A Poisson autoregressive model to understand COVID-19 contagion dynamics

Arianna Agosto and Paolo Giudici
University of Pavia, Italy

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The model

Proposal

We propose an EXPLAINABLE predictive method, which:

- is based on the available data on Covid-19 daily NEW infected counts, for a country or for a region;
- estimates and updates daily the SHAPE and the possible future path of the contagion growth curve, using three parameters: ω, α, β;
- allows informed and reliable POLICY MAKING decisions.

The model

Definition

We assume that the statistical distribution of new cases at time (day) t, conditional on the information up to $t-1$, is Poisson, with a log-linear and AUTOREGRESSIVE intensity:

$$Y_t|\mathcal{F}_{t-1} \sim Poisson(\lambda_t)$$

$$\log(\lambda_t) = \omega + \alpha \log(1 + y_{t-1}) + \beta \log(\lambda_{t-1}),$$

where $y \in \mathbb{N}$ is observed, and $\omega \in \mathbb{R}$, $\alpha \in \mathbb{R}$, $\beta \in \mathbb{R}$ are to be estimated from the data up to t.

The model

Interpretation

- $\alpha + \beta$ expresses the "persistence" of contagion, similarly to the exponential growth parameter, from which R_0 can be daily updated.
- If $|\alpha + \beta| < 1$ the process converges to "saturation" (stationarity level).
- α represents short-term dependence and β long-term dependence. $\beta > \alpha$ suggest the process is still growing, and the higher the β the steeper the growth.
- ω is the intercept: the higher, the lower the dependence on time.

Results

China - I

Parameter	Estimate	Std error (p-value)
ω	0.410	0.319 (0.101)
α	0.814	0.072 (0.000)
β	0.131	0.062 (0.019)

Table: Model estimates for China, based on WHO data from January 20th onwards

- $\alpha + \beta$ still high: the process persists. But α prevails: China is in a downward trend.
- Further interpretation and model validation can be obtained with a (retrospective) dynamic plot of the parameters.

Results

China - II

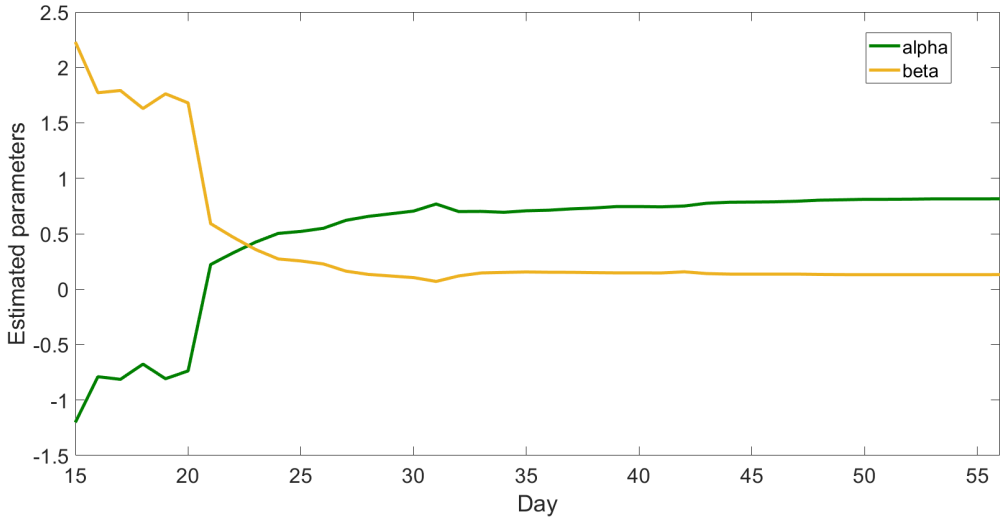

Figure: Evolution of the α and β parameters for China, from day 15 onwards

- Day 16 (February 4th): rapid decrease in persistence (this was actually the peak)
- Day 23 (February 11th): α becomes greater than β, downtrending confirmed (this was actually the case).

Results

Iran, South Korea and Italy

	Iran		South Korea		Italy	
Parameter	Estimate	Std error (p-value)	Estimate	Std error (p-value)	Estimate	Std error (p-value)
ω	1.037	0.101 (0.000)	0.778	0.538 (0.081)	1.295	0.004 (0.000)
α	-0.004	0.056 (0.473)	0.878	0.134 (0.000)	-0.571	0.024 (0.000)
β	0.860	0.039 (0.000)	-0.01	0.152 (0.476)	1.418	0.029 (0.000)

Table: Model estimates for Iran, South Korea and Italy, based on WHO data from February 20th

- Iran: strong ω: low time dependence
- South Korea: only α significant: downward trend
- Italy: both α and β significant: upward trend (persistence is now decreasing)

Work in progress (with Alexandra Campmas and Andrea Renda, CEPS)

European countries

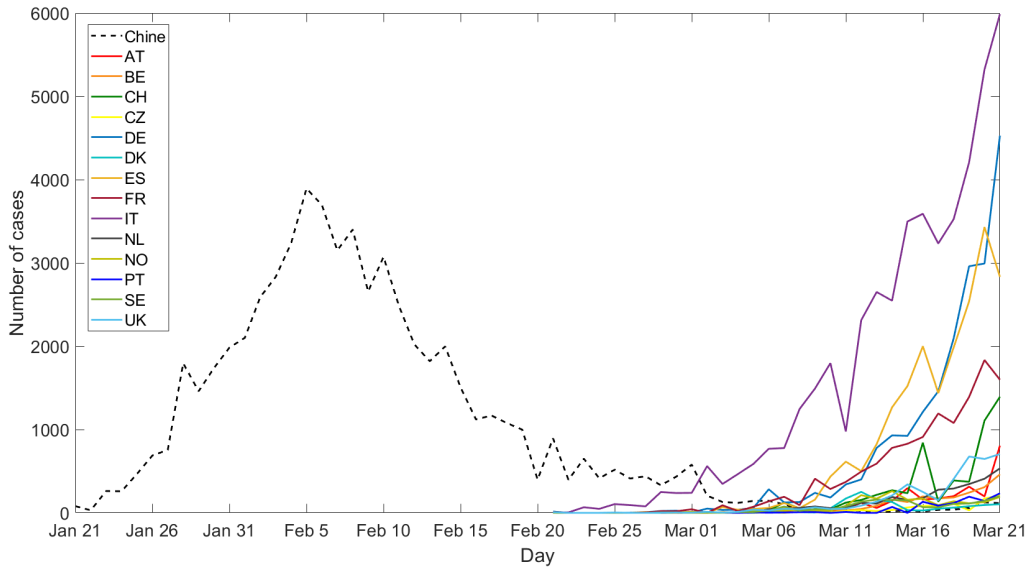

Figure: Evolution of the new cases for European countries, from February 20th