Estimating the effective reproduction rate, R_t

We estimate R_t using a simplified version of standard SIRD epidemic model and traditional time-series econometric methods. Examples of the SIRD class of models originated from seminal work by Kermack, McKendrick (1927). See Hethcote (2000) for a useful overview, as well as Imperial College COVID-19 Response Team (2020) for examples of how these models are used to inform policy decisions. The model can be written as:

$$\begin{aligned} S_{t+1} &= S_t - \beta_t S_t I_t / N \\ I_{t+1} &= I_t + \beta_t S_t I_t / N - \gamma I_t \\ R_{t+1} &= R_t + \gamma I_t - \theta R_t \\ D_{t+1} &= D_t + \delta \theta R_t \\ C_{t+1} &= C_t + (1-\delta)\theta R_t \end{aligned}$$

where S_t is the susceptible, I_t is the infected, R_t is the resolving, D_t is the dead and C_t is the recovered individuals at time t. We calibrate $\gamma = 1/7$, $\delta = 0.01$, $\theta = 0.1$ in line with the existing literature.

We treat D_t and I_t as observable for our econometric model, by constructing a series for $I_t = I_{t-1} + \text{new cases}_t$ from the published cases data. Using the SIRD model above, we back-out the linear relationship between R_t and functions of our observables. We then implore standard state space methods and the Kalman filter to estimate R_t. For more information, see Arroyo-Marioli et al. (2020) and Fernandez-Villaverde, Jones (2020).

Figure 1 below shows the estimated R_t for each of the 50 states in the US. We can also use state output shares to calculate the GDP-weighted share of US states with R_t above 1, as shown in Figure 2 below.

The impact of localised lockdowns on aggregate US GDP

We utilise the sectoral output share approach, inspired by the OECD Economics Department (2020)'s assessment of the initial impact of the COVID-19 containment measures. For each state i, we calculate the output share of sector j as of Q4 2019, $s_{i,j}$, and the output share of each state as a percentage of US GDP, p_i. Similar to the OECD, we make assumptions (see Table 1 below) on the share of sector output lost under a full lockdown, q_j. Our assumptions are informed by the OECD's choices as well as our reading of the US-specific situation. We can calculate the percentage effect of state i's lockdown on US GDP, and then the total effect of US GDP with a nation-wide lockdown, ξ_N, as

$$\xi_N = \sum_{i=1}^{50} p_i \Big(\sum_{j=1}^{N} s_{i,j} * (-q_j) \Big)$$

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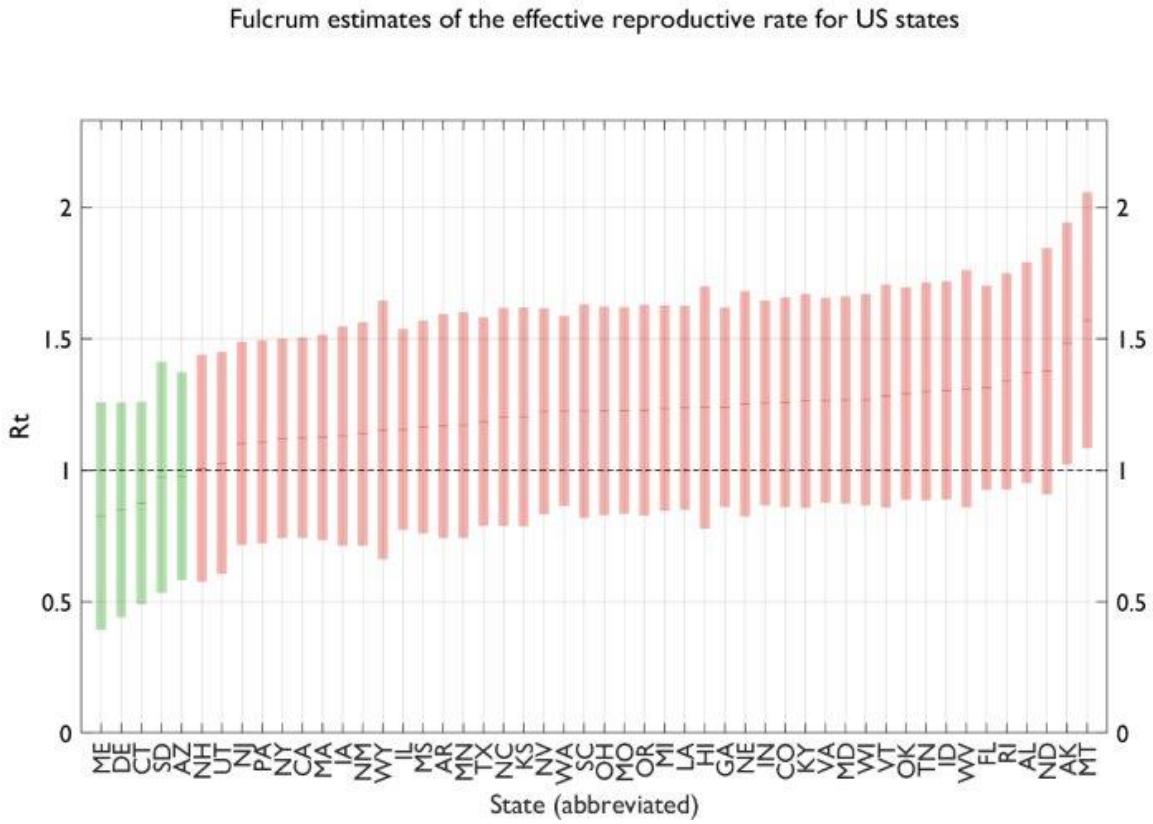

Figure 1: Source: Fulcrum estimates. Notes: Green shading indicates the state has a median estimated R_t below 1; red shading indicates a median R_t of above 1. The shaded areas indicate the 68% confidence interval.

To include localised lockdowns into the analysis, we assume that the severity of the lockdown measures depend on the effective reproductive rate R_t. We define a "lockdown factor" l_i for state i, such that $l_i = 1$ if $R_t > 1.5$, and $l_i = 0.75$ if $1.25 < R_t < 1.5$ and $l_i = 0$ otherwise. We can then calculate the total effect of localised lockdowns on US GDP, ξ_L, as:

$$\xi_L = \sum_{i=1}^{50} p_i \Big(\sum_{j=1}^{N} s_{i,j} * (-q_j) * l_i \Big)$$

Results: Under this methodology, we find that the impact of state-imposed lockdowns of varying degrees on US national GDP is -7.2%. Note that these calculations are conditional on Fulcrum's current estimate of the effective reproductive rate.

It is important to note that these calculations are from a purely accounting exercise and therefore only intended to be indicative "ball-park" figures. They do not consider the fact that sectors are interlinked through inputs and outputs of production, nor do they account for general equilibrium feedback effects. It also makes no assumption on the state governments' fiscal response. To do so would require a fully-fledged structural economic model. See

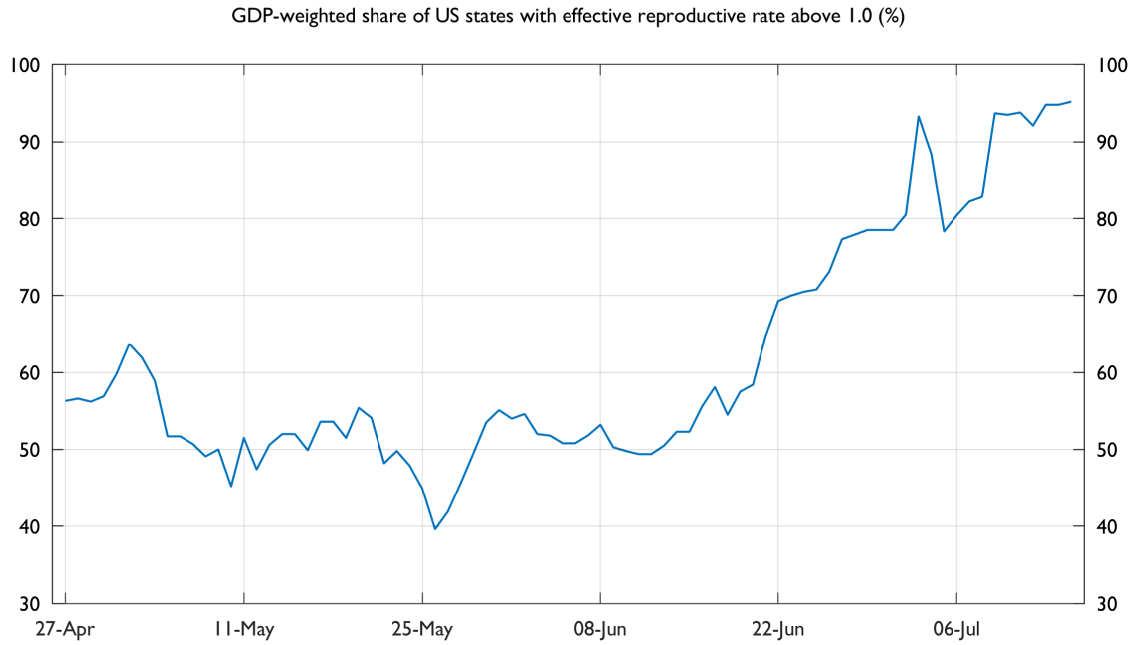

Figure 2: Source: Fulcrum estimates, Bureau of Economic Analysis

Guerrieri et al. (2020) for an example.

Assumptions on the effect of a full lockdown on sector output

Sector	% closed due to full lockdown
Agriculture, forestry, fishing and hunting	0
Mining, quarrying, and oil and gas extraction	0
Utilities	0
Construction	50
Manufacturing	17*
Wholesale trade	50**
Retail trade	75
Transportation and warehousing	50*
Information	0
Finance and insurance	0
Real estate and rental and leasing	32.5*
Professional, scientific, and technical services	50
Management of companies and enterprises	0
Administrative support and waste management	0
Educational services	75**
Health care and social assistance	20**
Arts, entertainment, and recreation	40*
Accommodation and food services	75
Other services	40*
Government and government enterprises	0

Table 1: Source: Bureau of Economic Analysis, OECD. Notes: $*$ – Adjustments made from OECD assumptions due to differences in sector classifications. For example, the OECD suggests a full shutdown for "other personal services". But personal services is only 40% of the "other services" classification by the BEA, so we assume that 40% of the "other services" sector is shutdown. $**$ – Additional adjustments made by Fulcrum Macroeconomic Research. OECD makes no explicit assumptions for these sectors.

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