An Exploratory Data Analysis of OECD's 2012 PISA Surveys

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Iowa State University

Joint exploration with
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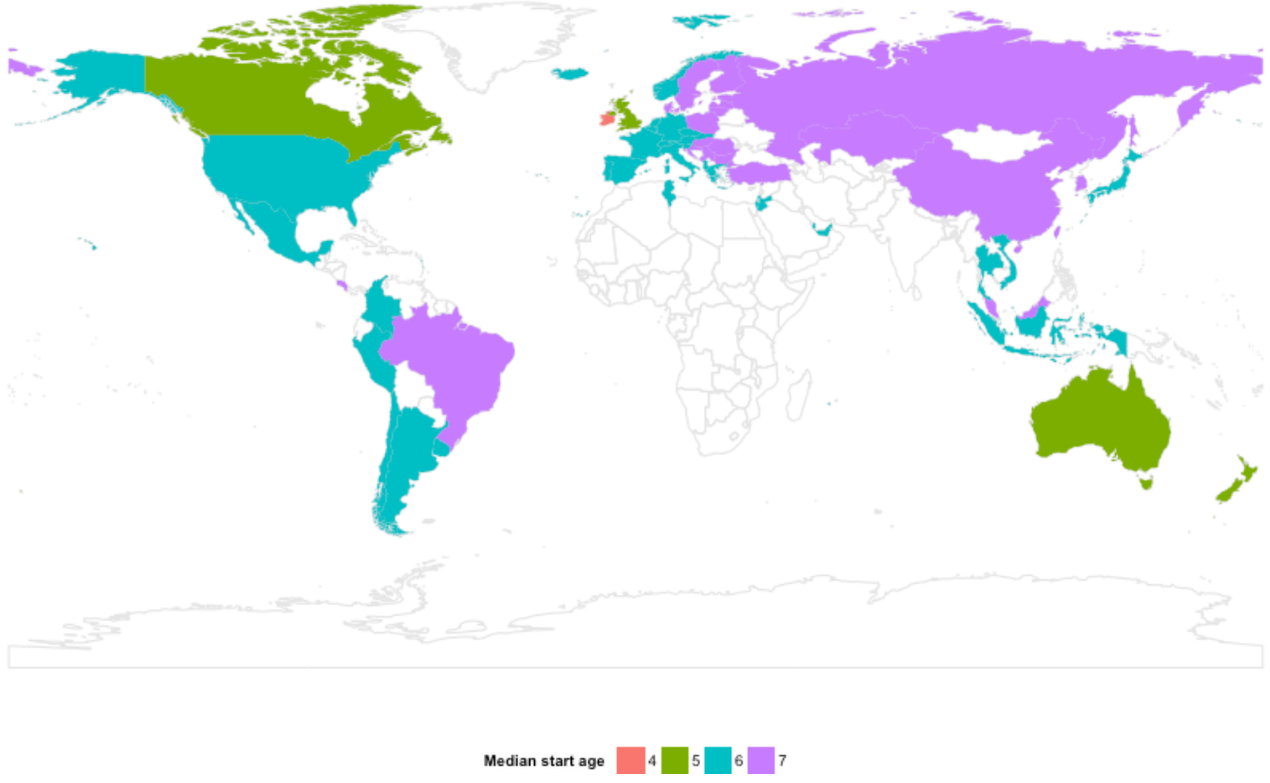
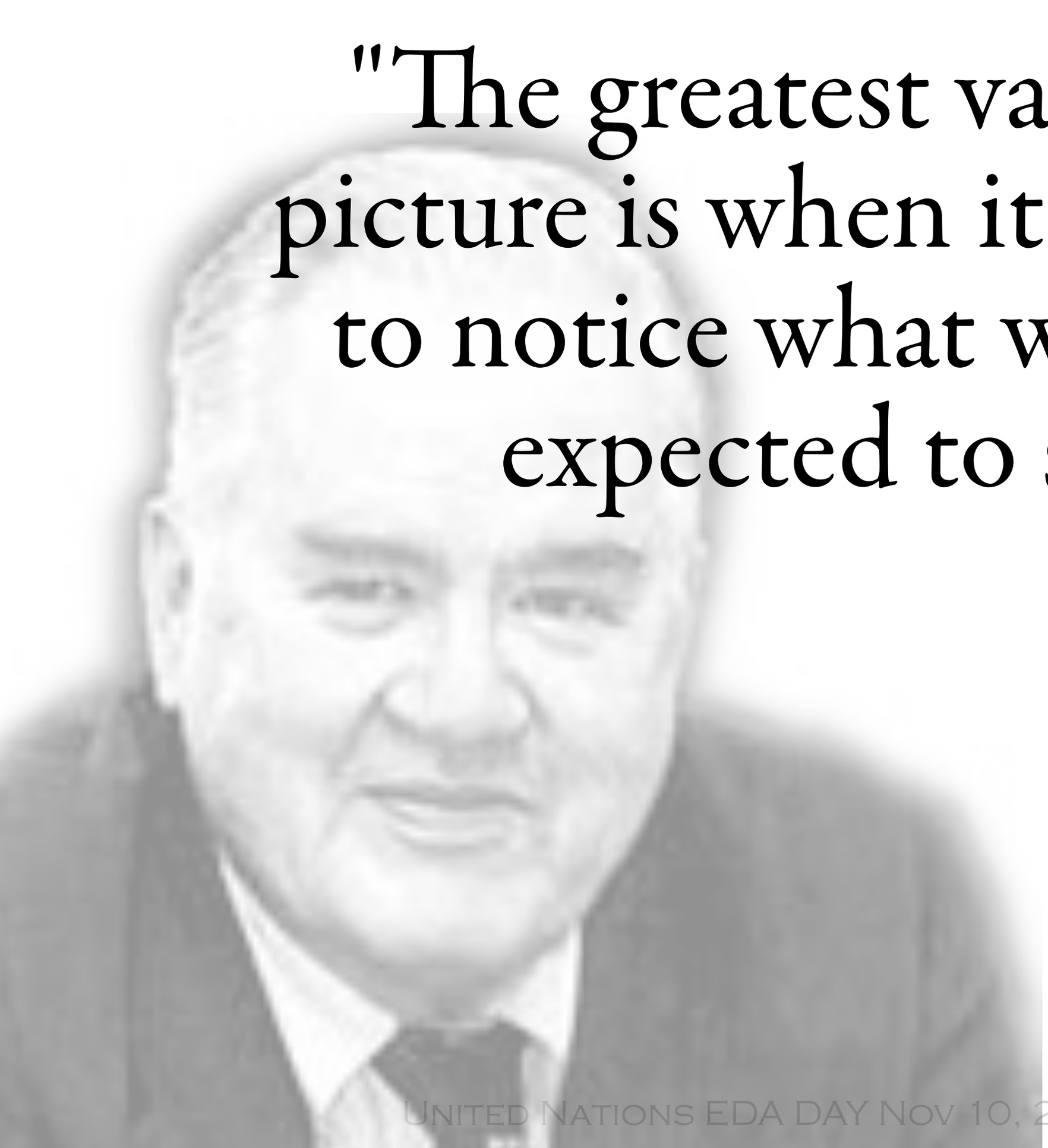
Ian Lyttle



United Nations EDA DAY Nov 10 2014



"The greatest value of a picture is when it forces us to notice what we never expected to see."

Education - my expectations

- Gender gap: “boys are better at math”
- USA doesn’t perform well compared to other countries
- Would expect parents, time studying and socioeconomic status to be important.

DATA

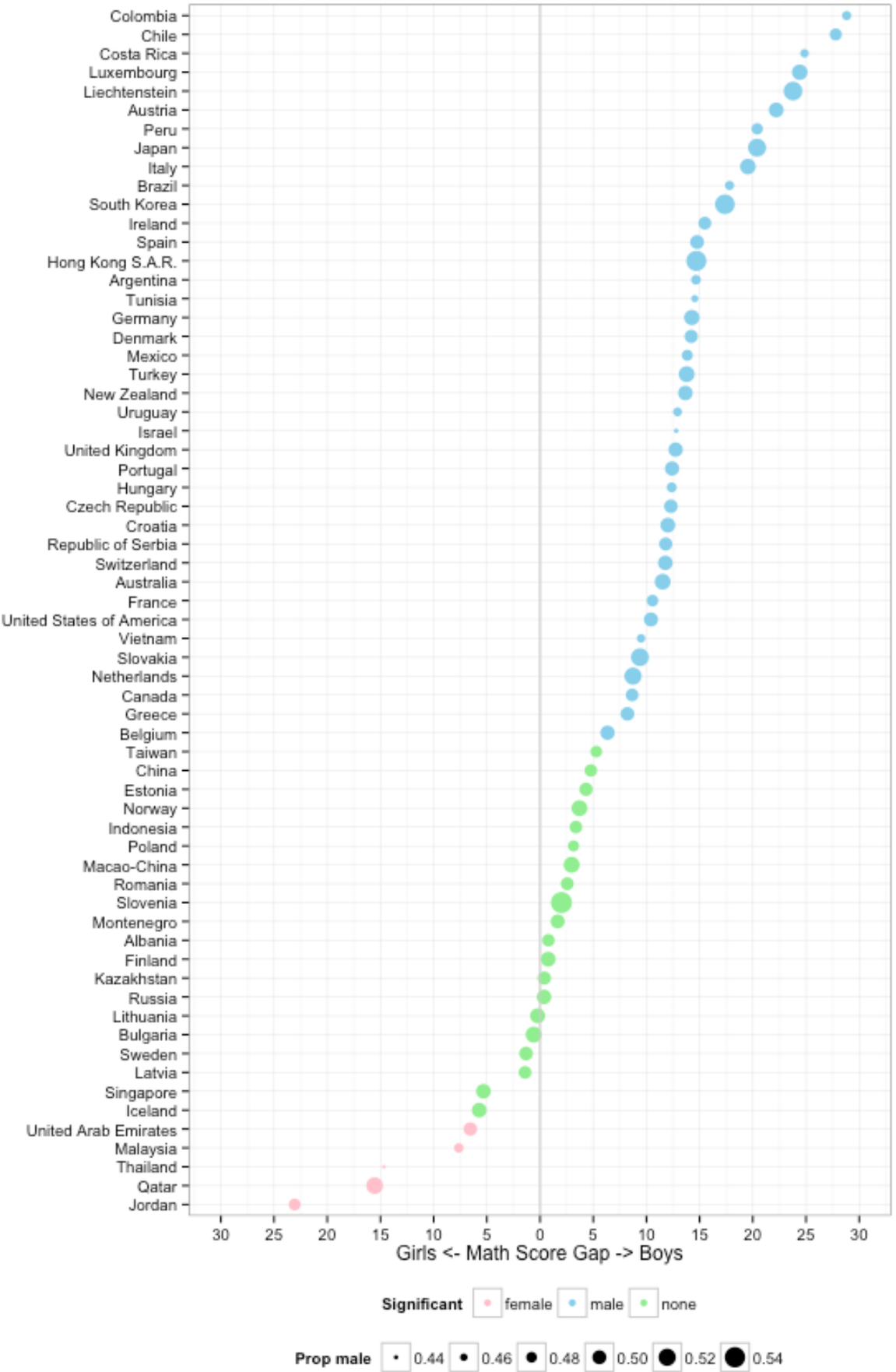
Results from 2012 OECD PISA tests: "the world's global metric for quality, equity and efficiency in school education".

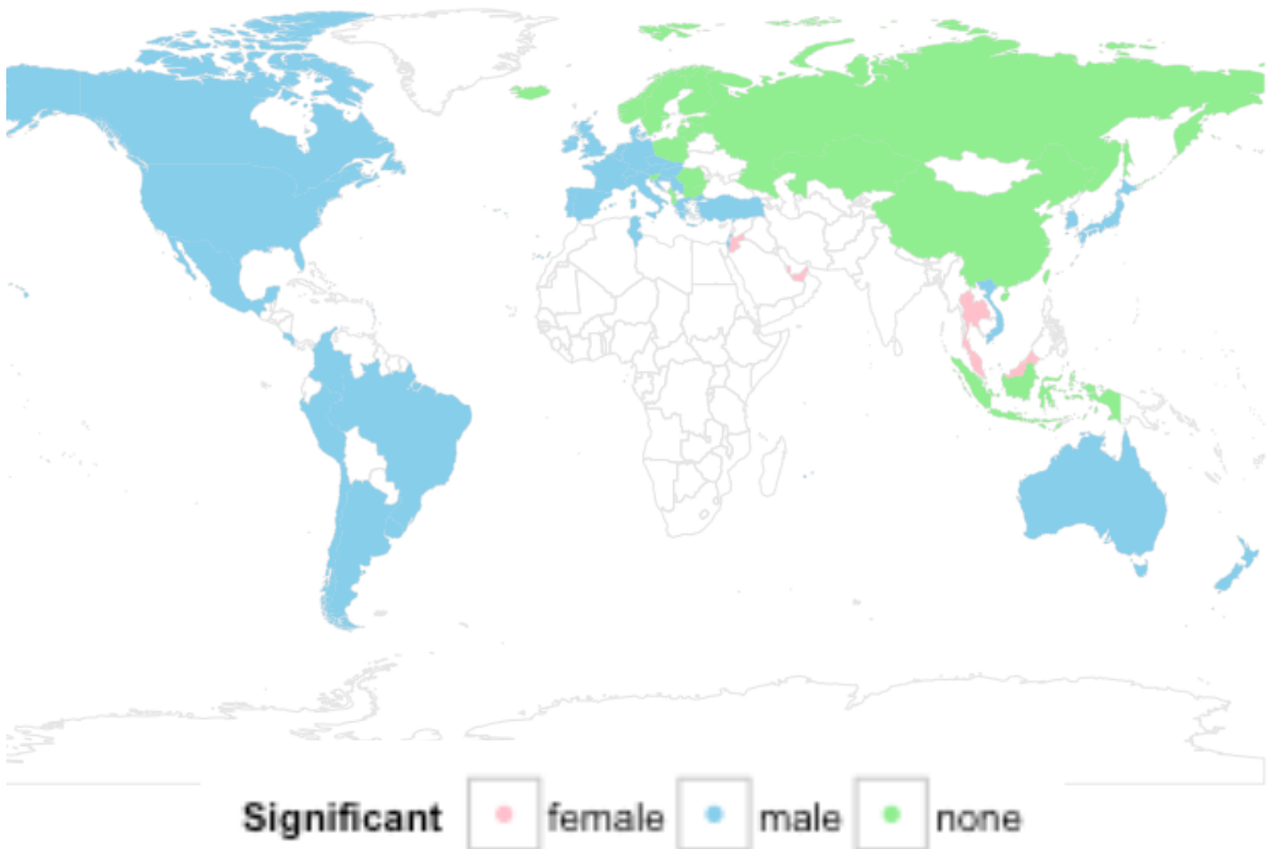
- 485,490 students math, science and reading test scores
- 65 countries, between 100-1500 schools in each
- Student questionnaires about their environment (635 vars)
- Parents surveyed on work, life, income (143 vars)
- Principals provide information about their schools (291 vars)

“Show the data."

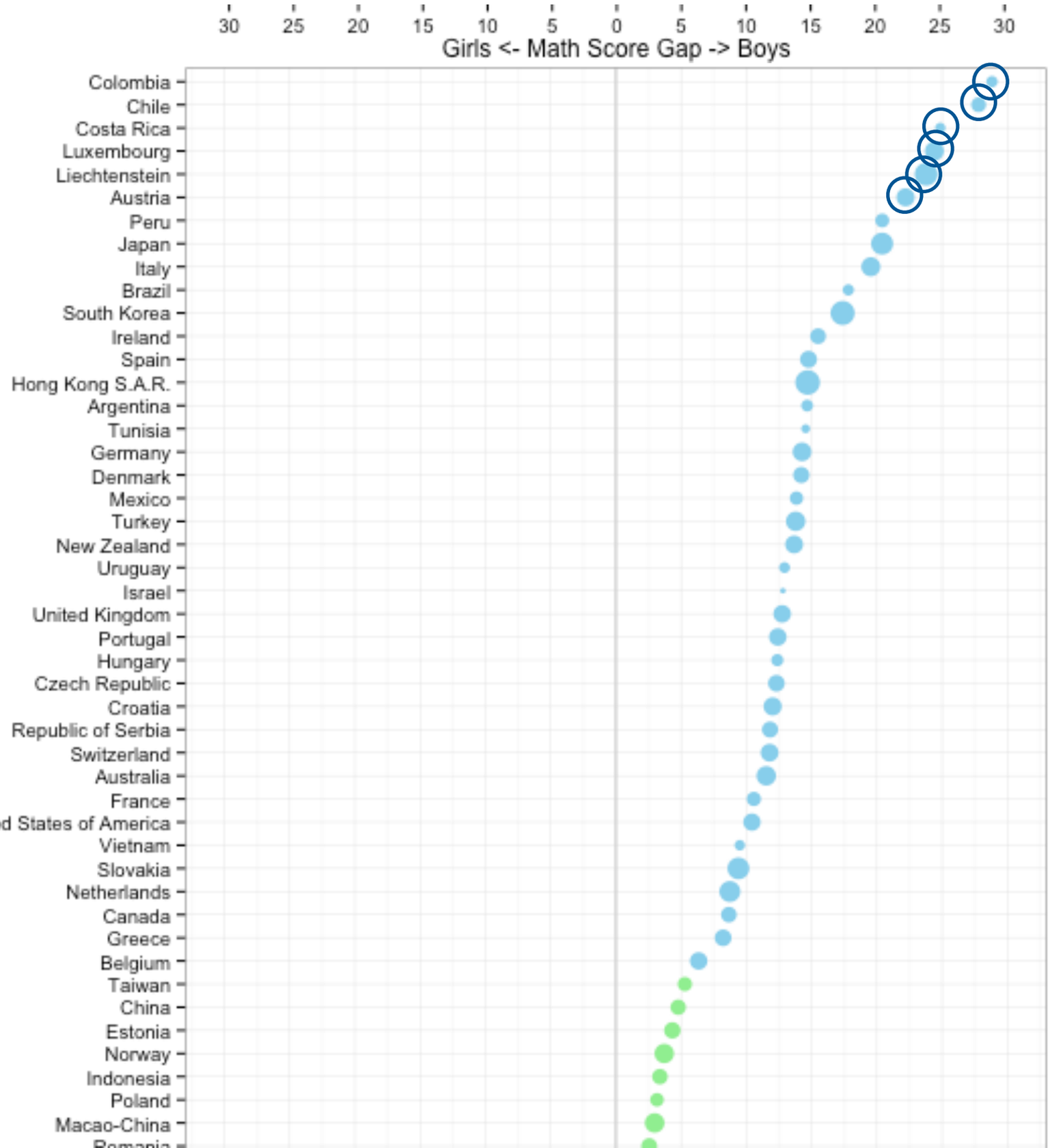
Gender & Math

1. Compute means by country and by gender.
2. Show mean difference by country





Gender & Math



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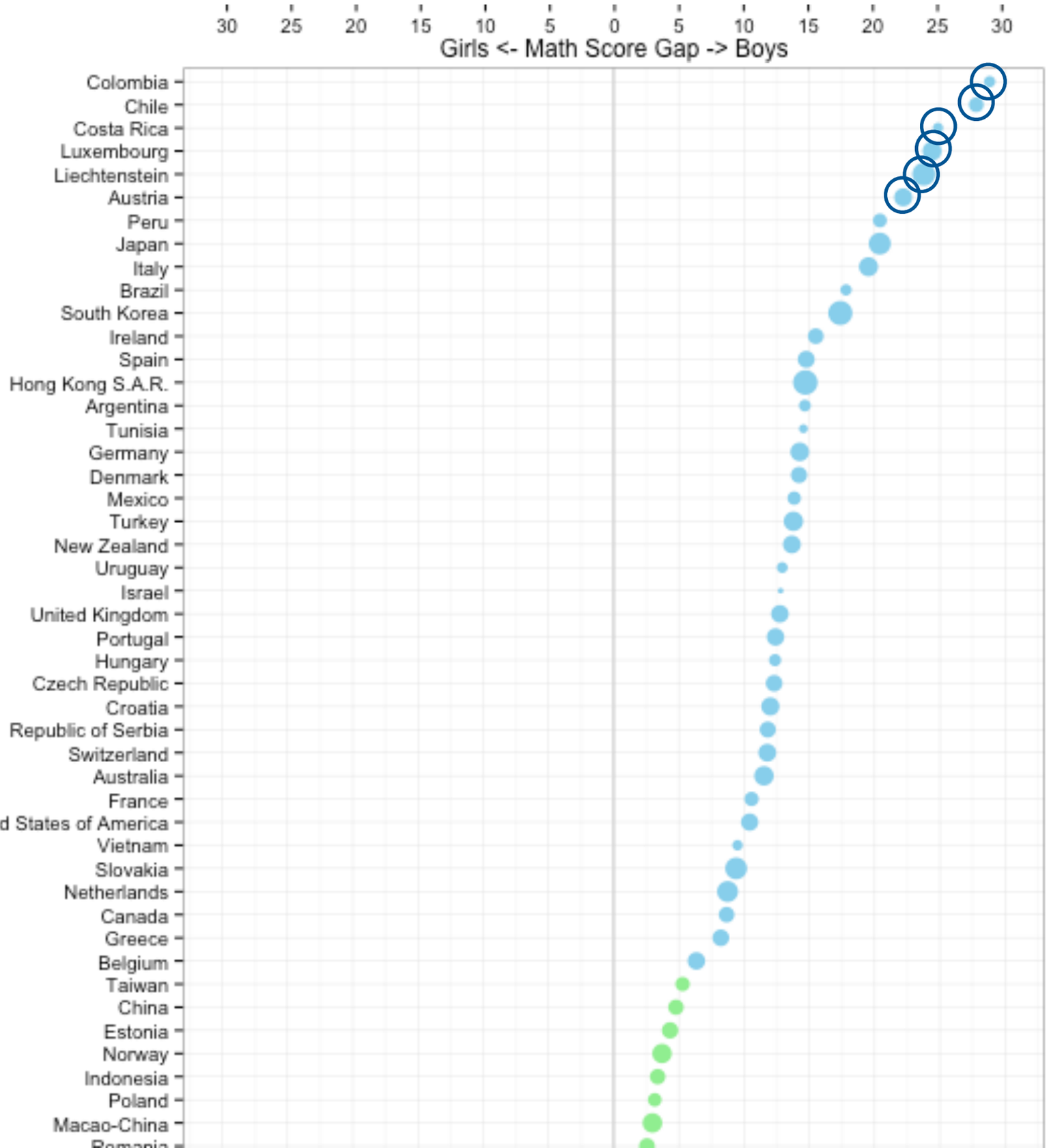
Chile
Costa Rica
Luxembourg
Liechtenstein
Austria

2014

Gender & Math



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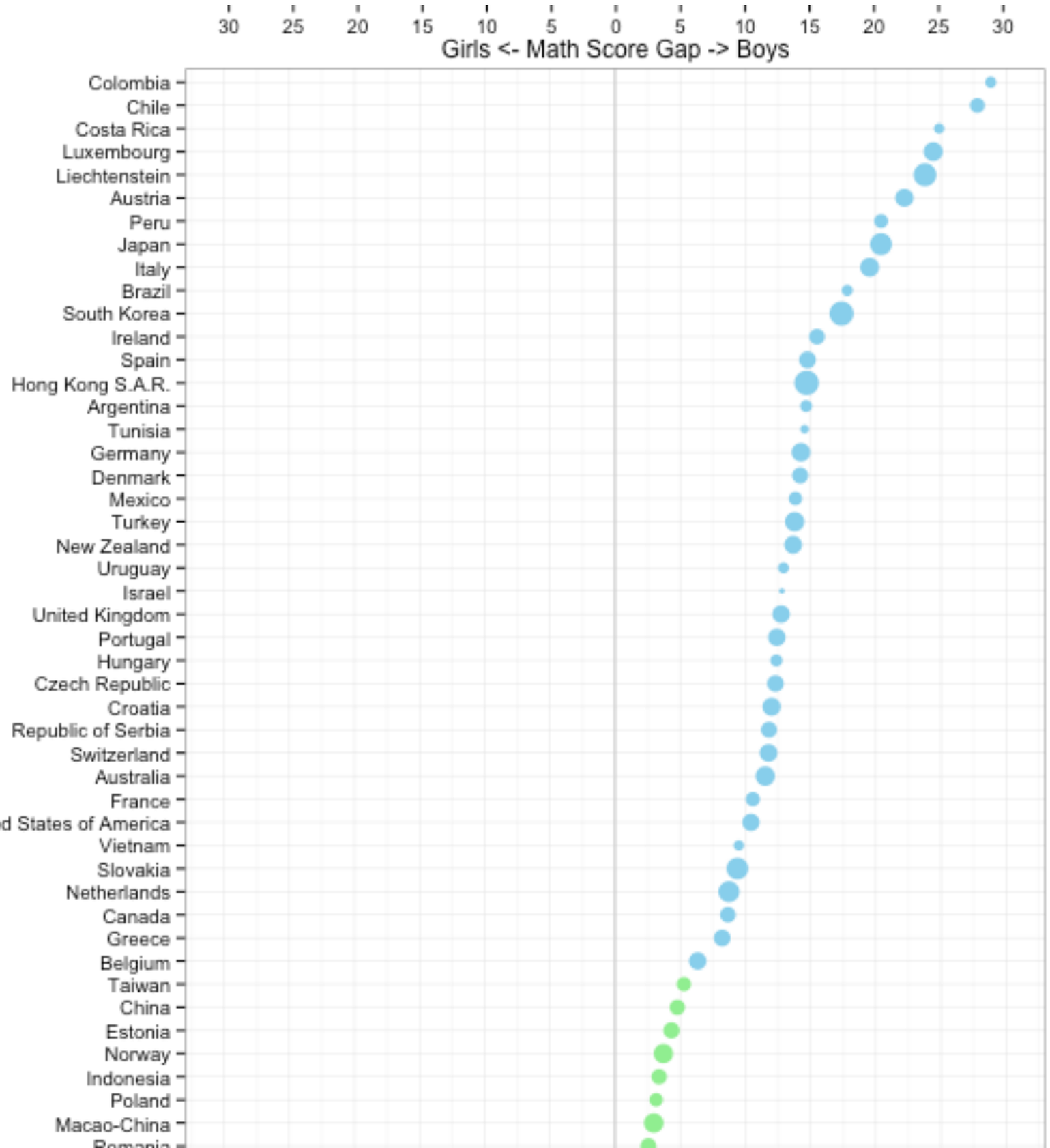

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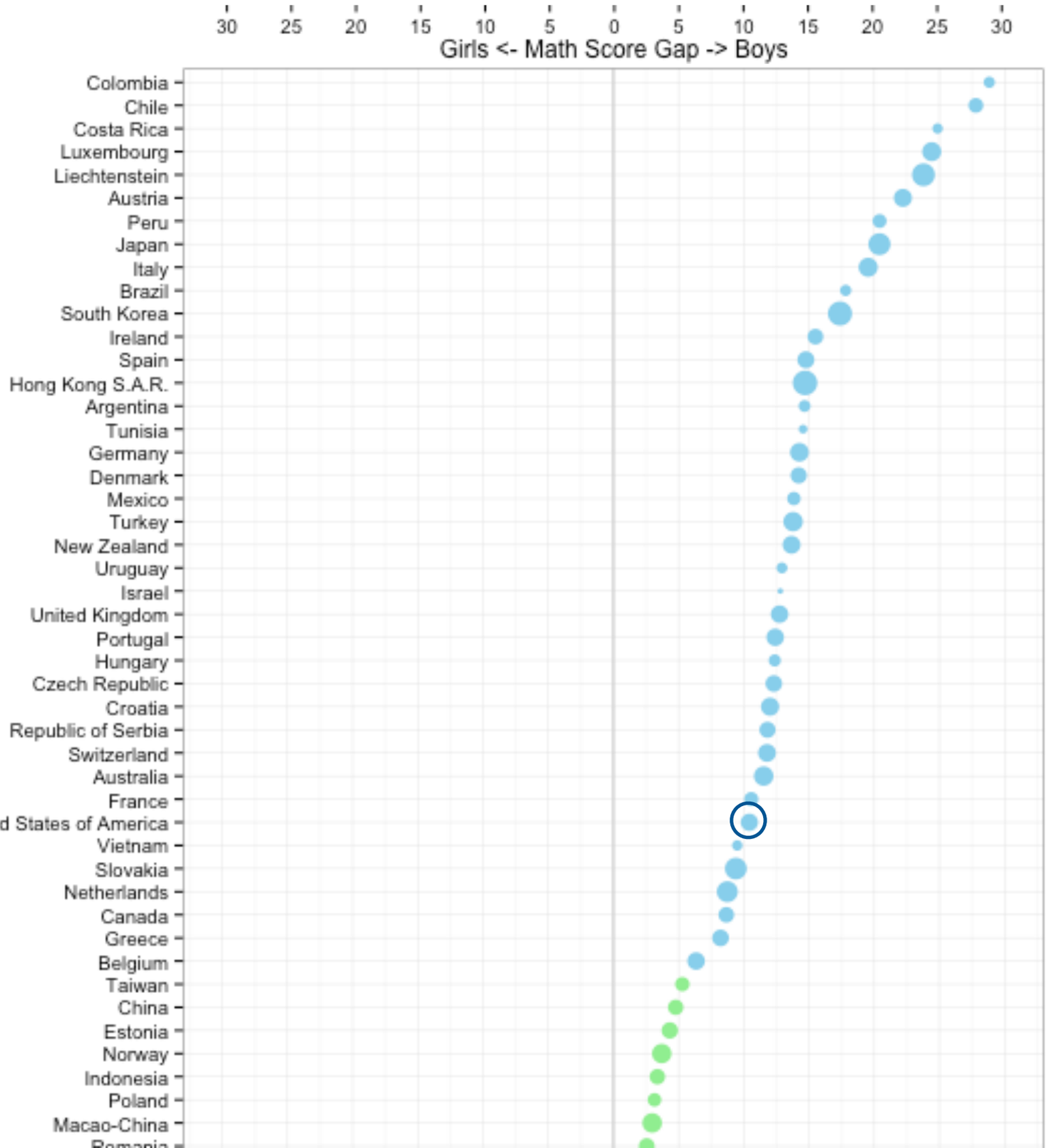

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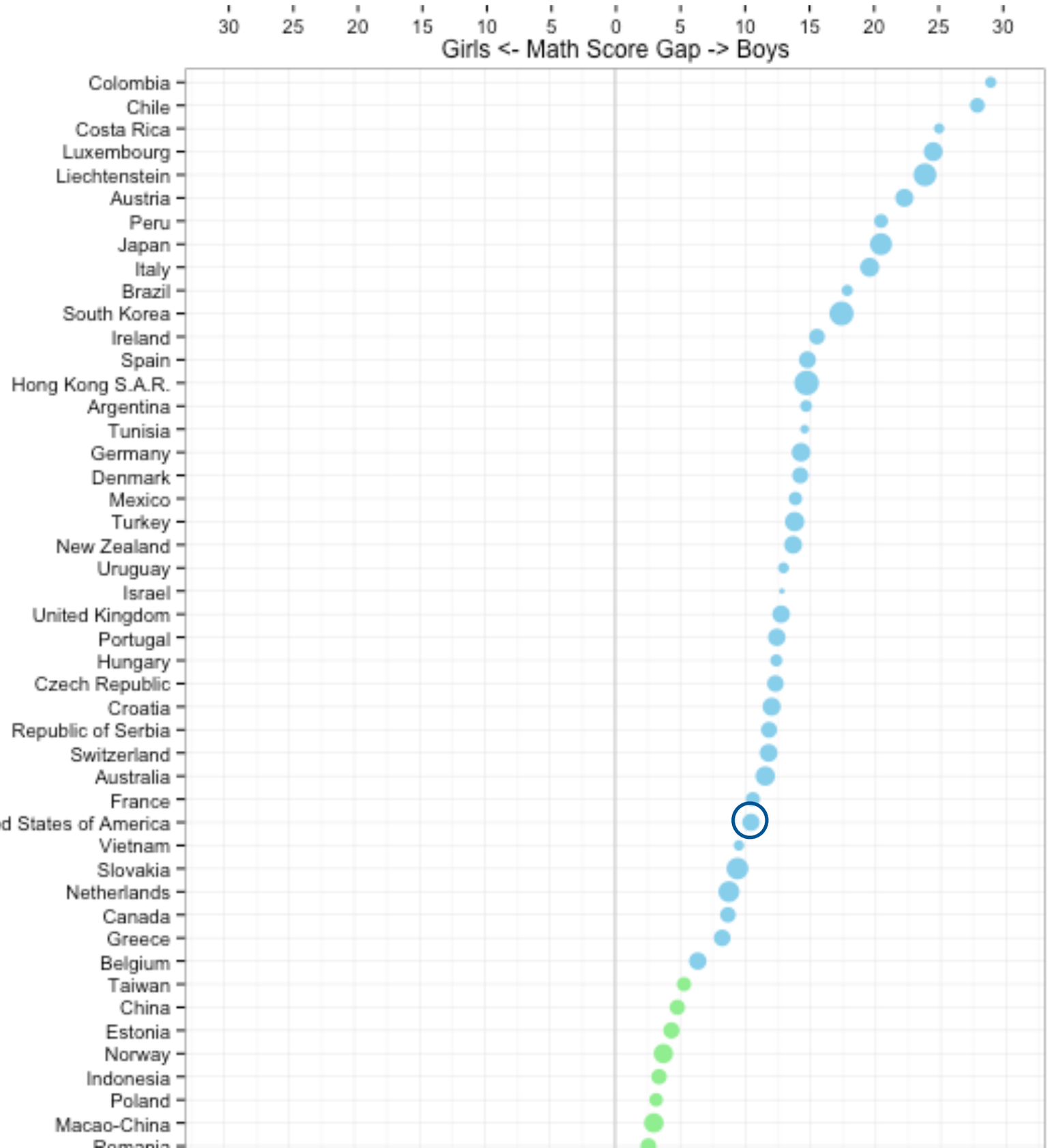
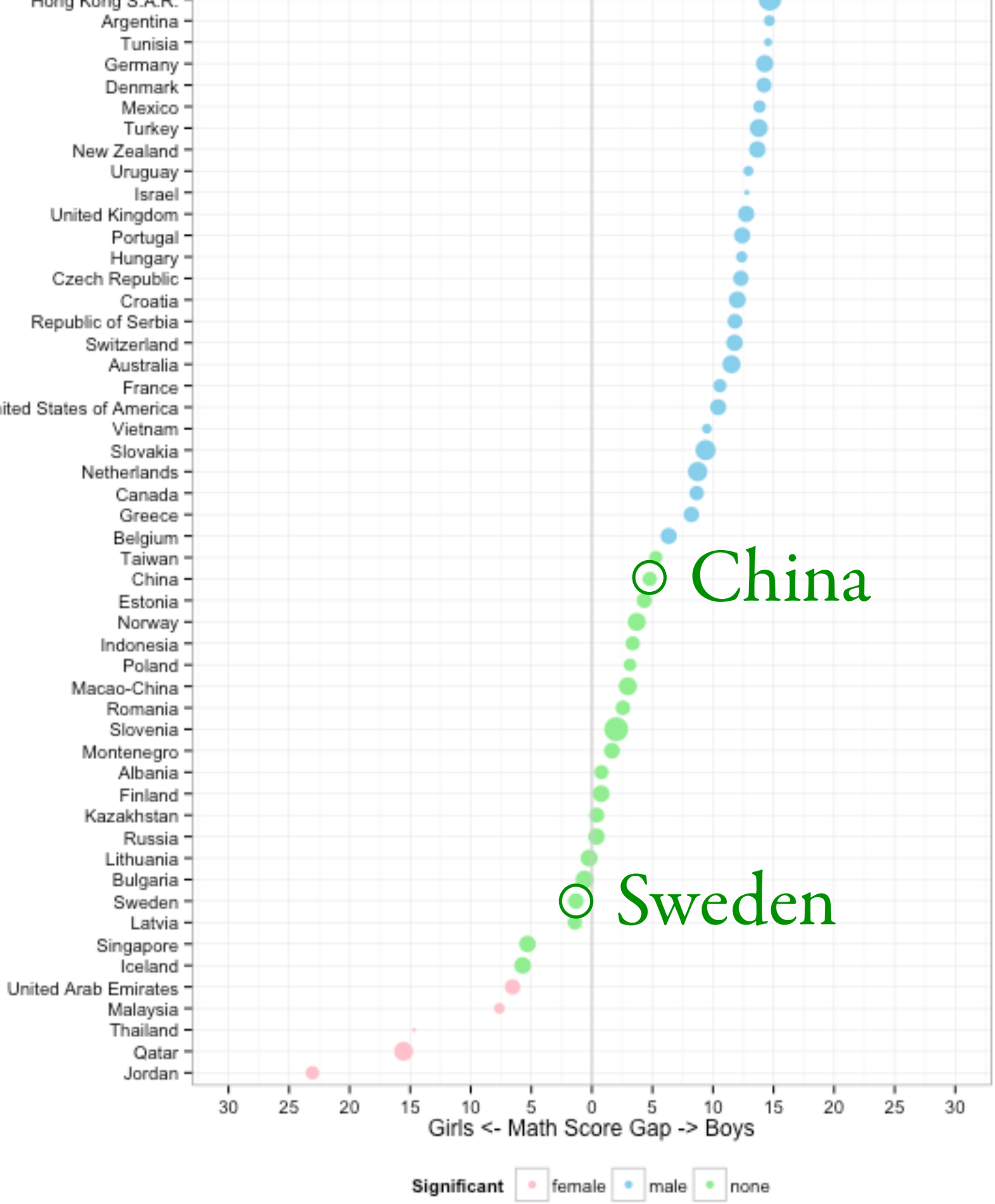


USA

2014

Gender & Math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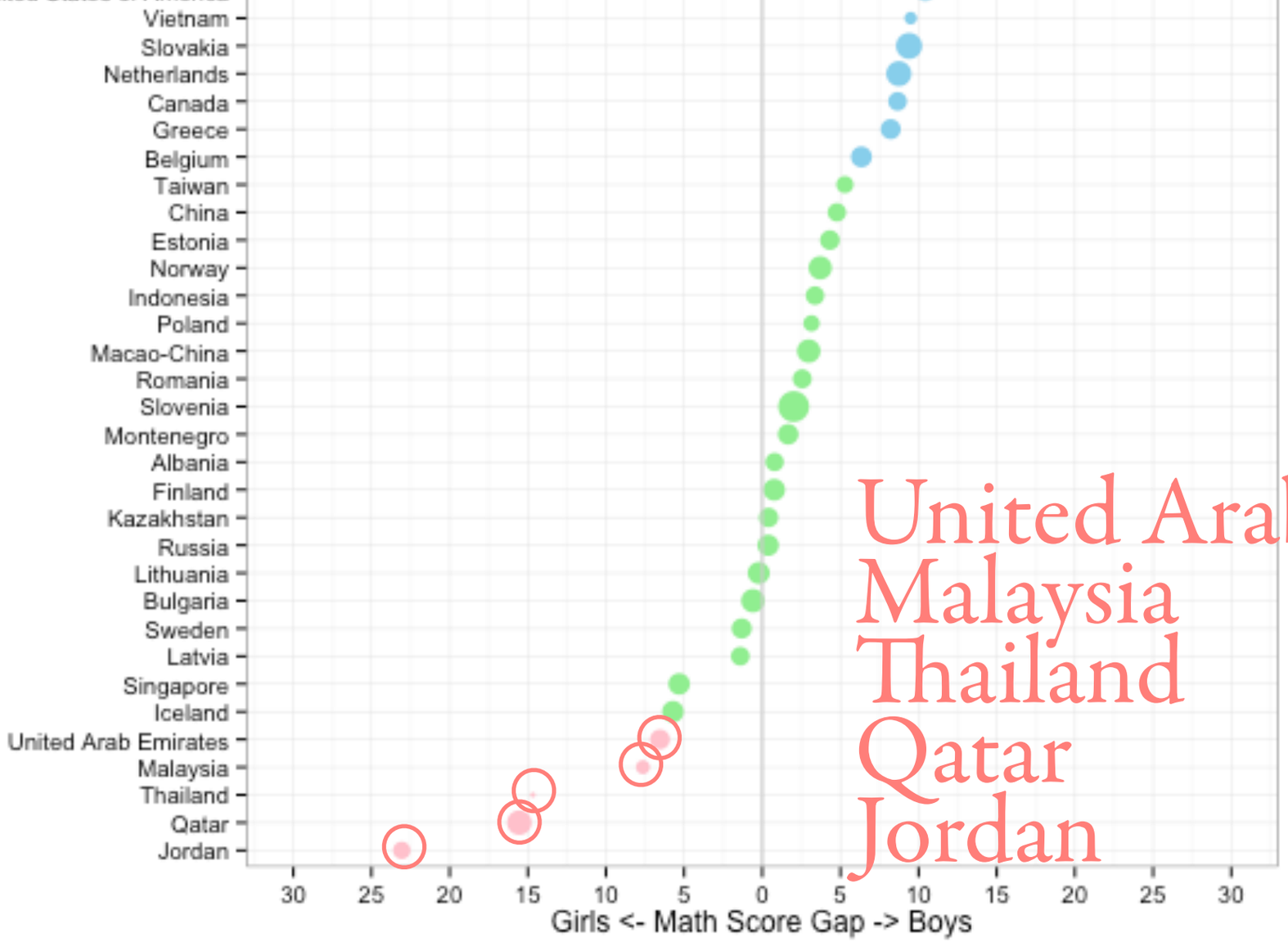
Gender & Math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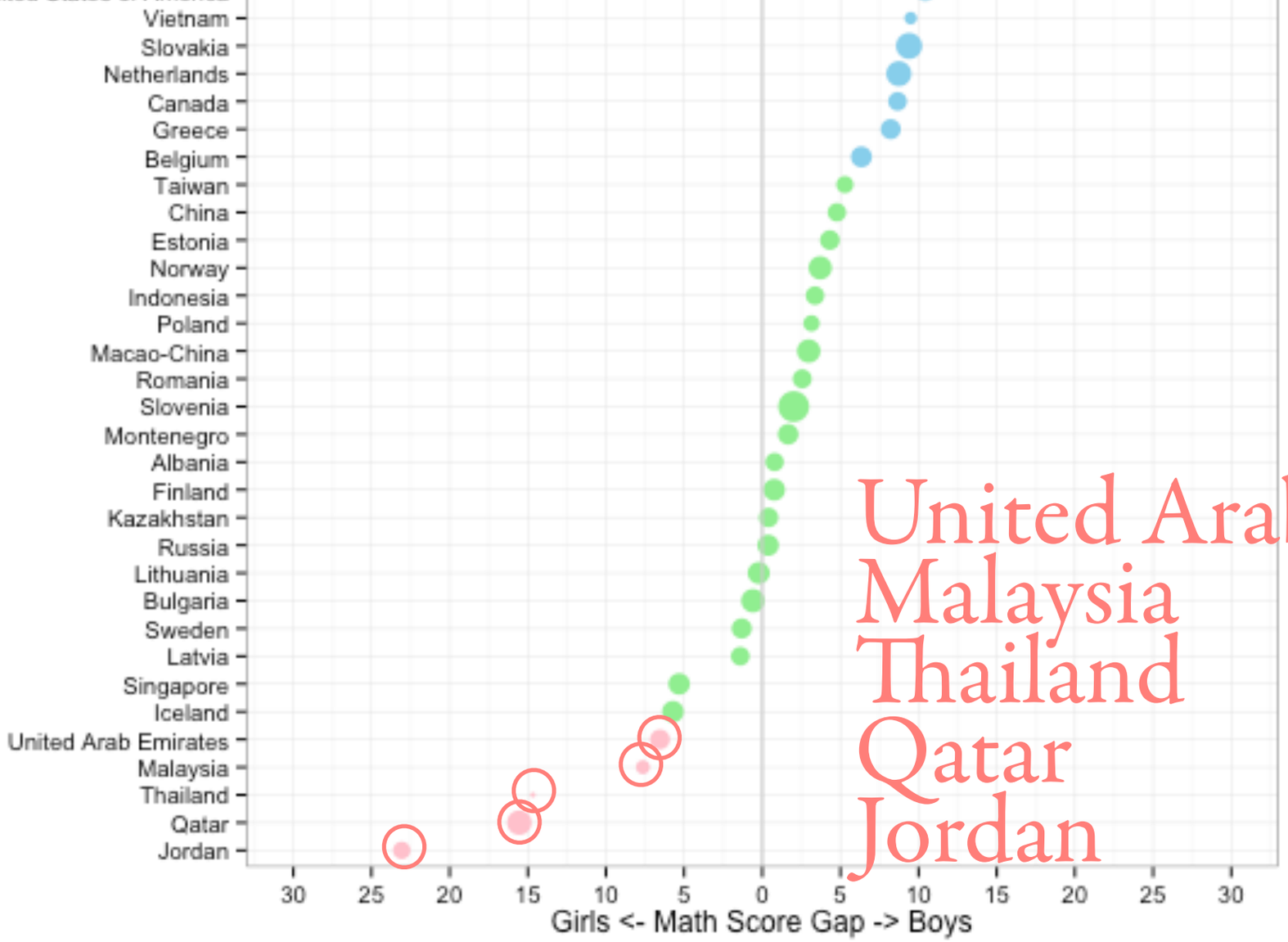
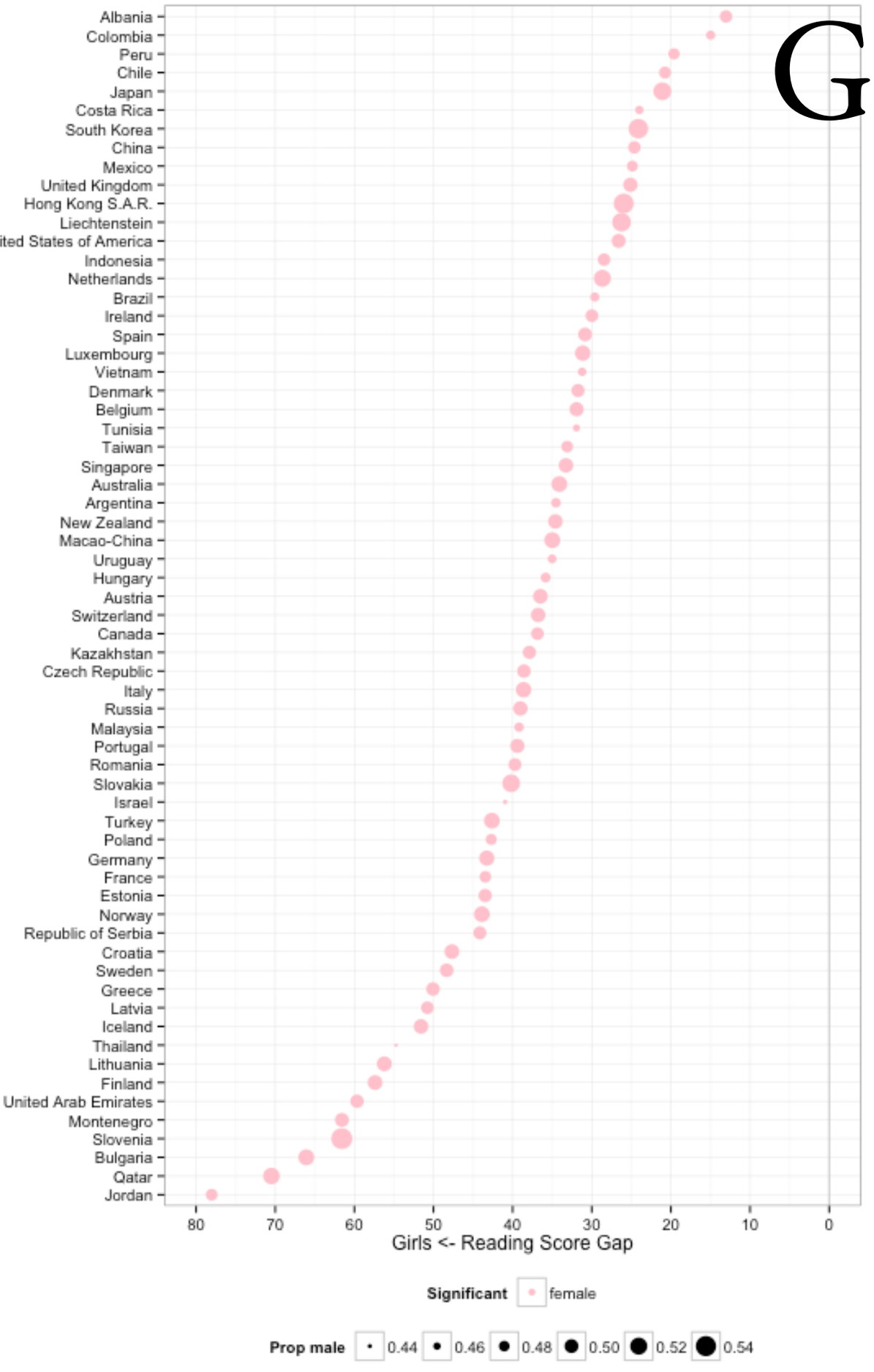
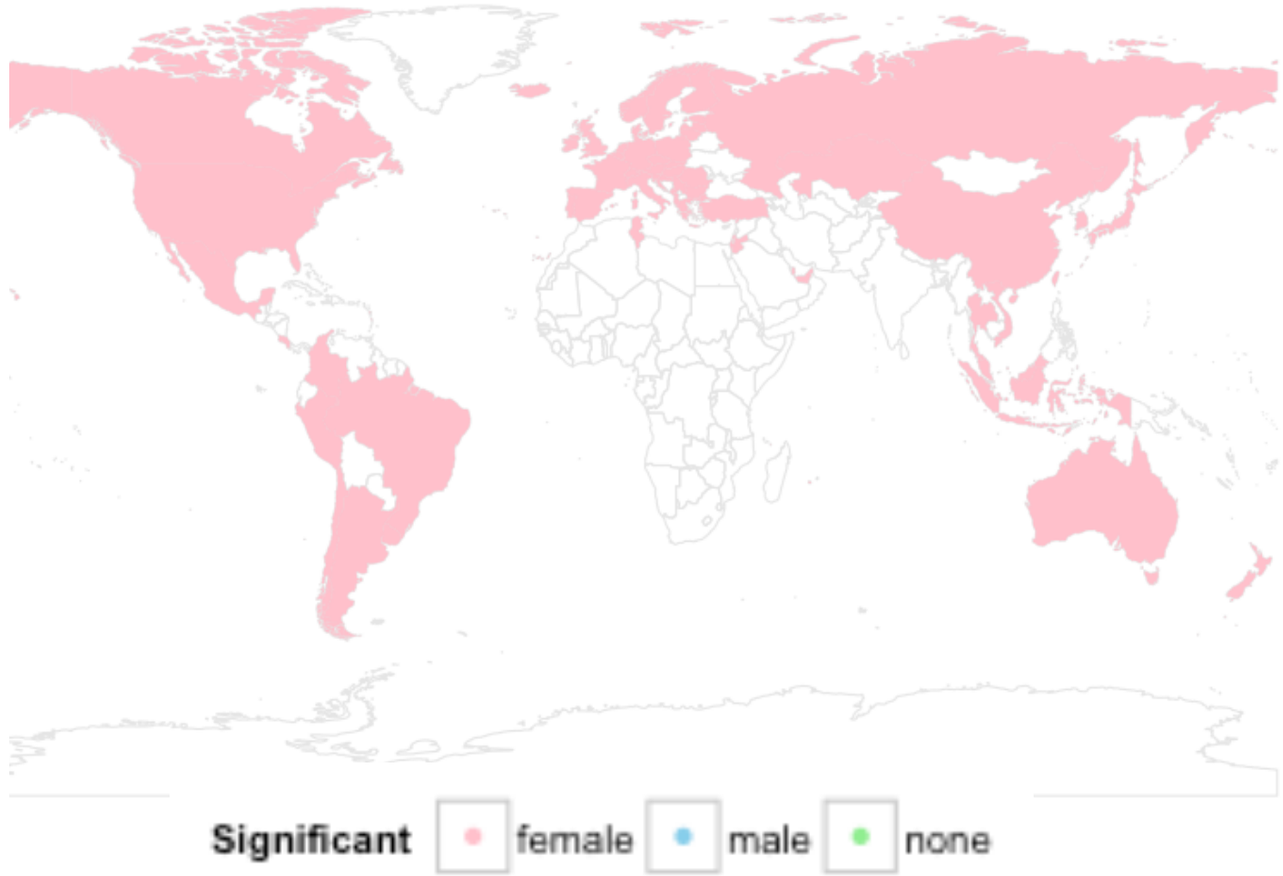


Surprised?

Gender & Reading





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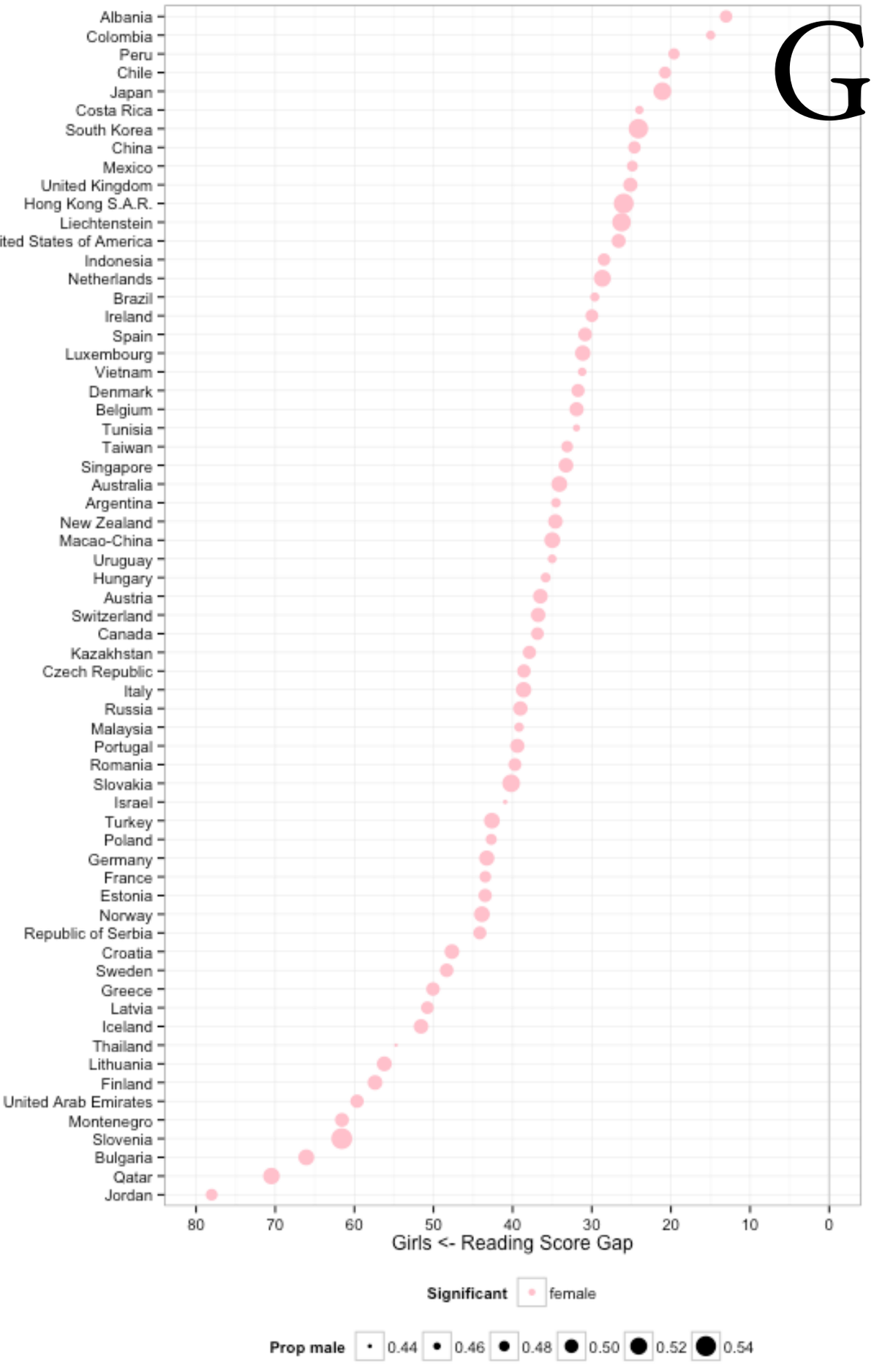

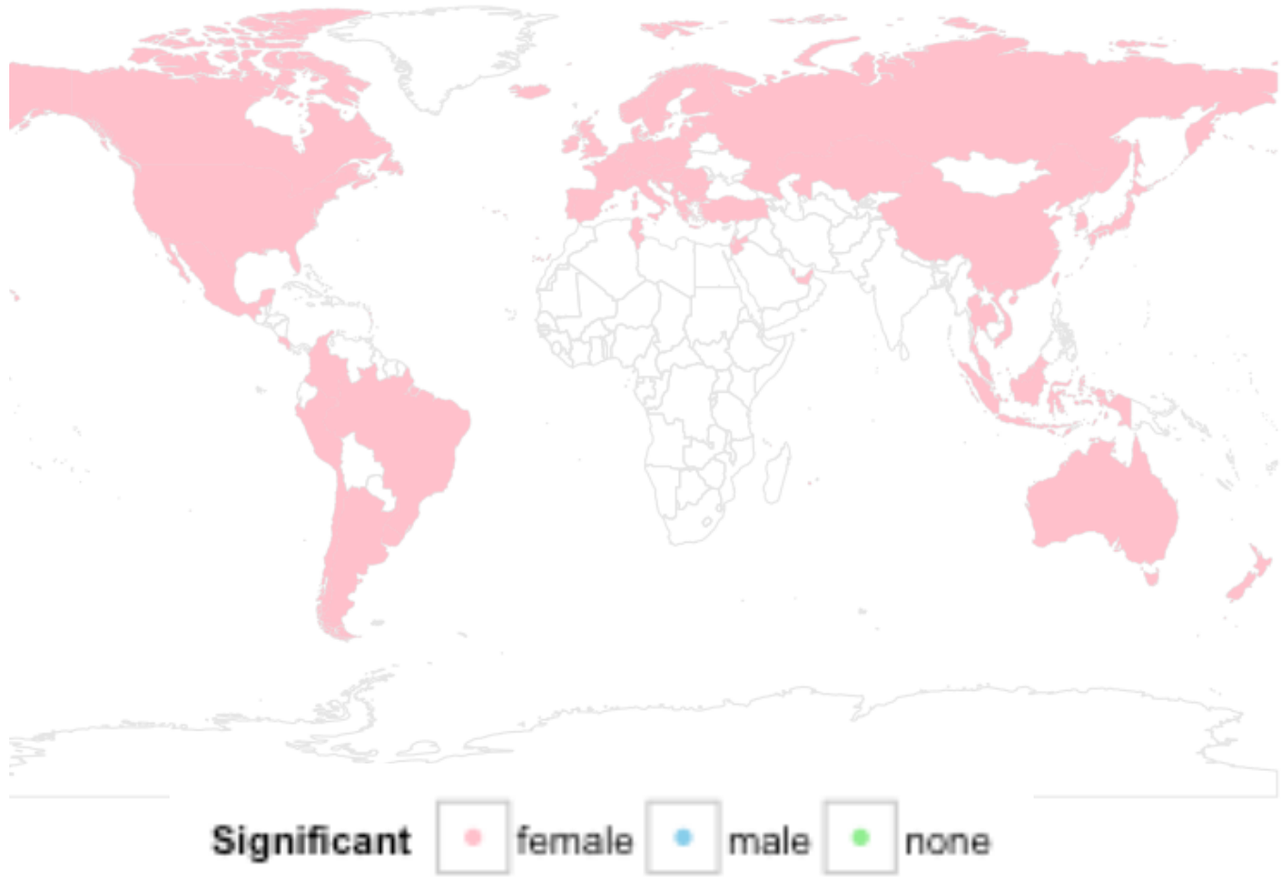

Surprised again?

In reading scores, the world is PINK!
In EVERY COUNTRY tested GIRLS score significantly BETTER THAN BOYS. Why don't we talk about the gender gap in reading?

Individuals

- Test scores range from 0-1000.
- Gaps for math were at most 30 points.
- For reading at most 80 points.
- Differences are tiny.

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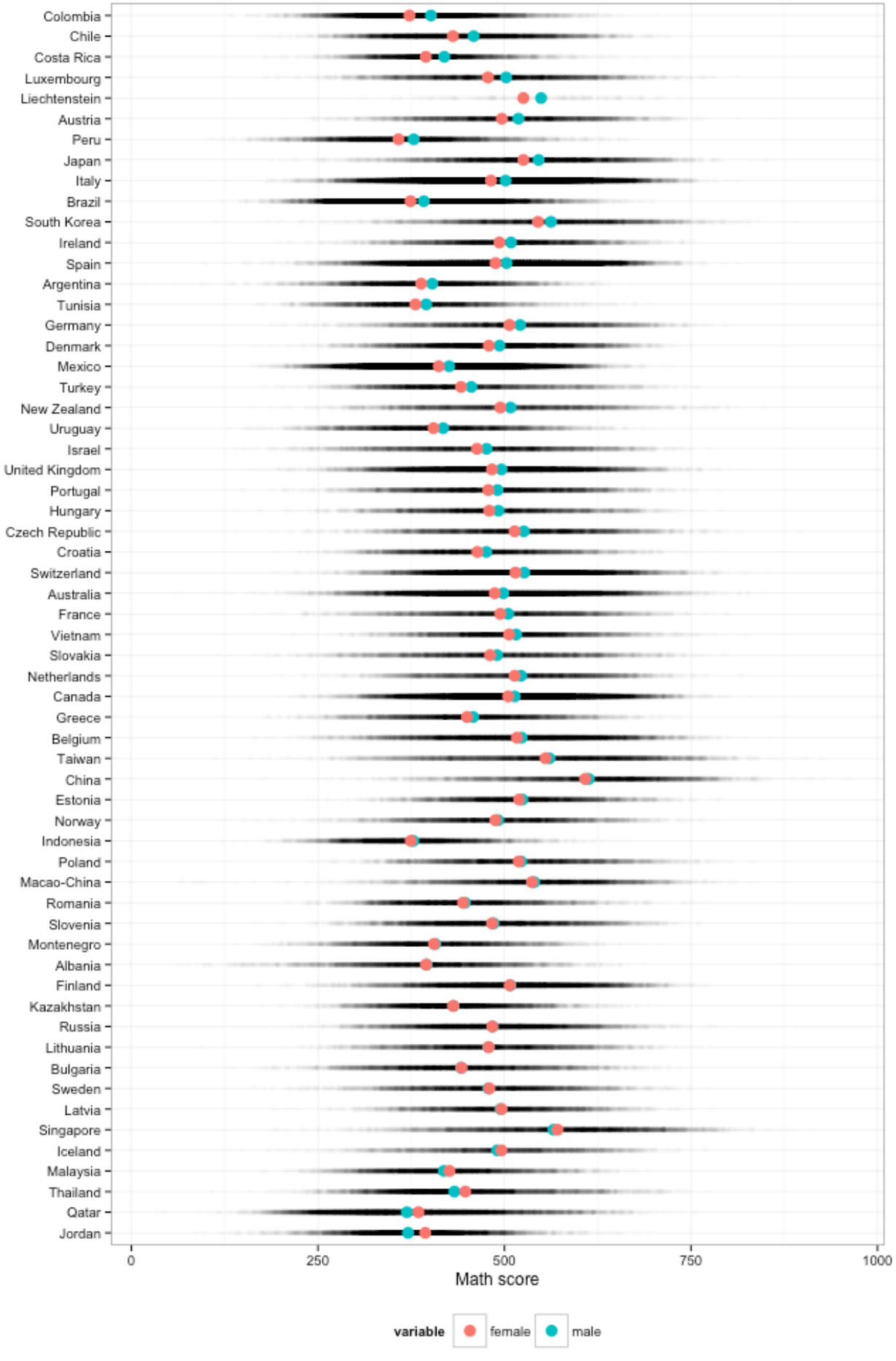

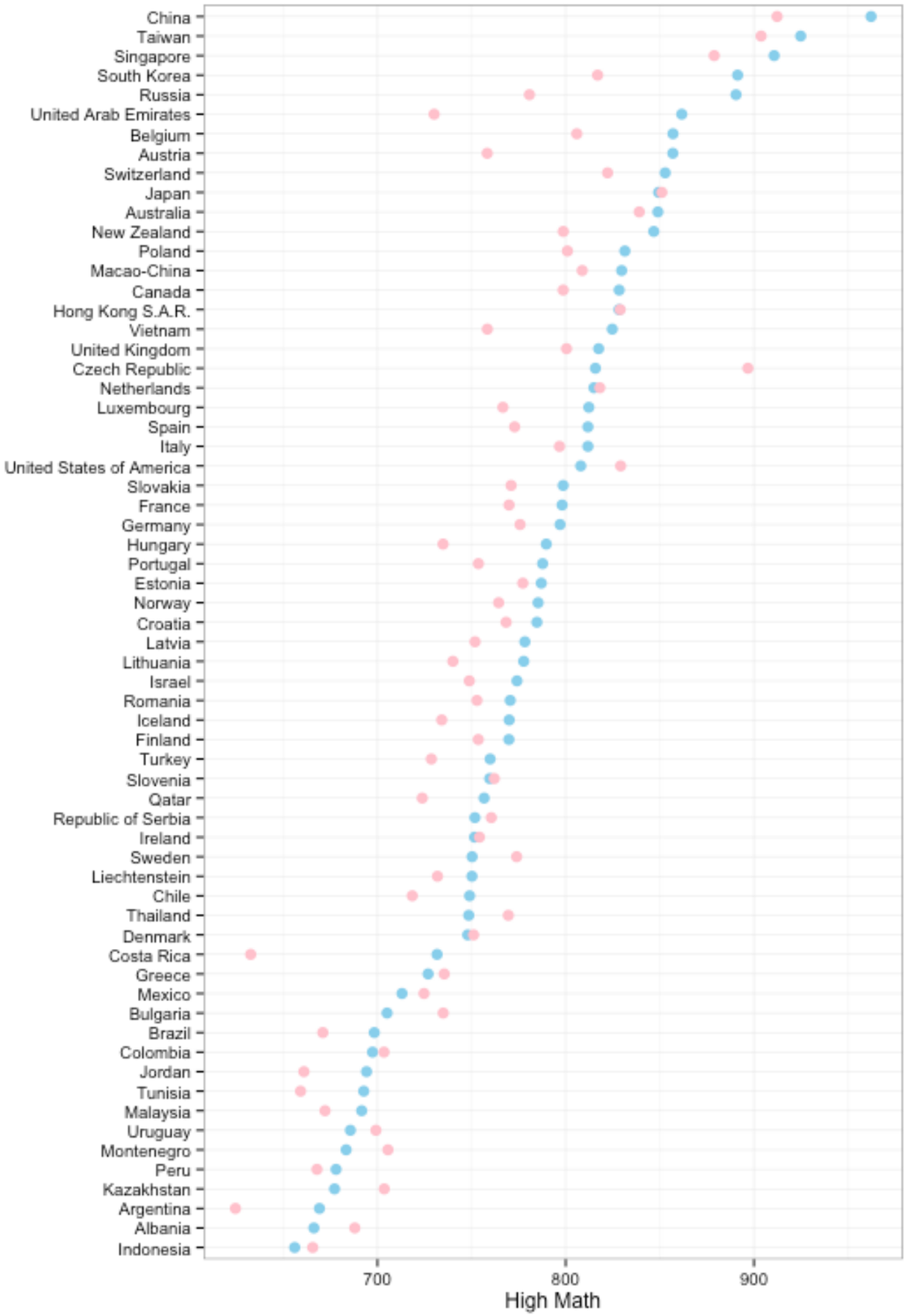

Individuals

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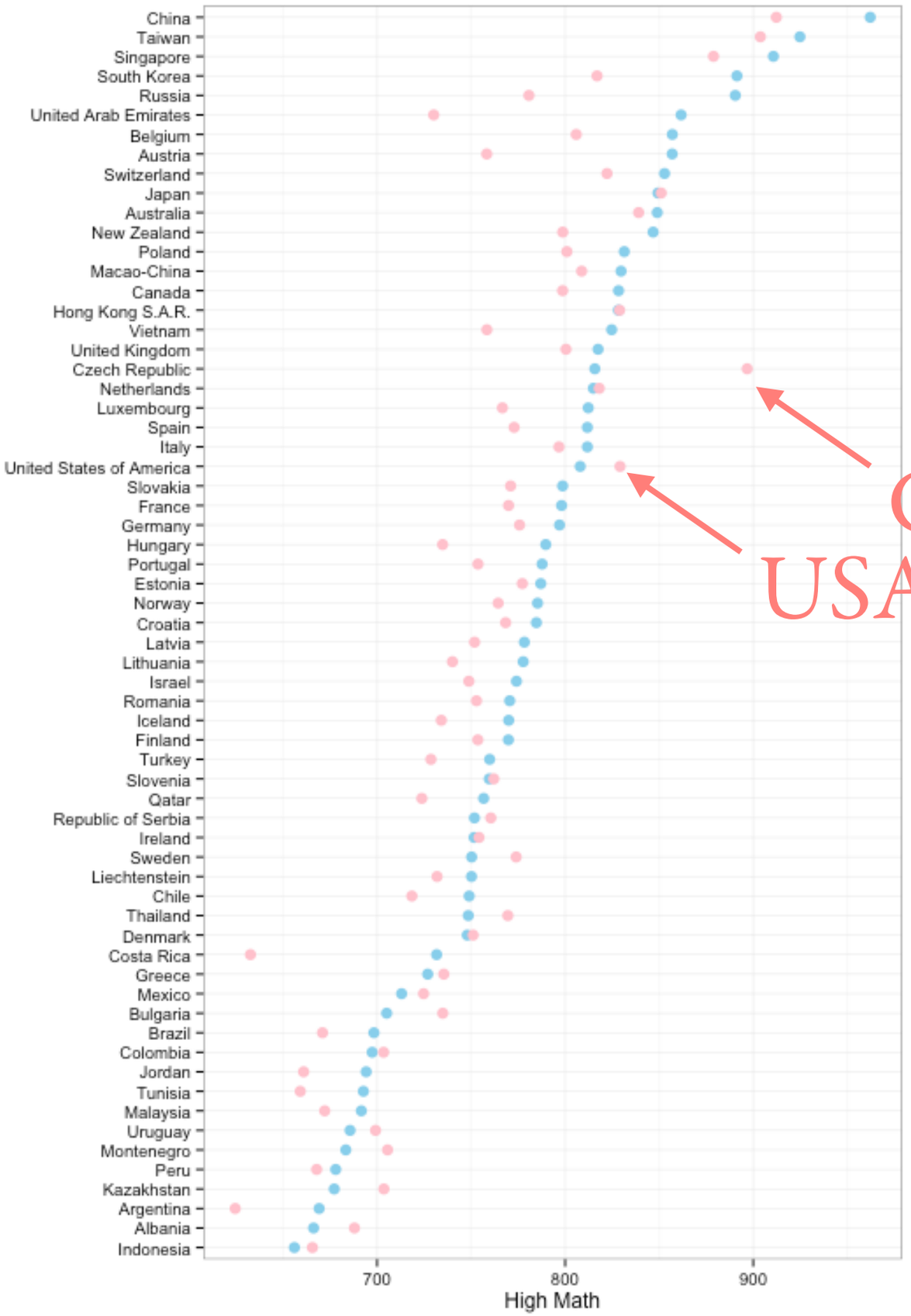

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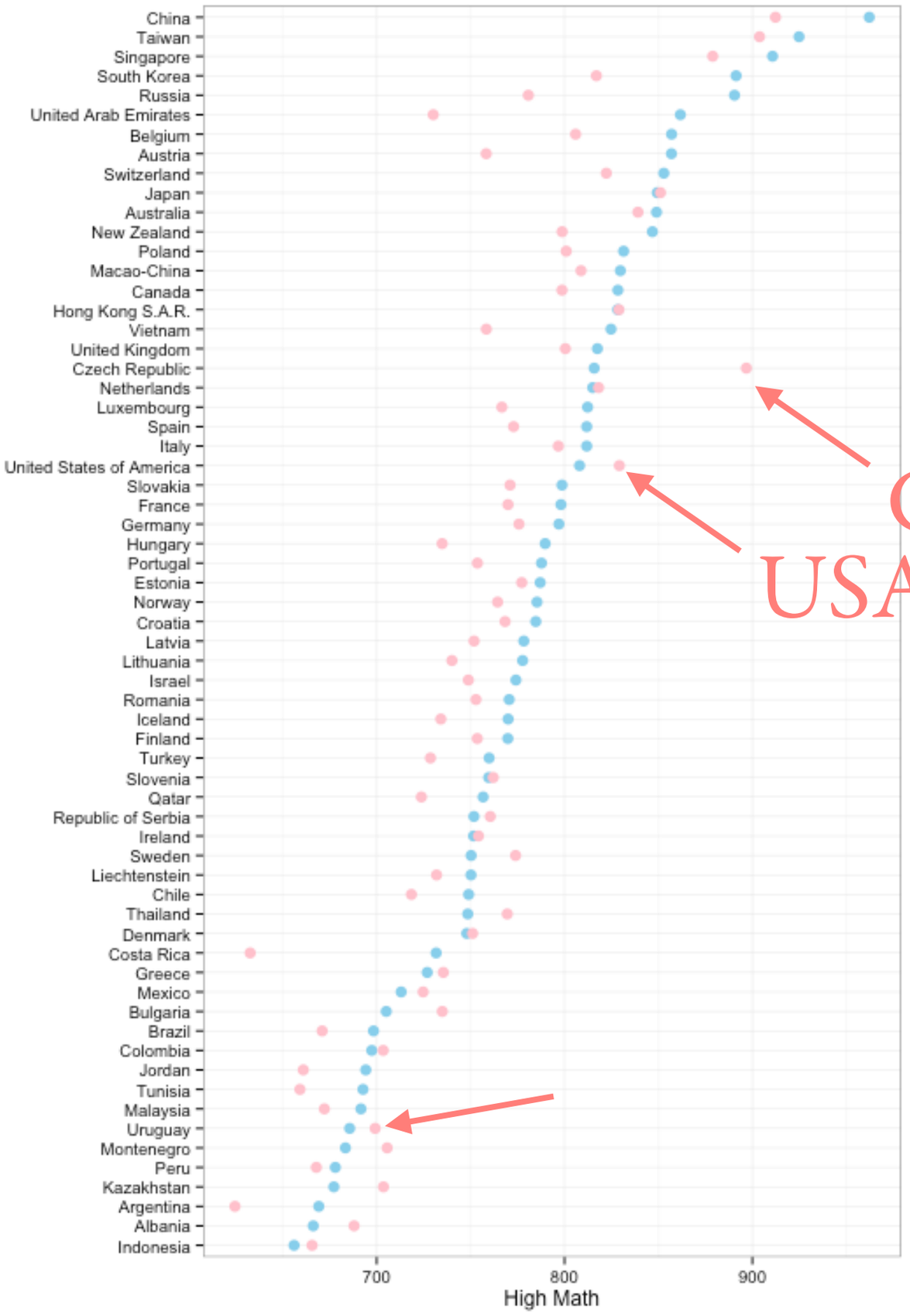

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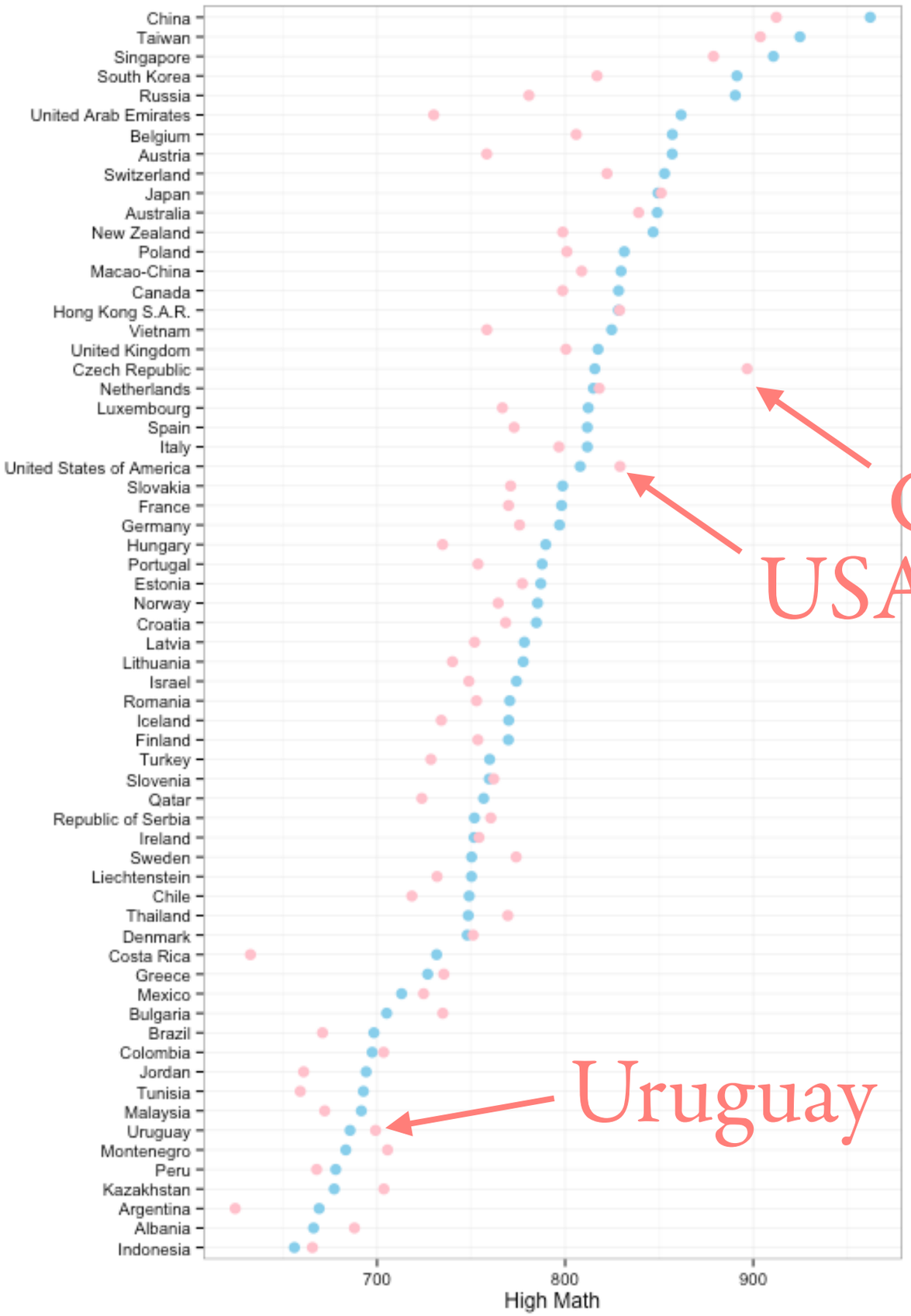

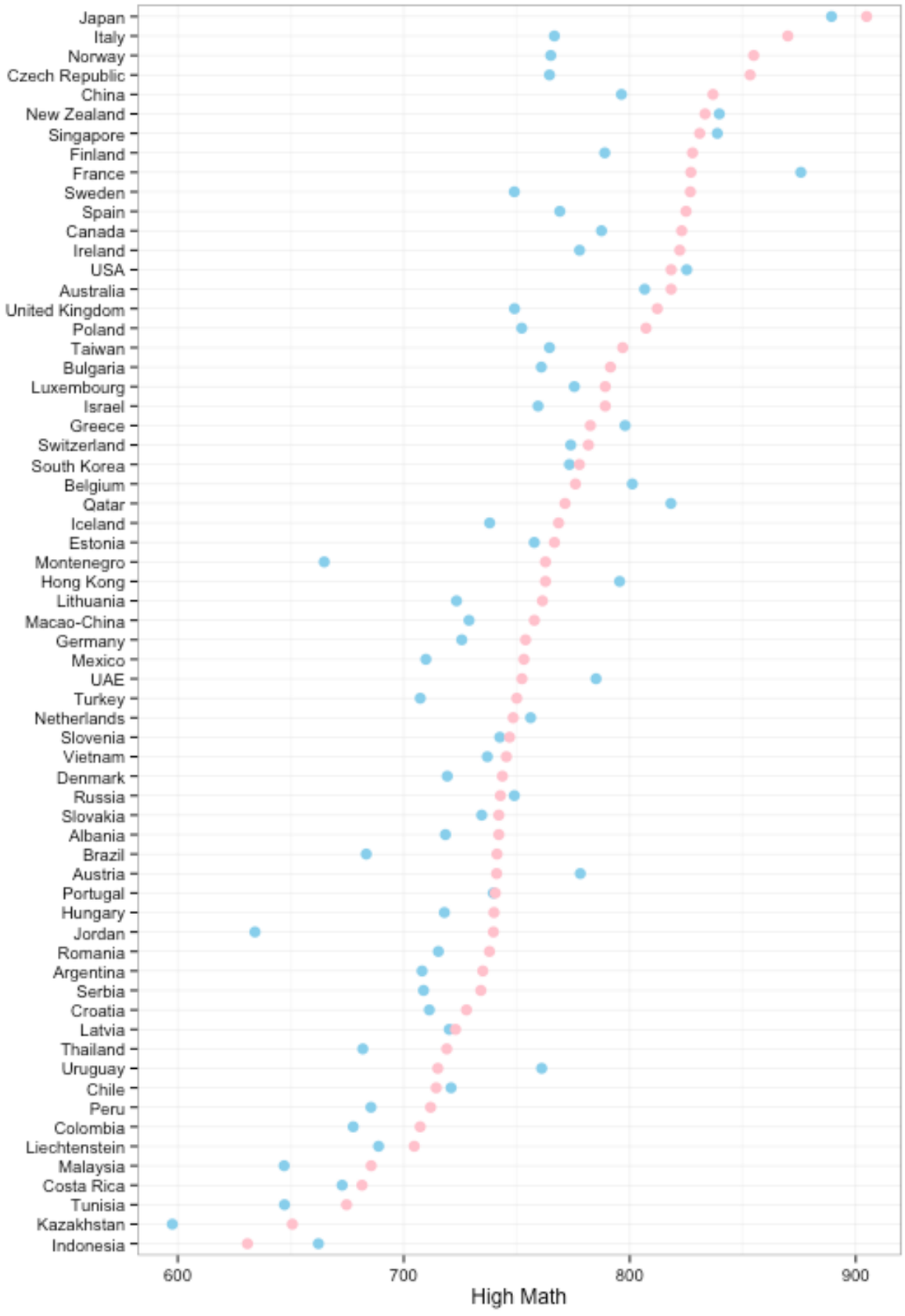

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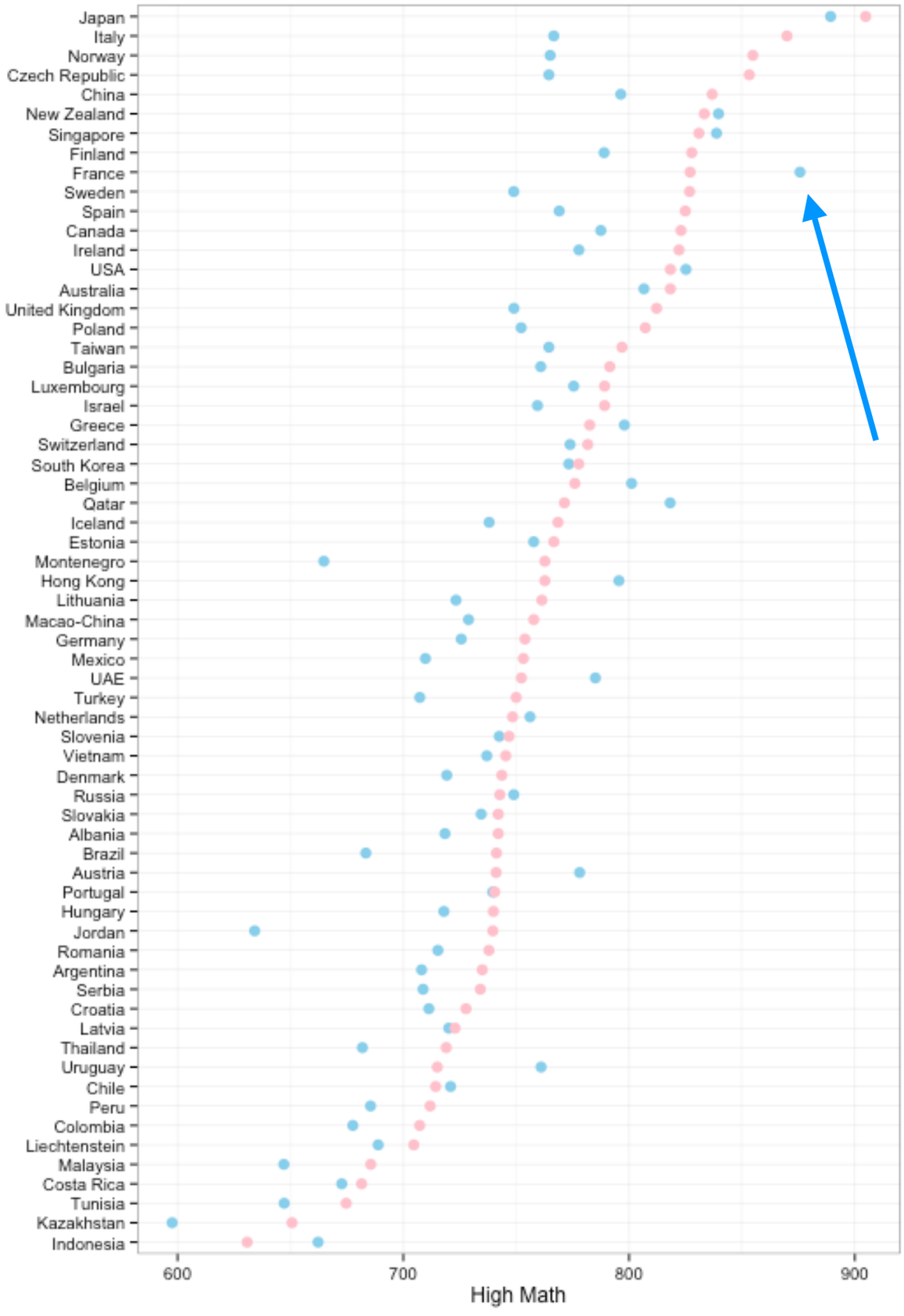

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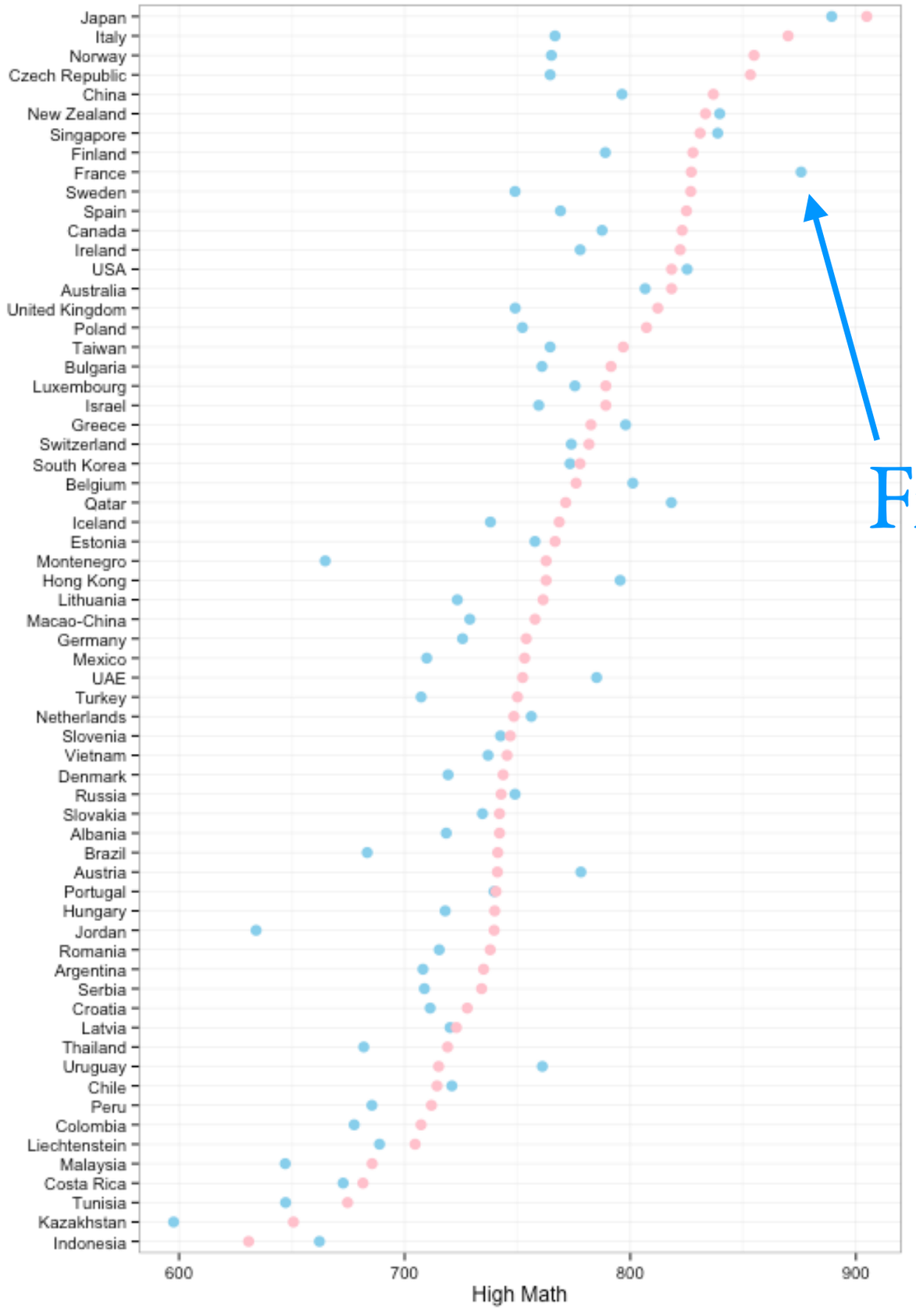

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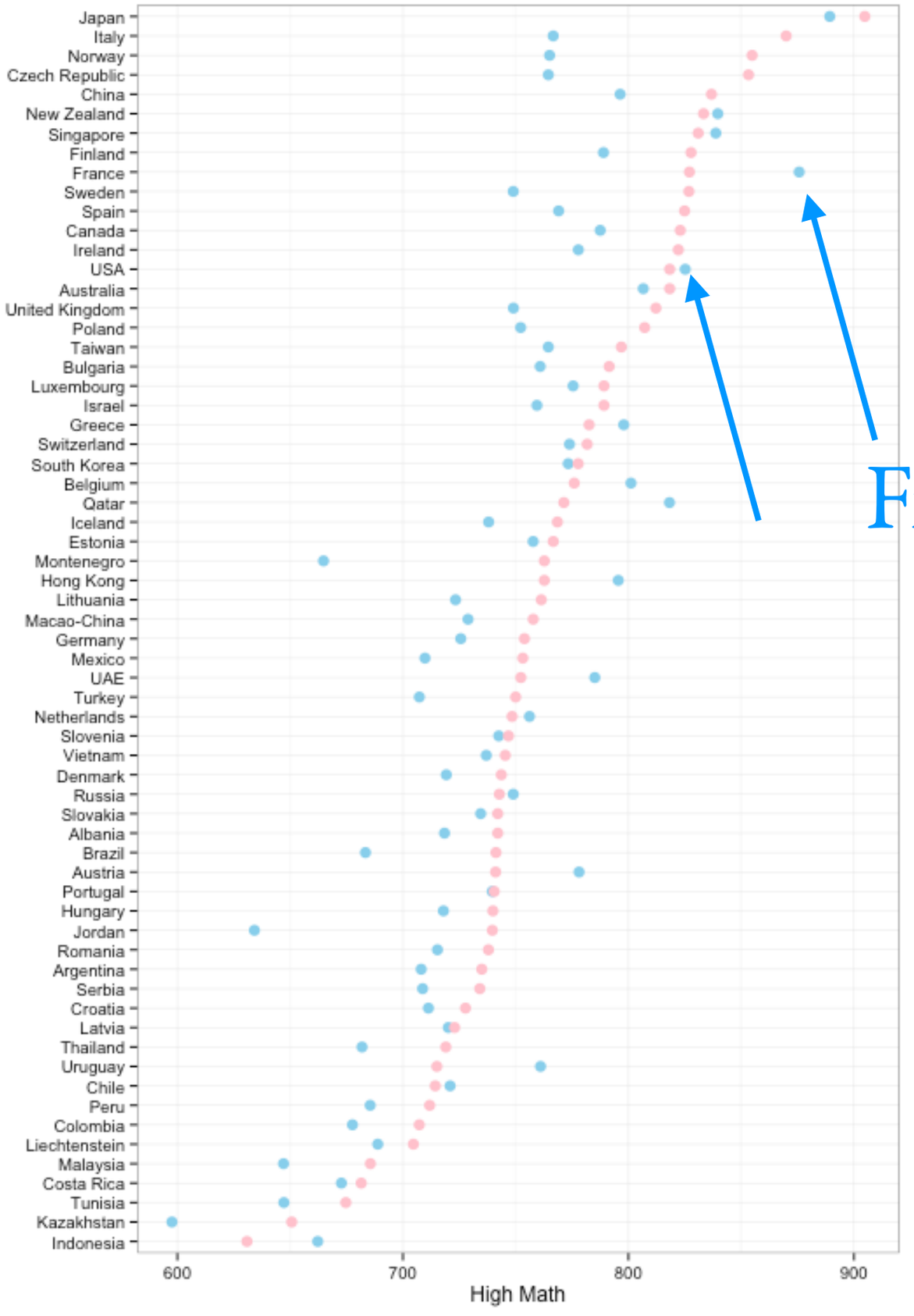

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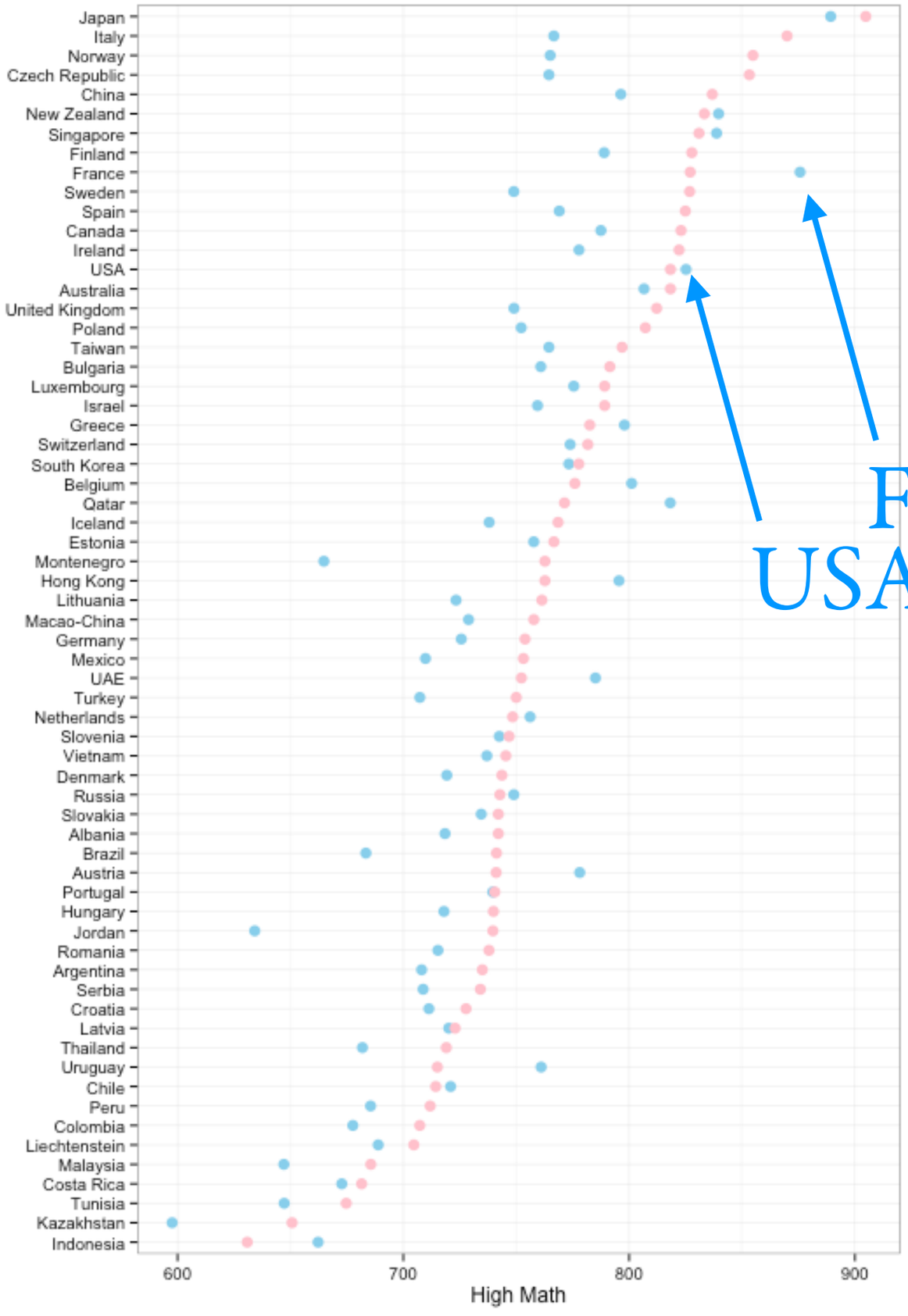

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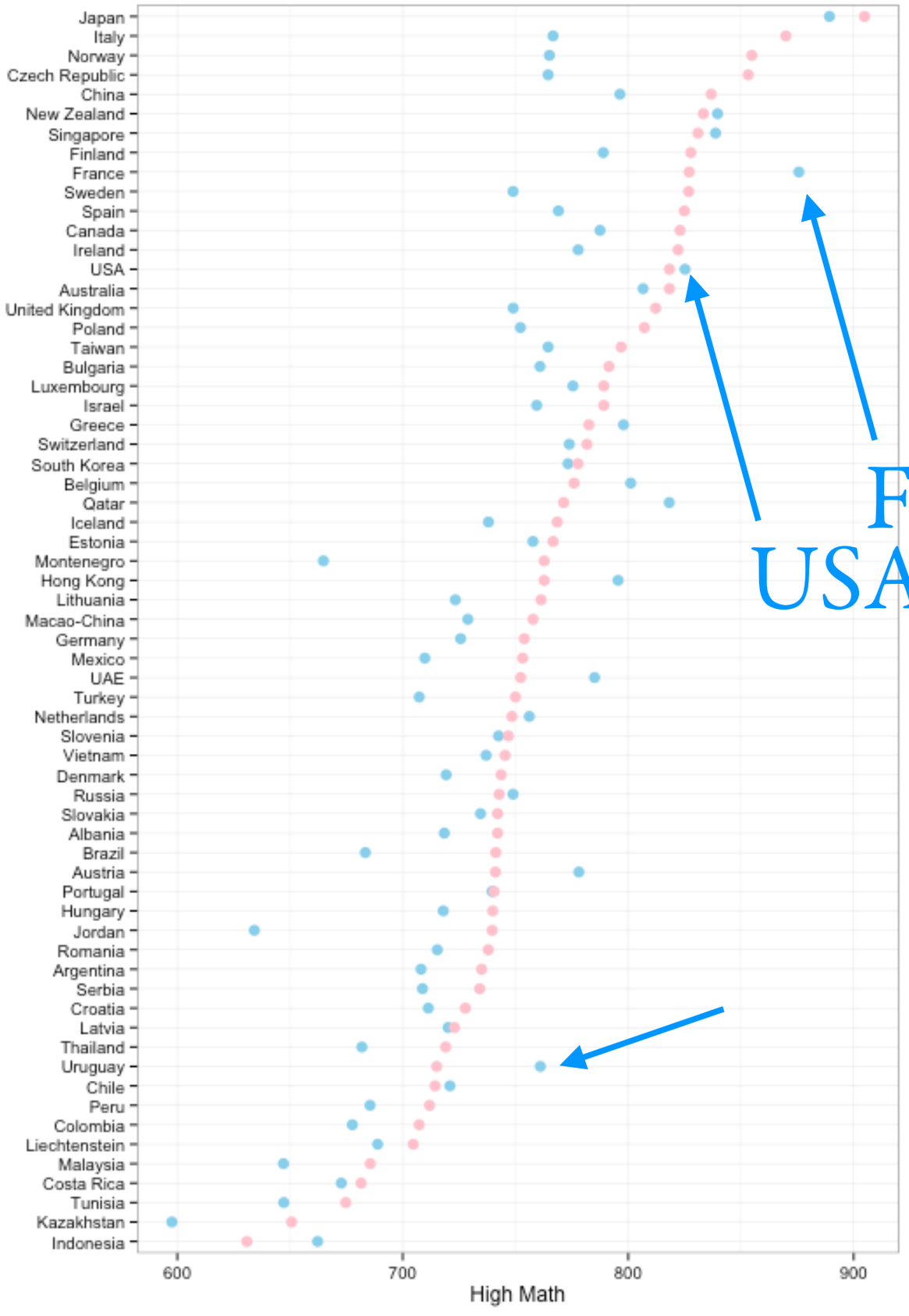

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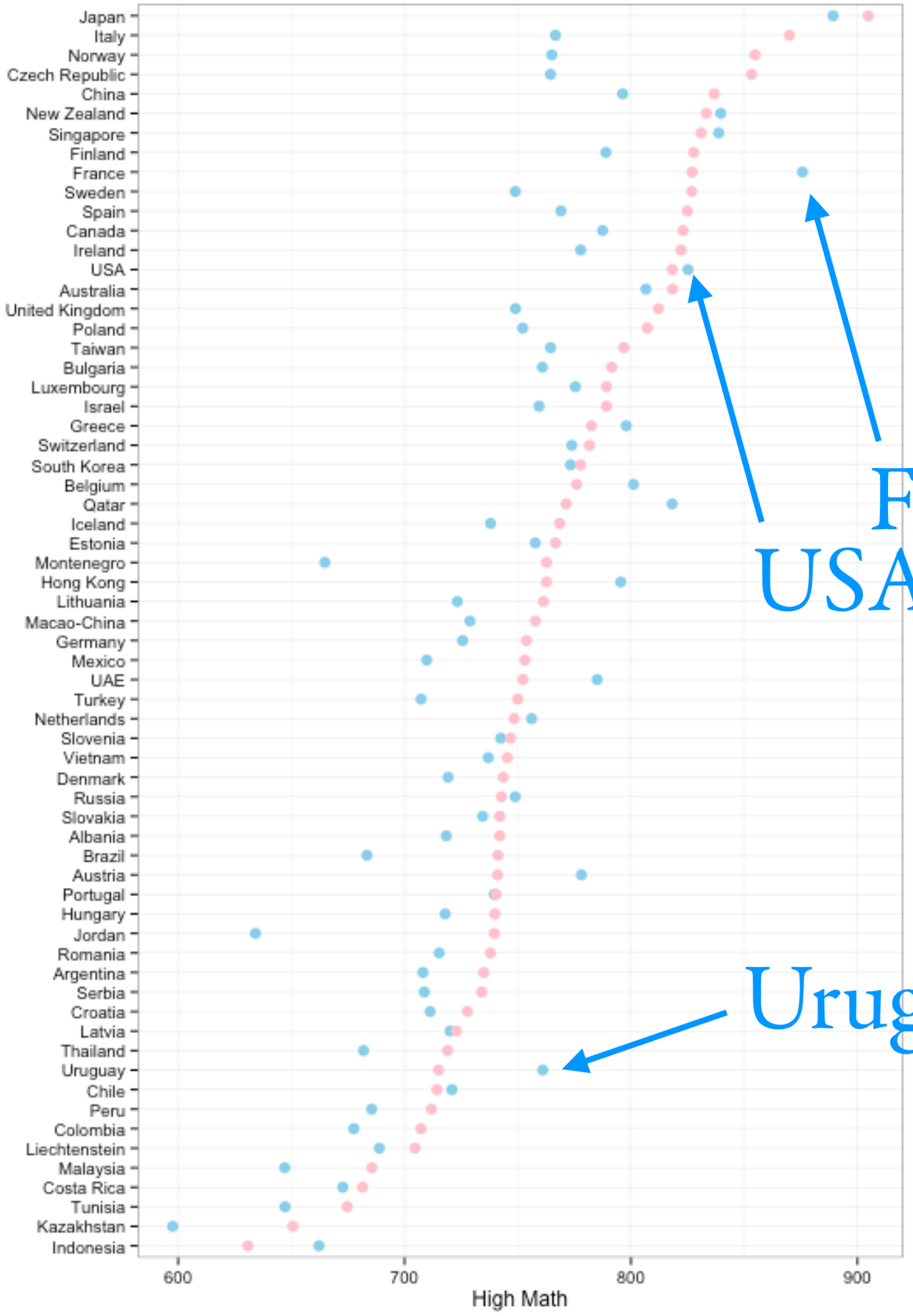
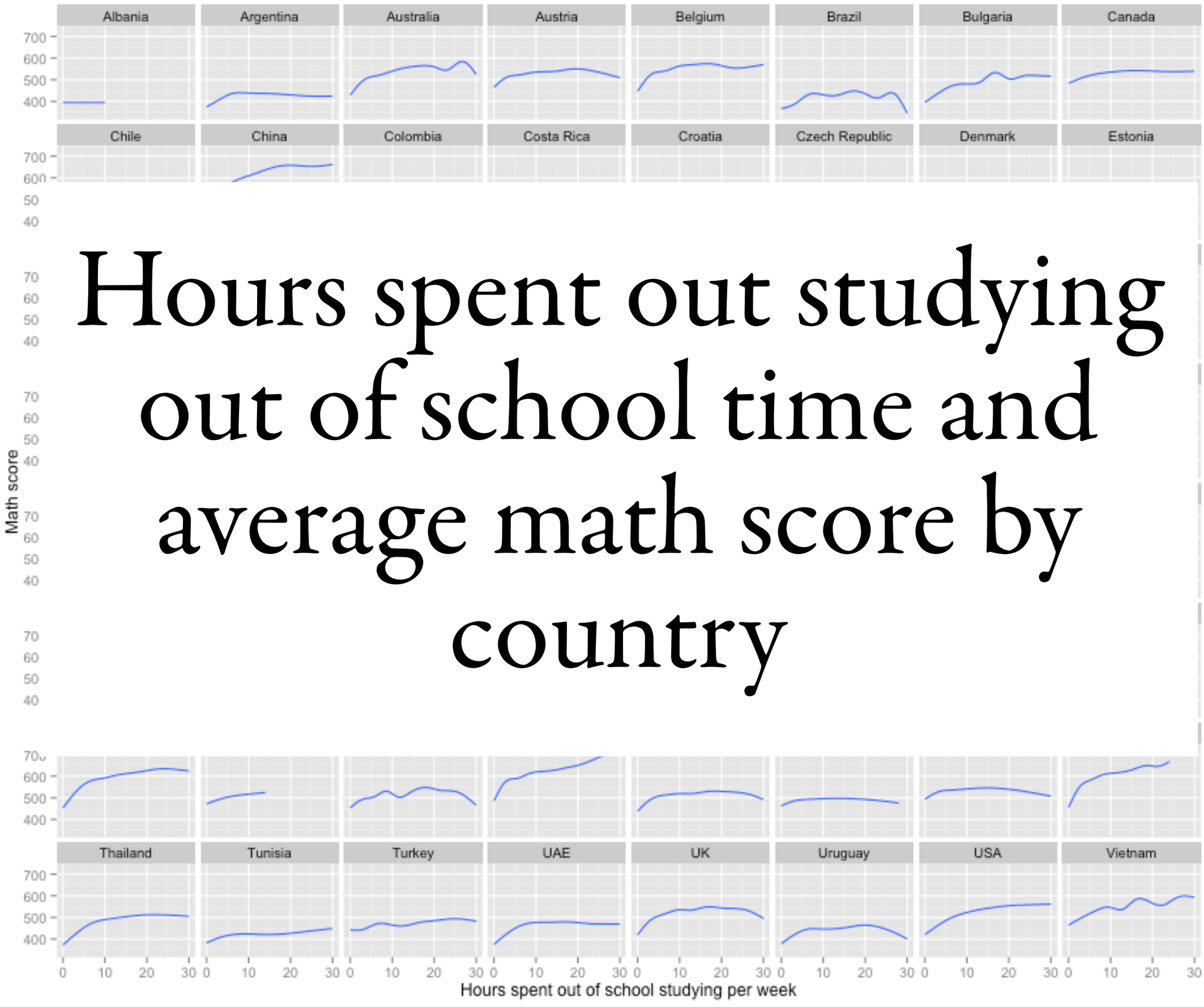
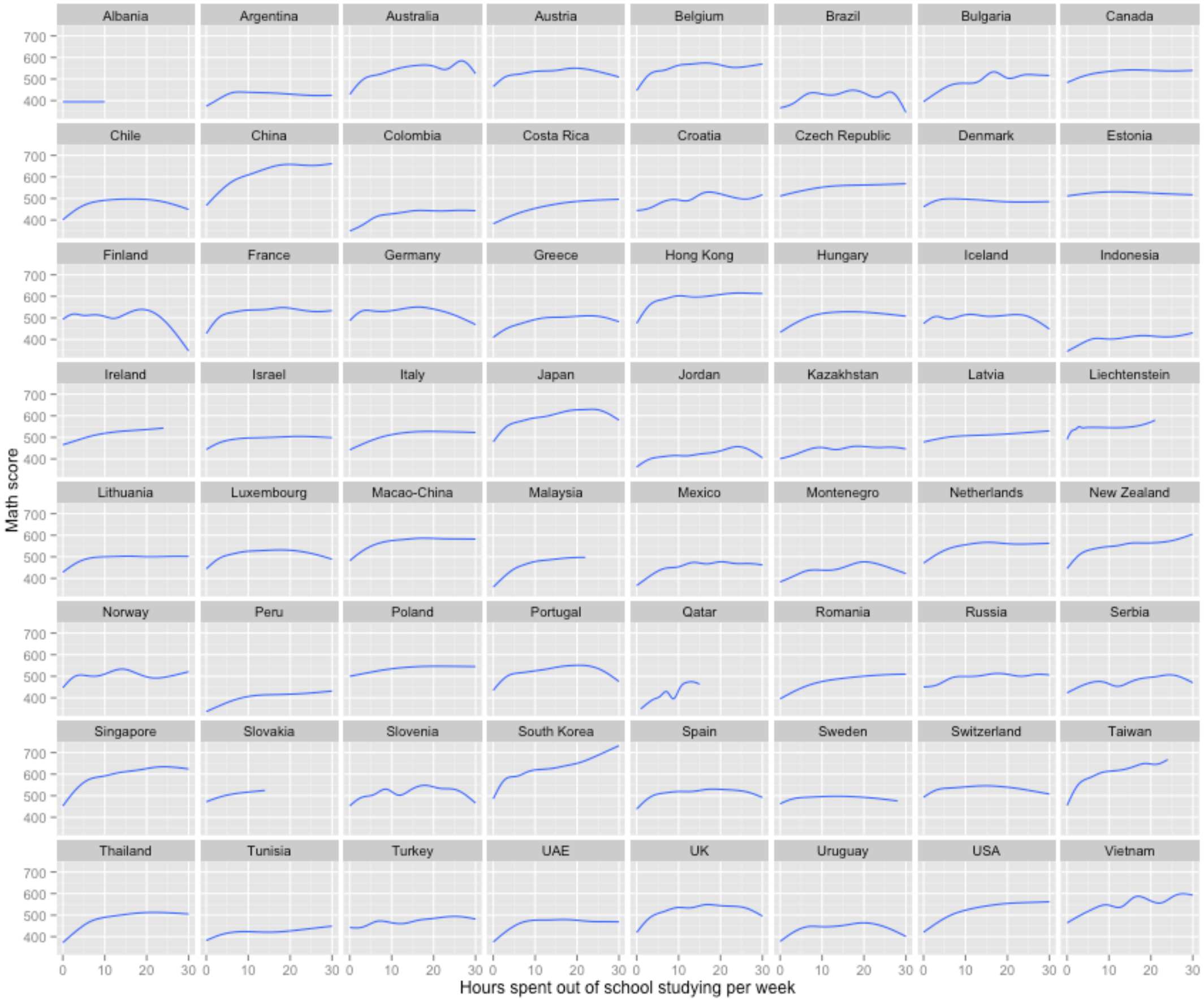


Hours spent out studying out of school time and average math score by country

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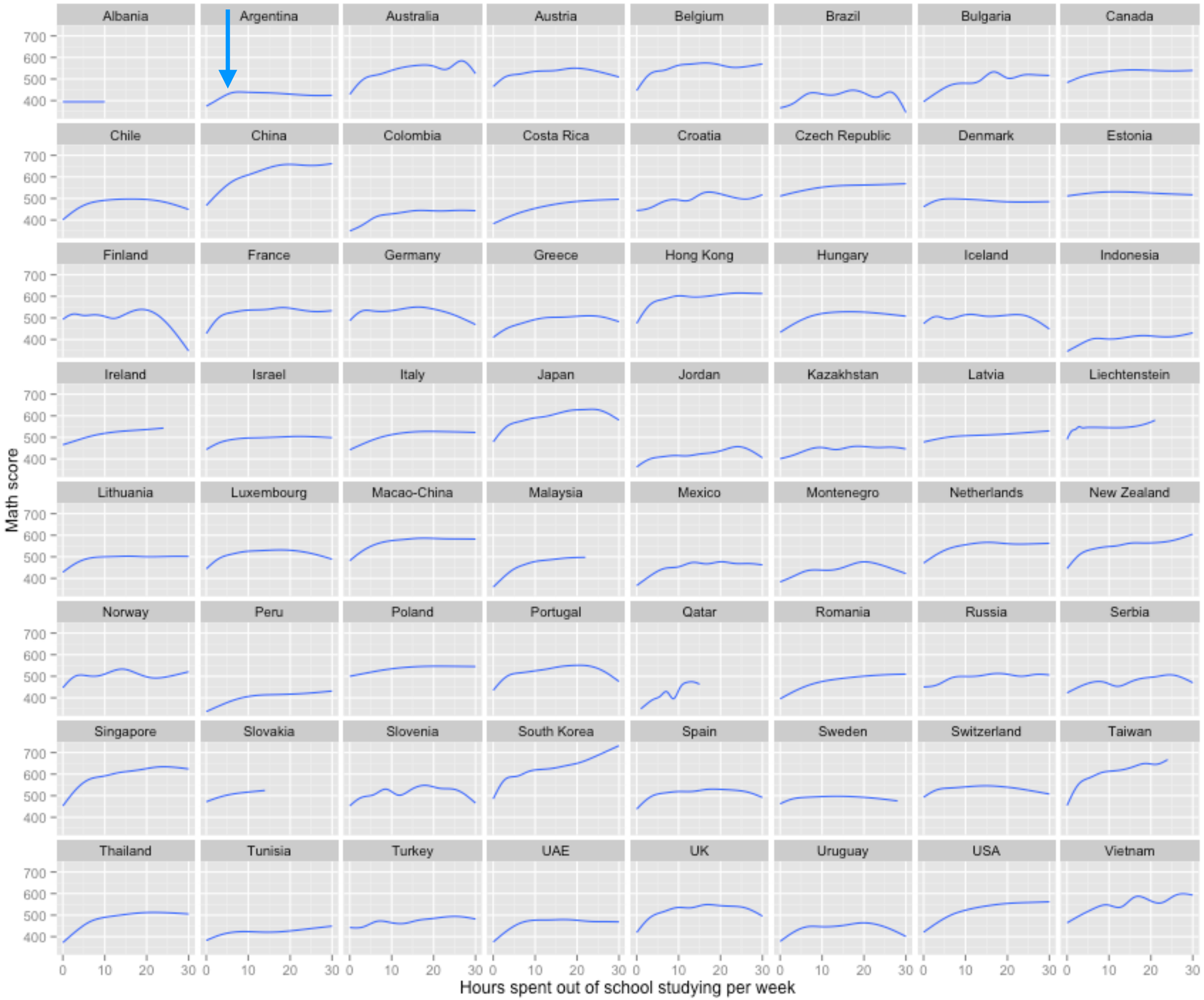
Hours spent out of school studying per week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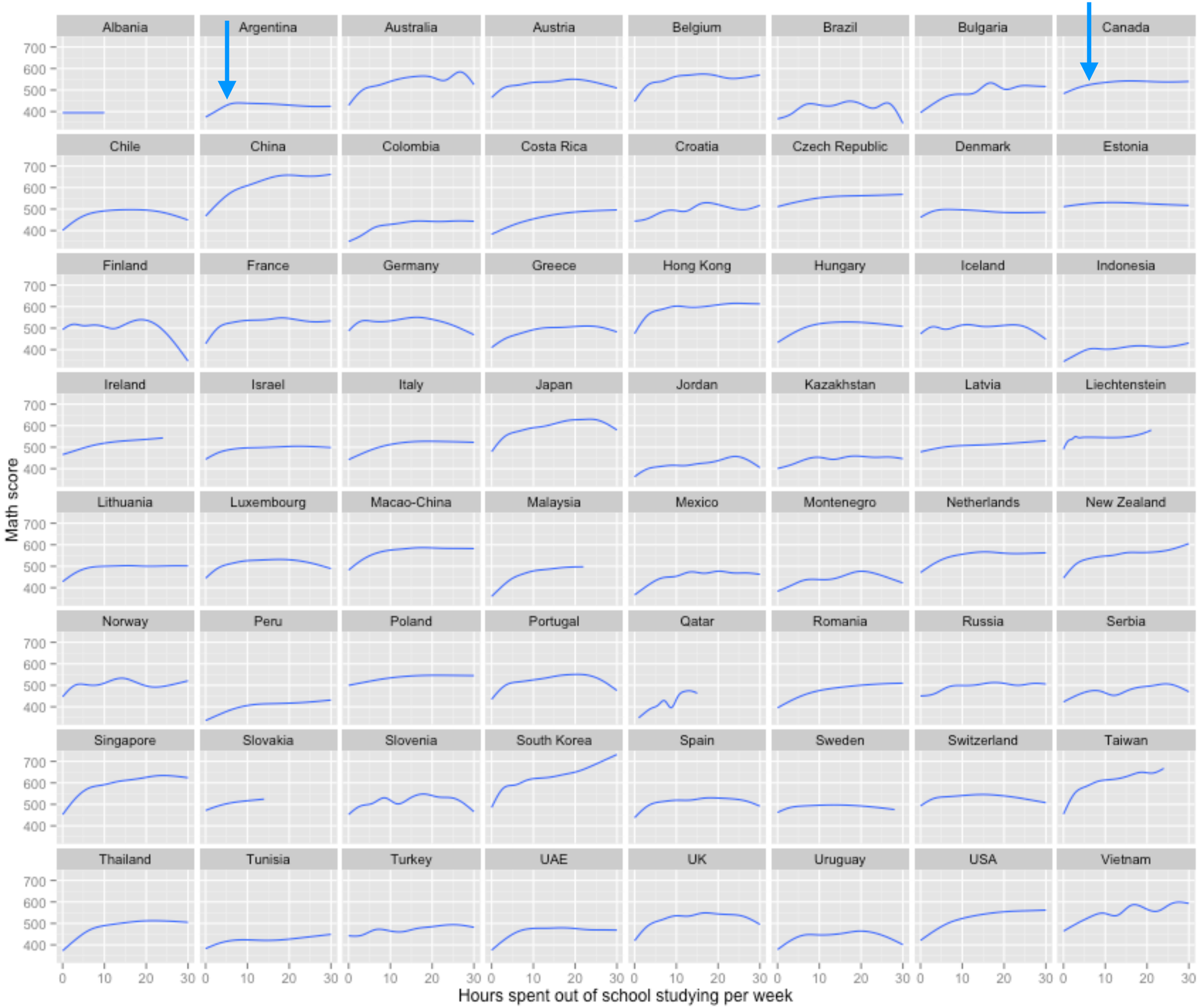
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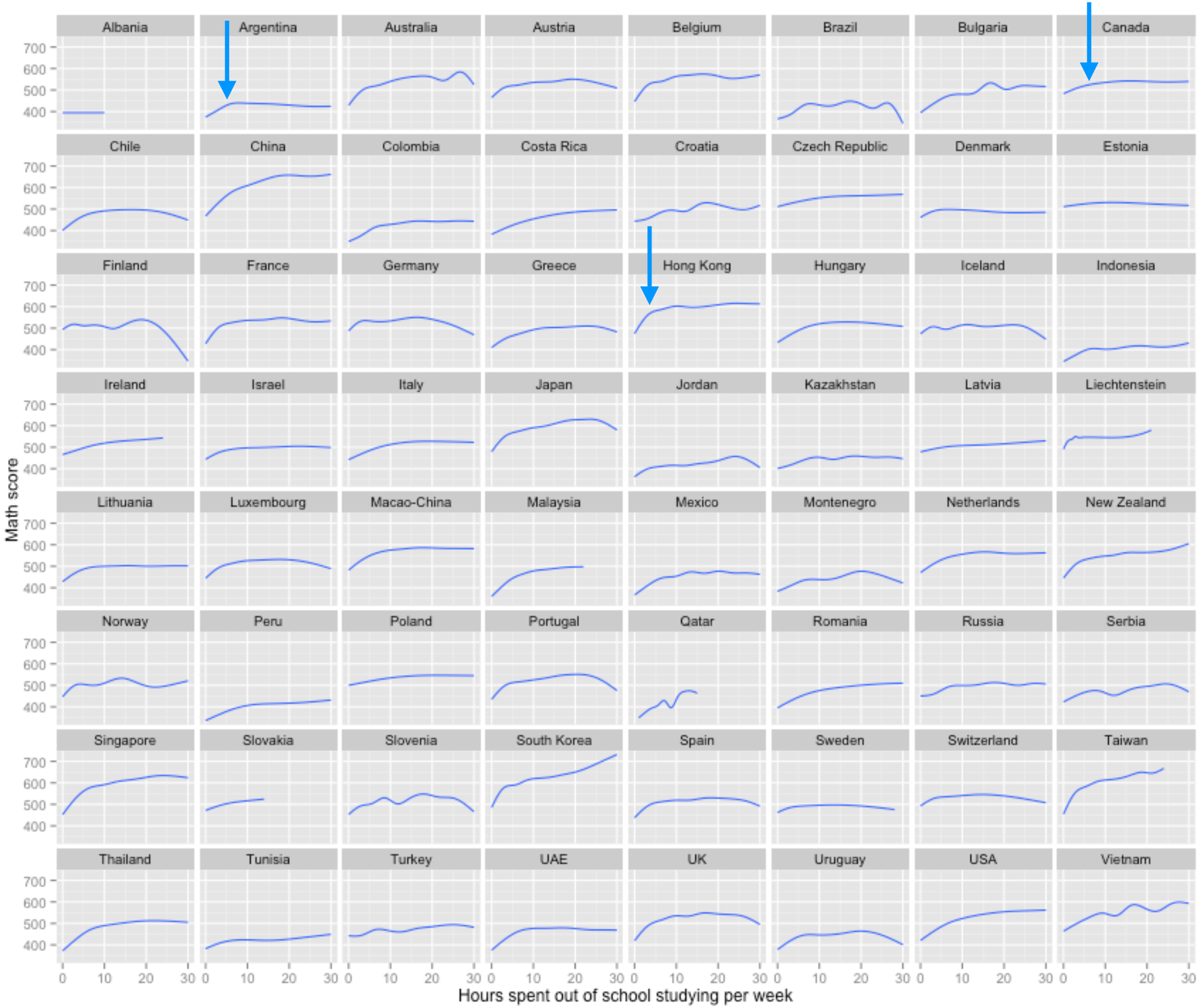
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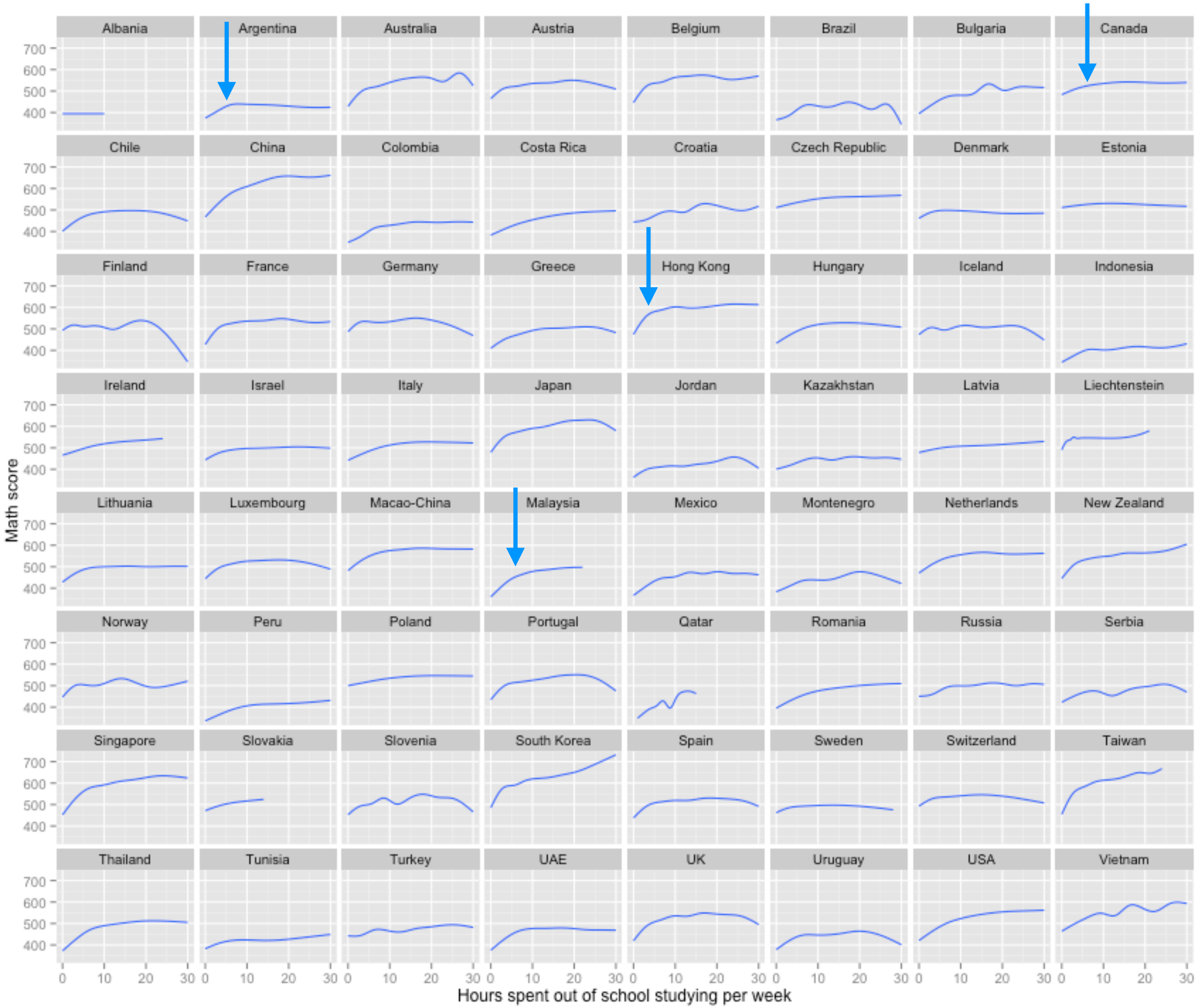
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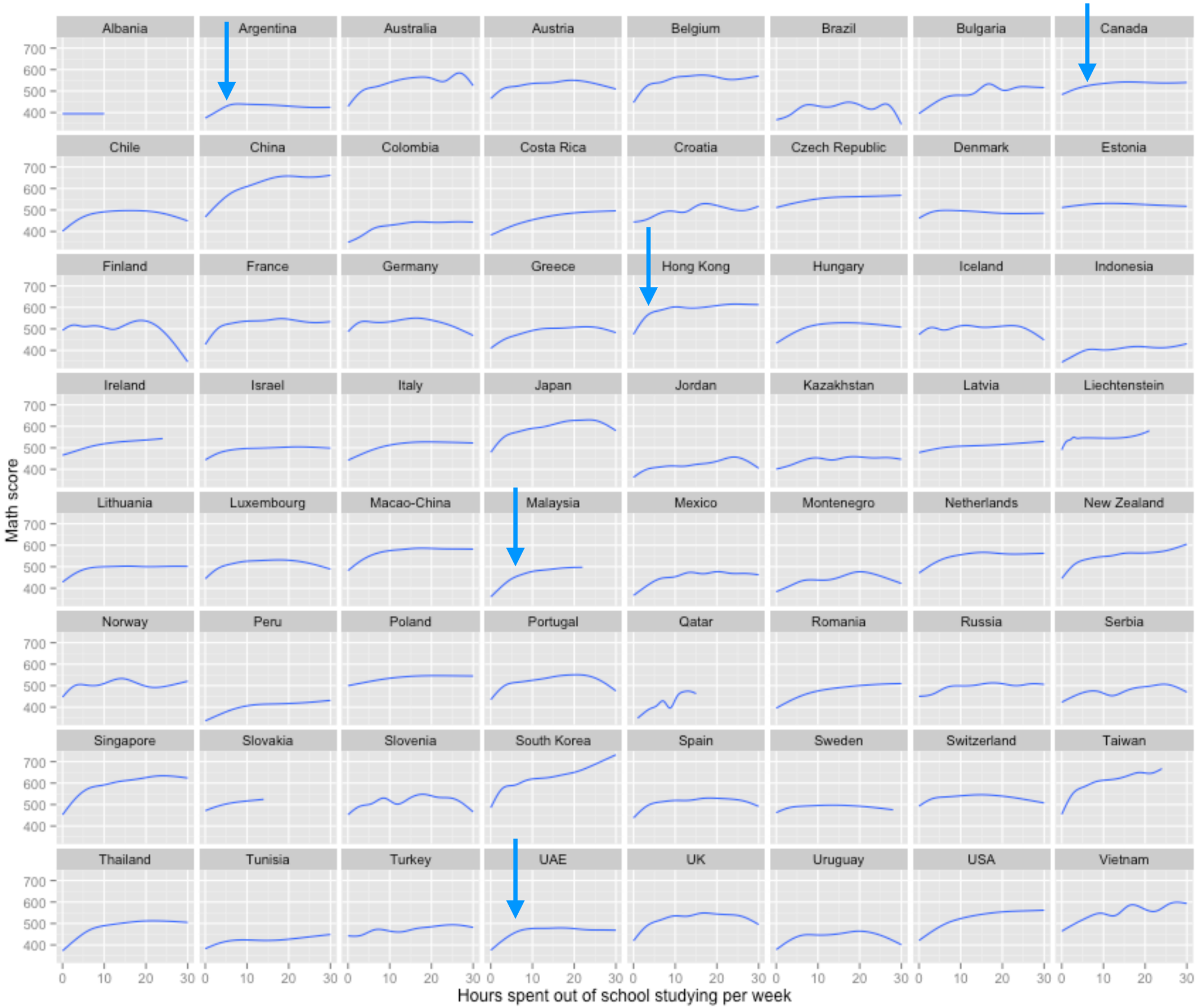
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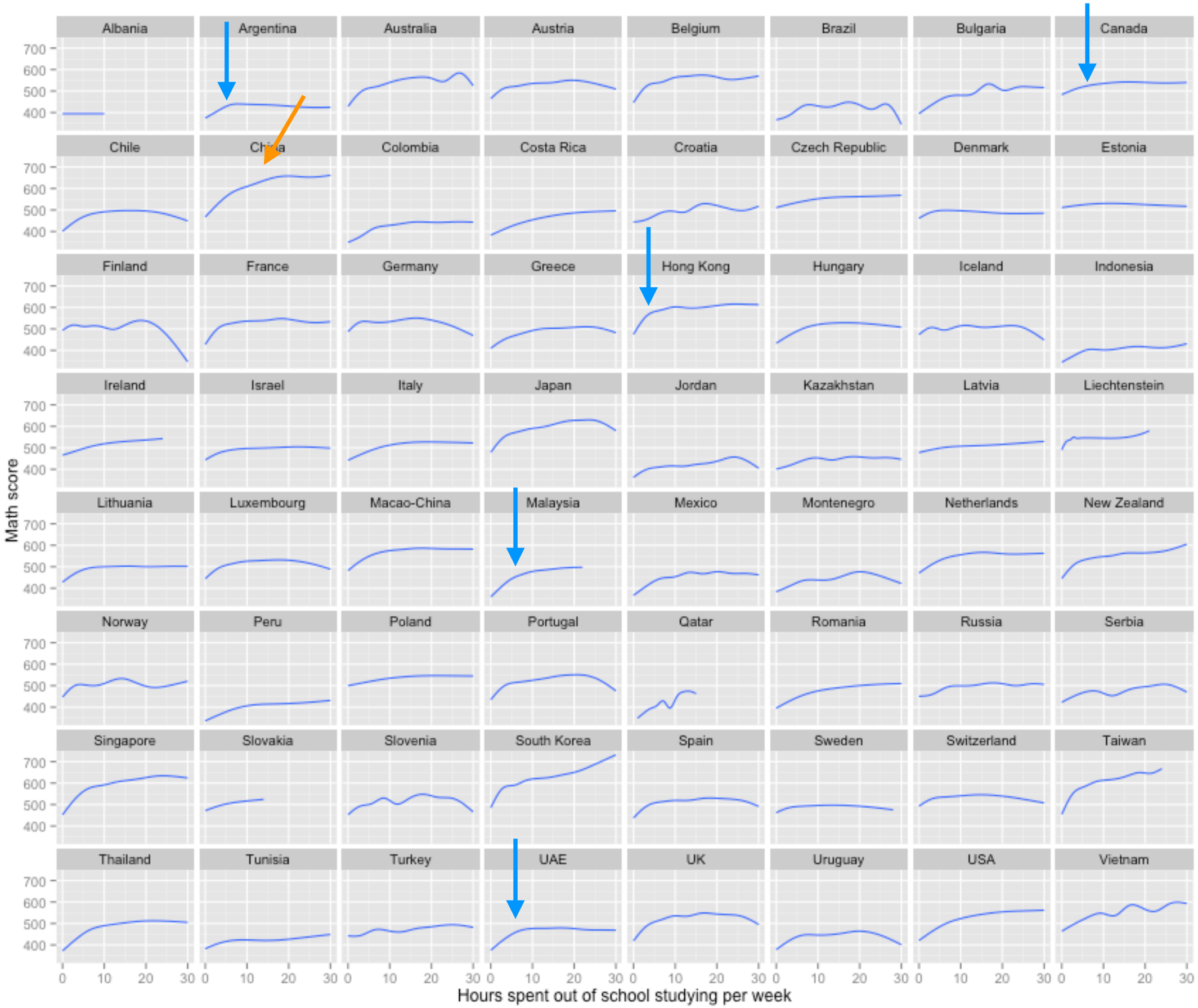
Hours spent out of school studying per week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Math score
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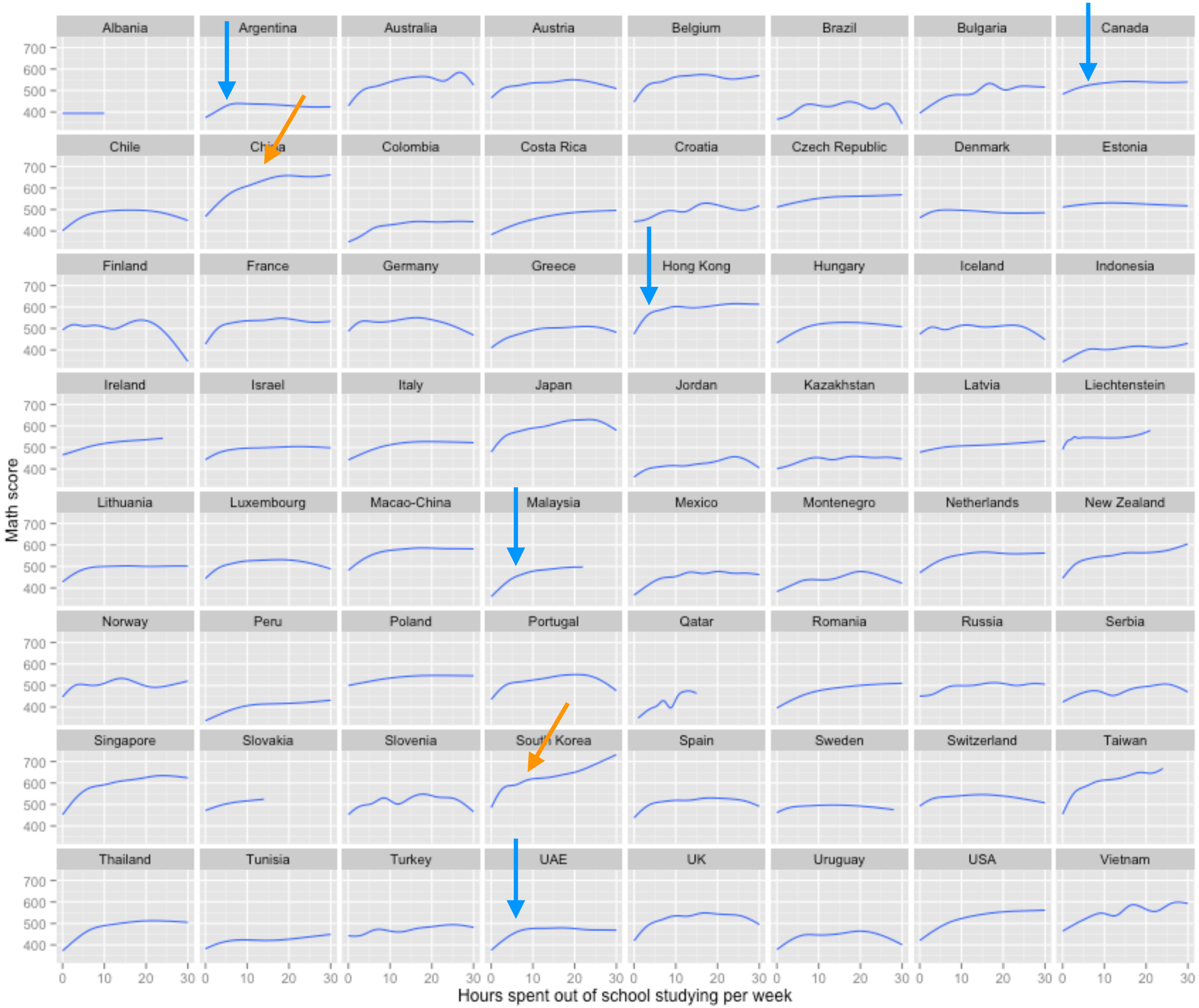
Hours spent out of school studying per week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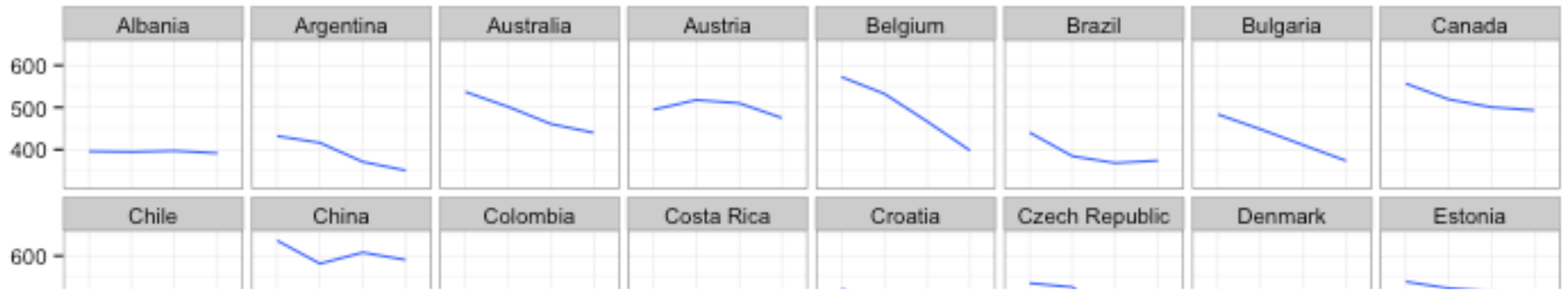
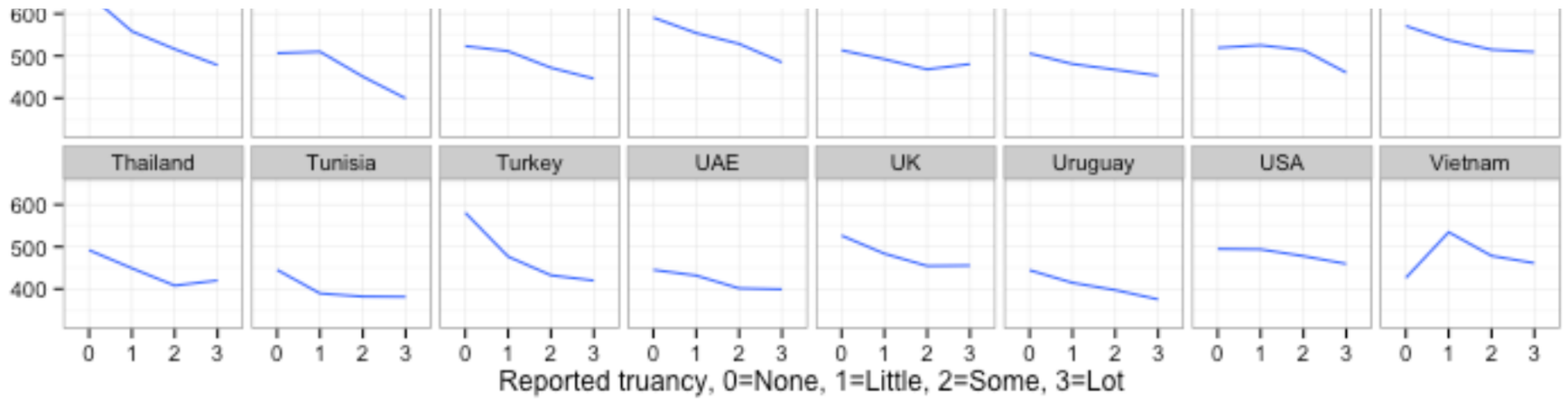
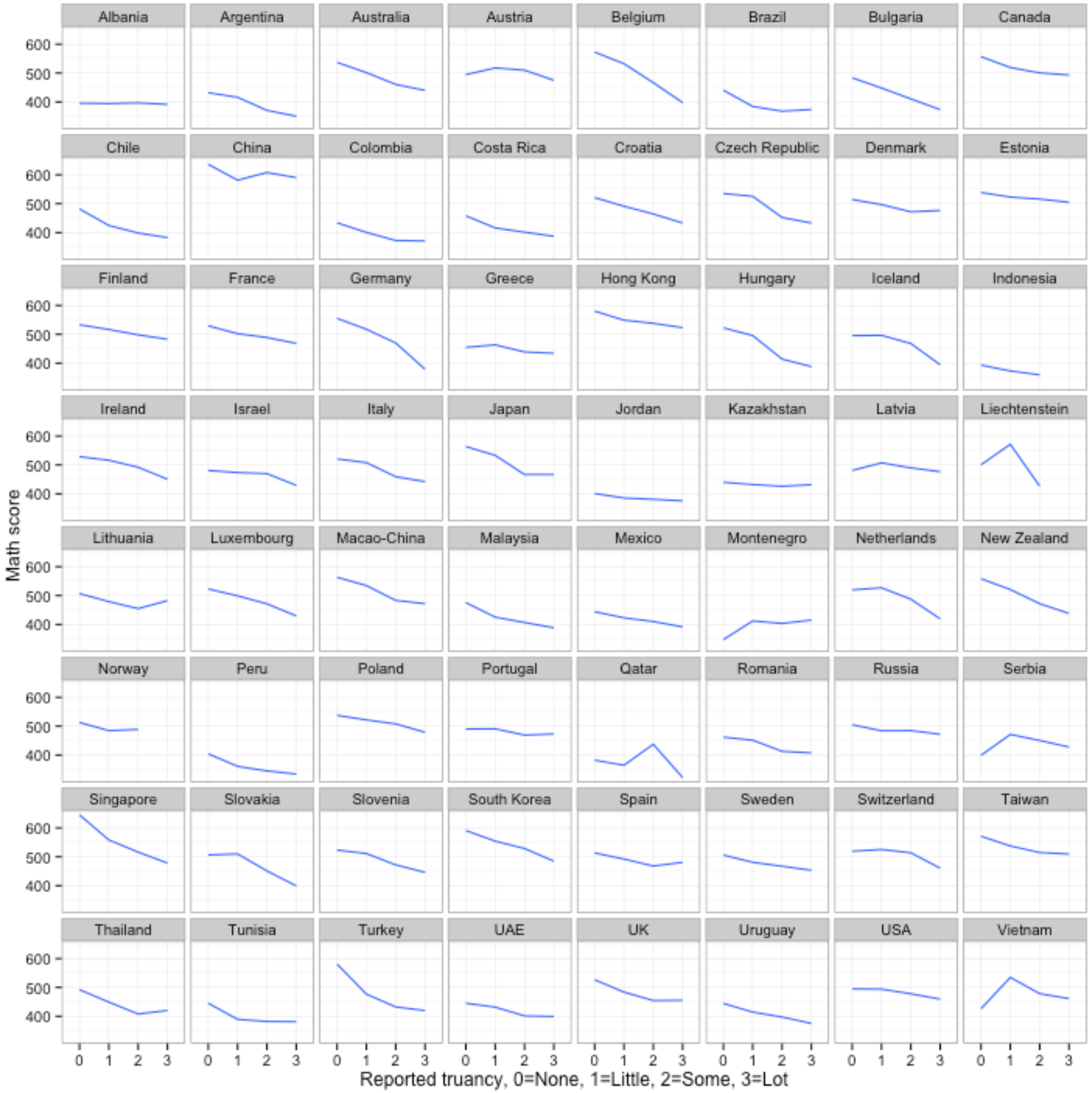
Math score
Hours spent out of school studying per week



Reported truancy and average math score by country

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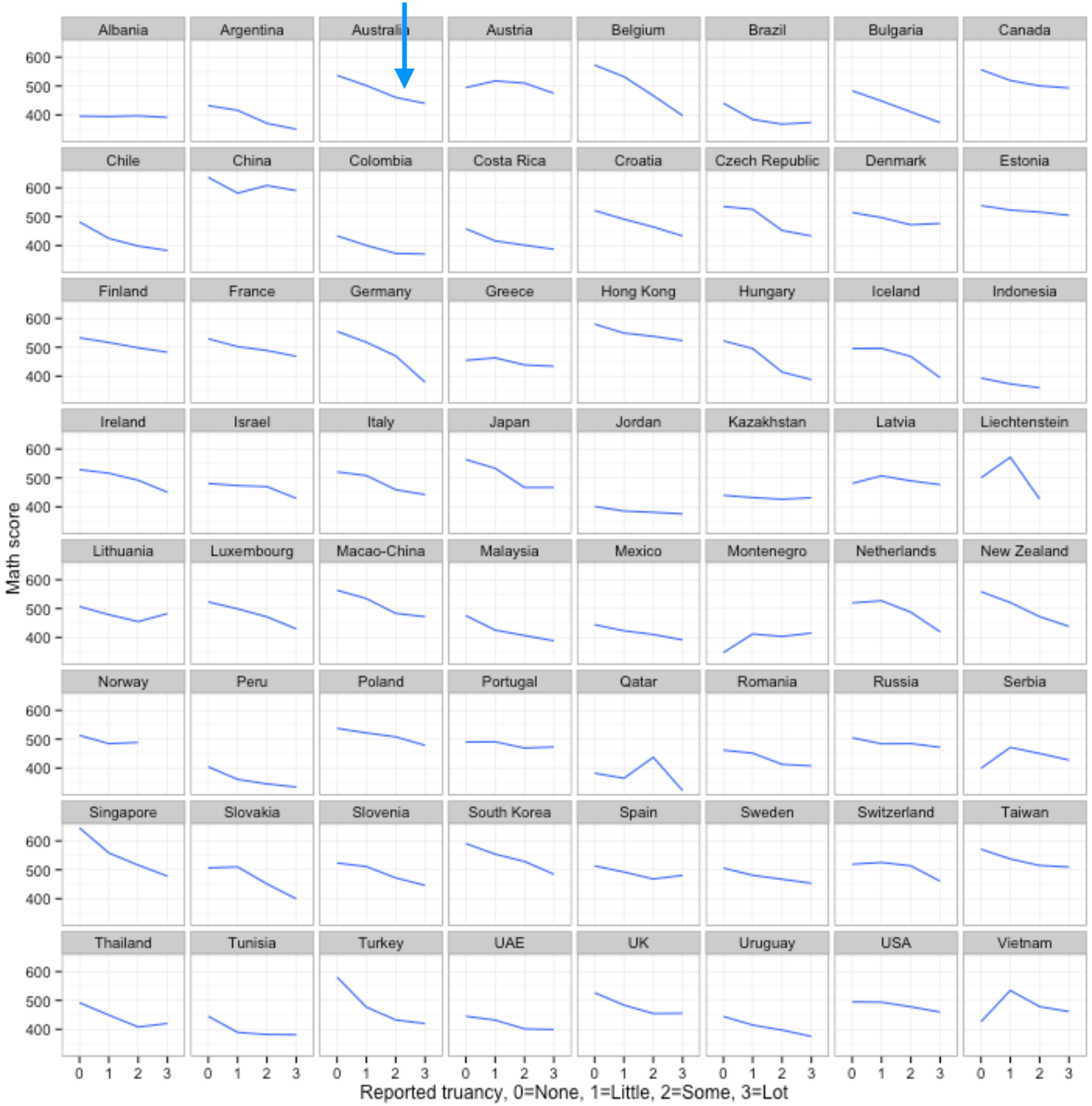
Reported truancy, 0=None, 1=Little, 2=Some, 3=Lot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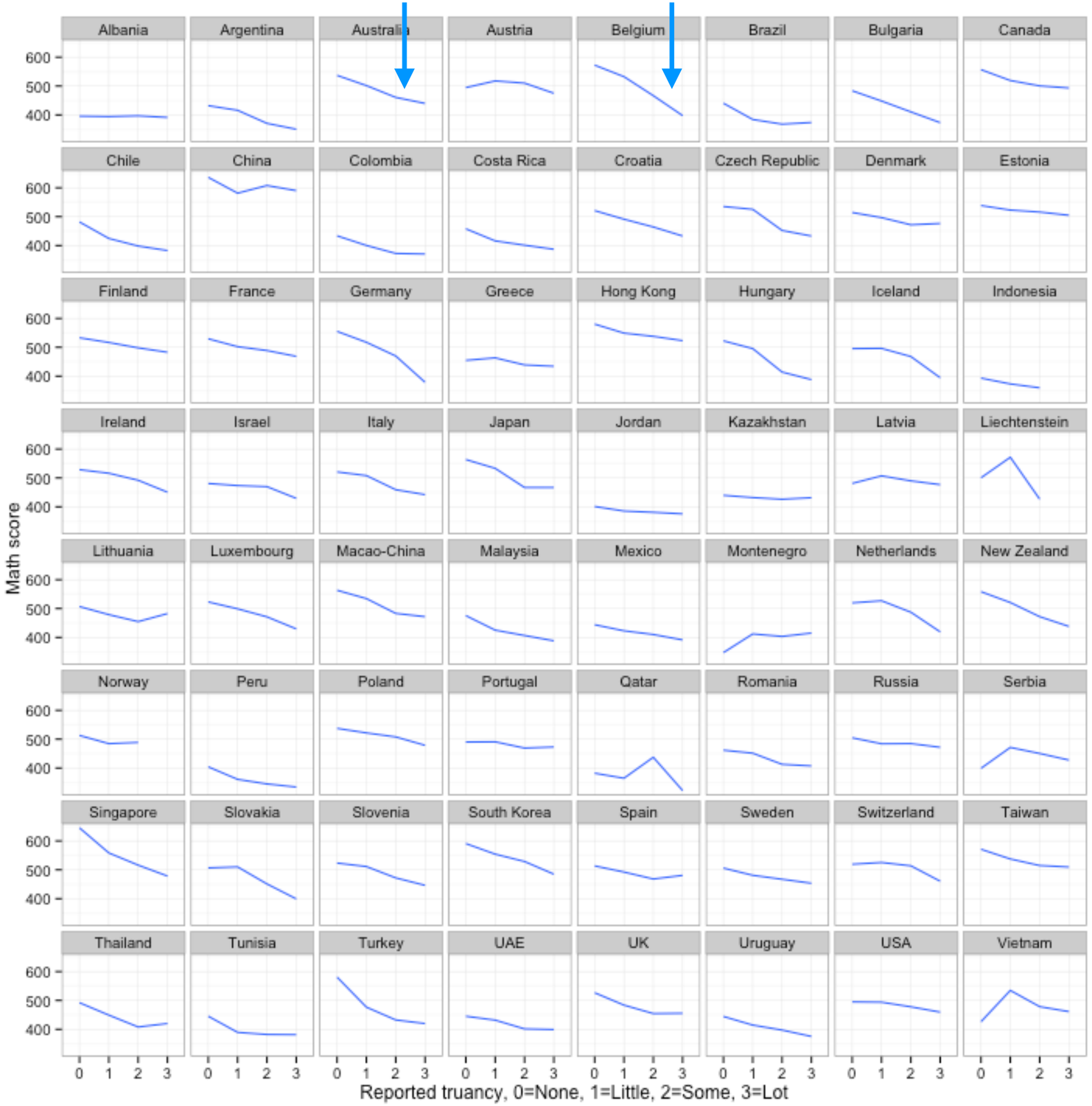
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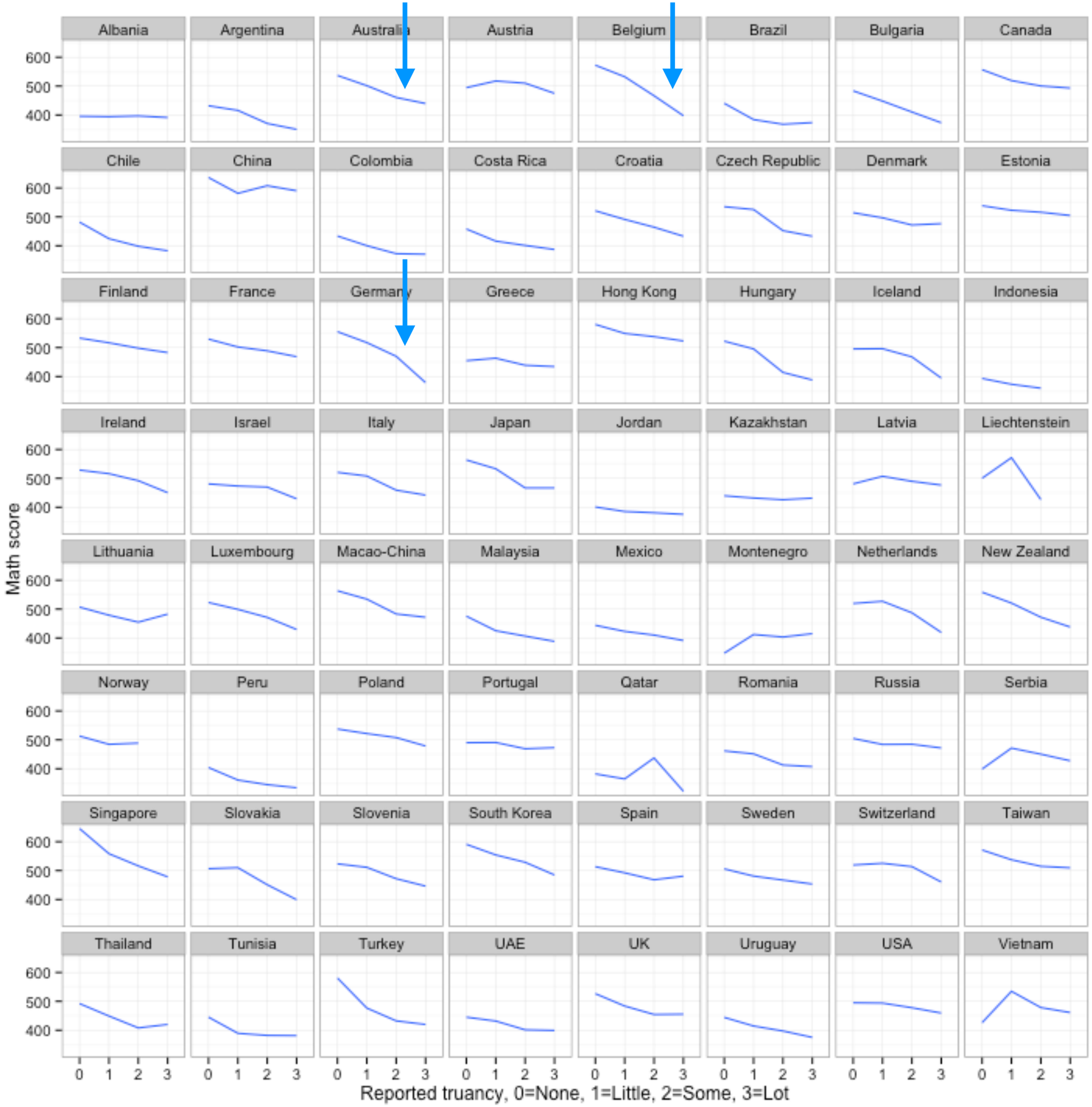
Reported truancy, 0=None, 1=Little, 2=Some, 3=Lot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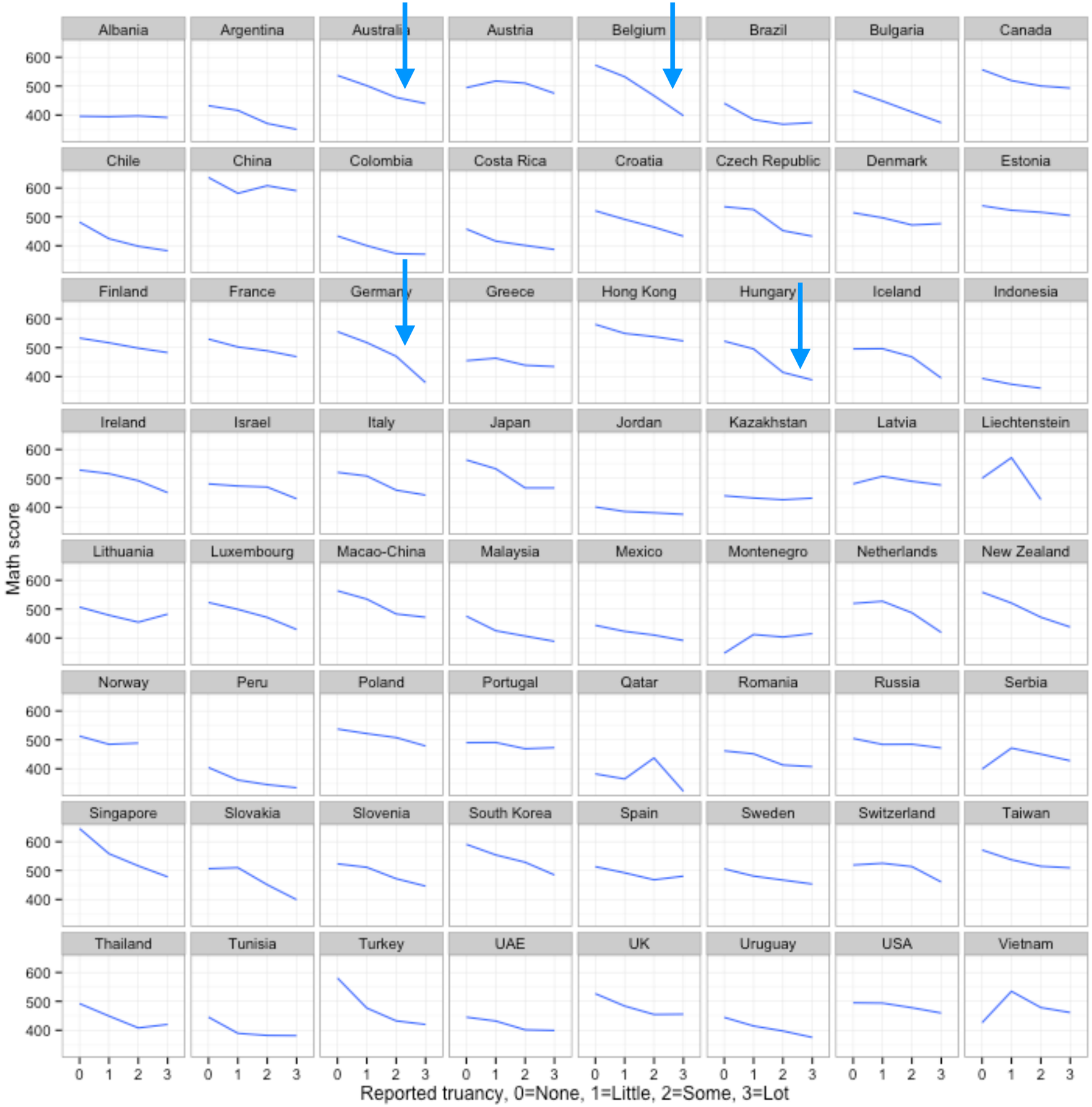
Reported truancy, 0=None, 1=Little, 2=Some, 3=Lot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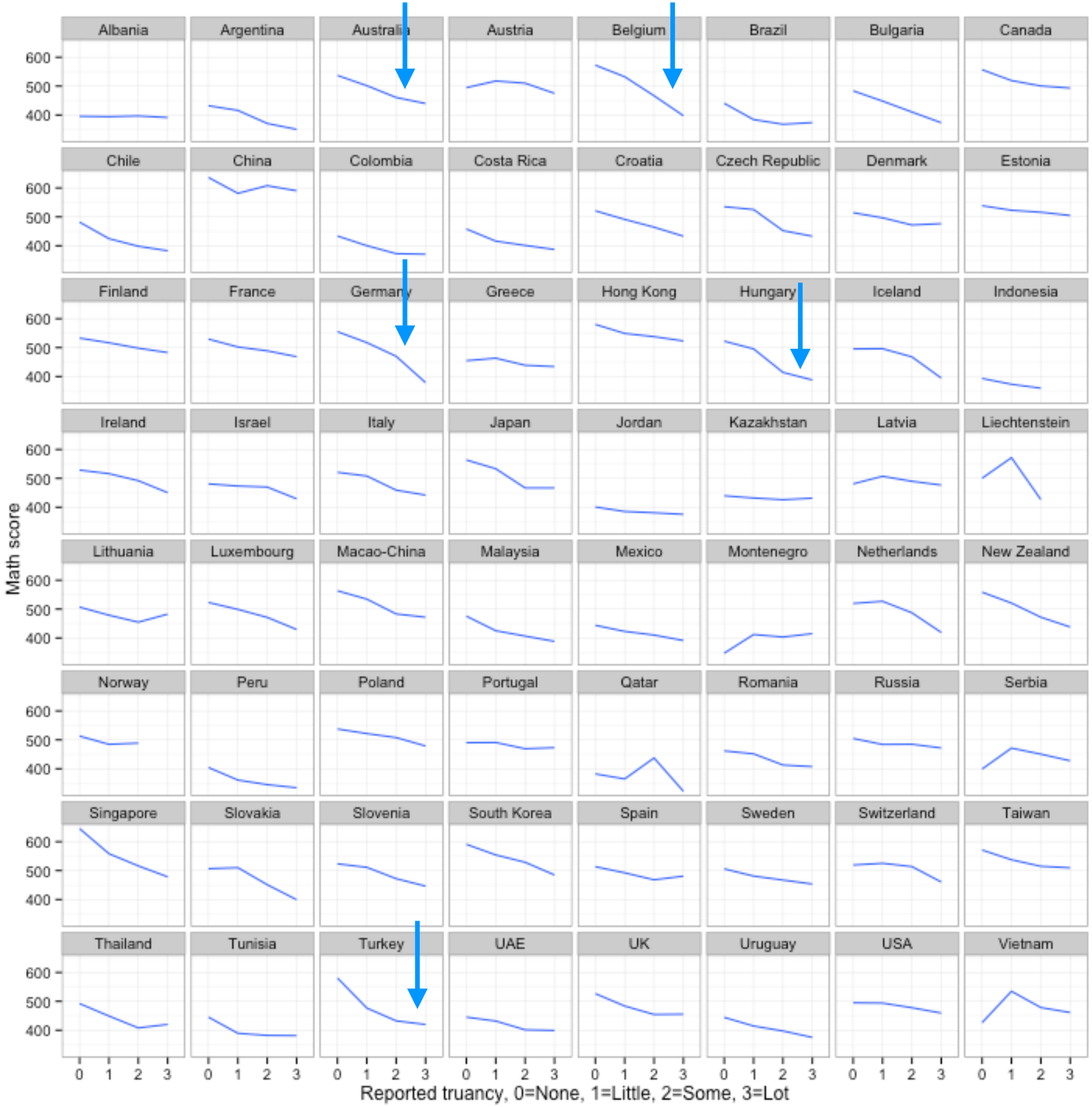
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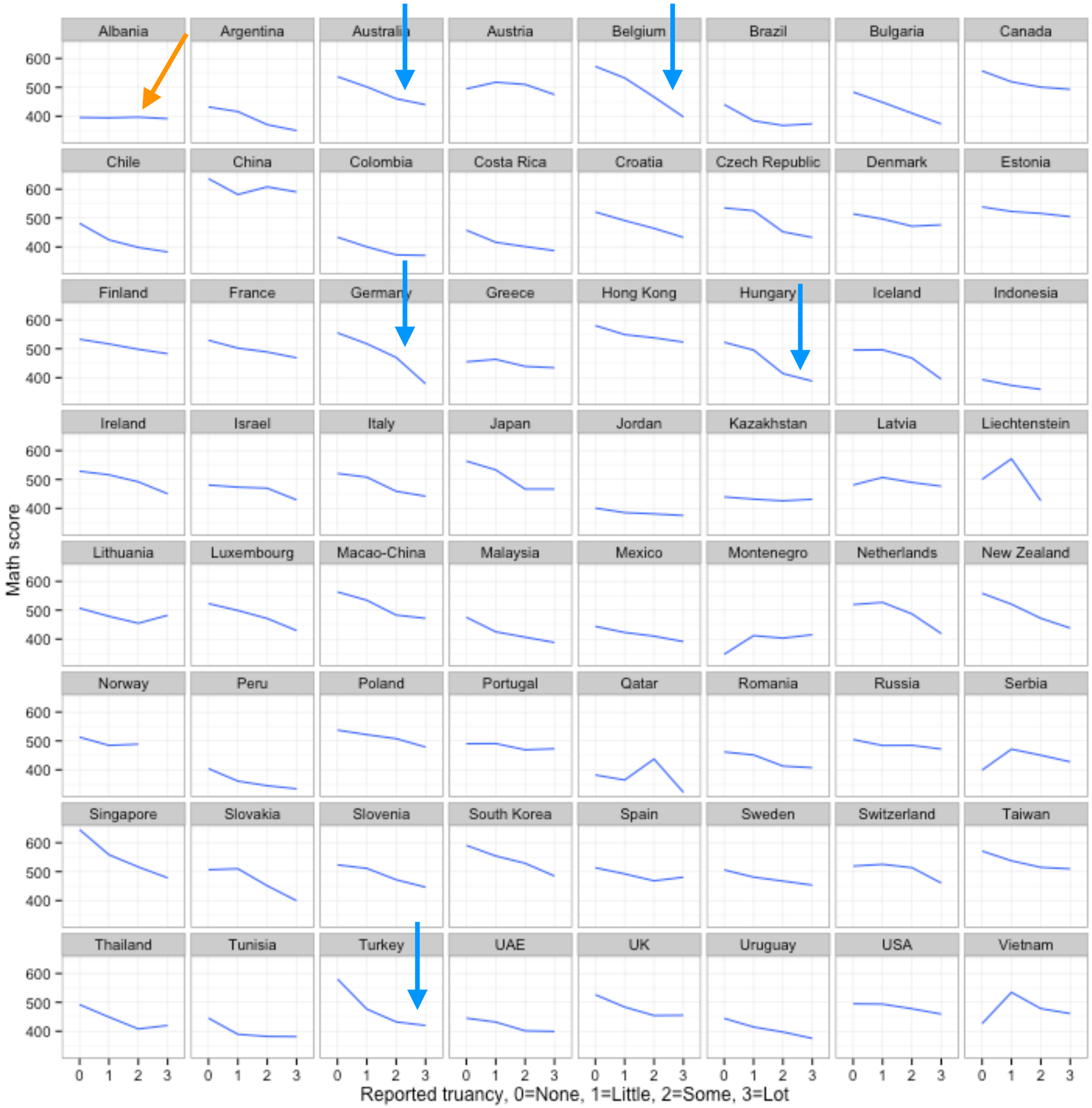
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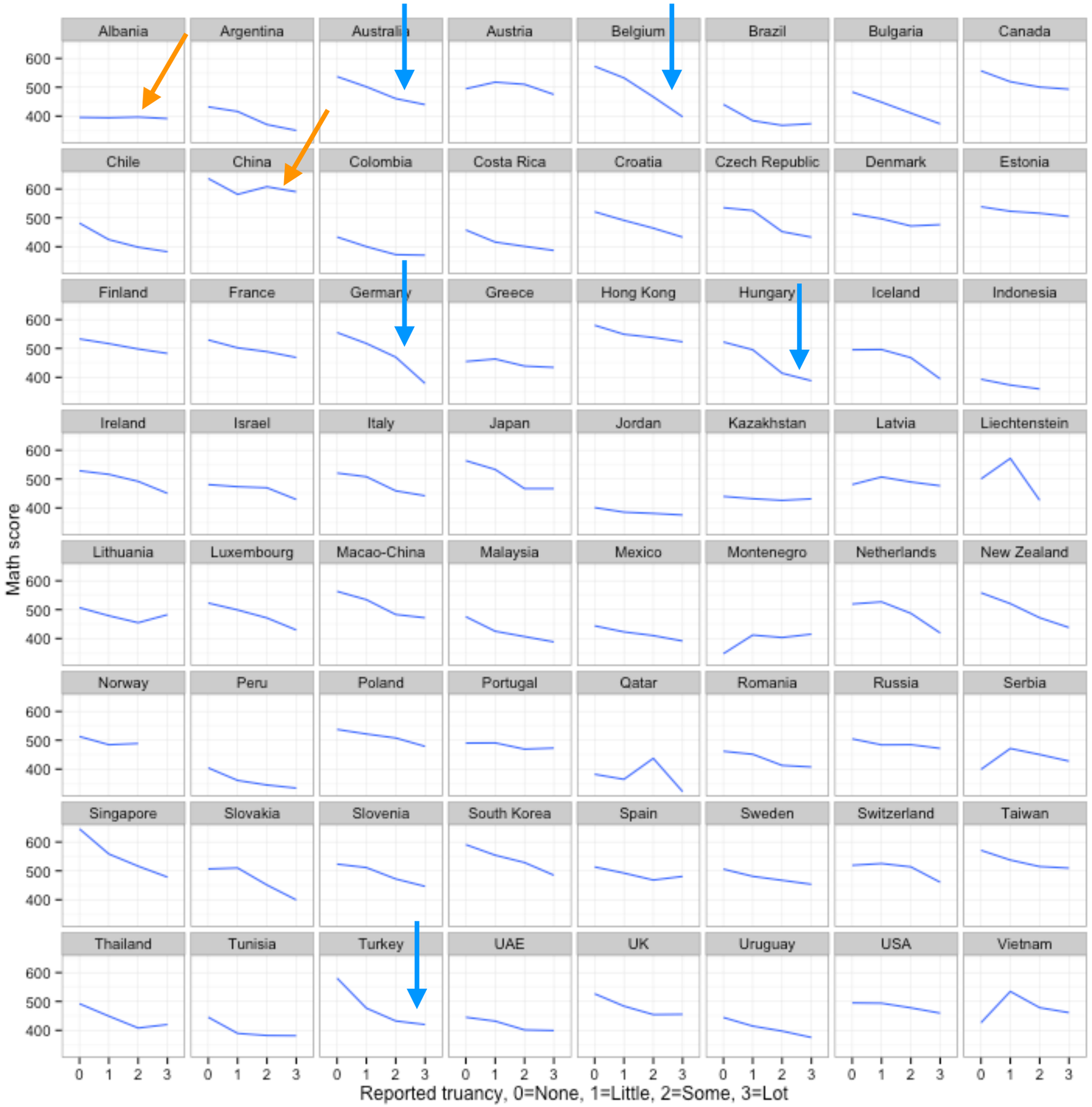
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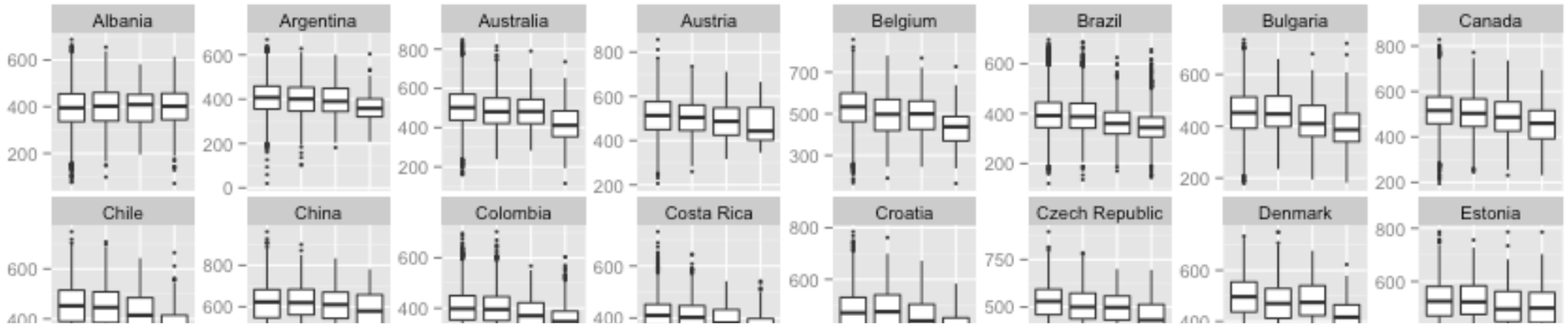
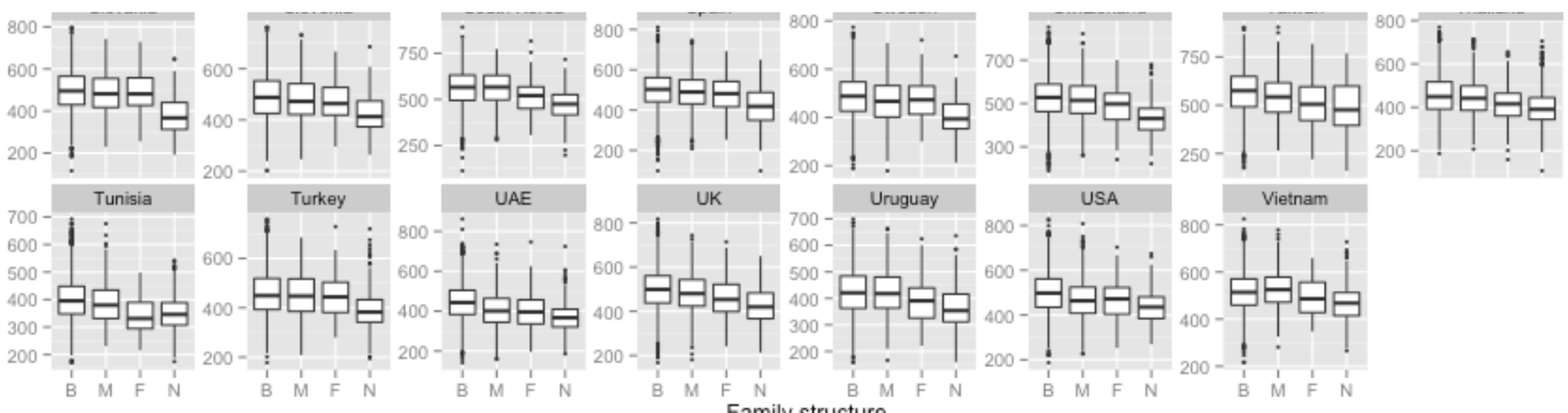
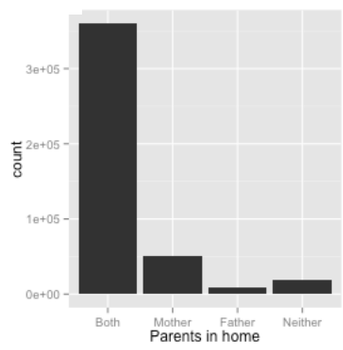
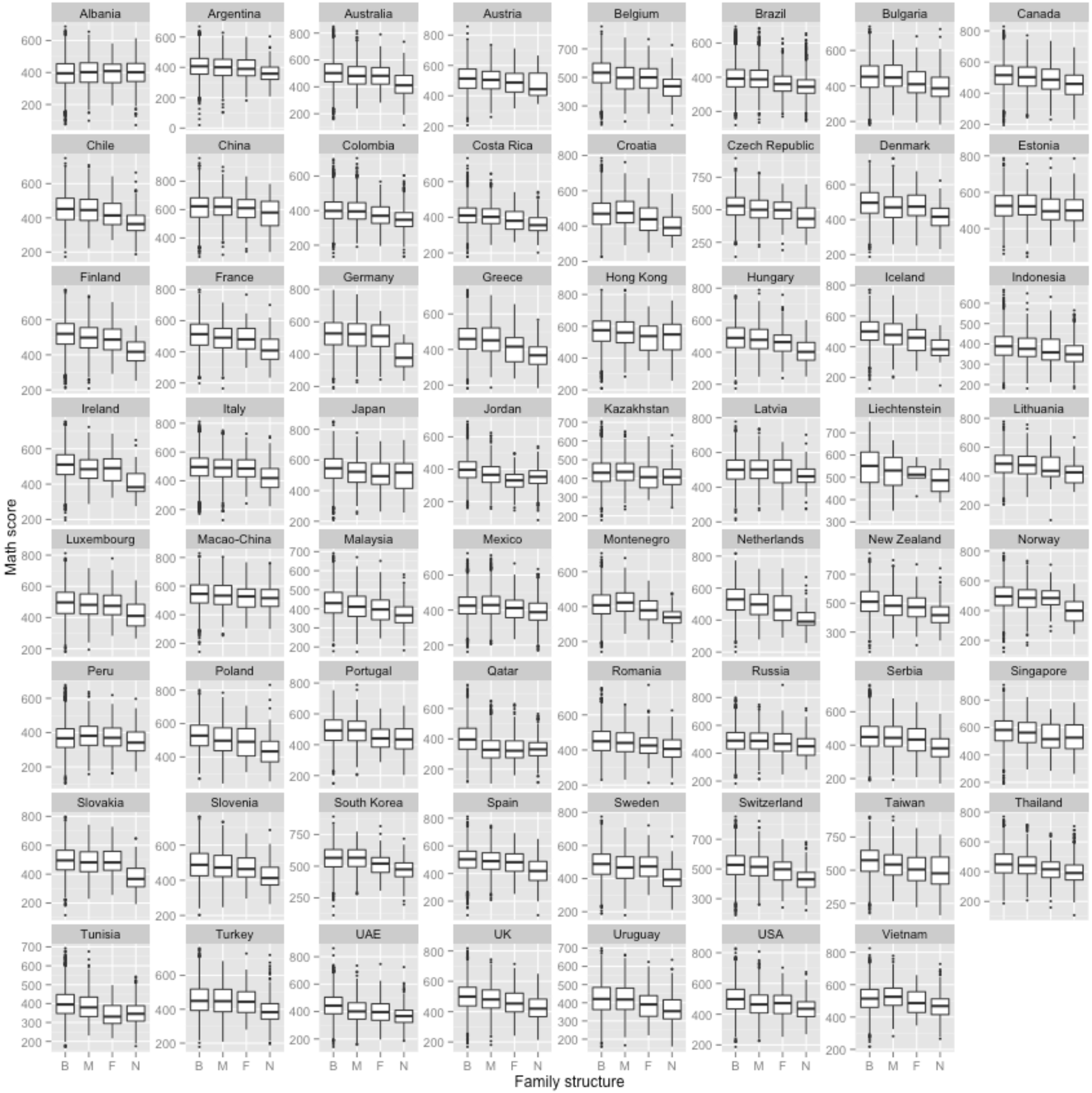


Parents in the home and average math score by country



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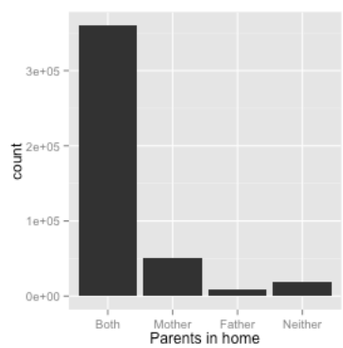
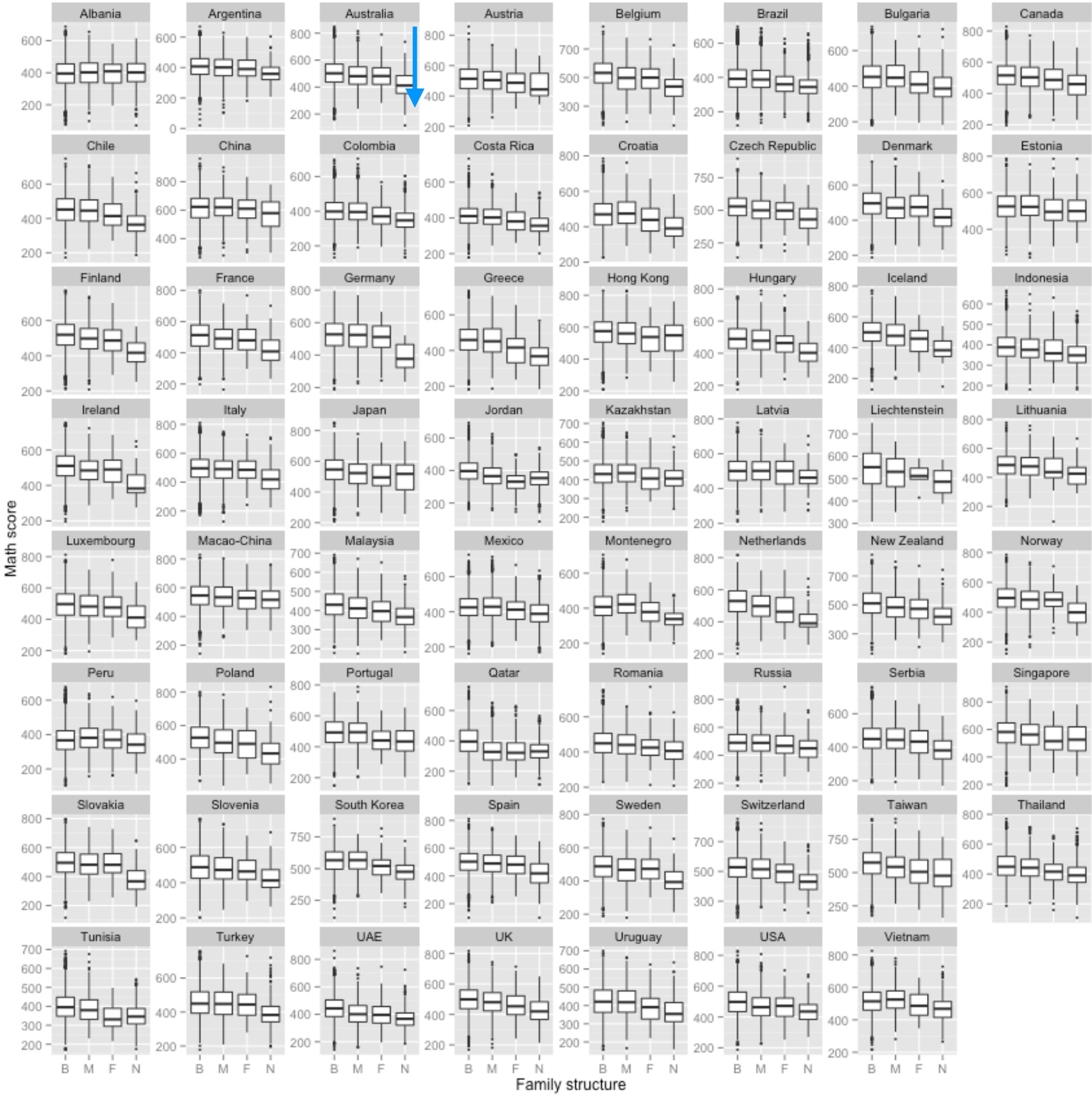
Math score
B M F N
Family structure


count
Both
Mother
Father
Neither
Parents in home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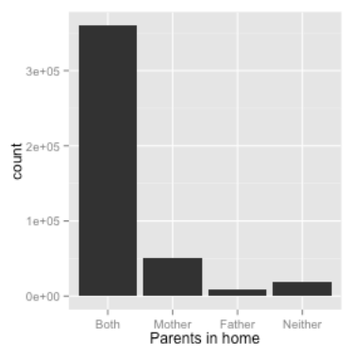
Math score
B M F N
Family structure


count
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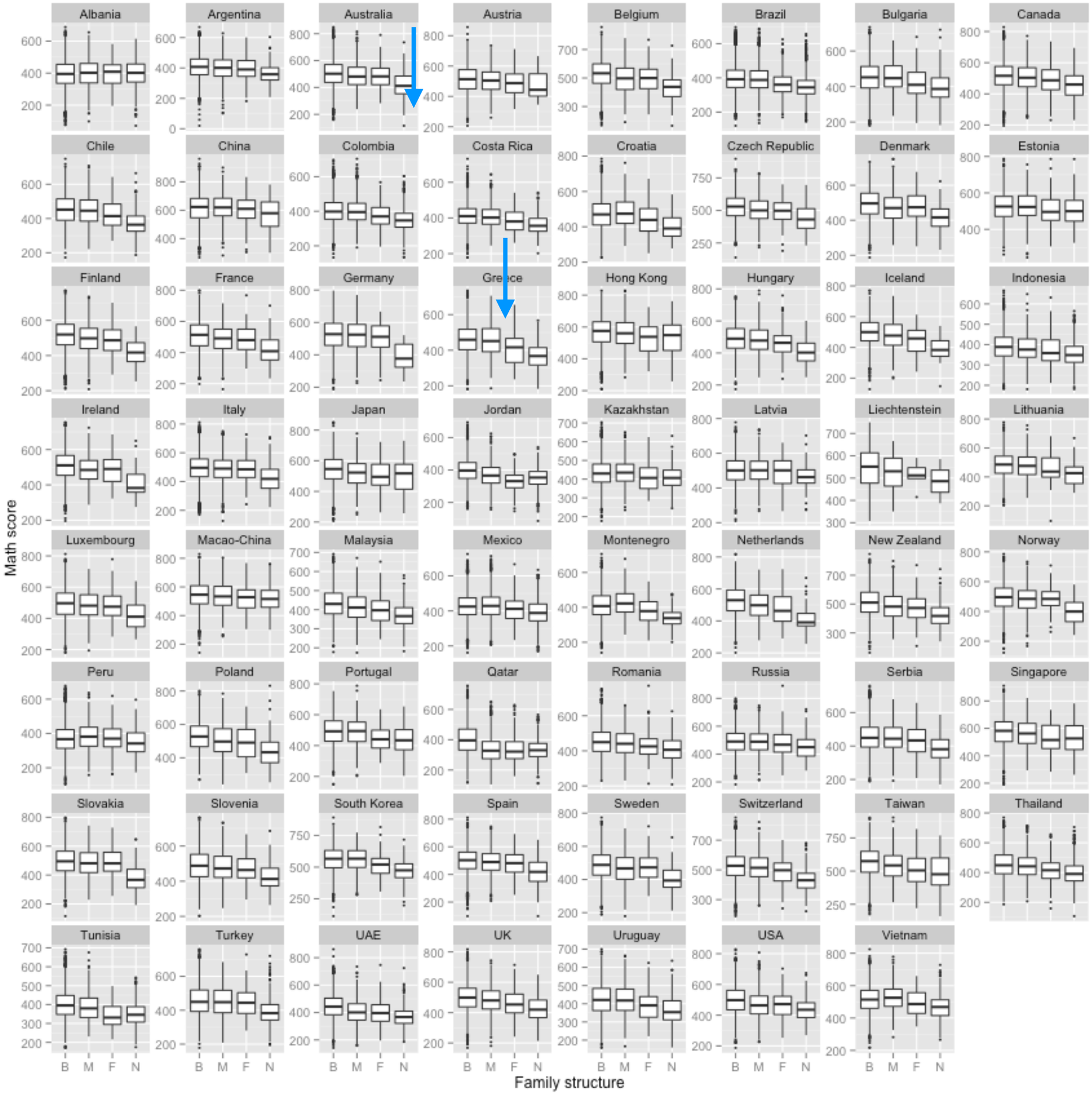
2e+05
1e+05
0e+00
Both
Mother
Father
Neither
Parents in home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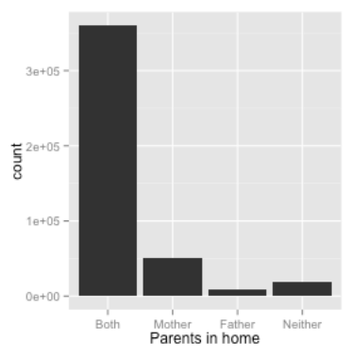
B M F N
Family structure
Math score


count
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Mother
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Neither
Parents in home

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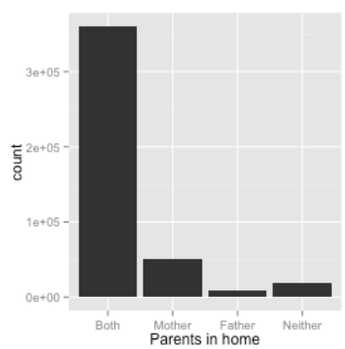
B M F N
Family structure
Math score


count
Both
Mother
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Parents in home

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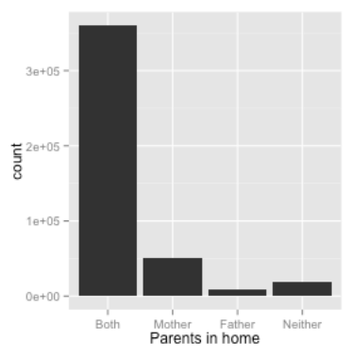
B M F N
Family structure
Math score


count
3e+05
2e+05
1e+05
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Both
Mother
Father
Neither
Parents in home

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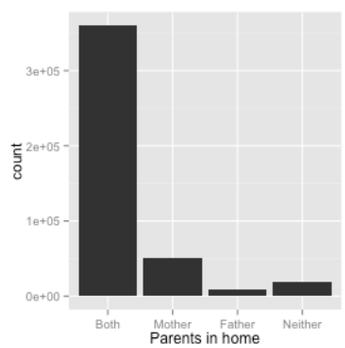
Vietnam
Math score
B M F N
Family structure


count
Both
Mother
Father
Neither
Parents in home

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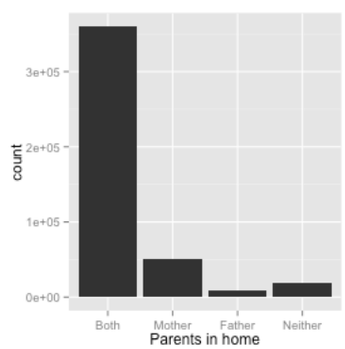
Family structure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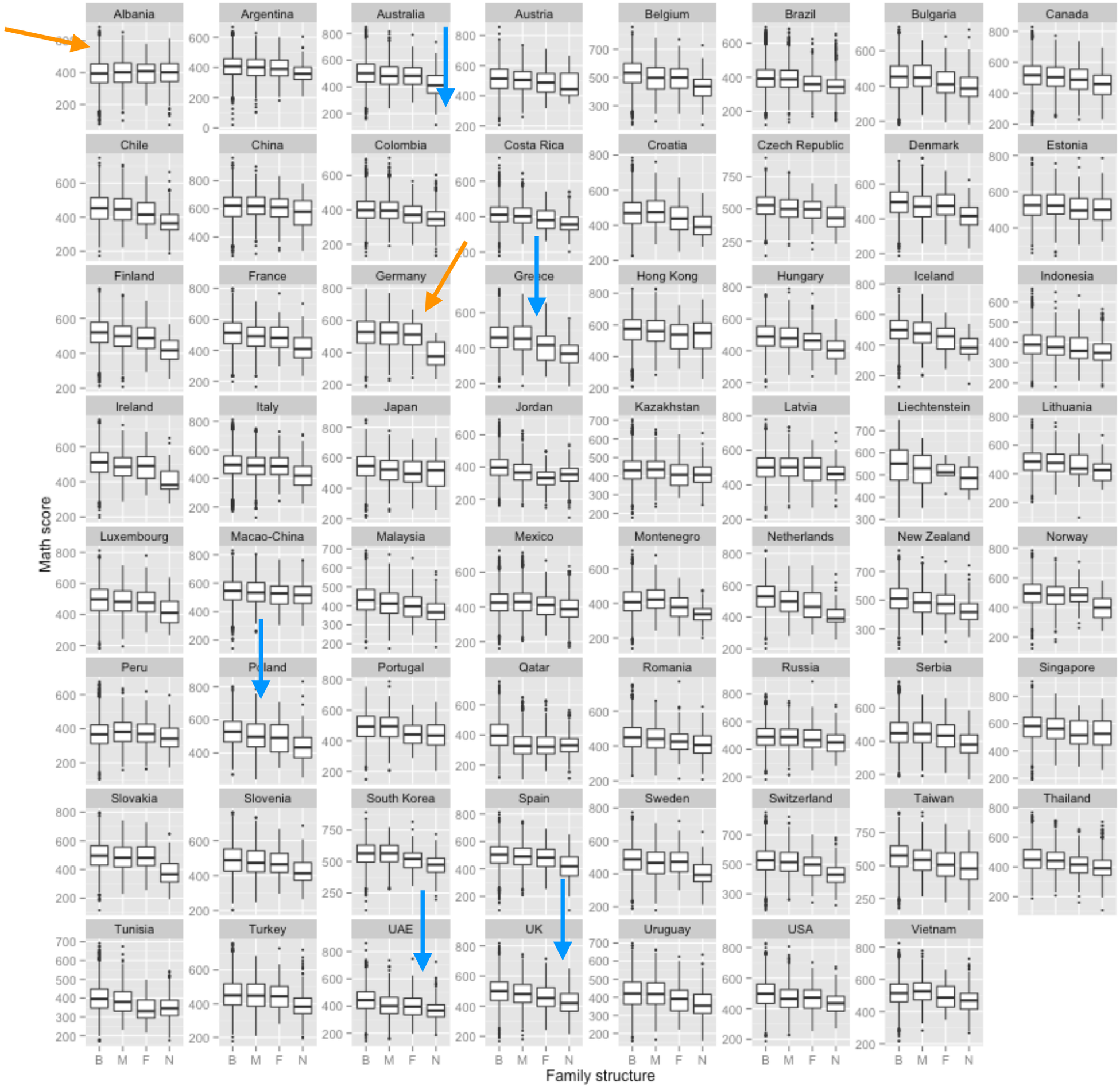
Parents in home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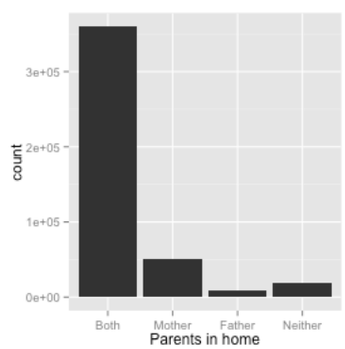
Family structure


count
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2e+05
1e+05
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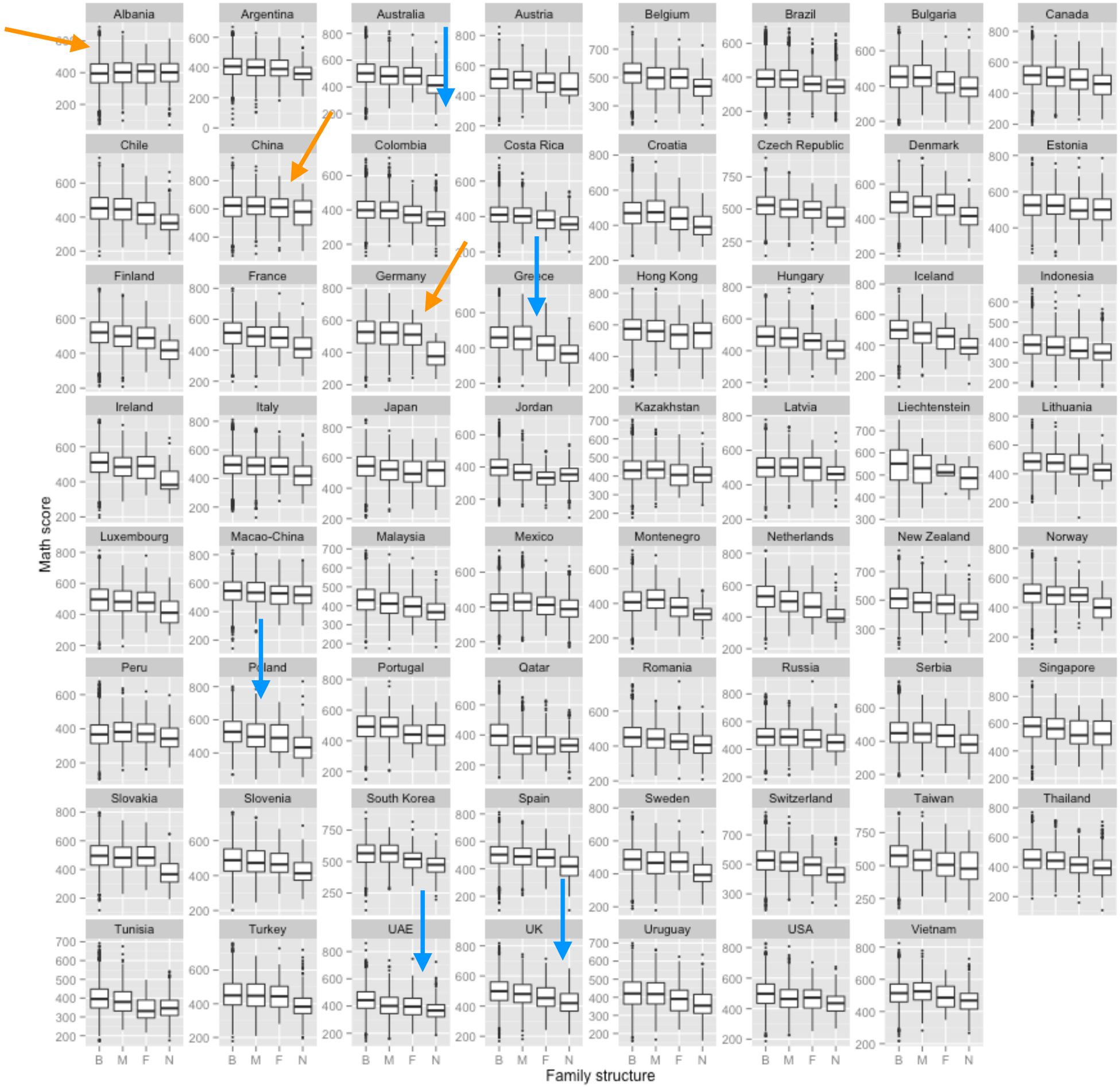
Both
Mother
Father
Neither
Parents in home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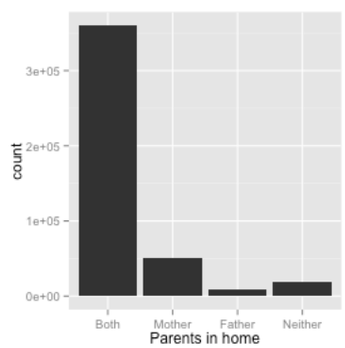
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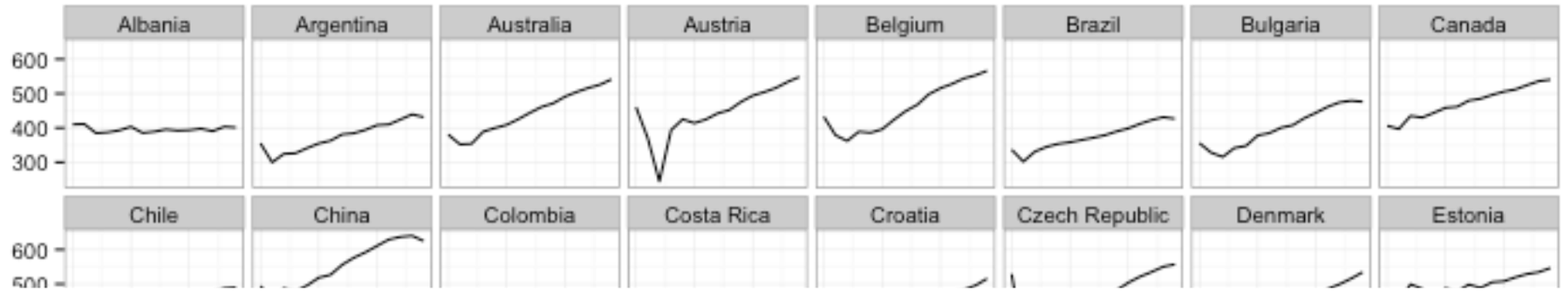
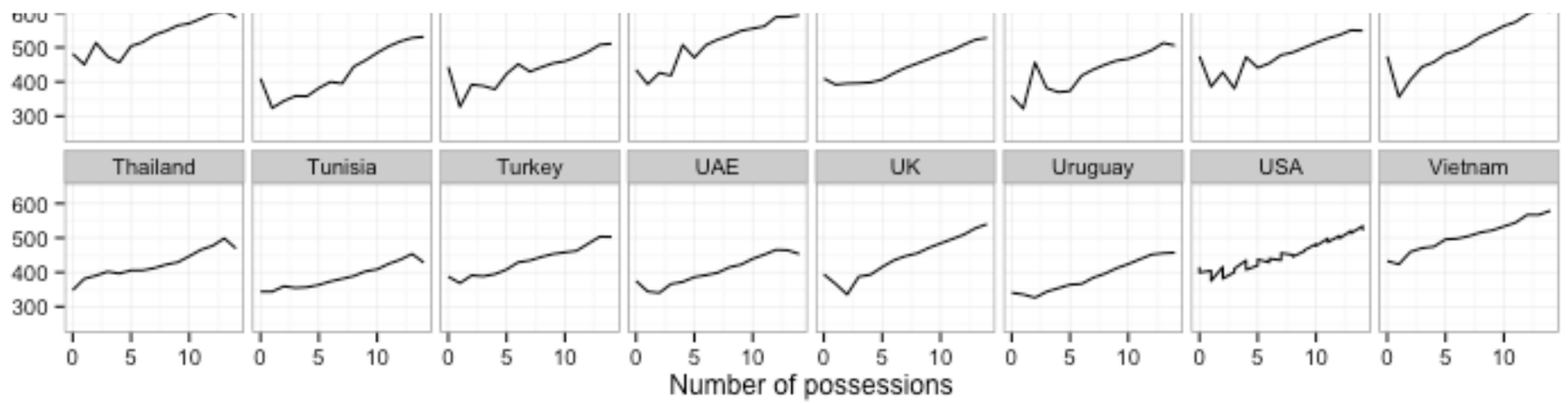
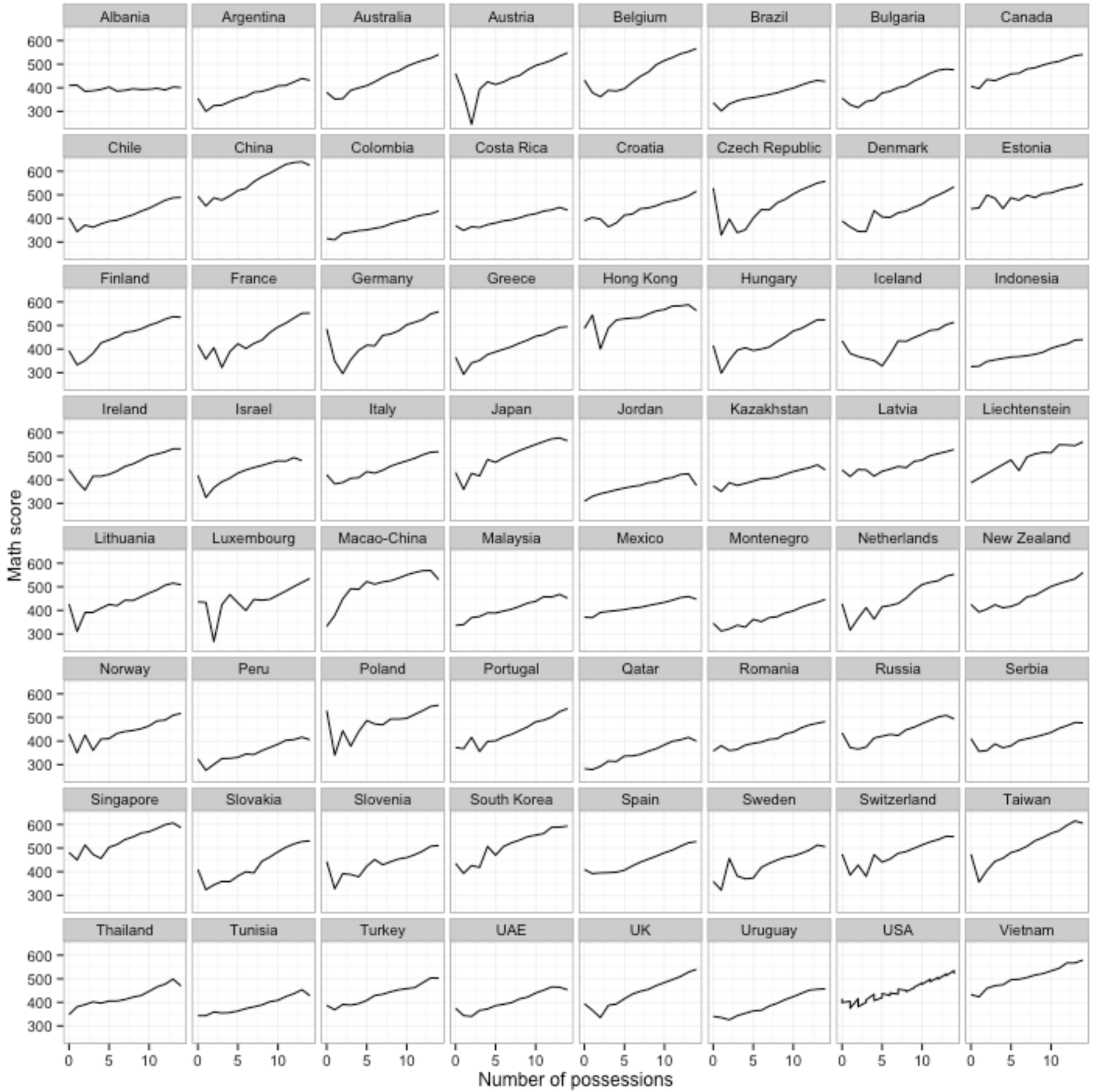


Possessions and average math score by country

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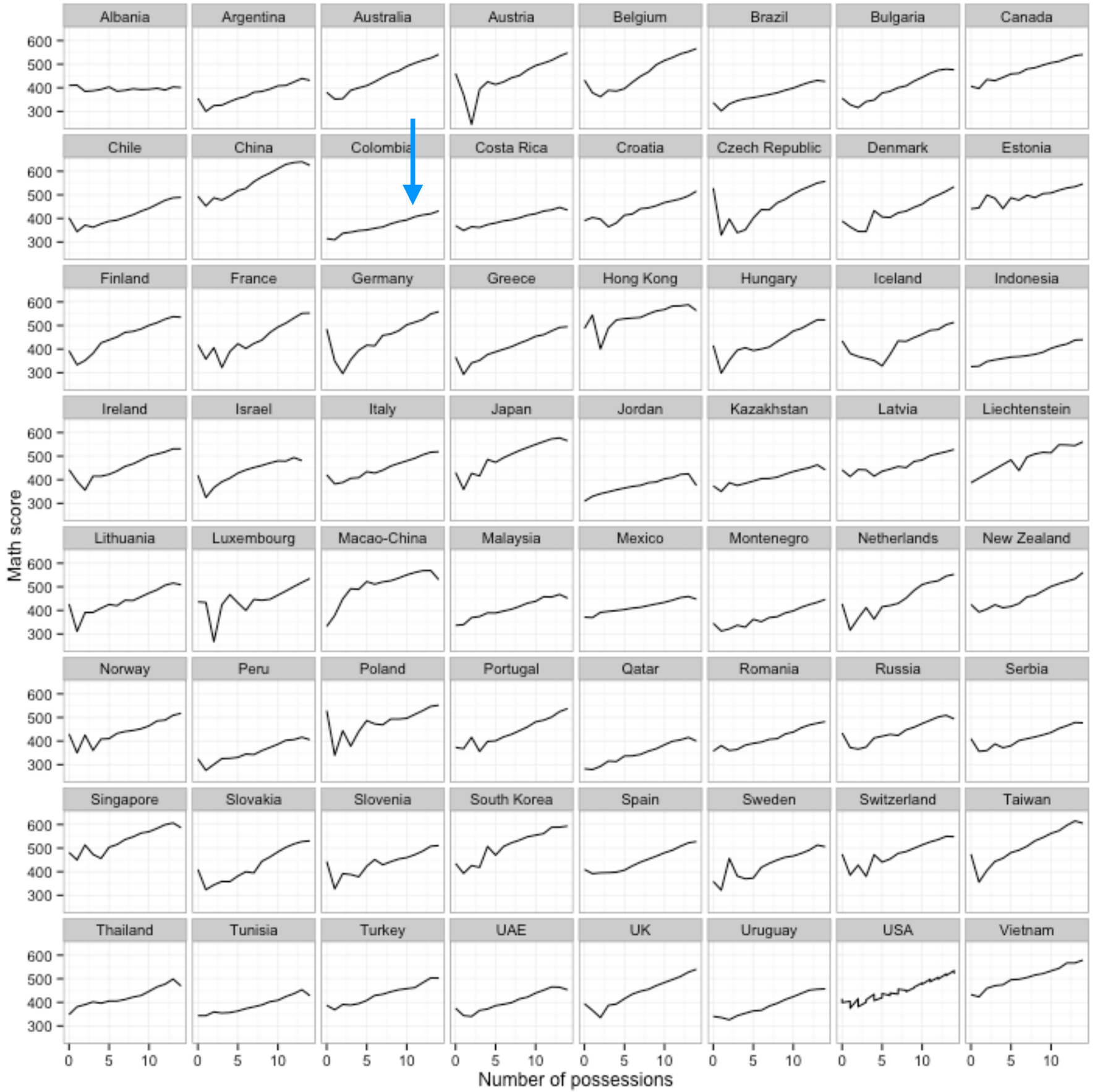
Number of possessions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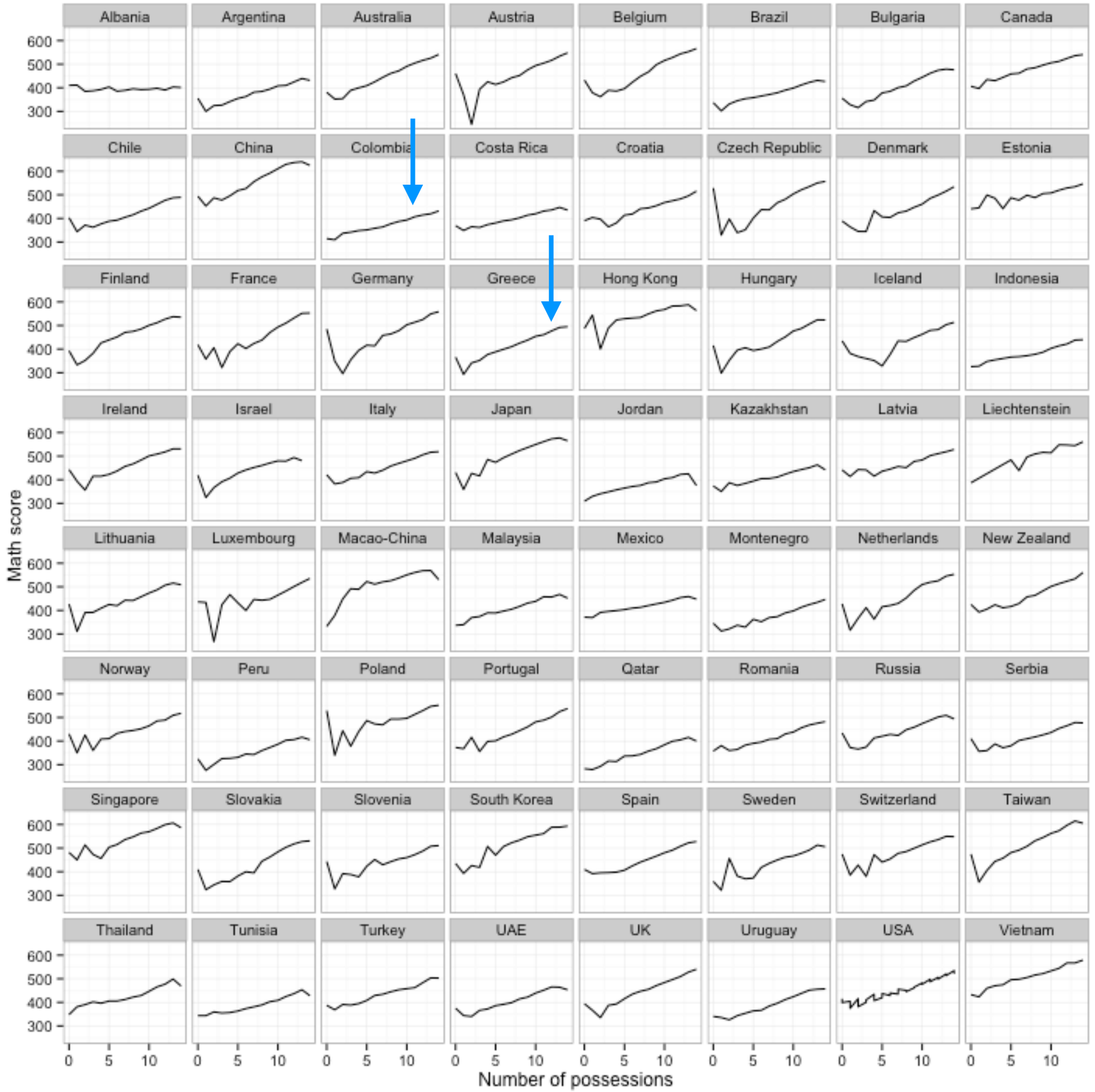
Number of possessions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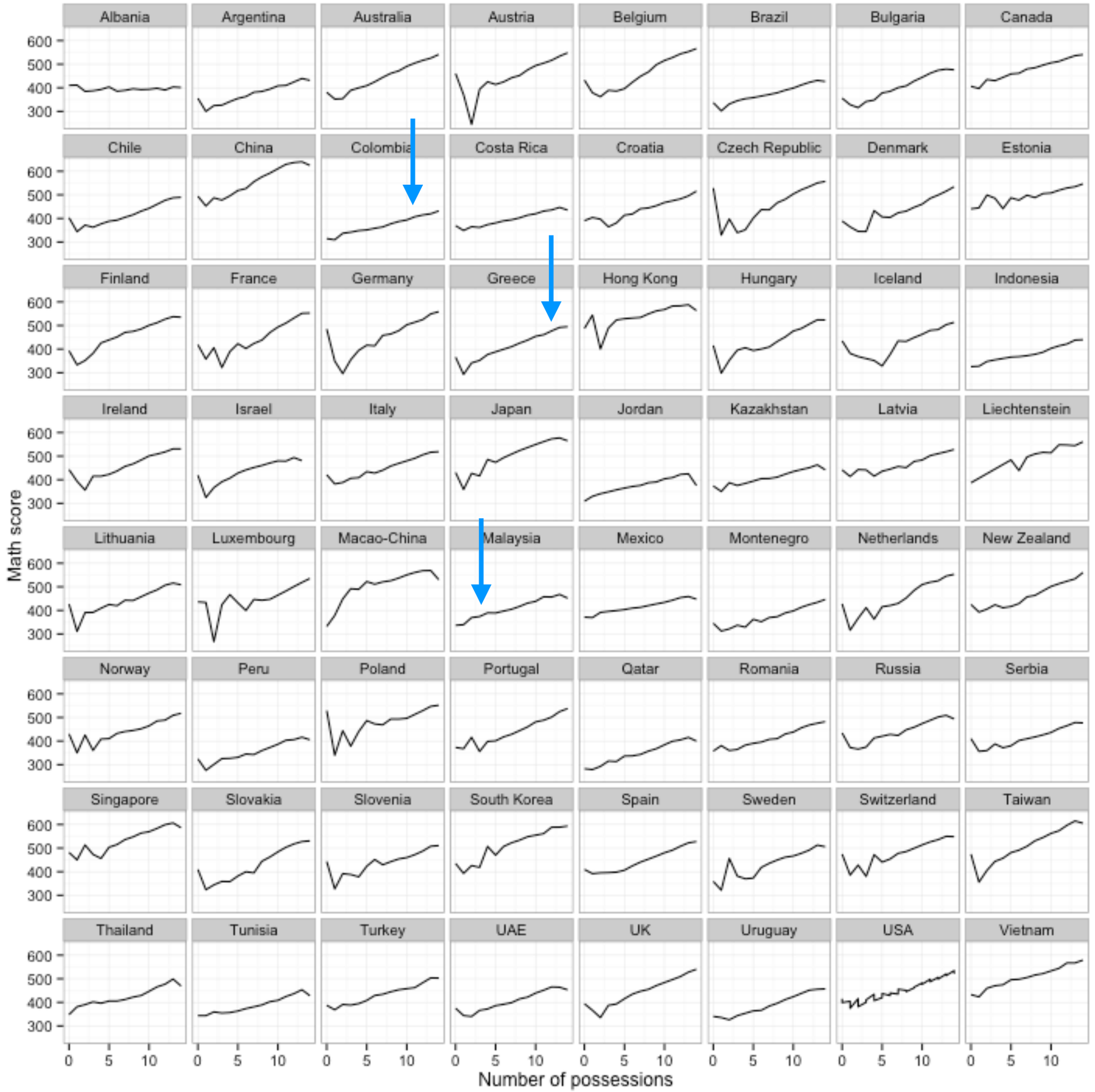
Number of possessions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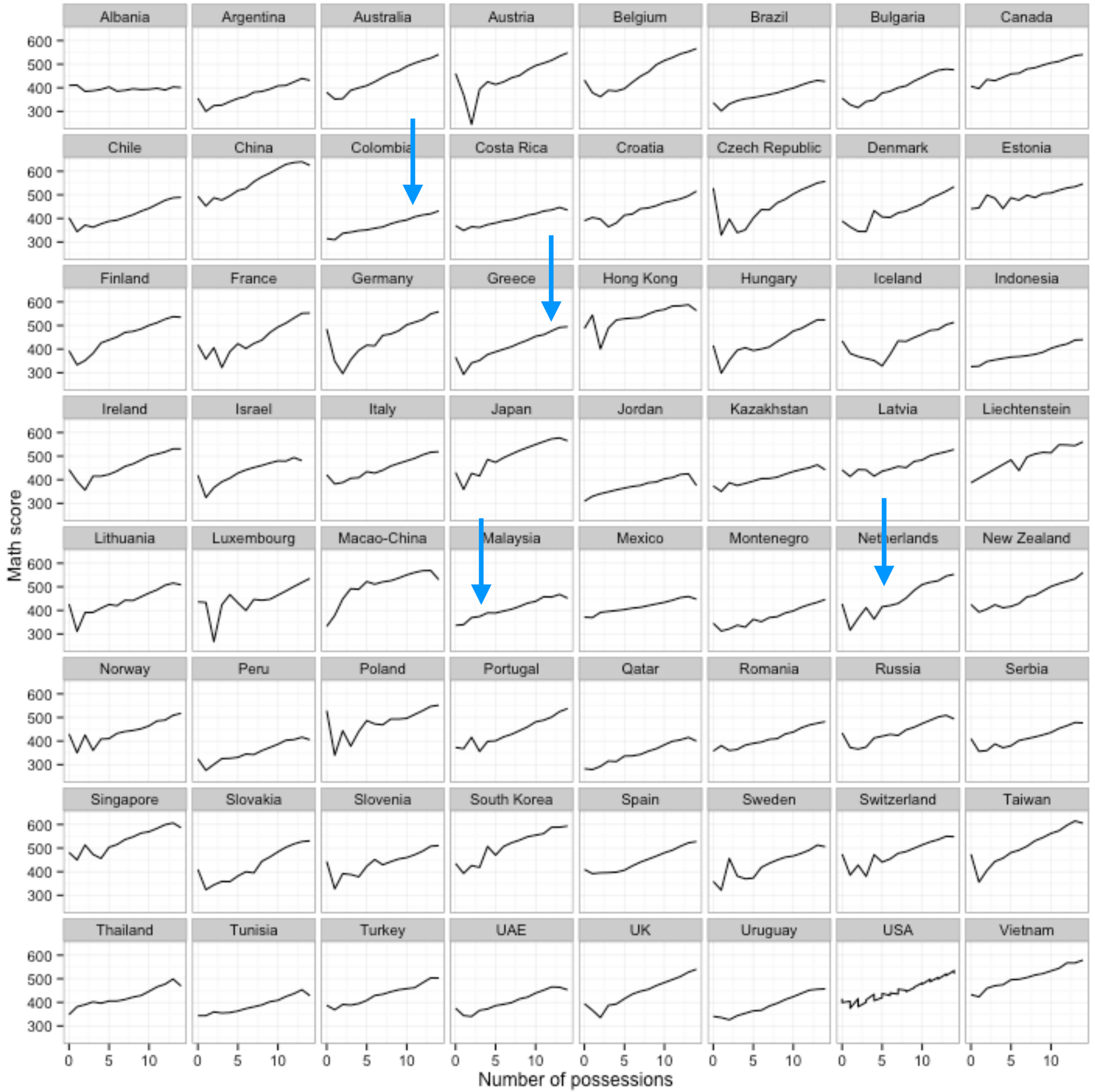
Math score
Number of possessions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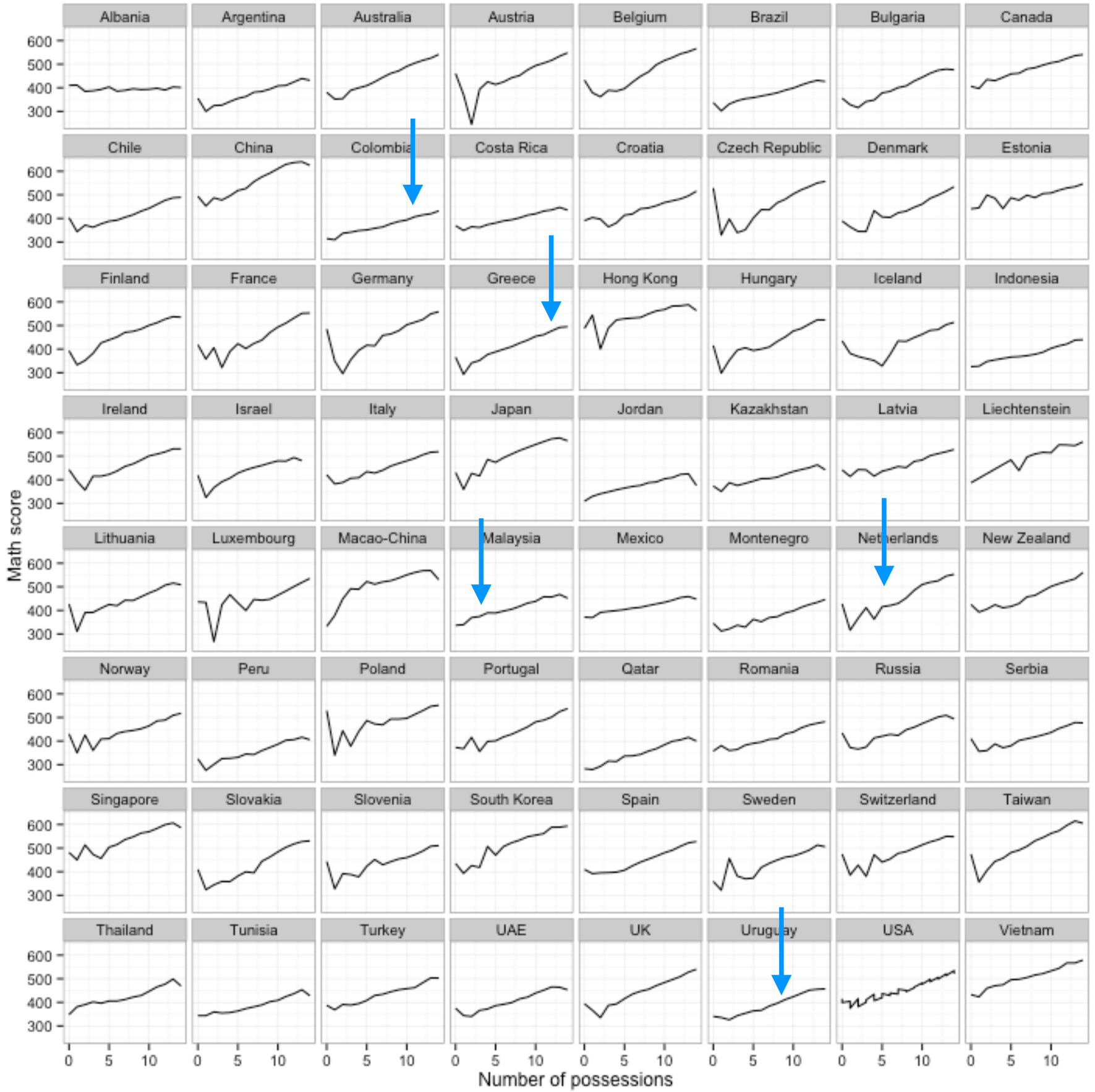
Math score
Number of possessions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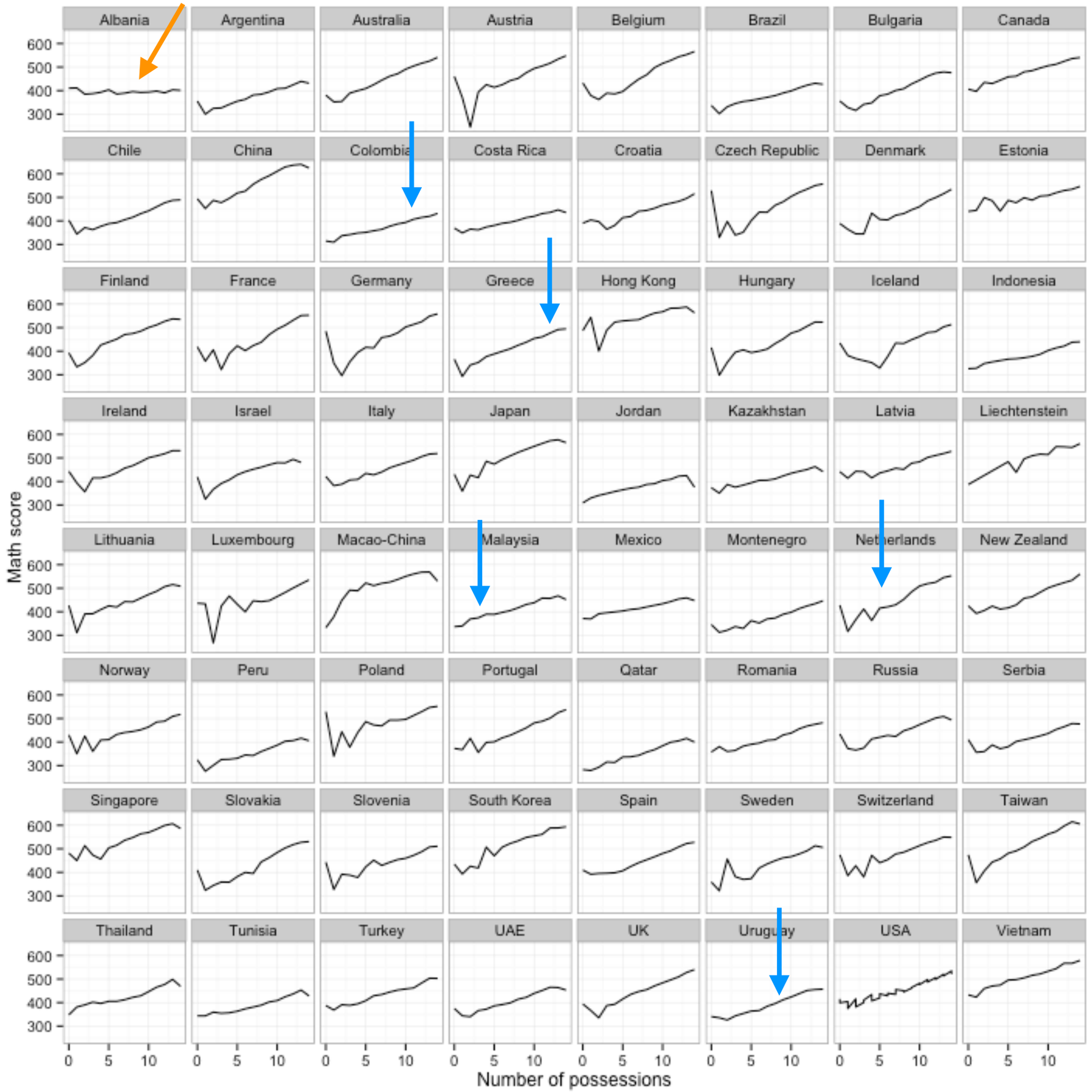
Math score
Number of possessions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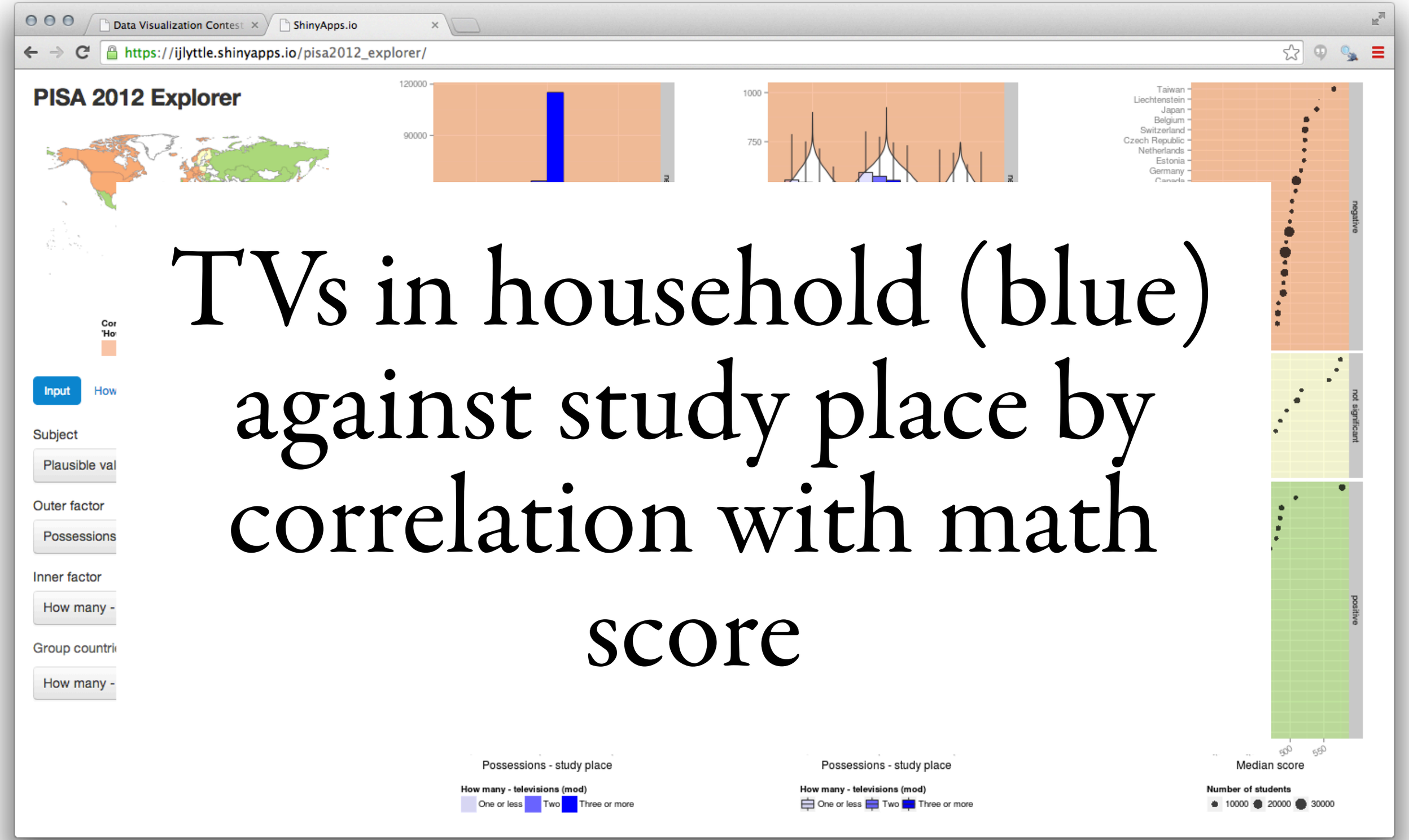


TVs in household (blue) against study place by correlation with math score

http://bit.ly/pisa2012_explorer

Data Visualization Contest | ShinyApps.io

https://ijlyttle.shinyapps.io/pisa2012_explorer/

PISA 2012 Explorer

Correlation between 'Score' and 'How many - televisions (mod)'

negative | not significant | positive

Input | How-to | Example | Details | About

Subject

Plausible value 1 in mathematics

Outer factor

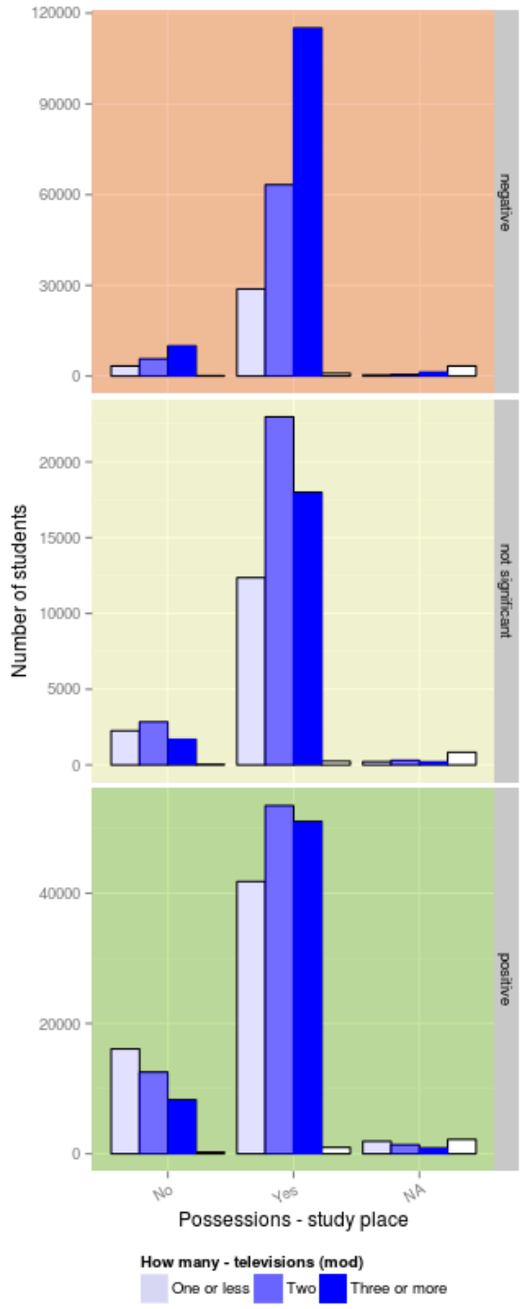
Possessions - study place

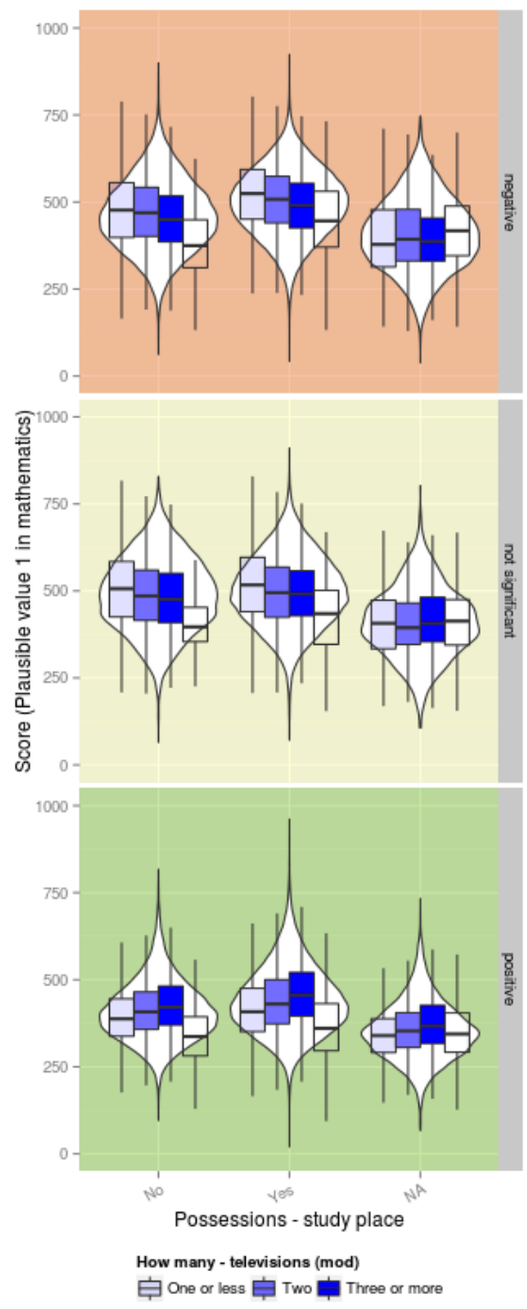
Inner factor

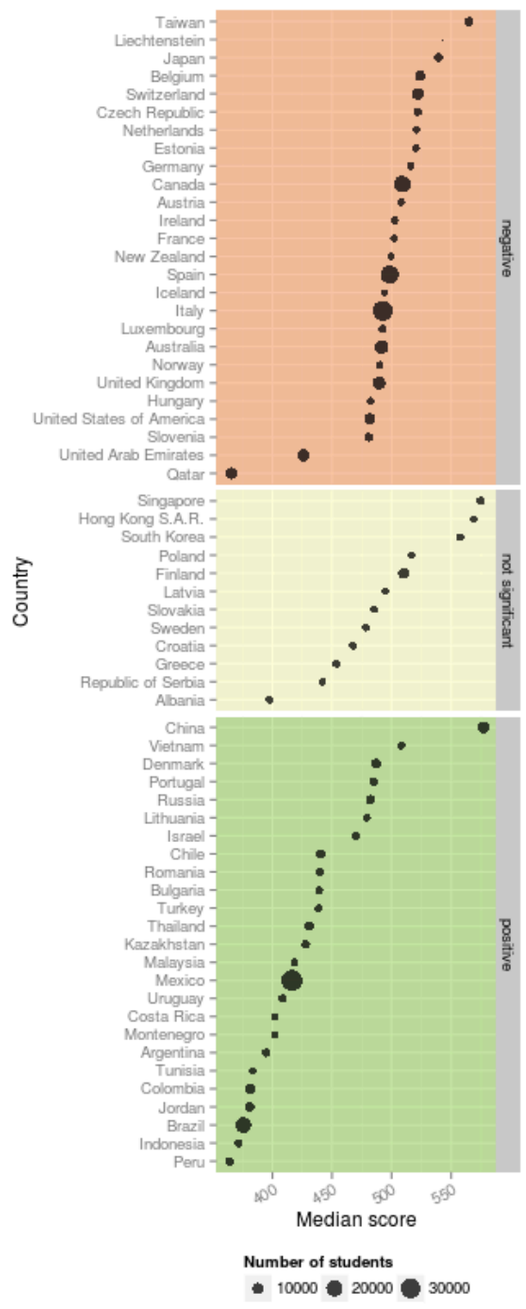
How many - televisions (mod)

Group countries by correlation of **score** and

How many - televisions (mod)







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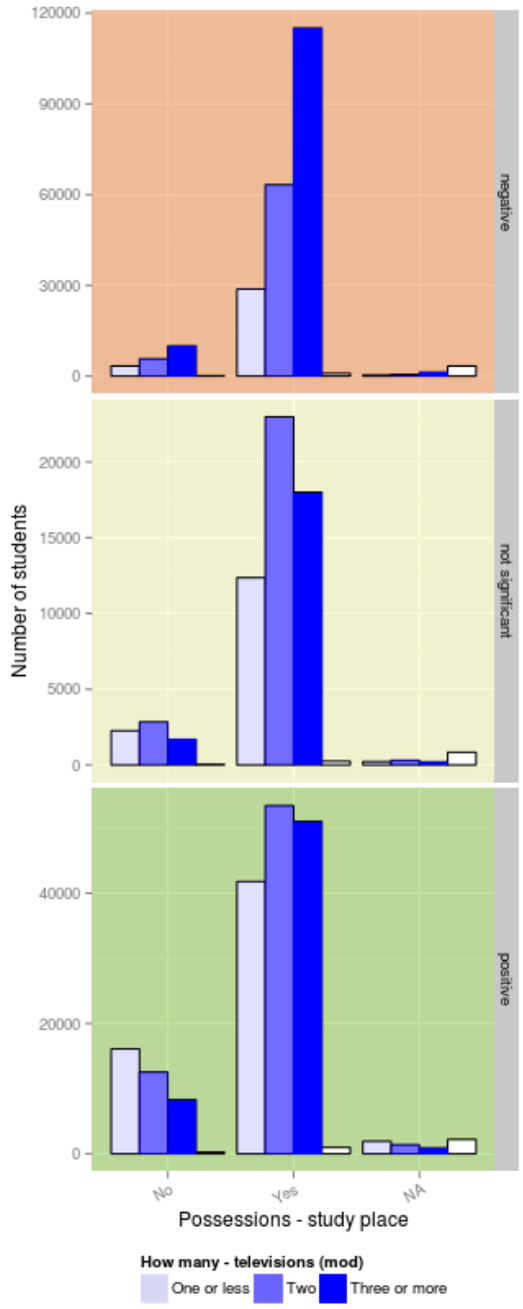
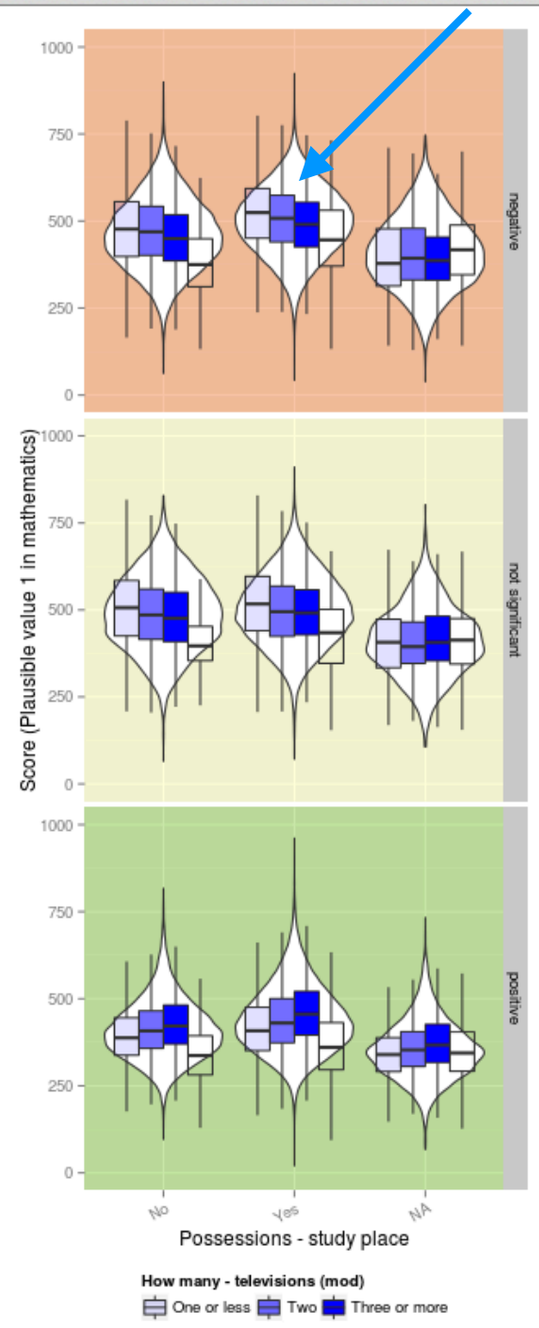
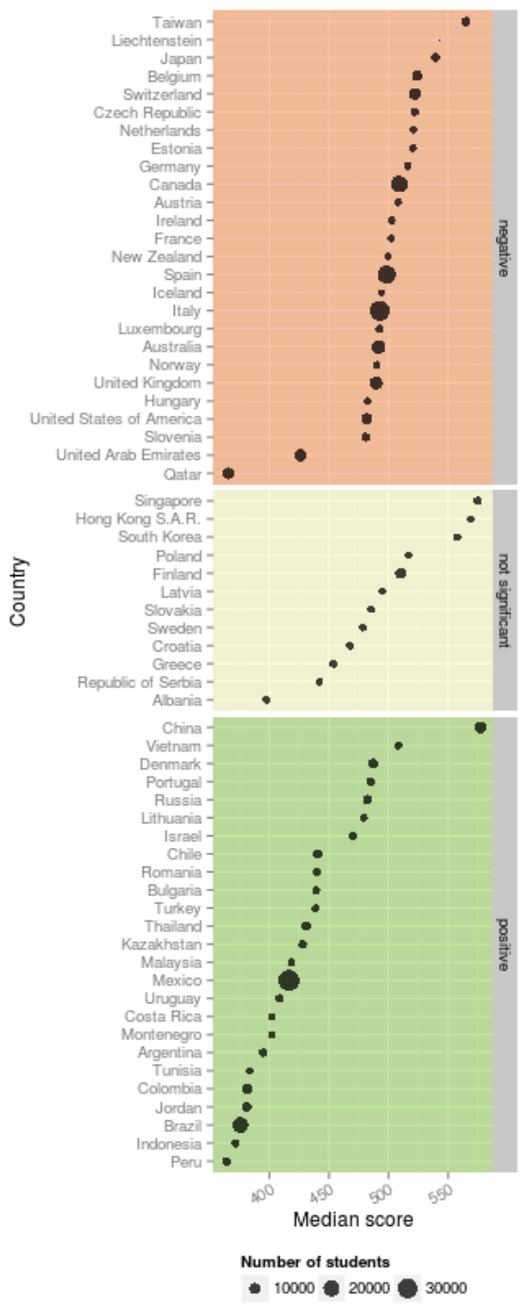
Group countries by correlation of **score** and

How many - televisions (mod)







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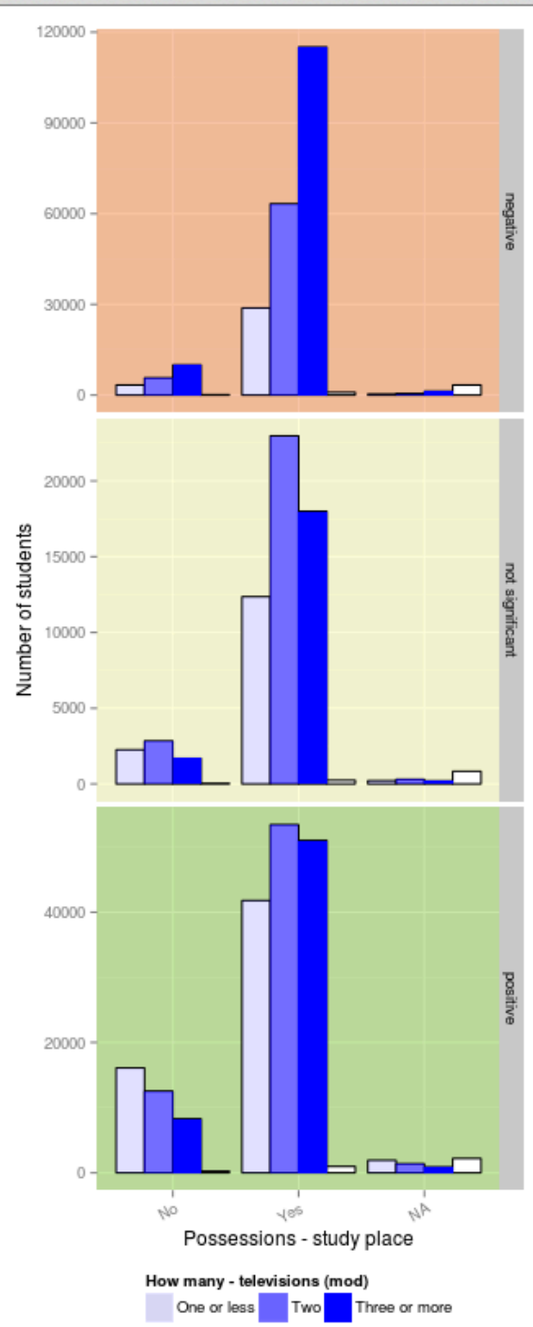

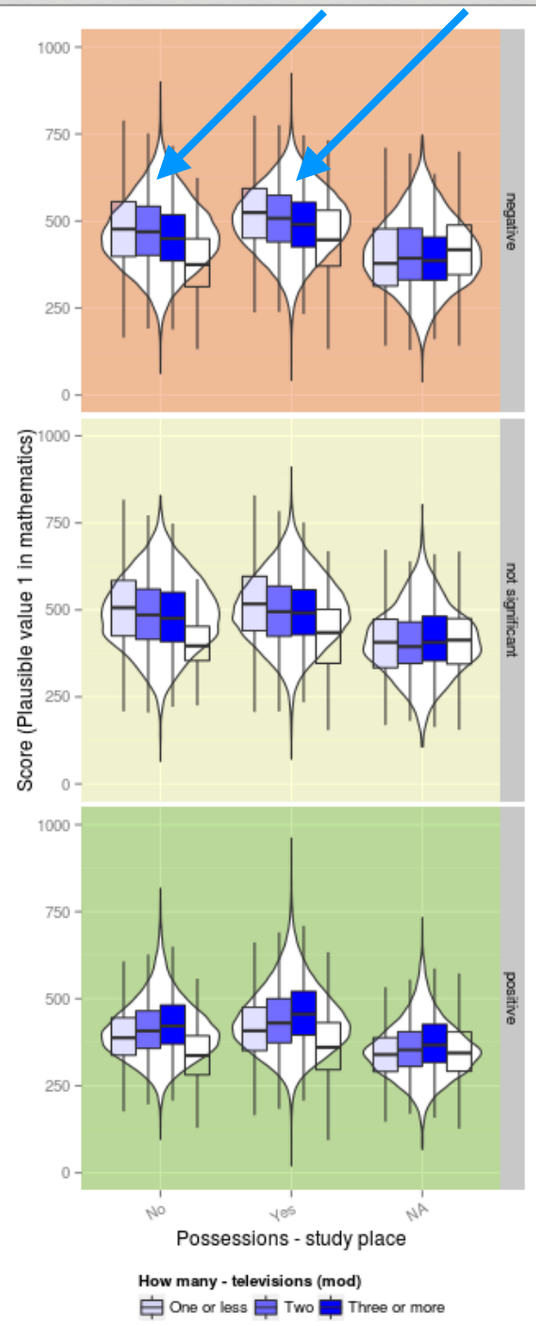

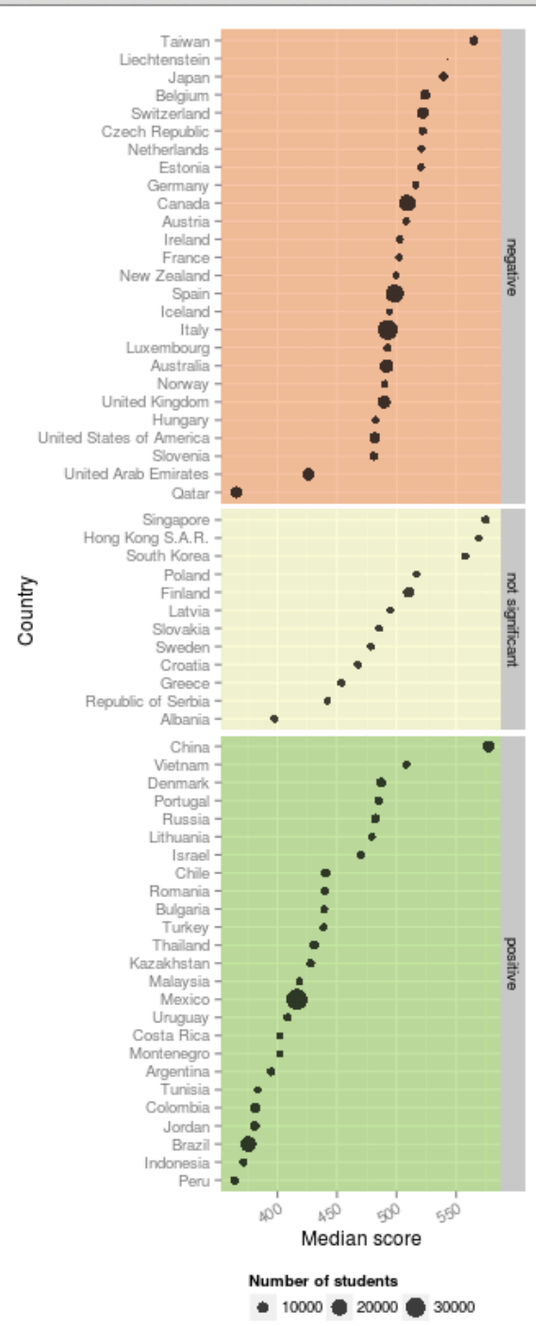

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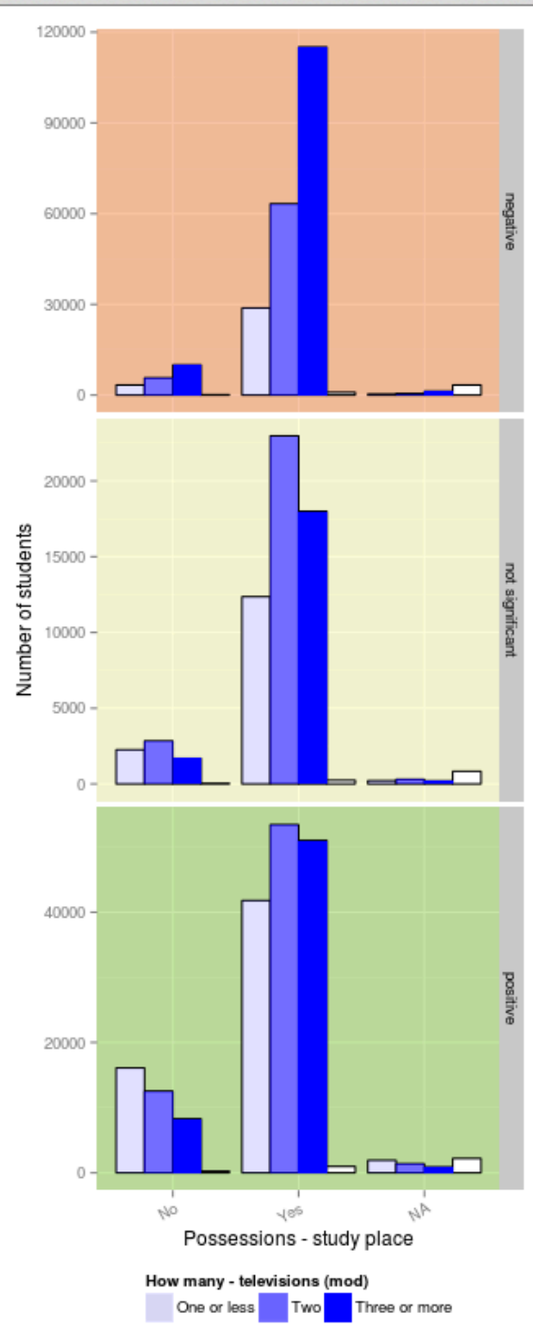

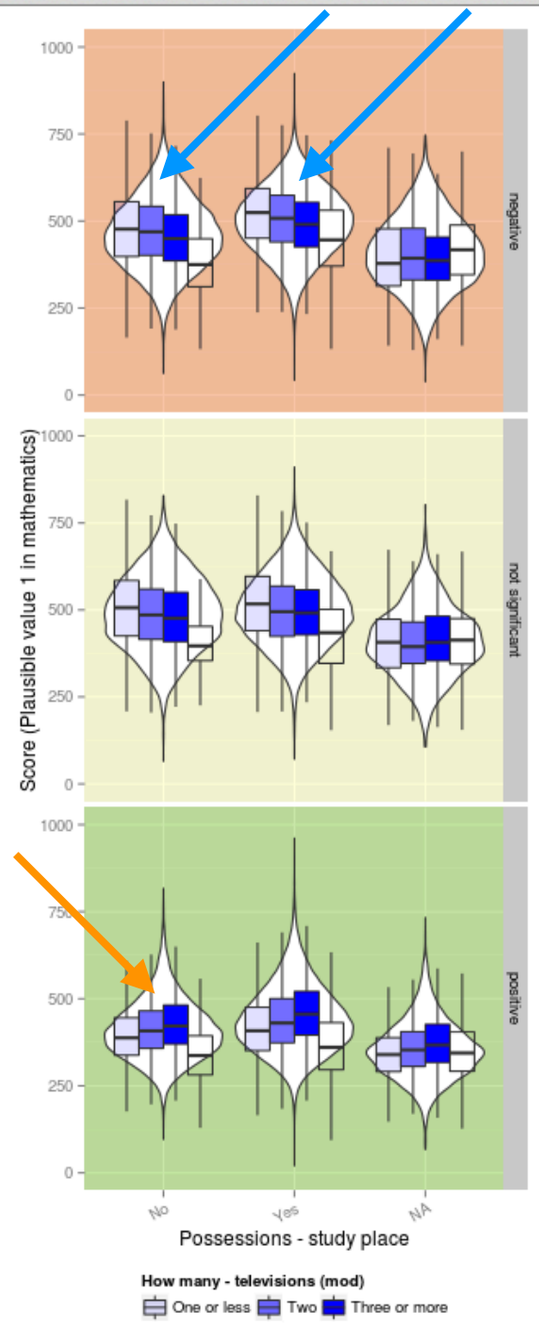

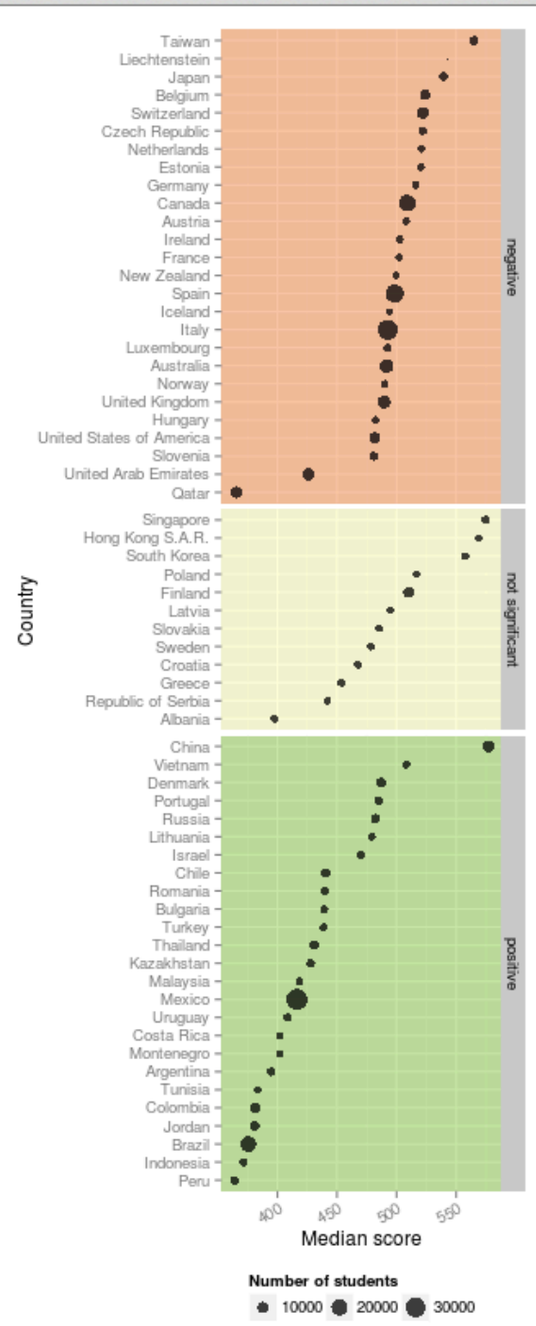

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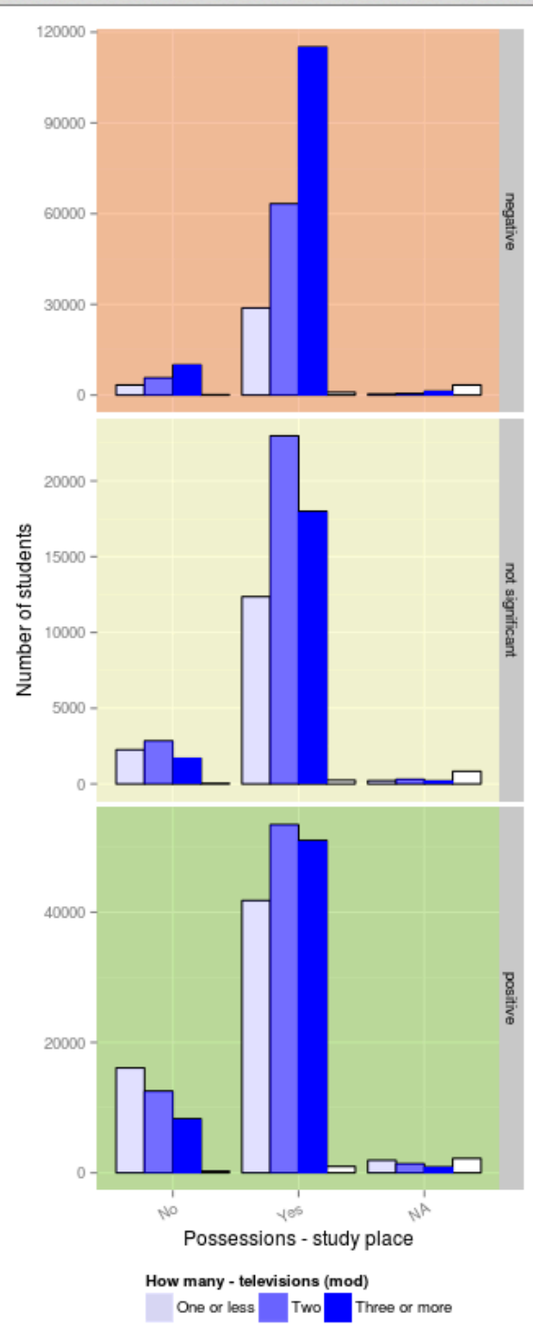
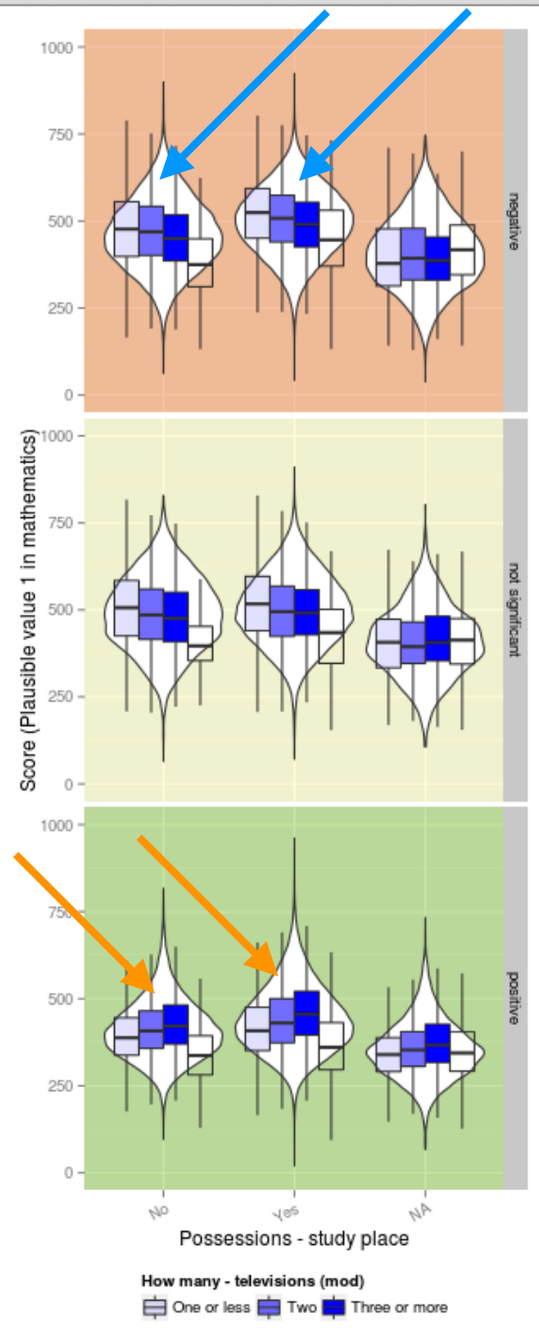
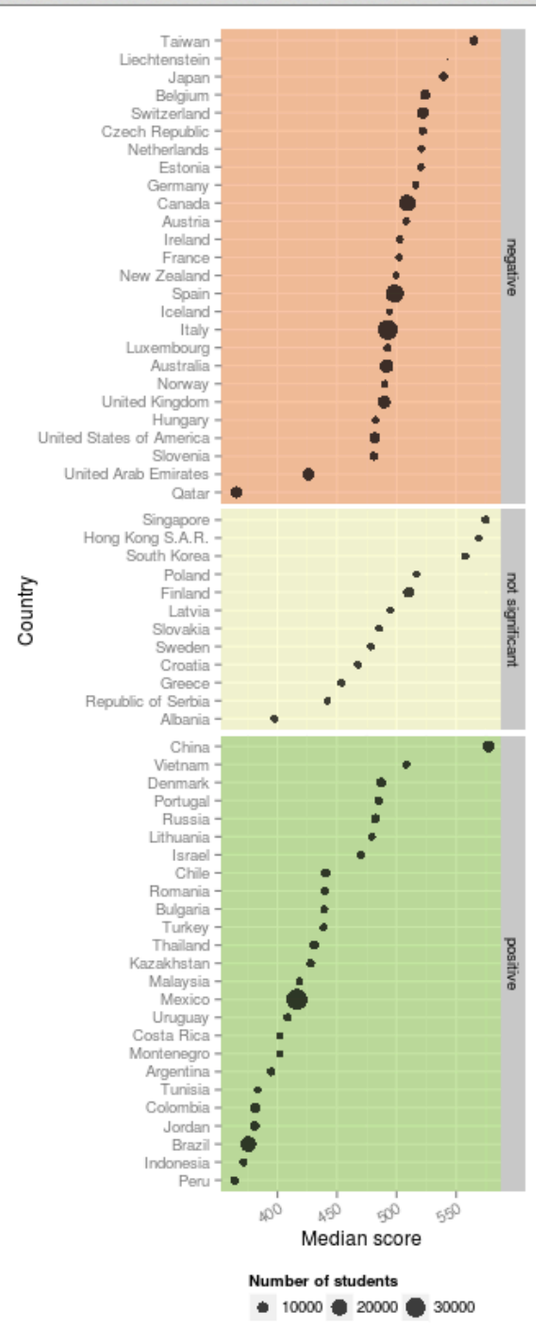




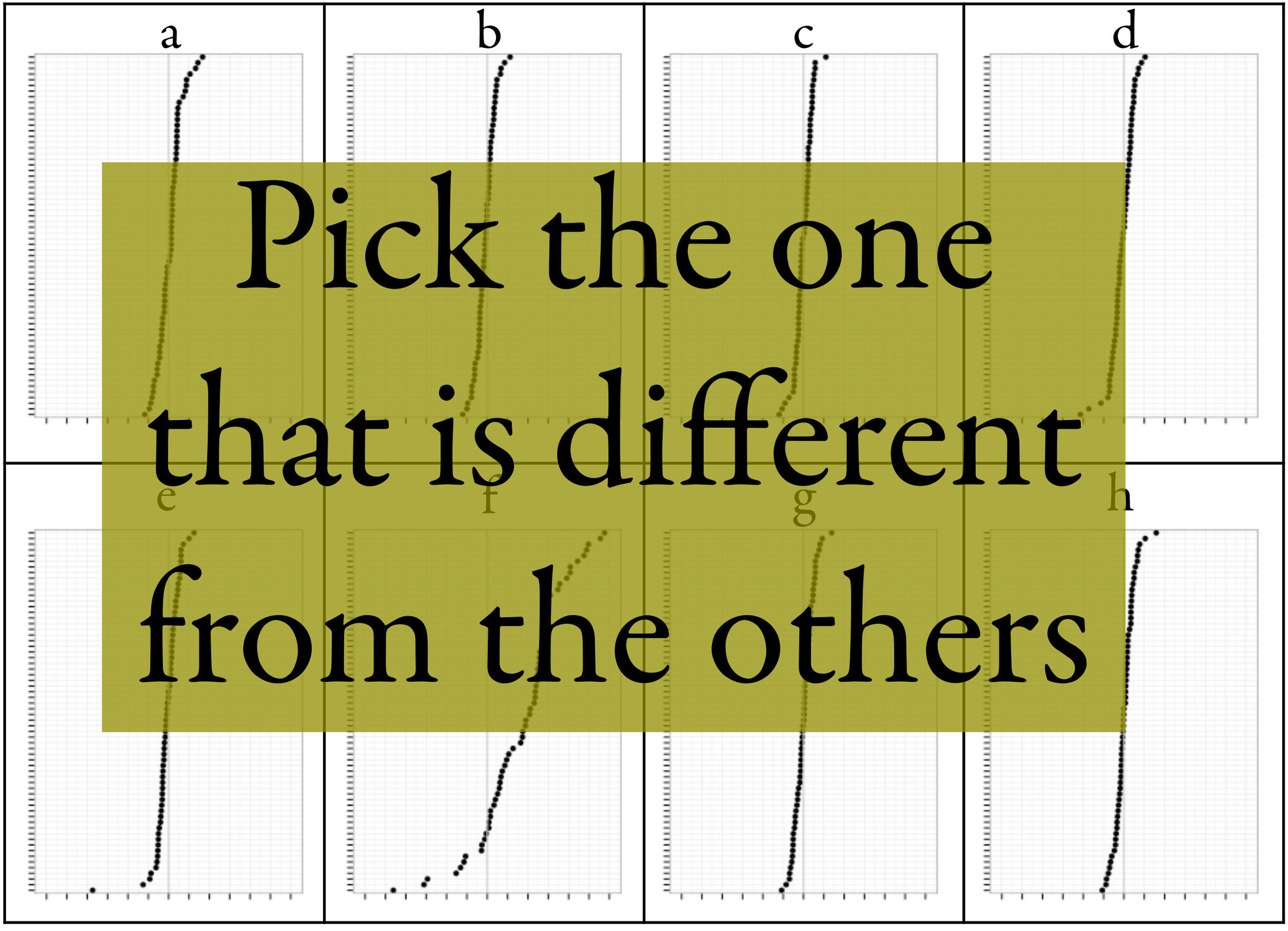


http://bit.ly/pisa2012_explorer

EDA & Inference

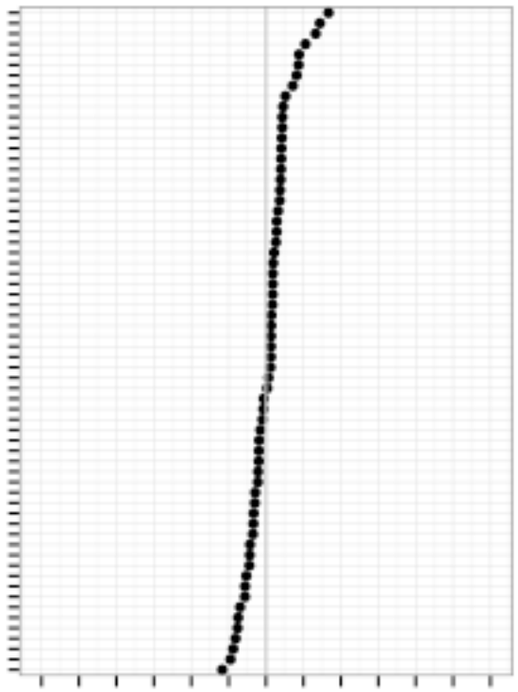
- I have just reported a huge number of conclusions based purely on exploratory methods.
- Do you believe them?
- Exploratory and inferential ARE NOT mutually exclusive.
- I could have showed you the exploratory statistics in the context of NOTHING HAPPENING. From this we could have obtained statistical significance or lack of it.

Here is the math gap exploration placed in the CONTEXT of there being NO MATH GAP ...

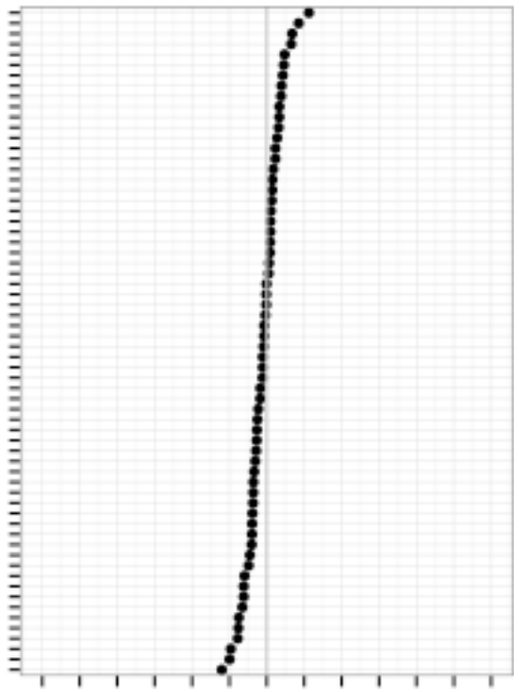


Pick the one that is different from the others

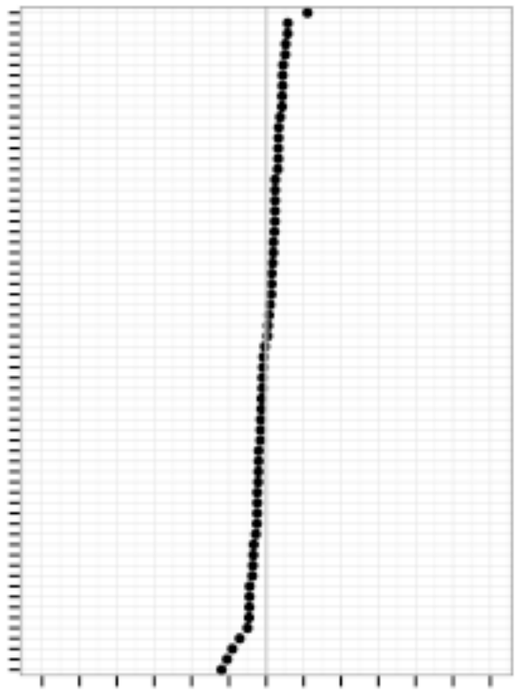
a



b



c



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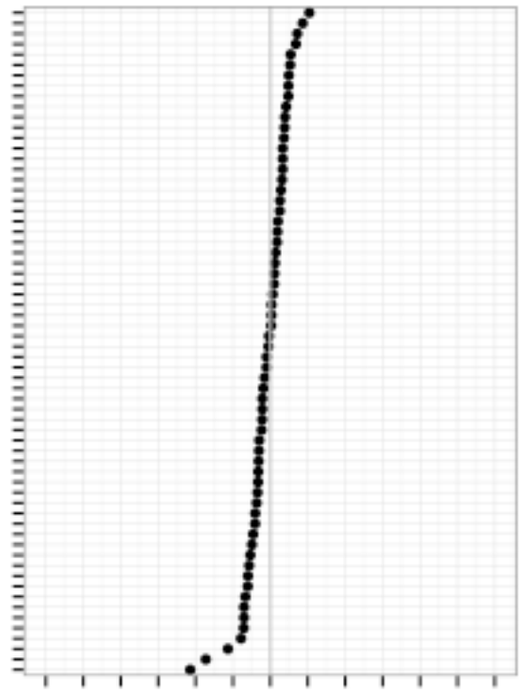
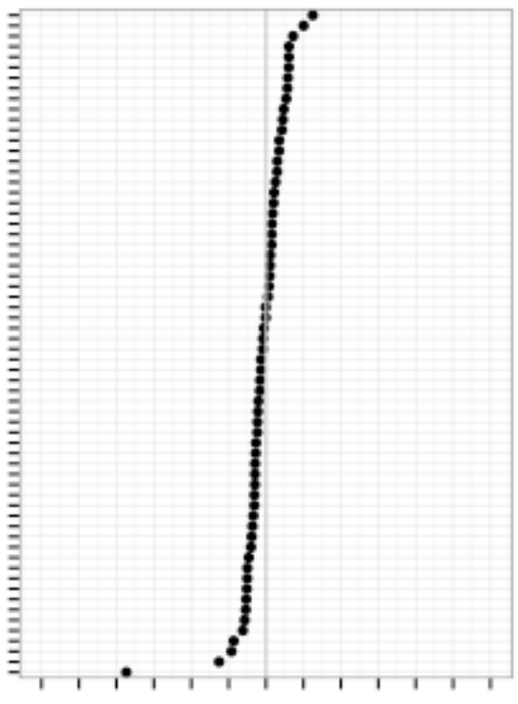


e



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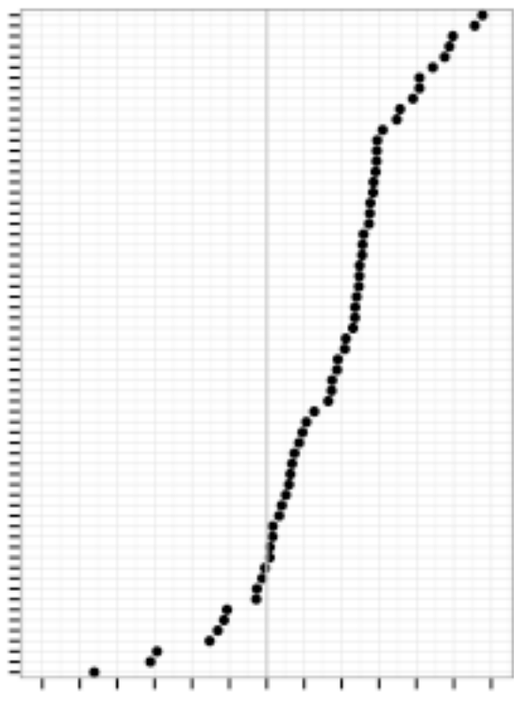
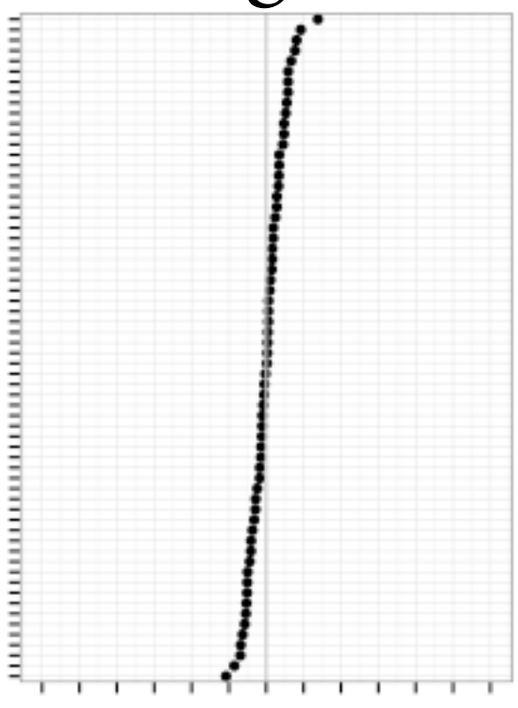
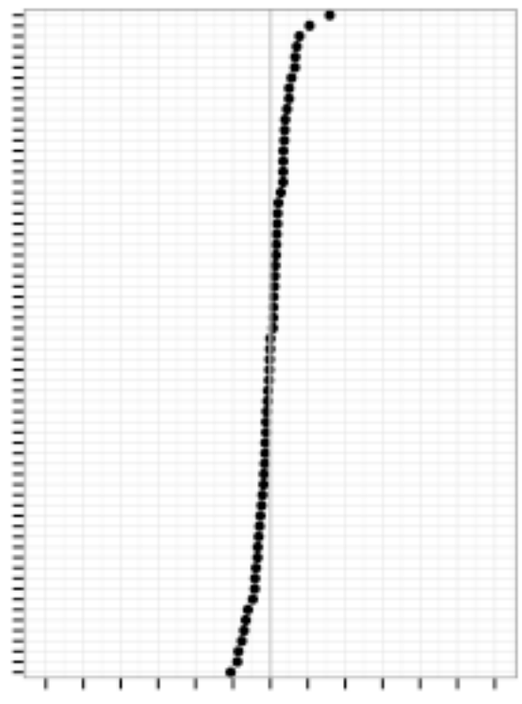
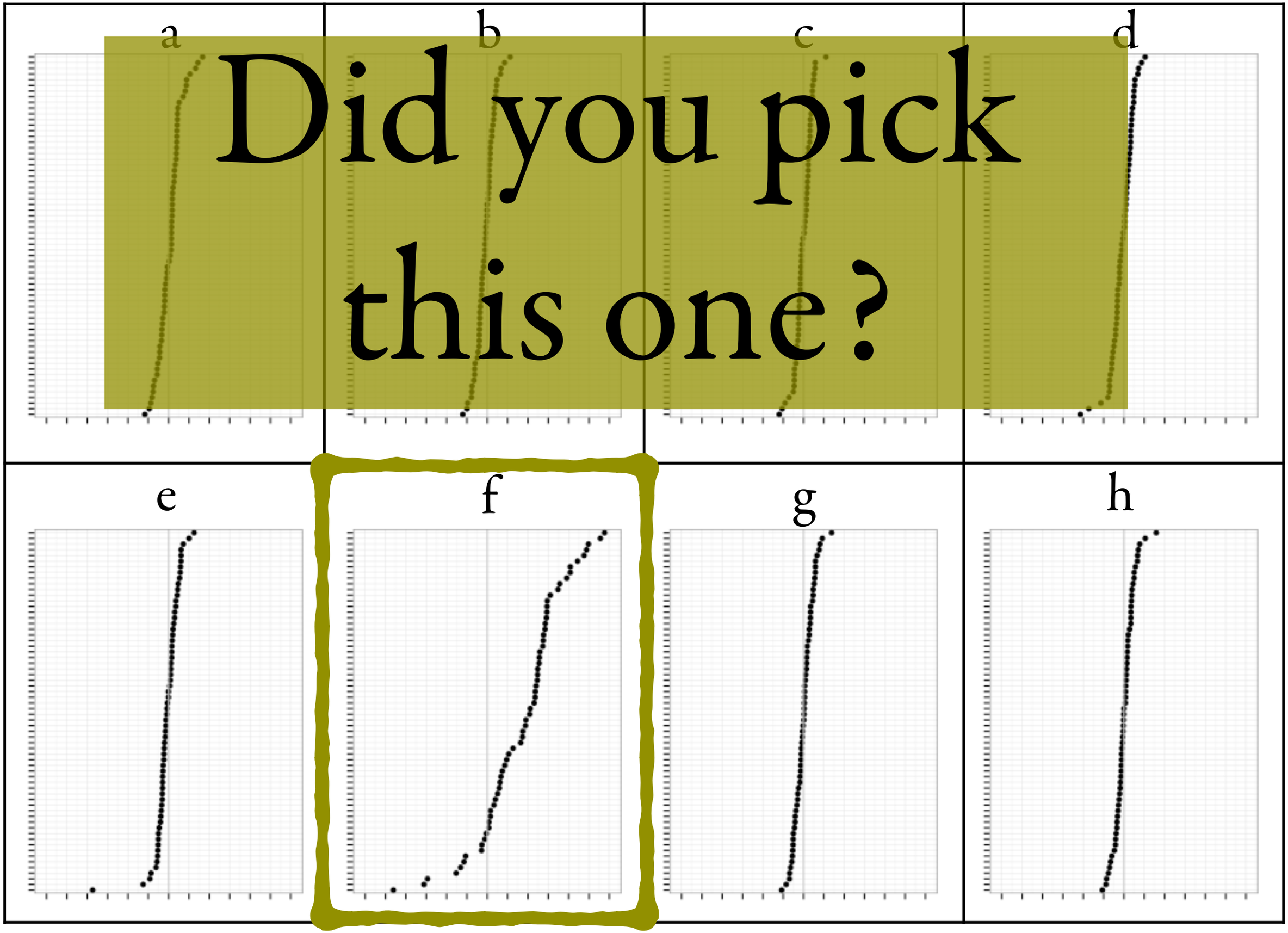


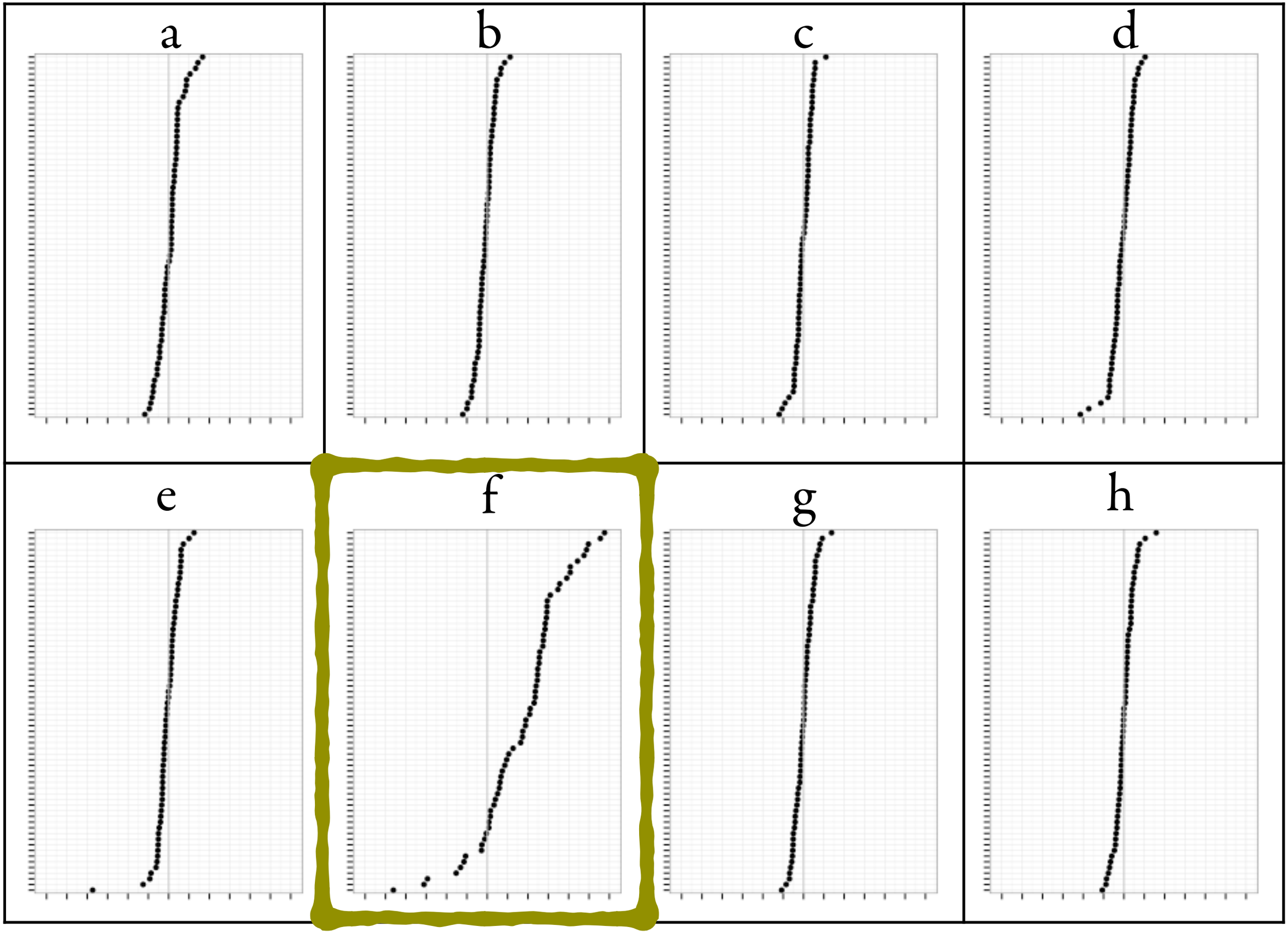
g



h




a
b
c
d
Did you pick this one?
e
f
g
h


a
b
c
d
e
f
g
h

EDA & Inference

If the plot that is picked is the plot of the real data, this is statistical significance, and a *p*-value can be placed on the discovery.

- Buja et al (2009) RSPT A (econ eg)
- Wickham et al (2010) InfoVis/TVCG
- Hofmann et al (2012) InfoVis/TVCG
- Majumder et al (2013) JASA
- Roy Chowdhury et al (2014) Comput. Stat.
- Zhao et al (2014) IJITAS

Nulls by permutation

- Hold country fixed (subset by country)
- Permute the gender labels, so that the math scores are randomly assigned to a boy or girl
- Recalculate the difference between the means
- Plot the mean difference by country again

Mapping data to plots

- Making good plots of data is not straight forward!
- There are more bad data plots than good.
- Learning how to effectively plot data should be in CORE statistics/data science curricula

Reproducibility

- Being able to reproduce the analysis is critically important.
- I used RStudio, with knitr and Rmarkdown to embed analysis with documentation.
- This is what I use in my statistics labs today, so that students learn to document their analysis, and enable others to see what they did to the data, and re-run the analysis themselves.

“Show the data."

What we learned

- Gender gap is not universal in math.
- Gender gap is universal in reading.
- Individual differences trump everything else.
- Parents matter! Mothers more than fathers!
- Socioeconomic status matters.
- Turn the TV off, if you live in a developed country!
- Something's funny about Albania's data.

Tools

- `ggplot2`, by Hadley Wickham and the RStudio team (look for their interactive web graphics ggvis soon!)
- `knitr`, by Yihui Xie and the RStudio team. So good and easy now that first year statistics students can use for their homeworks and labs!
- `shiny`, by RStudio, for the interactive web app.