

Reproductibility in Empirical Economics Issues and Solutions

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Reproductibility in Empirical Economics Issues and Solutions

Victor Gay

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Fall 2022



- The credibility revolution.
- The reproductibility crisis.
- Reproductibility in practice: workflow, coding, and reporting principles.

The credibility revolution

- Trends toward empirical research. Angrist et al. (2017)
- Trends toward design-based methods. Angrist and Pischke (2010)

Angrist et al. (2017)

- Analysis of 135k papers in 80 journals, 1980–2015.
- Slight trends toward microeconomics and non-traditional fields.
- Large empirical shift within fields.
- Hamermesh (2013) documents similar trends.

Publication Shares by Field



Source: Angrist et al. (2017).

Fraction Empirical by Field



Source: Angrist et al. (2017).

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Publications by Style



Source: Angrist et al. (2017).

Citations by Style



Source: Angrist et al. (2017).



Source: Oliveira and Davila-Fernandez (2020).

Applied Articles in "Top-3"



Source: Oliveira and Davila-Fernandez (2020).

Trends toward design-based methods

Angrist and Pischke (2010)

- Until 1980s, regression analysis with causal claims.
- No attention to endogeneity (OVB) or reverse causality.

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- Example: education production function literature:
 - Causal effect of class size on student performance?

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- Until 1980s, regression analysis with causal claims.
- No attention to endogeneity (OVB) or reverse causality.
- Example: education production function literature:
 - Causal effect of class size on student performance?
 - Regressions of performance on size yields negative estimates.
 - But selection: struggling students often grouped in smaller classes.

Trends Toward Design-Based Methods

- In the 1980s, increasing doubts about validity. Learner (1983)
- In the 1990s, trend toward design-based methods to make causal claims. E.g. Card and Krueger (1994)
 - Gold standard: randomization studies.
 - Often not possible \implies search for quasi-natural experiments.
 - Main methods: matching, DiD, IV, RDDs.
 - Focus on exogenous sources of identifying variation (LATE).

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 - Gold standard: randomization studies.
 - Often not possible \implies search for quasi-natural experiments.
 - Main methods: matching, DiD, IV, RDDs.
 - Focus on exogenous sources of identifying variation (LATE).
- Much more transparent causal claims.
- Focus on exogeneity and design, less on statistical aspects.

• External validity. Deaton (2010) Heckman and Urzua (2009)

- External validity. Deaton (2010) Heckman and Urzua (2009)
 - High internal validity but weak external validity.
 - Sources of identifying variations very local \implies little extrapolation.
 - But ... "better LATE than nothing." Imbens (2010)
 - Empirical evidence is always local.
 - Replications helps understand heterogeneity due to context

• Tackle unimportant questions ("playing small ball").

- Tackle unimportant questions ("playing small ball").
 - Research driven by search for natural experiments.
 - Ends up giving trivial answers.
 - True: think about questions first, and design second.
 - But confounds triviality with narrow context.
 - Small balls win big games.

The reproductibility crisis

The Reproductibility Crisis

- Reproductibility issues:
 - Little reproductibility of published research findings.
 - Issues with *p*-values (publication bias, *p*-hacking...).
 - HARKing: hypothesizing ex-post.
 - Low statistical power.
 - Researcher degrees of freedom.

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 - Low statistical power.
 - Researcher degrees of freedom.
- Consequences for knowledge accumulation: a Bayesian approach.
- Replications as a solution.

On these issues, see also Doucouliagos and Stanley (2011), Franco et al. (2014), Mervis (2014), Camerer et al. (2016), Duyx et al. (2017), Christensen and Miguel (2018), Andrews and Kasy (2019), Gordon et al. (2020), Ferraro and Shukla (2020)

Reproductibility issues

Chang and Li (2017, 2022)

- Attempt to replicate 67 macro papers in 13 top journals.
- Use author-provided data and code.
- Successful replication: reproduce results qualitatively.

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- Attempt to replicate 67 macro papers in 13 top journals.
- Use author-provided data and code.
- Successful replication: reproduce results qualitatively.
- Result:
 - Replicate 22 of 67 papers (33%).
 - Excluding papers with confidential data: 49% success rate.
 - Main reason: authors don't provide data and code.
 - When all files provided, 1/3 do not produce same qualitative results.



FIGURE 1. REPLICATION SUCCESS AND FAILURE RATES



FIGURE 2. REPLICATION SUCCESS BY JOURNAL TYPE

- Statistical inference:
 - To test hypothesis H_1 , suppose null H_0 is true.
 - E.g. H_0 : $\overline{X} = 0$, H_1 : $\overline{X} \neq 0$.
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 - Usually $\alpha = 0.05$, but heated debates. Benjamin et al. (2017)

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Issues with *P*-Values

Random variable X follows standard normal: X ~ N(0,1).


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• p-value = 0.05 \implies z-score = ± 1.96 s.d.

- Common misunderstanding and misuse of *p*-values.
- The "cult of statistical significance." Ziliak and McCloskey (2008)
- American Statistical Association issued 6-point statement. Wasserstein and Lazar (2016)

 \implies Everyone should read "Statistical tests, *p*-values, confidence intervals, and power: a guide to misinterpretations." Greenland et al. (2016)

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- 3 Scientific conclusions should not be based only on whether a *p*-value passes a specific threshold.
- **4** Proper inference requires full reporting and transparency.
- A *p*-value, or statistical significance, does not measure the size of an effect or the importance of a result.
- **6** By itself, a *p*-value does not provide a good measure of evidence regarding a model or hypothesis.

Brodeur et al. (2016)

- Collect 50k test statistics from 641 articles in top-3 economics journals 2005–2011.
- Assume selection by journals is monotonically increasing with value of test statistics (standardized *z*-statistics).
- Extract residual from *selection* process to identify *inflation*.

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- Collect 50k test statistics from 641 articles in top-3 economics journals 2005–2011.
- Assume selection by journals is monotonically increasing with value of test statistics (standardized *z*-statistics).
- Extract residual from *selection* process to identify *inflation*.
- Find a two-humped camel shape with
 - Too little marginally insignificant results (*p*-value of 0.10–0.25).
 - Too many marginally significant results (*p*-value of 0.05–0.10)
- \implies Evidence of *p*-hacking and specification searching.



Distribution of z-Statistics

Brodeur et al. (2020)

- Assess how sensitive this issue is to empirical design.
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- For IV: same result for F-statistic at 10-threshold.

Issues with *P*-Values

z-Curves by Method



Issues with *P*-Values

z-Curves by Method



• But "speed" of z-changes vary by method.

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Reproductibility in Empirical Economics

First Stage F-Statistics



- HARKing: hypothesizing after the results are known. Kerr (1998)
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- Damaging to science: translate type I error into theory.

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- Examine 159 meta-analyzes, providing 64k estimates from 7k studies.
- Half of economic literatures have 90% of results under-powered.
- Median statistical power is 18%.

Researcher Degrees of Freedom

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- How much variation or noise induced by unreported decisions?

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- Hundreds of hidden decisions made from data cleaning to variable definition, even if empirical approach constant.
- How much variation or noise induced by unreported decisions?
- Many-analyst approach independently on same raw data and same question. Hungtington-Klein et al. (2020)
 - Allow researcher freedom in construction and cleaning dataset.
 - Focus on one estimate in 2 studies, each replicated 7 times:
 - Black et al. (2008) Effect of compulsory schooling on teenage pregnancy.
 - Fairlie et al. (2011) Effect of employer-based health insurance on entrepreneurship.
 - Main reason for differences: data cleaning.





A Bayesian approach to knowledge accumulation

Statistics Reminder

- Statistical inference:
 - To test hypothesis H_1 , suppose null H_0 is true.
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 - Type I error (false positive): $\alpha = \Pr(p \le \alpha | H_0)$.
 - Usually $\alpha =$ 0.05, but heated debates.
- Statistical power 1β :
 - Type II error (false negative): $\beta = \Pr(\texttt{fail reject } H_0 | H_0 \texttt{ false}).$
 - Effect size and sample size affect power.

	Null hypothesis H_0	
	True	False
Reject H_0	Type I error false positive α	$\begin{array}{c} {\sf Correct} \\ {\it true \ positive \ 1-\beta} \end{array}$
Fail to reject <i>H</i> 0	Correct true negative $1-lpha$	Type II error false negative β

A Bayesian Approach to Knowledge

Ioannidis (2005) Maniadis, Tufano and List (2014, 2017)

- Notations:
 - *n*: number of scientific associations to be investigated.
 - π : fraction of true associations (or prior).
 - 1β : power of test.
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 - False associations declared true: $\alpha \cdot (1 \pi) \cdot n$

- Post-study probability (PSP):
 - PSP: probability that an association declared true is actually true.
 - $PSP = Pr(H_0 \text{ false} | reject H_0).$

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$$PSP = \frac{(1-\beta) \pi}{\underbrace{(1-\beta) \pi}_{\text{true positives}} + \underbrace{\alpha (1-\pi)}_{\text{false positives}}}$$

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PSP: probability that an association declared true is actually true.

Post-Study Probability =
$$\frac{(1-\beta) \pi}{\underbrace{(1-\beta) \pi}_{\text{true positives}} + \underbrace{\alpha (1-\pi)}_{\text{false positives}}}$$

Comparative statics:

- Prior $\pi \uparrow \Longrightarrow \mathsf{PSP} \uparrow$.
- Statistical significance $\alpha \downarrow \Longrightarrow \mathsf{PSP} \uparrow$.
- Power $1 \beta \uparrow \Longrightarrow \mathsf{PSP} \uparrow$.

What Can We Learn From One Study?



What Can We Learn From One Study?



Statistical significance $\alpha \downarrow \Longrightarrow \mathsf{PSP} \uparrow$

What Can We Learn From One Study?



Statistical power $1 - \beta \uparrow \Longrightarrow \mathsf{PSP} \uparrow$

- Usually number of researchers simultaneously working k > 1.
- Two implications:
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- Two implications:
 - Number of true positives \uparrow .
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- But false positives \uparrow faster than true positives.
- \implies Post-study probability \downarrow when number of researchers \uparrow

What Can We Learn From Many Studies?



k = 1 researcher

What Can We Learn From Many Studies?



k = 10 researchers

What Can We Learn From Many Studies?



k = 50 researchers

Replication as a Solution

Clemens (2017)

- Replication tests:
 - Verification tests:
 - Original data, same sample, identical method.
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 - Reproduction tests:
 - Resampling same population, identical method.
 - Solves sampling errors, low power.
- Robustness tests:
 - Reanalysis: same population, different method.
 - Extension: resampling, different method.

Replication as a Solution





Starting prior: $\pi = 1\%$.

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Starting prior: $\pi = 1\%$. \downarrow statistical significance $\alpha \Longrightarrow \uparrow \mathsf{PSP}$ But perverse incentives for achieving low α .



Starting prior: $\pi = 1\%$.



Starting prior: $\pi = 1\%$. \downarrow statistical power $1 - \beta \Longrightarrow \downarrow \mathsf{PSP}$



Starting prior: $\pi = 1\%$.

Replication as a Solution



Starting prior: $\pi = 1\%$. \uparrow researchers $k \Longrightarrow \downarrow \mathsf{PSP}$

- Replications are relatively rare in economics. Berry et al. (2017) Hamermesh (2017)
- Incentives are not well-aligned.
 Duvendack et al. (2017) Gertler et al. (2018)

Replication as a Solution

- Changing journal policies. Christensen and Miguel (2018)
 - Many require code and data online.
 - Some replicate results before publication e.g. JAE, AJPS.
 - JDE allows for registered reports approved before analysis.
 - Some have explicit sections for replication e.g. JAE.
 - Some have special replication issues e.g. AEPP 2022.

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 - Some have explicit sections for replication e.g. JAE.
 - Some have special replication issues e.g. AEPP 2022.
- Replication wiki platform: https://replication.uni-goettingen.de/
- Replication journal with specific guidelines: *Journal of Comments and Replications in Economics.*
- BITTS' Accelerating Computational Reproductibility in the Social Sciences initiative.

Ferraro and Shukla (2020)

- Emphasize questions rather than results.
- Emphasize designs rather than results.
- Specify research plan through preregistration.
- Run replications.
- Report results (and data) with transparency.

Reproductibility in Practice

- Replication recipes.
- Workflow.
- Coding.
- Documenting.
- Reporting.

Replication recipes

A few guides to conducting replications.

- Define replication. Clemens (2015)
- Make a precise preanalysis plan. Chang (2018)
- Define replication paradigm and space. Anderson (2017)
- The problem of statistical adequacy. Owen (2018)
- Diagnostic approach for replications. Brown and Wood (2018)
- General guidelines in *Journal of Comments and Replications in Economics*.

Workflow

Orozco et al. (2020) Gentzkow and Shapiro (2014)

- A lot of research process happens in background.
- Systematic practices are key for reproducible research.
- Three general principles:
 - Organize your work.
 - Code for others.
 - Automate as much as possible.

- Very helpful when working in teams.
- Organize and track progress and tasks.
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- Simple text file, or electronic laboratory notebook (ELN) to synchronize across collaborators e.g. Evernote, OneNote, Etherpad.
- Task management systems (TMS) for more general collaborative and centralized task organization e.g. Trello, Asana, MS Project, Wrike.

Organize Your Work: Files

- Important to be consistent with:
 - Directory structure.
 - Naming convention.

Organize Your Work: Files

- Important to be consistent with:
 - Directory structure.
 - Naming convention.
- Directory structure:
 - No perfect solution, but project should have distinct folders.
 - Ideas and notes, Data, Analysis, Paper, Literature.
- My usual structure:
 - notes
 - literature
 - source_data
 - source_code (data.do, analysis.do, temp_files)
 - output
 - paper

- Shared working spaces:
 - Necessary for any collaborative work.
 - Dropbox is most convenient (synchronization on computer).
 - Other options: Google drive, Joomla, Agora, SharePoint.
 - To share files: We Transfer, JustBeamIt, FileSender (RENATER).

Organize Your Work: Writing

- Collaborative writing can be tricky.
- Depends on writing software:
 - WYSIWYG (What You See Is What You Get) e.g. MS Word. Use Google doc.
 - WYSIWYM (What You See Is What You Mean) e.g. Latex. Use OverLeaf.
- References:
 - Reference managers: Mendeley, Zotero.
 - Use BibTex for Latex.

Coding

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 - Your TAs and professors.
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- Only thing to change: directory and globals.
- Make it as automated, generic, and clear as possible.

- Some guides:
 - Pep 8 Style Guide
 - Julian Reif's Stata Coding Guide.
 - Social Science Data Editors guide.

General Coding Conventions

- Limit the length to 80 characters (there is a vertical line).
- To jump line, use /// at length 80.
- For comments, use /*...*/
- Have a space around mathematical operators (=, +, -, >, <...)
- Make layout structure as clear as possible.
- Document code with sections using e.g. * I. CLEAN DATASET
- Use consistent variables naming convention.
- DRY: Don't Repeat Yourself.

Example

- Illustrate coding principles through example (on Moodle).
- Data based on Boehnke and Gay (2022)
 - Study in Open Access: 10.3368/jhr.57.4.0419-10151R1.
 - Replication data: 10.7910/DVN/AP1HZ8.
 - Impact of WWI military fatalities on FLFP in France using DiD.
 - Panel of 90 départements from 1901 to 1936.

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 - Panel of 90 départements from 1901 to 1936.
- Steps:
 - Setting up the .do file.
 - Cleaning the (fake) raw dataset.
 - Run the analysis.

• Many different ways, this is the spirit.

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- File information: title, coder, date of creation, date and author of last edits...

- Many different ways, this is the spirit.
- File information: title, coder, date of creation, date and author of last edits...
- Program setup:
 - Stata version: version 16. Avoid compatibility issues.
 - Clear memory: clear all.
 - No stop when output window full: set more off.
 - Line size if create TeX tables in Stata: set linesize 82
 - System diagnostic (optional): version, variant

- Relative paths (very important!).
 - Directory.
 - Input and output globals.
 - You can add a permanent global (see Julian Reif's guide).
- For reproducibility, create relevant folders in replication file.

Coding Principles: Document Your Preamble

*	M1 APPLIED ECONOMETRICS, FALL 2022	*
*	AUTHOR: VICTOR GAY	*
*	CREATED: SEPTEMBER 15 2022	*
*	LAST MODIFIED: SEPTEMBER 15 2022	*
*	LAST MODIFIED BY: VICTOR GAY	*

* PROGRAM SETUP *

version 16 clear all set more off set linesize 82

* DIRECTORY *

global PATH "ENTER YOUR DIRECTORY HERE"
cd "\$PATH/source_code"

* GLOBALS *

global DATA "\$PATH/source_data"
global OUTPUT "\$PATH/output"
global TEMP "\$PATH/source_code/temp_files"

- Check the format of your data.
 - Use codebook.
 - Directly see the data using edit (strings are red, numerical are black).
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- Label your data.
 - Name and label appropriately your variables.
 - Use value labels for categorical variables, then tabulate with fre.
 - You might need to install it.
 - Data with value labels are in blue in the dataset.
 - Generally, avoid strings. But sometimes no choice.

label variable flfp "Female labor force participation rate" codebook flfp

• Some départements in Germany before WWI.

** I.4. VALUE LABELS

```
codebook sample
ssc install fre
fre sample
/* generate new variable */
generate dep_type = .
replace dep_type = 1 if sample == "new"
replace dep_type = 2 if sample == "non-war" | sample == "war"
/* use value labels */
label define dep_type 1 "New département" 2 "Old département"
label values dep_type dep_type
fre dep_type
fre dep_type, after(sample)
drop sample
```

- Document missing values!
- There should be no undocumented missing values.
- Use extended missing values rather than ad hoc values.
- Assign value labels to document missings.
- Here: no military death rates in "old" départements.

** I.5. EXTENDED MISSING VALUES

codebook deathrate replace deathrate = . a if deathrate == . label define deathrate .a "New departement" label values deathrate deathrate codebook deathrate fre deathrate if deathrate >= .

- Summarize all your data and check units.
- In particular, check all are expressed in same unit.
- Usually: careful with shares (0-1) and percent (0-100).
- Matters (a lot!) for the interpretation.
- Adjust your variable labels.
- ** I.6. CHECK UNITS

```
summarize deathrate flfp rural bindep
replace flfp = flfp * 100
label variable flfp "Female labor force participation (%)"
codebook deathrate flfp bindep
```

```
save "$TEMP/dataset_temp", replace
```

- Sometimes the data is in wide form, but you want long form.
- Learn how to reshape.
- Don't hesitate to use help reshape!

```
** I.7. RESHAPE
```

```
use "$DATA/dataset_wide", clear
help reshape
reshape long deathrate, i(dep_id) j(year)
```

- Sometimes, you need to merge datasets (here: add rural).
- Learn how to use merge
- Never use m:m, always 1:m or 1:1 or 1:m.
- Always use assert for no surprise.
- Use keep as needed after having checked _merge.

 \implies Btw: use assert extensively for integrity tests.

```
use "$TEMP/dataset_temp", clear
merge 1:1 dep_id year using "$DATA/dataset_rural", assert(1 3)
fre dep_type if _merge == 1
drop if dep_type == 1
assert__merge == 3)
drop _merge
erase "$TEMP/dataset_temp.dta"
* alternative: merge 1:1 dep id year using "$DATA/dataset rural", assert(1 3) keep(3)
```

Coding Principles: Data Cleaning

- Looping over variables is useful.
- Use a foreach loop.
- In this example, I also preserve and restore the data.
- ** I.9. LOOPS

```
/* loop over variables and transform percent into shares */
preserve
foreach v of varlist flfp deathrate bindep rural {
   summarize 'v'
```

```
summarize 'v' = 'v' / 100
summarize 'v'
display "Now 'v' is a share"
}
restore
```

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```
** I.9. LOOPS
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• You can also loop over values: forvalues i = 1 / 10

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```
** I.9. LOOPS
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```
inteach v of variat filp deachate bindep fulat {
   replace 'v' = 'v' / 100
   summarize 'v'
   display "Now 'v' is a share"
   }
   restore
```

- You can also loop over values: forvalues i = 1 / 10
- Sometimes it is very useful to loop of all values of a variable.

```
levelsof year, local(years)
foreach y of local years {
  display 'y'
}
```

- Declare your panel structure using xtset unit time.
- Unit should be numeric. If string: encode.
- This will help with fixed effects regressions.

```
encode dep_id, generate(dep_id1)
order dep_id1, after(dep_id)
xtset dep_id1 year
```

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```

- Use locals to make code readable, e.g. for controls.
- No need for xi:... anymore: use operator i...
- Use i.categorical#c.continuous for interactions.
- If no need for FE estimates, absorb with reghdfe.

- Example from Boehnke and Gay (2022).
- Impact of WWI military fatalities on FLFP in France (1901–1936).
- Empirical strategy: difference-in-differences.

$$\texttt{FLFP}_{d,t} = \beta \texttt{ death_rate}_d \times \texttt{post}_t + \gamma_d + \delta_t + \varepsilon_{d,t}$$

- $post_t = indicator for t > 1918.$
- $\gamma_d = \text{department fixed effects.}$
- $\delta_t =$ year fixed effects.
- Standard errors clustered at département level.
- Censuses: 1901, 1906, 1911, 1921, 1926, 1931, 1936.

Victor Gay (UT1, TSE, IAST)

Reproductibility in Empirical Economics

- Many ways to run fixed-effects regressions:
 - regress
 - xtreg
 - areg
 - reghdfe
- All provide same point estimates.
- xtreg and reghdfe adjust s.e. when FE nested within clusters.

global controls "rural bindep"

regress flfp deathrate_post \$controls i.year i.dep_id, cluster(dep_id)
areg flfp deathrate_post \$controls i.year, a(dep_id) cluster(dep_id)
xtreg flfp deathrate_post \$controls i.year, fe cluster(dep_id)
reghdfe flfp deathrate_post \$controls i.year, absorb(dep_id) cluster(dep_id)
Coding Principles: Analysis

- Many ways to run fixed-effects regressions:
 - regress
 - xtreg
 - areg
 - reghdfe
- All provide same point estimates.
- xtreg and reghdfe adjust s.e. when FE nested within clusters.

global controls "rural bindep"

regress flfp deathrate_post \$controls i.year i.dep_id, cluster(dep_id)
areg flfp deathrate_post \$controls i.year, a(dep_id) cluster(dep_id)
xtreg flfp deathrate_post \$controls i.year, fe cluster(dep_id)
reghdfe flfp deathrate_post \$controls i.year, absorb(dep_id) cluster(dep_id)

- Generally: use xtreg.
- Prefer reghdfe if multi-way clustering and/or IV and/or many FE.

ssc install reghdfe
ssc install ftools

Victor Gay (UT1, TSE, IAST)

- Always cluster at some appropriate level.
- reghdfe allows easy adjustments.
- For a difference-in-differences, cluster over time and space.

```
reghdfe flfp deathrate_post 'controls' i.year, absorb(dep_id) cluster(year)
reghdfe flfp deathrate_post 'controls' i.year, absorb(dep_id) cluster(dep_id year)
```

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- For a difference-in-differences, cluster over time and space.

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reghdfe flfp deathrate_post 'controls' i.year, absorb(dep_id) cluster(dep_id year)
```

- Export results using estab or estout.
- Alternative: use parmest to create datasets of estimates, then construct your personalized Latex table in your .do file.

Documenting

• Document so that your work can be reproduced by others.

- Write enough details in the main text.
- Put exact details in appendix.
- Exact procedures are in the code.
- Some necessary elements:
 - Data sources (be exact).
 - Sample selection procedures.
 - Data transformations.

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- If not transparent from text, write it down e.g. $H_1: \overline{X} \neq 0$.

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- What is the hypothesis you want to test?
- If not transparent from text, write it down e.g. $H_1: \overline{X} \neq 0$.
- What is your design?
- What is your exogenous source of identifying variation?
- What is the identifying assumption?
- If proper design, no need for controls except those determinant for assignment to treatment.
- Therefore: no specification search or *p*-hacking!
- Only show coefficients of interest.

- Always interpret the estimates.
- What do they say exactly?
- What about their magnitude? Think in terms of means and/or standard deviations of your outcome and treatment.
- Is it large? Useful to use Cohen's d.
 - Relative size of coefficient relative to sample standard deviation in treatment, normalize by sample standard deviation in outcome.

•
$$\widehat{\beta} \times \frac{\widehat{\sigma}_{\chi}}{\widehat{\sigma}_{\chi}}$$

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 - List of all subfolders and their content.
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 - Order in which compile (e.g. data then analysis).

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- Paper
- Appendix with details on robustness and data:
 - Data sources.
 - Transformation of raw data.
 - Variables definitions.
 - Example: see data appendix of Boehnke and Gay (2022)

- Raw data.
- Code to go from raw to final data (in 1 click!).
- Code to run the analysis (in 1 click!).
- The only variable element is the directory and globals.