# I. ESTIMATES OF DYNAMICS OF THE COVID-19 PANDEMIC AND OF ITS IMPACT ON THE ECONOMY[1]

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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 will follow in all fields (humanitarian, social, economic). The pandemic impact is difficult to be evaluated until it stops 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 approaches. In order to analyse the dynamics of the spread of epidemic among the population, we built a model with differential equations for a special logistic time-function, which resulted in certain key-values and four phases of 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 until the end of this year.*

**Keywords**: Covid-19, logistic model, pandemic phases, inflection, concave trajectory

**JEL Classification**: C61, I10, I18, J10

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## 1. Introduction

During the current 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 account evaluation from the health and economic perspectives, are seriously affected by the answer to the questions of how much the epidemic will expand among the citizens and how long will last the period until when this pandemic may be stopped.

After the official announcement of the World Health Organization (WHO) about the Covid-19 pandemic there have been published several studies on this topic. Many authors concentrate their analyses on the medical side, trying to estimate how much will the medical system be exposed at the maximum expansion level of this virus. Other authors try to directly model the expansion mechanism within the population, as are those presenting simulation models to evaluate instantaneously 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 the GDP growth or to propose solutions for economic recovery, some authors attempted to evaluate the impact on certain economic sectors, (Ataguba, Ivanov, Karnon, Sirkeci and Yucesahin, Zhang *et al*., etc.). A remarkable study approaches 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). Other 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 the 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 the correct economic policy measures. Therefore, based on the last available statistical data (June 9), 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 within the population is based on data published officially as “COVID-19 Coronavirus Pandemic” by international sources. This paper contributes to the analysis of pandemic dynamic and its economic impact by proposing a new simulation model elaborated within the Institute for Economic Forecasting (IEF).

## 2. Mechanism of Pandemic Dynamics and the IEF Model

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

Based on such data, in line with specialised studies, in order to build a model for estimating the extent of the epidemic within the population, we consider 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 re-tested at least once, 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 within the population, we built a model with differential equations for a special logistic time-function. 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 still active cases (persons still infected), ka. For each variable, the estimated (theoretical) values are denoted by kT, dT, rT, and kaT, respectively.

Considering the initial conditions, related to real data in the moment selected as origin of time (indeed, the first registered recovered case appears later than the first person registered as dead), as well as those related to the limit case when time tends to infinite, 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, br and cr are parameters, and (by construction) the asymptotic value for the rT(t) 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 recovered people. At the end time of epidemic, there will be no more infected people (active cases, in epidemiological terminology), so the variable ka will eventually take zero value.

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 estimated 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 applying 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, except for the variable ka as dashed line. As colours, we used black for k and ka, red for d and blue for r; the time, as days elapsed since the onset of the pandemic, being marked on the horizontal axis by t (real time) and tT (theoretical or 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 disappears either by increasing the total number of deaths or those cured (recovered), unlike the trajectories of the other three variables (having no local maximum and each of them presenting only one inflection point, tINFk, tINFd, and tINFr).

Four standard phases in pandemic dynamics (where D1 and D2 are the first two-time derivatives) can be identified on the trajectory of the variable kaT, presenting two inflection points, tINFka1 < tMAXka and tINFka2 > tMAXka (tMAXka being the day when ka reaches its maximum value):

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

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

P3) *slow decrease* (kaT↓ and D1↓), so pandemic regression, up to the second inflection point on 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* (kaT↓ and 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 three scenarios:

S1) The first scenario, denoted by yL%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, denoted by yL%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).

S3) The third scenario, denoted by yL%S3 (on graphs, the trajectory is shown by a dotted line), corresponds to the IMF forecast (World Economic Outlook, April 2020: The Great Lockdown, April 2020).

The relations for estimating the annual loss, as proportion of a normal unaffected income (in case of pandemic absence) for the three scenarios, YL%S1, YL%S2, and YL%S3, are the following:

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

$$YL\%S3 := \frac{\sum_{tT=1}^{366-t0-1} yL\%S3(tT)}{366}$$

where: yL%S1, yL%S2, and yL%S3 are the daily losses and t0 means the starting day of the pandemic (for instance, if February 15th is the first day of pandemic, then t0 = 46).

# 3. Forecasts of Pandemic Dynamics and Its Economic Impact

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

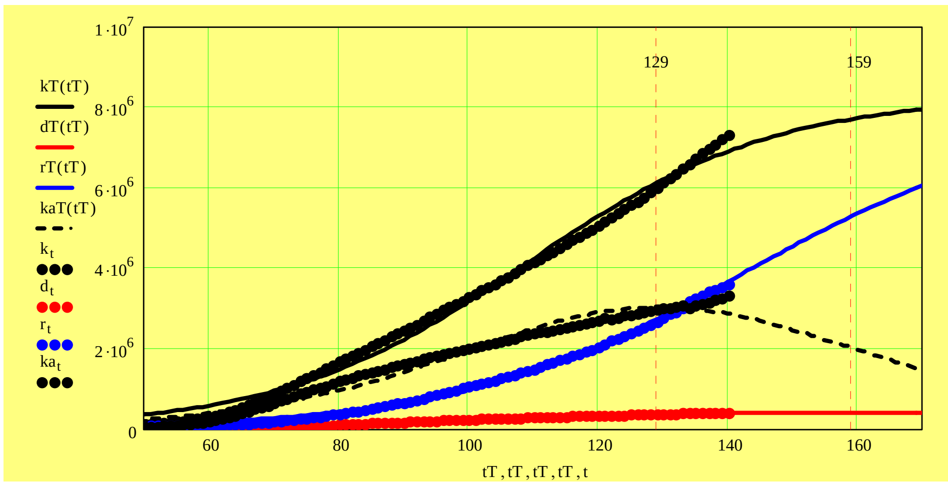
## *3.1. Global Forecasts*

The daily global data used to apply the IEF model cover the period January 22nd - June 9th, 2020 (namely 140 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: P1 (accelerated growth) extends from January 22nd to the first inflection point of the variable ka (active cases), *i.e.* to the peak of the daily increase in active cases, corresponding to t = 100 (April 30th); P2 (slow growth) covers the period up to the peak of the pandemic (t = 129, corresponding to May 29th), when the daily theoretical increase in the active cases becomes zero; P3 (slow decline) marks a regression of the pandemic, up to the second inflection point, *i.e.* the time t = 159 (June 28th), when the daily variation will become negative; P4) (accelerated decrease) marks the period of the disappearance of the pandemic, where the daily variation becomes accentuate negative and the trajectory convex again. Figure 1a shows the pandemic dynamics at the global level.

**Figure 1a.**

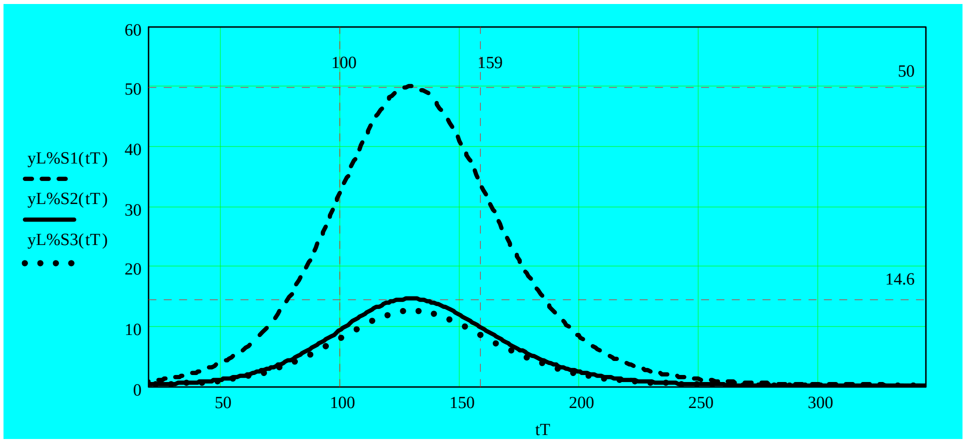
Dynamics of pandemic at global level (June 9)




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 pandemic) predicts that for the entire year 2020 will result a loss of -11.9%. The second scenario S2, calibrated to result an annual economic downturn in 2020 of -3.5% (equal to that estimated by the European Commission), demonstrates a 14.6% damage at the maximum point of the pandemic to the world economy. The third scenario S3, corresponding to -3.0% decrease in 2020 (as in the IMF forecast) implies a 12.6% damage in the day representing the maximum point of pandemic. Figure 1b shows the daily losses provoked by pandemic at the global economy level until the end of 2020.

**Figure 1b.**

Macroeconomic impact at global level (June 9)




The hypotheses of 14.6% and 12.6% damages 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 which introduced severe lockdown measures, many other countries in the world have either been less affected by the pandemic or have not introduced too restrictive measures. For example, in China and India, two countries with a significant share in the world, even an economic growth is expected in 2020, of +1.0 (EC forecast) to +1.2% (IMF forecast) and +1.1% (EC forecast) to +1.9% (IMF forecast), respectively, they being the only economies that will advance this year. At the same time, the forecast reports of the European Commission and the IMF provide for a rapid recovery of the world economy in 2021, the forecasted growth being +5.2% and +5.8%, respectively, after in 2019 it reached +2.9%.

According to the EC report, the 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.

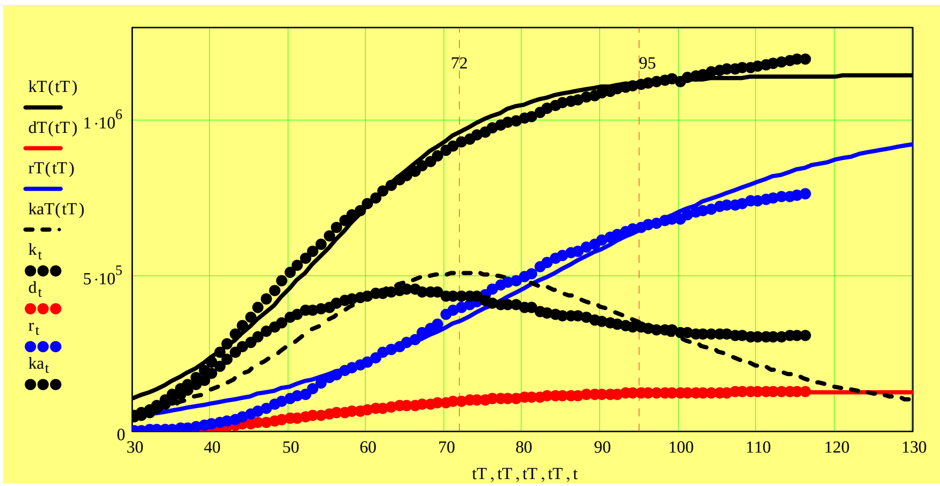
## *3.2. Forecasts at the European Union Level*

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$^{th}$ - June 9$^{th}$, 2020 (116 days after the first case reported in the EU).

According to the results of the model, the four phases of the epidemic follow one another as follows: P1 (accelerated growth) covered the period up to the first inflection point, *i.e.* to the peak of the daily increase in active cases, corresponding to t = 51 (April 5$^{th}$); P2 (slow growth) took place to the peak of the epidemic in the EU (t = 72, corresponding to April 26$^{th}$), when the daily theoretical increase in active cases becomes zero, in this phase the trajectory becoming concave-ascending; P3 (slow decrease) marks the period of pandemic regression, down to the second inflection point, corresponding to t = 95 (May 19$^{th}$), in which the daily variation becomes negative, the trajectory being concave-descending; P4 (accelerated decrease) will be the period that will mark the transition to epidemic extinction, where the daily variation becomes accentuate negative, and the trajectory convex-descending. Figure 2a shows the daily impact of the epidemic at the EU level.

**Figure 2a.**

Dynamics of pandemic in EU (June 9)



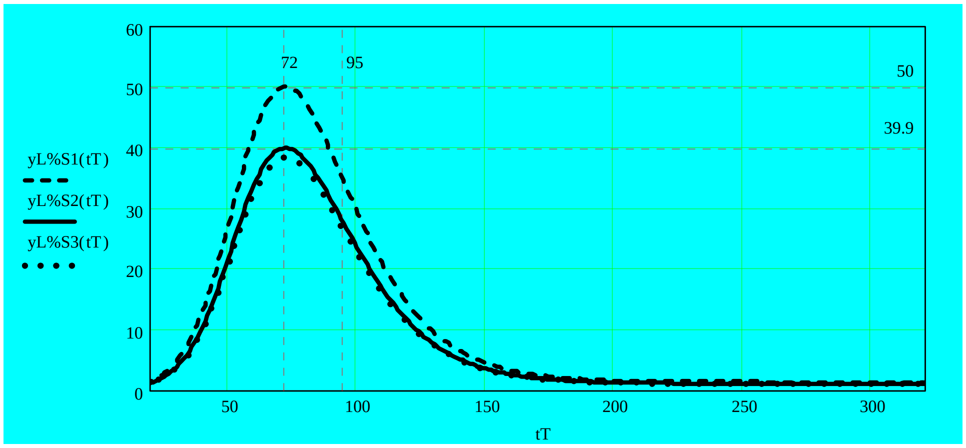

Relevant for the application of the model is that in many EU countries the so-called relaxation began in the first part of May, which, according to the theoretical trajectory in our model means the entry into or preparation for entry into the fourth phase of the epidemic. Of course, this will only happen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

To assess the impact of the pandemic on the EU economy, we estimated the daily economic loss in the three scenarios. The first one (S1) predicts for the whole year 2020 a loss of -9.3%, while the second (S2) scenario and the third (S3) scenario implies an annual economic decrease of -7.4% and -7.1%, respectively. The first scenario is based on a damage to the EU economy of 50% at the peak of the epidemic, while the second and third scenarios correspond to damages of 39.9% and 38.3%, respectively. Unlike the situation in the global economy, at EU level the last two trajectories are located close to the standard scenario (S1). Figure 2b shows the dynamics of daily impact of the epidemic at the EU level by the end of 2020.

In the case of EU, a damage at the day of the peak of pandemic higher than 38% could be explained by the fact that the Member States, especially the Western ones (such as Italy, Spain, France, etc.) were more affected than other countries in the world (with the exception of the USA and the UK). For the next year, the forecast report of the European Commission provides for a rapid recovery of the EU economy, the projected growth rate being + 6.1%, after in 2019 it would reach only + 1.5%.

**Figure 2b.**

Macroeconomic impact in EU (June 9)




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.

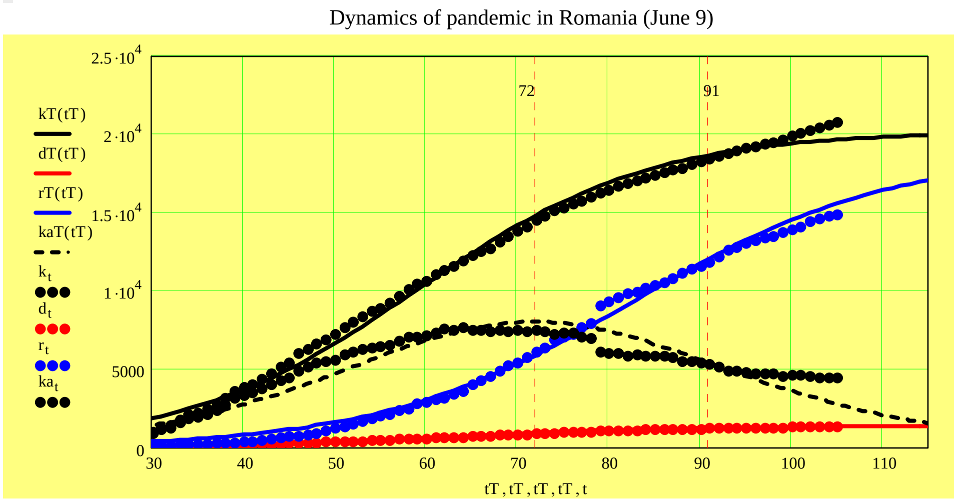
### *3.3. Forecasts for Romania*

At national level, considering the date of the first Covid-19 case reported in Romania, we estimated the parameters of the model for the daily data published for the period February 26$^{th}$ - June 9$^{th}$, 2020 (105 days).

Based on applying the estimation model, the four phases in the dynamics of the epidemic in Romania follow one another as follows: P1 (accelerated growth) extends to the first inflection point, *i.e.* to the peak of the daily increase in active cases, which corresponds to time t = 52 (April 17$^{th}$), in this phase the trajectory being convex-ascending; P2 (slow growth) took place until the theoretical maximum point of the epidemic (t = 72, corresponding to May 7$^{th}$), when the daily theoretical increase in active cases becomes zero, in this phase the trajectory being concave-increasing; P3 (slow decrease) covers the first period of pandemic regression, until the second inflection point, corresponding to t = 91 (May 26$^{th}$), in which the daily theoretical variation becomes negative and the trajectory being concave-descending; P4) (accelerated decrease) will be the period after May 26$^{th}$, in which will be an advance towards the extinction of epidemic, the daily variation becoming accentuate negative and the trajectory being convex-descending. Figure 3a shows the dynamics of the epidemic in Romania.

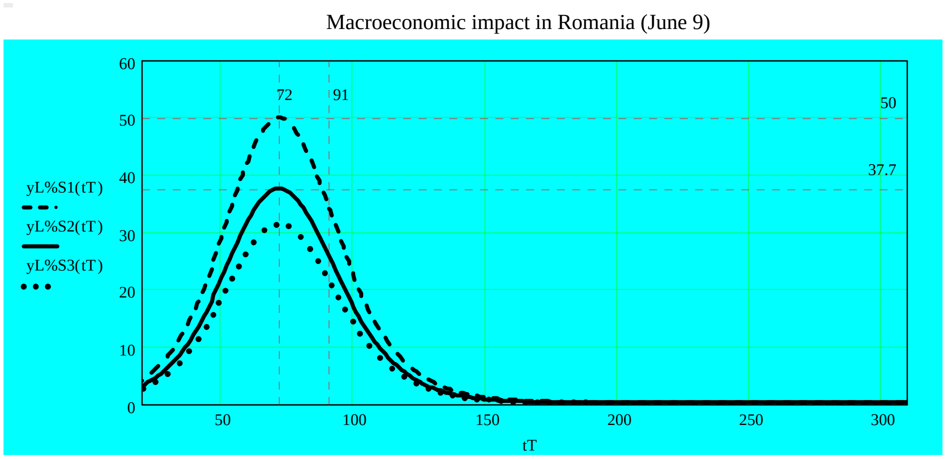
In the context of our application, it is not surprising that the relaxation of the measures imposed by the authorities in Romania starts in mid-May, which, according to the theoretical trajectory means the transition to the fourth phase, namely the beginning of the epidemic regression, of course only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

**Figure 3a.**




The results regarding the impact of the epidemic on the national economy predict in the case of the first scenario (S1) a loss of -7.9% for the entire year 2020, while the second (S2) and third scenarios (S3) imply contractions of -6.0% and -5.0%, respectively. Our estimates show that in the case of the second and third scenarios damages of 37.7% and 31.5%, respectively, at the level of national economy were implicitly presumed (at the peak of the epidemic), thus higher than in global economy but lower than in the EU. Figure 3b shows the daily impact of the epidemic in Romania until the end of 2020.

**Figure 3b.**



In the case of Romania, a more favourable trajectory of daily losses (at the peak of the pandemic) is revealed in the cases of the second and third scenarios, as compared to that of the EU (37.7% against 39.9% and 31.5% against 38.3%, respectively). We consider that the implicit degree of damage to the Romanian economy at the peak of the epidemic, below that at the 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 the next year, the EC forecast provides for a significant recovery in Romania, the forecasted growth rate being +4.2%, after in 2019 it would be + 4.1% (thus, 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 it 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 might 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, through the return to the country of the former Romanian emigrants, could be resorbed, implicitly leading to the increase in population's income and to additional income to the budget. In fact, Romania is currently ranking last in the EU in terms of share of government spending in the GDP (only 36% in 2019, as 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, as 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 expansion towards generalization of digitalization of the administration.

## 4. Conclusions

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

In the first scenario, we assumed that output will contract at the peak of the pandemic in proportion of 50%, which will result in a total GDP loss of -11.9% in 2020 at the world economy level. The second scenario was calibrated to produce an economic slowdown of -

3.5% (equal to the figure estimated by the European Commission), implying a 14.6% damage of economic activity at the maximum point of the pandemic. The third scenario was calibrated in accordance with the IMF forecast, thus a decrease of -3.0%, implying a -12.6% damage at the maximum point of pandemic.

Using the same methodology, we estimated the parameters of the logistics model for the European Union, obtaining in the first scenario a GDP slowdown of -9.3% in 2020, while for the second and third scenarios the economic losses will be -7.4% and -7.1%, respectively, corresponding to 39.9% and 38.3%, respectively, damages at the maximum point of the pandemic.

The results of the model applied in the case of Romania show that in the first scenario there will be a decrease in the GDP of -7.9% in 2020, while the second and third scenarios yield losses of -6.0% and -5.0%, respectively, corresponding to 37.7% and 31.5%, respectively, damages at the maximum point of the epidemic.

In order to stimulate economic growth during the Covid-19 pandemic, the 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 could contribute to restoring growth levels both worldwide and in the case of the EU countries.

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