Gravity in Stata: a short workshop

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This page is dedicated to teach students on running the gravity model in Stata. We uses dataset from CEPII, specifically BACI and the gravity dataset. We rely on ppmlhdfe when demonstrating PPML. We try to replicate Silva and Tenreyro (2006), an excellent paper for an introduction to the log gravity model and PPML.

For the latest version click here.

Introduction

The gravity model is probably the most popular model in international trade. Many uses them. It is very intuitive, great predictive power, and most importantly, tweakable (Yotov 2022). But the even most important is that UI students love them. If you're doing trade for your thesis, then you probably going to use the gravity model as your backbone.

This guide is my attempt to help you learn gravity model much easier. The most important part is probably the data and the model itself. What is the minimum things you need in the gravity model, how to arrange the database, run them, and interpret them. You must familiarize yourself with the data and its wrangling (80% of your coding) as well as the main gravity specification to date. I encourage students to pay careful attention to Yotov (2022) as it hosts the recent development in the gravity model, a must read if you're planning to utilize gravity model.

I use Stata here because most economists I know are still using Stata. I myself quite often do R these days. However, the two language aren't very different. You can do the same thing on both, but you may need to google a bit. It's okay to use google a lot. I did as well even right now.

Oh yeah I also informed you guys know Stata already so I won't go into too much basic stuff. For example, you probably already know the function `gen` and `egen`, also `import` and `cd`. Some I will repeat but won't discuss too much. Also, you'd want to learn how to use `outreg2`, a package to save regression results.

By the way, for the R version of gravity, you can consult to this page.

Data

I procure data for this workshop from CEPII. From their website, CEPII is:

> The CEPII is the leading French center for research and expertise on the world economy. It contributes to the policy making process trough its independent in-depth analyses on international trade, migrations, macroeconomics and finance. The CEPII also produces databases and provides a platform for debate among academics, experts, practitioners, decision makers and other private and public stakeholders. Founded in 1978, the CEPII is part of the network coordinated by France Strategy, within the Prime Minister's services.

I use their BACI dataset (Gaulier and Zignago 2010) and gravity dataset (Conte, Cotterlaz, and Mayer 2022). You can get those from this link. BACI is under "international trade" banner while gravity is under "Gravity" banner. Specifically, I downloaded the 2017-2022 version of BACI and for the gravity dataset I downloaded the R version. You can of course download whichever version you like but for the purpose of this workshop maybe its best to stick with the same dataset as I.

You can also download from my drive.

Note that the data here is **extremely large** in size so be mindful. You need hefty internet quota and reasonable speed. Also, you can try opening it with spreadsheet software but unless you have a strong computer, i'd advice against it. Use R instead.

In the CEPII website you can use various other dataset that may be useful for you. At the same time, there are various other source you can utilise for your actual project that's not necessarily from CEPII.

working directory

If you finished downloading data and installing softwares, you then need to set up a working directory. A working directory is basically a folder where you have all the data and your do file. For now what you want is to have a **folder filled with your downloaded data**. Make sure you know the path to this folder. I tend to use easy path for my projects and move it somewhere else when I finished. If you use github or the likes, it'll be even nicer because you can actually wipe out your local repo when you're done.

All in all, you should have a folder with these stuff in it:

BACI_HS17_Y2017_V202401b	16/05/2024 2:50 PM	Microsoft Excel Co...	463,663 KB
BACI_HS17_Y2018_V202401b	16/05/2024 2:50 PM	Microsoft Excel Co...	503,136 KB
BACI_HS17_Y2019_V202401b	16/05/2024 2:50 PM	Microsoft Excel Co...	521,064 KB
BACI_HS17_Y2020_V202401b	16/05/2024 2:50 PM	Microsoft Excel Co...	510,148 KB
BACI_HS17_Y2021_V202401b	16/05/2024 2:50 PM	Microsoft Excel Co...	536,717 KB
BACI_HS17_Y2022_V202401b	16/05/2024 2:51 PM	Microsoft Excel Co...	529,356 KB
country_codes_V202401b	16/05/2024 2:51 PM	Microsoft Excel Co...	6 KB
Gravity_V202211.rds	16/05/2024 2:50 PM	RDS File	128,696 KB
product_codes_HS17_V202401b	16/05/2024 2:51 PM	Microsoft Excel Co...	585 KB
Readme	16/05/2024 2:51 PM	Text Document	1 KB

Notes about the data country_codes, product_codes and Readme are all for reading BACI. Moreover, you wont need Gravity_V202211.rds because it's an R file. Take the dta one.

Simple gravity specification

Theory

The earliest (e.g., naive) gravity model taking directly from Newtonian gravity theory looks something like this:

$$X_{ij} = \tilde{G}\frac{Y_i E_j}{T_{ij}^{\theta}} \tag{0.1}$$

where X_{it} is the value of trade flow from country i to country j, $\tilde{G}$ is the gravitational constant (aka our usual constant), Y_i is the output in country i E_j is the value of expenditure in country j and T_{ij} is the total bilateral trade frictions / trade cost between country i and country j.

There are various other types of gravity equations, but let's start with a relatively simple one. One of my favorite simple gravity specification is a budget version of Silva and Tenreyro (2006) which is taken from Anderson and Wincoop (2003) which looks like this:

$$X_{ij} = \alpha_0 Y_i^{\alpha_1} Y_j^{\alpha_2} D_{ij}^{\alpha_3} e^{\theta_i d_i + \theta_j d_j} \tag{0.2}$$

where α_0 is your $\tilde{G}$, while Y is the output and expenditure which is proxied with GDP. D_{ij} is the distance between the two countries, which can be generalized as a vector of trade cost measures. Typically we use physical distance but also other types of bilateral trade cost. Lastly, the d_i and d_j is country-specific characteristics.

There are various variables used in Silva and Tenreyro (2006). log of exporter's and importer's GDP and GDP per capita. Various "distance" variables is used as well e.g., physical distance and variables like contiguity, common-language dummy, colonial-tie dummy and free trade agreement dummy.

Note that our regression consists only of two indices: exporter i and importer j. We are going to use the gravity data I mentioned earlier, slice the dataset to cover only one year chosen arbitrarily (which is 2019), and run Equation 0.2.

Setting data

First of all, let me share you my typical routine at the top:

```
// preambule
clear all
set more off
cd C:\github\statagravity
```

Change the working directory after cd with your own working directory. sometimes I set logs but sometimes I am too lazy. Anyway, the next is to read our gravity dataset. First of all, we want to filter countries to match Silva and Tenreyro (2006). First we read our country key, then we use it to filter out the gravity data so we only have those countries.

```
\\ read data
use Countries_V202211,clear
keep if country=="Albania" | country == "Denmark" | country == "Kenya" | country == "Roman

//// There's certainly a better way to do the above. maybe next time.

/// we need to select destination and origin in two step

gen iso3_o=iso3 // select origin countries

save ctr,replace
clear all
use Gravity_V202211,clear
merge m:1 iso3_o using ctr
keep if _merge==3
drop _merge

save grav,replace

clear all
use ctr,clear

rename iso3_o iso3_d  // now select destination country
save ctr,replace
clear all
use grav,clear
merge m:1 iso3_d using ctr
keep if _merge==3
drop _merge

save grav,replace
```

The above is preparation for the gravity dataset we're doing. It is complicated but I put comments to help. This kind of manipulation would be what you will do a lot.

The first thing to do is `sum` your data to see what variables you have and its descriptive statistics. Descriptive statistics helps with visualizing the overall data in your head, and typically a must-do when you write your thesis. Some put it in chapter 3, some in 4. You can use `ds` if you'd like to see variable names.

If you ran either `sum` or `ds`, you will see that the column names are so plenty. Consult to the CEPII website or Conte, Cotterlaz, and Mayer (2022) to learn more. We will only use some of them, so we will filter these data to make it more concise. Specifically, we will (1) remove some countries, (2) remove non-2019, and (3) remove variables we are not using.

For variables, we will keep iso3_o, iso3_d, distw_harmonic, contig, comcol, comlang_off,gdp_o,gdp_d, gdpcap_o, gdpcap_d,fta_wto. Note that o means origin / exporter and d means destination / importer. We then add log version of variables.

```
/// Now we keep variable we need

keep iso3num_o iso3num_d year iso3_o iso3_d distw_harmonic contig comcol comlang_off gdp_o

/// add log version

gen ldist=log(distw_harmonic)
gen lgdpo=log(gdp_o)
gen lgdpd=log(gdp_d)
gen lgdpco=log(gdpcap_o)
gen lgdpcd=log(gdpcap_d)
gen logtrade=log(1+tradeflow_baci)

save grav,replace
```

you can quickly `sum` our new grav.

Regression

Let's do 2 types of regression. First we do a regression using a normal ols, and secondly we do ppml.

```
// regression
/// generate factor variable first
encode iso3_d,generate(iiso3_d)
encode iso3_o,generate(iiso3_o)
/// we keep 1 year for now, you can experiment later
keep if year==2019
reg logtrade lgdpo lgdpd lgdpco lgdpcd ldist contig comcol comlang_off fta_wto
outreg2 using myreg.doc, replace label ctitle(OLS) title(Table XX: my amazing regression)
reg logtrade lgdpo lgdpd lgdpco lgdpcd ldist contig comcol comlang_off fta_wto iiso3_d iis
outreg2 using myreg.doc, append label ctitle(FE)
ppmlhdfe logtrade lgdpo lgdpd lgdpco lgdpcd ldist contig comcol comlang_off fta_wto
outreg2 using myreg.doc, append label ctitle(PPML)
ppmlhdfe logtrade lgdpo lgdpd lgdpco lgdpcd ldist contig comcol comlang_off fta_wto,absorb
outreg2 using myreg.doc, append label ctitle(PPML FE)
```

Results are saved in your working directory as myreg.doc. It should look like this:

You can compare results with Silva and Tenreyro (2006). Note that they don't use fixed effects. Remember, PPML interpretation is percent change for logged independent variable and e^{β} magnitude (around $\beta \times 100\%$) for level independent variable.

TABLE 3.—THE TRADITIONAL GRAVITY EQUATION

Estimator: Dependent Variable:	OLS $\ln(T_{ij})$	OLS $\ln(1 + T_{ij})$	Tobit $\ln(a + T_{ij})$	NLS T_{ij}	PPML $T_{ij} > 0$	PPML T_{ij}
Log exporter's GDP	0.938**	1.128**	1.058**	0.738**	0.721**	0.733**
	(0.012)	(0.011)	(0.012)	(0.038)	(0.027)	(0.027)
Log importer's GDP	0.798**	0.866**	0.847**	0.862**	0.732**	0.741**
	(0.012)	(0.012)	(0.011)	(0.041)	(0.028)	(0.027)
Log exporter's GDP per capita	0.207**	0.277**	0.227**	0.396**	0.154**	0.157**
	(0.017)	(0.018)	(0.015)	(0.116)	(0.053)	(0.053)
Log importer's GDP per capita	0.106**	0.217**	0.178**	−0.033	0.133**	0.135**
	(0.018)	(0.018)	(0.015)	(0.062)	(0.044)	(0.045)
Log distance	−1.166**	−1.151**	−1.160**	−0.924**	−0.776**	−0.784**
	(0.034)	(0.040)	(0.034)	(0.072)	(0.055)	(0.055)
Contiguity dummy	0.314*	−0.241	−0.225	−0.081	0.202	0.193
	(0.127)	(0.201)	(0.152)	(0.100)	(0.105)	(0.104)
Common-language dummy	0.678**	0.742**	0.759**	0.689**	0.752**	0.746**
	(0.067)	(0.067)	(0.060)	(0.085)	(0.134)	(0.135)
Colonial-tie dummy	0.397**	0.392**	0.416**	0.036	0.019	0.024
	(0.070)	(0.070)	(0.063)	(0.125)	(0.150)	(0.150)
Landlocked-exporter dummy	−0.062	0.106*	−0.038	−1.367**	−0.873**	−0.864**
	(0.062)	(0.054)	(0.052)	(0.202)	(0.157)	(0.157)
Landlocked-importer dummy	−0.665**	−0.278**	−0.479**	−0.471**	−0.704**	−0.697**
	(0.060)	(0.055)	(0.051)	(0.184)	(0.141)	(0.141)
Exporter's remoteness	0.467**	0.526**	0.563**	1.188**	0.647**	0.660**
	(0.079)	(0.087)	(0.068)	(0.182)	(0.135)	(0.134)
Importer's remoteness	−0.205*	−0.109	−0.032	1.010**	0.549**	0.561**
	(0.085)	(0.091)	(0.073)	(0.154)	(0.120)	(0.118)
Free-trade agreement dummy	0.491**	1.289**	0.729**	0.443**	0.179*	0.181*
	(0.097)	(0.124)	(0.103)	(0.109)	(0.090)	(0.088)
Openness	−0.170**	0.739**	0.310**	0.928**	−0.139	−0.107
	(0.053)	(0.050)	(0.045)	(0.191)	(0.133)	(0.131)
Observations	9613	18360	18360	18360	9613	18360
RESET test p-values	0.000	0.000	0.204	0.000	0.941	0.331

Figure 1: source: Silva and Tenreyro (2006)

PPML HDFE

Here I show a multiyear version of the regression. Instead of keep year at 2019, we use all observation.

We use exporter-year fixed effect and importer-year fixed effect in this exercise, following Yotov (2022). In the PPMLHDFE, sometimes you'd see inability for the model to converge, which is quite normal in PPML. The more fixed effect you add, the more likely it is to not converge.

```
clear all
use grav,clear
keep if contig!=. //drop multi input

encode iso3_d,generate(iiso3_d)
encode iso3_o,generate(iiso3_o)
egen id=group(iso3_o iso3_d)
```

```
xtset id year
xtreg logtrade lgdpo lgdpd lgdpco lgdpcd ldist contig comcol comlang_off fta_wto, r
outreg2 using myreg2.doc, replace label ctitle(OLS) title(Table XX: my amazing regression)
xtreg logtrade lgdpo lgdpd lgdpco lgdpcd ldist contig comcol comlang_off fta_wto,fe r
outreg2 using myreg2.doc, append label ctitle(FE)
ppmlhdfe tradeflow_baci lgdpo lgdpd lgdpco lgdpcd ldist contig comcol comlang_off fta_wto,
outreg2 using myreg2.doc, append label ctitle(PPML)
ppmlhdfe tradeflow_baci lgdpo lgdpd lgdpco lgdpcd ldist contig comcol comlang_off fta_wto,
outreg2 using myreg2.doc, append label ctitle(PPMLHDFE)
```

Product level gravity

Theory

We then proceed to a higher-dimension trade data which you may be interested in. In the field, UI students often interested largely in Indonesian affairs. That is, we are not interested so much in the bilateral flow of all countries, but only on Indonesia. However, we often use more granular dimension than just exporter/importer. Often times we use indices like time, commodities or industries, or even firms (shamelessly inserting my paper here Gupta (2023)).

Now, if you are planning to do these kinds of studies, then you are going to need to tackle higher degree dataset and merging the gravity variables. Most often you can get these variables from World Development Indicators but CEPII is ok for now (note the main problem of CEPII is its timeliness).

The theory isn't so different compared to our previous gravity model. What we want is an additional indices. We are going to estimate something similar as Equation 0.2 but with more indices. We need to care about multilateral resistance (MR) and we can use dummies since we now have more variations from indices like time and HS code.

According to Yotov (2022), we need at least 3 dummies to run a multi-country, multi-time and multi-goods/sectors[1]. We need to have exporter-time dummy, importer-time dummy and country-pair dummy. We need to construct this first. Note that these dummies will likely absorb some of your variables like distance (consistant between pair across time, typically).

So we will do the HS,time varying version of Equation 0.2:

$$X_{ijpt} = \alpha_0 Y_{it}^{\alpha_1} Y_{jt}^{\alpha_2} D_{ijpt}^{\alpha_3} e^{\theta_1 o_{it} + \theta_2 d_{jt} + \theta_3 p_{ij}} \tag{0.3}$$

[1] unless you have domestic trade data which we typically don't. If you do, then there's borders dummy. More on Yotov (2022).

Setting data

As you can see, the BACI dataset is not combined into 1 dataset. We kinda has to combine 'em. So we gotta read 'em 1 by 1. This process reuire quite a long line of code in Stata but you'd do fine once you're experienced.

```
// BACI
clear all
// combine into 1 file

import delimited "BACI_HS17_Y2017_V202401b.csv",numericcols(6) // for some reason my stata
save baci2017,replace
import delimited "BACI_HS17_Y2018_V202401b.csv",numericcols(6) clear
save baci2018,replace
import delimited "BACI_HS17_Y2019_V202401b.csv",numericcols(6) clear
save baci2019,replace
import delimited "BACI_HS17_Y2020_V202401b.csv",numericcols(6) clear
save baci2020,replace
import delimited "BACI_HS17_Y2021_V202401b.csv",numericcols(6) clear
save baci2021,replace
import delimited "BACI_HS17_Y2022_V202401b.csv",numericcols(6) clear
save baci2022,replace
// appending
use baci2017,clear
append using baci2018
append using baci2019
append using baci2020
append using baci2021
append using baci2022
save baci,replace // the complete baci
// remove individual files to save space
rm baci2017.dta
rm baci2018.dta
rm baci2019.dta
rm baci2020.dta
rm baci2021.dta
rm baci2022.dta
```

There are only 6 columns / variables. Here's some information on what thos means. You notice that we need more information from our grav dataset (note that baci doesn't have gravity information like distance and GDP). We are going to use t,i, and j as a key to merge grav and baci.

Table 1: Variable explanations

var	meaning	grav equivalence
t	year	year
i	exporter	iso3num_o
j	importer	iso3num_d
k	product	-
v	value	-
q	quantity	-

If you `sum` this data, you'll see that we have a very big data! It kinda look like this

Variable	Obs	Mean	Std. dev.	Min	Max
t	65,646,558	2019.568	1.693688	2017	2022
i	65,646,558	459.1649	254.8952	4	894
j	65,646,558	440.4721	250.8702	4	894
k	65,646,558	608204.3	262333.9	10121	970600
v	65,646,558	1768.199	70660.18	.001	1.17e+08
q	63,945,234	1344.1	264960.9	0	7.41e+08

Their country code is in number so you need to combine the information we get from our grav data. We need to rename some of the key in our baci dataset to match with our grav data.

```
/// merge baci with grav
/// rename to match key
rename t year
rename i iso3num_o
rename j iso3num_d
/// merging
merge m:1 year iso3num_o iso3num_d using grav
/// keep only if both match
keep if _merge==3
drop _merge // no longer need this variable
// add log version of hs6digit trade
gen lvv=log(1+v)
gen lq=log(1+q)
```

you can try sum again to see that we trimmed some countries we don't need! Also you now have all information from the grav dataset!

Variable	Obs	Mean	Std. dev.	Min	Max
year	18,683,150	2019.048	1.407073	2017	2021
iso3num_o	18,683,150	424.0933	255.543	8	862
iso3num_d	18,683,150	415.504	250.7267	8	862
k	18,683,150	608002.8	262140.6	10121	970600
v	18,683,150	1554.84	60363.49	.001	9.93e+07
q	18,250,153	1421.785	402117.7	.001	7.12e+08
iso3_o	0				
iso3_d	0				
distw_harm~c	18,683,150	6289.257	4721.105	149	19677
contig	18,683,150	.0745564	.2626743	0	1
comlang_off	18,683,150	.1804525	.3845639	0	1
comcol	18,683,150	.0425465	.2018324	0	1
gdp_o	18,646,185	2.16e+09	3.91e+09	177935.3	1.77e+10
gdp_d	18,575,809	9.30e+08	2.31e+09	177935.3	1.77e+10
gdpcap_o	18,646,185	28.39713	21.44036	.224	99.152
gdpcap_d	18,575,809	22.62192	22.08858	.224	99.152
fta_wto	18,683,150	.4678275	.4989639	0	1
tradeflow_~i	14,709,001	4961208	1.53e+07	.001	2.85e+08
ldist	18,683,150	8.340346	1.037297	5.003946	9.887206
lgdpo	18,646,185	20.35449	1.606125	12.08918	23.59875
lgdpd	18,575,809	19.12765	1.926491	12.08918	23.59875
lgdpco	18,646,185	2.907837	1.083836	-1.496109	4.596654
lgdpcd	18,575,809	2.428226	1.353248	-1.496109	4.596654
logtrade	14,709,001	13.25453	2.434556	.0009995	19.46802

Regression

Now let's do the regression! We again is going to use `xtreg` and `ppmlhdfe`. Note that now you have several dimension: year, exporter,importer, and hs6digit! We need to use group again for the xtreg, but ppmlhdfe does not require such thing!

```
// Regression
/// creating id
encode iso3_d,generate(iiso3_d) // encoding again for fixed effect
encode iso3_o,generate(iiso3_o)
egen id=group(iso3_d iso3_o k) // grouping all non-time index
xtset id year

xtreg lvv lgdpo lgdpd lgdpco lgdpcd contig comcol comlang_off fta_wto ldist,r
outreg2 using myreg3.doc, replace label ctitle(OLS) title(Table XX: my amazing regression)
```

```
xtreg lvv lgdpo lgdpd lgdpco lgdpcd contig comcol comlang_off fta_wto ldist,fe r
outreg2 using myreg3.doc, append label ctitle(FE)
ppmlhdfe v lgdpo lgdpd lgdpco lgdpcd contig comcol comlang_off fta_wto ldist,vce(robust)
outreg2 using myreg3.doc, append label ctitle(PPML)
ppmlhdfe v lgdpo lgdpd lgdpco lgdpcd contig comcol comlang_off fta_wto ldist,abs(i.iiso3_d
outreg2 using myreg3.doc, append label ctitle(PPMLHDFE)
```

Results below

As you can see, results from goods gravity is less clear compared to total trade value. The main reason is comparative advantage. Some countries are just good at making a set of HS6s, that you bought it from them no matter how large/small their GDP and/or how far their distance is. We need to acknowledge heterogeneity in those goods, that trade restrictions among those HSes are very different (e.g., agricultures are generally more restricted than manufacturing).

HS-related gravity typically is used when we want to regress certain goods in certain countries. Of course if you need to run multi-HS goods, you're going to need various controls (e.g., industry or HS fixed effect). As you can see, I only use exporter-year and importer-year FE, which isn't enough to control all possible non-observed heterogeneity.

You might notice how long it took for the whole process to run. We have very long time to read data and run the regression algorithm. This is due to the size of our gravity dataset. Stata (and R and python for that matter) is, to my understanding, an optimisation for ease to code and speed. Remember, our main goal is TO UNDERSTAND the results. If you know how to code an algorithm, that's cool. But as an economist, understanding economic phenomenon and inferring the results is arguably more important.

Closing

OKay now you are ready to run regression yourself, so no more excuse "tapi pak saya gak ngerti gravity model". Try to replicate what I do here and you prolly finished 50% of your thesis. You then can work to update this with your own hypothesis, adding more variable and more specific on some issues.

Of course typically we want to add more trade cost variables, comparative advantage variable and other types of policy variables. For example, export ban dummy, subsidy variable in certain sector, anti-dumping, etc. While you'd do various other variables, you'd want these variables presented in this class at the minimum.

Running this on R is also excellent. I must confess that R is also speedy (these guys making the package is extremely good), but Stata is a bit more intuitive and compute you with important stats as well such as pseudo-R. Nevertheless, now you should be able to do both!

As you are a student now, I encourage you to explore as much as you can because this is the moment. Once you're a proper adult, you must think more mundane stuff so please value your freedom at this point and explore as much as you can! Go out there make mistakes while you can!

I cannot emphasize enough references in Yotov (2022). Whatever you want to do, a paper prolly covered it already. Learn from them and look for an insight to add. Work with your spv and you'll be fine.

References

Anderson, James E., and Eric van Wincoop. 2003. "Gravity with Gravitas: A Solution to the Border Puzzle." Journal Article. *The American Economic Review* 93 (1): 24.

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