Estimates on the dynamics of the COVID-19 pandemic and its impact on the economy

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Abstract

Economic growth forecasts have been revised downwards in most countries, but the incertitude regarding the duration or the evolution of the crisis persist. Under the pressure of the Covid-19 pandemic expansion, today it is supposed that a huge global crisis to follow in all fields (humanitarian, social, economic). The pandemic impact is difficult to be evaluated until it will be stopped or at least its peak will be reached. As a contribution to such work, we propose an estimation-simulation model, as an alternative to other models coming from probabilistic, genetic algorithms or other approach. In order to analyse the dynamics of the spread of epidemic among the population, we built a model with differential equations for a special time-function of logistic type, from which resulted certain key-values and four phases in its evolution. Moreover, by simulating the daily dynamics of pandemic at three levels (world, EU, and Romania) we estimated the impact of pandemic on the economic growth to the end of this year.

Keywords: *Covid-19*, Logistic model, Pandemic Phases, Inflection, Concave Trajectory.
JEL classification: C61, I10, I18, J10.

1. Introduction

During present period marked by the pandemic, together with unprecedented actions required to improve the health system, it is necessary a firm preparation of the economy for a new crisis, also expected as an unprecedented one. First of all, the estimations, taking into consideration the evaluation from the health and economic perspectives, are seriously affected by the answer to the question of how much the epidemic will extend among citizens and how long will last the period until when this pandemic could be stopped.

After the official announcement of the World Health Organization (WHO) about the Covid-19 pandemic there have been many studies published on this topic. Many authors concentrate their analyses on medical side, trying to estimate how much will be exposed the medical system at the maximum level of this virus expansion. Other authors are trying to directly model the expansion mechanism among population, as are those presenting simulation models to evaluate instantaneous the dynamics of pandemic, on some specialised web sites or in dedicated articles (Harpedanne, 2020). Although it is recognised that the uncertainty regarding the evolution and duration of coronavirus crisis makes it exceedingly difficult to forecast losses in GDP growth or to propose solutions for economic recovery, a number of authors are preoccupied to evaluate the impact on certain economic sectors, (Ataguba, Ivanov, Karnon, Sirkeci and Yucesahin, Zhang et al., etc.). A remarkable study treats the subject of macroeconomics of epidemics, in which the authors expose a complex macroeconomic model and simulate certain scenarios of the impact of pandemic (Eichenbaum et al, 2020). A number of papers study the impact of coronavirus pandemic on the whole economy (Barro et al., 2020; Correia et al., 2020; IMF, 2020; Jordà et al., 2020; Kohlscheen et al., 2020; McKibbin and Fernando, 2020; OECD, 2020; Saez and Zucman, 2020; UNCTAD, 2020).

A significant idea derived from published studies is that in the absence of some estimates of the extent to which the population will be affected and the period of epidemic expansion (at global, regional and national levels), it will be difficult to evaluate the impact on the macroeconomic framework and to establish correct economic policy measures. Therefore, based on the statistical data available at the present moment (May 15), in this study we try firstly to estimate the size and phases of the epidemic and secondly to evaluate its aggregate impact on the economy for this year, at three levels (global, EU, and national). Our approach for assessing the spread of Covid-19 pandemic in the population is based on statistical data published officially as "COVID-19 Coronavirus Pandemic", on World Bank database or other sources. This paper contributes to the analysis of pandemic dynamic and its economic impact by proposing a new simulating model elaborated within the Institute for Economic Forecasting (IEF).

2. Mechanism of pandemic dynamics and IEF model

At present there are many data sources about the Coronavirus Pandemic extension. The most popular is hosted by Worldometer, where near in real time are published the official data for eleven indicators regarding the pandemic extension, both at the global level and for each individual country (https://www.worldometers.info/coronavirus/).

Based on such data , in line with specialised studies, in order to build a model for estimating the extent of the epidemic among the population we are considering the following comprehensive scheme of population structuring: Total Population, of which: Untested and Tested, of which: Uninfected and Infected (Total Cases), of which: Active Cases and Closed Cases, of which: Total Deaths and Total Recovered.

It is known that the number of tests is not relevant for determining the number of people tested (each person initially tested being at least once re-tested, to finally reconfirm his/her status as recovered (cured) or still infected (active case). Therefore, assuming that testing is done preferentially among people susceptible to disease (testing the entire population being virtually impossible), increasing the number of tests will lead to a permanent increase in the total number of cases and the need to re-estimate the parameters in the forecast models. In such context, the starting variable in our models is the total number of confirmed cases.

To study the dynamics of the spread of epidemic among the population, we built a model with differential equations for a special time-function of logistic type. The variables of the model are: the total number of infected persons (total confirmed cases), k, the total number of deaths, d, and the total number of recovered persons (cured), r, and as well as the number of cases still active (persons still infected), ka. For each variable, the estimated (theoretical) values are denoted by kT, dT, rT, and respectively kaT.

Considering the initial conditions, related to real data in the moment selected as origin of timeseries (indeed the first registered recovered case appears later than the first person registered as dead), the individual logistic functions for the first three variables are as follows:

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

where ak, bk, ck, ad, bd, cd, ASr, br and cr are parameters, and the asymptote for the kaT function is ASr = ak – ad.

It is known from empirical analysis that the total number of confirmed cases (k), and the total number of deaths (d), being cumulative ones, increase monotonously towards finite values (asymptotes parallel to the horizontal axis). As time increases, the proximity of real values to the two asymptotes means a decrease in the strength of the epidemic, and the difference between these two values will ultimately give the total number of people recovered. At the end time of epidemic, there will be no more infected people (active cases, in epidemiological terminology), so the variable ka will eventually have the value zero. Considering the basic balance relationship according to which in every moment the ka variable is the residual of the difference k – d – r, a significant result of our model is an analytical solution obtained for the estimating time-function of kaT, as follows:

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

In the following section, we graphically present the results of application of the logistics model at three levels (global, EU and Romania), both on the side of pandemic dynamics and on its impact on the economy. In the case of pandemic dynamics, for each reference level the trajectories for the four basic variables are presented together, actual data as thickened points and those estimated as solid lines, excepting variable ka as dashed line. As colours, we used black for k and ka, red for d and blue for r, time, in days elapsed since the onset of the pandemic, being marked on the horizontal axis by t (real time) and tT (future time).

Among the variables, essential for characterizing the dynamics of the pandemic is the number of active cases at any given time (ka), which subsequently disappear either by increasing the total number of deaths or those cured (recovered). Four standard phases in pandemic dynamics (where D1 and D2 are the first two time derivatives) can be identified based on the analysis of trajectory of this variable, presenting two inflection points (unlike the trajectories of the other three variables that have only an inflection point):

P1) *accelerated growth* (D1↑) to the first inflection point of the graph of the kaT function, i.e. to the peak of the daily increase of active cases, the trajectory of the function being convex (D2> 0).

P2) *slow growth* (D1↓) to the point of pandemic maximum, when the daily increase of active cases becomes zero, the trajectory of the function being concave (D2 <0).

P3) *slow decrease* (D1↓), so pandemic regression, up to the second inflection point of the graph of the kaT function, in which the daily variation becomes negative, the trajectory of the function remaining concave (D2 <0).

P4) *accelerated decrease* (D1↑) until the pandemic disappearance, where the daily variation continues to be negative and the trajectory becomes convex again (D2> 0).

For the application regarding the pandemic impact on the economic activity, at the three levels (global, EU, and Romania), we estimated, based on our simulation model, the daily loss (as %) for two scenarios:

S1) The first scenario, denoted by y%S1, assumes that at the peak of the pandemic, corresponding to the maximum point of the kaT trajectory, the economic activity is affected in proportion of 50% (on graphs, the trajectory is shown by a dashed line). Based on the model simulations, we calculated the degree of damage to the economy for each day in 2020, and by cumulation, considering all 366 days this year, we estimated the annual proportion in which the economy will be affected.

S2) The second scenario, noted as y%S2 (on graphs, the trajectory is shown by a solid line), was calibrated so as to result in an annual economic downturn in 2020 equal to that estimated by the European Commission in its last forecasting report (European Economic Forecast – Spring 2020, European Commission, May 2020).

The relations for estimating the annual loss, as proportion of a normal unaffected income (in case of pandemic absence) for the two scenarios, YL%S1 and YL%S2, are the following:

$$YL\%S1 := \frac{\sum_{tT=1}^{366-t0-1} yL\%S1(tT)}{366} \qquad YL\%S2 := \frac{\sum_{tT=1}^{366-t0-1} yL\%S2(tT)}{366}$$

where yL%S1 and yL%S2 are the daily losses and t0 means the starting day of the pandemic (for instance, if 15 February is the first day of pandemic then t0 = 46).

3. Forecast of the pandemic dynamics and its economic impact

In this section of our study, based on applying IEF model at the three levels (World, EU, and Romania), we are reporting some significant results.

Global forecasts

The daily global data used to apply the IEF model cover the period January 22 - May 15, 2020 (so 115 days from the date of the onset of the pandemic, at that date not yet officially declared by the WHO).

Based on these data, the resulting classification by phases of the pandemic is as follows: F1 (accelerated growth) extends from January 22 to the first inflection point of the variable ka (active cases), i.e. to the peak of the daily increase of active cases, corresponding to t = 86 (April 15); F2 (slow growth) covered the period up to the peak of the pandemic (t = 110, corresponding to May 8), when the daily theoretical increase in active cases becomes zero; F3 (slow decline) marks a regression of the pandemic, up to the second inflection point, i.e. the time t = 134 (June 1), when the daily variation will become negative; F4) (accelerated decrease) marks the period of the disappearance of the pandemic, where the daily variation becomes accentuate negative and the trajectory convex again. In Figure 1a is shown the pandemic dynamics at the global level.

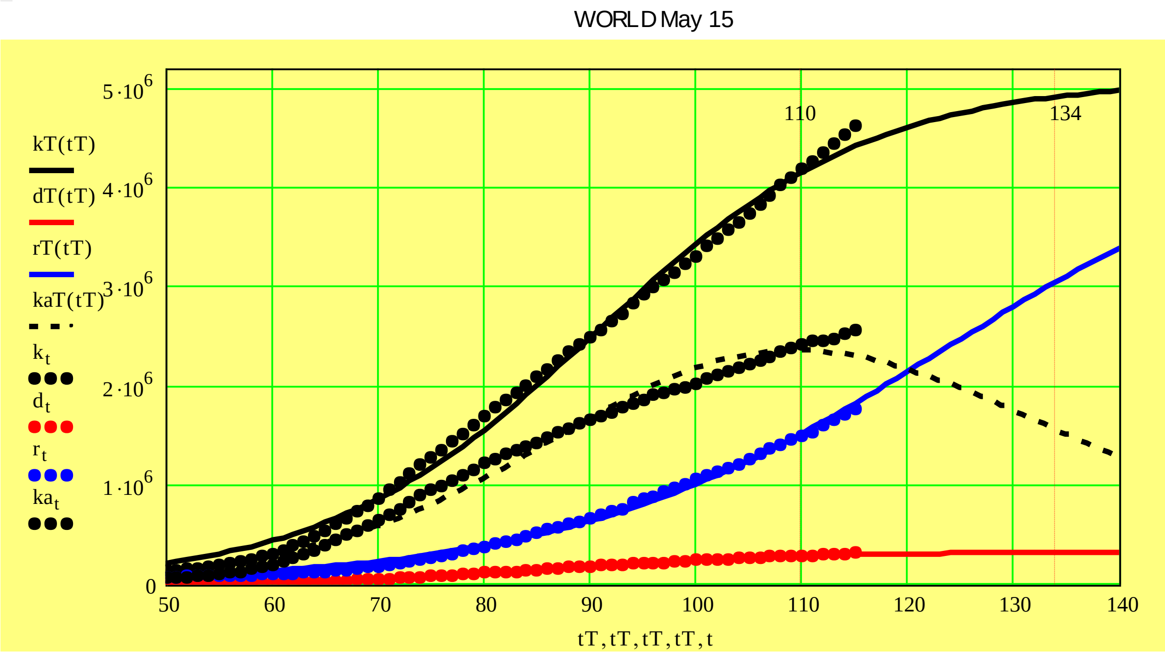

Figure 1a.

Regarding the impact of the pandemic on the world economy, the standard scenario S1 (supposing a 50% degree of damage to the economy at the peak of the pandemic) predicts that at the level of the whole year 2020 will result in a loss of -9.2%. The second scenario S2, calibrated to result in an annual economic downturn in 2020 of -3.5% (equal to that estimated by the European Commission), demonstrates a 19% damage in the maximum point of the pandemic to the world economy. Figure 1b shows the daily loss provoked by the pandemic at the global economy level until the end of 2020.

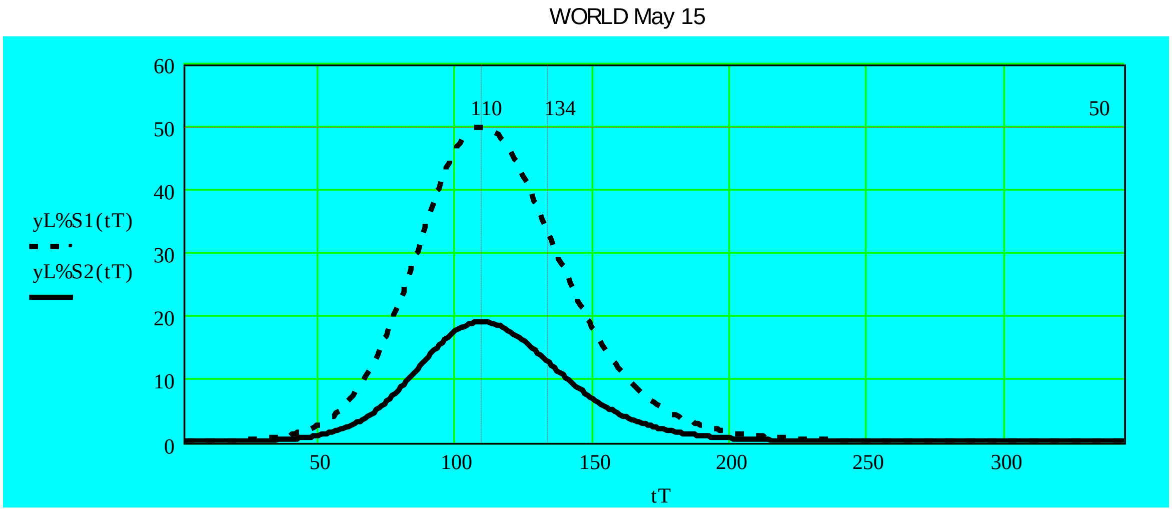

Figure 1b.

The hypothesis of 19% damage to the world economy during the pandemic peak seems plausible, because, in addition to the highly developed countries in Europe and the US, which have been seriously affected and introduced severe restrictive measures, many other countries in the world have either been less affected by the pandemic or have not introduced too restrictive measures. For example, for China and India, two countries with a significant share in the world, it is expected even economic growth in 2020, of + 1.0% and respectively + 1.1% (being the only economies that will advance this year). At the same time, the forecast report of the European Commission provides for a rapid recovery for the world economy in 2021, the forecasted growth rate being + 5.2%, after in 2019 it was + 2.9%.

According to the EC report, world trade will be more severely affected by the pandemic, with the expected decline of -11.9% for exports and -11.0% for imports, as well as other macroeconomic indicators, such as budget deficit, government debt, current account deficit and the international financial market in general.

Forecasts at the European Union level

Based on the same methodology, we estimated the parameters of the logistics model throughout the European Union (27 countries after Brexit), using daily data published for the period February 15 - May 15, 2020 (91 days after the first case in the EU).

According to the results of applying the model, the four phases of the epidemic follow one another as follows: F1 (accelerated growth) covered the period up to the first inflection point, i.e. to the peak of the daily increase of active cases, corresponding to time t = 50 (April 4); F2 (slow growth) took place to the peak of the epidemic in the EU (t = 67, corresponding to April 21), when the daily theoretical increase in active cases becomes zero, in this phase the trajectory becoming concave-ascending; F3 (slow decrease) marks the regression period of the epidemic, up to the second inflection point, corresponding to the moment t = 86 (May 10), in which the daily variation becomes negative, the trajectory being concave-descending; F4) (accelerated decrease) will be the period that will mark the transition to extinguishing the epidemic, where the daily variation becomes accentuate negative, and the trajectory convex-descending. Figure 2a shows the daily impact of the epidemic at EU level.

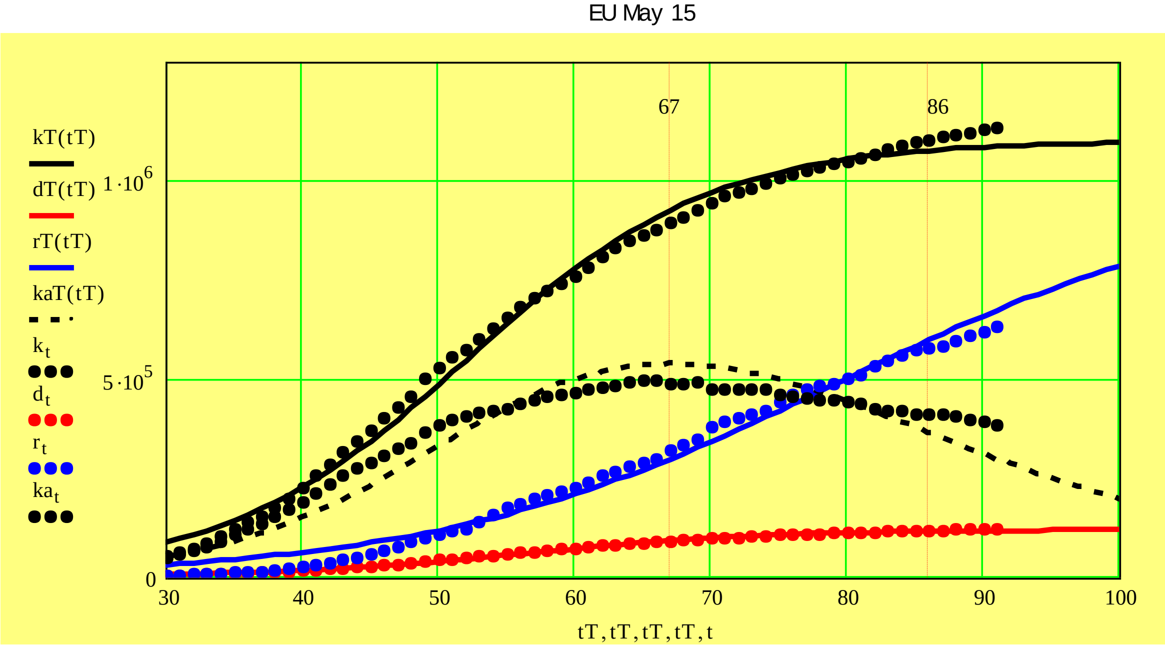

Figure 2a.

Relevant for the application of the model is that in many EU countries the so-called relaxation began in the first part of May, which, according to the theoretical trajectory in our model means the entry or preparation for entry into the fourth phase of the epidemic. Of course, this will only happen in the absence of a second wave of the epidemic, the danger of which some epidemiologists still warn.

To assess the impact of the pandemic on the EU economy, we estimated the daily economic loss in the two scenarios. The first one (S1) predicts that for the whole year 2020 a loss of -7.2% will result, while the second (S2) implies an annual decrease of the economy of -7.4%. The first scenario is based on a damage to the EU economy of 50% at the peak of the epidemic, while in the second scenario is corresponding to 51%. Unlike the situation in the global economy, at EU level the trajectory in case of the second scenario is placed just a little above the standard one. Figure 2b shows the daily impact of the epidemic at EU level by the end of 2020.

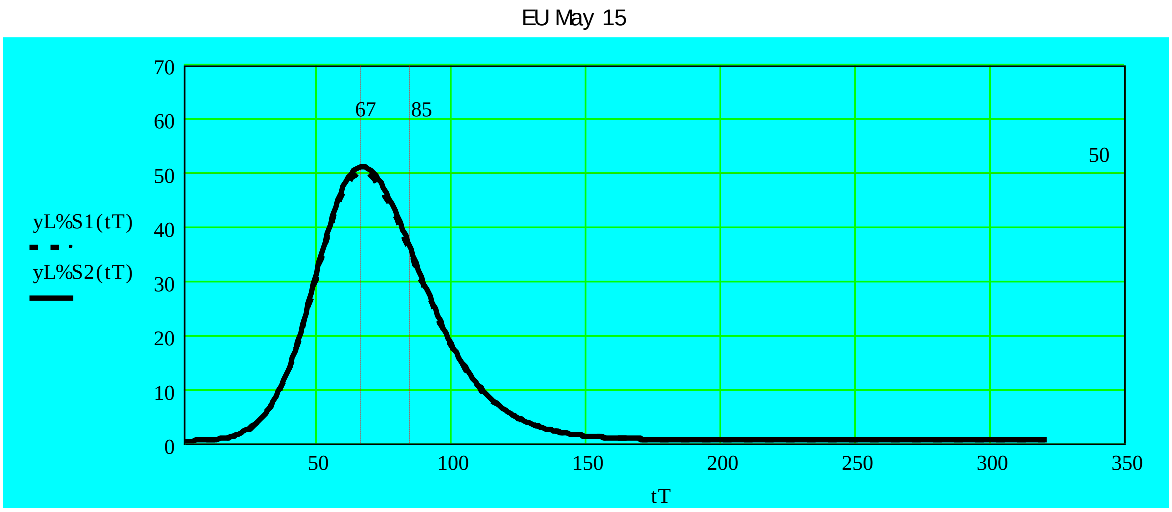

Figure 2b.

We consider that a damage to the EU economy at the peak of the pandemic of 50-51% is plausible, as it is already known that Member States, especially Western ones (such as Italy, Spain, France, etc.) were affected to a much greater extent than other countries in the world (with the exception of USA and UK). For next year, the forecast report of the European Commission provides for a rapid recovery for the EU economy, the projected growth rate being + 6.1%, after in 2019 it had been only + 1.5%.

Among the most affected areas, according to the EC report, foreign trade will have a serious decline, being estimated a decrease of -12.8%, both for exports and imports, after which a rapid recovery would follow in 2021 (+9.5%). Other macroeconomic indicators will also be negatively influenced, such as the current account (a decline of over 36 billion euros), public debt (a significant increase from 79.4% of GDP in 2019 to an alarming 95.1% in 2020), budget deficit (-6.7%, after + 1.0% in 2019), unemployment (from 6.7% in 2019 to 9.0% in 2020) etc.

Forecasts for Romania

At national level, considering the date of the first Covid-19 case in Romania, we estimated the parameters of the model for the daily data published for the period February 26 - May 15, 2020 (80 days).

Based on the estimation results, the four phases in the dynamics of the epidemic in Romania follow one another as follows: F1 (accelerated growth) extends to the first inflection point, i.e. to the peak of the daily increase of active cases, which corresponds to time t = 49 (April 14), in this phase the trajectory being convex-ascending; F2 (slow growth) took place until the theoretical maximum point of the epidemic (t = 66, corresponding to May 1), when the daily theoretical increase of active cases becomes zero, in this phase the trajectory being concave-increasing; F3 (slow decrease) covers the first period of regression of the epidemic, until the second inflection point, corresponding to the moment t = 82 (May 17), in which the daily theoretical variation becomes negative, the trajectory being concave-descending; F4) (accelerated decrease) will be the period after May 16, in which it will advance towards the extinction of the epidemic, the daily variation becoming accentuated negative and in which the trajectory is convex-descending. Figure 3a shows the dynamics of the epidemic in Romania.

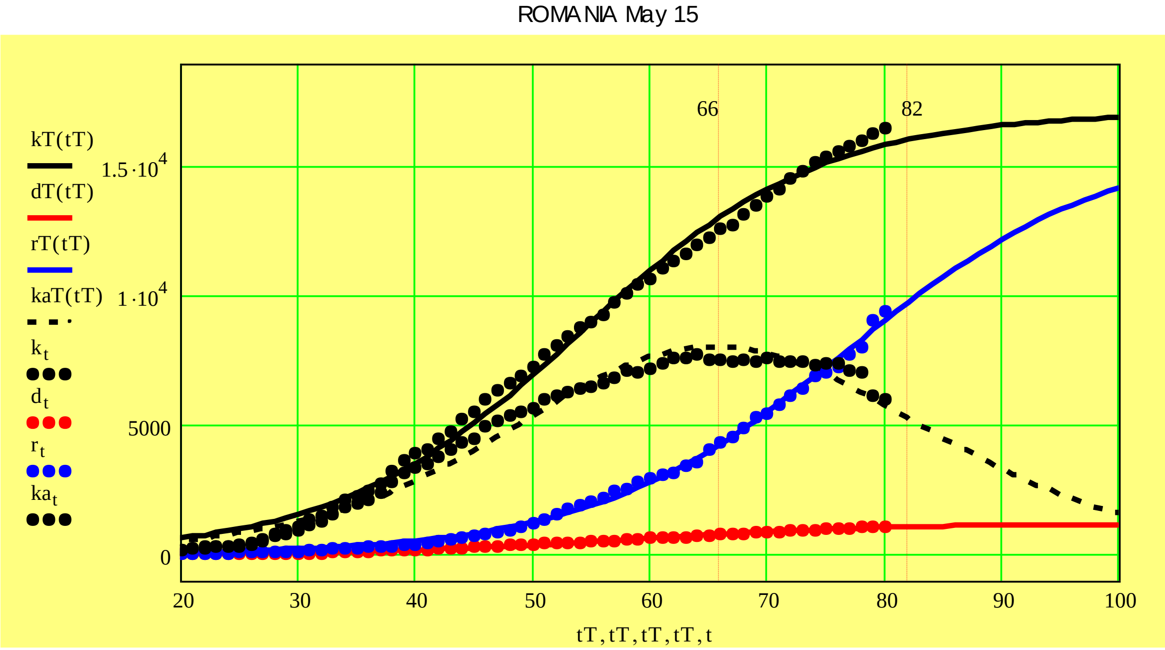

Figure 3a.

In the context of our application, it is not surprising that the relaxation of the measures imposed by the authorities in Romania starts in mid-May, which, according to the theoretical trajectory means the transition to the fourth phase, namely the beginning of the epidemic regression, of course only in case of no second wave of epidemic.

The results regarding the impact of the epidemic on the national economy predict in the case of the first scenario (S1) a loss of -6.4% for the whole year 2020, while the second one (S2) implies an annual decrease of the economy of -6.0%. Our estimates show that in the case of the second scenario a 47% damage to the national economy level was assumed (at the peak of the pandemic), thus close to the value given by the standard scenario (50%). Figure 3b shows the daily impact of the epidemic in Romania by the end of 2020.

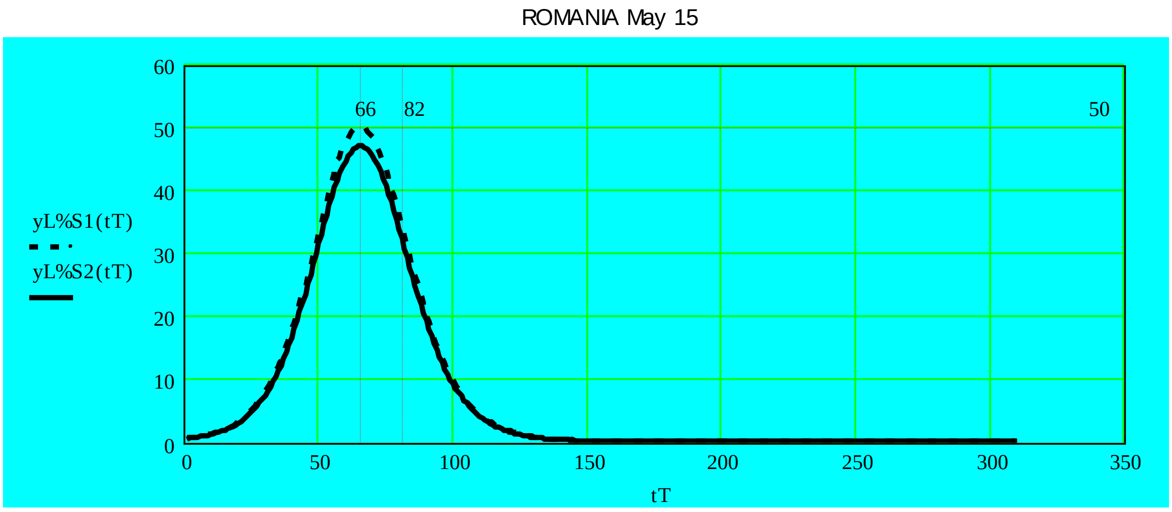

Figure 3b.

It is observed in the case of Romania, a favourable trajectory of losses in case of the second scenario, calibrated in relation to the EC forecast, comparing to that of EU (47% against 51%). We consider that the implicit degree of damage to the Romanian economy at the peak of the epidemic, below that at EU level, correctly reflects the situation, as it is known that in many other EU countries, especially in the western ones, the epidemic was more severe. For next year, the EC forecast report provides for a significant recovery for Romania, the forecasted growth rate being + 4.2%, after in 2019 it was + 4.1% (so a return to the trend before the epidemic).

Among the most affected areas in Romania, according to the EC forecast, foreign trade will suffer a severe decline, being estimated a decrease of -12.8% for exports and 14.4% for imports, but will be followed by a rapid recovery in 2021 (+ 9.9% and + 9.8% respectively). Other macroeconomic indicators affected will be public debt (a significant increase from 35.2% of GDP in 2019 to 46.2% in 2020 and 54.7% in 2021), the budget deficit (-9.2% in 2020 and -11.4% in 2021), unemployment (from 3.9% in 2019 to 6.5% in 2020), investments (projected decrease of -15% in 2020, followed by an insufficient increase of +5 % in 2021) etc.

Based on the analysis of the current structure of the national economy, the experience of other states and the results of estimates of the impact of the epidemic, some measures can be outlined that the authorities could consider since the expansion of the epidemic, but especially after its extinction. Thus, in addition to stimulating consumption, useful in the short term in the early period of the recovery, improving investment is essential for Romania. Until a solid recovery, the government should start large-scale infrastructure investments, which can play a significant propagating (multiplier) role in the economy. Thus, the rising unemployment, by the return to the country of the former Romanian emigrants, could be resorbed, implicitly leading to the increase of the population's income and to additional income to the budget. In fact, Romania is currently on the last places in the EU in terms of the share of government spending in GDP (only 36% in 2019, compared to 46.7% as the EU average).

In correlation with the current unbalanced budgetary situation, also in terms of the share of government revenues, Romania ranks last in the EU (31.7% in 2019, compared to 46.2% EU average). In this regard, better revenue collection by taxpayers, expanding the tax base as well as initiating tax incentives, could attract significant resources to the budget, reduce tax fraud and evasion, and restrict the informal economy. The direct effect could thus materialize in the efficiency of the budgetary apparatus, one of the pressing problems of the current administration. One of the major directions, with all the problems related to the epidemic, should be the extension to generalization of the digitalization of the administration.

4. Conclusions

In order to analyse the dynamics of epidemic spread among population, we used a special type of logistic model. Based on our simulations, the pandemic evolution can be classified in four distinct phases. Also, we have built two scenarios to estimate the economic impact of epidemic at three levels (world, EU, and Romania).

In the first scenario, we have assumed that output will contract at the peak of the pandemic in proportion of 50%, which will result in a total GDP loss of -9.2% in 2020 at the world economy level. The second scenario is calibrated to produce an economic slowdown of -3.5% (equal to the figure estimated by the European Commission), implying a 19% damage of economic activity in the maximum point of the pandemic.

Using the same methodology, we have estimated the parameters of the logistics model for European Union, obtaining in the first scenario a GDP slowdown of -7.2% in 2020, while for the second scenario total economic growth loss will be -7.4%.

The results of the model applied in case of Romania show that in the first scenario there will be a decrease in GDP of -6.4% in 2020, while the second scenario yields a loss of -6.0%. In order to stimulate economic growth during the pandemic Covid-19, economic measures should encourage consumption in the first phase, on the basis of massive fiscal stimulus injected by governments in order to support the population and companies affected by the interruption of production activities. On long-term an economic programme based on large investment expenses could contribute to restoring growth levels both worldwide and in case of EU countries.

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