Visualizing Multilevel Models

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2025-09-16

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1 Introduction

An evolving set of notes on visualizing results from multilevel models.

The examples below use the `simulated_multilevel_data.dta` file from my text book on *Multilevel Thinking*. Here is a link to download the data.

This document relies on the extraordinary `Statamarkdown` library (Hemken 2023).

2 Organizing Questions

Try to think about some of the advantages and disadvantages of different approaches to visualizing multilevel models. In multilevel models, we don't want to just *control for* variation, but to start to *explore* the variation. Put concretely:

- Some approaches use *dots*. Some approaches use *lines*. Some approaches use *dots and lines*.
- Some approaches use the *raw unadjusted* data. Other approaches use *adjusted or model predicted* data.
- Some approaches attempt to show the *Level 2 specific regression lines*; some approaches only show an *average regression line*.
- What approaches might work well with *large numbers* of Level 2 units? What approaches might work well with *smaller numbers* of Level 2 units?

What approach(es) do you prefer?

3 Setup

I am not terrifically fond of the default `s2color` graph scheme in earlier versions of Stata. Here I make use of the `michigan` graph scheme available at: https://agrogan1.github.io/Stata/michigan-graph-scheme/.

```
set scheme michigan
```

Stata's `stcolor` scheme–available in newer versions of Stata–would also be an option as would be Asjad Naqvi's incredible `schemepack`: https://github.com/asjadnaqvi/stata-schemepack.

Throughout the tutorial, I make frequent use of the `mcolor(%30)` option to add some visual interest to scatterplots by adding transparency to the markers.

4 Get Data

```
use "simulated_multilevel_data.dta", clear
```

5 Scatterplots (`twoway scatter y x`)

```
twoway scatter outcome warmth, mcolor(%30)

graph export myscatter.png, width(1500) replace
```

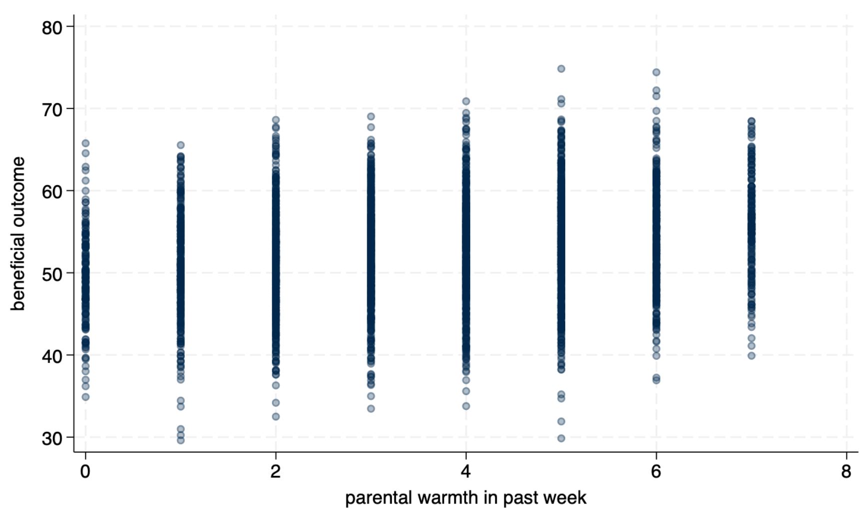

Figure 1: Scatterplot

6 Simple Linear Fit (`twoway lfit y x`)

```
twoway lfit outcome warmth

graph export mylinear.png, width(1500) replace
```

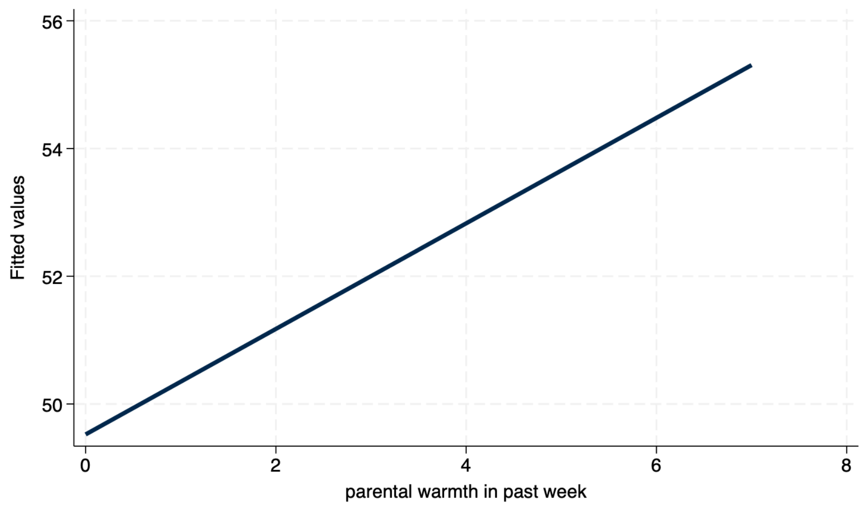

Figure 2: Linear Fit

7 Linear Fit With Confidence Interval (`twoway lfitci y x`)

```
twoway lfitci outcome warmth

graph export mylfitci.png, width(1500) replace
```

8 Combine Scatterplot and Linear Fit (`twoway (scatter y x) (lfit y x)`)

```
twoway (scatter outcome warmth, mcolor(%30)) (lfit outcome warmth)

graph export myscatterlinear.png, width(1500) replace
```

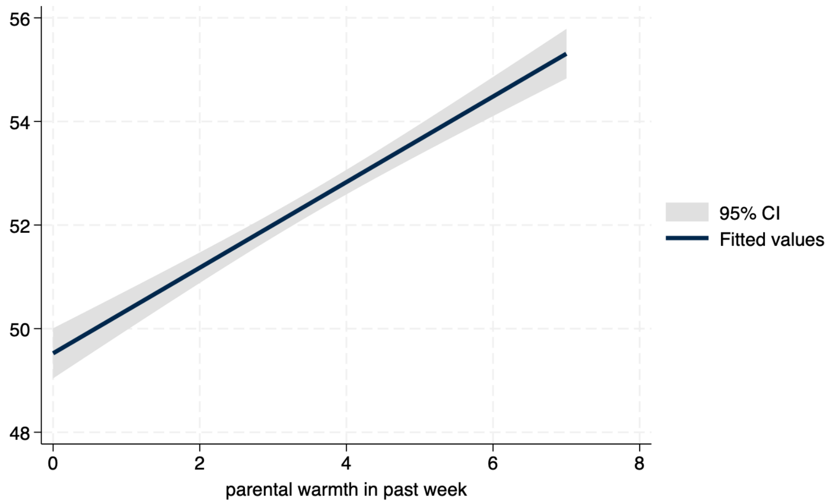

Figure 3: Linear Fit With Confidence Interval

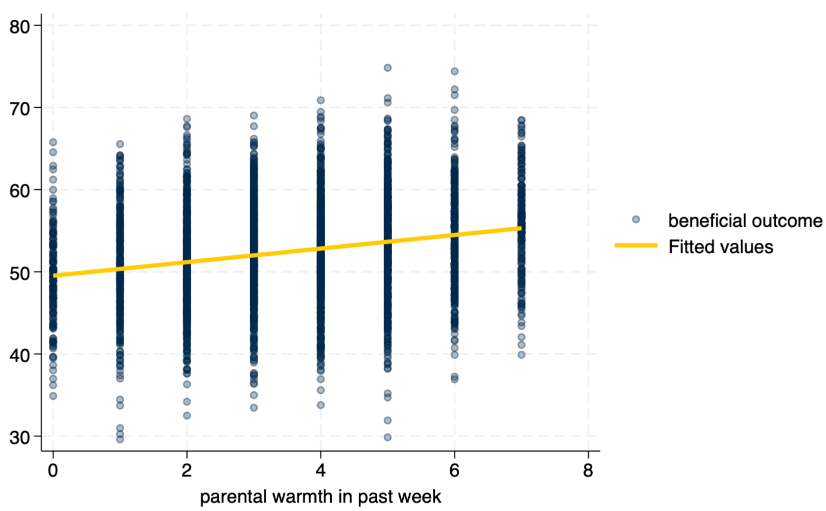

Figure 4: Scatterplot and Linear Fit

9 Spaghetti Plots (`spagplot y x, id(group)`)

```
spagplot outcome warmth, id(country)

graph export myspaghetti.png, width(1500) replace
```

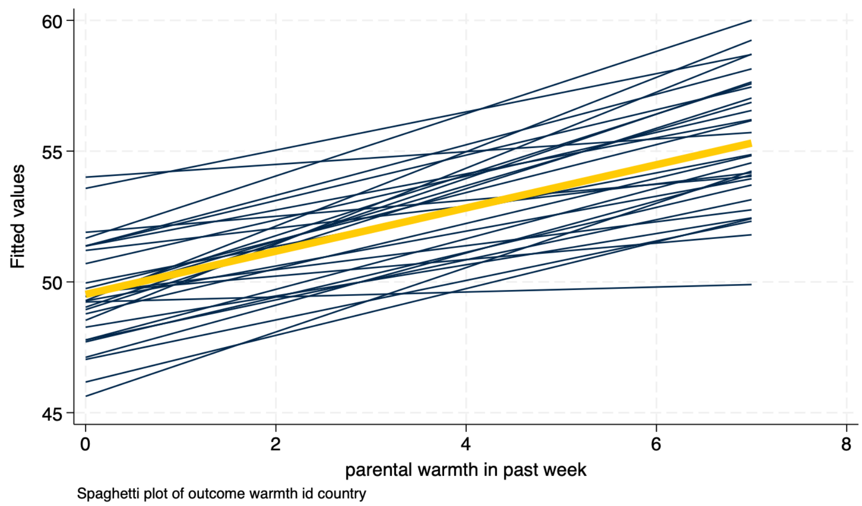

Figure 5: Spaghetti Plot

10 Small Multiples (`twoway y x, by(group)`)

Small Multiples, showing a separate graph for each group in the data, are an increasingly popular data visualization technique. Below, I build a small multiples graph using the `by` option in Stata. I use the `aspect` option to adjust the *aspect ratio* of the graph for better visual presentation.

```
twoway (scatter outcome warmth, mcolor(%30)) ///
(lfit outcome warmth), ///
by(country) aspect(1)

graph export mysmallmultiples.png, width(1500) replace
```

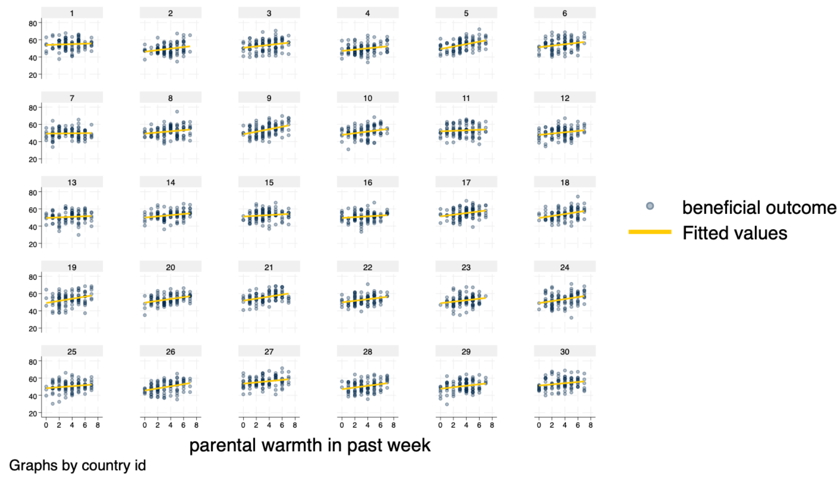

Figure 6: Small Multiples

11 Small Multiples With A Random Sample

At times, we may have *too many* Level 2 units to effectively display them on a *spaghetti plot*, or using *small multiples*. If this is the case, we may need to *randomly sample* **Level 2** units. This can be difficult to accomplish as our standard `sample` command operates on each row, or on Level 1 units.

We can accomplish random sampling at Level 2, with a little bit of code.

```
set seed 3846 // random seed for reproducibility

gen randomid = runiform() // generate a random id variable

* by country (i.e. by Level 2 unit) replace the randomid
* with the first randomid for that country (Level 2 unit)
* so that every person in that country has the same random id

bysort country: replace randomid = randomid[1]

summarize randomid // descriptive statistics for random id

twoway (scatter outcome warmth, mcolor(%30)) /// scatterplot
(lfit outcome warmth) /// linear fit
if randomid < .5, /// only use a subset of randomids
```

```
by(country) aspect(1) // by country

quietly: graph export mysmallmultiples2.png, width(1500) replace
```

```
(2,970 real changes made)

    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
    randomid |      3,000    .6174022    .2374704   .0733026   .9657055
```

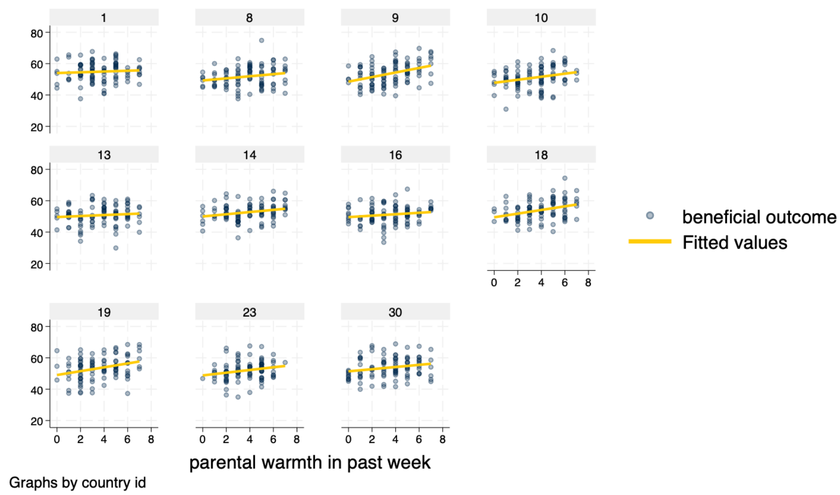

Figure 7: Small Multiples With A Random Sample Of Countries

12 Multivariate (Predicted) Relationships

A sometimes unacknowledged point is that graphs–unless we take steps to correct this–reflect *unadjusted*, or *bivariate* associations. We may sometimes wish to develop a graphs that reflect the *adjusted* or *predicted* estimates from our models.

12.1 Using Predicted Values (`predict`)

`predict` generates a predicted value for *every observation in the data.*

In multilevel models, *prediction* is a complex question. Prediction may–or may not–incorporate the information from the random effects. The procedures below outline graphs that incorporate predictions using the random effects, by using the `predict ..., fitted` syntax.

12.1.1 Estimate The Model

```
mixed outcome warmth physical_punishment i.intervention || country: // estimate MLM
```

```
Performing EM optimization ...

Performing gradient-based optimization:
Iteration 0:  Log likelihood = -9628.1621
Iteration 1:  Log likelihood = -9628.1621

Computing standard errors ...

Mixed-effects ML regression                     Number of obs    =  3,000
Group variable: country                         Number of groups =     30
                                                Obs per group:
                                                             min =    100
                                                             avg =  100.0
                                                             max =    100
                                                Wald chi2(3)     = 370.90
Log likelihood = -9628.1621                     Prob > chi2      = 0.0000

------------------------------------------------------------------------------------
           outcome | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------------+----------------------------------------------------------------
            warmth |   .8330937   .0574809    14.49   0.000     .7204332    .9457543
physical_punishm~t |  -.9937819   .0798493   -12.45   0.000    -1.150284   -.8372801
    1.intervention |   .6406043   .2175496     2.94   0.003      .214215    1.066994
             _cons |   51.65238   .4664841   110.73   0.000     50.73809    52.56668
------------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects parameters  |   Estimate   Std. err.     [95% conf. interval]
-----------------------------+------------------------------------------------
country: Identity            |
                  var(_cons) |   3.371762   .9613269      1.928279    5.895816
```

```
-----------------------------+------------------------------------------------
               var(Residual) |    35.0675    .910002      33.32853    36.89721
------------------------------------------------------------------------------
LR test vs. linear model: chibar2(01) = 204.14        Prob >= chibar2 = 0.0000
```

12.1.2 Generate Predicted Values

```
predict outcome_hat, fitted // predict yhat (`fitted` uses fixed AND random effects)
```

12.1.3 Graph With `twoway` Syntax

```
twoway (scatter outcome_hat warmth, mcolor(%30)) (lfit outcome_hat warmth)

graph export mypredictedvalues.png, width(1500) replace

twoway (lfit outcome_hat warmth)

graph export mypredictedvalues2.png, width(1500) replace
```

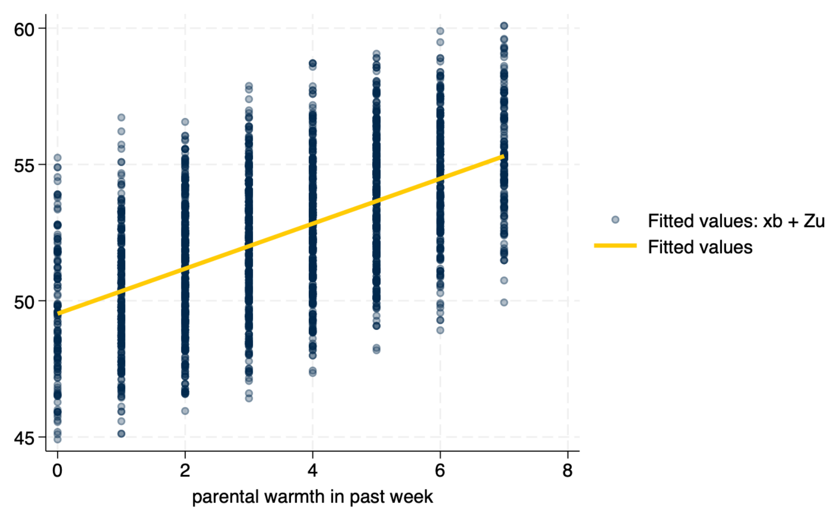

Figure 8: Predicted Values From `predict`

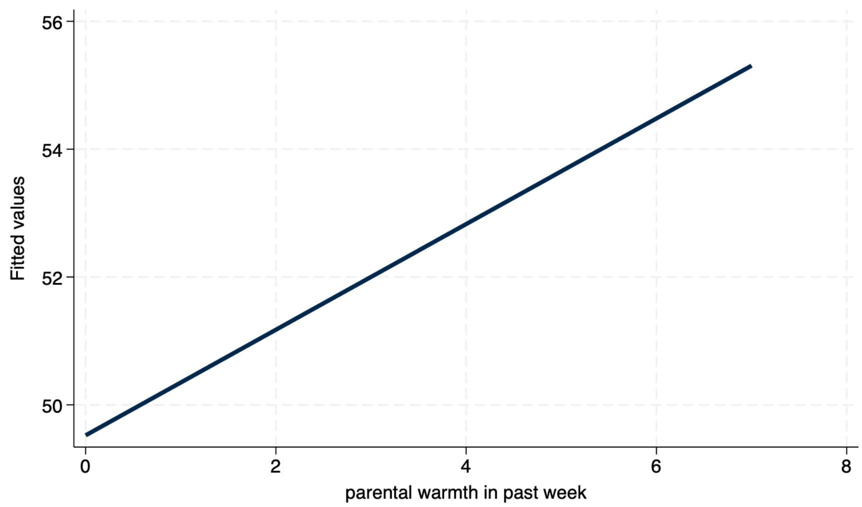

Figure 9: Predicted Values From `predict` With Only Linear Fit

12.1.4 Spaghetti Plot With Predicted Values

```
spagplot outcome_hat warmth, id(country)

graph export myspaghetti2.png, width(1500) replace
```

12.2 `margins` and `marginsplot`

In contrast to `predict`, which generates a predicted value for *every observation in the data*, `margins` generates predicted values at *specific values of certain variables*.

12.2.1 Estimate The Model

```
mixed outcome warmth physical_punishment i.intervention || country: // estimate MLM
```

```
Performing EM optimization ...

Performing gradient-based optimization:
Iteration 0:  Log likelihood = -9628.1621
```

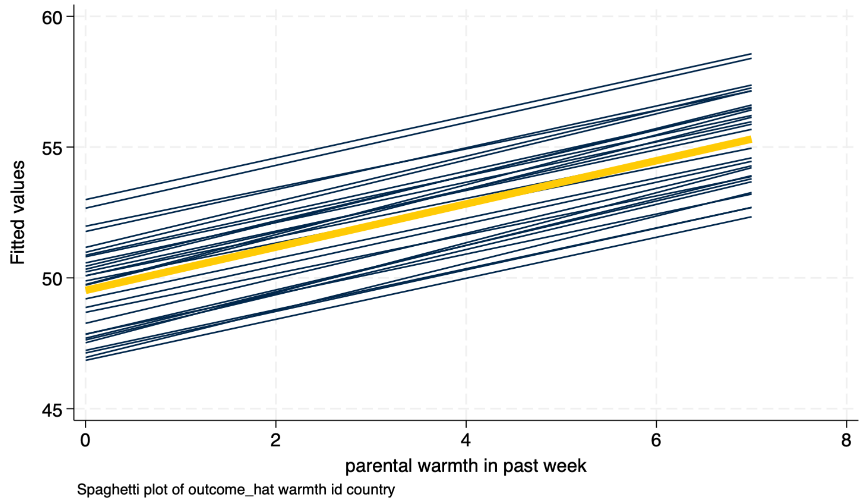

Figure 10: Spaghetti Plot With Predicted Values

```
Iteration 1:  Log likelihood = -9628.1621

Computing standard errors ...

Mixed-effects ML regression                         Number of obs    =  3,000
Group variable: country                             Number of groups =     30
                                                    Obs per group:
                                                                 min =    100
                                                                 avg =  100.0
                                                                 max =    100
                                                    Wald chi2(3)     = 370.90
Log likelihood = -9628.1621                         Prob > chi2      = 0.0000

------------------------------------------------------------------------------------
           outcome | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------------+----------------------------------------------------------------
            warmth |   .8330937   .0574809    14.49   0.000     .7204332    .9457543
physical_punishm~t |  -.9937819   .0798493   -12.45   0.000    -1.150284   -.8372801
    1.intervention |   .6406043   .2175496     2.94   0.003      .214215    1.066994
             _cons |   51.65238   .4664841   110.73   0.000     50.73809    52.56668
------------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects parameters  |   Estimate   Std. err.     [95% conf. interval]
-----------------------------+------------------------------------------------
```

```
country: Identity            |
                  var(_cons) |   3.371762   .9613269      1.928279    5.895816
-----------------------------+------------------------------------------------
               var(Residual) |    35.0675    .910002      33.32853    36.89721
------------------------------------------------------------------------------
LR test vs. linear model: chibar2(01) = 204.14        Prob >= chibar2 = 0.0000
```

12.2.2 Generate Predicted Values *At Specified Values* With margins

```
margins intervention, at(warmth = (1 2 3 4 5 6 7)) // predictive *margins*
```

```
Predictive margins                                      Number of obs = 3,000

Expression: Linear prediction, fixed portion, predict()
1._at: warmth = 1
2._at: warmth = 2
3._at: warmth = 3
4._at: warmth = 4
5._at: warmth = 5
6._at: warmth = 6
7._at: warmth = 7

----------------------------------------------------------------------------------
                 |            Delta-method
                 |     Margin   std. err.      z    P>|z|     [95% conf. interval]
-----------------+----------------------------------------------------------------
_at#intervention |
             1 0 |   50.02222   .3966755   126.10   0.000     49.24475    50.79969
             1 1 |   50.66283   .3955286   128.09   0.000     49.88761    51.43805
             2 0 |   50.85532   .3788571   134.23   0.000     50.11277    51.59786
             2 1 |   51.49592   .3789096   135.91   0.000     50.75327    52.23857
             3 0 |   51.68841   .3692182   139.99   0.000     50.96476    52.41207
             3 1 |   52.32902    .370554   141.22   0.000     51.60274    53.05529
             4 0 |   52.52151   .3684014   142.57   0.000     51.79945    53.24356
             4 1 |   53.16211   .3710204   143.29   0.000     52.43492     53.8893
             5 0 |    53.3546    .376464   141.73   0.000     52.61674    54.09246
             5 1 |    53.9952   .3802764   141.99   0.000     53.24988    54.74053
             6 0 |   54.18769   .3928599   137.93   0.000      53.4177    54.95768
             6 1 |    54.8283   .3977088   137.86   0.000      54.0488    55.60779
             7 0 |   55.02079   .4166062   132.07   0.000     54.20425    55.83732
```

```
          7 1  |   55.66139   .4223062   131.80   0.000     54.83369    56.4891
------------------------------------------------------------------------------
```

12.2.3 Graph With `marginsplot`

```
marginsplot // plot of predicted values

graph export mymarginsplot.png, width(1500) replace
```

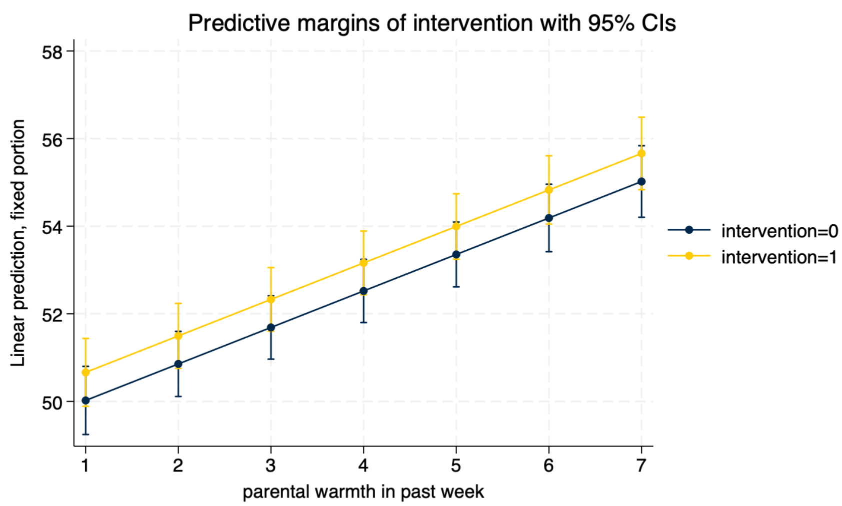

Figure 11: Predicted Values From `margins` and `marginsplot`

13 Scatterplot With Linear Fit and Marginal Density Plots (`twoway ...`)

As another possibility, we may wish to show more of the variation, by showing the variation in the *independent* variable and the *dependent* variable along with a *scatterplot* and *linear fit*. This is a complex graph and requires a little bit of manual programming in Stata.

> You could also investigate the user written program `binscatterhist` (`ssc install binscatterhist`) which produces a similar looking graph, and automates much of this work.

13.1 Manually Generate The Densities To Plot Them Below (`kdensity ...`)

We generate the density for *warmth* at only a few points (`n(8)`) since this variable has relatively few categories.

```
kdensity warmth, generate(warmth_x warmth_d) n(8) // manually generate outcome densities

kdensity outcome, generate(outcome_y outcome_d) // manually generate outcome densities
```

13.2 Rescale The Densities So They Plot Well

You may have to experiment with the scaling and moving factors.

```
replace warmth_d = 100 * warmth_d // rescale the density so it plots well

replace outcome_d = 5 * outcome_d - .5 // rescale AND MOVE the density so it plots well

label variable outcome_y "density: beneficial outcome" // relabel y variable
```

```
(8 real changes made)

(50 real changes made)
```

13.3 Make The Graph (`twoway ...`)

You may have to experiment with whether scatterplots or line plots work best for displaying the x and y densities.

```
twoway (scatter outcome warmth, mcolor(%10)) /// scatterplot w some transparency
(lfit outcome warmth) /// linear fit
(line warmth_d warmth_x) /// line plot of x density
(line outcome_y outcome_d), /// line plot of y density (note flipped order)
title("Outcome by Warmth") /// title
ytitle("beneficial outcome") /// manual ytitle
xtitle("parental warmth") /// manual xtitle
legend(position(6) rows(2) ) /// legend at bottom; 2 rows
xlabel(0 1 2 3 4 5 6 7) /// manual x labels
name(mynewscatter, replace)

graph export mynewscatter.png, width(1500) replace
```

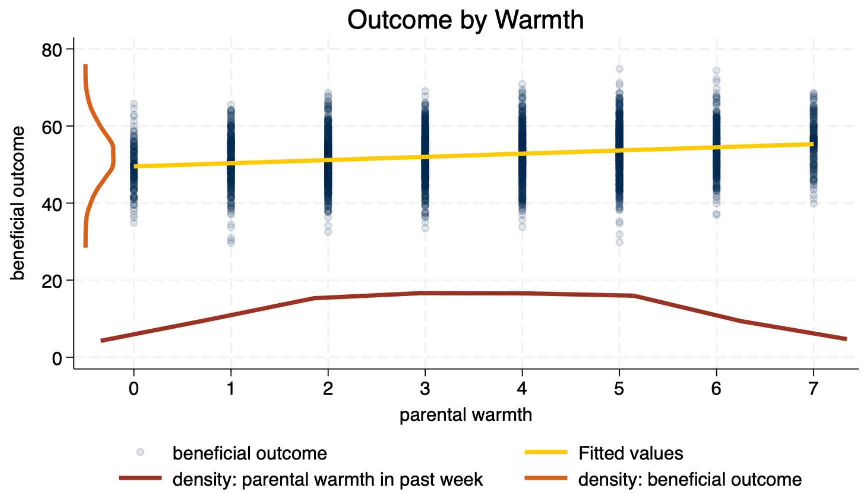

Figure 12: Scatterplot and Linear Fit With Marginal Density Plots

References

Hemken, Doug. 2023. *Statamarkdown: 'Stata' Markdown*. https://CRAN.R-project.org/package=Statamarkdown.