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How Much Will the Coronavirus Pandemic Expand?

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Abstract

The Covid-19 pandemic is going to provoke a huge global crisis in all fields (humanitarian, social, economic). To evaluate its impact is difficult until the pandemic crisis will be stopped or at least its peak will be reached. In order to contribute to such work, we propose in this study a new estimation-simulation model, as an alternative to those models coming from probabilistic, genetic algorithms or other approach. Inspired by classical mechanic dynamics of systems, our model tries to formalize the dynamics of affected population by Covid-19 pandemic. By using a logistic model, in order to find the main characteristics of the system's dynamics we resort to the first two differentiate function by time for four basic indicators (variables). Essentially for obtaining a solution to estimate the system's dynamics, we used a balance equation for the variable of active cases, as the difference between the total number of infected and the sum between the number of healed (recovered) and the number of deaths, on the one hand, and the hypothesis that at the end of pandemic this variable must be zero, on the other hand. Because for this key-variable doesn't exist an analytical solution we used a numerical method to obtain some key-values for it. Finally, based on such methodology we classified the Covid-19 pandemic evolution in four phases.

Keywords: Epidemic, Coronavirus, Infected population structure, Logistic function, Simultaneous equations, Concavity

JEL Codes: C61, I10, I18, J10

1. Introduction

In the current period, marked by the pandemic, in parallel with the unprecedented actions required for the health system, it is necessary to prepare the economy for a crisis, also unprecedented. The development of a set of measures in this regard is seriously affected by the fact that at present it is not known how much the epidemic will extend among the population nor the period during which it can be stopped. First of all, the extraordinary dynamics of abrupt day-to-day data regarding the extension of the infection of citizens, doubled by the actions of the authorities aimed at isolating the population at home and implicitly the severe restriction of the economic activities, makes the set of measures that could be proposed to undergo major changes frequently.

Despite a short time since pandemic expanded, already there is an explosion of the number of publications on this topic. Many authors are concentrated on medical side of virus contamination, finding now a not very well preparation in this matter of the health systems. In the same time, a number of authors are preoccupied to evaluate the impact of pandemic on various economic sectors, as it is reflected by publications since only the beginning of this year (Ataguba, Ivanov, Karnon, Sirkeci and Yucesahin, Zhang et al., etc.). Moreover, it can be highlighted a remarkable study recently published on macroeconomics of epidemics, where the authors expose a complex macroeconomic model simulating certain scenarios of the impact of pandemic (Eichenbaum et al, 2020). Other authors are trying to model directly the expansion mechanism of this strange virus among population, as are those presenting simulation models to evaluate instantaneous the dynamics of pandemic, on some specialised web sites or in dedicated articles (as is a recent study published by Harpedanne (2020).

Prominent in this period, preceding the large-scale global crisis that will surely follow, is the estimation of the extent to which the population will be affected and the period of epidemic expansion, both at the level of the world economy, but also at the level of the European Union and at the national level. This is because, unlike other crises, the present one, affecting all the economies of the main partners of a state, will have a huge impact on the national economy in multiple aspects.

Therefore, based on the statistical data available at the moment (April 9), in the study, as a starting point for assessing the economic impact of the pandemic, we present our estimates regarding the size of the global epidemic and the period at which it will reach the maximum level. In the absence of such assessments, it will be practically impossible to estimate the impact on the macroeconomic framework and to establish correct economic policy measures.

2. Estimates regarding the spread of the pandemic worldwide

Our approach for estimating the spread of the pandemic among the population is based on the international data officially published under the aegis of "COVID-19 Coronavirus Pandemic" (<https://www.worldometers.info/coronavirus/#countries>), which are updated daily.

This database covers all the states of the world that have been affected by the pandemic, as well as the global total, being updated in almost real time the values for 11 indicators: the total number of cases (infected), new cases, total deaths, new deaths (daily), total recoveries (cures), active cases, serious cases (serious and critical), total number of cases per million inhabitants, number of deaths per million inhabitants, total number of tests and tests per million inhabitants. Also, for each state a special page can be accessed, which contains the daily dynamics of several key indicators for the period elapsed since the registration of the first case of infection.

According to the specialized studies, in order to build a model for estimating the extent of the epidemic spread among the population, we considered the following integral scheme of population structure:

Total population, of which:

- Untested
- Tested, din care:
 - Uninfected
 - Infected (total cases), of which:
 - Active cases
 - Closed cases, of which:
 - Deaths
 - Recovered (healed)

Also, to study the dynamics of the spread of the epidemic among the population, we used, as in most of the profile studies, a special model of exponential type, namely the model of the logistic function or simply the logistic model. For the present study, for reasons related to the efficiency of parameter estimation algorithms, we selected the following form of logistics:

$$f(t) = a / (1 + b * e^{-c * t})$$

where f is the function of the dependent variable (indicator) of the time variable (expressed by the number of days elapsed since the beginning of the infections, t , and e is the basis of the natural logarithms ($e = 2.718281828 \dots$)). At the same time, in studying the dynamics of the indicators (variables) we will be useful to use the differentials, in relation to the time, first order, $D1$ (function of the first derivative), and respectively of the second order, $D2$ (function of the second derivative), according to the following formulas:

$$D1(f) := \frac{a}{(1 + b \cdot \exp(-c \cdot t))^2} \cdot b \cdot c \cdot \exp(-c \cdot t)$$

$$D2(f) := 2 \cdot \frac{a}{(1 + b \cdot \exp(-c \cdot t))^3} \cdot b^2 \cdot c^2 \cdot \exp(-c \cdot t)^2 - \frac{a}{(1 + b \cdot \exp(-c \cdot t))^2} \cdot b \cdot c^2 \cdot \exp(-c \cdot t)$$

We mention that being conditioned by the existence of dynamic series of variables, our study, as well as many other profile researches, starts from the analysis of the dynamics of the number of people registered as infected (total cases), a variable that we note by k . In this case, according to the above structural scheme, the other time-dependent variables are the number of deaths, d , the number of those recovered (healed), r , and respectively the number of cases still active (persons still infected), ka .

Initially, we start from estimating the parameters of the cumulative function of the logistic type presented above for the variables the total number of cases, k , and respectively the total number of deaths, d . So, for estimates, $f(t)$ will become $k(t)$ and respectively $d(t)$. Correspondingly, the parameters a , b and c , will be noted by ak , bk and ck , in the first case, and by ad , bd and cd , in the second case.

It is known that the total number of confirmed cases (variable k) and total number of deaths (variable d) increase monotonically to two finite values (asymptotes parallel to the horizontal axis), which, according to the logistic model selected by us, are ka and da respectively. In the case of these two variables, as time increases, the approximation of the real values by the two asymptotes signifies the closeness to the end time of the epidemic, and the difference between the two values will finally give the total number of people cured. Also, at the time of the outbreak of the epidemic there will be no more infected, so the variable ka will have zero value. With these correlations we can write the following time dynamics equations of the variables, where the attachment of the letter T signifies the theoretical quantities:

$$kT(t) := \frac{ak}{(1 + bk \cdot e^{-ck \cdot t})} \quad dT(t) := \frac{ad}{(1 + bd \cdot e^{-cd \cdot t})} \quad rT(t) := \frac{arTe}{(1 + br \cdot e^{-cr \cdot t})}$$

$$kaT(t) := \frac{ak}{(1 + bk \cdot e^{-ck \cdot t})} - \frac{ad}{(1 + bd \cdot e^{-cd \cdot t})} - \frac{ak - ad}{(1 + br \cdot e^{-cr \cdot t})}$$

It is observed that the function that gives at any time the number of those still infected (the number of active cases) we deduced it as a balance equation, being the difference between the total number of infected and the sum between the number of healed (recovered) and the number of deaths. It is also found that the maximum theoretical value (at the end of the epidemic) of the total number of those recovered, $arTe$, is equal to $ak - ad$, that is precisely the difference between the total number of infections and the total number of deaths.

In the following, we summarize the results of our estimates, obtained using the daily published data globally for the period January 22 - April 9, 2020 (79 days after the outbreak of the pandemic). The following graphs, presenting comparatively the dynamics of the real data (the thickened trajectories) with the ones based on the simulations (the trajectories represented by the continuous lines), are grouped on the four basic variables, as follows:

- for the number of infected (total confirmed cases) - variable k , in Figure 1;
- for the number of deaths - variable d , in Figure 2;
- for the number of healed (recoveries) - variable r , in Figure 3;
- for the number of active cases - the variable ka , in Figure 4.

The graphs show the asymptotes (by dotted horizontal lines) and the inflection points by $tINF$, on the abscissa, and the corresponding value of the ordinate function. For the trajectories on the graphs we used the black colour for the variables k and ka respectively, red for the variable d and blue for the variable r .

According to our estimates, for the variable k (the total cumulative number of people confirmed with the virus) it can be seen from the graphs in Figure 1 that the maximum (ak) at the end of the epidemic will be over 4.7 million people, compared to only 1.6 million on April 9 ($t = 79$). The maximum daily increase of new infected persons will be reached after April 15 ($tINFk = 85.3$), which can be seen on the second graph of the $D1kT$ function, which corresponds to the intersection, on the third graph, of the $D2kT$ function, with the axis of the abscissae.

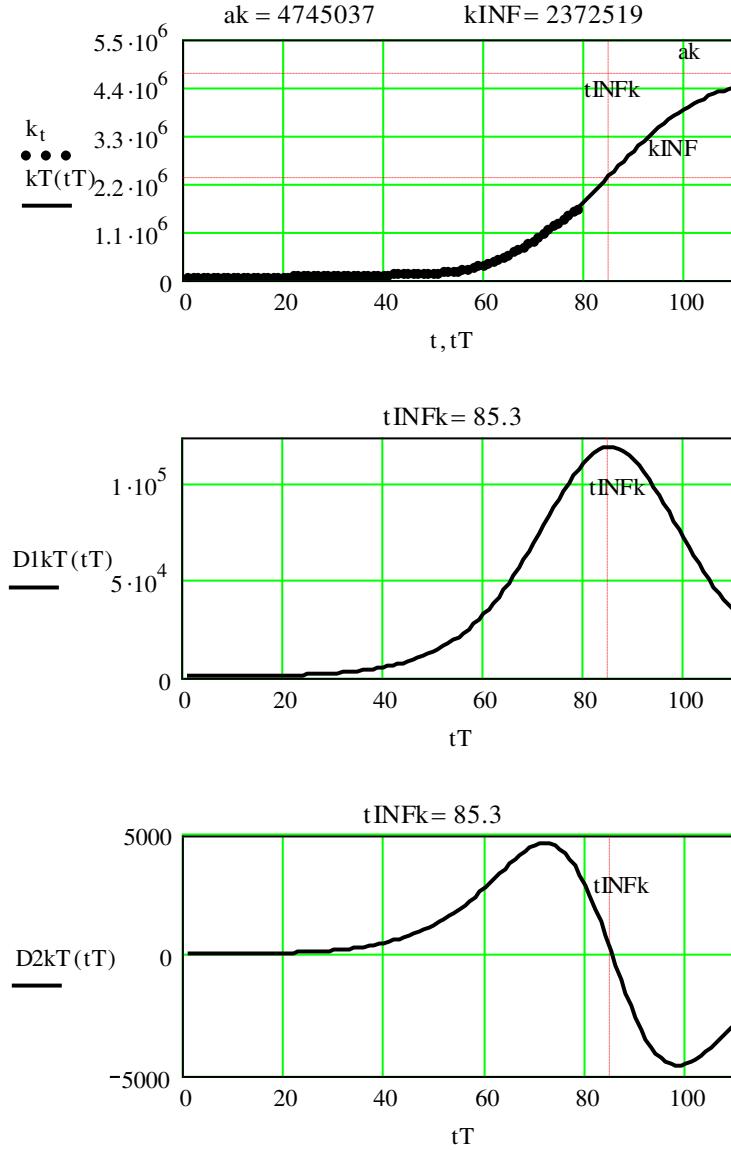


Figure 1.

According to estimates, for variable d (the cumulative total number of deaths) it is observed from the graphs in Figure 2 that the maximum (ad), at the end of the epidemic will be over 255 thousand people, compared to just over 95 thousand on April 9 ($t = 79$). The maximum daily increase in deaths will be reached after April 13 ($t_{\text{INF}d} = 83.1$), which can be seen on the second graph of the $D1dT$ function, corresponding to its intersection, on the third graph of the $D2dT$ function, with the axis of the abscissae.

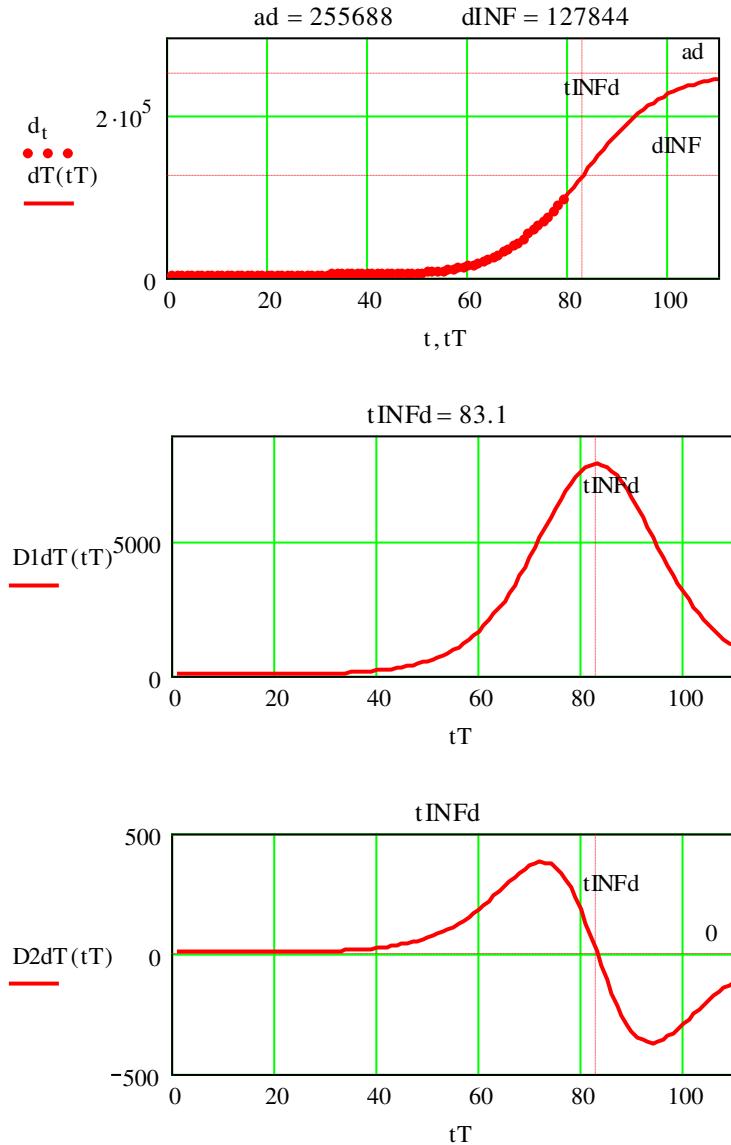


Figure 2.

For the variable r (the total cumulative number of those cured or recovered), according to the estimates, it can be seen from the graphs in Figure 3 that the maximum ($ak - ad$) at the end of the epidemic will be over 4.4 million people, compared to just something over 356 thousand on April 9 ($t = 79$). The maximum daily increase in recovery (recovery) will be reached after May 19 ($tINFr = 119.8$), which can be seen on the second graph of the $D1rT$ function, which corresponds to the intersection, on the third graph, of the $D2rT$ function with the abscissa axis.

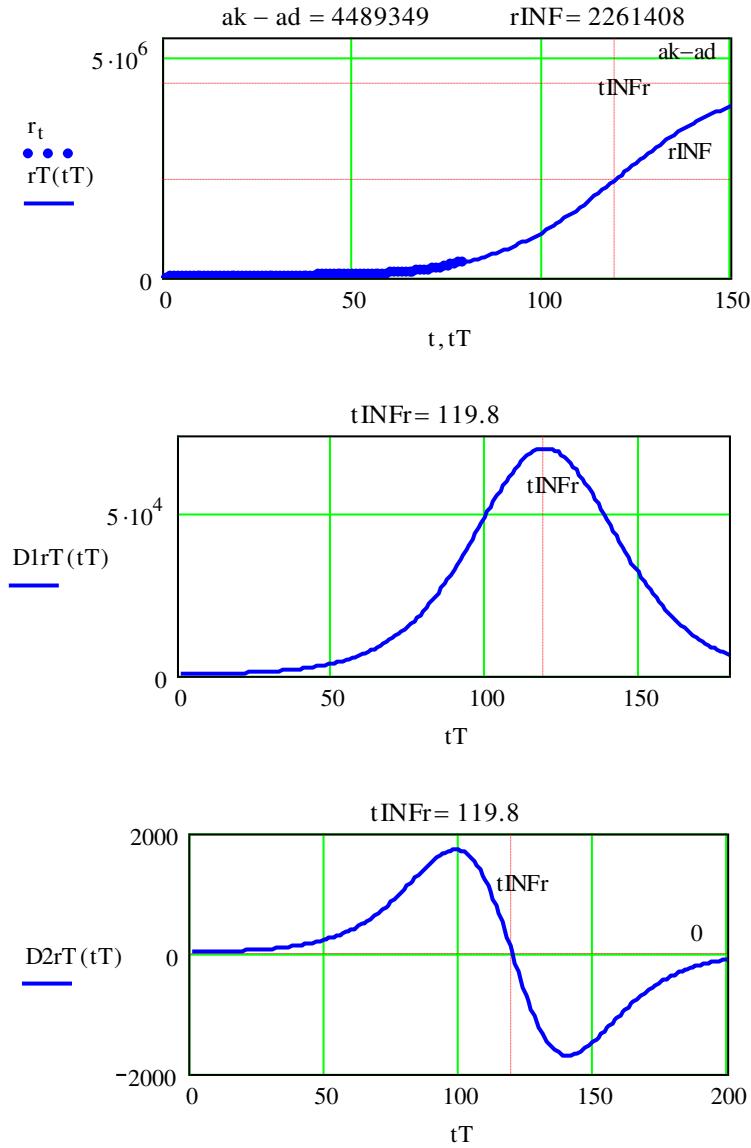


Figure 3.

The most important in terms of pandemic extinction is the dynamics of the ka variable (daily number of cases still active). According to estimates, it can be seen from the graphs in Figure 4 that the maximum (kaMAX) at the peak of the pandemic will be over 2.6 million people, compared to only 1.6 million on April 9 ($t = 79$). It will be reached on May 3 ($t = 103$), after April 13 ($t = 83$) the maximum daily increase in the number of active cases, represented as the maximum of the $D1kaT$ function, will be reached on the third the second graph.

The moment marked by $t = 83$ corresponds to the third graph, of the function $D2kaT$, its first intersection with the axis of the abscissae, that is to a first inflection point (in the pandemic extension stage), $tINF1ka$, from the graph of the kaT function. On the graph of the function of

the variable kaT , however, there is a second turning point, placed this time in the regression phase of the pandemic, namely on May 26 ($t = 126$). The second turning point on the graph of the kaT function corresponds to the third graph, of the $D2kaT$ function, to its second intersection with the axis of the abscissae.

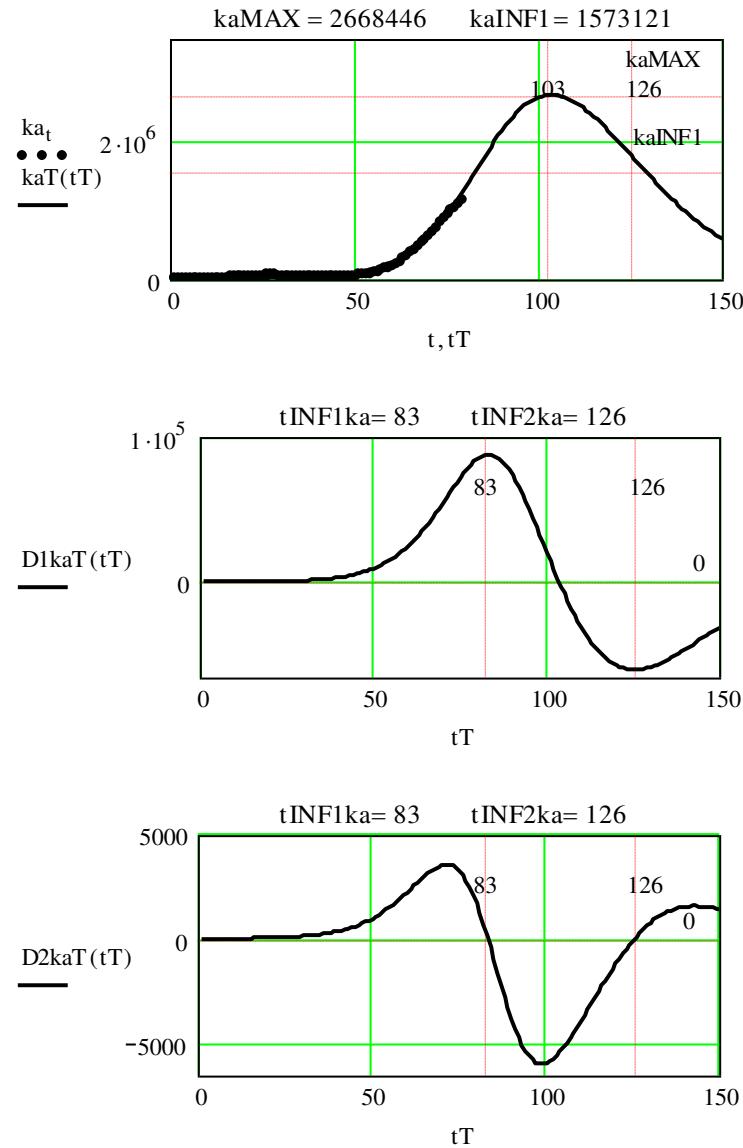


Figure 4.

Of course, permanently the estimates will have to be redone as new data is published. In addition, this first application, being at the level of aggregated data for the whole world, will need individual estimates by states or by groups of states, such as the EU, for example. Given that the functions of cumulative variables k , d and r are monotonically increasing, suggestive

for capturing the moment when the epidemic crisis recedes is the trajectory of the variable ka , which is not monotonically increasing, but has several phases:

- 1) the accelerated growth phase to the first inflection point, meaning to the peak of the daily increase (corresponding to the moment $t = 83$), in which the function is convex (the second positive derivative);
- 2) the slow growth phase to the maximum point of the pandemic ($t = 103$), which corresponds to a zero daily gain, in which the function is concave (the second positive derivative);
- 3) the phase of relatively slow decline, regression of the pandemic, to the second inflection point (corresponding to the moment $t = 126$), in which the daily variation is negative and in which the function is also concave (the derivative of positive second);
- 4) the phase of accelerated decrease until the complete disappearance of the pandemic (when the value of ka becomes zero), in which the daily variation continues to be negative and in which the function becomes convex again (the second positive derivative).

As examples, in Appendix is shown the real daily dynamics (until April 9) of active cases in several countries. It is quite clear that in countries such as the United Kingdom, France and Romania, the epidemic crisis is still in the first phase, of accelerated expansion of the epidemic, while in other states, such as Italy and Spain, it seems that the phase has passed before the peak of the crisis. At the end of the pandemic crisis, the dynamics will show for all states the same as in the case of China, also presented in Appendix, as the last graph - the country being in the phase of extinction of the epidemic, according to published data.

3. Conclusion

Based on the stimulating of our model for a large number of future days, the main output is that the evolution everywhere in the world should shows the same pattern like in countries that passed the peak of number of active cases (similar to China's past evolution), indeed only if the reported data reflect correctly the real dynamics.

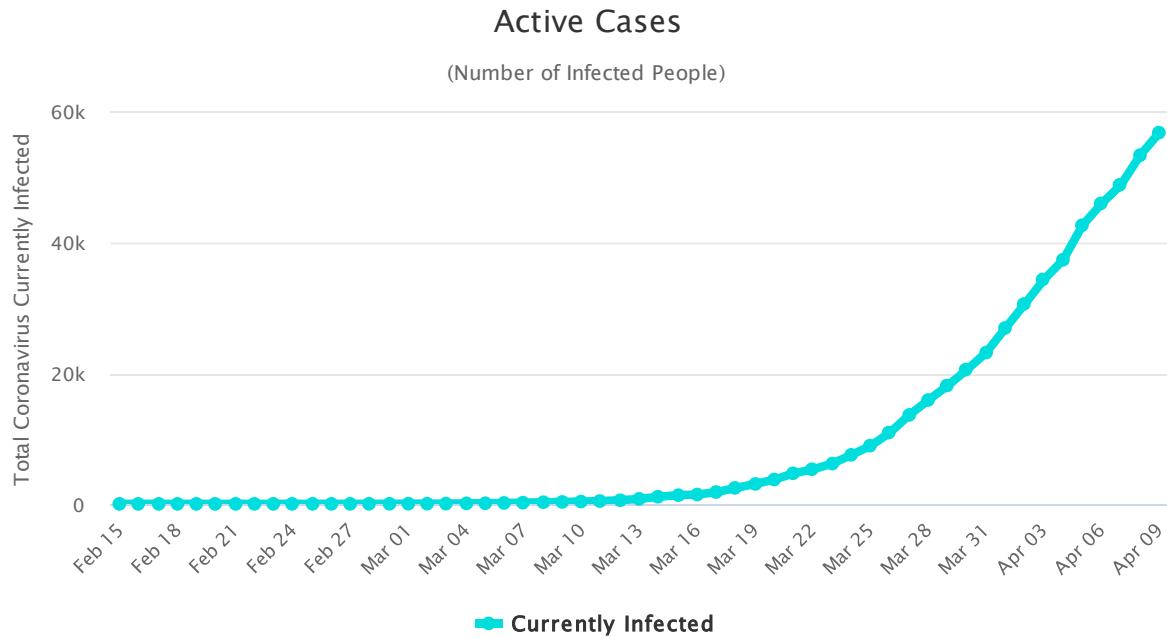
Suggestive in order to capture the moment when the epidemic crisis recedes is the trajectory of the variable "persons still infected" (ka), which, as resulted from our model, is not monotonically increasing, but has four phases: accelerated growth, slow growth, slow decline, and accelerated decrease, as the final phase.

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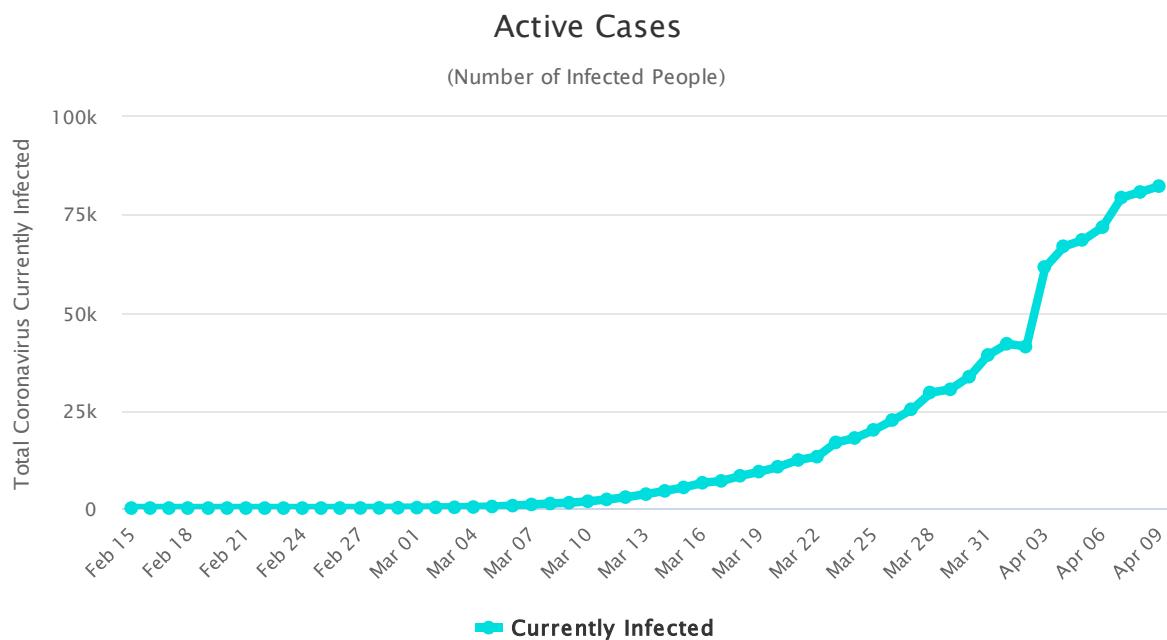
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Appendix

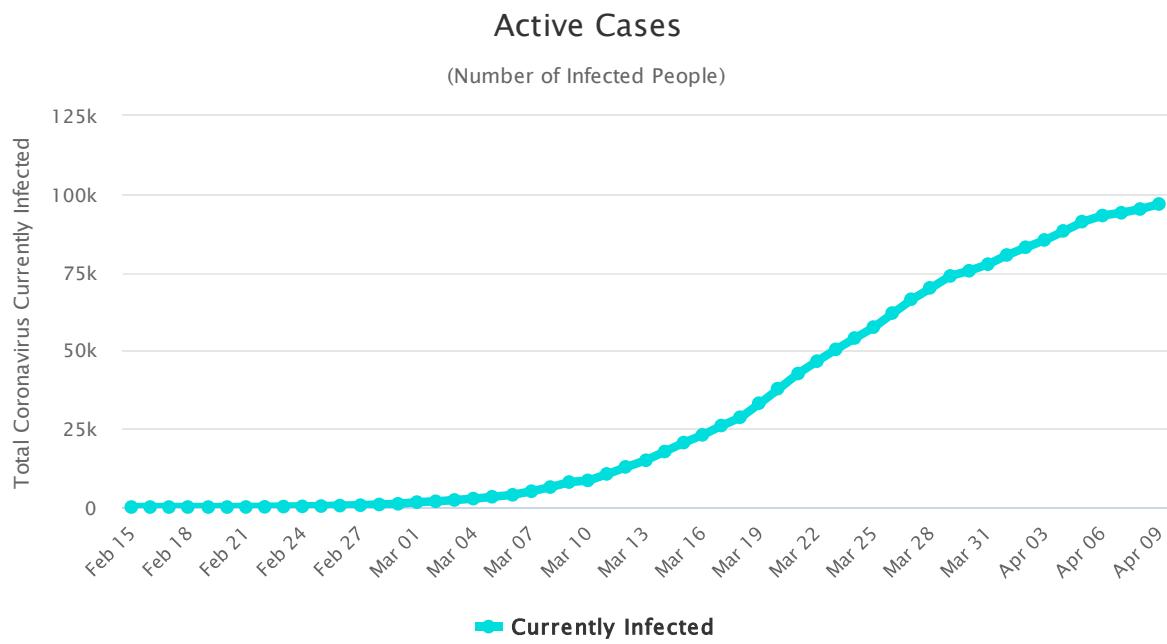
United Kingdom



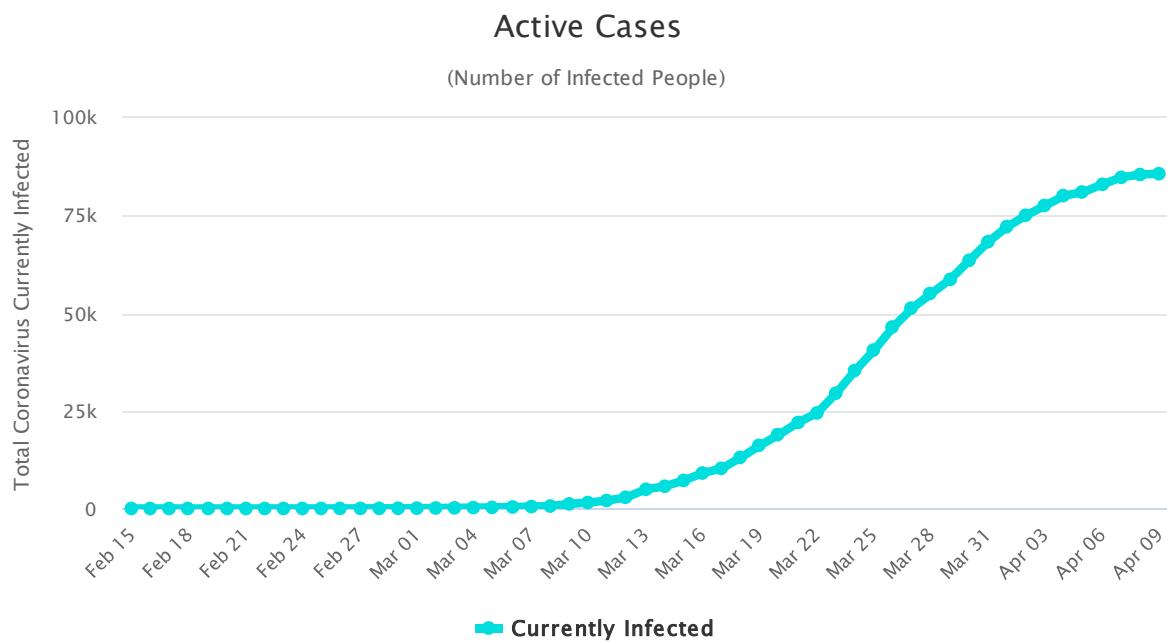
France



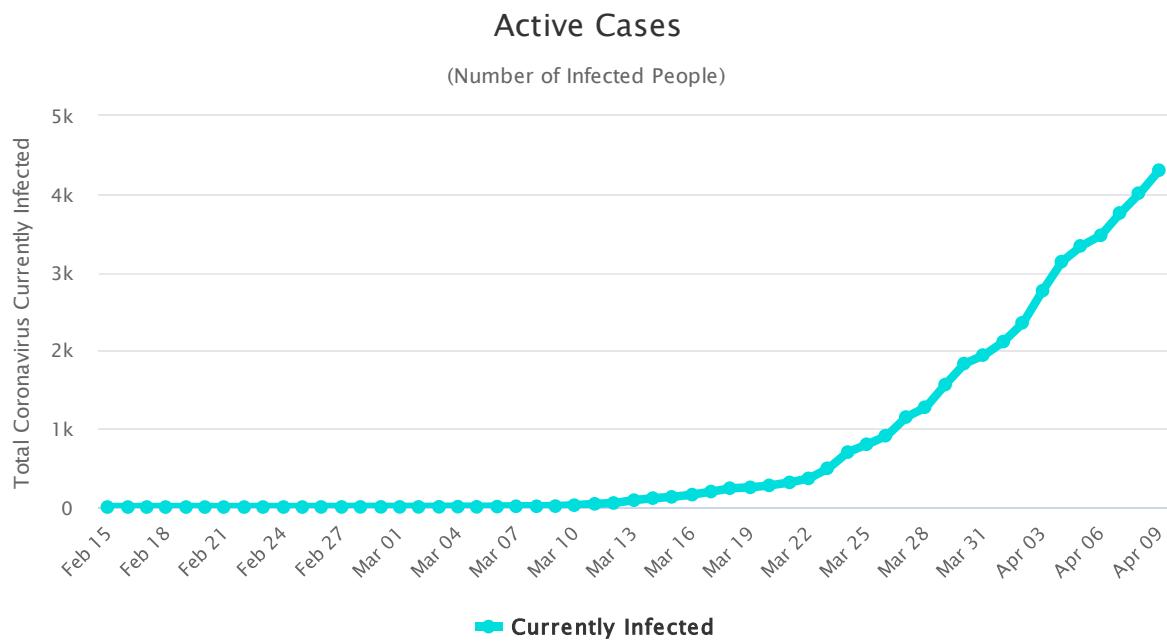
Italy



Spain



Romania



China

