Army Operations Research Symposium

CAA Covid Model and Estimating Effective R_0

MAJ Dusty Turner

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Who am I?

Army

- Combat Engineer
- Platoon Leader / XO / Company Commander
- Geospatial / Sapper / Route Clearance
- Hawaii / White Sands Missile Range / Iraq / Afghanistan

Education

- West Point ’07
  - Operations Research, BS
- Missouri University of Science and Technology ’12
  - Engineering Management, MS
- THE Ohio State ’16
  - Integrated Systems Engineering, MS
  - Applied Statistics, Graduate Minor

Data Science

- R User Since ’14
- Catch me on Twitter @dtdusty
- dusty.s.turner.com

Road Map

- SEIR Overview
- Introduce the basic reproduction number (R_0)
- Problems with R_0
- Addressing the problems with R_0

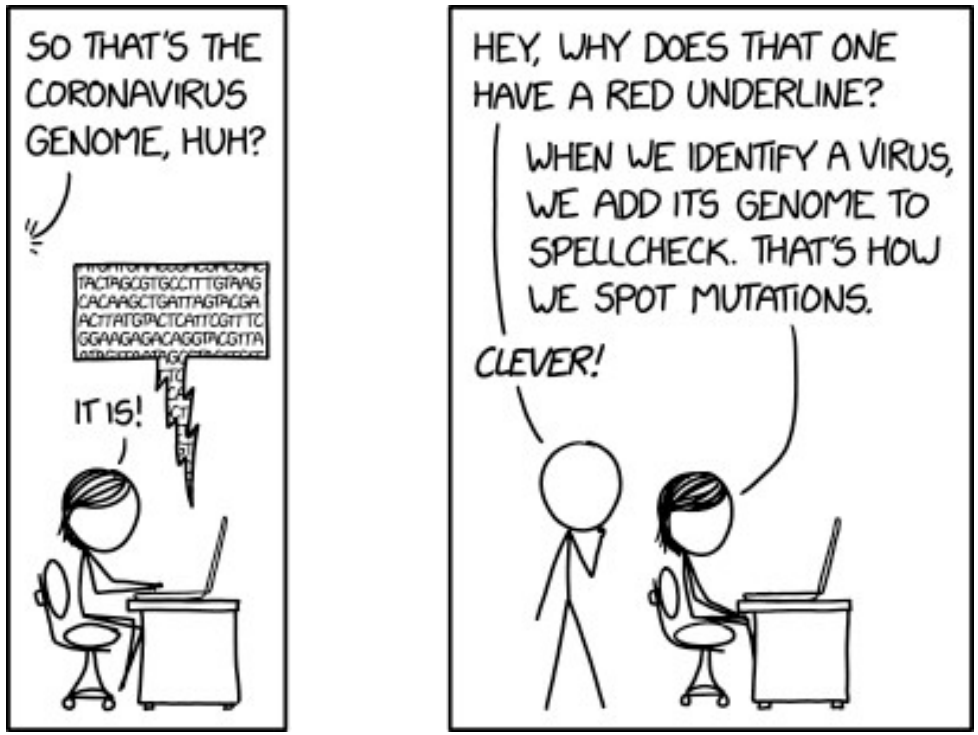
Bad Jokes

What am I assuming about you?

Background with Coronavirus Disease (COVID)

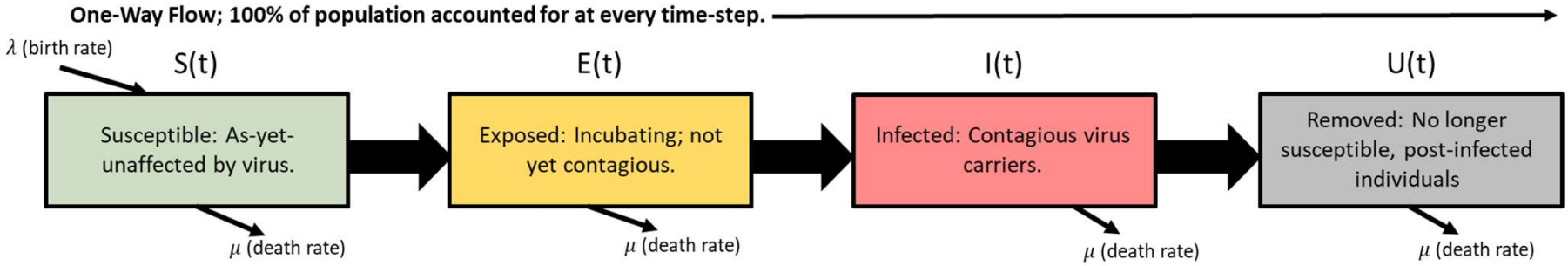
Moderate Statistics Background

You find things like this funny….



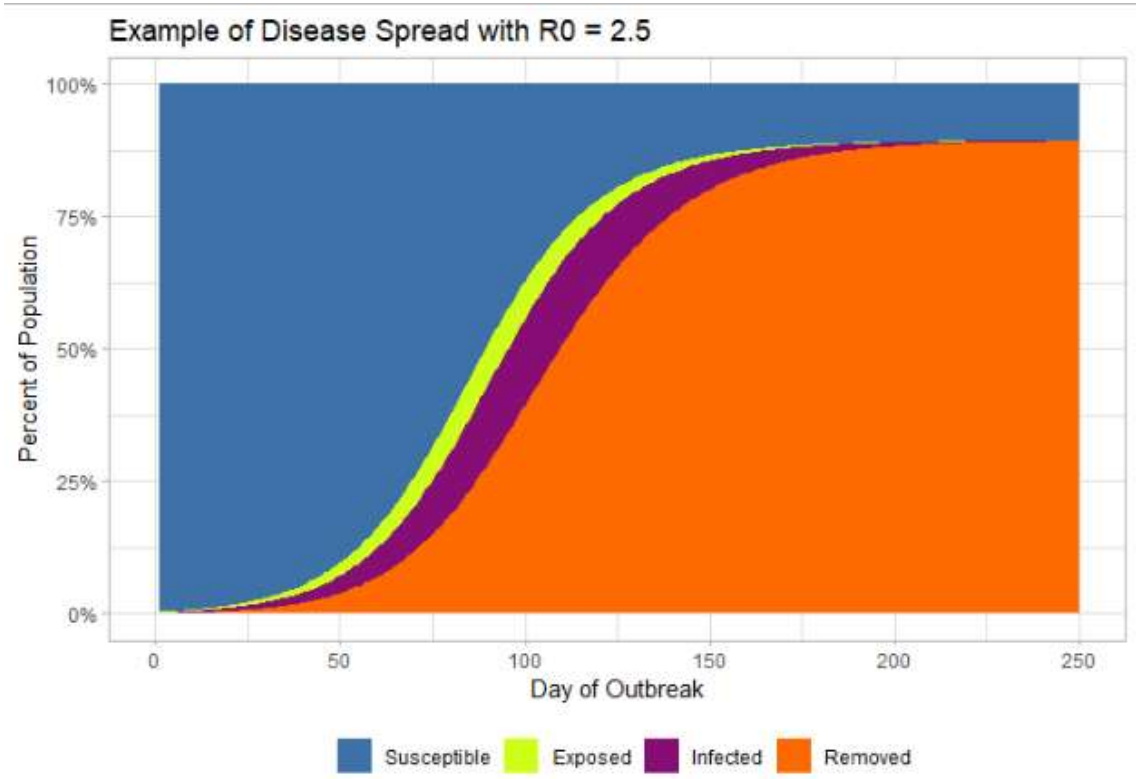
https://xkcd.com/2298/

SEIR in a Nutshell



Compartment	Ordinary Differential Equation (ODE)
Susceptible	$\frac{ds}{dt} = -\beta I(t)S(t)$
Exposed	$\frac{de}{dt} = \beta I(t)S(t) - \sigma E(t)$
Infected	$\frac{di}{dt} = \sigma E(t) - \gamma I(t)$
Removed	$\frac{du}{dt} = 1 - \left(\frac{ds}{dt} + \frac{de}{dt} + \frac{di}{dt}\right)$

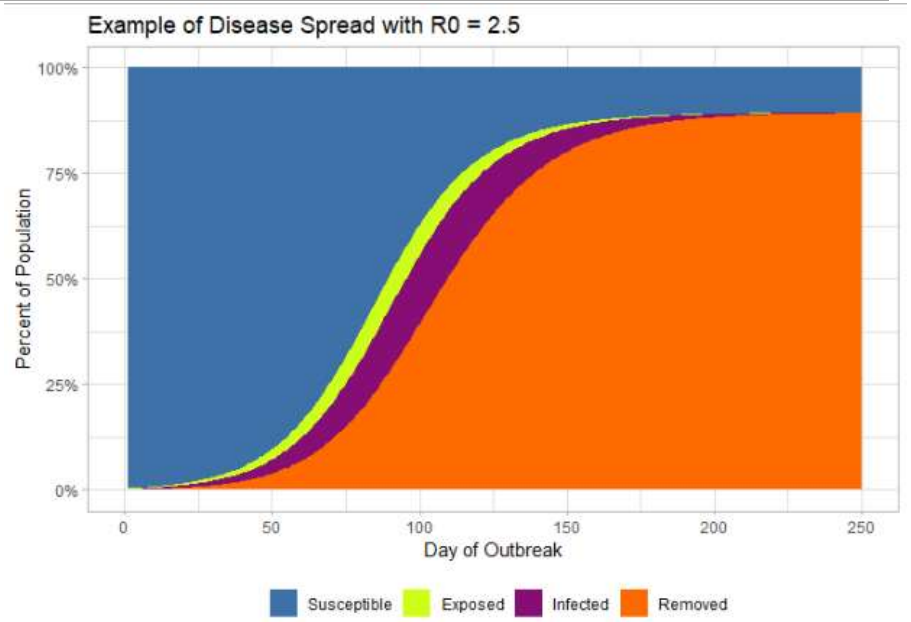
$$R_0 = \left(\frac{\beta}{\gamma}\right)$$

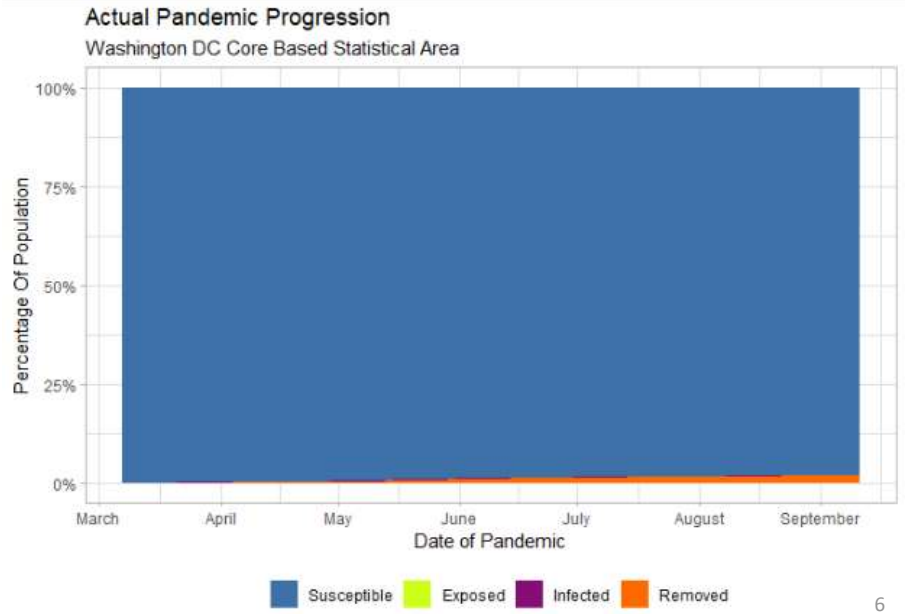


The Problem:

Compartment	ODE
Susceptible	$\frac{ds}{dt} = -\beta I(t)S(t)$
Exposed	$\frac{de}{dt} = \beta I(t)S(t) - \sigma E(t)$
Infected	$\frac{di}{dt} = \sigma E(t) - \gamma I(t)$
Removed	$\frac{du}{dt} = 1 - \left(\frac{ds}{dt} + \frac{de}{dt} + \frac{di}{dt}\right)$

$$R_0 = \left(\frac{\beta}{\gamma}\right)$$





The Culprits: Individual Behavior

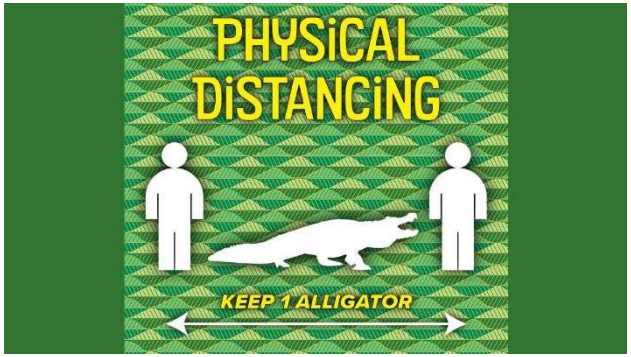
https://www.jimnolansblog.com/2012/08/cartoon-for-back-to-school.html

$$R_0 = \left(\frac{\beta}{\gamma}\right)$$

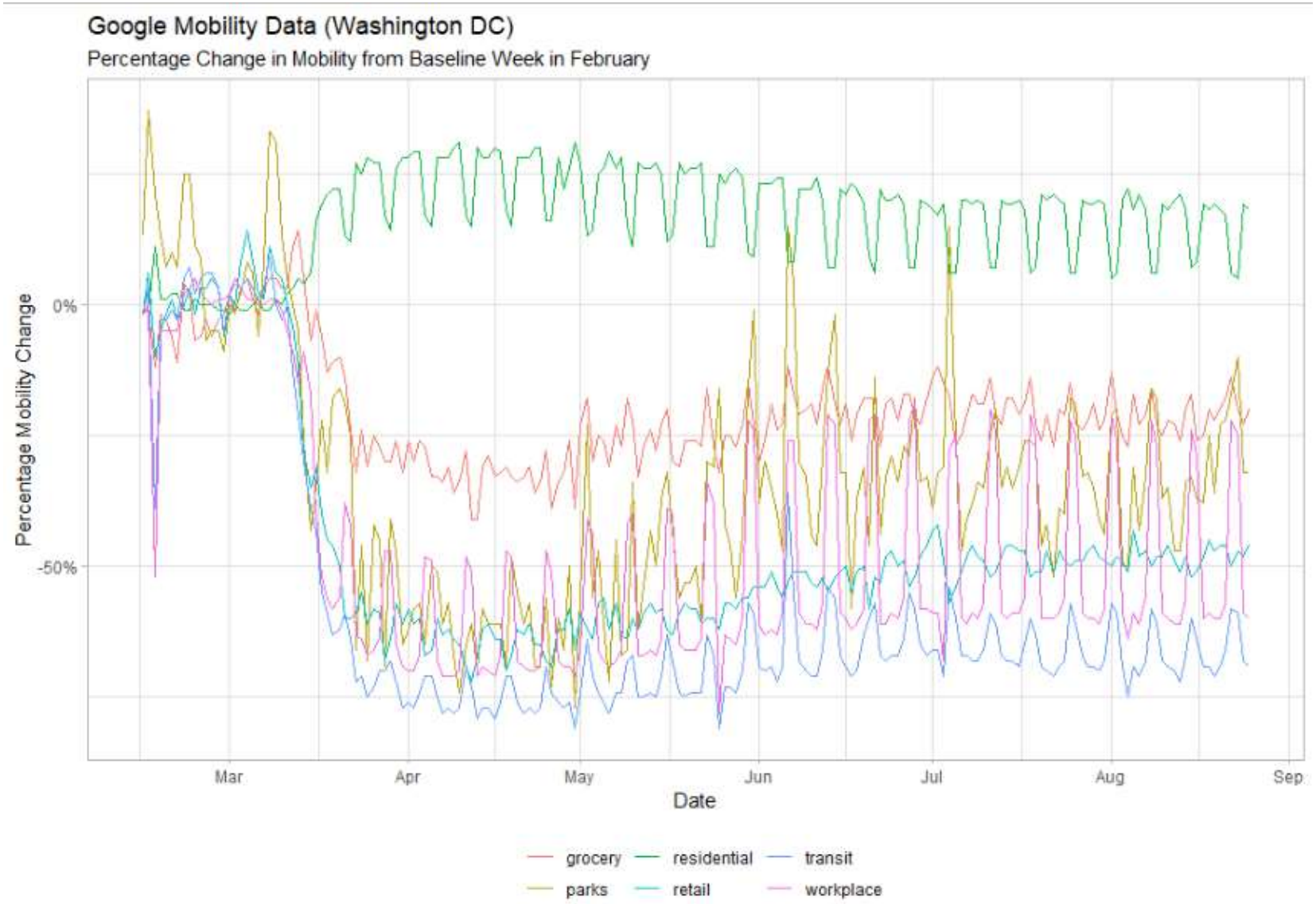
https://www.dezeen.com/2020/02/17/alternative-coronavirus-masks-max-siedentopf/

https://www.ocregister.com/2020/03/15/will-coronavirus-kill-local-open-houses-and-home-sales/

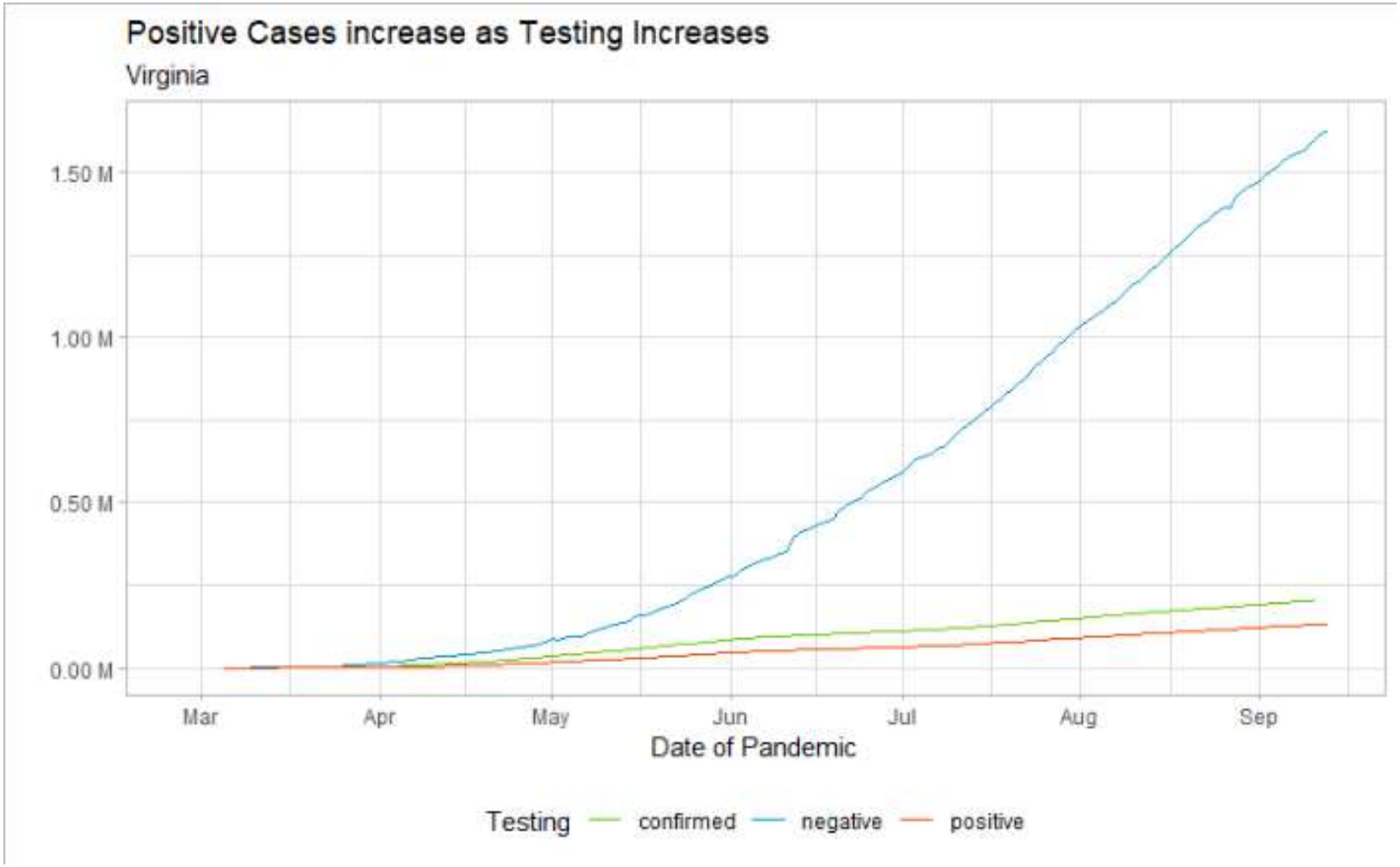
https://www.clickorlando.com/news/local/2020/04/05/this-is-the-most-florida-way-to-remember-the-cdcs-guidelines-on-coronavirus-social-distancing/



The Culprits: Less Mobility / Interaction



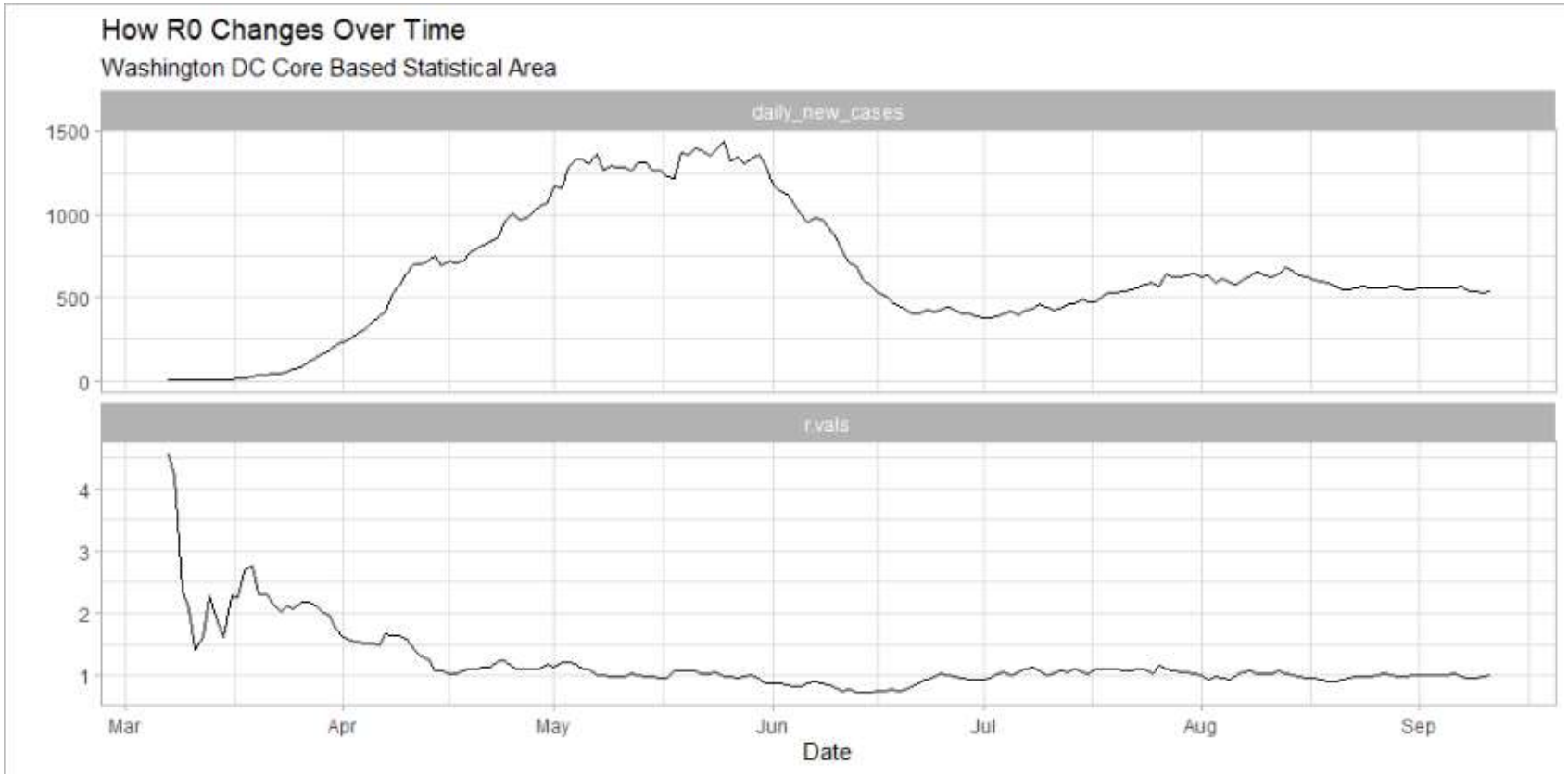
The Culprits: Testing



The Culprits: Policy

State Policy Data Sample		
Date closed K-12 schools	State ended statewide mask use by individuals in public spaces	Reopen bars
Closed day cares	Attempt by state government to prevent local governments from implementing face mask orders	Reopened hair salons/barber shops
Reopen day cares	Alcohol/liquor stores open	Reopen religious gatherings
Date banned visitors to nursing homes	Allow restaurants to sell takeout alcohol	Reopen non-essential retail
Stay at home / shelter in place	Allow restaurants to deliver alcohol	Begin to re-close bars
End /relax stay at home / shelter in place	Keep firearms sellers open	Re-close bars (statewide)
Closed non-essential businesses	Closed restaurants except take out	Re-close movie theaters (statewide)
Began to reopen businesses	Reopen restaurants	Re-close gyms (statewide)
Religious gatherings exempt without clear social distance mandate	Initially reopen restaurants for outdoor dining only	Re-close indoor dining (statewide)
Mandate face mask use by all individuals in public spaces	Closed gyms	
Face mask mandate enforced by fines	Reopened gyms	
Face mask mandate enforced by criminal charge/citation	Closed movie theaters	
No legal enforcement of face mask mandate	Reopened movie theaters	
Mandate face mask use by employees in public-facing businesses	Closed bars	

Identifying the Solution

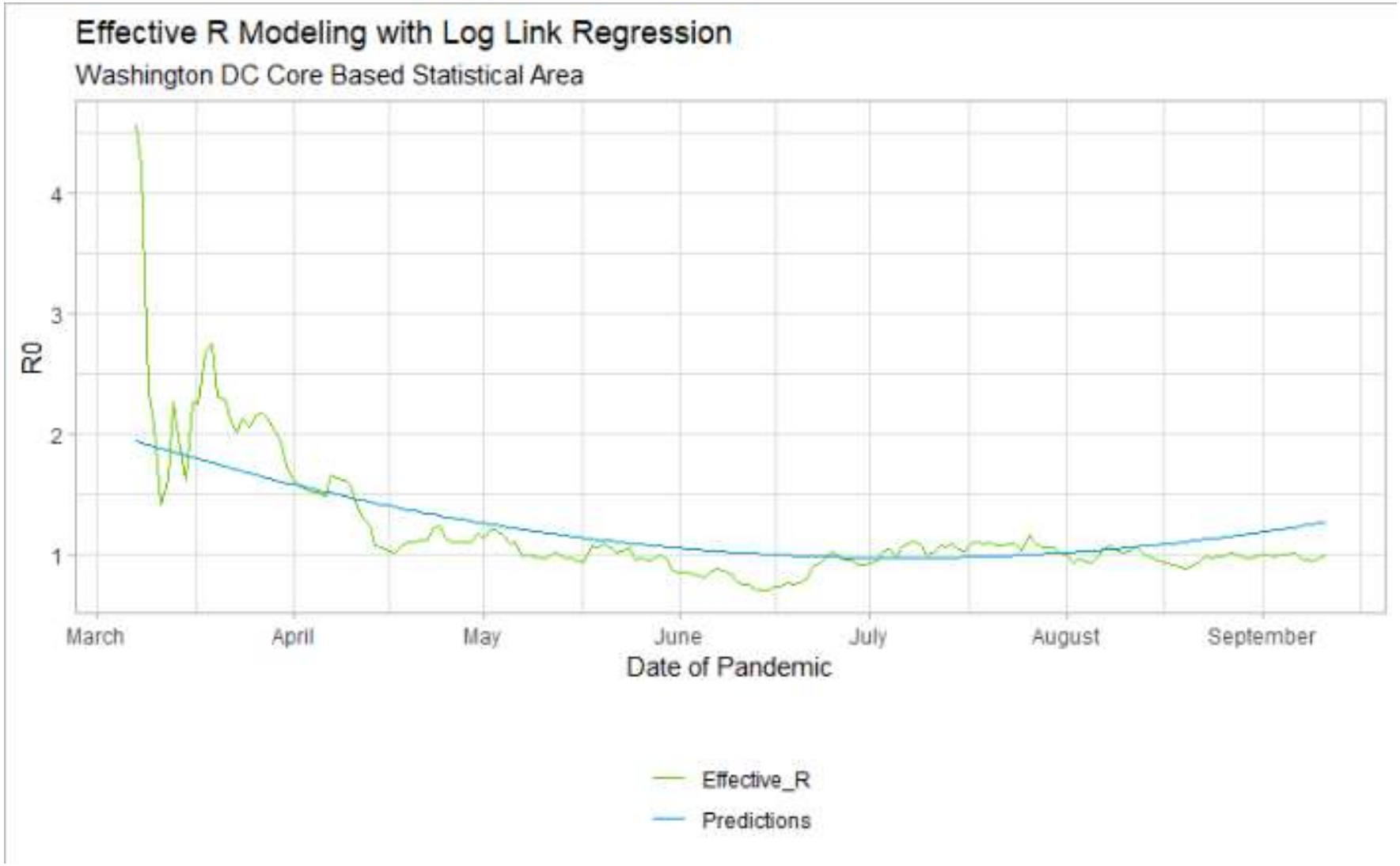


$$R_{eff_i} = \frac{c_i}{\sum_{n=0}^{i} c_{i-n} * w_n}$$

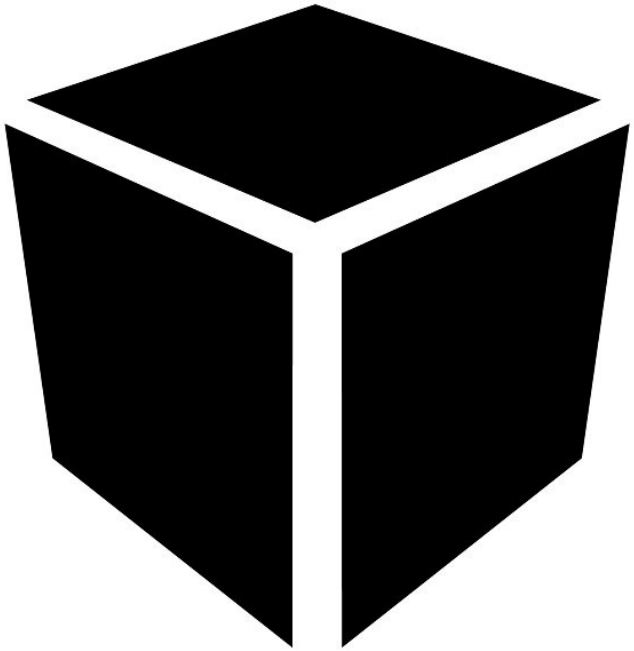
Nishiura H., Chowell G. (2009) The Effective Reproduction Number as a Prelude to Statistical Estimation of Time-Dependent Epidemic Trends. In: Chowell G., Hyman J.M., Bettencourt L.M.A., Castillo-Chavez C. (eds) Mathematical and Statistical Estimation Approaches in Epidemiology. Springer, Dordrecht

https://www.nicholasjsclark.com/2020/04/30/2020-04-30-time-varying-reproductive-number/

Attempts to Model Effective R

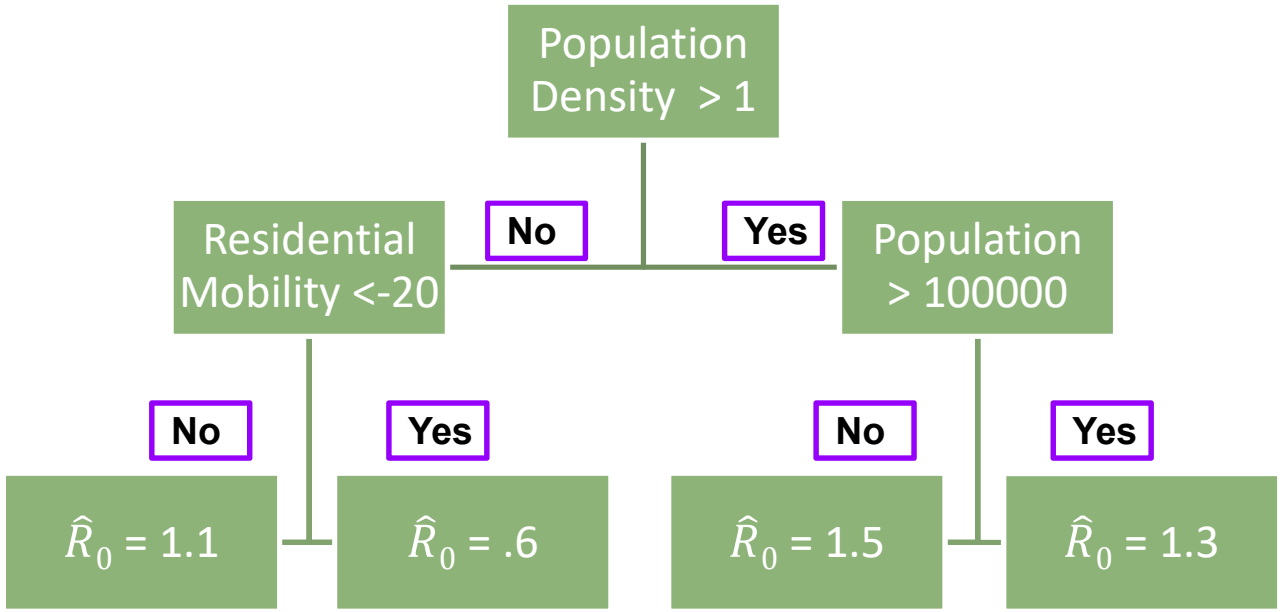


XGBoost



Example: Tree (1 of 12)

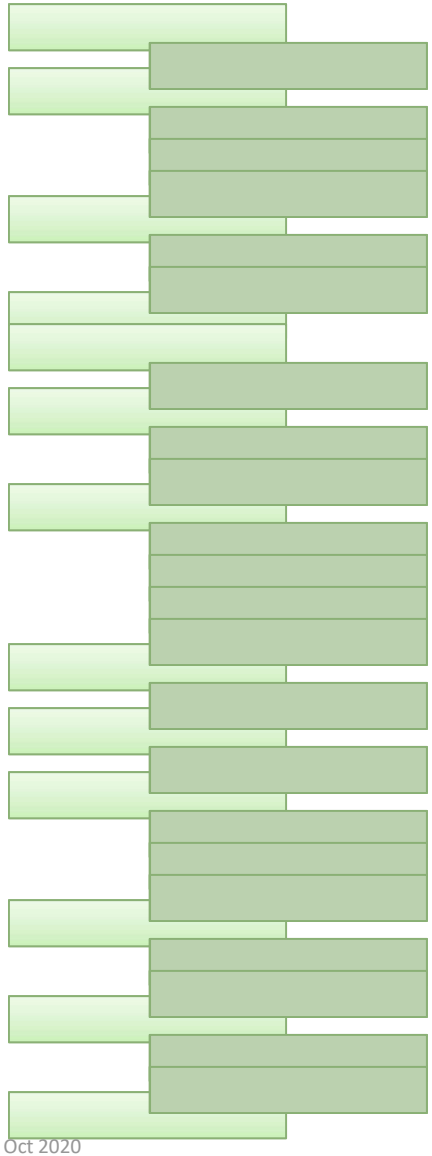
35 Factors

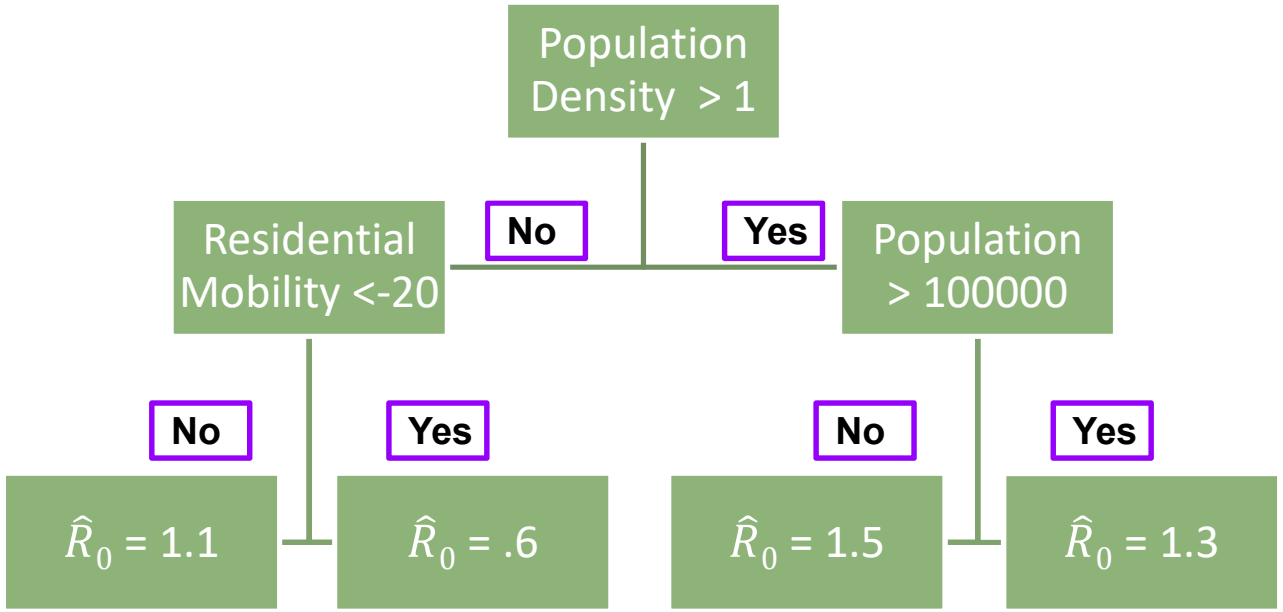


$$\boldsymbol{Min} \sum (R_0 - \hat{R}_0)^2$$

Example: Bootstrap (2 of 12)

35 Factors

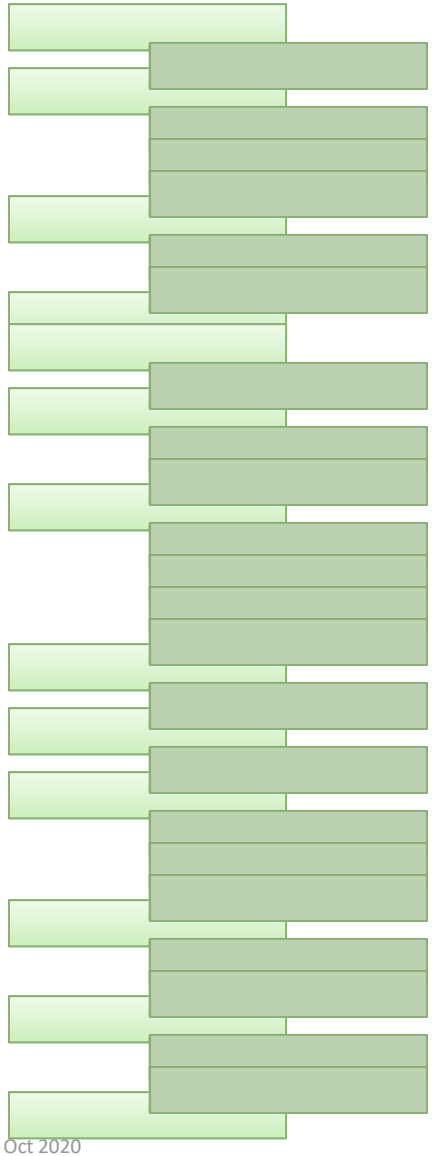


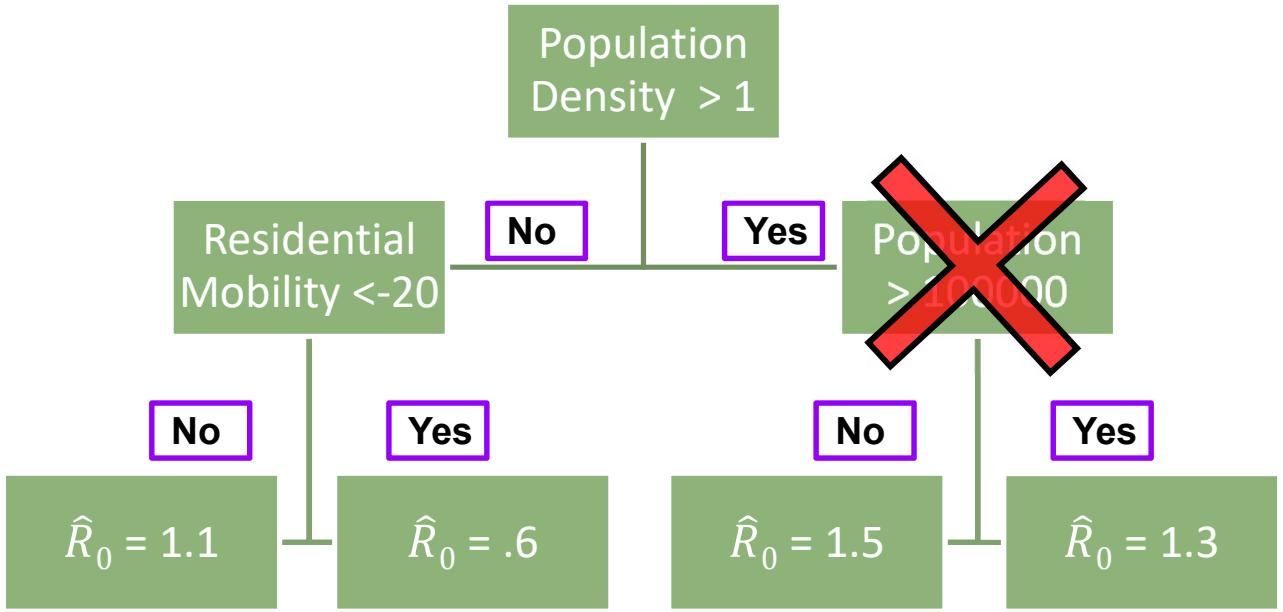


$$\boldsymbol{Min} \sum (R_0 - \hat{R}_0)^2$$

Example: Bootstrap (3 of 12)

35 Factors

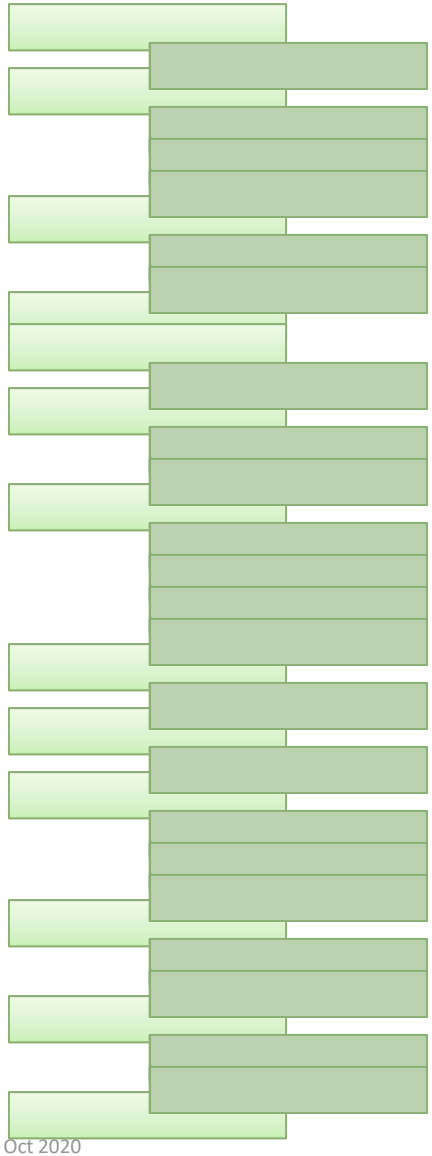


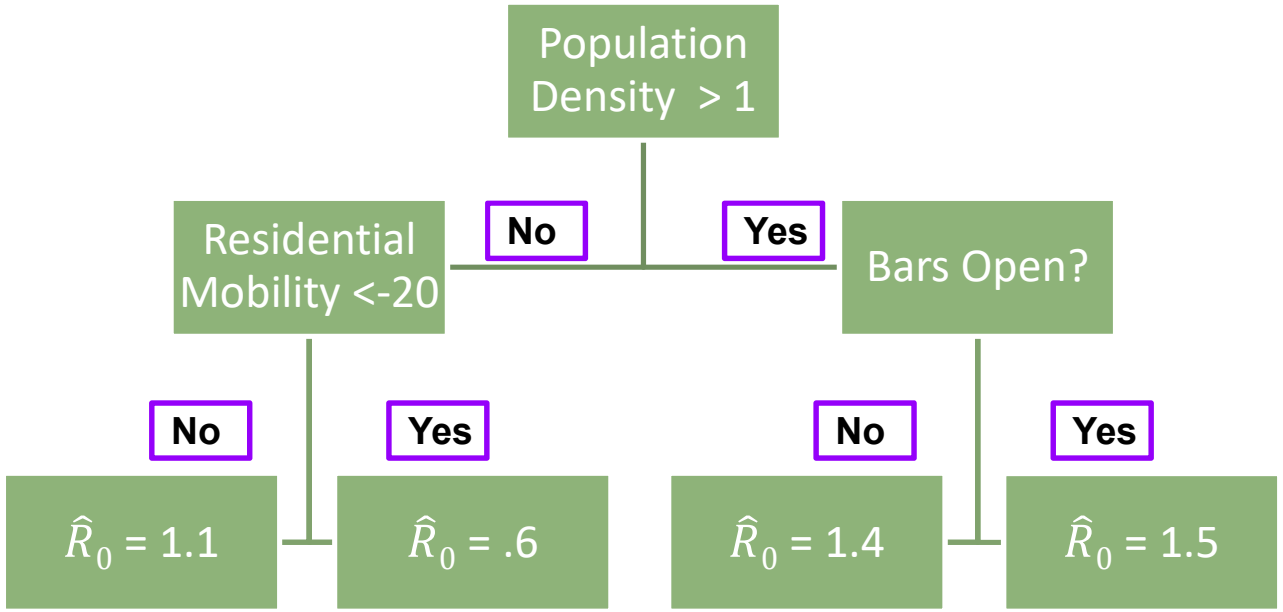


$$\boldsymbol{Min} \sum (R_0 - \hat{R}_0)^2$$

Example: Bootstrap (4 of 12)

35 Factors

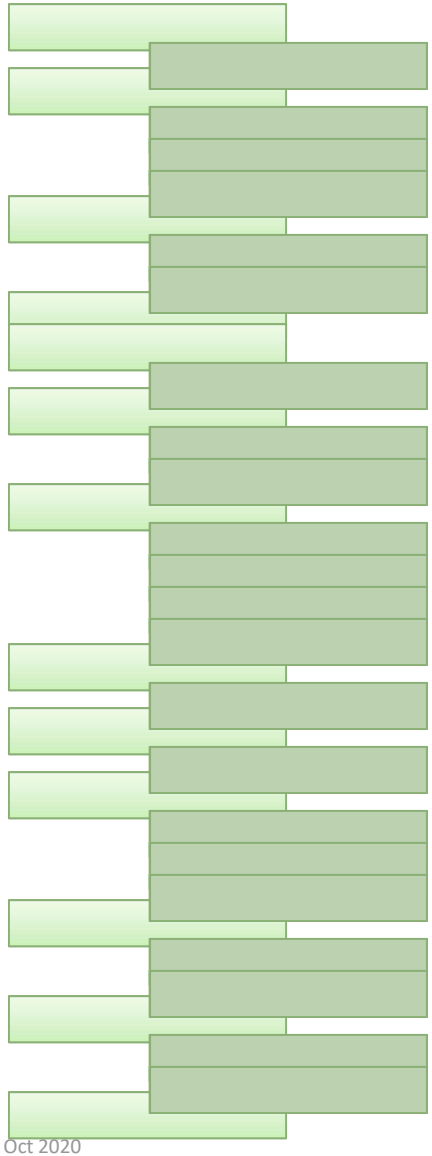


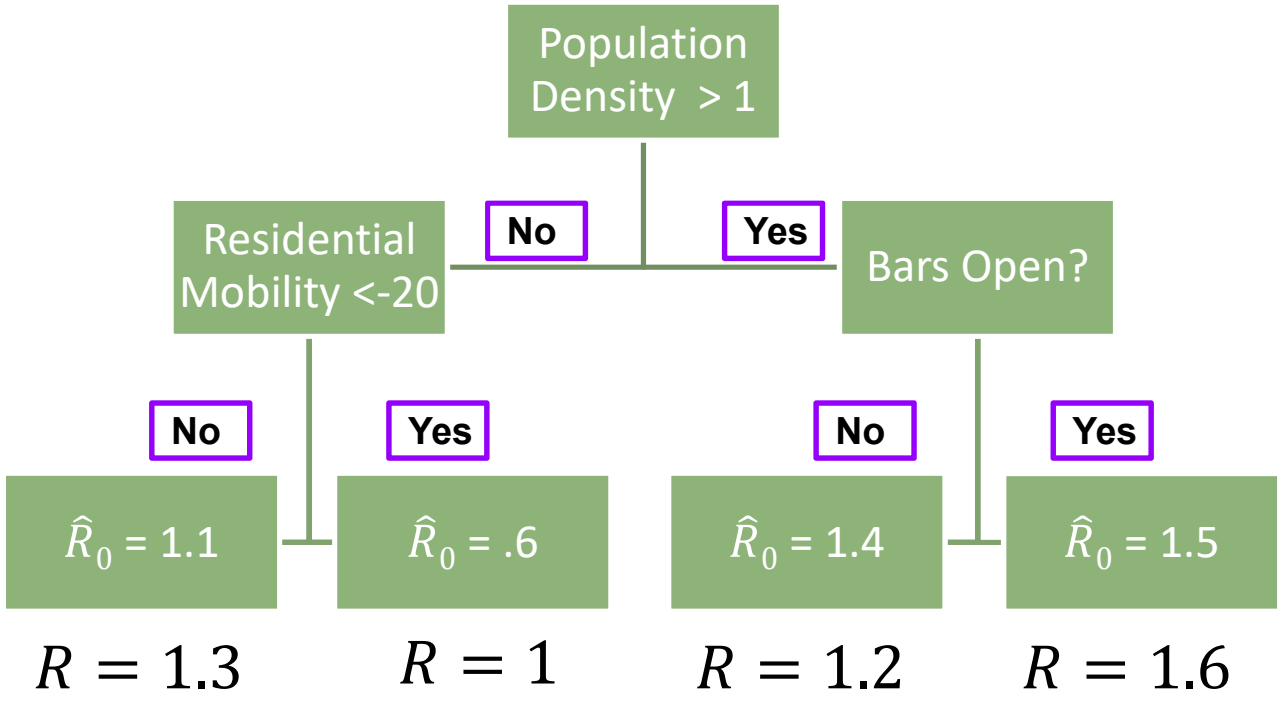


$$\boldsymbol{Min} \sum (R_0 - \hat{R}_0)^2$$

Example: Bootstrap (5 of 12)

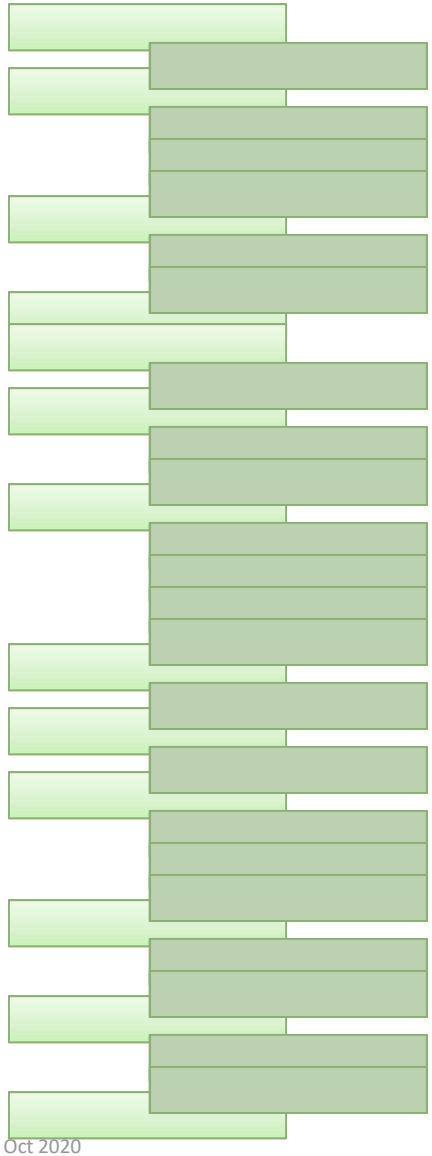
35 Factors

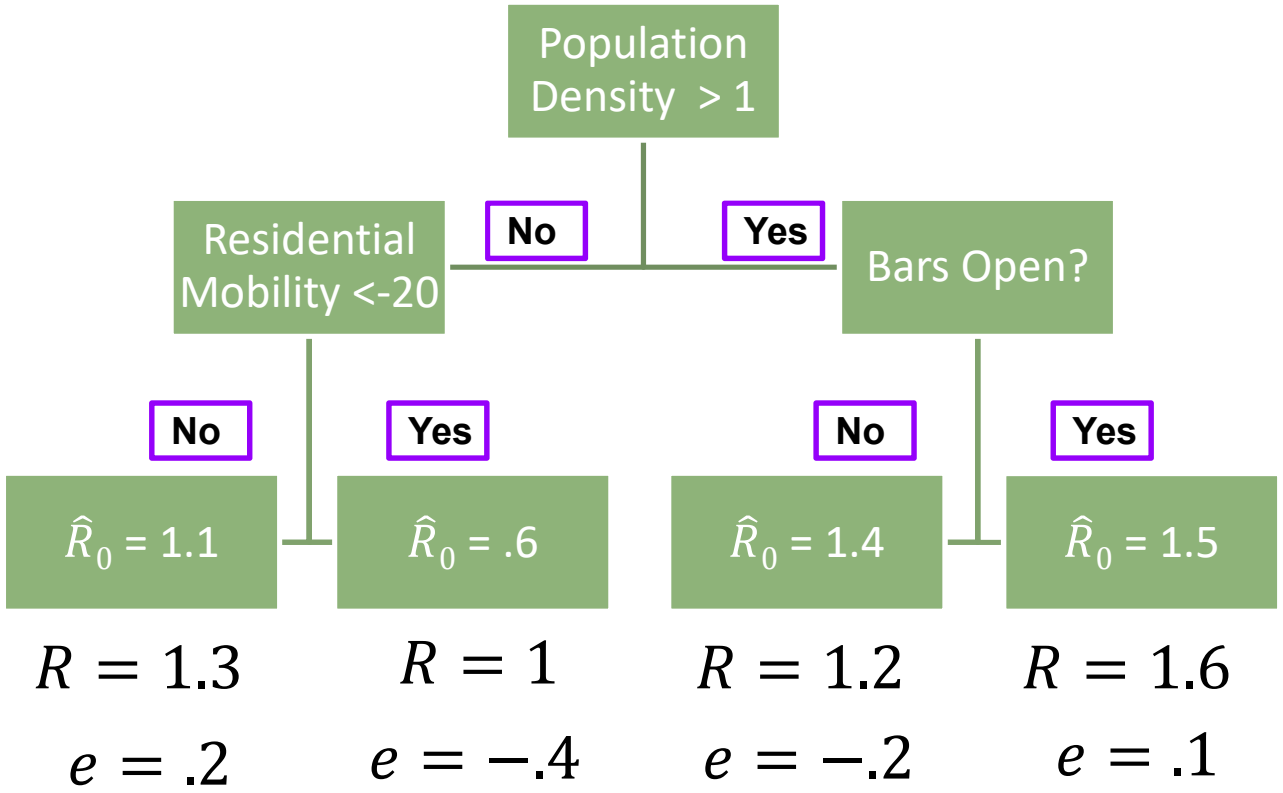




Example: Bootstrap (6 of 12)

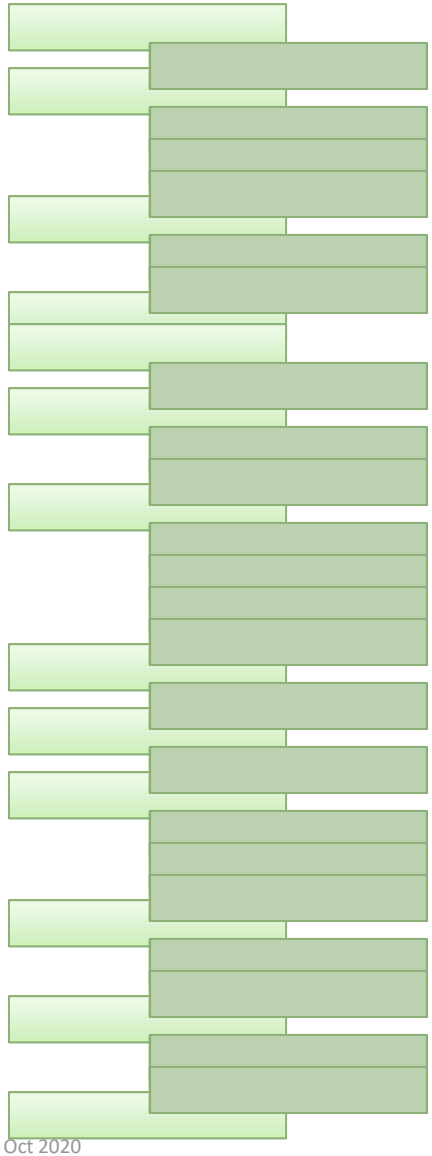
35 Factors

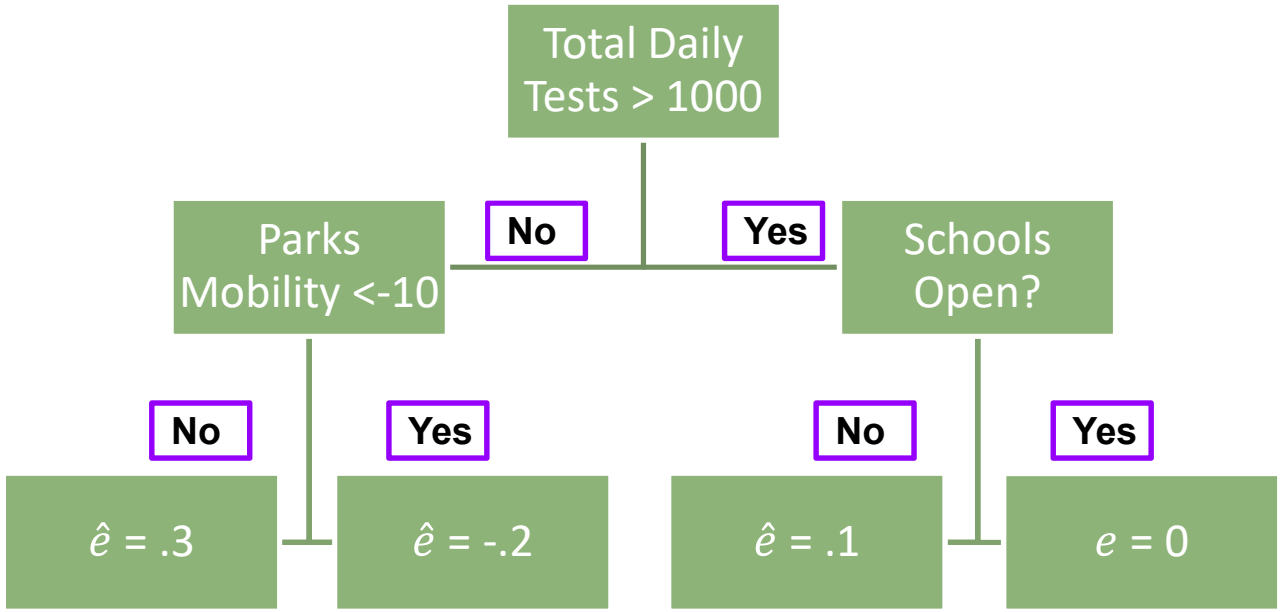




Example: Stacking (7 of 12)

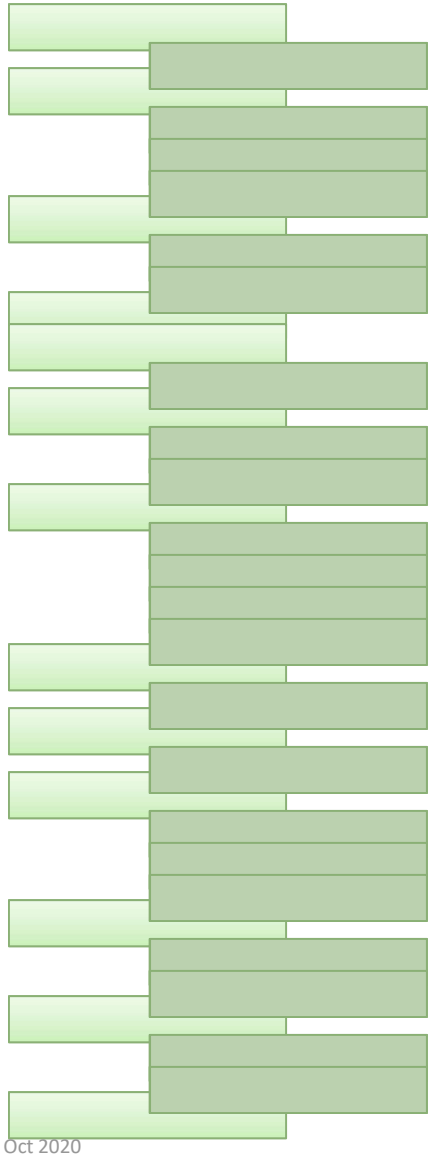
35 Factors

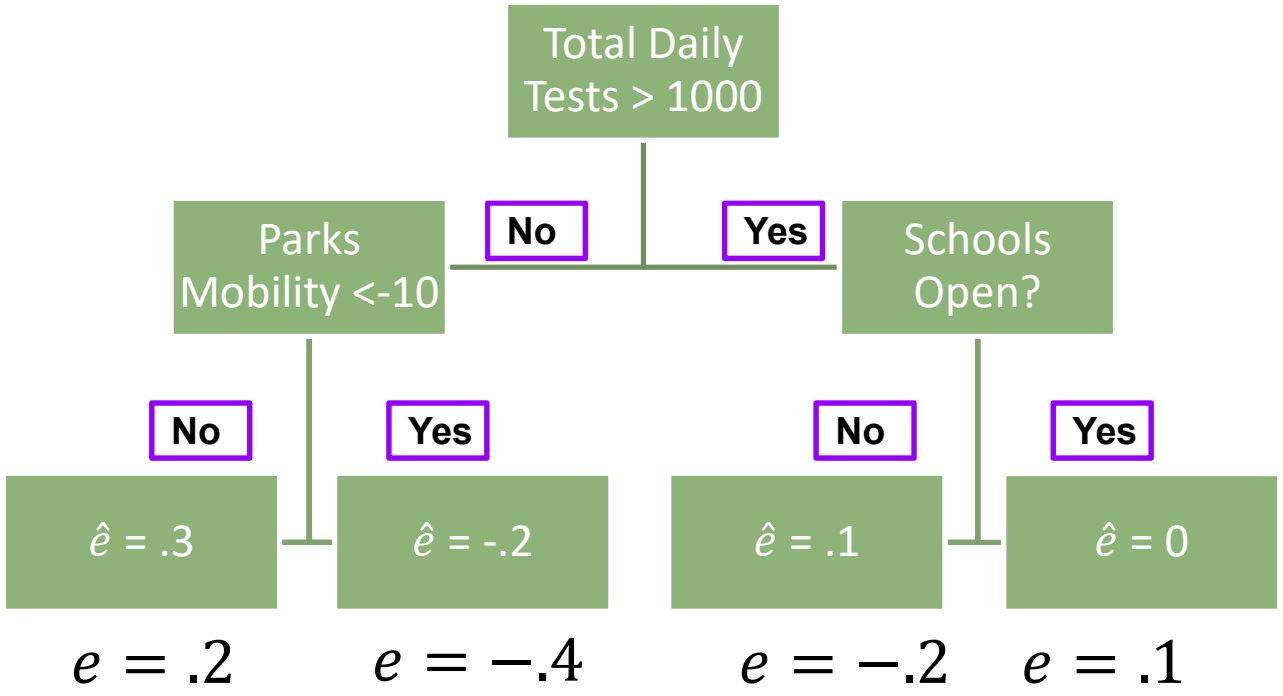




Example: Stacking (8 of 12)

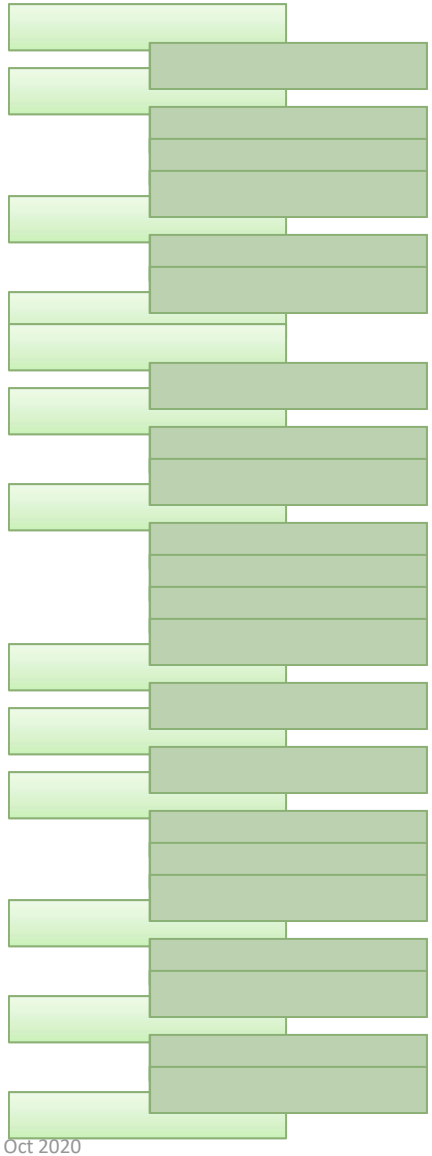
35 Factors

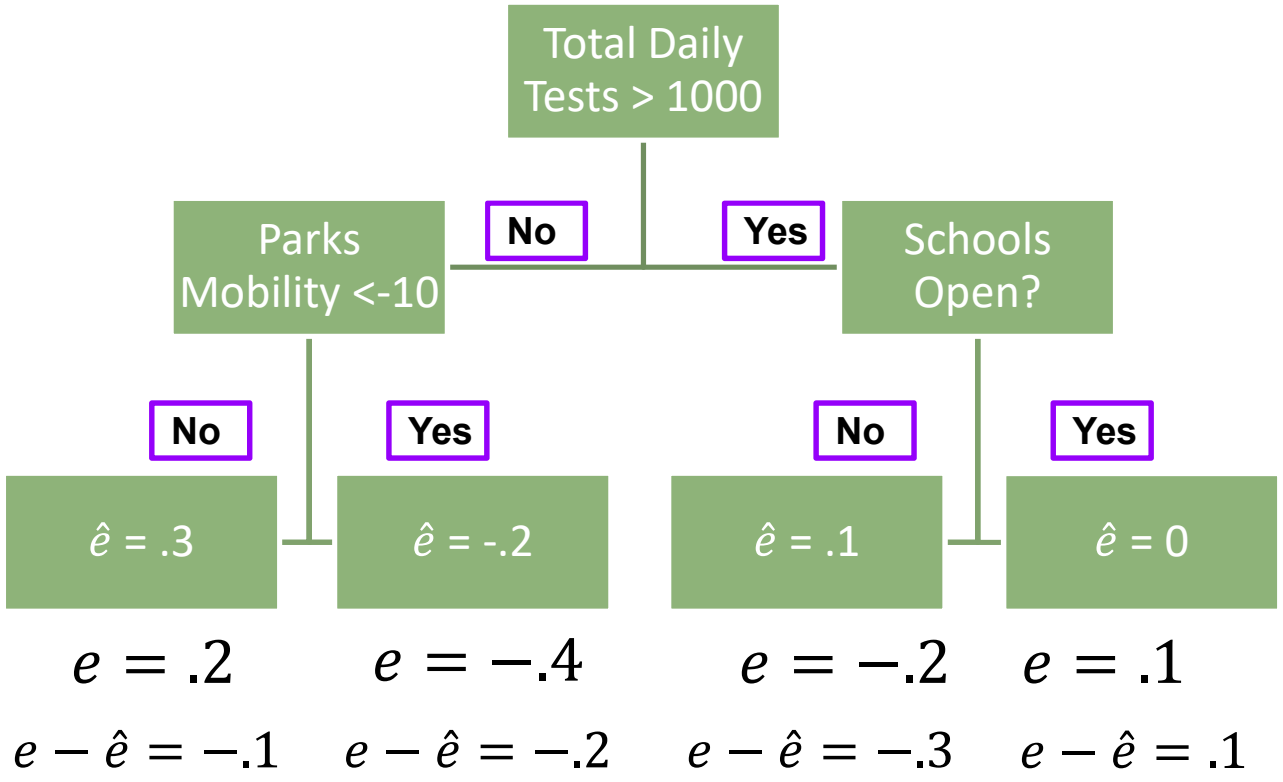




Example: Stacking (9 of 12)

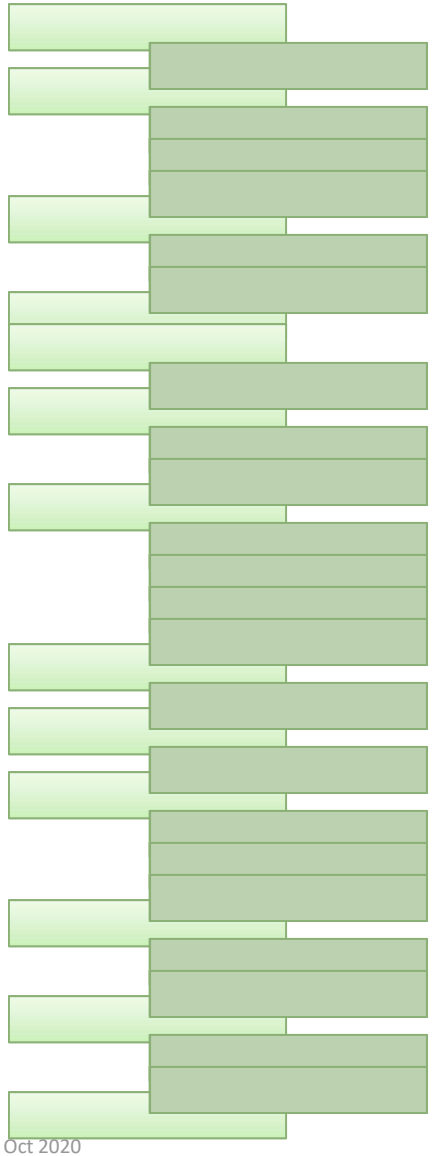
35 Factors

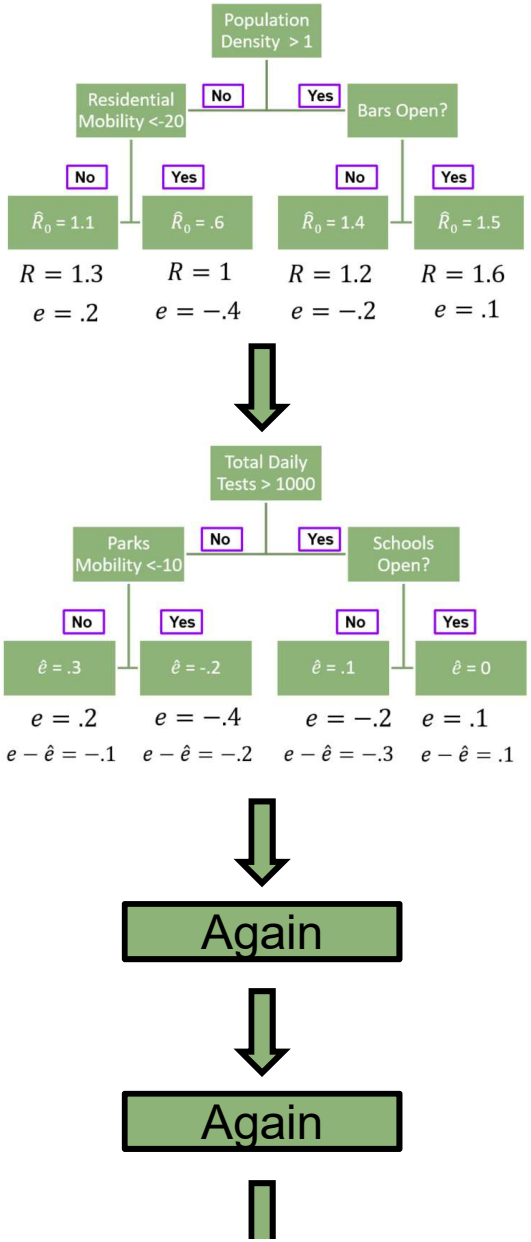




Example: Stacking (10 of 12)

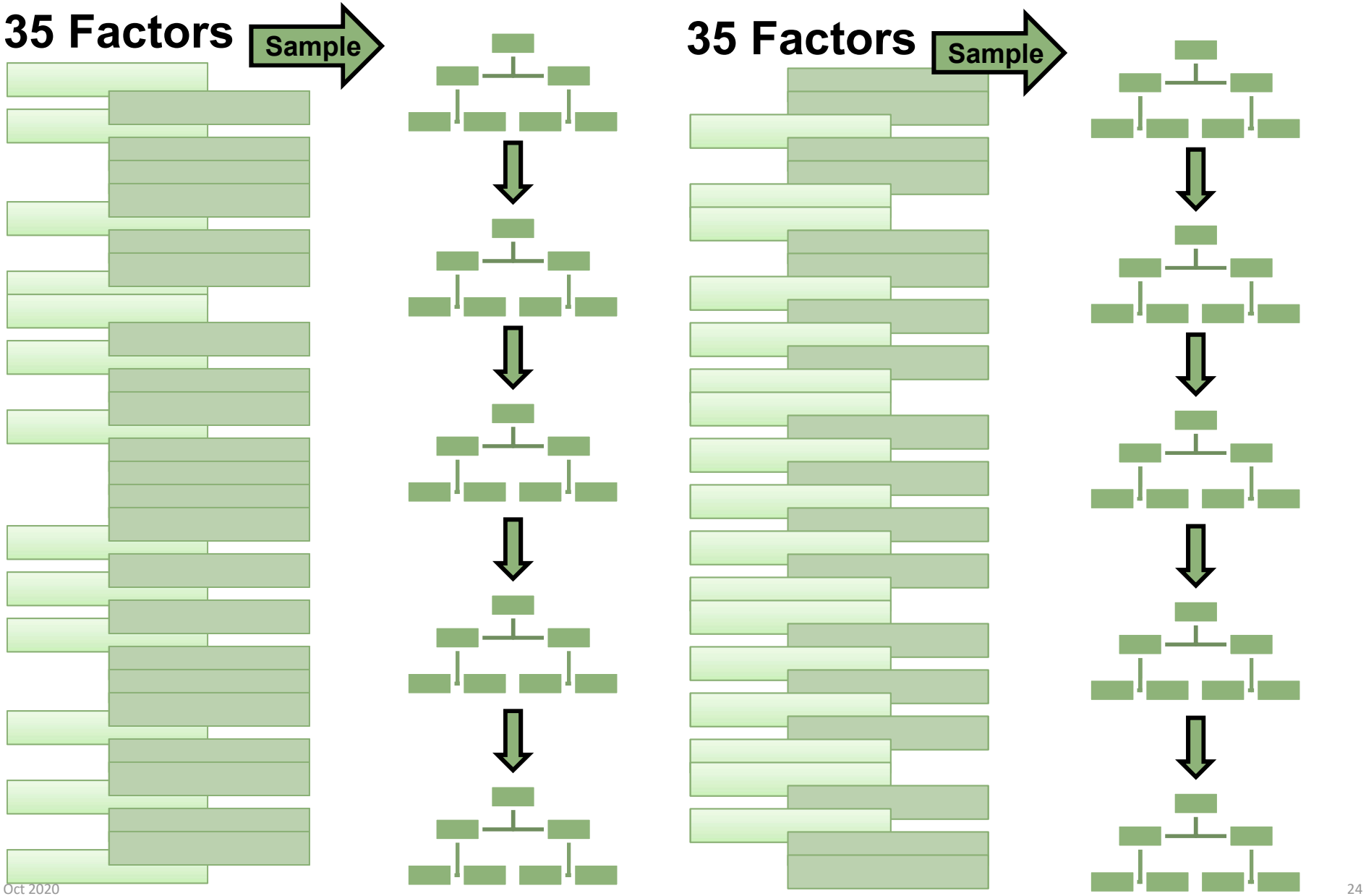
35 Factors



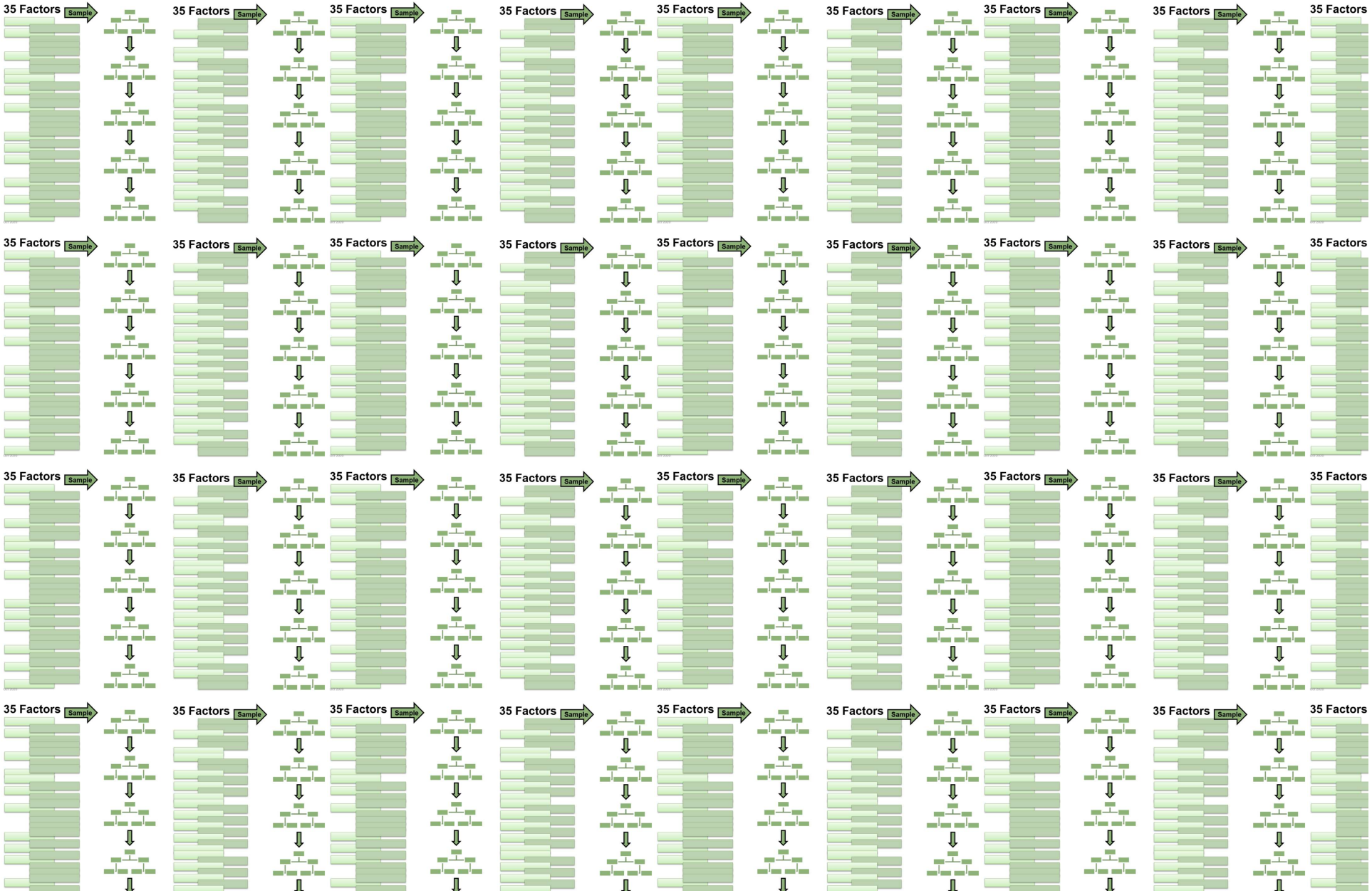


Stop stacking trees when $\hat{e}$ reaches a predetermined criteria

Example: Bootstrap Aggregation (Bagging) (11 of 12)



Example: Bootstrap Aggregation (Bagging) (12 of 12)

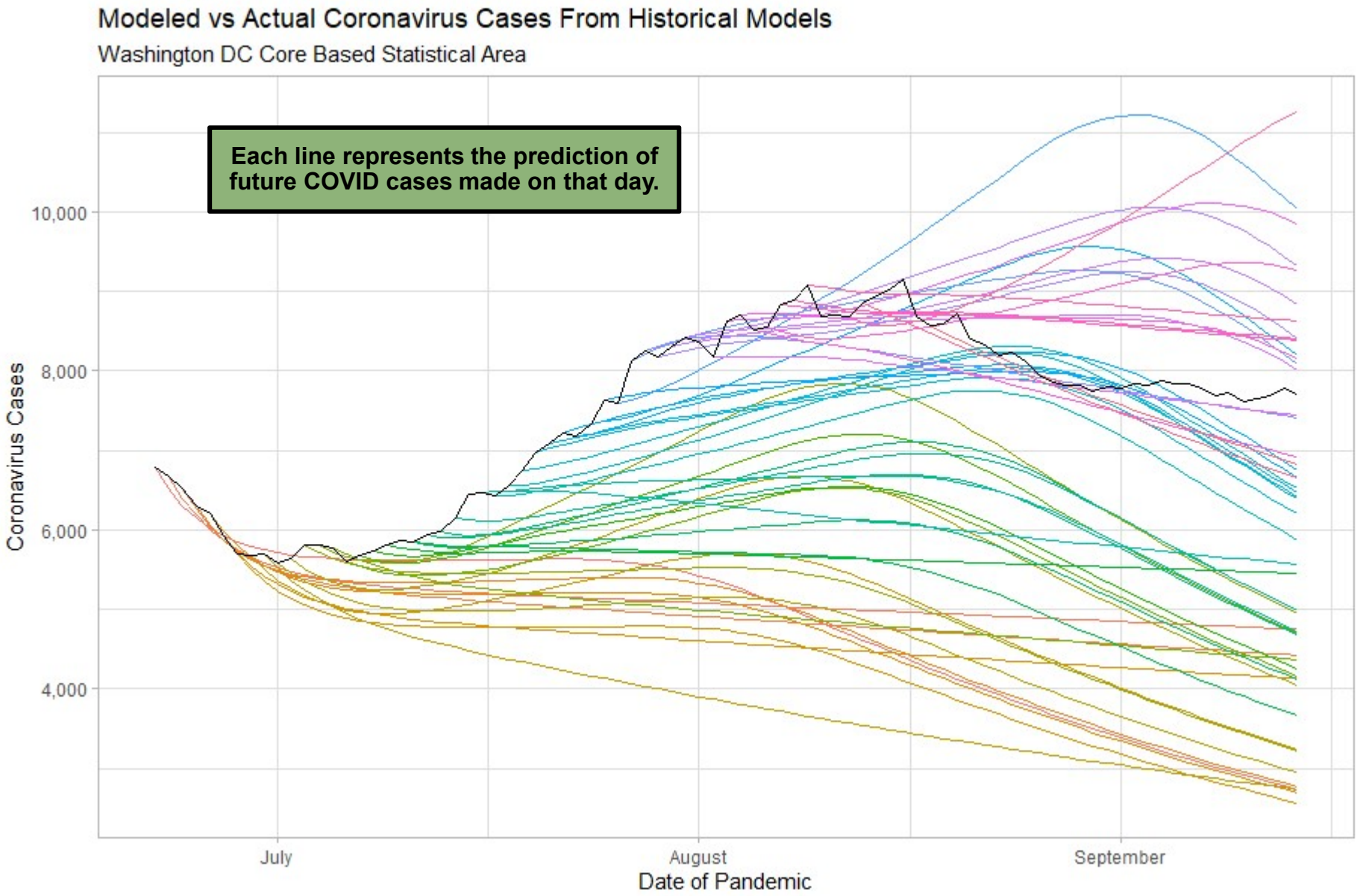


XGBoost Tuning Parameters

Tuning Parameters	Description
Step Size Shrinkage	Weight of successive trees to avoid over fitting
Minimum Loss Reduction	Amount of error improvement required to split a new branch
Max Depth	How 'deep' a tree can split
Min Child Weight	How many observances must be in a 'leaf'
Subsample	Percentage of data selected prior to building a tree
Column Sample Percentage	Number of features to randomly select for each tree
Lambda	L2 regularization term (Squared Magnitude for penalty)
Alpha	L1 regularization term (Magnitude for penalty)
Tree Method	Choice affects speed

https://xgboost.readthedocs.io/en/latest/parameter.html#general-parameters

Accuracy


Modeled vs Actual Coronavirus Cases From Historical Models
Washington DC Core Based Statistical Area
Each line represents the prediction of future COVID cases made on that day.
10,000
8,000
6,000
4,000
Coronavirus Cases
July
August
September
Date of Pandemic

Thanks!

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Contact me!