HIERARCHICAL AND MIXED EFFECTS MODELS

Linear mixed effect model- Birth rates data

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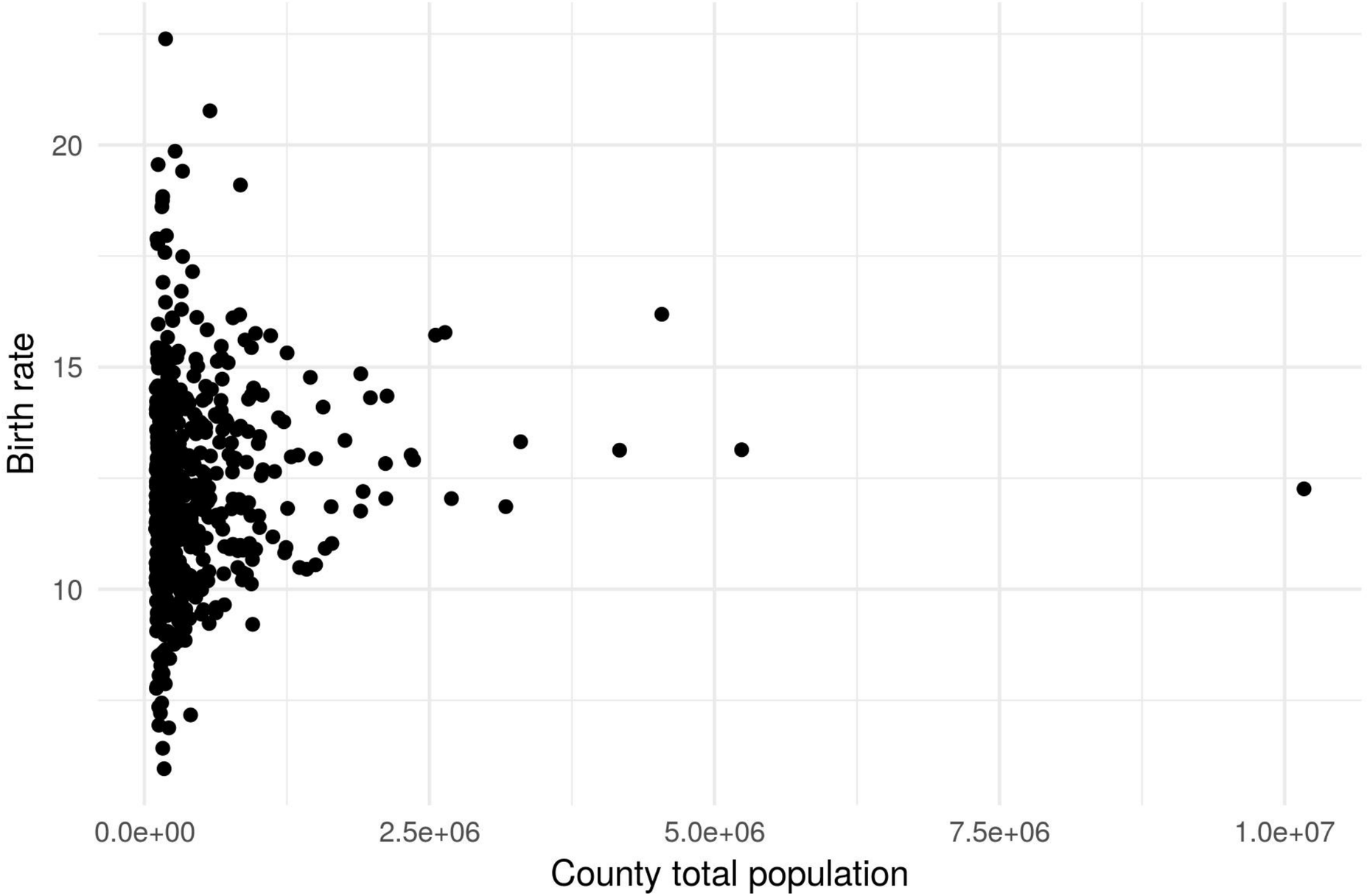
Birth rates data

- Small populations subject to stochasticity
- Random-effects one solution to this problem
- Birth rates one such variable

How does a mothers age impact birth rate?

- Does a mother's age impact birth rate?
- Marketing and policy implications


Birth rate
20
15
10
0.0e+00
2.5e+06
5.0e+06
7.5e+06
1.0e+07
County total population

lmer syntax in R

```
library(lme4)
lmer( y ~ x + (Random-effect), data = myData)
```

Random-effect syntax

- `( 1 | group )`: Random intercept with fixed mean
- `(1 | g1/g2)`: Intercepts vary among `g1` and `g2` within `g2`
- `(1 | g1) + (1 | g2)`: Random intercepts for 2 variables
- `x + (x | g)`: Correlated random slope and intercept
- `x + (x || g)`: Uncorrelated random slope and intercept
- See `lme4` for additional details

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Let's practice!

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Understanding and reporting the output of a lmer

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The model

```
out <- lmer(BirthRate ~ AverageAgeofMother +
                        (AverageAgeofMother|State),
            data = countyBirthsData)
```

Print

```
> out # print(out) is what R is calling
Linear mixed model fit by REML ['lmerMod']
Formula: BirthRate ~ AverageAgeofMother + (AverageAgeofMother | State)
   Data: countyBirthsData
REML criterion at convergence: 2337.506
Random effects:
 Groups   Name                Std.Dev. Corr
 State    (Intercept)         8.8744
          AverageAgeofMother  0.2912   -0.99
 Residual                     1.6742
Number of obs: 578, groups:  State, 50
Fixed Effects:
       (Intercept)  AverageAgeofMother
           27.2204             -0.5235
```

Summary

```
> summary(out)
#    ...
Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.8399 -0.5966 -0.1133  0.5228  5.1815

Random effects:
 Groups   Name                Variance Std.Dev. Corr
 State    (Intercept)         78.75478 8.8744
          AverageAgeofMother   0.08482 0.2912   -0.99
 Residual                      2.80306 1.6742
Number of obs: 578, groups:  State, 50

Fixed effects:
                   Estimate Std. Error t value
(Intercept)        27.22041    2.41279  11.282
AverageAgeofMother -0.52347    0.08302  -6.306

Correlation of Fixed Effects:
            (Intr)
AvrgAgfMthr -0.997
```

Extracting fixed-effects estimates

```
> fixef(out)
       (Intercept) AverageAgeofMother
         34.5756764          -0.7556129
```

Extracting fixed-effects confidence intervals

```
> confint(out)
    Computing profile confidence intervals #...
                             2.5 %    97.5 %
    .sig01                0.9458700  1.612440
    .sigma                1.6091447  1.815929
    (Intercept)          24.0121843 31.146685
    AverageAgeofMother -0.6605319 -0.411231
```

Extracting random-effects

```
> ranef(out)
    $State
    AK  1.03549148
    AL -0.52500819
    AR  0.48023356
    AZ -1.04094123
    CA  0.50530542
    CO  0.09585582
    CT -1.91638101
    DC  0.96029531
    DE -0.38938118
    FL -1.87440508
    GA  0.39776424
    #...
```

Reporting lmer output

- Know your audience
- Figure
- Table
- In-text

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Statistical inference with Maryland crime data

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Maryland crime data

- Number of violent crimes per year by County

```
          County    Year Crime
ANNE ARUNDEL   2006  3167
BALTIMORE CITY 2006 10871
```

- Useful for policy/crime analysis or insurance
- Is the crime rate changing through time across counties?

Null hypothesis test

- H_0 : No difference exists
- H_a: A difference exists

P-values with lmer

```
library(lmerTest)
summary(lmer(...))
```

ANOVA

- Analysis of Variance (ANOVA)
- Compare variability of model with and without parameter
- `lmer(response ~ (1| group))` **VS** `lmer(response ~ predictor + (1|group))`

Summary

- Null hypothesis testing and ANOVAs
- Build and compare models
- High-level details, important assumptions covered in other DataCamp courses

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Let's practice!