Model O

December 28, 2021

Model of Delta

Weekly cases X_t, simple model

$$X_t = r_t I_{t-1} c_{t-2} s_{t-1} X_{t-1} + \epsilon_t \tag{1}$$

where r_t is the "basic reproduction number" (see later), c_t is the contact reduction (1 corresponds to pre-pandemics), $s_t = 1 + \gamma \cos(at + b)$ where $\gamma (= 0.18)$ is a constant and a, b, are such that the period is one year and the max is in the half of January, $\epsilon_t, \mathbb{E}\epsilon_t = 0$ is a residuum with standard deviation $\sim X_{t-1}$ and

$$I_t = (1 - \frac{u_t}{\alpha})V_t, \qquad V_t = (1 - v_t - w_t) \tag{2}$$

is the immunity coefficient where $\alpha (= 0.4)$ is the ascertainment,

$$u_t = (\rho \circ x)_t, \qquad w_t = (\psi \circ b)_t$$

where ρ is the waning of natural immunity (= 2% a month), ψ is the booster waning (probably same as second dose waning), $x_t = \frac{\sum_s^t X_s}{population}$, $b_t = \frac{B_t}{population}$, B_t is the number of boosters and $\circ$ is convolution. With full (1 or 2 shot) vaccination it is a bit more complex.

$$v_t = (\phi \circ f^t)_t$$

where ϕ is the immunity waning of final doses (=5% a month), $f_\tau^t = \frac{F_\tau^t}{population}$, F_τ^t is the number of people who got final doses at τ but did not get boosters by t.

Practically

- r_t can be estimated by regression (since July 21 should be constant $r_t = r^\delta$),
$$\frac{X_t}{X_{t-1}} = r^\delta \underbrace{I_{t-1} c_{t-2} s_{t-1}}_{\text{independet var}}$$
- X (hence x) can be got from public datasets
- F and B probably best from ockovani.csv (boosters can be got as difference total-first-second)

Omicron

Denote Y_t^v the numbers of omicron infections given that previous infection by infection delta did not take place and Y_t^δ the number of those who had delta before. Assume that $Y_\tau^v = i$ for some (import) i and starting time τ and $Y_\tau^\delta = 0, Y_t^v = 0, Y_t^\delta = 0, \tau < t$.

Let (1) keep holding with $r_t = r^\delta$ and

$$u_t = u_t^\delta, \qquad u_t^\delta = (\rho \circ y^v)_t + (\rho \circ (x - y^\delta))_t + (\rho \circ y^\delta)_t = (\rho \circ (x + y^v))_t$$

where$y_t^v = \frac{\sum_s^t Y_s^v}{population}$, $y_t^\delta = \frac{\sum_s^t Y_s^\delta}{population}$. Finally, put $Y_t = Y_t^\delta + Y_t^v$.

For $t > \tau$, the population fraction not having reported infection is $u^{ov} = x_t + y_t^v$ so the virgin population is $1 - \frac{u_t^{ov}}{\alpha}$, hence

$$Y_t^v = r^o J_{t-1}^v c_{t-2} s_{t-1} Y_{t-1} + \varepsilon_t$$

where

$$J_t^v = (1 - \frac{u_t^{ov}}{\alpha}) W_t, \qquad W_t = 1 - (\iota v_t + \upsilon w_t)$$

where $\iota, \upsilon \in [0, 1]$ is the omicron's immunity escape from finished vaccination, booster, respectively, immunity (one means no escape).

Further, out of those having had reported delta, only $e(\rho \circ x)_t$ is protected from omicron, where e is the immunity escape from post-infection immunity, so the fraction $u_t^{o\delta} = x_t - e(\rho \circ x)_t$ is susceptible; consequently,

$$Y_t^\delta = r^o J_{t-1}^\delta c_{t-2} s_{t-1} Y_{t-1} + \varepsilon_t, \qquad J_t^\delta = \frac{u_t^{o\delta}}{\alpha} W_t$$

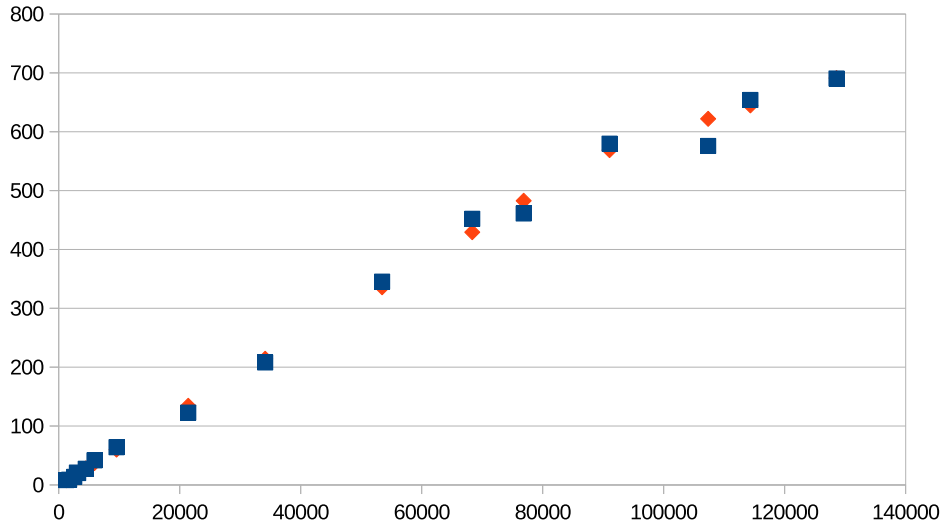
Estimation of α

From regression

$$\begin{aligned} \frac{X_t}{X_{t-1}} &= r^\delta (1 - \frac{u_t}{\alpha})(1 - v_t - w_t) c_{t-2} s_{t-1} \\ &= r^\delta \underbrace{(1 - v_t - w_t) c_{t-2} s_{t-1}}_{1st\text{independet var}} + \underbrace{\beta}_{=-\frac{r^\delta}{\alpha}} \underbrace{u_t (1 - v_t - w_t) c_{t-2} s_{t-1}}_{\text{2nd independent var}} \end{aligned}$$

Hospitalization

Data show that number H_t of newly admitted to hospital best correlate with X_t, These are data from autumn 2021 (boxes):



The graph shows a nearly perfect linear dependece up to approx 550 admissions, then there is a kink. We fit this as

$$H_t = f(\gamma^\delta X_t) \qquad f(x) = x - \delta(x-\eta)^+, \qquad \gamma^\delta = 0.00628, \delta = 0.4802, \eta = 565$$

(diamonds show the fit).

With o variant present, we will assume

$$H_t = f(\gamma^\delta X_t + \gamma^o Y_t)$$

for some γ^o.

Simulation of Omicron onset

As a base, we take waning parameters from [Andrews et al., Effectiveness of COVID-19 vaccines against the Omicron (B.1.1.529) variant of concern, https://www.medrxiv.org/content/10.1 $\iota = 0.5, \upsilon = 0.8$. We assume that the reduction e of post-infection immunity is similar to that of boosters. Further we, in line with Report 50 of Ferguson et al. (https://www.imperial.ac.uk/media/imperial-college/medicine/mrc-gida/2021-12-22-COVID19-Report-50.pdf?fbclid=IwAR2OB0rvk9l7N4dFR6YlN84Od-4_hAWzXKPC-UrWe1pPpzSp2E6eqcgICeA) assume that the hospitalization rate of omicron is approx two times less than that of delta. According to accumulating evidence, we estimate r^o to be around 2.5 times more than r^δ.[1]Further,

[1]The growth rate r^o can aůsp be computed from the reported doubling time d by formula

$$r^o = \exp\{7\ln(2)/d\}/J, \qquad J = (1-eu)(1-(\iota v+\upsilon w)) = (1-e\times 0.5)(1-(\iota\times 0.3+\upsilon\times 0.3)) \quad (3)$$

Here, J is the omicron's immunity factor in UK at time of omicron onset. (after imposing into the omicron's regression equation, it produces the weekly grow corresponding to the doubling time d).

by the latest estimate by UZIS, omicron now forms about one tenth of cases, which means that $i \doteq 5000$ by December 27.

We compute 3^5 scenarios by perturbing following parameters

- $\iota \in \{0.4, 0.5, 0.6\}$
- $\upsilon \in \{0.7, 0.8, 0.9\}$
- $e \in \{0.7, 0.8, 0.9\}$
- $r^o \in \{2r^\delta, 2.5r^\delta, 3r^\delta\}$
- $\gamma^o \in \{0.4\gamma^\delta, 0.5\gamma^\delta, 0.6\gamma^\delta\}$