Write-up on Bayesian Structural Time Series Analysis on Covid 19 Data

To understand the behavior of Covid-19 cases' time series data for different countries, Bayesian Structural Time Series models were applied to get some insight on forecasting behavior for different variants of the models.

The data on the number of confirmed cases, reported deaths and recovered cases are taken from the Johns Hopkins database.The data for country wise population size is taken from the World Bank database. The data is aggregated for different countries reported for the time period, from 22nd Jan 2020 to 30th March 2020, as of now.

The general structure of the Bayesian Structural Time Series model is defined by using two equations, namely,

$$y_t = Z_t^T \alpha_t + \epsilon_t$$

$$\alpha_{t+1} = T_t \alpha_t + R_t \eta_t$$

Where y_t denotes the time series data, α_t denotes the latent states of the model, ϵ_t and η_t are Gaussian noise independent of all other quantities. Z_t, T_t and R_t are structural parameters of the model.

For the time being, we are assuming that we do not have data on any covariates and we model the data using various latent state specifications. From existing literature we can see that there are several structures of the latent state variable, α_t like the Local Trend, Local Linear Trend, Semi-Local Linear Trend etc. For a brief overview of the different structures and an overview on Bayesian Structural Time Series modeling,, one may refer to : http://www.unofficialgoogledatascience.com/2017/07/fitting-bayesian-structural-time-series.html

In our case, the response data y_t denotes the number of deaths on day t per 100,000 size of the population. Since the response data is non-negative we use the log of number of deaths per 100,000 of the population size and fit a Bayesian Structural Time Series model using different state specifications for the trend. Since the data is spread across a few months only, Seasonality or cyclical patterns are not considered for this data. The time series fed into the model starts from the first instance of a confirmed case for a country till 30th March 2020.

Several state specifications were checked such as Local, Local Trend, Semi Local, AR and Sparse AR. The last 2 options are not performing well at all for any of the countries, using the criterion of MAPE (Mean Absolute Percentage Error) as compared to the other state specification models.

Once the best model is ascertained country wise using MAPE, we use the best-fitted model to predict the outcome (number of deaths per 100,000 size of the population) for the next 10 days. However, in selection of the best model even at a country wise level, there can be several other factors that are of interest such as nature of the predicted curve, over-fitting and interpretability.

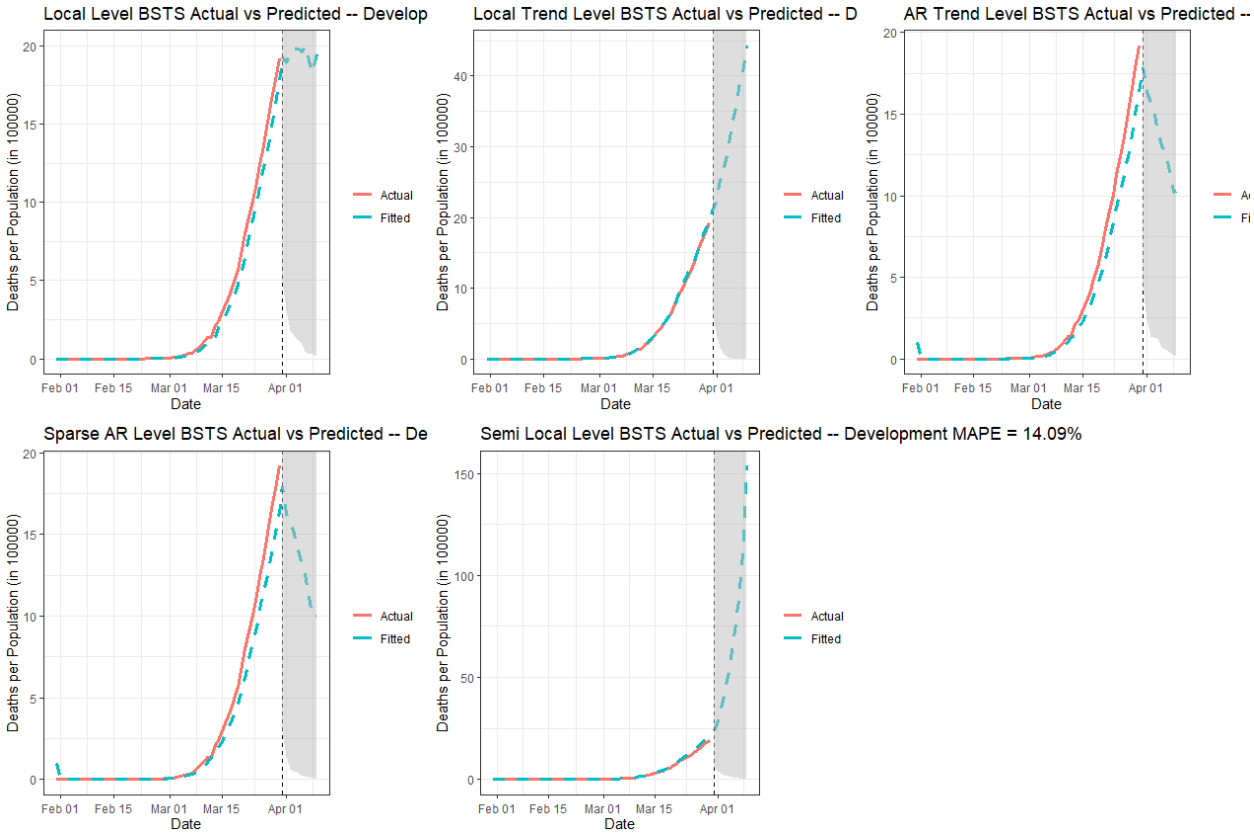
Analysis was performed for several countries checking the best latent state specification in terms of the lowest value of MAPE. Below are the results for some of the countries:

Country	**BSTS Variant**
Italy	Semi Local

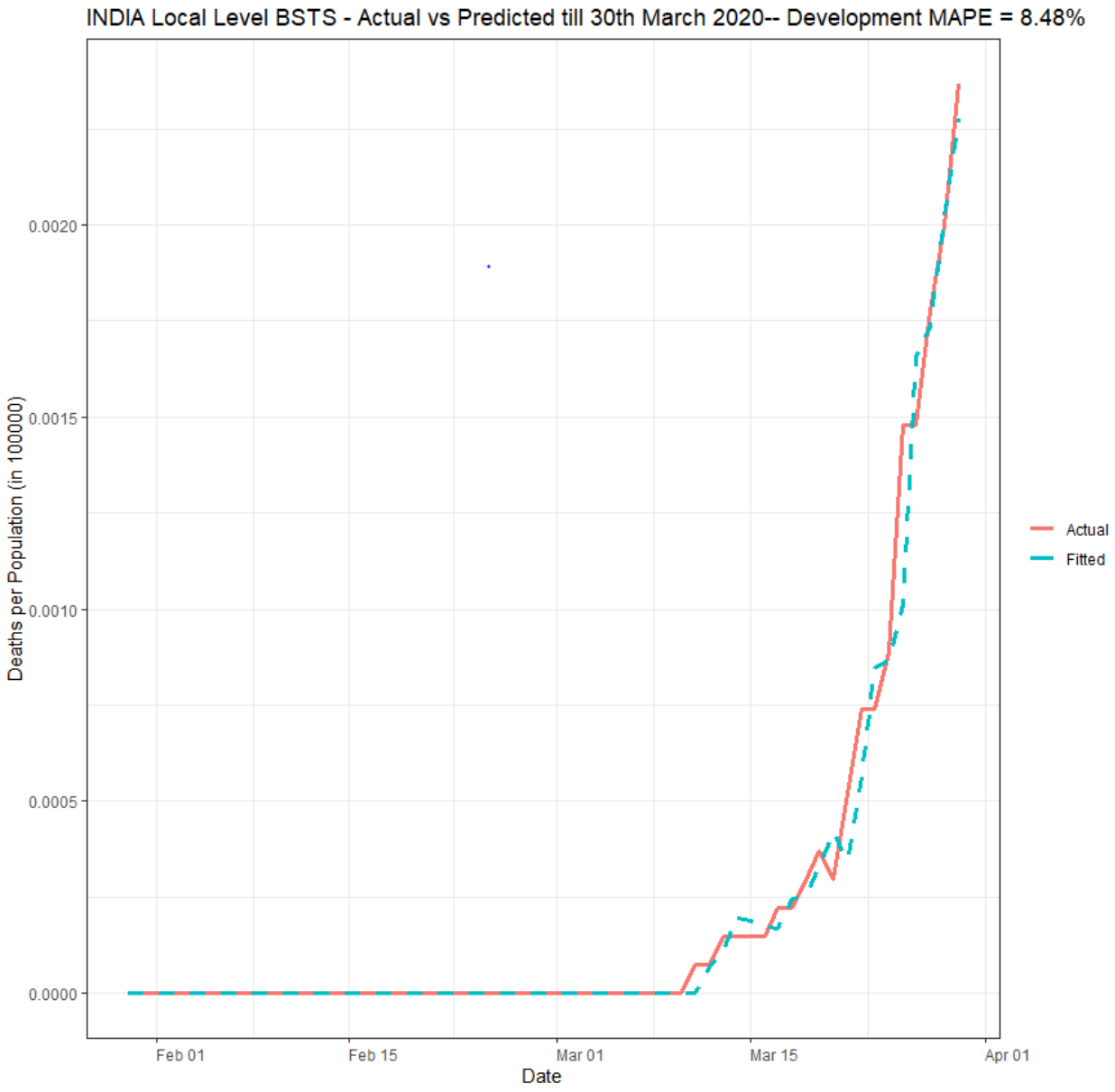
Spain	Local Trend
United Kingdom	Local
Switzerland	Semi Local
Portugal	Semi Local
Iran	Semi Local
France	Local
India	Local
Pakistan	Semi Local
Bangladesh	Semi Local
Sri Lanka	Local Trend
US	Local
China	Local Trend
Australia	Local
Thailand	Local
United Arab Emirates	Local

For some countries the best variant comes out to be the Local state specification, whereas for others the Semi Local seems to be working best. However, in the majority of the cases, there isn't a huge difference in terms of magnitude of MAPE for the top 2 variants. Thus, for final selection, the forecasted curve structure and any evidence of over-fitting might be crucial in identifying the best variant.

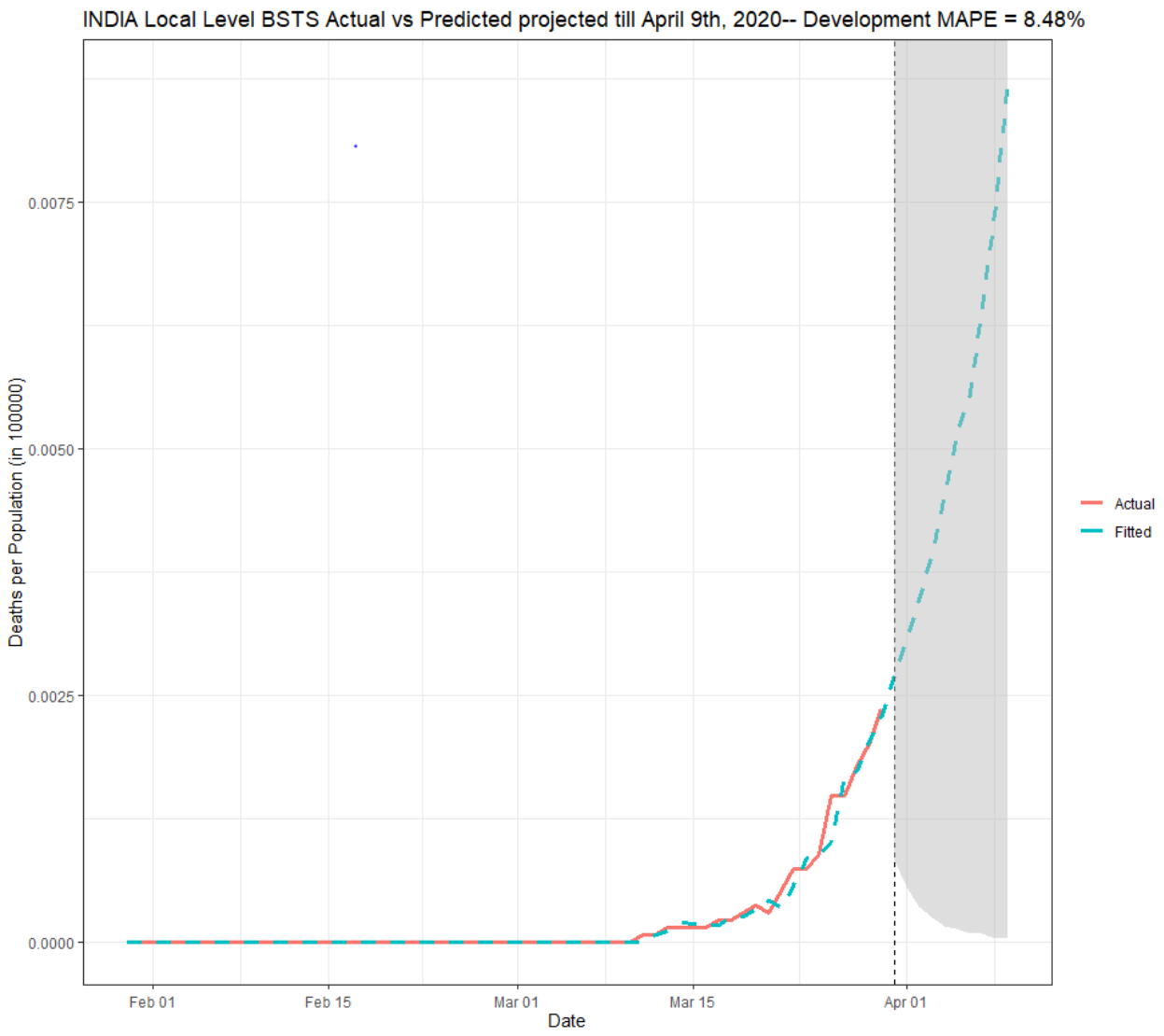
For each country, MAPE for the different state specification variants were observed along with forecasted graphs for the same. For example, the following graph is obtained for Italy :



To give an example of the fitted values obtained, considering the case of India, below is a plot of the actual vs fitted values (using Local Level BSTS model as it has the lowest MAPE for India among other variants) across the period for which data is available:



Next, forecasts for the next 10 days are obtained using the same model. The mean of the posterior distribution are plotted for the forecasted range, and the 95% credible intervals are shaded as grey. Based on preliminary analysis, it seems that modeling the data only on latent state specifications and not covariates are resulting in quite wide credible intervals. Below is a plot for the same:



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The next phase is to identify any one state specification variant which can be used for all the countries and add on to that by using regressors or covariates, which can make the forecasting more robust.