GSERM - St. Gallen 2025

Analyzing Panel Data

June 16, 2025

Preliminaries

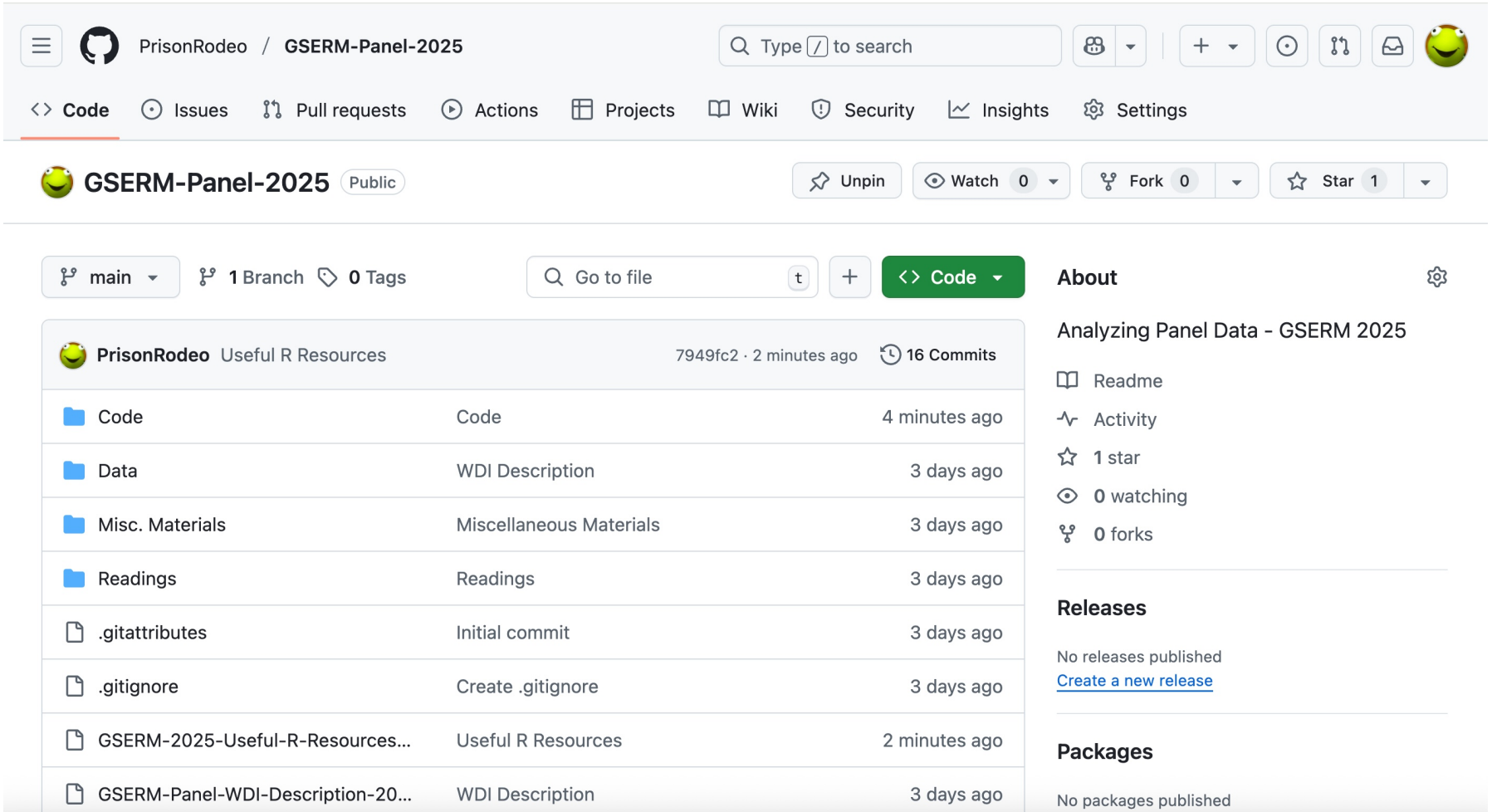
Logistics:

- Instructor: Prof. Christopher Zorn
  - Email: zorn@psu.edu
  - Phone: +1-803-553-4077
  - Bluesky / Instagram / etc.: @prisonrodeo

- Class: June 16-20, 2025, 09:15-15:15 CET.

- The course outline / syllabus is here.

- More important: The syllabus, slides, readings, code, data, etc. are all available on the course github repo (viewable at https://github.com/PrisonRodeo/GSERM-Panel-2025).


PrisonRodeo / GSERM-Panel-2025
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About
Analyzing Panel Data - GSERM 2025
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1 star
0 watching
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Releases
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Create a new release
Packages
No packages published

Assessment

Evaluation at GSERM isn't easy... the plan:

- One "homework exercise"
  - Practical exercise – "real" data analysis and discussion
  - Assigned Tuesday (June 17); due Friday (June 20)
  - Worth 300 possible points

- Final Examination
  - Multiple essay-style questions + "real" data analysis
  - Some choice of questions to answer
  - Assigned Friday (June 20) at noon
  - Due either Friday, June 20, 2025 at 6:00 p.m. ("in-class" alternative) or Friday, June 27, 2025 ("take-home" alternative)
  - Worth 700 possible points

- Total course = 1000 possible points

- Grades assessed on Swiss (1 - 6) scale

Software

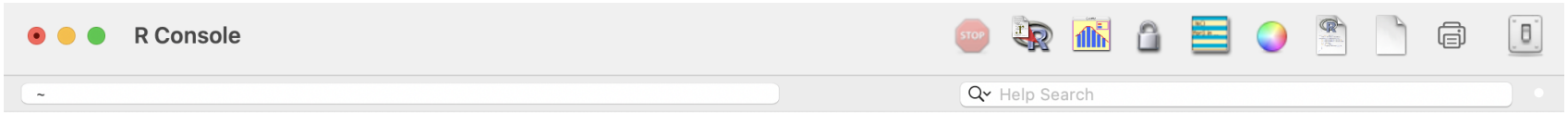
R

- All examples, plots, etc. are generated using R
- Current version (as of last Friday) is 4.5.1
- Desktop: Be sure to get the RStudio / Posit IDE...
- Alternatively: Can be run in a browser, using Posit Cloud
- The course Github repo contains a bit of introductory code for people who may never have used R, and a list of R resources.
- A few of the primary packages we'll use include:
  - `plm`
  - `lme4`
  - `gee`

  See the econometrics R task view for more.

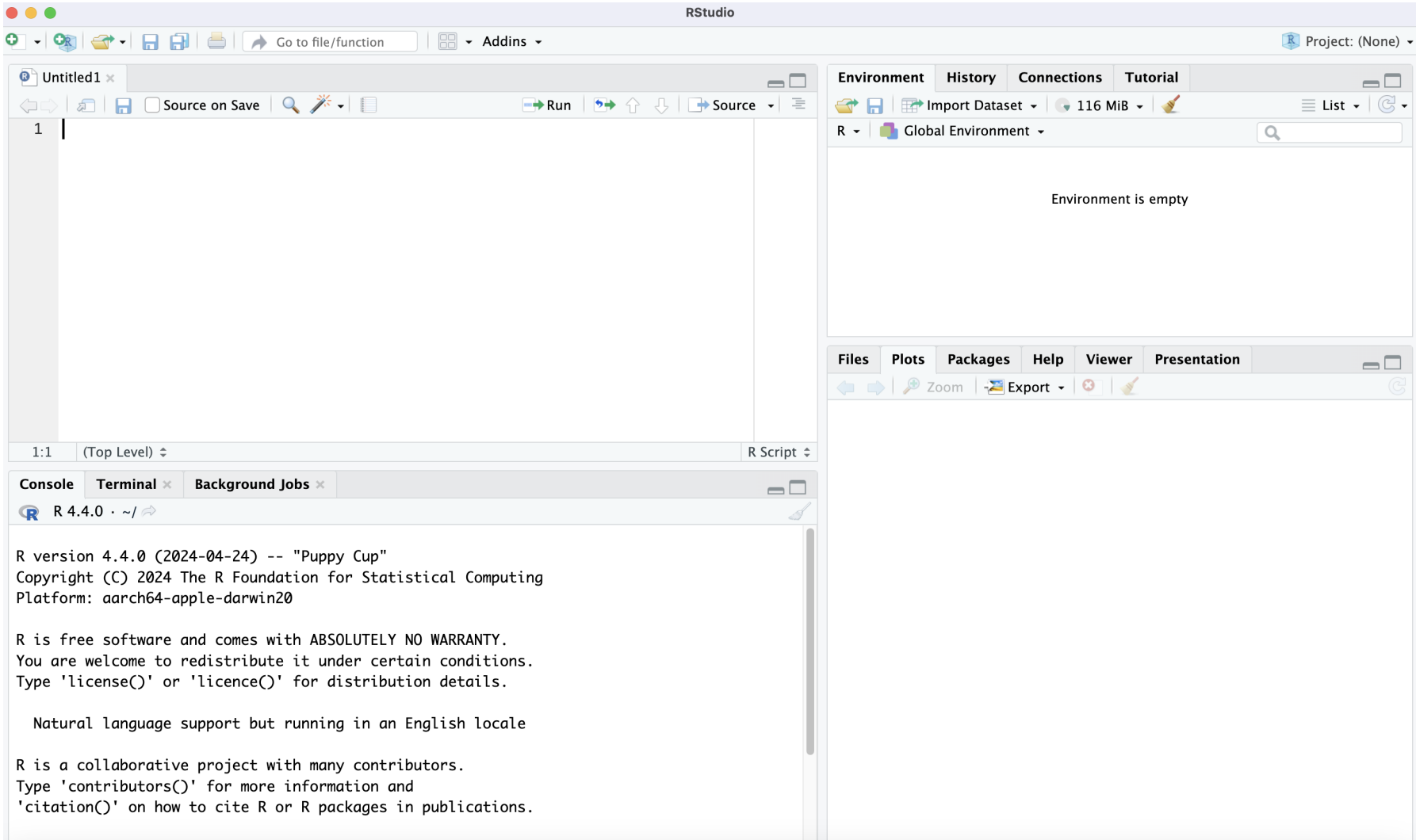
Stata

- Current version is v. 19
- Mostly use the `-xt-` series of commands (for "cross-sectional time series")

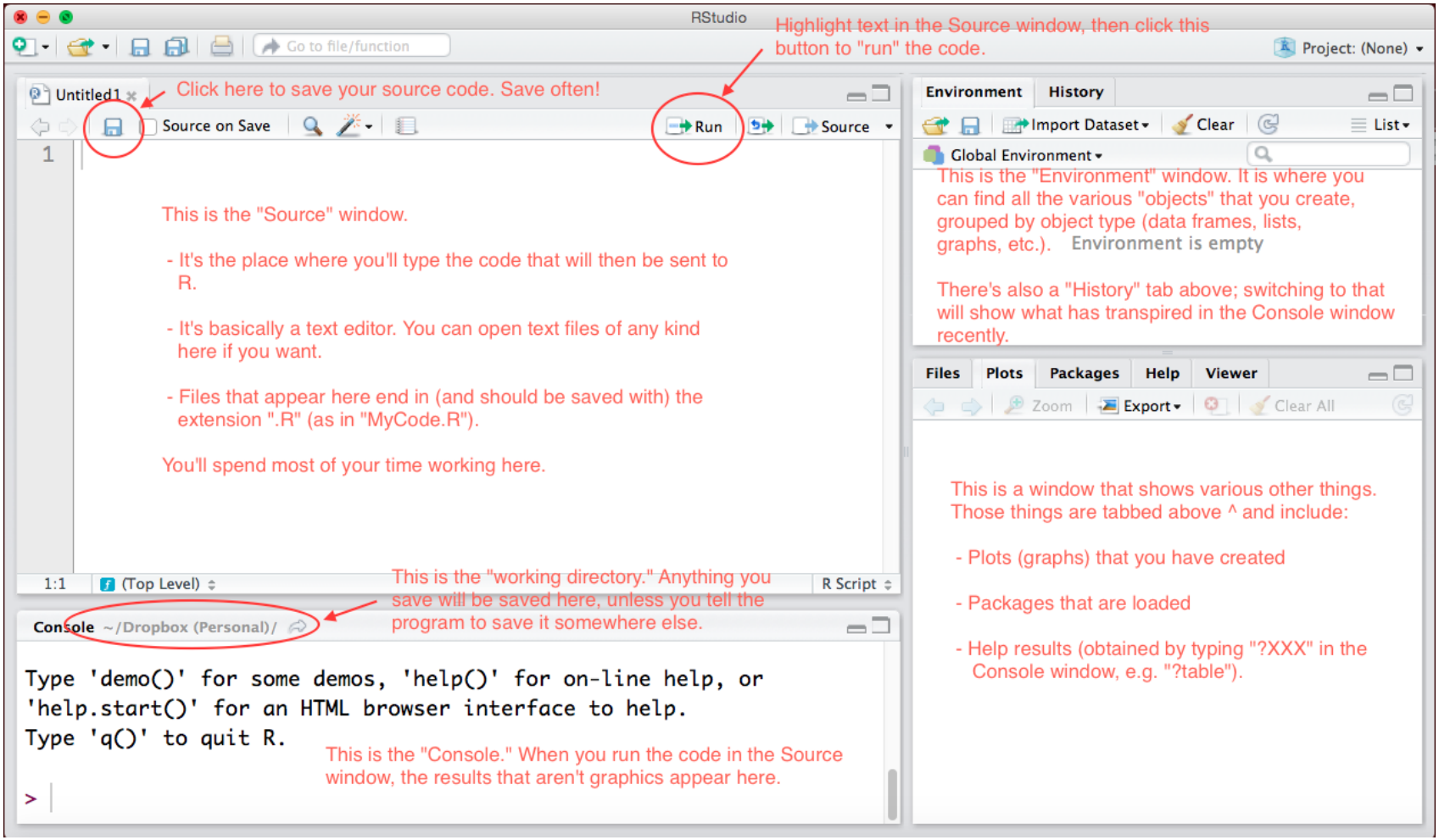



```
R version 4.4.0 (2024-04-24) -- "Puppy Cup"
Copyright (C) 2024 The R Foundation for Statistical Computing
Platform: aarch64-apple-darwin20

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

[R.app GUI 1.80 (8376) aarch64-apple-darwin20]

[History restored from /Users/cuz10/.Rapp.history]

> 
```

RStudio / Posit



RStudio (annotated)



Starting Points

- Panel data: Data comprising repeated observations over time on a set of cross-sectional units.
- Terminology:
  - "Unit" / "Units" / "Units of observation" / "Panels" = Things we observe repeatedly
  - "Observations" = Each (one) measurement of a unit
  - "Time points" = When each observation on a unit is made
  - $i \in \{1....N\}$ indexes units
  - $t \in \{1...T\}$ or $\{1...T_i\}$ indexes observations / time points
  - If $T_i = T \; \forall i$ then we have **"balanced"** panels / units
  - Balanced panels also imply $N_t = N \; \forall \; t$
  - NT = Total number of observations (if balanced)
- "Panel" $\neq$ "Time Series"
- "Panel" $\neq$ "Multilevel" / "Hierarchical" / etc.

More Terminology

$N >> T \rightarrow$ "panel" data...

- (American) National Election Study panel studies ($N \approx 2000, T = 3$)
- Swiss Household Panel (FORS) ($N =$ large, $T = 25$)
- Often:
  - Cross-sectional units are a sample from a population
  - T is (relatively) fixed

$T >> N$ or $T \approx N \rightarrow$ "time-series cross-sectional" ("TSCS") data

- National OECD data ($N = 20$ original members, $T \approx 60$)
- Often:
  - N is an entire population, and is (relatively) fixed
  - Asymptotics are in T

$N = 1 \rightarrow$ "time series" data

$T = 1 \rightarrow$ "cross-sectional" data

Panel Data Structure + Organization

Typical: "long":

id	t	Y	X	...
1	1	250	3.4	...
1	2	290	3.3	...
⋮	⋮	⋮	⋮	...
2	1	160	4.7	...
2	2	150	4.9	...
⋮	⋮	⋮	⋮	...

Sometimes: "wide":

id	$Y1$	$Y2$	...	$X1$	$X2$	...
1	250	290	...	3.4	3.3	...
2	160	1250	...	4.7	4.9	...
⋮	⋮	⋮	⋮	⋮	⋮	⋮

Introduction to Panel Variation: A Tiny (Fake) Example

Firm	Year	Sector	Inflation	FemaleCEO	NPM
1	2021	IT	0.6	0	21.6
1	2022	IT	2.8	0	19.9
1	2023	IT	2.1	0	23.1
1	2024	IT	1.1	0	22.0
2	2021	Energy	0.6	0	13.7
2	2022	Energy	2.8	0	12.1
2	2023	Energy	2.1	0	12.3
2	2024	Energy	1.1	0	13.0
3	2021	Retail	0.6	1	5.1
3	2022	Retail	2.8	1	4.9
3	2023	Retail	2.1	1	4.8
3	2024	Retail	1.1	0	5.0

Aggregation (means)

Cross-Sectional:

Firm	Year	Sector	Inflation	FemaleCEO	NPM
1	2022	IT	1.65	0.00	21.65
2	2022	Energy	1.65	0.00	12.78
3	2022	Retail	1.65	0.75	4.95

Temporal:

Year	Firm	Inflation	FemaleCEO	NPM
2021	2	0.6	0.333	13.5
2022	2	2.8	0.333	12.3
2023	2	2.1	0.333	13.4
2024	2	1.1	0.000	13.3

The Point

Aggregation:

- *Always* loses information
- Occasionally forces *arbitrary decisions* / transformations
- Sometimes *distorts* relationships

If you have variation in multiple dimensions, use it.

Two-Way Variation

Two "dimensions" of variation:

- Cross-sectional variation: how each unit is – on average – different from other units – a/k/a **between-unit** variation
- Temporal variation: how each measurement / time point is – on average – different from other time points on average – a/k/a/ **within-unit** variation

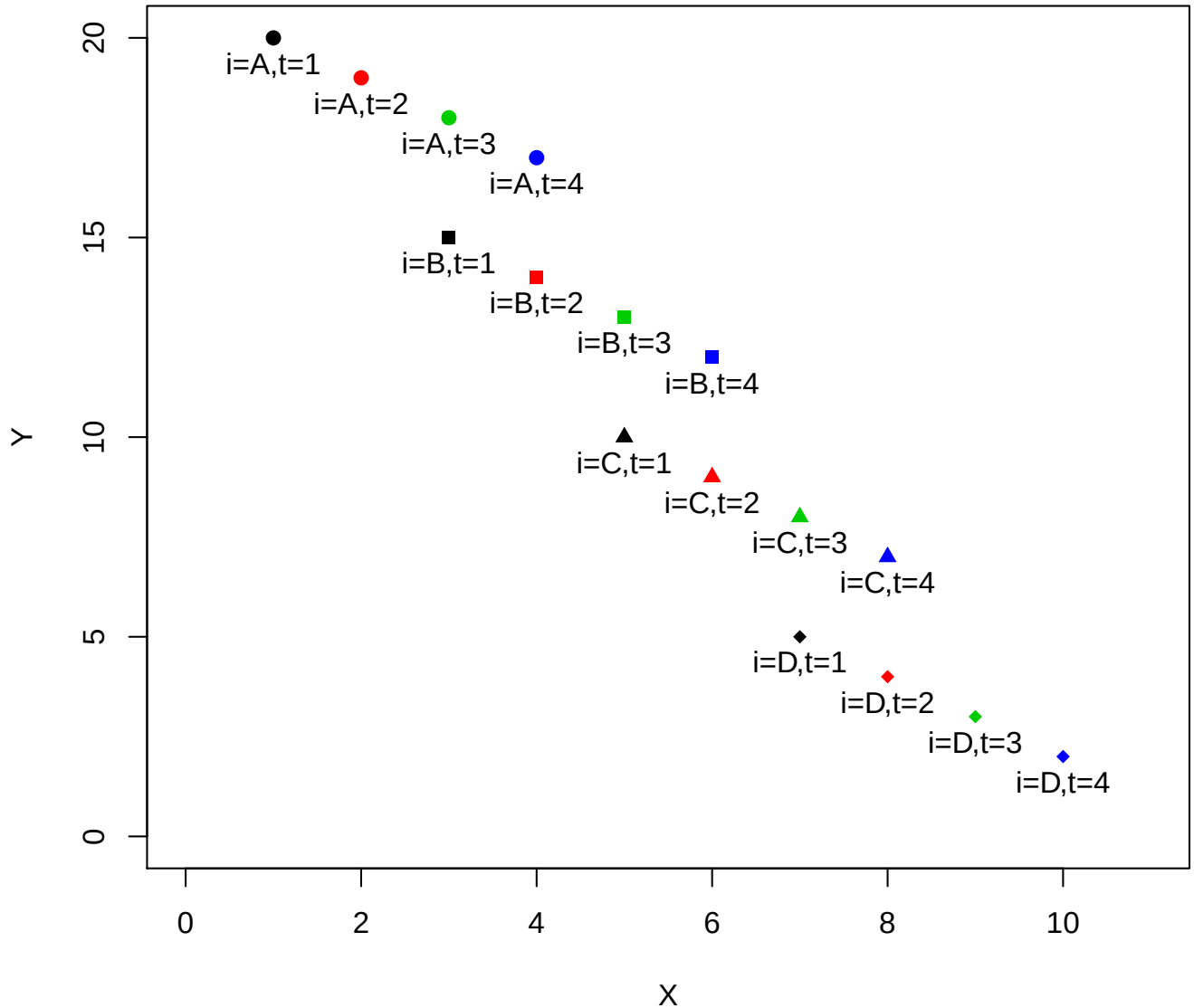
In panel data, a random variable may:

- Have only between-unit variation (i.e., lack *temporal variation*)
- Have only within-unit variation (i.e., lack *cross-sectional variation*)
- Have *both* within- and between-unit variation

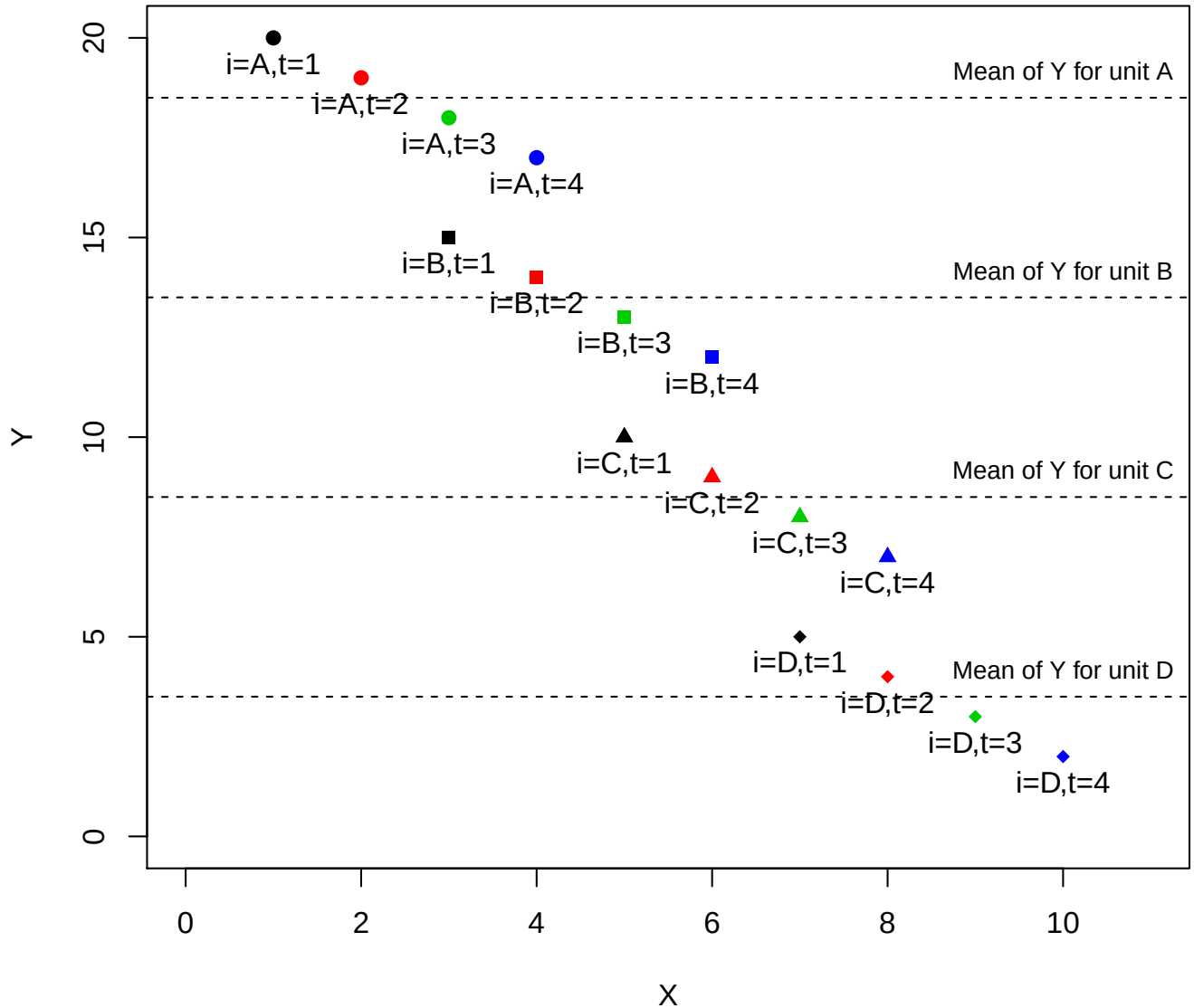
For Y_{it}, a variable that varies over both units and time:

- $\bar{Y}_i = \frac{1}{T_i} \sum_{t=1}^{T} Y_{it}$ is the over-time mean of Y for unit i,
- $\bar{Y}_t = \frac{1}{N_t} \sum_{i=1}^{N} Y_{it}$ is the across-unit mean of Y at time t, and
- $\bar{Y} = \frac{1}{NT} \sum_{i=1}^{N} \sum_{t=1}^{T} Y_{it}$ is the grand mean of Y.

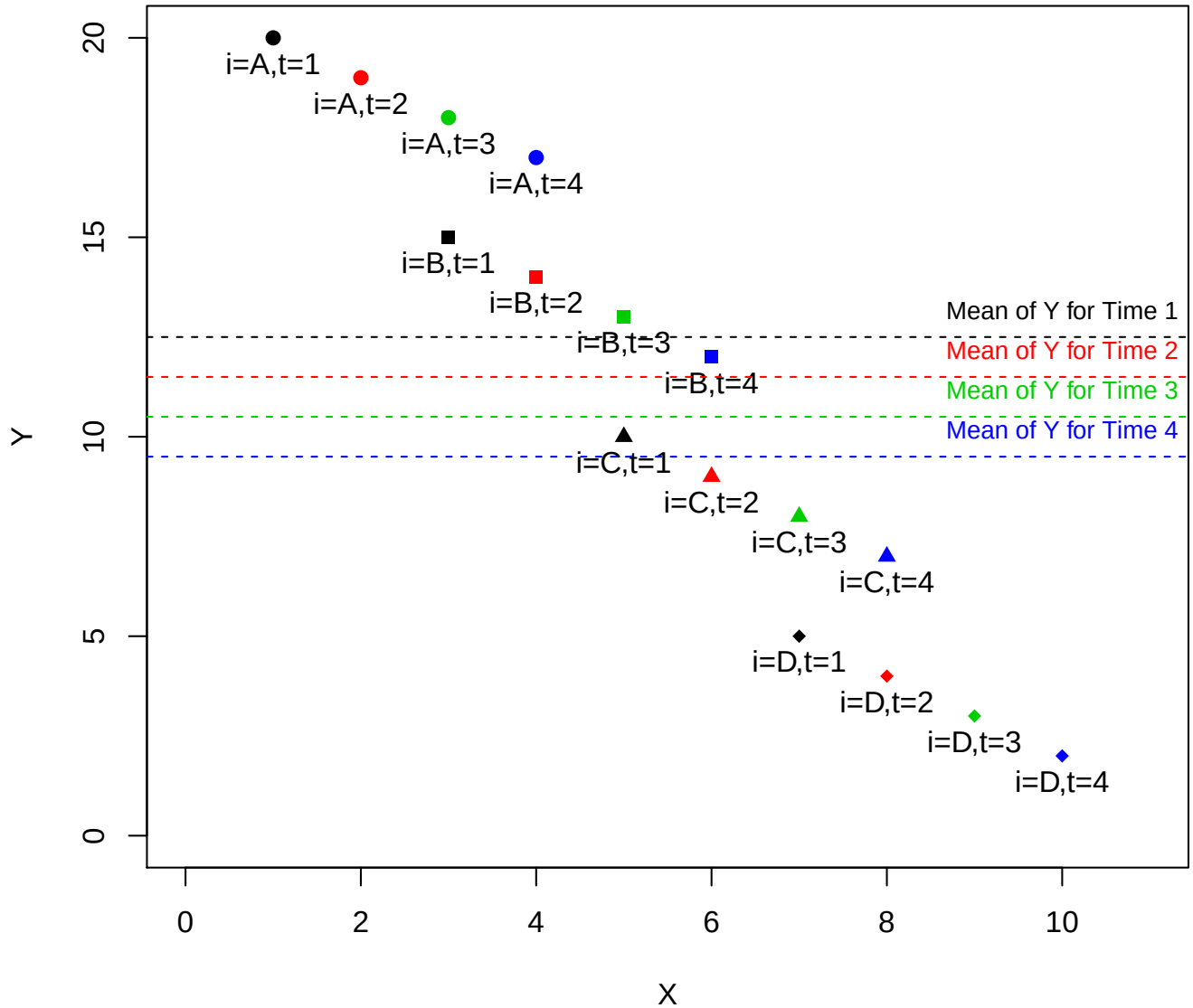
Dimensions of Variation



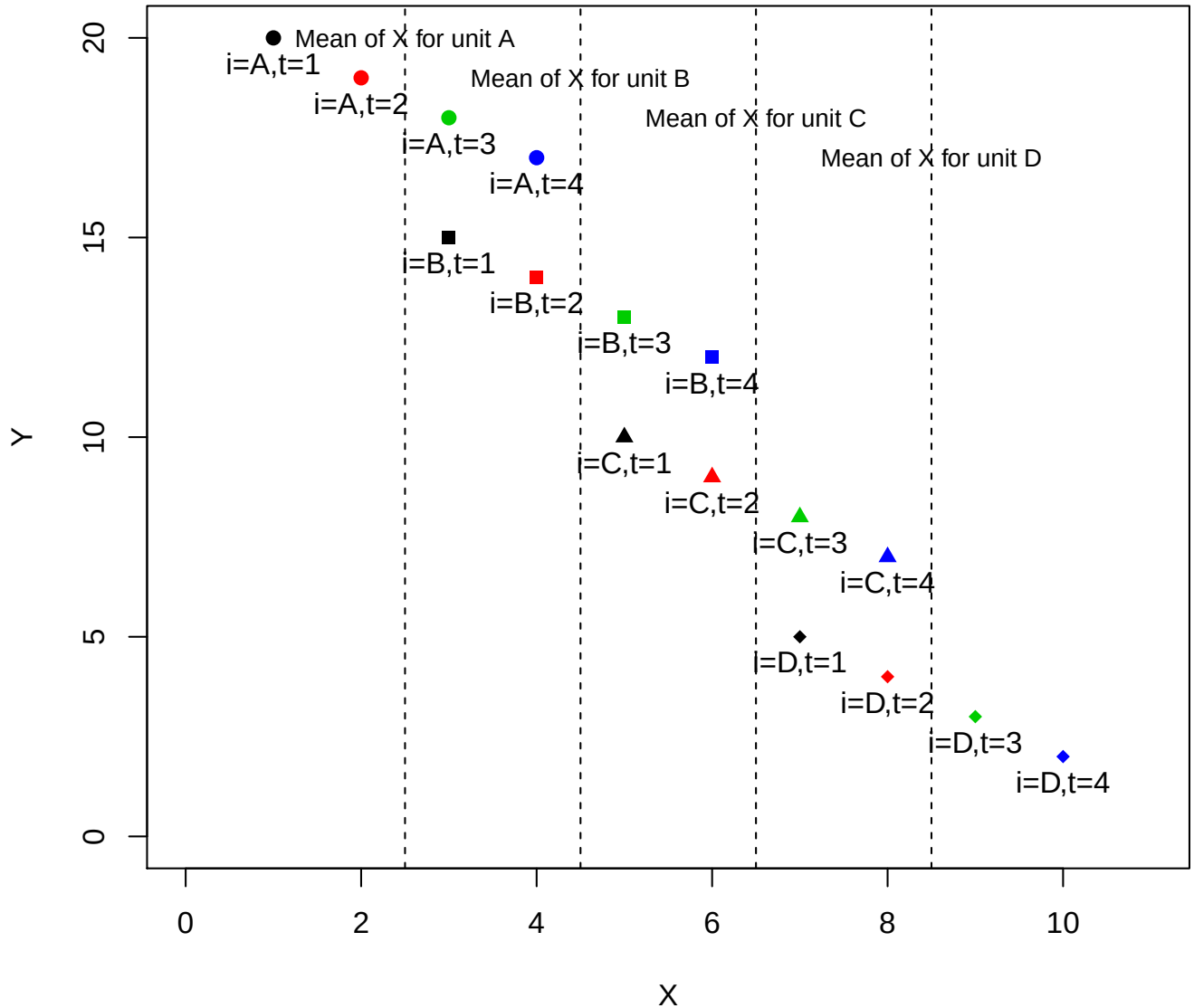
Dimensions of Variation: Y



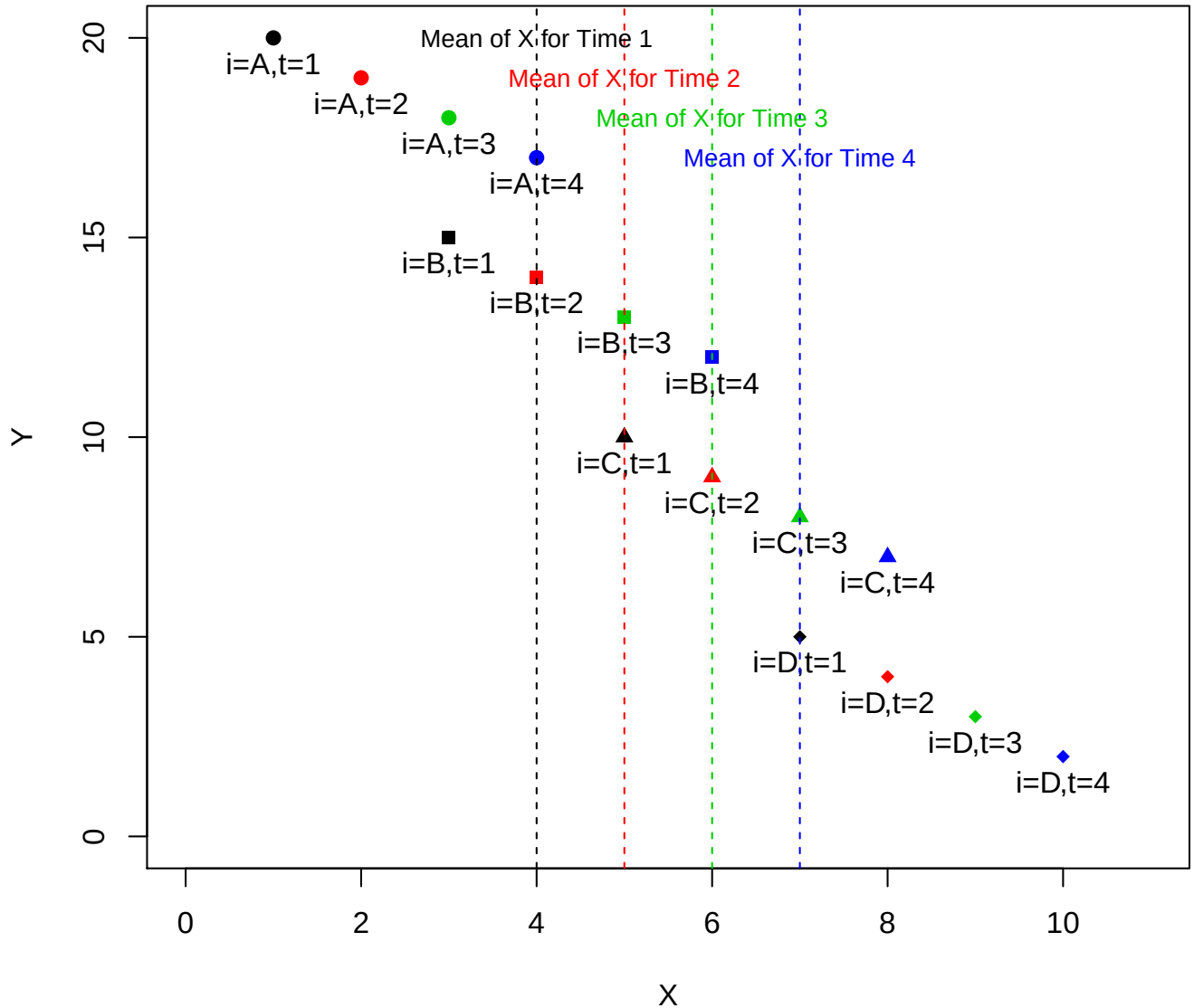
Dimensions of Variation: Y



Dimensions of Variation: X



Dimensions of Variation: X



Within- and Between-Unit Variation

The *within-unit mean* of Y is:

$$\bar{Y}_i = \frac{1}{T_i} \sum_{t=1}^{T_i} Y_{it}$$

That means that we can write:

$$Y_{it} = \bar{Y}_i + (Y_{it} - \bar{Y}_i).$$

That is, the *total* variation in Y_{it} can be decomposed into:

- The *between-unit* variation in the $\bar{Y}_i$s, and
- The *within-unit* variation around $\bar{Y}_i$ (that is, $Y_{it} - \bar{Y}_i$).

Within- and Between-Time Point Variation

Note that (while unusual) one could do a similar decomposition vis-à-vis time:

$$Y_{it} = \bar{Y}_t + (Y_{it} - \bar{Y}_t).$$

That is, the *total* variation in Y_{it} can be decomposed into:

- The *temporal* variation in the $\bar{Y}_t$s, and
- The *within-time-point* variation around $\bar{Y}_t$ (that is, $Y_{it} - \bar{Y}_t$).

In a similar fashion, we can also calculate the within- and between-unit variability (e.g., the standard deviations) of the constituent variables $\bar{Y}_i$ and $(Y_{it} - \bar{Y}_i)$...

Variation ("Toy" Data from Above, Y)

"Total" Variation:

```
> with(toy, describe(Y))
   vars  n mean  sd median trimmed mad min max range skew kurtosis  se
X1    1 16   11 5.9     11      11 7.4   2  20    18    0     -1.5 1.5
```

"Between" Variation:

```
> Ymeans <- ddply(toy, .(ID), summarise, Y=mean(Y))
> with(Ymeans, describe(Y)) # between-unit variation
   vars n mean  sd median trimmed mad min max range skew kurtosis  se
X1    1 4   11 6.5     11      11 7.4 3.5  18    15    0     -2.1 3.2
```

"Within" Variation:

```
> toy <- ddply(toy, .(ID), mutate, Ymean=mean(Y))
> toy$within <- with(toy, Y-Ymean)
> with(toy, describe(within)) # within-unit variation
   vars  n mean  sd median trimmed mad  min max range skew kurtosis   se
X1    1 16    0 1.1      0       0 1.5 -1.5 1.5     3    0     -1.6 0.29
```

Regression!

Cross-sectional regression:

$$\underset{N\times 1}{\mathbf{Y}_i} = \underset{N\times K}{\mathbf{X}_i}\ \underset{K\times 1}{\boldsymbol{\beta}} + \underset{N\times 1}{\mathbf{u}_i}$$

...requires all the usual OLS assumptions:

- $\mathrm{E}(\mathbf{u} = 0)$
- $\mathrm{E}(\mathbf{u}\mathbf{u}') = \sigma^2\mathbf{I}$
- $\mathrm{Cov}(\mathbf{X}, \mathbf{u}) = 0$
- $\mathrm{Rank}(\mathbf{X}) = K$

In addition, we usually assume:

- $\boldsymbol{\beta}_i = \boldsymbol{\beta}\ \forall\ i$

Key point: For the model

$$\mathbf{Y}_{it} = \mathbf{X}_{it}\boldsymbol{\beta} + \mathbf{u}_{it}$$

...the same is true.

Variable Intercepts

Unit-specific intercepts:

$$Y_{it} = \beta_{0i} + \beta_1 X_{it} + u_{it} \tag{1}$$

Time-point-specific intercepts:

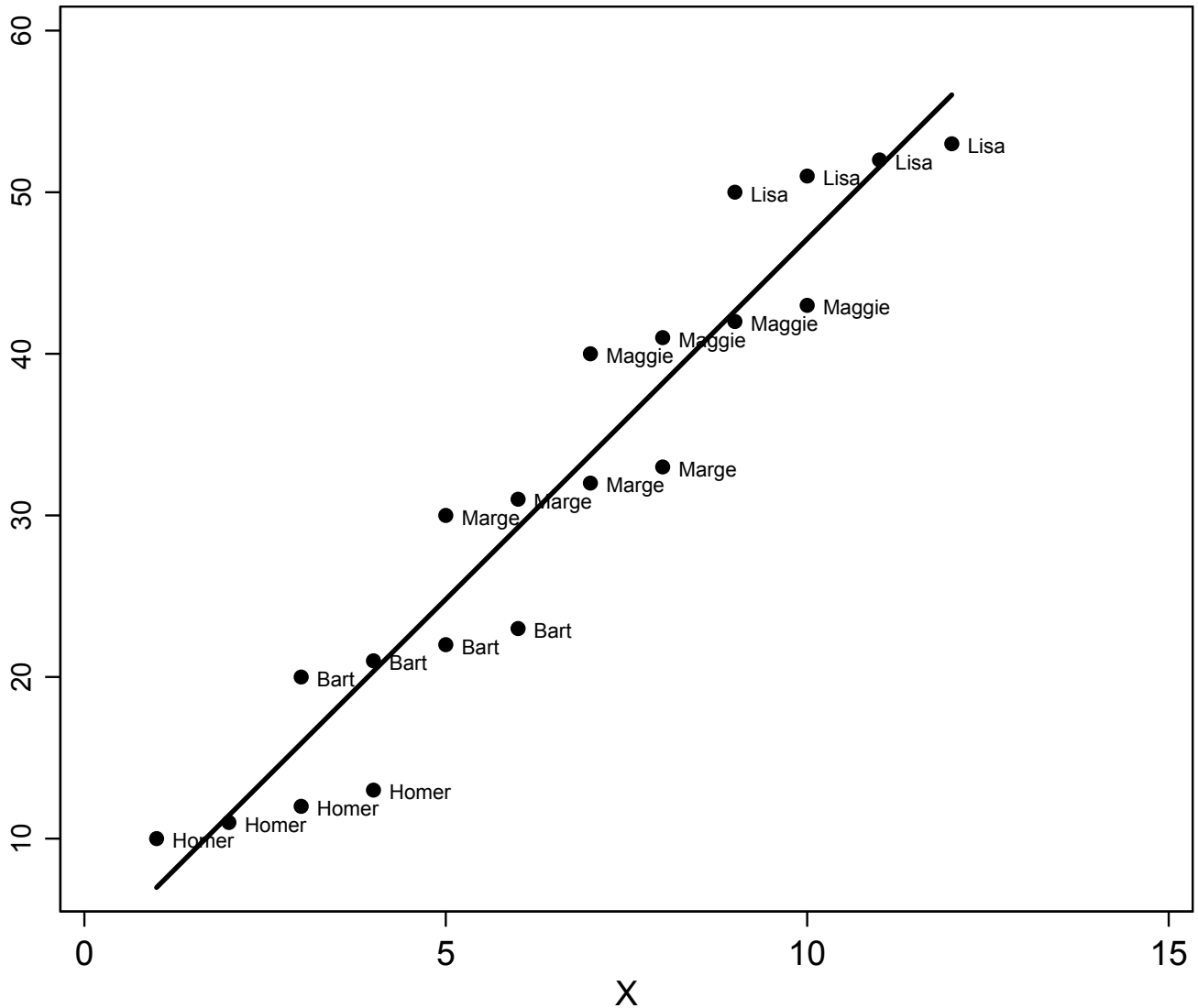
$$Y_{it} = \beta_{0t} + \beta_1 X_{it} + u_{it} \tag{2}$$

Both:

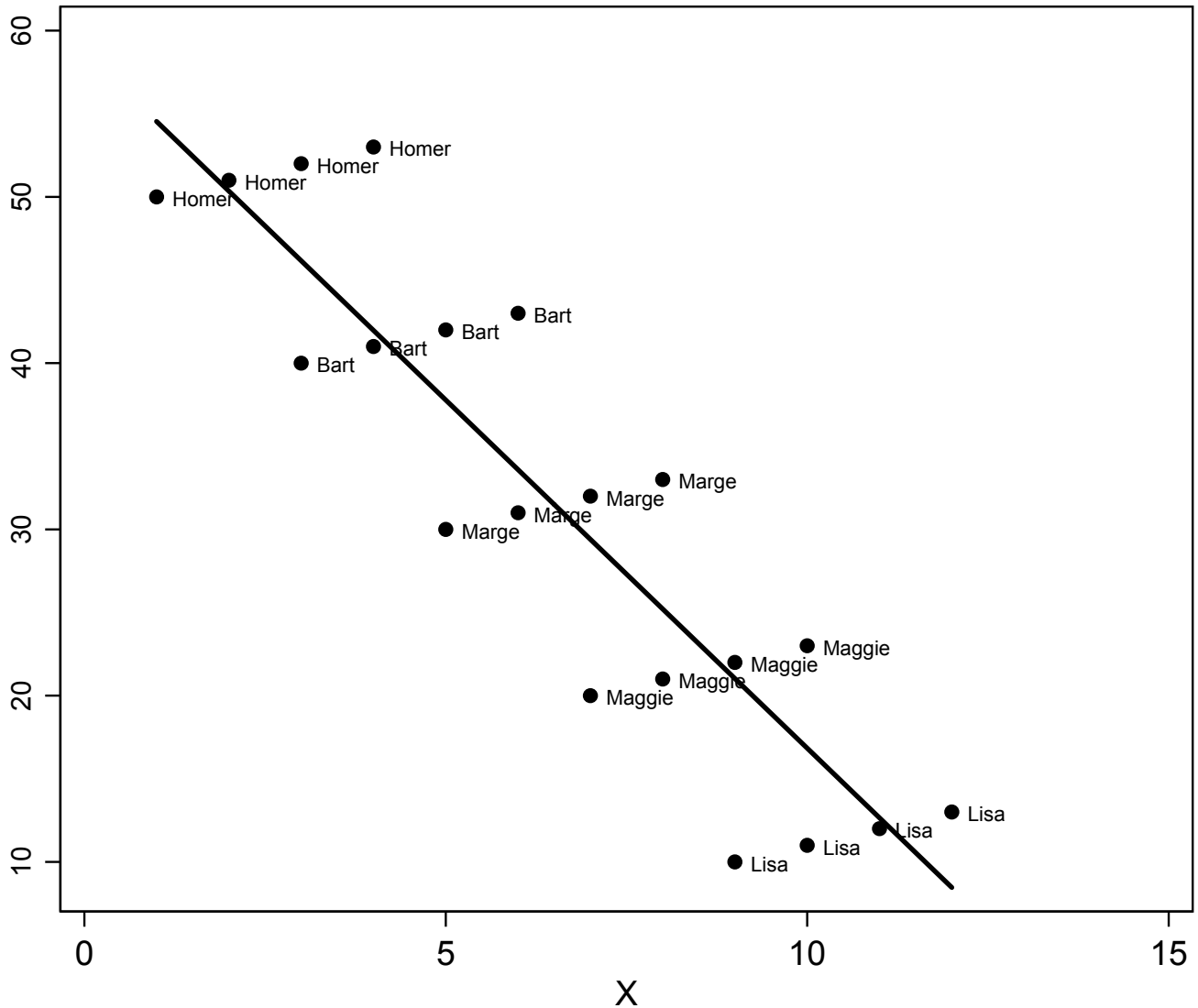
$$Y_{it} = \beta_{0it} + \beta_1 X_{it} + u_{it} \tag{3}$$

Note: Equation 3 is not identified (as written)!

Varying Intercepts



Varying Intercepts



Varying Slopes (+ Intercepts)

Unit-specific slopes:

$$Y_{it} = \beta_0 + \beta_{1i} X_{it} + u_{it} \tag{4}$$

(...one can also have time-point specific slopes, or both – again, the last of those is not identified as written.)

Unit-specific slopes + intercepts:

$$Y_{it} = \beta_{0i} + \beta_{1i} X_{it} + u_{it} \tag{5}$$

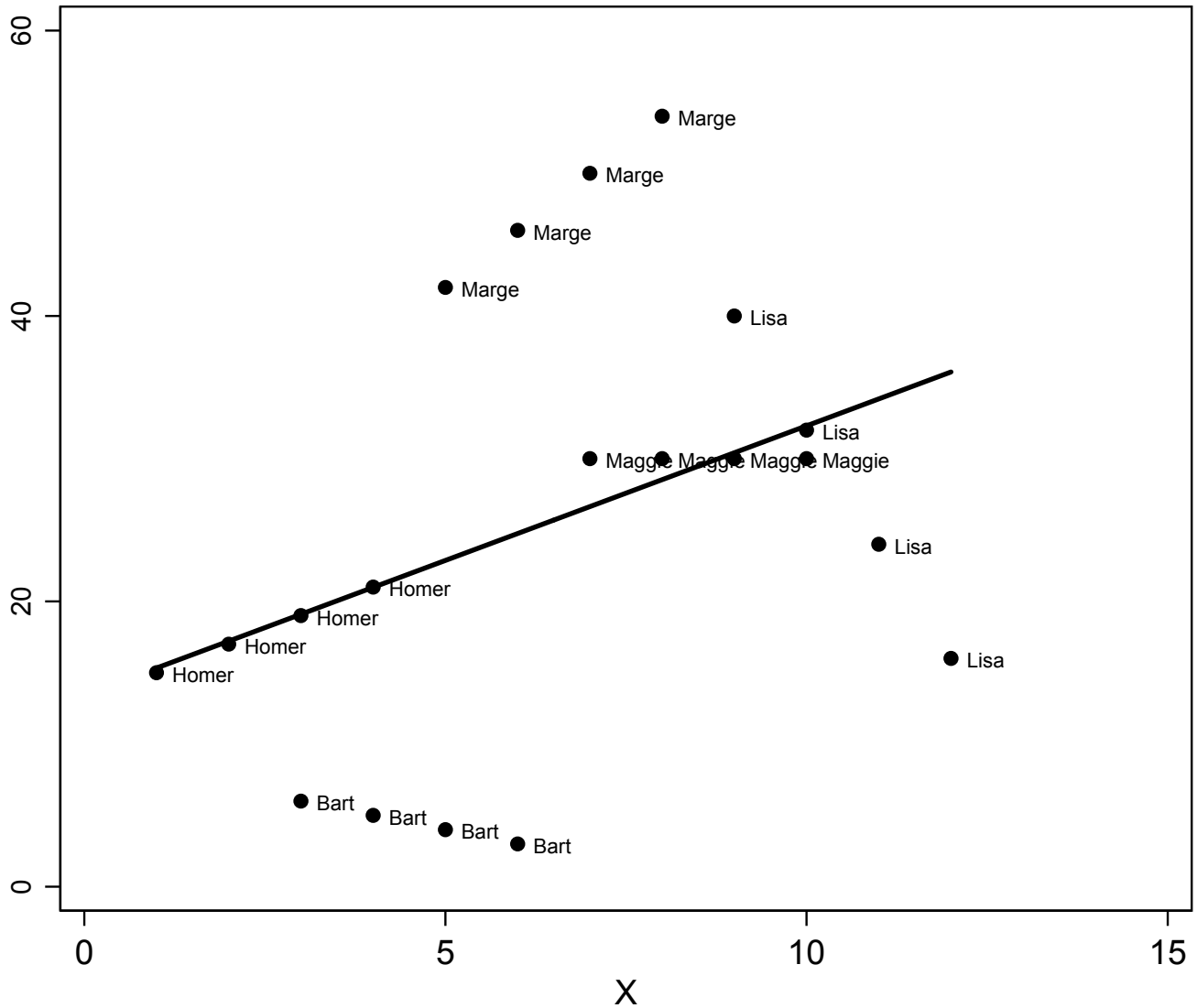
Time-point-specific slopes + intercepts:

$$Y_{it} = \beta_{0t} + \beta_{1t} X_{it} + u_{it} \tag{6}$$

Both...:

$$Y_{it} = \beta_{0it} + \beta_{1it} X_{it} + u_{it} \tag{7}$$

Varying Slopes + Intercepts



The Error Term...

Usual OLS assumption:

$$u_{it} \sim \text{i.i.d.} N(0, \sigma^2) \; \forall \; i, t$$

or, equivalently:

$$\mathbf{u}\mathbf{u}' \sim \sigma^2 \mathbf{I}$$

implies:

$$\begin{aligned}
\text{Var}(u_{it}) &= \text{Var}(u_{jt}) \; \forall \; i \neq j \text{ (i.e., no cross-unit heteroscedasticity)} \\
\text{Var}(u_{it}) &= \text{Var}(u_{is}) \; \forall \; t \neq s \text{ (i.e., no temporal heteroscedasticity)} \\
\text{Cov}(u_{it}, u_{js}) &= 0 \; \forall \; i \neq j, \; \forall \; t \neq s \text{ (i.e., no auto- or spatial correlation)}
\end{aligned}$$

Pooling

Pooling = combining (repeated) observations on different units, and/or observations on different time points, into a single data frame.

Why should we pool data?:

- Adds data ($\rightarrow$ increases *precision*)
- Enhances *generalizability*

Every panel dataset requires that we make decisions about pooling.

Pooling Challenges

Fitting (say) the model:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + u_{it}$$

implies:

- that the process governing the relationship between X and Y is exactly the same for each i,
- that the process governing the relationship between X and Y is the same for all t,
- that the process governing the us is the same $\forall$ i and t as well.

Q: When can we "pool" data on different units?

"Partial" Pooling (Bartels 1996)

Two regimes:

$$Y_A = \beta_A' \mathbf{X}_A + u_A$$

$$Y_B = \beta_B' \mathbf{X}_B + u_B$$

with $\sigma_A^2 = \sigma_B^2$, and $\text{Cov}(u_A, u_B) = 0$.

Estimators:

$$\hat{\beta}_{A,B} = (\mathbf{X}_{A,B}' \mathbf{X}_{A,B})^{-1} \mathbf{X}_{A,B}' Y_{A,B}$$

and

$$\widehat{\text{Var}(\beta_{A,B})} = \hat{\sigma}_{A,B}^2 (\mathbf{X}_{A,B}' \mathbf{X}_{A,B})^{-1},$$

A Pooled Estimator

Pooling As and Bs gives:

$$\begin{aligned}\hat{\beta}_P &= (\mathbf{X}_A'\mathbf{X}_A + \mathbf{X}_B'\mathbf{X}_B)^{-1}(\mathbf{X}_A'Y_A + \mathbf{X}_B'Y_B) \\ &= (\mathbf{X}_A'\mathbf{X}_A + \mathbf{X}_B'\mathbf{X}_B)^{-1}[\beta_A(\mathbf{X}_A'\mathbf{X}_A) + \beta_B(\mathbf{X}_B'\mathbf{X}_B)],\end{aligned}$$

What is the expectation?

$$\begin{aligned}\mathsf{E}(\hat{\beta}_P) &= \beta_A + (\mathbf{X}_A'\mathbf{X}_A + \mathbf{X}_B'\mathbf{X}_B)^{-1}\mathbf{X}_B'\mathbf{X}_B(\beta_B - \beta_A) \\ &= \beta_B + (\mathbf{X}_A'\mathbf{X}_A + \mathbf{X}_B'\mathbf{X}_B)^{-1}\mathbf{X}_A'\mathbf{X}_A(\beta_A - \beta_B)\end{aligned}$$

Pooling: A Test

We can assess whether $\hat{\beta}_A = \hat{\beta}_B$ via:

$$F = \frac{\frac{\hat{\mathbf{u}}_P'\hat{\mathbf{u}}_P - (\hat{\mathbf{u}}_A'\hat{\mathbf{u}}_A + \hat{\mathbf{u}}_B'\hat{\mathbf{u}}_B)}{K}}{\frac{(\hat{\mathbf{u}}_A'\hat{\mathbf{u}}_A + \hat{\mathbf{u}}_B'\hat{\mathbf{u}}_B)}{(N_A + N_B - 2K)}} \sim F_{[K,(N_A+N_B-2K)]}$$

Fractional Pooling

Bartels suggests:

$$\hat{\beta}_\lambda = (\lambda^2 \mathbf{X}_A' \mathbf{X}_A + \mathbf{X}_B' \mathbf{X}_B)^{-1} (\lambda^2 \mathbf{X}_A' Y_A + \mathbf{X}_B' Y_B)$$

with $\lambda \in [0, 1]$:

- $\lambda = 0 \ \rightarrow$ separate estimators for $\hat{\beta}_A$ and $\hat{\beta}_B$,
- $\lambda = 1 \ \rightarrow$ "fully pooled" estimator $\hat{\beta}_P$,
- $0 < \lambda < 1 \ \rightarrow$ a regression where data in regime A are given some "partial" weighting in their contribution towards an estimate of β.

Pooling, Summarized

"(R)oughly speaking, it makes sense to pool disparate observations if the underlying parameters governing those observations are sufficiently similar, but not otherwise."

- Bartels (1996)

Our "Running Example" Data: WDI, 1960-2024

The World Development Indicators

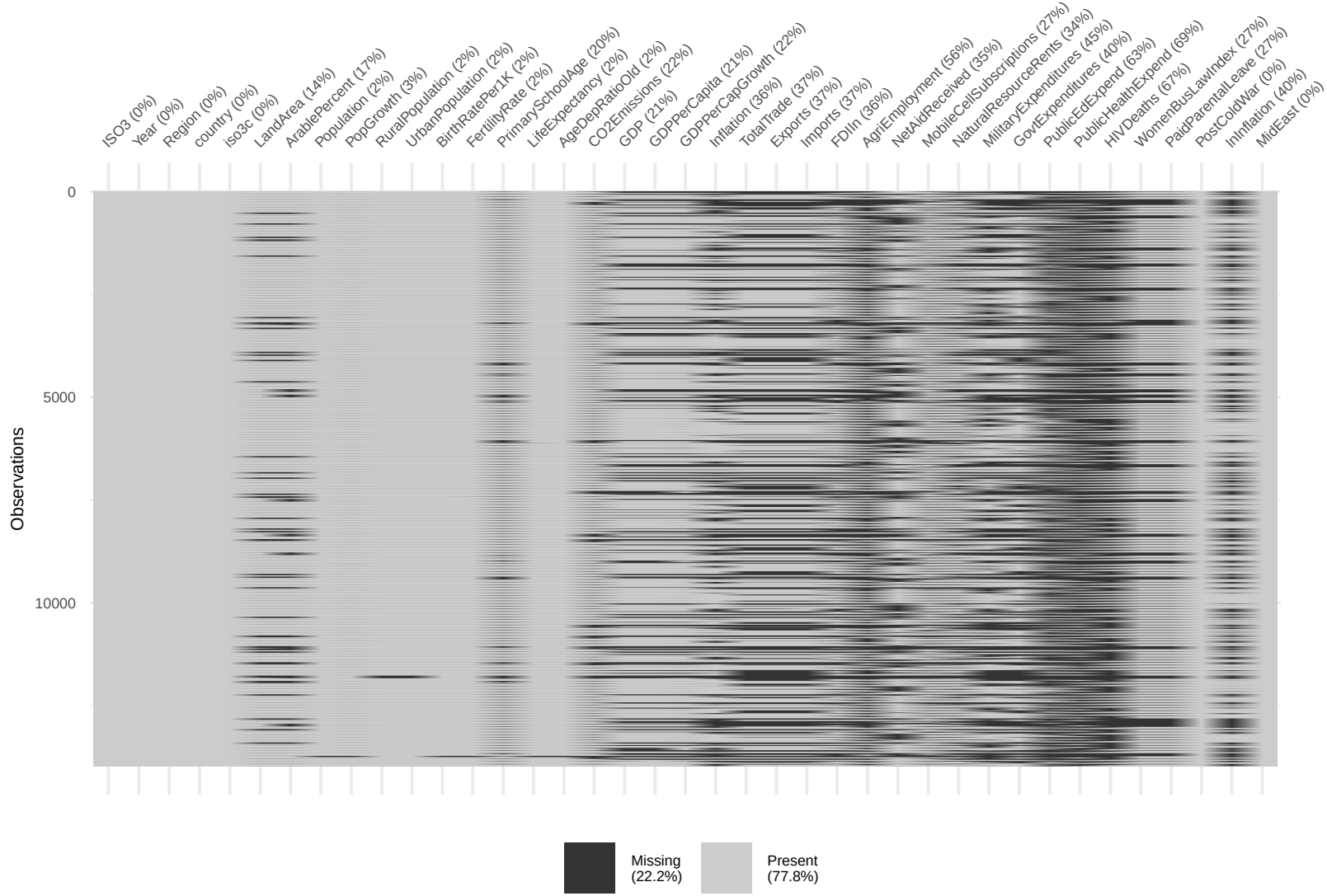
- Cross-national country-level panel data
- $N = 215$ countries, $T = 65$ years (1960-2024) + missingness
- Variable types:
  - Geography: land area, arable land
  - Population indicators
  - Demographics: Birth rates, life expectancy, etc.
  - Economics: GDP, inflation, trade, FDI, etc.
  - Governments: expenditures, policies, etc.
- Full descriptions are listed in the Github repo here.

Summary Statistics: WDI Data

```
> describe(wdi,fast=TRUE,ranges=FALSE,check=TRUE)
                        vars     n             mean               sd  skew kurtosis             se
ISO3                       1 13975              NaN               NA    NA       NA             NA
Year                       2 13975          1992.00            18.76  0.00    -1.20           0.16
Region                     3 13975              NaN               NA    NA       NA             NA
country                    4 13975              NaN               NA    NA       NA             NA
iso3c                      5 13975              NaN               NA    NA       NA             NA
LandArea                   6 12068        596744.44       1643440.14  5.45    34.69       14960.16
ArablePercent              7 11662            13.40            13.67  1.47     1.97           0.13
Population                 8 13730      25346115.55     105429954.52  9.73   105.72      899764.29
PopGrowth                  9 13513             1.75             1.81  0.73    21.38           0.02
RuralPopulation           10 13696            48.11            25.74 -0.11    -1.00           0.22
UrbanPopulation           11 13696            51.89            25.74  0.11    -1.00           0.22
BirthRatePer1K            12 13730            27.67            13.17  0.24    -1.24           0.11
FertilityRate             13 13728             3.82             1.99  0.43    -1.18           0.02
PrimarySchoolAge          14 11120             6.13             0.61 -0.04     0.11           0.01
LifeExpectancy            15 13726            65.17            11.25 -0.76     0.18           0.10
AgeDepRatioOld            16 13730            10.76             7.16  1.79     5.00           0.06
CO2Emissions              17 10962             5.05            11.40  8.70   102.13           0.11
GDP                       18 11040 240200887836.82 1130067880812.37 11.48   160.11 10755237244.82
GDPPerCapita              19 11045        12332.27         19272.78  3.11    14.10         183.38
GDPPerCapGrowth           20 10970             1.89             6.49  1.68    41.63           0.06
Inflation                 21  8882            22.90           320.90 54.09  3625.88           3.40
TotalTrade                22  8777            77.93            53.26  3.03    18.39           0.57
Exports                   23  8777            36.19            28.54  2.99    16.80           0.30
Imports                   24  8786            41.75            27.29  2.54    13.97           0.29
FDIIn                     25  8969             5.53            45.10 15.13   541.91           0.48
AgriEmployment            26  6134            28.11            23.70  0.66    -0.67           0.30
NetAidReceived            27  9043    506951242.00     997064633.65  8.32   157.34    10484966.48
MobileCellSubscriptions   28 10212            36.32            51.76  1.29     1.14           0.51
NaturalResourceRents      29  9211             6.85            11.06  2.60     8.04           0.12
MilitaryExpenditures      30  7733             2.71             3.18  9.43   239.85           0.04
GovtExpenditures          31  8421            16.34             8.27  3.63    32.81           0.09
PublicEdExpend            32  5177             4.35             2.14  6.89   166.21           0.03
PublicHealthExpend        33  4346             3.29             2.37  1.33     3.08           0.04
HIVDeaths                 34  4656          6473.06         18922.25  5.78    45.97         277.31
WomenBusLawIndex          35 10152            59.85            18.74  0.02    -0.58           0.19
PaidParentalLeave         36 10152             0.11             0.31  2.50     4.27           0.00
PostColdWar               37 13975             0.54             0.50 -0.15    -1.98           0.00
```

Missing Data

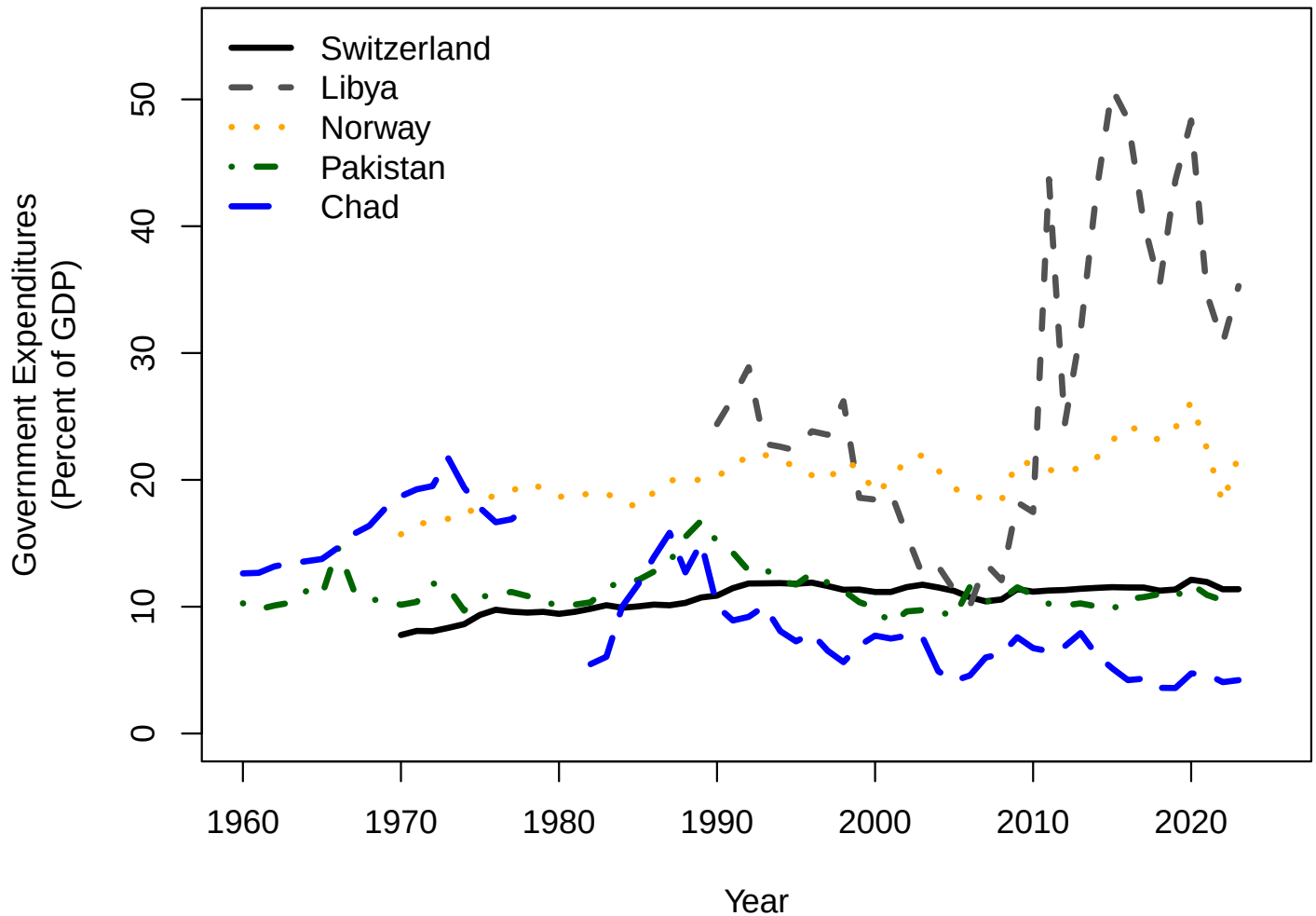
```
> library(naniar)
> vis_miss(wdi)
```



Exploring Variation: GovtExpenditures

General Government Final Consumption Expenditure (% of GDP)

"General government final consumption expenditure (formerly general government consumption) includes all government current expenditures for purchases of goods and services (including compensation of employees). It also includes most expenditures on national defense and security, but excludes government military expenditures that are part of government capital formation."



Panel Summary Statistics: `GovtExpenditures`

Summary: Government Expenditures

Variable	Dim	Mean	SD	Min	Max	Observations
GovtExpenditures	overall	16.338	8.27	0	147.735	$NT = 8421$
	between		9.721	2.26	79.279	$N = 186$
	within		4.364	-34.745	84.794	$T = 45.274$

This means:

- The overall average of `GovtExpenditures` is 16.3
- The overall standard deviation of `GovtExpenditures` is 8.3
- The between-country standard deviation (standard deviation of the 185 country-level means) of `GovtExpenditures` is 9.7
- The within-country standard deviation of `GovtExpenditures` is 4.4
- `GovtExpenditures` is *cross-sectionally dominated*

Exploring Variation: `Inflation`

Inflation, Consumer Prices (Annual %)

> *"Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly. The Laspeyres formula is generally used."*

Summary: (logged) Inflation[1]

Variable	Dim	Mean	SD	Min	Max	Observations
lnInflation	overall	1.661	1.293	-6.909	10.076	$NT = 8342$
	between		0.779	-1.2	3.978	$N = 191$
	within		1.101	-6.559	8.854	$T = 43.675$

The point: Inflation is *temporally dominated*.

[1] Note: Logging inflation leads to missing values in the (relatively rare) instances where deflation occurs.

Exploring Variation: `MidEast`

Create a variable that $= 1$ if the country is in the Middle East, 0 otherwise:

```
> wdi$MidEast<-ifelse(wdi$Region=="Middle East & North Africa",1,0)
```

Summary: Mid-East

Variable	Dim	Mean	SD	Min	Max	Observations
MidEast	overall	0.098	0.297	0	1	$NT = 13975$
	between		0.298	0	1	$N = 215$
	within		0	0.098	0.098	$T = 65$

Note:

- Approximately 9.8 percent of all the country-years in the data are for countries defined as being in the Middle East
- `MidEast` has *no* within-country variation, so...
- ...it has the same value for a particular country for every year in which that country is in the data.

Exploring Variation: `PostColdWar`

The `PostColdWar` variable is coded:

- 0 if that observation occurred $\leq$ 1989
- 1 if that observation occurred $\geq$ 1990

Summary: Post-Cold War

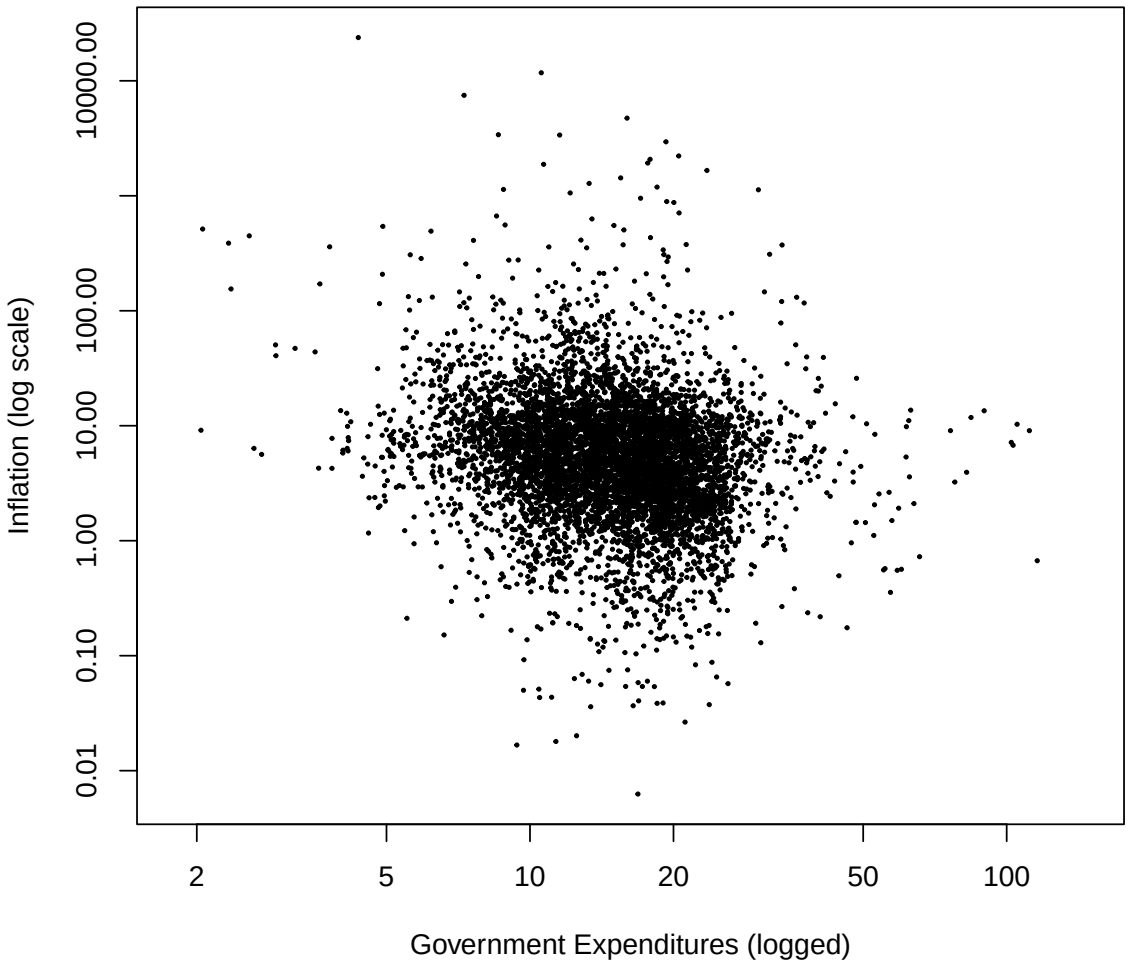
Variable	Dim	Mean	SD	Min	Max	Observations
PostColdWar	overall	0.538	0.499	0	1	$NT = 13975$
	between		0	0.538	0.538	$N = 215$
	within		0.499	0	1	$T = 65$

Note:

- Approximately 54 percent of all the country-years in the data occur after the end of the Cold War
- `PostColdWar` has *no* between-country variation, so...
- ...in a given year, it has the same value for every country that is in the data that year.

Regression!

Q: What, if anything, is the (contemporaneous) relationship between (logged) inflation rates and (logged) government spending?

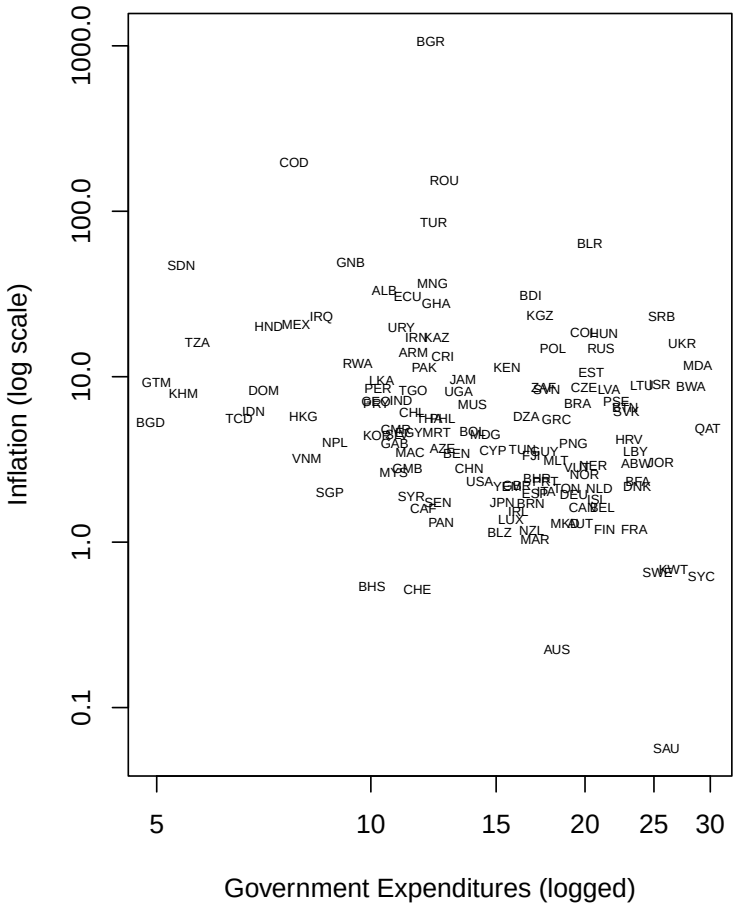


Inflation: Regression

Regression of `lnInflation` on (logged) `GovtExpenditures`: all / pooled data:

```
> Inf.fit<-lm(lnInflation~lnGovtExp,data=wdi)
> summary(Inf.fit)

Call:
lm(formula = lnInflation ~ lnGovtExp, data = wdi)

Residuals:
   Min     1Q Median     3Q    Max
-8.808 -0.689 -0.005  0.714  7.711

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   3.2578     0.1042    31.3   <2e-16 ***
lnGovtExp    -0.6060     0.0383   -15.8   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.26 on 6583 degrees of freedom
  (7390 observations deleted due to missingness)
Multiple R-squared:  0.0366, Adjusted R-squared:  0.0364
F-statistic:  250 on 1 and 6583 DF,  p-value: <2e-16
```

Inflation Regression: 1997 only

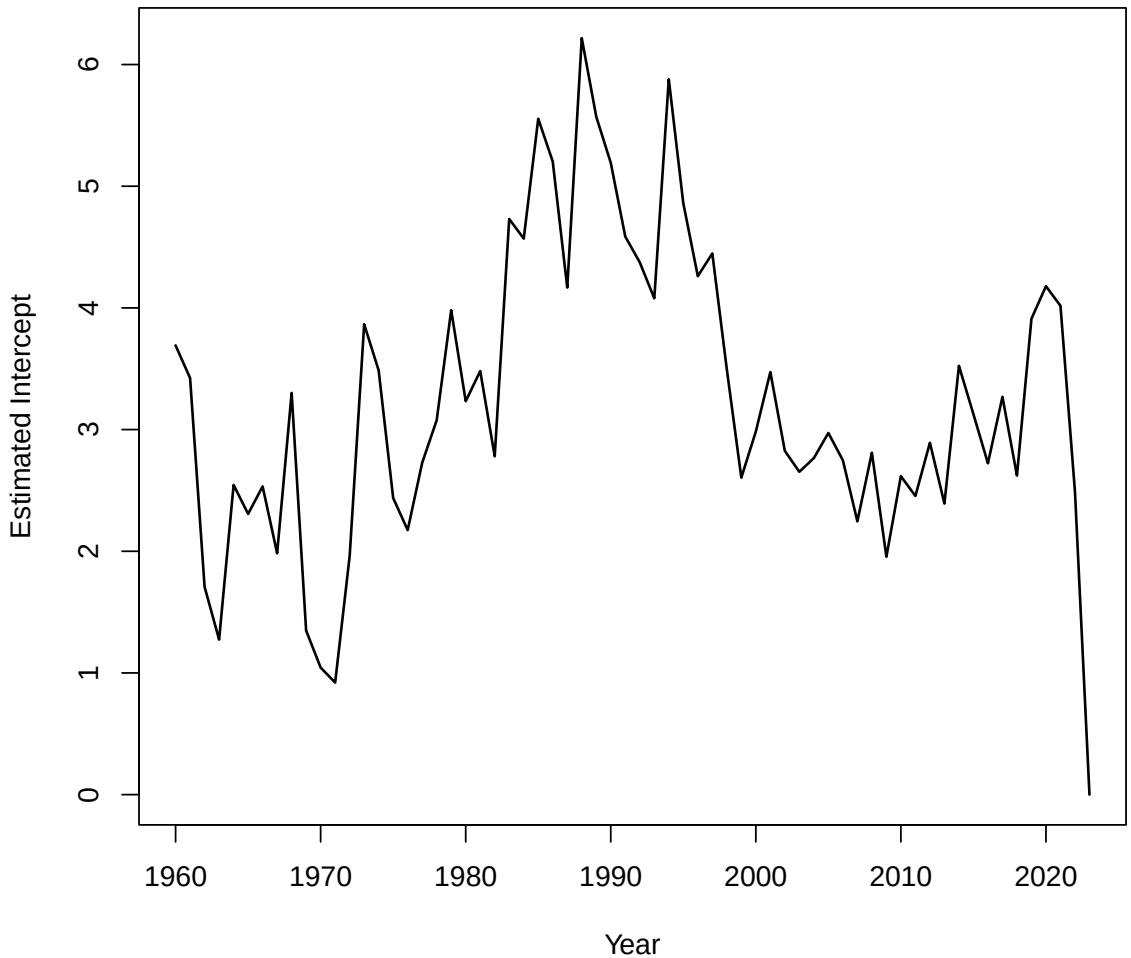


Inflation and spending, 1997:

```
> Inf.fit97<-lm(lnInflation~lnGovtExp,data=wdi97)
> summary(Inf.fit97)

Call:
lm(formula = lnInflation ~ lnGovtExp, data = wdi97)

Residuals:
   Min     1Q Median     3Q    Max
-3.930 -0.758 -0.207  0.741  5.125

Coefficients:
            Estimate Std. Error t value    Pr(>|t|)
(Intercept)    4.312      0.723    5.97 0.000000021 ***
lnGovtExp     -0.990      0.267   -3.71     0.00031 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.25 on 131 degrees of freedom
  (82 observations deleted due to missingness)
Multiple R-squared:  0.095, Adjusted R-squared:  0.0881
F-statistic: 13.7 on 1 and 131 DF,  p-value: 0.000308
```

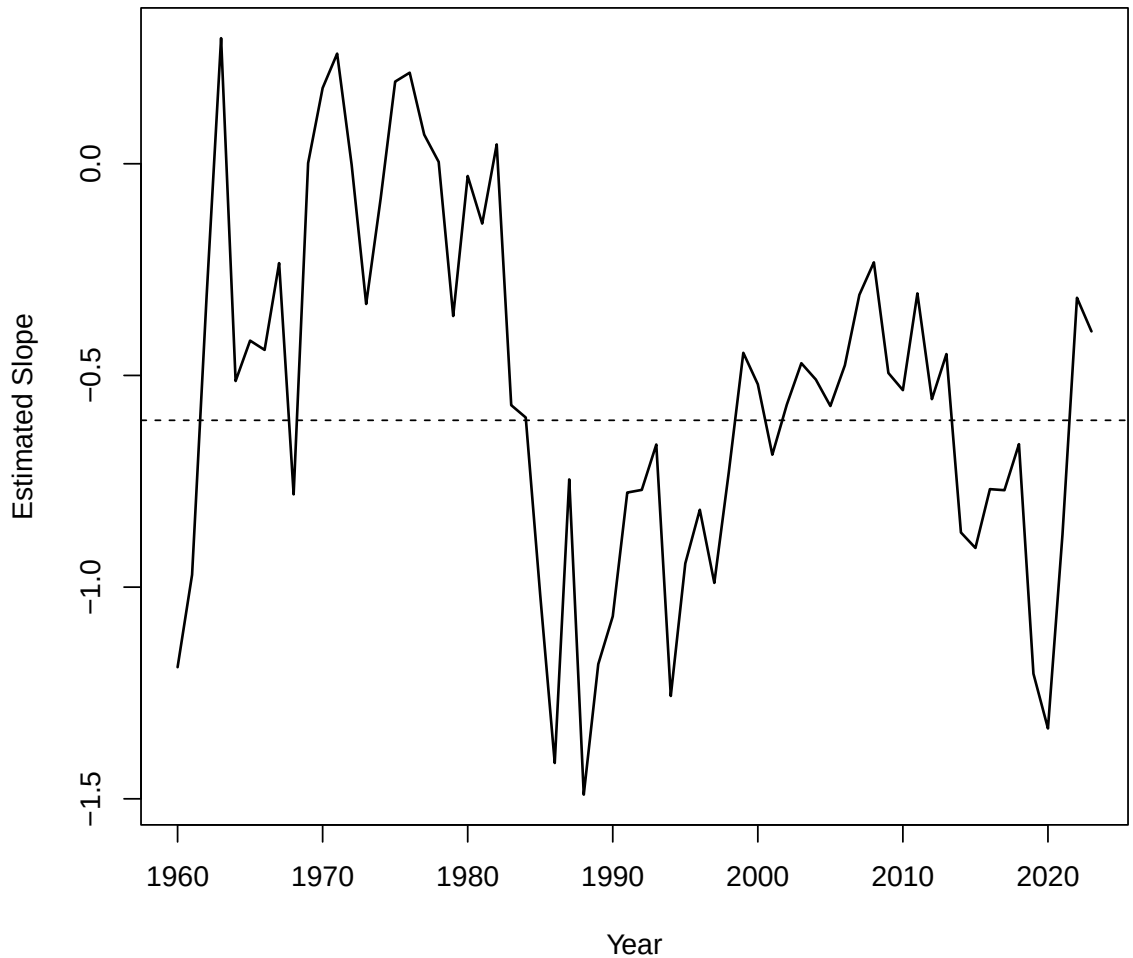
Intercepts For Every Year, 1960-2024

Estimated intercepts:



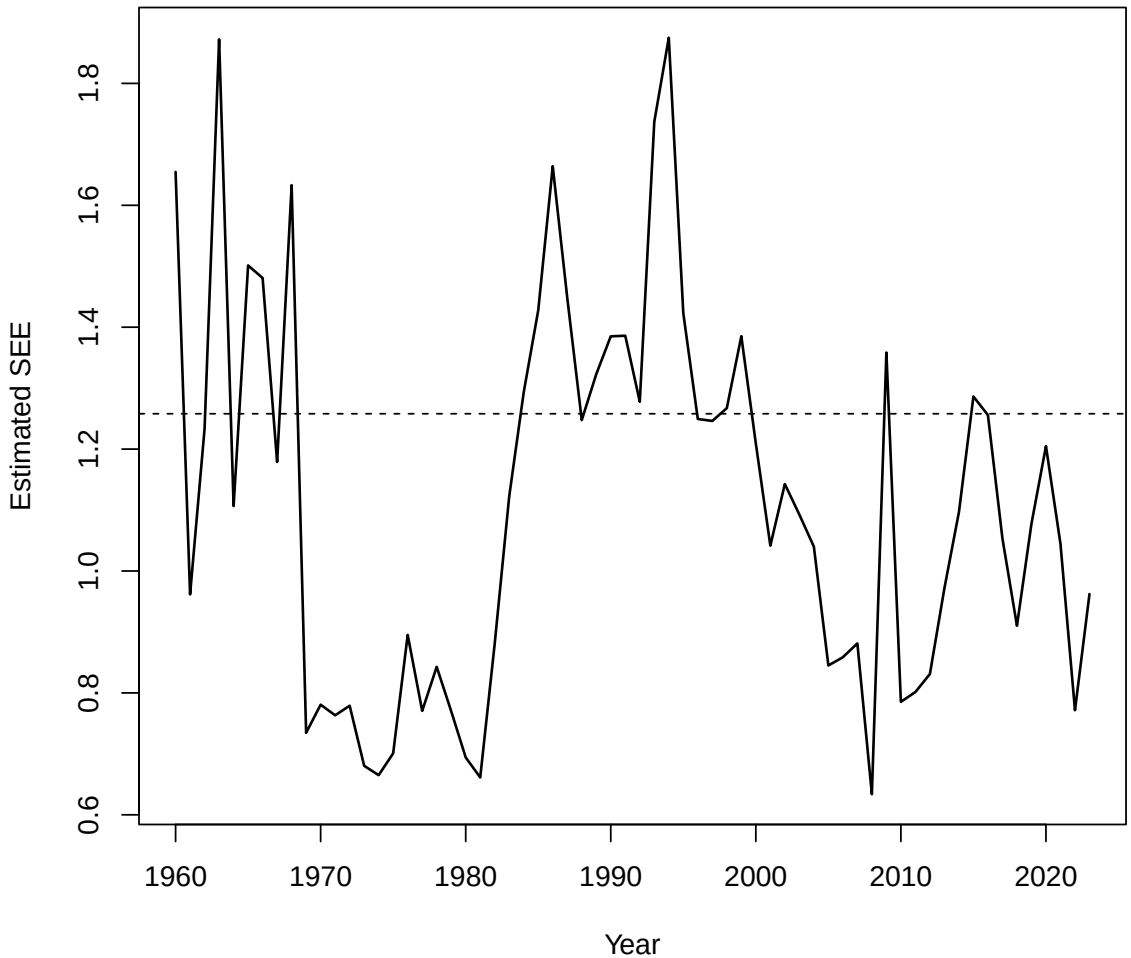
Slopes For Every Year, 1960-2023

Estimated slopes:

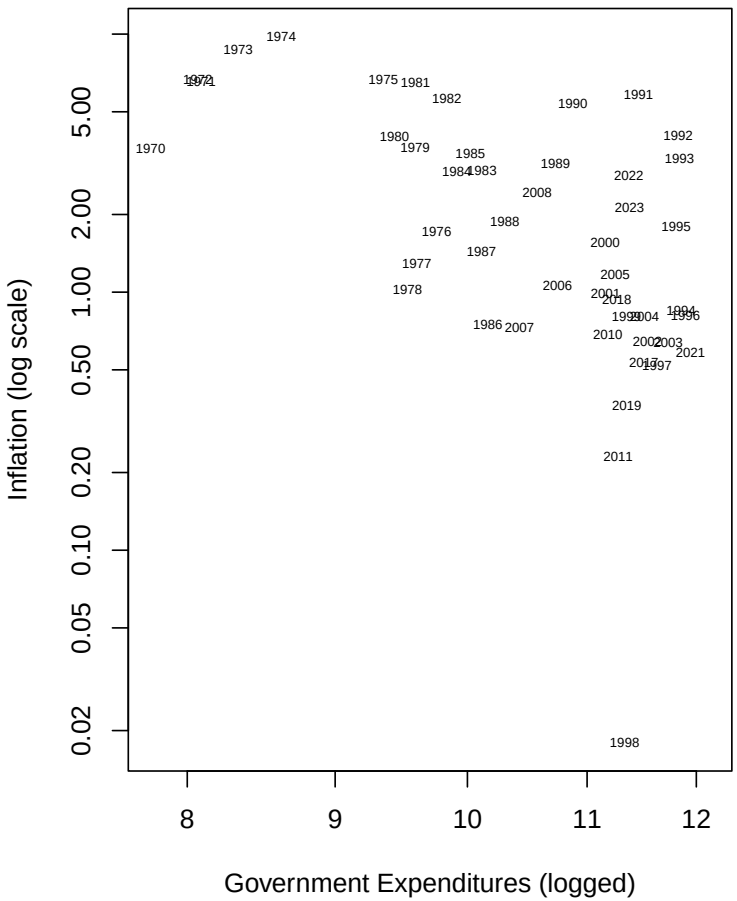


SEEs ($\hat{\sigma}$) For Every Year, 1960-2023

Estimated SEEs:



Time Series Regression: Switzerland

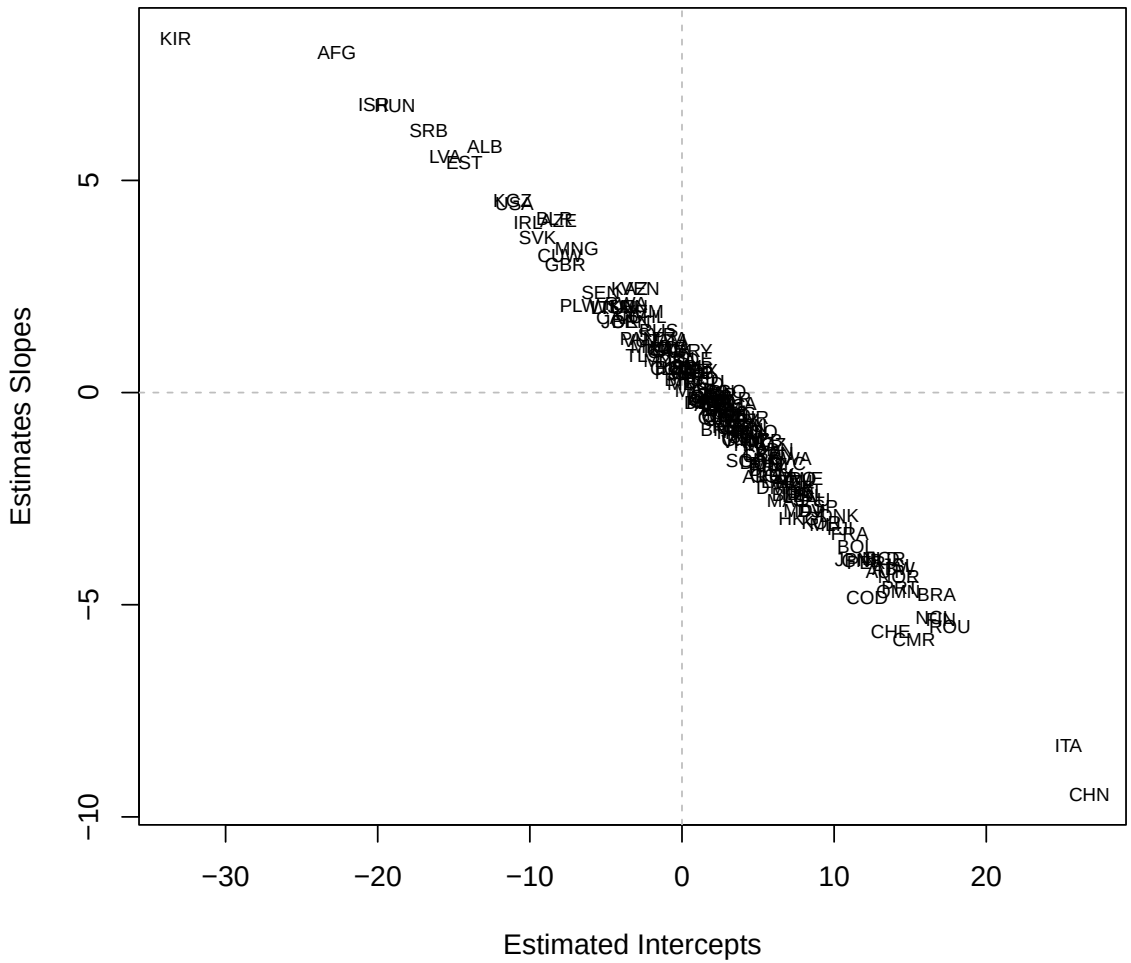


Inflation and spending in Switzerland:

```
> Inf.fitCHE<-lm(lnInflation~lnGovtExp,data=CHE)
> summary(Inf.fitCHE)

Call:
lm(formula = lnInflation ~ lnGovtExp, data = CHE)

Residuals:
   Min     1Q Median     3Q    Max
-4.023 -0.377  0.008  0.585  1.773

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)    13.72       2.90    4.73 0.000023 ***
lnGovtExp      -5.63       1.23   -4.56 0.000039 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.958 on 45 degrees of freedom
  (18 observations deleted due to missingness)
Multiple R-squared:  0.316, Adjusted R-squared:  0.301
F-statistic: 20.8 on 1 and 45 DF,  p-value: 0.0000387
```

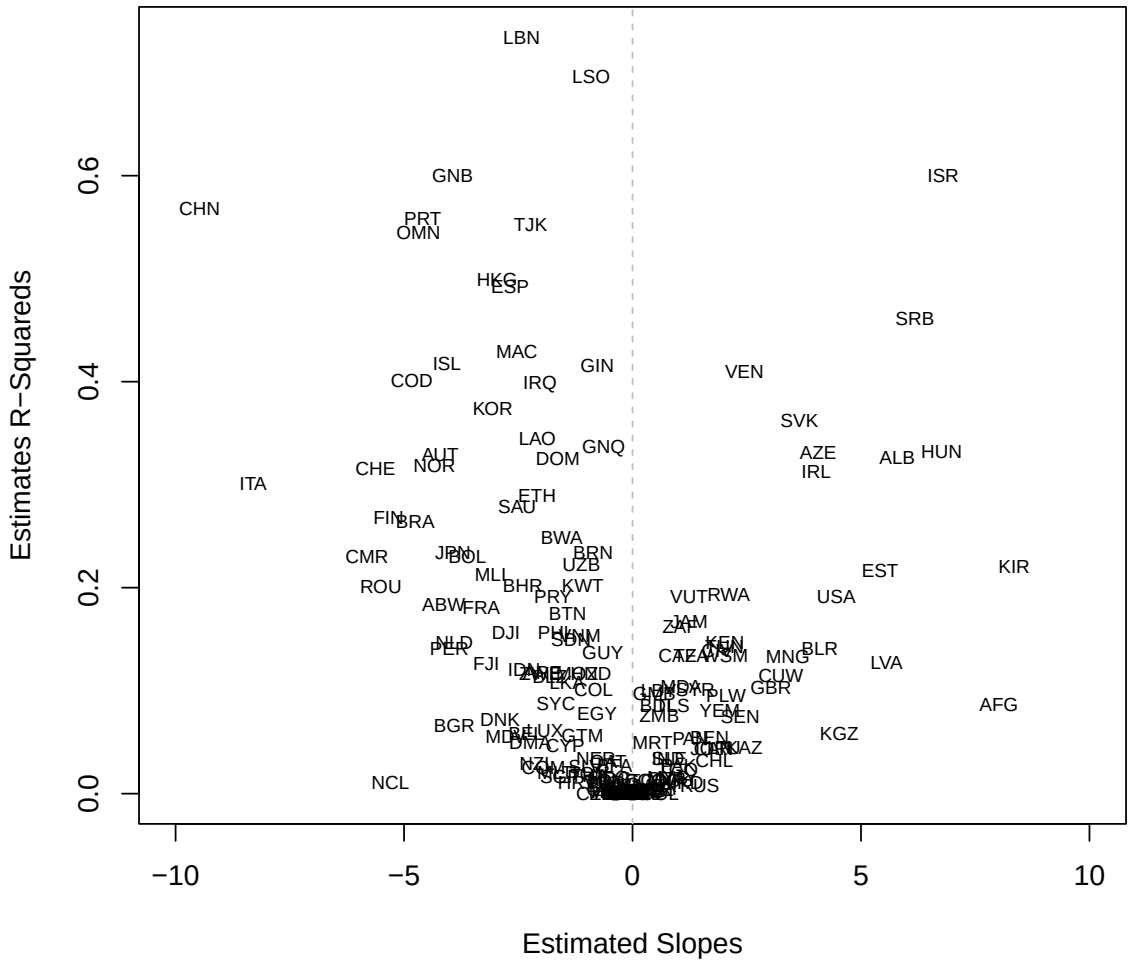
Country-Level Regressions: Intercepts & Slopes

Estimated intercepts and slopes:

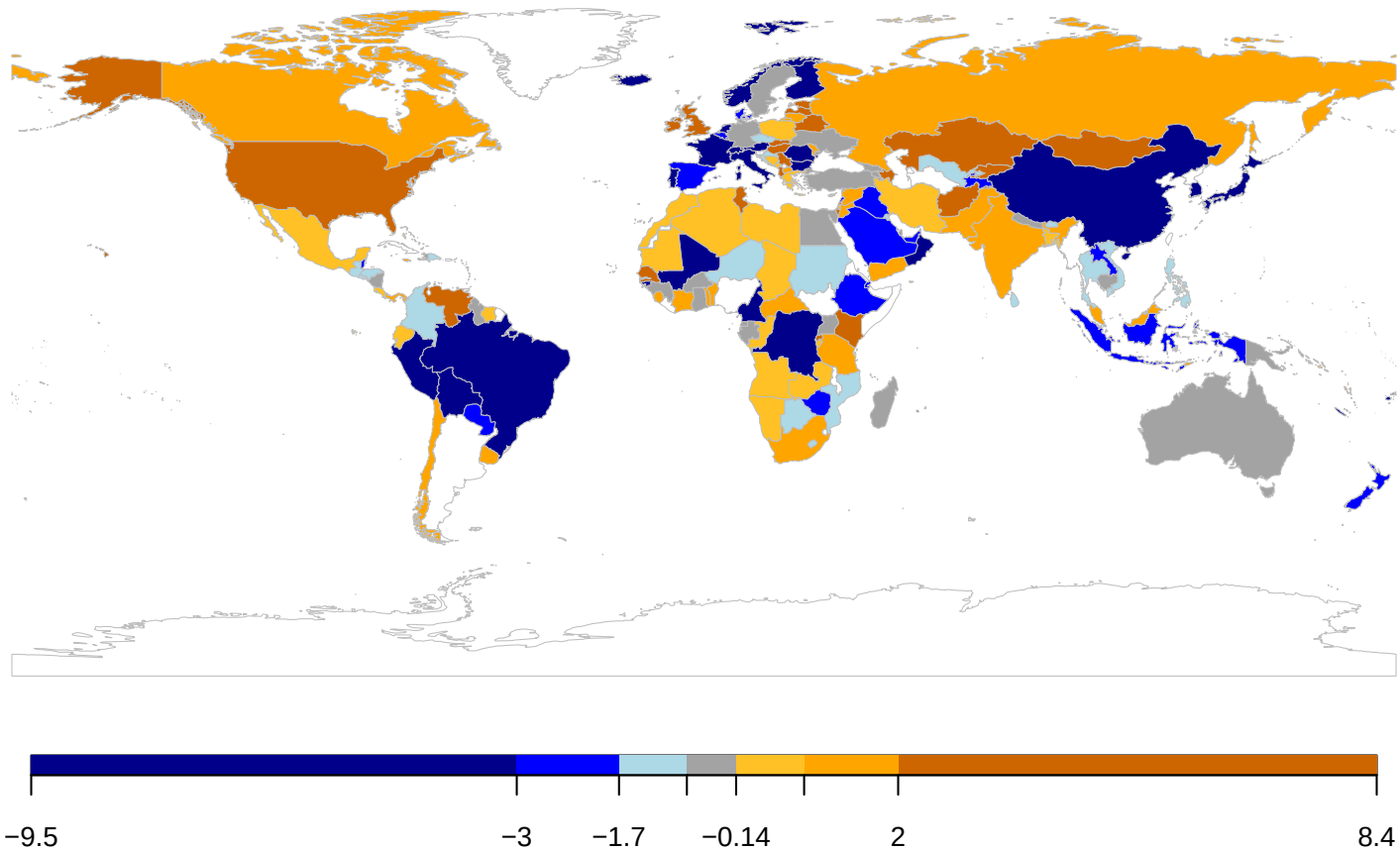


Country-Level Regressions: Slopes & R^2s

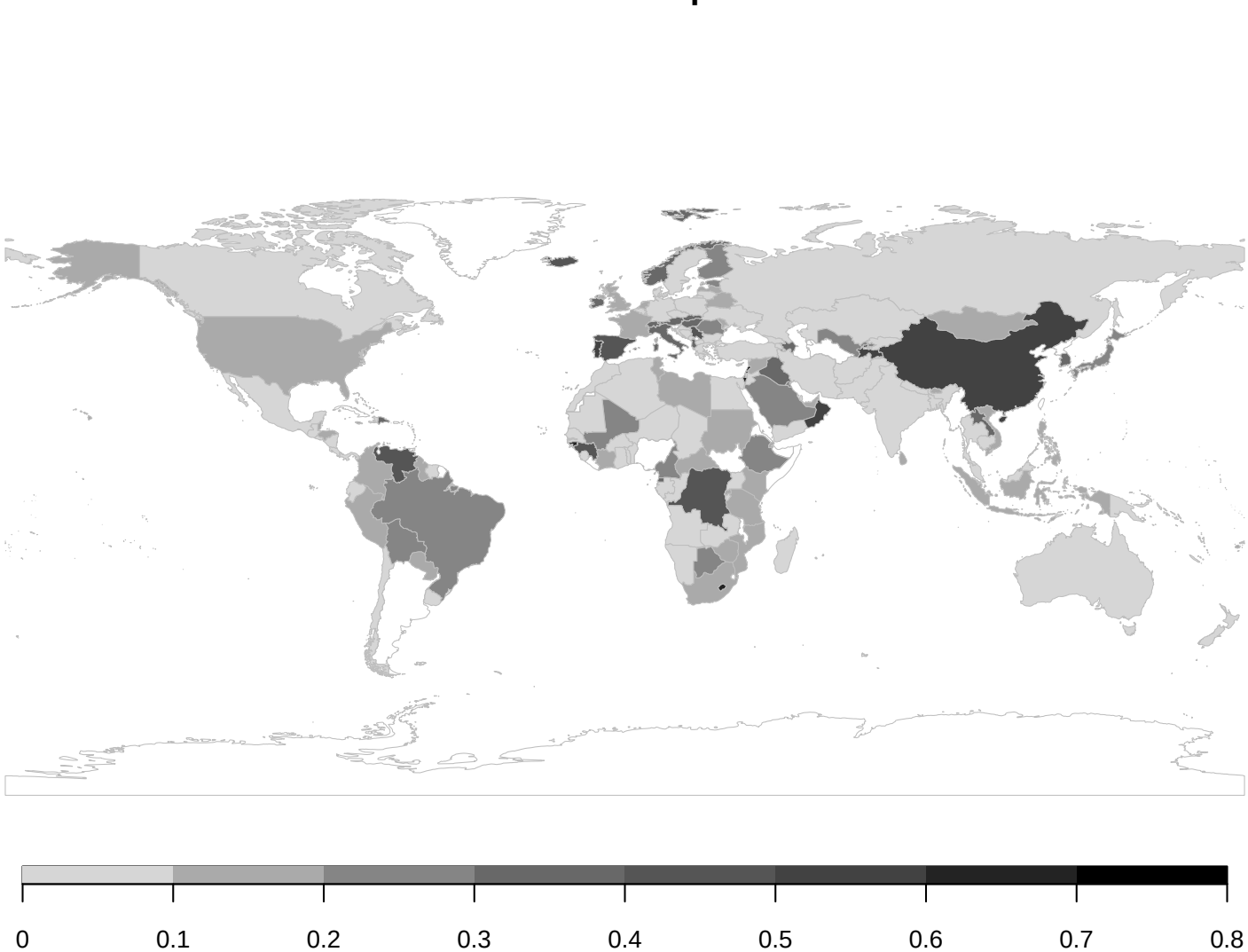
Estimated slopes and R^2s:



Maps! Country-Level Slopes ($\hat{\beta}_1$s)



Maps! Country-Level R^2s



Visualization: ExPanDaR

An interactive tool for exploring panel data...

- Creator: Joachim Gassen (Department of Accounting, Humboldt-Universität zu Berlin)
- Built upon / consistent with `ggplot` / `tidyverse`
- Requires installing the `ExPanDaR` package
- Calling

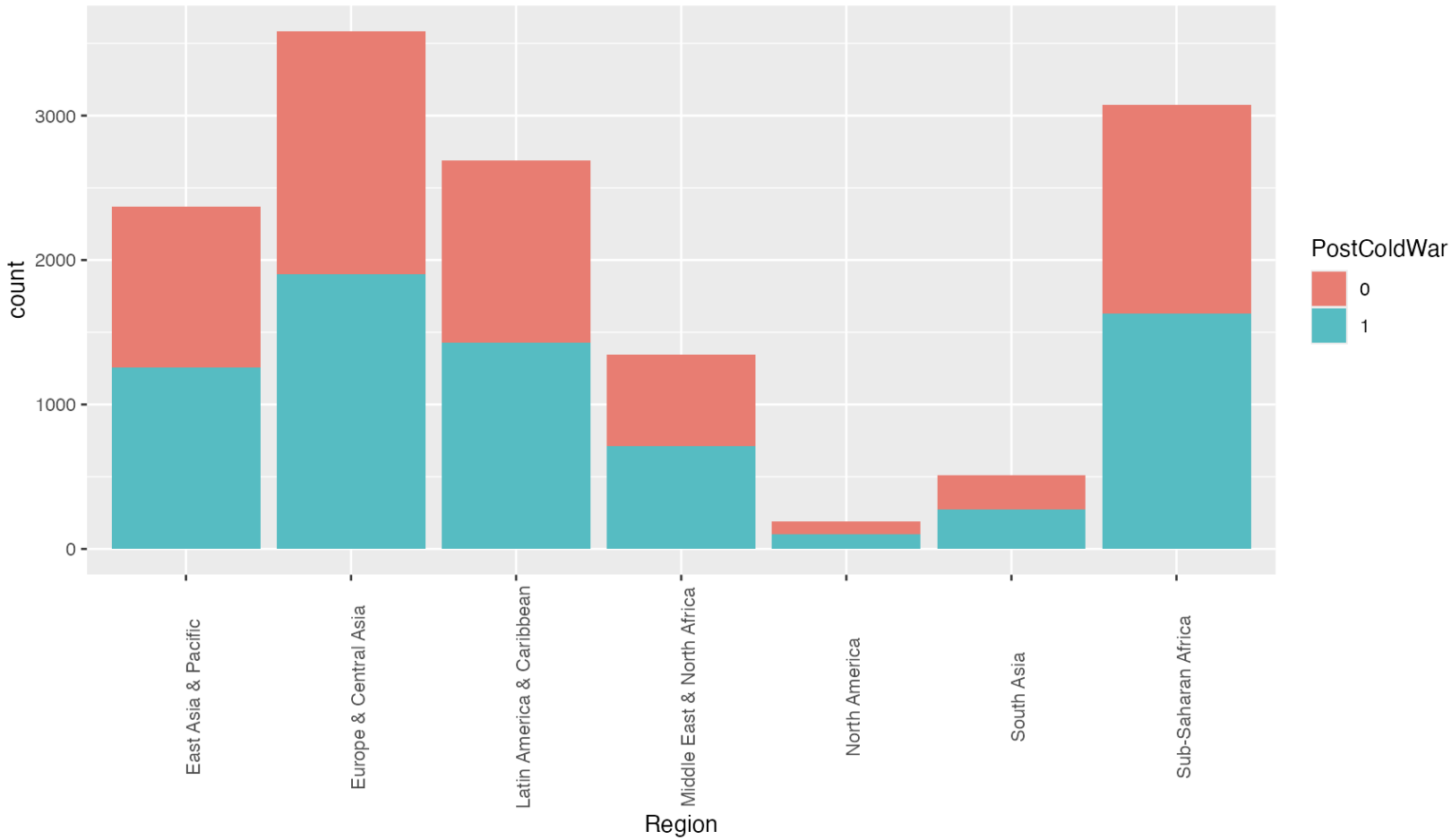
  ```
  > ExPanD()
  ```

  ...opens the Shiny app, and asks for a (pre-formatted) data frame (typically in CSV format)
- More information is here: https://github.com/trr266/ExPanDaR

Some examples...

ExPanDaR: Summaries

Counts by factors:



ExPanDaR: More Summaries

Summary statistics:

Descriptive Statistics

Hover over variable names with mouse to see variable definitions.

Select Tab to choose the analysis set of variables or the base set of variables (to define new variables).

Click here to delete selected variables from the analysis sample.

Delete Variables

Click here to delete all user defined variables and to restore the original variable set of the analysis sample.

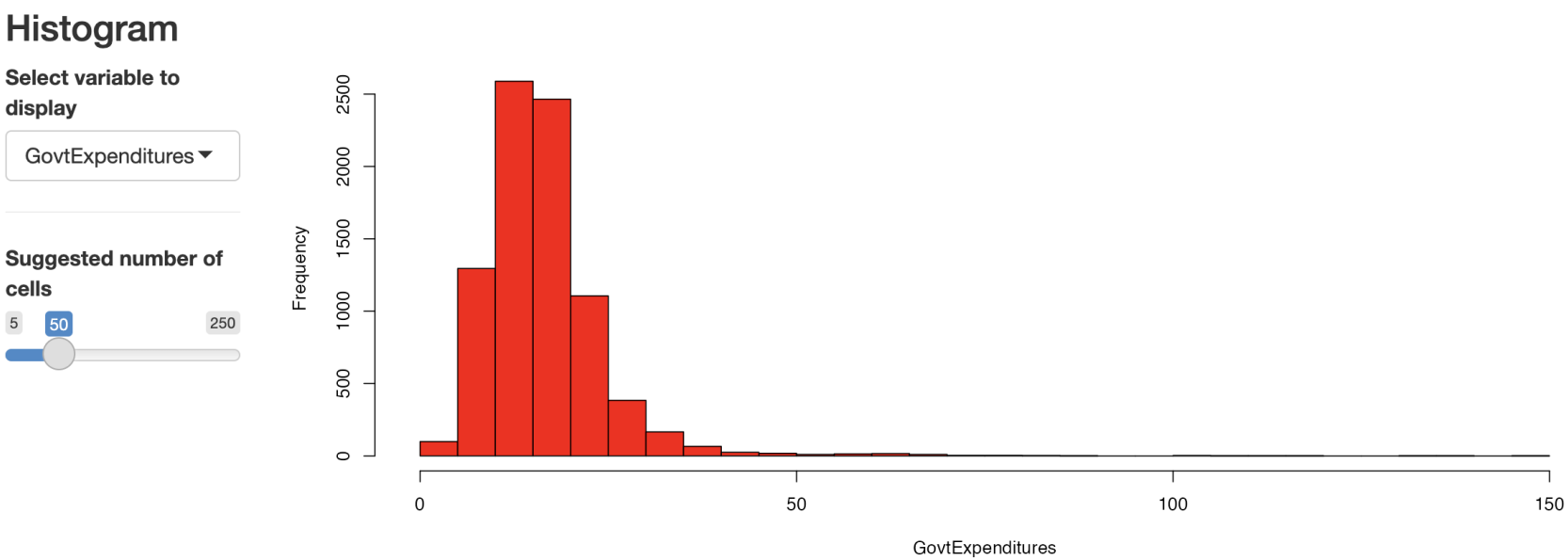
Restore Sample

Analysis Set | Base Set

Variable	N	Mean	Std. dev.	Min.	25 %	Median	75 %	Max.
V1	13,760	6,880.500	3,972.314	1.000	3,440.750	6,880.500	10,320.250	13,760.000
LandArea	11,941	605,302.933	1,639,812.915	2.027	10,230.000	107,160.000	472,710.000	16,389,950.000
ArablePercent	11,542	13.345	13.606	0.043	2.889	9.303	19.002	73.389
Population	13,515	25,109,276.976	104,750,539.243	2,646.000	504,676.000	4,294,396.000	13,872,632.500	1,417,173,173.000
PopGrowth	13,298	1.754	1.783	-27.722	0.690	1.702	2.651	20.473
RuralPopulation	13,482	48.283	25.740	0.000	27.394	49.083	69.380	97.923
UrbanPopulation	13,482	51.717	25.740	2.077	30.620	50.917	72.606	100.000
BirthRatePer1K	12,937	28.018	13.084	5.000	16.100	26.604	39.778	58.121
FertilityRate	12,779	3.906	2.000	0.772	2.080	3.418	5.791	8.864
PrimarySchoolAge	10,896	6.136	0.614	4.000	6.000	6.000	7.000	8.000
LifeExpectancy	12,766	64.627	11.291	11.995	57.540	67.467	72.941	85.498
AgeDepRatioOld	13,515	10.698	7.037	0.200	5.905	7.826	14.082	70.360
CO2Emissions	5,920	4.241	5.446	0.000	0.579	2.284	6.184	47.657
GDP	10,099	250,284,546,944.349	1,140,901,242,824.164	21,562,114.297	3,698,198,246.005	15,734,874,525.098	102,516,943,295.367	20,926,835,051,000.000
Inflation	8,547	23.496	327.098	-17.640	2.134	4.858	10.182	23,773.132
TotalTrade	8,622	78.378	53.993	0.021	44.566	67.412	97.594	863.195
Exports	8,622	36.511	28.891	0.005	18.169	29.339	46.489	433.836
Imports	8,631	41.877	27.655	0.016	24.106	35.224	52.702	429.359

ExPanDaR: Distributions

Histograms:



ExPanDaR: Outliers

Outlier Detection:

Extreme Observations

Select variable to sort data by

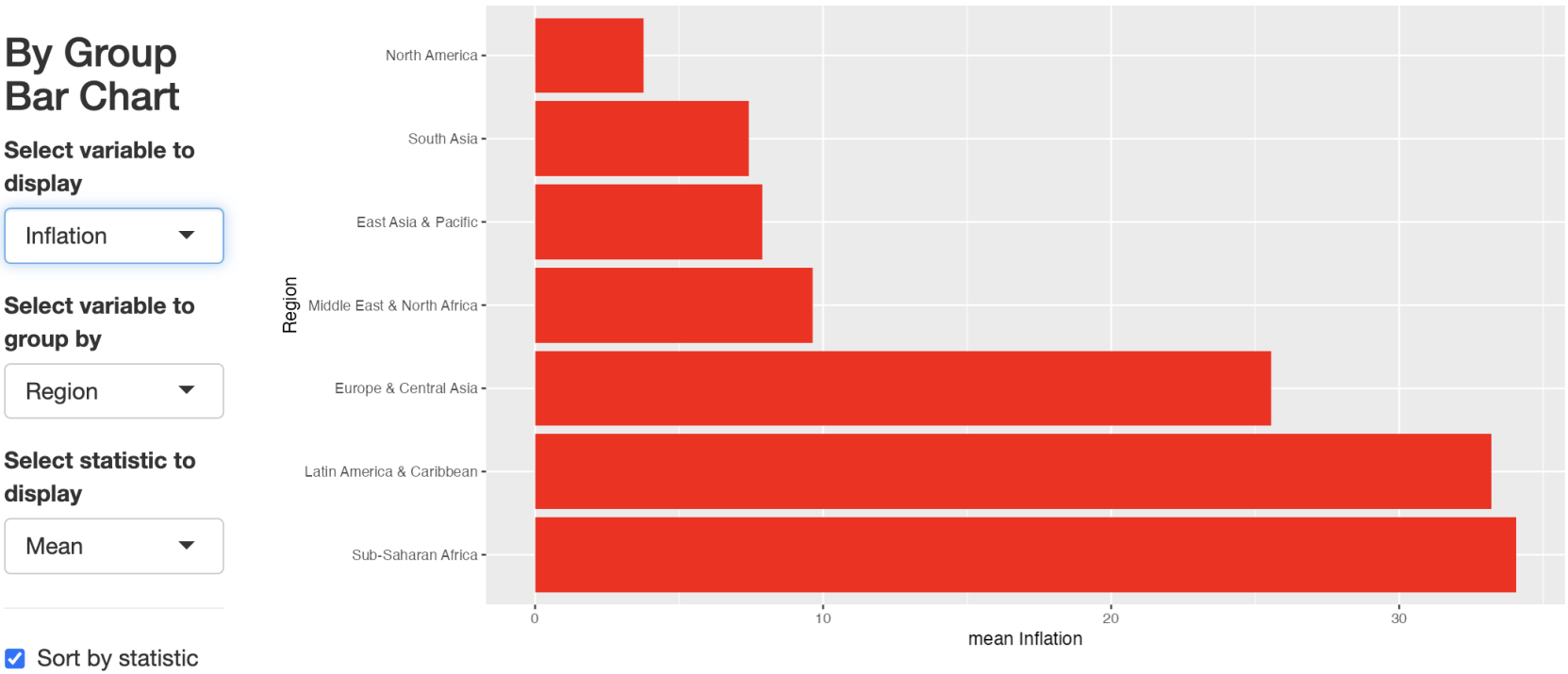
Inflation

Select period to subset to

All

ISO3	Year	Inflation
COD	1994	23,773.1
BOL	1985	11,749.6
PER	1990	7,481.7
UKR	1993	4,734.9
AGO	1996	4,145.1
...	...	...
TCD	1986	-13.1
GNQ	1987	-13.2
IRQ	1996	-16.1
LSO	2009	-16.9
GNQ	1986	-17.6

Bar Charts of Means (by factors):



ExPanDaR: More Plots

Violin Plots:

By Group Violin Chart

Select variable to display

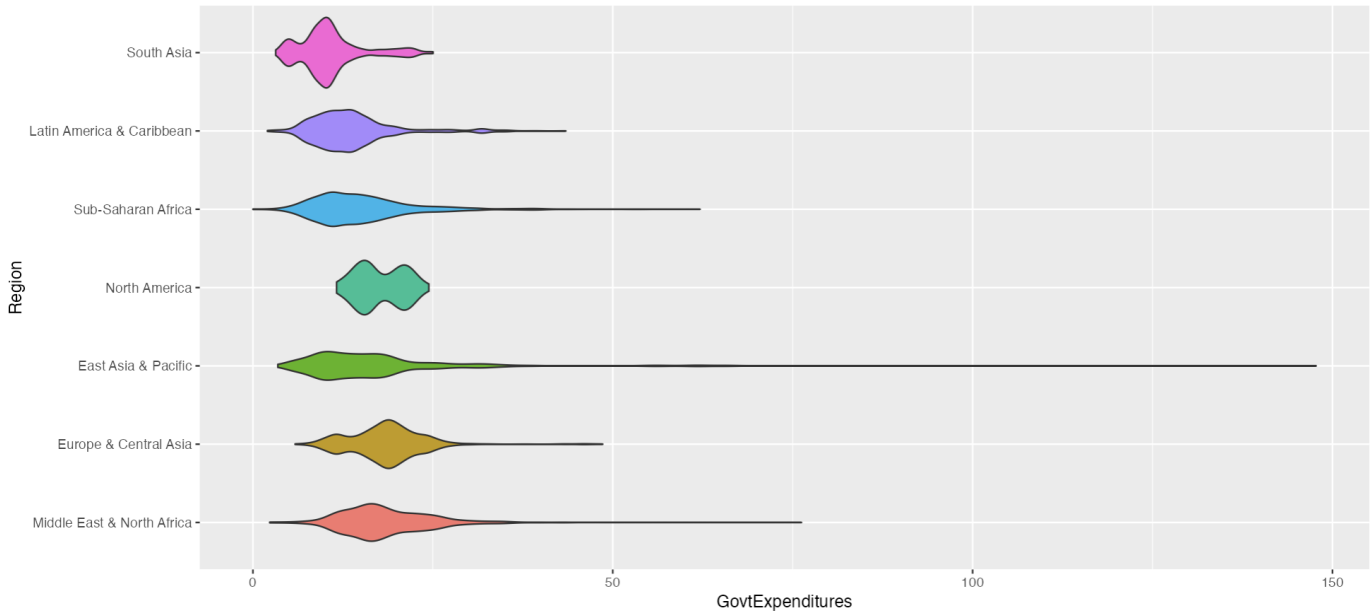
GovtExpenditures

Select variable to group by

Region

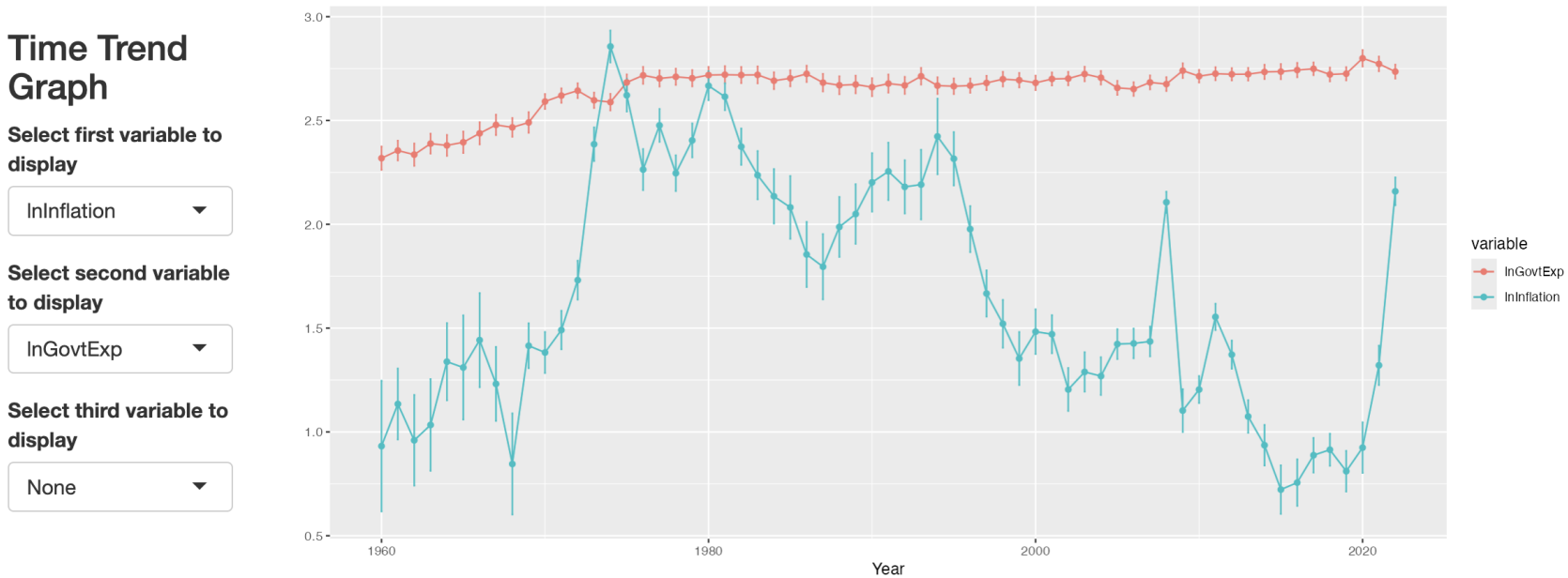
Sort by group means

(Note: Consider treating your outliers if this graph looks odd)



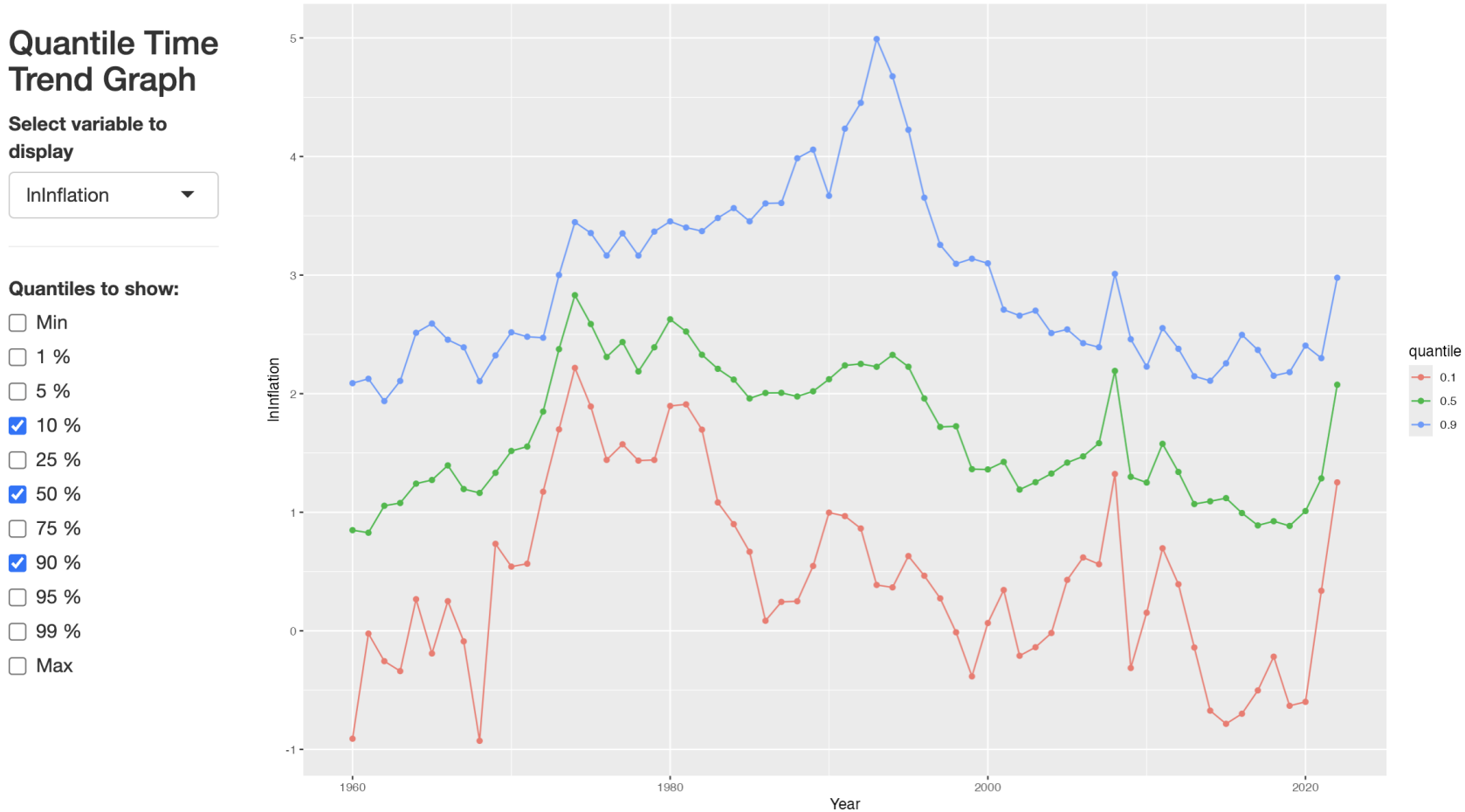
ExPanDaR: Trends

General Trends + Variation:



ExPanDaR: More Trends

Trends in Quantiles:



ExPanDaR: Even More Trends

Trends By Group:

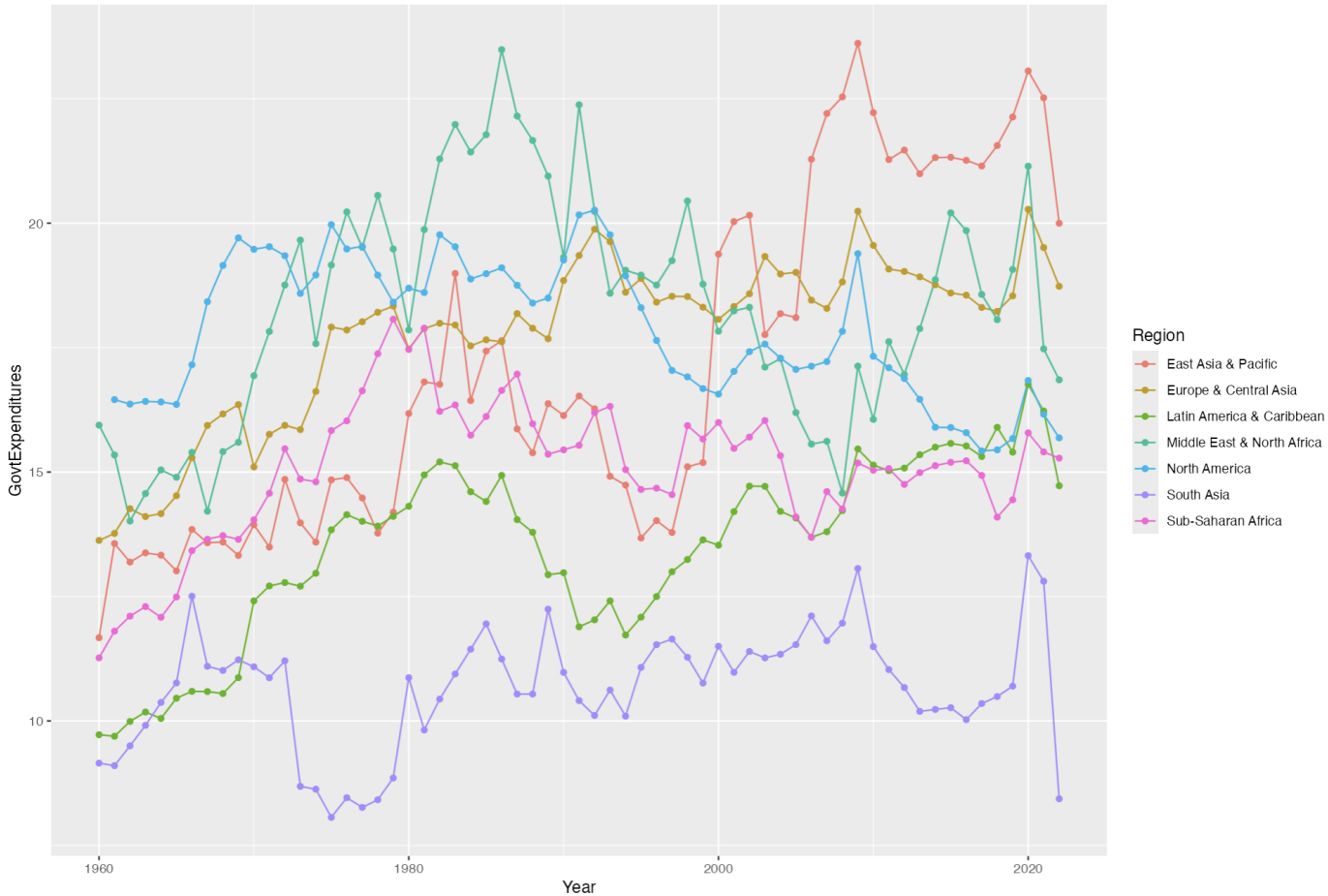
By Group Time Trend Graph

Select variable to display

GovtExpenditures

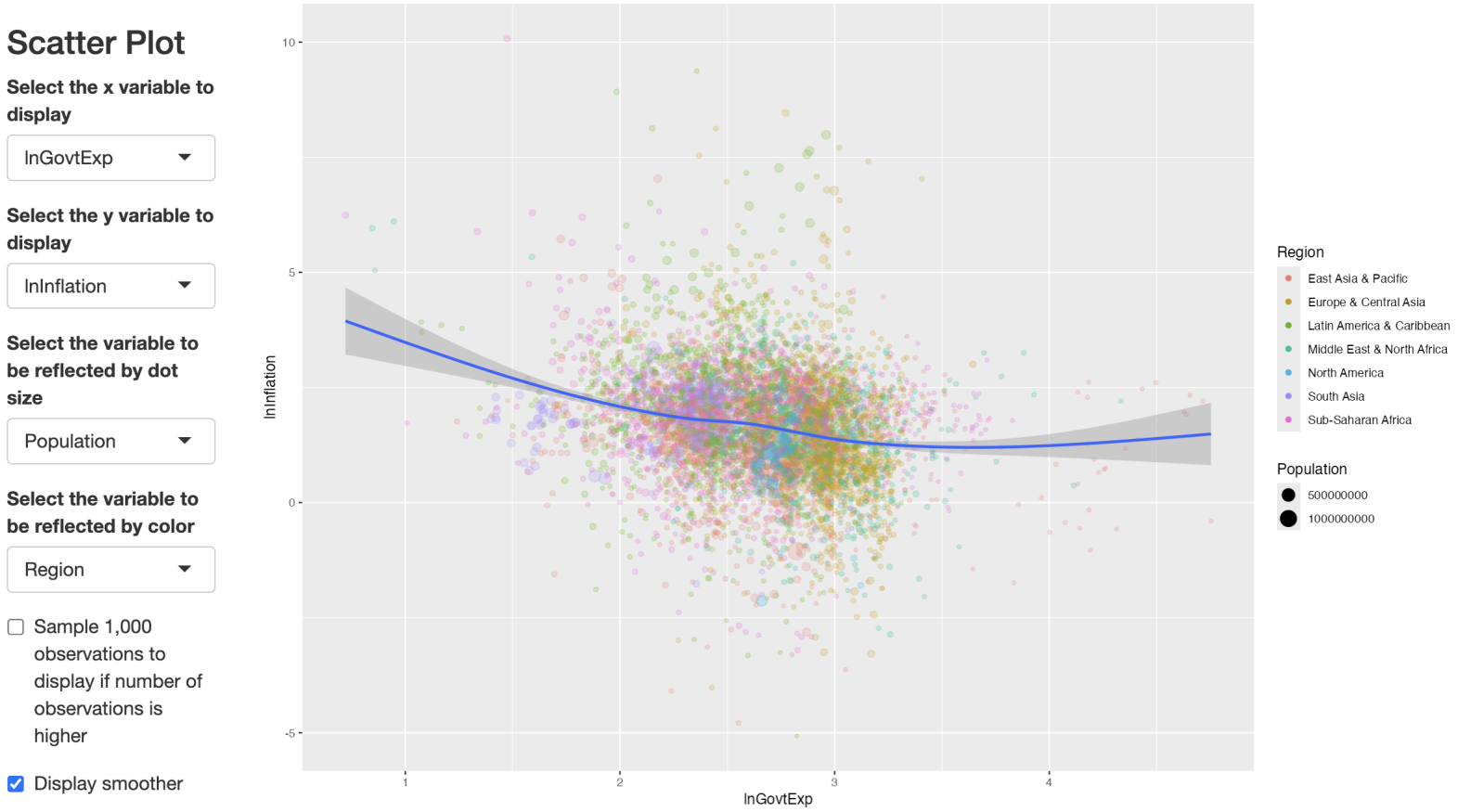
Select variable to group by

Region



ExPanDaR: Scatterplots

Fancy Scatterplots:

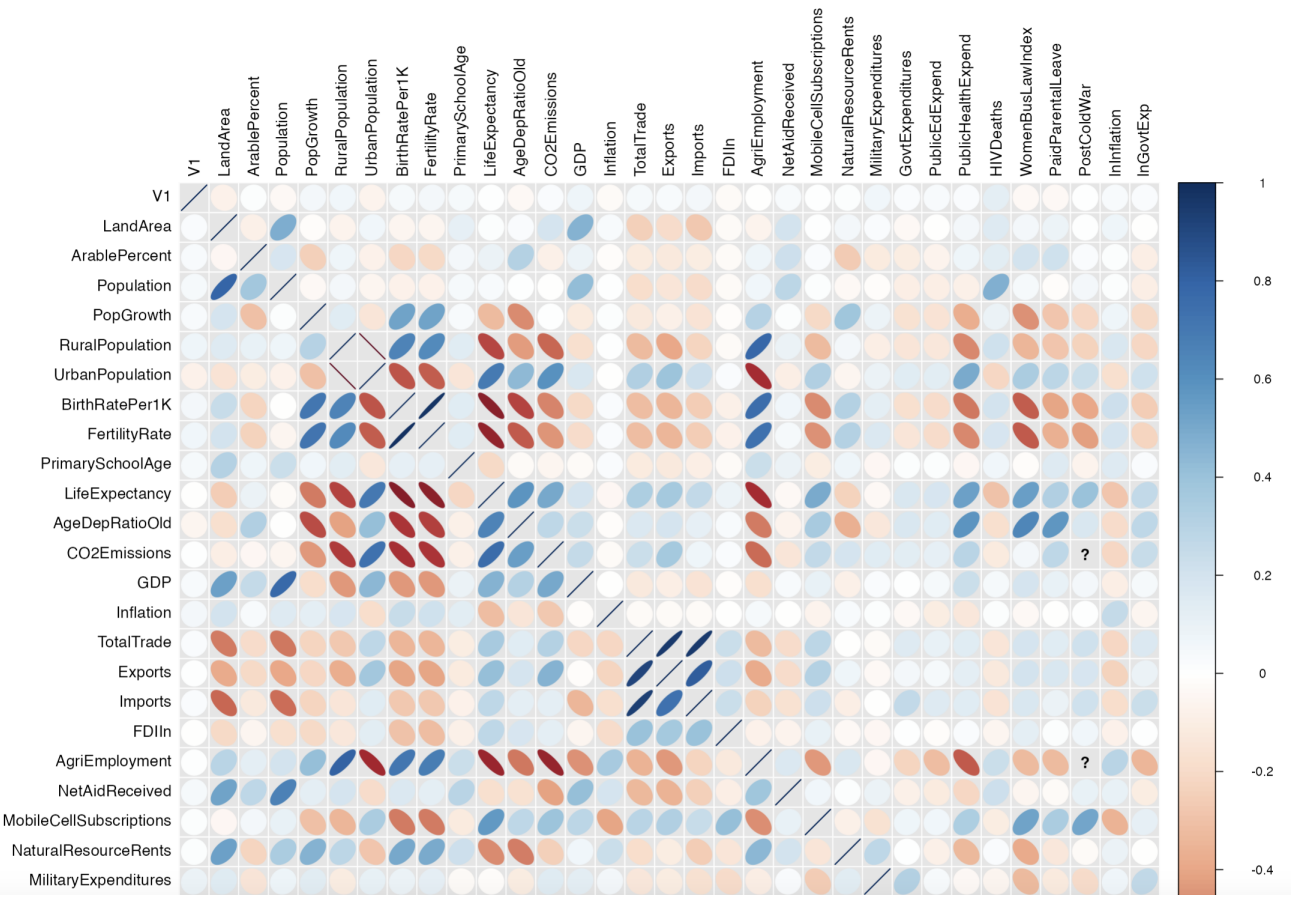


ExPanDaR: Correlations

Bivariate Correlations:

Correlation Plot

This plot visualizes sample correlations (Pearson above, Spearman below diagonal). Reports correlations for all continuous variables. Hover over ellipse to get rho, P-Value and n.



ExPanDaR: Regression

Regression (OLS) Analysis:

Regression Analysis

Select the dependent variable

lnInflation

Select independent variable(s)

- lnGovtExp
- PopGrowth
- PostColdWar
- TotalTrade
- FDIln

Select a categorial variable as the first fixed effect

None

	Dependent variable:
	lnInflation
lnGovtExp	-0.647***
	(0.040)
PopGrowth	-0.001
	(0.010)
PostColdWar	-0.652***
	(0.035)
TotalTrade	-0.004***
	(0.0003)
FDIln	-0.002**
	(0.001)
Constant	4.160***
	(0.115)
Estimator	ols
Fixed effects	None
Std. errors clustered	No
Observations	5,901
R^2	0.143
Adjusted R^2	0.142
Note:	*p<0.1; **p<0.05; ***p<0.01

The Course Plan

- Tuesday, June 17: One- and Two-Way "Unit Effects" Models (fixed, "random," etc.)
- Wednesday, June 18: Dynamics in Panel Data
- Thursday, June 19: Panel Data and Causal Inference
- Friday, June 20: Models for Discrete Responses (+ Exam)