Discussion (Session 1) Peter J Diggle (Lancaster University)

My comments relate to how and why one might want to make inferences about a spatially and temporally varying growth rate.

As to the "how," we suggest an intermediate approach between the two that Parag, Thompson and Donnelly compare in their insightful paper. Let Y_{ij} denote observed log-transformed incidence at each of n locations x_i and m times t_j. Assume that

$$Y(x_i, t_j) = d(x_i, t_j)'\beta + \int_0^t S(x_i, u)du + Z_{ij},$$

where the *predictive target* $S(x,t)$ is a Gaussian process, $d(x,t)$ is a set of covariates and mutually independent $Z_{ij} \sim \mathrm{N}(0, \tau^2)$ represent sampling variation. Diggle, Sousa and Asar (2015) describe a purely temporal version of this model in a different medical setting.

Likelihood-based parameter estimation is straightforward, and the joint predictive distribution for the values of $S(x,t)$ at any combination of locations and times follows by an application of Bayes' Theorem. This could be thought of as a principled approach to linear smoothing that naturally incorporates whatever combination of covariate effects a particular application merits, whilst avoiding mechanistic assumptions that might be hard to validate.

As to the "why," the arguments for a more mechanistic approach rest on the availability of well-founded scientific knowledge of the disease in question that can usefully add to the empirical information provided by the data. This suggests that mechanistic modelling is most convincing for epidemics evolving in a relatively homogeneous, natural environment that is perhaps typical of diseases in poor communities in ow-income settings where the opportunities for effective policy interventions and consequent behavioural changes may be more limited than in wealthy societies. Empirical statistical modelling of the kind suggested here is arguably a better choice when the epidemic is subject to a complex combination of formal (policy-directive) and informal (behaviourally responsive) changes over space and time, and when the objective is to build a general-purpose, spatially refined, real-time surveillance system, in which a disease-agnostic model can be fitted to a range of important health outcomes with disease-specific covariates and parameter estimates. A primary aim of such a system would be to provide early warnings of anomalous patterns over a range of public health outcomes. we believe that the absence of such a system did us no favours in the early months of 2020. I hope very much that public health agencies will be given the resources they need to remedy this before the next public health crisis hits us.

Diggle, P.J., Sousa, I. and Asar, O. (2015). Real-time monitoring of progression towards renal failure in primary care patients. *Biostatistics*, **16**, 522–536