Dissertation Workshop: Panel Data

Philipp Broniecki

University College London

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Research Question

Rentier States and the Resource Curse

Rentier capitalism on a systemic level may be a curse. The theory is that states that extract rents from easily lootable resources instead of taxing their people develop institutions that become unresponsive to their citizens and provide less public goods. It's: "no representation without taxation".

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Rentier capitalism on a systemic level may be a curse. The theory is that states that extract rents from easily lootable resources instead of taxing their people develop institutions that become unresponsive to their citizens and provide less public goods. It's: "no representation without taxation".

- $H1$: Oil rents lead to worse institutional quality
- $H2$: Foreign aid leads to worse institutional quality

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- To answer our research question, we need to observe institutional quality, oil rents, foreign aid, and possible confounders
- What could be confounding factors?
  - Colonial Heritage
  - Culture
  - Wealth
- With panel data we can reduce the problem of omitted variable bias in observational data without actually observing some of the confounders

Panel Data Structure

Time-Series & Cross-Section (Panel)

If we observe multiple "subjects" at multiple points in in time, we call this a time-series cross-section.

	country	year	institutions	oil	aid
32	Argentina	2006	-0.18904536	466	2.586741
33	Argentina	2007	-0.19333504	423	2.482334
34	Argentina	2008	-0.29212948	427	2.977121
128	Brazil	2006	-0.09034931	365	1.724852
129	Brazil	2007	-0.08698201	300	2.531870
130	Brazil	2008	-0.01245712	361	2.726142
176	Colombia	2006	-0.42296874	474	4.089946
177	Colombia	2007	-0.39988048	433	4.358290
178	Colombia	2008	-0.40020383	482	4.342707

Before and After Comparison 2006 - 2008

$$\text{institutions}_{\mathrm{i,t}} = \beta_0 + \beta_1 \text{oil}_{i,t} + \beta_{2 \cdots p} \underbrace{Z_i}_{\textit{confounders}} + u_{i,t}$$

- where i indexes countries and t indexes time. Note that Z is time invariant because it does not have the subscript t
- To compare 2006 and 2008, we can look at the years separately

$$\text{institutions}_{i,2006} = \beta_0 + \beta_1 \text{oil}_{i,2006} + \beta_{2 \cdots p} Z_i + u_{i,2006} \tag{1}$$

$$\text{institutions}_{i,2008} = \beta_0 + \beta_1 \text{oil}_{i,2008} + \beta_{2 \cdots p} Z_i + u_{i,2008} \tag{2}$$

Before and After Comparison 2006 - 2008 II

- We can look at the change in the dependent variable by combining equations (1) and (2)

$$\text{institutions}_{i,2008} - \text{institutions}_{i,2006} = \beta_1(\text{oil}_{i,2008} - \text{oil}_{i,2006}) + u_{i,2008} - u_{i,2006}$$

- If Z does not change between 2006 and 2008, then the change in institutional quality must be due to other sources (i.e., oil and other factors that change between 2006 and 2008)
- By looking at change in the dependent variable over time we can eliminate confounders that are constant over time
- Before and after works for 2 time periods, for more time periods we need fixed effects

Confounders we Controlled for

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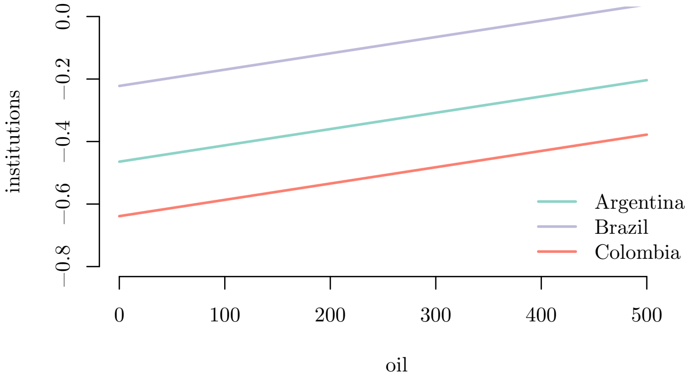
  - Colonial heritage? yes b/c it's constant over time
  - Culture? yes, it's constant over time (2006-2008)
  - Wealth? no, it fluctuates
- The longer the time difference, the less likely a variable remains constant
  - If it remains mostly constant, we control for much of its potential for confounding but not all

Effect of Differences Between Countries

- Z_i shifts the intercept but does not affect the slope



Fixed Effects Model

The basic fixed effects model

- FE is an extension of before-after for multiple time periods
- Its key advantage is that it enables us to control for all variables that vary across the cross-sectional units but are constant over time
  - Later we will see that we can also control for all variables that are constant across the units but vary over time
- It works when we have more than 2 observations per unit (e.g. Colombia, Argentina, and Brazil in 2006, 2007, and 2008)

Example: The Resource Curse

We will use our dataset on institutional quality. We use the following variables:

- *country* - country name
- *countrycode* - 3 letter country abbreviation
- *year*
- *aid* - net aid flow (% of GDP)
- *oil* - oil rents (% of GDP)
- *gdp.captia* - GDP per capita in constant 2000 US dollars
- *institutions* - world governance indicator index quality of institutions
- *polity2* - polity IV project index
- *population*
- *mortality* - rate (per 1000 live births)

The Institutional Quality Data

country	countrycode	year	aid	oil	gdp.capita	institutions	polity2	population	mortality
Afghanistan	AFG	1996	NA	NA	NA	-2.05886922	-7	17822884	105.6
Afghanistan	AFG	1998	NA	NA	NA	-2.09382143	-7	18863999	104.4
Afghanistan	AFG	2000	NA	NA	NA	-2.13289406	-7	20093756	104.2
Albania	ALB	1996	2.99015884	228	990.6532	-0.74621956	0	3168033	29.8
Albania	ALB	1998	1.65008065	129	1013.5143	-0.69075046	5	3128530	27.4
Albania	ALB	2000	3.87886086	218	1200.1374	-0.67570053	5	3089027	25.3
Albania	ALB	2002	3.03413506	187	1313.7227	-0.52489904	7	3051010	23.2
Albania	ALB	2003	3.14979054	185	1381.0408	-0.49836806	7	3039616	22.4
Albania	ALB	2004	4.57214198	173	1454.0229	-0.43238917	7	3026939	21.4
Albania	ALB	2005	3.13352262	208	1525.7236	-0.50894637	9	3011487	20.3
Albania	ALB	2006	3.56152310	250	1594.4951	-0.43504972	9	2992547	19.6
Albania	ALB	2007	6.18683777	215	1681.6139	-0.31232086	9	2970017	18.7
Albania	ALB	2008	7.39089006	236	1804.4194	-0.20589812	9	2947314	17.8
Albania	ALB	2009	7.95993176	197	1857.3529	-0.15141251	9	2927519	17.2
Albania	ALB	2010	9.35686981	277	1915.4245	-0.16648078	9	2913021	16.4
Argentina	ARG	1996	2.55320333	255	7484.0040	0.19092135	7	35419682	19.6
Argentina	ARG	1998	2.43876805	168	8205.4746	0.13740844	7	36241590	18.4

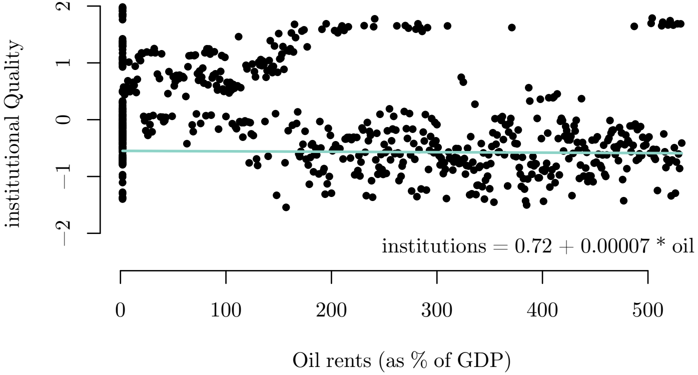
Assumptions of the fixed effects model

- The fixed effects model assumes that the true relationship is:

$$\text{institutions}_{i,t} = \beta_0 + \beta_1 \text{oil}_{i,t} + \beta_2 \text{aid}_{i,t} + \beta_{3 \cdots p} Z_i + u_{i,t} \qquad (3)$$

  where i is the country and t is the year
- Z_i does not have a time index and is therefore assumed to be constant over time
- Z_i could include, e.g., colonial heritage and culture in country i
  - In practice, the Z_i's are country dummies that soak up all the differences between countries like colonial heritage and culture

The Effect of Oil Rents on the Quality of Institutions



Assumptions of the fixed effects model

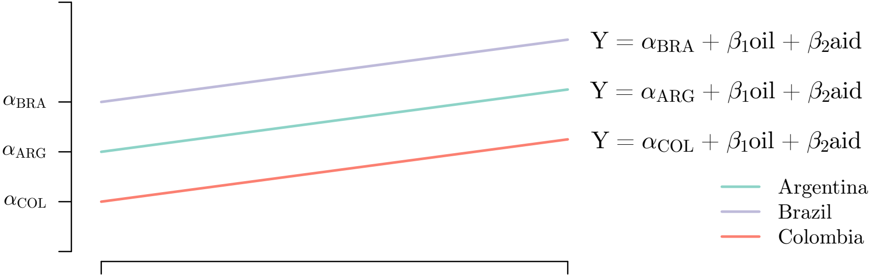
- If we define $\alpha_i = \beta_0 + \beta_{3 \dots p} Z_i$, then (3) simplifies to

$$y_{i,t} = \alpha_i + \beta_1 \mathrm{oil}_{i,t} + \beta_2 \mathrm{aid}_{i,t} + u_{i,t} \quad (4)$$

- The graphical interpretation of α_i is that it is the intercept of the relationship between oil rents and institutional quality in country i.
- If Z_i includes multiple variables (or is a country dummy), the intercepts α_i reflect the combined effect of several variables which are constant over time.

Regression Lines for 3 Countries

- X = oil (on the x-axis); Y = quality of institutions (on the y-axis)



Fixed Effects Model in R

```
# load plm library
library(plm)

# run fixed effects model
m3 <- plm(institutions ~ oil + aid + log.gdp +
            polity2 + log.pop + mortality,
          data = a,
          index = c("country", "year"),
          model = "within",
          effect = "individual")
```

Model Output if we Call: summary(m3)

```
Oneway (individual) effect Within Model

Call:
plm(formula = institutions ~ oil + aid + log.gdp + polity2 +
    log.pop + mortality, data = a, effect = "individual",
    model = "within", index = c("country", "year"))

Unbalanced Panel: n = 58, T = 1-12, N = 672

Residuals:
      Min.    1st Qu.     Median    3rd Qu.       Max.
-0.3936224 -0.0622048 -0.0019414  0.0580157  0.3903817

Coefficients:
             Estimate  Std. Error t-value  Pr(>|t|)
oil       -7.7706e-05  9.2452e-05 -0.8405  0.400961
aid        2.2502e-03  9.8040e-04  2.2951  0.022065 *
log.gdp    1.9083e-01  3.2397e-02  5.8905 6.374e-09 ***
polity2    1.6004e-02  2.7079e-03  5.9102 5.696e-09 ***
log.pop   -1.9049e-01  7.0708e-02 -2.6941  0.007253 **
mortality  8.2944e-03  1.5538e-03  5.3380 1.329e-07 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Total Sum of Squares:    8.8269
Residual Sum of Squares: 7.3822
R-Squared:      0.16367
Adj. R-Squared: 0.077009
F-statistic: 19.8307 on 6 and 608 DF, p-value: < 2.22e-16
```

A basic test of assumptions after FE estimation

- We can test for presence of individual (panel) effects:
  - H_0: unit fixed effects make no difference
  - H_A: there are differences between the countries

```
> # check for unit(country) fixed effects
> plmtest(m3, effect="individual")

Lagrange Multiplier Test - (Honda) for unbalanced panels

data:  institutions ~ oil + aid + log.gdp + polity2 + log.pop + mortality
normal = 53.332, p-value < 2.2e-16
alternative hypothesis: significant effects
```

Advantages and disadvantages of the fixed effects model

- The key advantage of the fixed effects model is that it allows us to control for all time invariant omitted variables.
- This is particularly important in the case of variables which are difficult or impossible to observe.
- The key disadvantage is that we have to estimate a number of additional parameters.
- Furthermore, it will be impossible to estimate the effect of variables which do not (or hardly) vary over time.

Time fixed effects

- The basic fixed effects model only prevents omitted variable bias from variables that do not change over time
- However, panel data allow us to control also for omitted variable bias from one other type of omitted variable
- In our resource curse example, the global oil price could fall over time and this trend could be correlated with institutional quality
- At the same time the oil price is global (i.e. does not vary across countries)

The Time Fixed Effect Model

```
# time fixed effects model
m4 <-  plm(institutions ~ oil + aid + log.gdp +
             polity2 + log.pop + mortality,
           data = a,
           index = c("country", "year"),
           model = "within",
           effect = "time")
```

Model Output Time Fixed Effects

```
Oneway (time) effect Within Model

Call:
plm(formula = institutions ~ oil + aid + log.gdp + polity2 +
    log.pop + mortality, data = a, effect = "time", model = "within",
    index = c("country", "year"))

Unbalanced Panel: n = 58, T = 1-12, N = 672

Residuals:
     Min.   1st Qu.    Median   3rd Qu.      Max.
-1.196568 -0.282023 -0.028316  0.291527  0.865248

Coefficients:
             Estimate  Std. Error t-value  Pr(>|t|)
oil       -0.00094474  0.00010632 -8.8855 < 2.2e-16 ***
aid        0.01147113  0.00307715  3.7278 0.0002099 ***
log.gdp    0.45007149  0.01913597 23.5197 < 2.2e-16 ***
polity2    0.03248425  0.00280650 11.5746 < 2.2e-16 ***
log.pop   -0.01333510  0.01052619 -1.2668 0.2056601
mortality  0.00360009  0.00119458  3.0137 0.0026806 **
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Total Sum of Squares:    457.29
Residual Sum of Squares: 106.31
R-Squared:      0.76752
Adj. R-Squared: 0.76148
F-statistic: 359.866 on 6 and 654 DF, p-value: < 2.22e-16
```

Test for Time Fixed Effects

- H_0: time fixed effects make no difference

```
> # test for time fixed effects
> plmtest(m4, effect="time")

Lagrange Multiplier Test - time effects (Honda) for unbalanced panels

data:  institutions ~ oil + aid + log.gdp + polity2 + log.pop + mortality
normal = 1.5508, p-value = 0.06048
alternative hypothesis: significant effects
```

Time and state fixed effects

- In most applications we use both state and time fixed effects at the same time.
- This model is sometimes referred to as the “twoway fixed effects” model.
- In the literature the cross-sectional fixed effects are referred to as “fixed effects”, “state (fixed) effects”, “firm (fixed) effects” or “person (fixed) effects”.
- Similarly, time fixed effects are often referred to as “time effects”.

Two-way fixed effects in R

```
# two-way fixed effects model
m5 <-  plm(institutions ~ oil + aid + log.gdp +
             polity2 + log.pop + mortality,
           data = a,
           index = c("country", "year"),
           model = "within",
           effect = "twoways")
```

Random Effects Model

Random effects

- An alternative to the model with fixed effects is the so called random effects model.
- This approach also assumes that the true relationship is

$$y_{i,t} = \beta_0 + \beta_1 x_{i,t} + \beta_2 z_i + u_{i,t} \tag{5}$$

- However, in contrast to the fixed effects model, it is assumed that the variable z_i is uncorrelated with $x_{i,t}$ and can therefore safely be included in the error term.

Random effects model R code

```
m6 <-  plm(institutions ~ oil + aid + log.gdp +
             polity2 + log.pop + mortality,
           data = a,
           index = c("country", "year"),
           model = "random")
```

Random effects model output part I

```
Call:
plm(formula = institutions ~ oil + aid + log.gdp + polity2 +
    log.pop + mortality, data = a, model = "random", index = c("country",
    "year"))

Unbalanced Panel: n = 58, T = 1-12, N = 672

Effects:
                  var std.dev share
idiosyncratic 0.01214 0.11019 0.071
individual    0.15870 0.39837 0.929
theta:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.7334  0.9204  0.9204  0.9194  0.9204  0.9204

Residuals:
    Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
-0.42270 -0.06989 -0.00032  0.00070  0.08034  0.37430
```

Random effects model output part II

```
Coefficients:
              Estimate  Std. Error t-value  Pr(>|t|)
(Intercept) -1.33884120  0.62959170 -2.1265  0.033827 *
oil         -0.00021206  0.00009369 -2.2634  0.023933 *
aid          0.00206725  0.00103411  1.9991  0.046009 *
log.gdp      0.31213762  0.02902202 10.7552 < 2.2e-16 ***
polity2      0.01942826  0.00273234  7.1105 2.994e-12 ***
log.pop     -0.09216364  0.03199441 -2.8806  0.004097 **
mortality    0.01026414  0.00129407  7.9317 9.172e-15 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Total Sum of Squares:    11.862
Residual Sum of Squares: 9.0511
R-Squared:      0.23701
Adj. R-Squared: 0.23013
F-statistic: 34.4236 on 6 and 665 DF, p-value: < 2.22e-16
```

Choosing between FE and RE

- We can use the Hausman Test to choose between FE and RE estimation.
- H_0 of this test is that the preferred model is random effects and H_1 the fixed effects.
- The test assesses whether the unique errors (u_i) are correlated with the regressors, where under the null hypothesis they are not.

```
> phtest(m5, m6)

Hausman Test

data:  institutions ~ oil + aid + log.gdp + polity2 + log.pop + mortality
chisq = 1408.1, df = 6, p-value < 2.2e-16
alternative hypothesis: one model is inconsistent
```

Random effects

- Unfortunately, the assumption that z_i and $x_{i,t}$ are uncorrelated is usually entirely implausible. Even if the Hausman test tells us otherwise.
  - Hausman test does not take time effects into account
  - Hausman test assumes homoskedastic errors
- Particularly if we care about linear regression Assumption 1.
- For this reason Stock and Watson do not even discuss this approach.
- However, other textbooks may discuss the random effects model.

Violations of Assumption 2 in Panel Data: Serial correlation

Assumption 2 in panel data

- Panel data is characterized by time dependency for each panel unit.
- This is a violation of the regression Assumption 2 (X and Y are i.i.d).
- Time dependency is often described as autocorrelation or serial correlation.
- The main approach to deal with serial correlation is by adjusting standard errors to take into account autocorrelation.

Serial correlation in the error term

- If there is substantial autocorrelation (serial correlation) in the error term, even heteroskedasticity-robust standard errors will be inconsistent.
- In panel data as in any other time series data, autocorrelation can be a very serious concern.

Choosing between FE and RE

- We can test for serial correlation after our fixed effects estimation using the Breusch-Godfrey test.
- The null hypothesis in this test is that the autocorrelation of the error term is 0.

```
> # Breusch-Godfrey test
> pbgtest(m5)

Breusch-Godfrey/Wooldridge test for serial correlation in panel models

data:  institutions ~ oil + aid + log.gdp + polity2 + log.pop + mortality
chisq = 513.77, df = 1, p-value < 2.2e-16
alternative hypothesis: serial correlation in idiosyncratic errors
```

Clustered standard error

- A popular solution to the problem of autocorrelation in the error term are clustered standard errors, aka heteroskedasticity and autocorrelation consistent (HAC) standard errors.
- Such standard errors assume no correlation between errors of different groups while allowing for heteroskedasticity across groups.
- For the *intragroup* error structure the assumption is that there is a general form of heteroskedasticity and autocorrelation.
- In panel data models with fixed effects HAC standard errors are calculated using the so called "arellano" method, suggested in Arellano (1987).

Clustered Standard Errors R Code (HAC)

```
> # heteroskedasticity and autocorrelation consistent standard errors
> library(sandwich)
> library(lmtest)
>
> m5.hac <- coeftest(m5, vcov = vcovHC(m5, method = "arellano", type = "HC3"))
> m5.hac

t test of coefficients:

             Estimate  Std. Error t value  Pr(>|t|)
oil       -0.00094474  0.00034260 -2.7575  0.005987 **
aid        0.01147113  0.00431615  2.6577  0.008059 **
log.gdp    0.45007149  0.04881216  9.2205 < 2.2e-16 ***
polity2    0.03248425  0.00698752  4.6489 4.038e-06 ***
log.pop   -0.01333510  0.02931157 -0.4549  0.649301
mortality  0.00360009  0.00267661  1.3450  0.179085
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1
```

Cross-Sectional Dependence

Cross-sectional dependence

- Cross-sectional dependence in panels may arise when e.g. countries respond to common shocks or if spatial diffusion processes are present (think the 1973 OPEC oil embargo, the Arab Spring, or shocks from the financial crisis).
- If cross-sectional dependence is present, this results, at least, in the inefficiency of the estimators and invalid inference when using standard estimation techniques.
- This is another instance of the violation of regression Assumption 2.

- We can test for cross-sectional dependence.
- If we assume that our earlier two-way fixed effects model specification is consistent, then we can test for residual cross-sectional dependence after the introduction of two-way fixed effects to account for common shocks.

```
> # Peasaran test for cross-sectional dependence
> pcdtest(m5)

Pesaran CD test for cross-sectional dependence in panels

data:  institutions ~ oil + aid + log.gdp + polity2 + log.pop + mortality
z = -2.2306, p-value = 0.02571
alternative hypothesis: cross-sectional dependence
```

Panel-corrected standard errors

Panel-corrected standard errors (Beck and Katz 1995)

1. panel heteroskedasticity: each country may have its own error variance
2. contemporaneous correlation of the errors: the error for one country may be correlated with the errors for other countries in the same year

- serially correlated errors: the errors for a given country are correlated with previous errors for that country

```
> # Beck and Katz Standard Errors
> m5.pcse <- coeftest(m5, vcov = vcovBK(m5, type = "HC3", cluster = "group"))
> m5.pcse

t test of coefficients:

             Estimate  Std. Error t value  Pr(>|t|)
oil       -0.00094474  0.00033008 -2.8621 0.0043429 **
aid        0.01147113  0.00536106  2.1397 0.0327473 *
log.gdp    0.45007149  0.06067917  7.4172 3.724e-13 ***
polity2    0.03248425  0.00866545  3.7487 0.0001935 ***
log.pop   -0.01333510  0.03392206 -0.3931 0.6943664
mortality  0.00360009  0.00379364  0.9490 0.3429802
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1
```

General approach to correlation between panels

- Driscoll and Kraay (1998) propose an estimator producing heteroskedasticity- and autocorrelation- consistent standard errors that are robust to general forms of spatial and temporal dependence. Often known as the SCC estimator.
- Panel Corrected Standard Errors (PCSE), while popular in political science, may not work well with shorter panels with large N (ratio of T/N is small).
- SCC estimator performs equally well in large N settings.

```
> # Driscoll and Kraay SCC standard errors
> m5.scc <- coeftest(m5, vcov = vcovSCC(m5, type = "HC3", cluster = "group"))
> m5.scc

t test of coefficients:

            Estimate  Std. Error t value  Pr(>|t|)
oil       -0.00094474  0.00034649 -2.7266  0.006571 **
aid        0.01147113  0.00421341  2.7225  0.006651 **
log.gdp    0.45007149  0.04894368  9.1957 < 2.2e-16 ***
polity2    0.03248425  0.00684752  4.7439 2.575e-06 ***
log.pop   -0.01333510  0.02865664 -0.4653  0.641842
mortality  0.00360009  0.00256795  1.4019  0.161410
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1
```

Putting it all together

```
# all models
library(texreg)
screenreg(list(m3,m4,m5,m5.hac,m5.pcse,m5.scc),
        custom.model.names = c("Unit FE", "Time FE", "Twoway FE",
                               "Twoway HAC", "Twoway PCSE", "Twoway SCC"))
==================================================================================
           Unit FE     Time FE     Twoway FE   Twoway HAC  Twoway PCSE  Twoway SCC
----------------------------------------------------------------------------------
oil         -0.00       -0.00 ***    0.00       -0.00 **    -0.00 **     -0.00 **
            (0.00)      (0.00)      (0.00)      (0.00)      (0.00)       (0.00)
aid          0.00 *      0.01 ***    0.00 **     0.01 **     0.01 *       0.01 **
            (0.00)      (0.00)      (0.00)      (0.00)      (0.01)       (0.00)
log.gdp      0.19 ***    0.45 ***    0.30 ***    0.45 ***    0.45 ***     0.45 ***
            (0.03)      (0.02)      (0.04)      (0.05)      (0.06)       (0.05)
polity2      0.02 ***    0.03 ***    0.02 ***    0.03 ***    0.03 ***     0.03 ***
            (0.00)      (0.00)      (0.00)      (0.01)      (0.01)       (0.01)
log.pop     -0.19 **    -0.01        0.02       -0.01       -0.01        -0.01
            (0.07)      (0.01)      (0.08)      (0.03)      (0.03)       (0.03)
mortality    0.01 ***    0.00 **     0.00 *      0.00        0.00         0.00
            (0.00)      (0.00)      (0.00)      (0.00)      (0.00)       (0.00)
----------------------------------------------------------------------------------
R^2          0.16        0.77        0.17
Adj. R^2     0.08        0.76        0.06
Num. obs.  672         672         672
==================================================================================
*** p < 0.001, ** p < 0.01, * p < 0.05
```

Your roadmap with panel data

1. Is it a fixed effects or random effects model?
   - Hausman test. But primarily the choice should be driven by theory!
   - If FE: it is not a mistake to estimate twoway FE but:
     - You can test for the presence of unit FEs and time FEs
2. Use robust standard errors, start with HAC.
3. Check whether there is any cross-sectional dependence:
   - If not, you can stick to HAC.
   - If you have cross-sectional dependence, you need to use PCSE or SCC (recommendation use SCC (although less common in polisci)).