Counterfactual Estimates of the 2019-2020 Flu Season: A Bayesian Approach

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## Introduction

Influenza in humans can come in two types - A and B - which are further divided into subtypes such as H1N1/H3N2 or Victoria/Yamagata respectively (CDC 2025). These subtypes come in various strains, which over the course of time compete with each other and die out as new strains emerge. This is theorized to occur because of novel antigen-responses producing cross-immunity against currently circulating viruses (Palese and Wang 2011). This has been observed in recent years as, following the COVID-19 Pandemic, global influenza surveillance systems have not detected meaningful circulation of B-Yamagata, thus leading to increased prevalence of IAV. As a result, the WHO changed its recommendations from quadrivalent to trivalent flu vaccines in 2023 (Del Riccio et al. 2025).

Influenza as a whole is a costly, contagious virus which in the United States results in over 300,000 annual hospitalizations as well as tens of thousands of death each year; a 2018 study estimated the annual cost to the American healthcare system to be $11.2 billion annually (Putri et al. 2018).

Hospitalization generally arises from complications developed during the course of the illness. This is commonly due to preexisting respiratory conditions or others such immune, liver, or blood conditions; CDC reports that, in recent years, roughly nine out of ten hospitalized cases had at least one preexisting condition (CDC 2025). A meta analysis analyzing studies from both High Income and Low-Middle Income Countries found that children and young people were at significantly less risk than the elderly for hospitalization or severe outcomes such as ICU admittance or death (Coleman et al. 2018). Vaccines are effective at reducing the risk of complications across all age groups, although the efficacy varies based on the predominant viral subtypes as vaccines are formulated to only protect against the expected strands (Trombetta et al. 2022).

Currently, a global effort is being led by the WHO to combat influenza by increasing surveillance and laboratory capacity, as well as by conducting effective vaccination campaigns (CDC 2024a). This international collaboration relies on nations freely sharing laboratory tests of strands to identify the prevalence of influenza subtypes across the world, as this information is passed onto vaccine manufacturers to produce effective vaccines. This system is fragile, and it is easily disrupted - as seen earlier in 2025 when, admist an H5N1 outbreak in America, CDC ceased sharing data with the WHO (Maxmen 2025). All further efforts against influenza rely on the free flow of data to develop effective vaccines as well as develop appropriate policy.

Influenza forecasting can inform public health’s decision making capacity, even down to the local level by determining the warrant for school closures or optimizing placement of healthcare workers to deal with peaks of cases (“Why CDC Supports Flu Forecasting CDC” 2023). A variety of forecasting efforts have been used in the past to inform early-response efforts, to various degrees of success. In 2013, Google Flu Trends attempted to predict influenza cases by harnessing the big data of symptom searches on Google, and yet its predictions invariably skewed higher than CDC data over 100/108 weeks (Lazer et al. 2014). During the same time period, CDC began the FluSight program, inviting academic partners to analyze ILINet data and compete to produce the most accurate forecast. This project has proved much more successful, although it was at times impacted by reporting delays (Reich et al. 2019).

This paper looks to analyze the difference between IAV and IBV trends, as they have noted different temporalities in the united states, where A is noted to peak in December while B peaks around February. This can be seen especially in pediatric cases, where IBV resulted in ~ 40 % of deaths in the 2023-2024 flu season, all concentrated after January (CDC 2024b). This comes at the a time as well when IBV has been varying in its temporality: (Borchering et al. 2021). G

Goal: analyze SIRC model - crossimunity, theorize how can contribtue to futurue changes. (Li and Guo, n.d.) (Laurie et al. 2018) B dynamics

## Data visualization

## Parameters

# A tibble: 14 × 6  
 calibration parameter median mean lower\_bound upper\_bound  
 <dbl> <chr> <dbl> <dbl> <dbl> <dbl>  
 1 17 Lambda 5.5 e- 1 8.3 e- 1 2.1 e- 1 1.89e+ 0  
 2 17 beta1 5 e- 1 7.5 e- 1 0 2.25e+ 0  
 3 17 beta2 2.74e+ 0 2.74e+ 0 2.1 e+ 0 3.38e+ 0  
 4 17 mu 1 e- 2 1 e- 2 0 3 e- 2  
 5 17 gamma1 9.11e+307 8.94e+307 4.04e+306 1.74e+308  
 6 17 gamma2 2.1 e- 1 2 e- 1 1 e- 2 4.7 e- 1  
 7 17 delta1 1 e+ 0 1.04e+ 0 3.2 e- 1 1.96e+ 0  
 8 17 delta2 2.31e+ 0 2.26e+ 0 1.57e+ 0 2.87e+ 0  
 9 17 alpha1 3.5 e- 1 5 e- 1 1.5 e- 1 1.34e+ 0  
10 17 alpha2 7 e- 2 8 e- 2 0 2.7 e- 1  
11 17 sigma12 5.3 e- 1 4.5 e- 1 1 e- 2 8 e- 1  
12 17 sigma21 2.3 e- 1 2.6 e- 1 3 e- 2 5.4 e- 1  
13 17 phi1 0 0 0 0   
14 17 phi2 1.74e+ 0 1.85e+ 0 1.12e+ 0 3.06e+ 0

## Citations

Borchering, Rebecca K., Christian E. Gunning, Deven V. Gokhale, K. Bodie Weedop, Arash Saeidpour, Tobias S. Brett, and Pejman Rohani. 2021. “Anomalous Influenza Seasonality in the United States and the Emergence of Novel Influenza B Viruses.” *Proceedings of the National Academy of Sciences of the United States of America* 118 (5): e2012327118. <https://doi.org/10.1073/pnas.2012327118>.

CDC. 2024a. “About CDC’s Global Influenza Program.” *Global Influenza*. https://www.cdc.gov/flu-global/about/index.html.

———. 2024b. “Influenza Activity in the United States During the 2023–2024 Season and Composition of the 2024–2025 Influenza Vaccine.” *Influenza (Flu)*. https://www.cdc.gov/flu/whats-new/flu-summary-2023-2024.html.

———. 2025. “People at Increased Risk for Flu Complications.” *Influenza (Flu)*. https://www.cdc.gov/flu/highrisk/index.htm.

Coleman, Brenda L., Shaza A. Fadel, Tiffany Fitzpatrick, and Sera-Melisa Thomas. 2018. “Risk Factors for Serious Outcomes Associated with Influenza Illness in High- Versus Low- and Middle-Income Countries: Systematic Literature Review and Meta-Analysis.” *Influenza and Other Respiratory Viruses* 12 (1): 22–29. <https://doi.org/10.1111/irv.12504>.

Del Riccio, Marco, Jojanneke van Summeren, Saverio Caini, Koos van der Velden, and Aura Timen. 2025. “How Has the Disappearance of Influenza B/Yamagata Altered the Proportion of Influenza A and B Cases? Early Findings From Post-COVID Pandemic Global Surveillance Data.” *Influenza and Other Respiratory Viruses* 19 (7): e70138. <https://doi.org/10.1111/irv.70138>.

Laurie, Karen L, William Horman, Louise A Carolan, Kok Fei Chan, Daniel Layton, Andrew Bean, Dhanasekaran Vijaykrishna, Patrick C Reading, James M McCaw, and Ian G Barr. 2018. “Evidence for Viral Interference and Cross-reactive Protective Immunity Between Influenza B Virus Lineages.” *The Journal of Infectious Diseases* 217 (4): 548–59. <https://doi.org/10.1093/infdis/jix509>.

Lazer, David, Ryan Kennedy, Gary King, and Alessandro Vespignani. 2014. “The Parable of Google Flu: Traps in Big Data Analysis.” *Science* 343 (6176): 1203–5. <https://doi.org/10.1126/science.1248506>.

Li, Haijiao, and Shangjiang Guo. n.d. “DYNAMICS OF A SIRC EPIDEMIOLOGICAL MODEL.”

Maxmen, Amy. 2025. “Urgent CDC Data and Analyses on Influenza and Bird Flu Go Missing as Outbreaks Escalate.” *KFF Health News*.

Palese, Peter, and Taia T. Wang. 2011. “Why Do Influenza Virus Subtypes Die Out? A Hypothesis.” *mBio* 2 (5): e00150–11. <https://doi.org/10.1128/mBio.00150-11>.

Putri, Wayan C. W. S., David J. Muscatello, Melissa S. Stockwell, and Anthony T. Newall. 2018. “Economic Burden of Seasonal Influenza in the United States.” *Vaccine* 36 (27): 3960–66. <https://doi.org/10.1016/j.vaccine.2018.05.057>.

Reich, Nicholas G., Logan C. Brooks, Spencer J. Fox, Sasikiran Kandula, Craig J. McGowan, Evan Moore, Dave Osthus, et al. 2019. “A Collaborative Multiyear, Multimodel Assessment of Seasonal Influenza Forecasting in the United States.” *Proceedings of the National Academy of Sciences* 116 (8): 3146–54. <https://doi.org/10.1073/pnas.1812594116>.

Trombetta, Claudia Maria, Otfried Kistner, Emanuele Montomoli, Simonetta Viviani, and Serena Marchi. 2022. “Influenza Viruses and Vaccines: The Role of Vaccine Effectiveness Studies for Evaluation of the Benefits of Influenza Vaccines.” *Vaccines* 10 (5): 714. <https://doi.org/10.3390/vaccines10050714>.

“Why CDC Supports Flu Forecasting CDC.” 2023. https://archive.cdc.gov/www\_cdc\_gov/flu/weekly/flusight/why-flu-forecasting.htm.