Handout 9

Put your name here!

In this handout, we are going to revisit the Reinhart and Rogoff data. We are going to try to uncover, if we can, any causal relationship between debt-to-GDP ratios and growth rates.

Topics and Concepts Covered

- Fitting and interpreting a linear model
- Granger-causality with panel data
- Fixed-effects for giving each observation its own baseline

R Commands Covered

- More on conditional plots using `coplot`
- Adding fixed effects in `lm` using `factor`
- Using `summary$coef` to extract coefficients, standard errors, t-values, and p-values from `lm`

Reinhart and Rogoff: An Analysis

To study sovereign debt and economic growth, the economists Carmen Reinhart and Ken Rogoff (Reinhart and Rogoff 2010) have constructed an impressive data set that encompasses over 70 countries and 800 years worth of observations including variables such as inflation, exchange rates, debt-to-GDP ratios and categorical variables indicating whether a country is suffering from a debt, inflation or banking crisis. While the research is multi-faceted, the aspect that has received the most public attention is the claim that once a country's debt-to-GDP ratio crosses a threshold of approximately 90%, growth rates plummet.

This argument is not strictly academic; policy makers in both the US and Europe have been arguing over whether the current economic downturn should be greeted with more or less government spending, viewpoints I will be referring to as "Keynesian" and "austerian." In a nutshell, the Keynesian argument is that governments should spend less during times of economic growth and more during times of economic downturn. Normally, this process is handled by the Federal Reserve, through adjusting interest rates (through buying or selling US Treasury Bonds).

At the moment, interest rates are approximately zero. Since the Federal Reserve cannot lower interest rates below zero, the Fed's direct policy interventions have been exhausted (QE1 and QE2 are indirect). Government spending is the only alternative when interest rates are at zero, since private spending is not able to fill the output gap in the short-run. The Keynesians argue that the government should assume more debt when interest rates are around zero, to fill this output gap.

The austerian argument leads to the opposite policy prescription. Austerians argue that spending through deficit-financing will lead to the accumulation of more debt, increasing the risk of future sovereign default. This increase in risk will raise interest rates in the future. Since these future expectations are factored into today's investment and consumption decisions, increasing debt will place an upward pressure on *present* interest rates, slowing down current growth.

Reinhart and Rogoff: The Controversy

As mentioned above, Reinhart and Rogoff provide(d) a key piece of empirical evidence to the austerians: countries above the debt-to-GDP threshold of about 90% face precipitous growth declines. A recent study, put out by Herndon et al. at U. Mass-Amherst, shows that the 90% threshold is a result of poor data analysis by Reinhart and Rogoff. We are going to build off of Herndon's analysis.

Though not required for his handout, I recommend referring to the following articles if you are interested in this data and the debate:

- The original paper positing the 90% threshold: Reinhart and Rogoff (2010)
- Herndon et al.'s reply: Herndon, Ash, and Pollin (2014) You should focus on the first 10 pages or so
- Stephen Colbert weighs in on the issue

A few more resources, if you find the topic interesting, are:

- Reinhart and Rogoff respond in the New York Times to the Herndon et al. paper
- Herndon's co-authors respond to their response, also in the New York Times
- An early critique by Irons and Bivens: (Irons and Bivens 2010) (link). See especially the section on causality
- A blog post and follow up on 'Rortybomb' laying out the issues involved

In the data folder you will find a file `RR.lags.csv`. This file contains the variables considered by Herndon, et al. We will focus on the following variables:

- `Country`: The country with observation
- `Year`: The year of the observation
- `Infl}`: Inflation rate
- `dRGDP`: Percent difference in real GDP (i.e. inflation-adjusted) from last year to the current year
- `debtgdp`: Debt-to-GDP ratio
- `lag.debtgdp1`, `lag.debtgdp2`, `lag.debtgdp3`: Lagged values of the debt-to-GDP ratio (i.e. if the observation is made in 1990, these are the debt-to-GDP ratios for that country in 1989, 1988, and 1987)
- `dRGDP1`, `dRGDP2`, `dRGDP3`: Lagged values of the percentage difference in `dRGDP`

Conditional Plots for Causal Analysis

The Reinhart and Rogoff data pose a particular problem: there is absolutely no hope of conducting an experiment, yet answering the central macroeconomic question of our data involves discerning a causal claim of some type. There are four different claims we can make:

1. Current GDP growth is caused by past debt (the austerian argument)
2. Current debt is caused by past GDP growth (the Keynesian argument)
3. The two appear to cause each other
4. There is no causal relationship between GDP and debt

We are going to start going through these different claims, in order to ascertain which is most consistent with the data. Let's first read in the data.

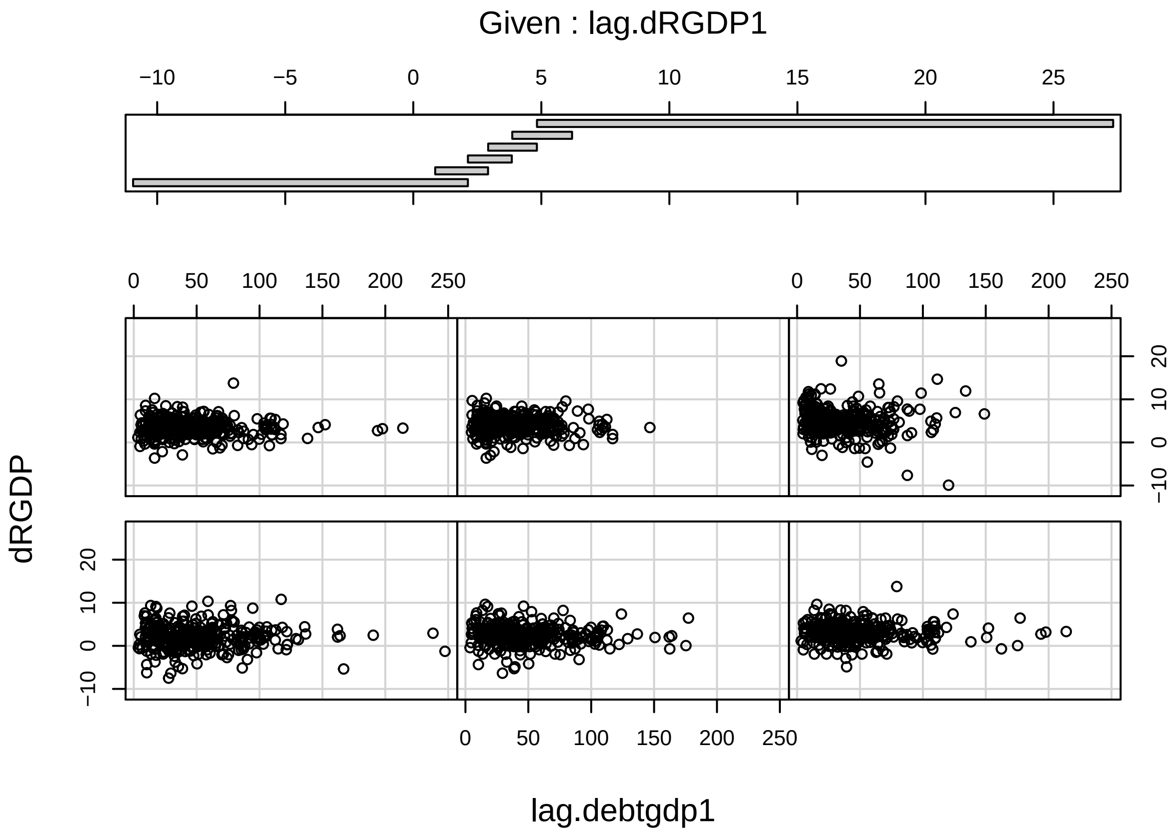
```
RR <- read.csv("data/RR.lags.csv", header = TRUE)
head(RR)
```

```
    Country Year     Infl     dRGDP   debtgdp lag.debtgdp1 lag.dRGDP1
1 Australia 1946  3.79658 -3.557951 190.41908           NA         NA
2 Australia 1947  6.80795  2.459475 177.32137     190.4191  -3.557951
3 Australia 1948 10.08840  6.437534 148.92981     177.3214   2.459475
4 Australia 1949  7.45671  6.611994 125.82870     148.9298   6.437534
5 Australia 1950  7.85522  6.920201 109.80940     125.8287   6.611994
6 Australia 1951 21.87614  4.272612  87.09448     109.8094   6.920201
  lag.debtgdp2 lag.dRGDP2 lag.debtgdp3 lag.dRGDP3
1           NA         NA           NA         NA
2           NA         NA           NA         NA
3     190.4191  -3.557951           NA         NA
4     177.3214   2.459475     190.4191  -3.557951
5     148.9298   6.437534     177.3214   2.459475
6     125.8287   6.611994     148.9298   6.437534
```

```r
attach(RR)
```

Next, we are going to look at a conditional plot.

```r
coplot(dRGDP ~ lag.debtgdp1 | lag.dRGDP1)
```

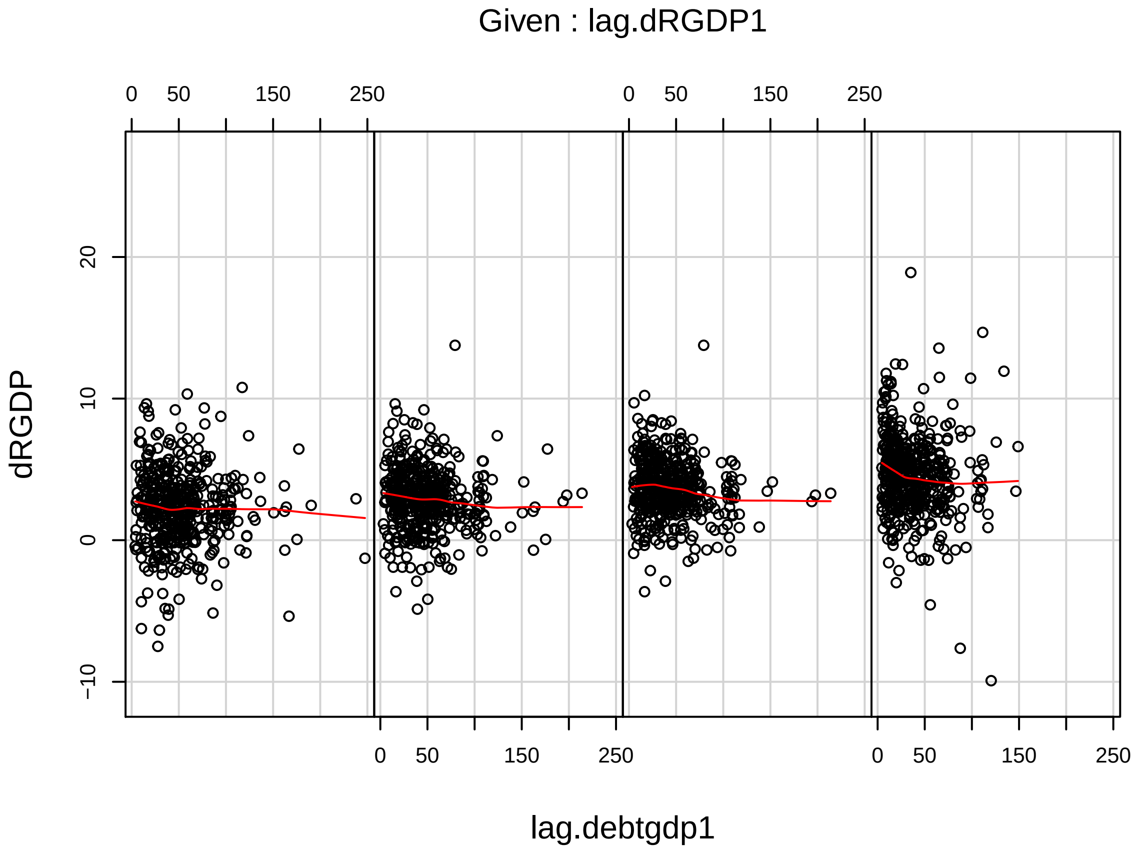



```
 Missing rows: 1, 65, 124, 187, 251, 277, 307, 371, 394, 425, 484, 524, 587, 646, 700, 753, 817, 881, 88
```

(You can ignore the line `missing.rows`. It is telling you that there is some missing data).

We are going to clean up the conditional plot a little bit. Instead of 2 x 3, let's make it a single row, with four panels. Also, let's get rid of the box up top, giving you the range of the conditioning variable. Finally, we can add a smooth curve to each panel, showing if there is any relationship between the variables in that panel. We do this with

```r
coplot(dRGDP ~ lag.debtgdp1 | lag.dRGDP1,
       panel = panel.smooth, number = 4,
       rows = 1, show.given = FALSE)
```




```
Missing rows: 1, 65, 124, 187, 251, 277, 307, 371, 394, 425, 484, 524, 587, 646, 700, 753, 817, 881, 88
```

Note the additions added into the call to `coplot`. These are

- `panel = panel.smooth` adds the smooth curves to each line
- `number = 4` tells how many boxes to produce for the figure
- `rows = 1` tells how many rows to use for the figure
- `show.given = FALSE` tells whether to include the component up top with the range of the conditioning variables.

Interpretation

The conditional plot allows us to assess the extent to which debt-to-GDP ratios in the previous time are predictive of current growth, if previous growth is held relatively constant. Each column of the conditional plot plots previous debt-to-GDP versus current growth rates. The leftmost column considers a set of homogenous observations, in the sense that their previous growth rate was low. The rightmost column considers observations for which the growth rate was highest. From this figure there appears, at best, a weak relationship between previous debt-to-GDP and current growth, if we adjust for the confounding of previous growth. This provides some suggestive evidence that previous debt is not causing a drop in current growth rates.

Do Past Values of Debt Predict Future Levels of Growth?

Next, we are going to do the same sort of assessment, except using linear models, with `lm`. We are going to see, first, whether past values of growth and debt-to-GDP are predictive of current GDP growth. We will do this through two linear models:

```r
lm1 <- lm(dRGDP ~ lag.dRGDP1 + lag.debtgdp1)
lm2 <- lm(dRGDP ~ lag.dRGDP1 + lag.dRGDP2 + lag.debtgdp1 + lag.debtgdp2)
```

To summarize these models, we can simply use `summary`. The results for the first model are:

```r
summary(lm1)
```

```
Call:
lm(formula = dRGDP ~ lag.dRGDP1 + lag.debtgdp1)

Residuals:
     Min       1Q   Median       3Q      Max 
-16.2249  -1.3755   0.0275   1.3682  12.9931 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept)   2.232344   0.176444  12.652   <2e-16 ***
lag.dRGDP1    0.390045   0.026911  14.494   <2e-16 ***
lag.debtgdp1 -0.004846   0.002395  -2.023   0.0433 *  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.564 on 1144 degrees of freedom
  (24 observations deleted due to missingness)
Multiple R-squared:  0.1701,    Adjusted R-squared:  0.1687 
F-statistic: 117.2 on 2 and 1144 DF,  p-value: < 2.2e-16
```

and for the second model are:

```r
summary(lm2)
```

```
Call:
lm(formula = dRGDP ~ lag.dRGDP1 + lag.dRGDP2 + lag.debtgdp1 + 
    lag.debtgdp2)

Residuals:
     Min       1Q   Median       3Q      Max 
-15.7384  -1.3258   0.0644   1.3784  12.3519 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept)   2.24395    0.21255  10.557   <2e-16 ***
lag.dRGDP1    0.35420    0.03220  11.000   <2e-16 ***
lag.dRGDP2    0.03301    0.02962   1.114    0.265    
lag.debtgdp1  0.01431    0.01859   0.770    0.442    
lag.debtgdp2 -0.01964    0.01786  -1.100    0.272    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.541 on 1119 degrees of freedom
  (47 observations deleted due to missingness)
Multiple R-squared:  0.1381,    Adjusted R-squared:  0.135 
F-statistic: 44.81 on 4 and 1119 DF,  p-value: < 2.2e-16
```

Let's focus in on `lm2`. We have created a regression where we want to see if *past* values of debt-to-GDP are predictive of *current* levels of growth, after accounting for previous values of *previous* levels of growth. The p-values on previous debt-to-GDP (`lag.debtgdp1`, `lag.debtgdp2`) are both well above 0.05. Therefore, these effects are not significant.

We have just shown that debt-to-GDP does not **Granger-cause** growth. This method, named after Clive Granger, strives to discern causal relationships from panel data (like when we observe the same countries over multiple years). We cannot use the method to claim that one variable causes another, but we can use it to say that one does not Granger-cause another. Basically, if a lagged independent variable is not predictive of the current levels of an outcome, when including previous values of the outcome as a predictor, then the independent variable does not Granger-cause the outcome. If the lagged value of the independent variable is predictive of the current outcome, when including the lagged outcome, then we can't say that the independent variable does not Granger-cause the outcome.

If that seems unfortunately circuitous, well, that's what happens when we try to extract causal claims from observational data in which an experiment is impossible. We can make headway, and reasonable arguments, but the analysis will require some logic and hedging.

Adding Fixed Effects

Recall that we are looking at panel data, in that we are observing the same observation (country) over multiple time periods. Often, when people analyze panel data, they will add *fixed effects* for each observation. These fixed effects can be thought of as giving each country its own intercept - we may want to include a term in the model that is simply an indicator variable for being that particular country. For example, let's do the same analysis as above, but with fixed effects by country:

```r
lm3 <- lm(dRGDP ~ lag.dRGDP1 + lag.debtgdp1 + factor(Country))
summary(lm3)
```

```
Call:
lm(formula = dRGDP ~ lag.dRGDP1 + lag.debtgdp1 + factor(Country))

Residuals:
     Min       1Q   Median       3Q      Max
-15.8825  -1.3809   0.0416   1.3539  12.9708

Coefficients:
                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                 2.622385   0.364095   7.202 1.08e-12 ***
lag.dRGDP1                  0.373352   0.027388  13.632  < 2e-16 ***
lag.debtgdp1               -0.004817   0.002840  -1.696   0.0901 .
factor(Country)Austria     -0.102503   0.468553  -0.219   0.8269
factor(Country)Belgium     -0.488013   0.471758  -1.034   0.3011
factor(Country)Canada      -0.023877   0.459850  -0.052   0.9586
factor(Country)Denmark     -0.864669   0.477074  -1.812   0.0702 .
factor(Country)Finland     -0.398587   0.459854  -0.867   0.3863
factor(Country)France      -0.157824   0.481272  -0.328   0.7430
factor(Country)Germany     -0.617679   0.472069  -1.308   0.1910
factor(Country)Greece      -0.629592   0.528777  -1.191   0.2340
factor(Country)Ireland      0.116714   0.465061   0.251   0.8019
factor(Country)Italy       -0.454844   0.468884  -0.970   0.3322
factor(Country)Japan        0.310694   0.480786   0.646   0.5183
factor(Country)Netherlands -0.579753   0.481544  -1.204   0.2289
factor(Country)New Zealand -0.536698   0.459781  -1.167   0.2433
factor(Country)Norway      -0.229523   0.459094  -0.500   0.6172
```

```
factor(Country)Portugal    -0.070717   0.473473  -0.149   0.8813
factor(Country)Spain       -0.401265   0.519480  -0.772   0.4400
factor(Country)Sweden      -0.680352   0.457930  -1.486   0.1376
factor(Country)UK          -0.659056   0.472684  -1.394   0.1635
factor(Country)US          -0.289167   0.459858  -0.629   0.5296
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.569 on 1125 degrees of freedom
  (24 observations deleted due to missingness)
Multiple R-squared:  0.1812,    Adjusted R-squared:  0.1659
F-statistic: 11.85 on 21 and 1125 DF,  p-value: < 2.2e-16
```

You will notice in the regression table that each country, except one, gets its own intercept. R will automatically drop the first level, which is Australia, in this data. The fixed effect is a means of capturing unexplained heterogeneity across countries. You do not know what, exactly, is unique about, say, Denmark, but the Denmark fixed effect of -0.865, gives all observations from Denmark a baseline specific to Denmark. Normally, when we encounter panel data, we add fixed effects for each observation (`Country`), by time period (`Year`), or both.

In terms of our analysis, note that the p-value on previous debt-to-GDP is no longer significant at the 0.05 level ($p = 0.0901$). It appears that, in this model as well, previous debt-to-GDP is not Granger causing current growth.

Precept Problems

In these problems, you are going to continue the analysis from above. (This means the data is already loaded).

Question 1

One observation has a value of `dRGDP` greater than 25! Find this observation, and explain why the value is so high.

Question 2

Next, revisit the conditional plot from the first part. This time evaluate whether previous GDP has a predictive effect on current debt-to-GDP, after accounting for the confounding of previous debt-to-GDP.

Taken together, what do these two figures suggest about the causal relationship between debt-to-GDP and growth?

Question 3

Repeat the same set of regressions from the second part, but try to explain current debt-to-GDP, instead of growth. Please try it without fixed effects, and then with different fixed effects specifications (country, year, country and year).

Question 4

Imagine you are at a conference with David Cameron, Angela Merkel, Barack Obama, and Shinzo Abe. (If you don't know who these people are, please look them up.) Ben Bernanke is moderating. Reinhart and Rogoff just presented their data (which, in fairness, involves more than we are looking at). They end up quoting an IMF report, which states:

> Much of the empirical work on debt overhangs seeks to identify the 'overhang threshold' beyond which the correlation between debt and growth becomes negative. The results are broadly similar:

> above a threshold of about 95 percent of G.D.P., a 10 percent increase in the ratio of debt to G.D.P. is identified with a decline in annual growth of about 0.15 to 0.20 percent per year. (link)

When they finish, the audience turns and looks to you. What do you say?

(You should have no doubt, by now, of my opinion on this issue. I cannot claim Absolute Correctness on this issue. If you disagree, feel free, and back it up however you wish—using this data, other citations, whatever works for you.)

References

Herndon, T., M. Ash, and R. Pollin. 2014. "Does High Public Debt Consistently Stifle Economic Growth? A Critique of Reinhart and Rogoff." *Cambridge Journal of Economics* 38 (2): 257–79. https://doi.org/10.1093/cje/bet075.

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Reinhart, Carmen M., and Kenneth S. Rogoff. 2010. "Growth in a Time of Debt." *American Economic Review* 100 (2): 573–78. https://doi.org/10.1257/aer.100.2.573.