted" variable.

$$\begin{aligned}
&\text{[Long regression]} && Y_i = c_1 + \beta_L X_i + \delta Z_i + e_i \\
&\text{[Short regression]} && Y_i = c_2 + \beta_S X_i + u_i \\
&\text{[Auxiliary regression]} && Z_i = c_3 + \gamma X_i + v_i
\end{aligned}$$

Then, the **Omitted variable bias formula** states that:

$$\underbrace{\beta_S}_{\text{Short =}} \quad = \quad \underbrace{\beta_L}_{\text{Long +}} \quad + \quad \underbrace{\delta}_{\text{Omitted} \times} \quad \cdot \quad \underbrace{\gamma}_{\text{Included}}$$

We call $\delta\gamma$ the **omitted variable bias**. We can appraise the direction of the bias by multiplying our guesses for the signs of δ and γ.

Recap: Understanding bias in OLS regressions

- We can use the OLS formula to understand how bias works in OLS regression

$$\hat{\beta}_1 = \frac{\text{Cov}(X_i, Y_i)}{\text{Var}(Y_i)}$$

- For **OVB**: We *know* the true Y_i and plug it in
- For **measurement error**: We **know** what X_i and plug it in
- Simplify using the following rules:

$\text{Var}(X + Y) = \text{Var}(X) + \text{Var}(Y) + 2\,\text{Cov}(X, Y)$

$\text{Var}(X - Y) = \text{Var}(X) + \text{Var}(Y) - 2\,\text{Cov}(X, Y)$

$\text{Cov}(aX + bY, Z) = a\,\text{Cov}(X, Z) + b\,\text{Cov}(Y, Z)$

$\text{Var}(aX) = a^2\,\text{Var}(X)$

$\text{Cov}(X, Y) = 0$, if X and Y are independent.

$\text{Var}(X) \geq 0$.

Recap: Making OLS more interesting

- We saw that we can extend the simple OLS framework

$$Y_i = \beta_0 + \beta_1 X_i + e_i$$

  to something richer:

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 X_i^2 + e_i$$

- We will get to know many more versions of this today
- All questions of the type *"how is Y_i expected to change if we change X_i"* can be solved with **partial derivatives** – in this case:

$$\frac{\partial Y_i}{\partial X_i} =$$

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$$\frac{\partial Y_i}{\partial X_i} = \beta_1 + 2 \cdot \beta_2 \cdot X_i$$

Interaction terms (Q6)

Interaction terms: Making OLS more interesting (Q6)

Let us consider the model

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + e_i$$

where Y_i is a country's GDP per capita, X_{1i} the value of its natural resources, and X_{2i} a measure of how democratic it is.

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1. How do we interpret β_1?
   Keeping democracy fixed, increasing the value of a country's natural resources by one unit is associated with β_1 higher GDP per capita.
2. How do we interpret β_2?

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2. How do we interpret β_2?
   Keeping natural resources fixed, increasing a country's democracy score by one unit is associated with β_2 higher GDP per capita.

Interaction Terms (ii) (Q6)

Now, let us extend the model to:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{1i} X_{2i} + e_i$$

1. What is the "effect" of X_{1i} on Y_i?

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4. How do we interpret $\beta_1 + \beta_3$?

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2. How do we interpret β_1? **The effect of an additional unit of X_{1i} , if X_{2i} is equal to 0.**
3. How do we interpret β_2? **The effect of an additional unit of X_{2i} , if X_{1i} is equal to 0.**
4. How do we interpret $\beta_1 + \beta_3$? **The effect of an additional unit of X_{1i} , if X_{2i} is equal to 1.**

Rule of thumb: Always use partial derivatives to make sure that you are right!

Practice exam question: 1a)

The Ministry of Truth is interested in a rumour that **air pollution could impact mental health**. One of the most harmful pollutants is fine particulate matter PM2.5, which comes from operations that involve the burning of fuels such as wood, oil, coal, etc. A research team is sent to investigate the rumour. The team **randomly** selects and surveys 19,920 people across 71 districts of the country. The key variable, Exposure E_i, is a **dummy variable** equal to 1 if the individual i is exposed to a large amount of PM2.5 in the last two years, and 0 otherwise. The team also conducts a standardised questionnaire to record **depressive symptoms** in the last month, called the Kessler Psychological Distress scale (K6). The questionnaire results in a score, Depression_i, that ranges from 0 to 24; and the higher the score, the more severe the depressive symptoms for individual i. The variable has a sample average of 2.96. **Running regressions with Depression D_i as the dependent variable, you obtain the following results**:

Practice exam question: 1a)

Dependent variable: Depression $_i$

Regressor	(1)	(2)	(3)
Exposure $_i$	0.834	0.614	0.554
	(0.032)	(0.045)	(0.042)
Exposure $_i \times$ Female $_i$		0.065	
		(0.024)	
Female $_i$		-0.739	-0.825
		(0.036)	(0.066)
Age_i			0.452
			(0.132)
Age_i^2			0.524
			(0.121)

Notes: All estimations contain a constant term. Robust standard errors are in the parentheses. Age_i is the age (years old) of individual i, and Age_i^2 is the square of Age_i.

a) Interpreting the coefficient in Column (1), a journalist, Katherine, claims: ”Since participants are randomly selected, we can infer that exposure to a large amount of PM2.5 does cause depression.”

i. Explain carefully why Katherine is wrong, specifying the direction of bias(es) if there is any. Which assumption(s) would she need to impose for the causality claim to hold?

ii. What is the correct interpretation from Column (1) that Katherine should have made?

Pratice Exam question: 1b)

b) Interpret column (2) of the regression table i. A colleague notes the the coefficient on Female_i is significant, and states: "The effect of being female on depression is significantly different from zero". Do you agree with the statement? Why or why not?
ii. How is pollution exposure related to depression, for men? And how for women?

Logs (Q4)

Notes on logarithms (Q4)

- We can take logs of whole equations to get linear models (problem set)
- We can also take logs of specific variables, especially when they have long tails (wealth in the US, GDP per capita, etc.)
- We can get to the right interpretation of log-specifications with just math

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- We can also take logs of specific variables, especially when they have long tails (wealth in the US, GDP per capita, etc.)
- We can get to the right interpretation of log-specifications with just math
- But I will make your life easier with a cheat sheet.

Logs: Cheatsheet (Wooldridge version) (Q4)

Summary of Functional Forms Involving Logarithms

Model	LHS	RHS	Interpretation of β_1
Level-level	y	x	$\Delta y = \beta_1 \Delta x$
Level-log	y	$\log(x)$	$\Delta y = (\beta_1/100)\,\%\Delta x$
Log-level	$\log(y)$	x	$\%\Delta y = (100\beta_1)\,\Delta x$
Log-log	$\log(y)$	$\log(x)$	$\%\Delta y = \beta_1 \%\Delta x$

Table taken from Wooldridge (2011)

Logs: Cheatsheet II (Jonathan's version) (Q4)

Model	LHS	RHS	A change in x by . . .	is associated with a change in y by . . .
Level-Level	y	x	1 unit	β_1 units
Level-Log	y	log(x)	1%	$\beta_1/100$ units
Log-Level	$\log(y)$	x	1 unit	$100\beta_1$%
Log-Log	log (y)	log (x)	1%	β_1 %

If you want to get a bonus star from me, write ”approximately” in log-interpretations.

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Bad controls

- Not all controls are good controls
- Some controls are called ”bad controls”. These are:
  1. Variables that are themselves outcomes of a treatment: What happens if you control for the change in English test scores in the regression below?

	Treatment	Control
Change in Math Scores	2	1
Change in English Scores	2	1

  2. Variables that moderate the treatment effect, e.g. controlling for occupation choice in gender wage gap regression . . .
- **Rule of Thumb: Good controls are either pre-determined or immutable characteristics.**
- Another way to think about it: Controls help us make ”apples to apples” comparisons. Which apples matter?

What if the outcome variable is binary (a dummy variable)?

Let's run the regression

$$\text{Defaulted}_i = \alpha + \beta \tilde{\text{Credit Score}}_i + e_i$$

where Defaulted_i is equal to 1 if individual i has ever defaulted on a loan (mortgage, credit card, auto loan, etc.), and $\tilde{\text{Credit Score}}_i$ is i's credit score, **minus the average credit score in the sample** (Note: US credit scores range from 300 to 850 points).

1. You run a regression and get $\hat{\alpha}$=0.1. How do you interpret this? Does this number make sense here?
2. Your estimate for β is $\hat{\beta} = 0.001$. Interpret.

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With a dummy dependent variable, changing X_i by one unit increases the probability of $Y_i = 1$ by $\hat{\beta} \cdot 100$ percentage points.

Inference and the variance of $\hat{\beta}_{OLS}$ (Q3)

The variance of the OLS estimator is $\mathsf{Var}(\hat{\beta}_1^{OLS}) = \frac{\sigma_\epsilon^2}{N \cdot \mathsf{Var}(X_i)}$.
We expect to get more precise estimates if

- The variance of X_i increases
- The variance of the error term ϵ_i decreases
- The sample size N increases

Hypothesis testing

$$\left|\frac{\hat{\beta}}{\mathrm{SE}(\hat{\beta})}\right| \geq 1.96$$

$$\Leftrightarrow |\,\text{t-stat}\,| \geq 1.96$$

$$\Leftrightarrow \text{p-value} \leq 0.05$$

If you are testing the null hypothesis H_0: $\beta = 0$, then all of these are equivalent, and you can use any of these.