

ECONOPHYSICS Section

THE IMPACT OF CORONAVIRUS COVID-19 ON WORLD ECONOMY – AN ECONOPHYSICS APPROACH AND MODEL

Ion SPÂNULESCU* and Anca GHEORGHIU*

Abstract. *In early 2020, the COVID-19 coronavirus pandemic spread rapidly in most countries of the world, causing many human casualties and a huge negative impact on the economies of the affected countries.*

In this article, on the basis of the principles of phenomenological econophysics, an econophysics model is proposed and theoretically substantiated, showing the ways of action to limit the economic impact of the COVID-19 coronavirus on the global economic development.

Keywords: *Coronavirus, COVID-19, econophysics model, phenomenological econophysics, economic amplifier, mixed economy, Cobb-Douglas, production function.*

1. Introduction

In addition to medical or protective measures to limit the spread of mass diseases with the new COVID-19 coronavirus, a number of administrative measures established by law enforcement or decision-makers at national or community level have been initiated and applied. During their application it was found that some of these measures were taken in haste, so they were insufficiently developed producing even some adverse effects, in addition to the beneficial ones established with the aim of limiting the spread of the pandemic with COVID-19. Thus, the limitation or even total interruption of activities or events with a large number of people (sports, cultural-artistic events etc.), educational activities, ceremonies etc. for certain periods are necessary to limit the spread of the effects of the pandemic, but the limitations or even the prohibition of productive activities for large periods must be done with great care to prevent economic-financial or food crises and even economic

* Hyperion University, Calea Călărașilor 169, Bucharest, 030615, e-mail: ion.spanulescu@gmail.com, anca.gheorghiu@gmail.com

collapses worldwide. These conclusions or findings can be based on economic models of analysis or forecasting, the most recommended and accurate of which are those in the field of econophysics, statistical physics, econometrics, mathematical statistics etc.

Modeling of economic processes or phenomena by physico-mathematical methods and laws has been proposed and analyzed extensively at numerous international conferences or symposiums, etc., as well as in numerous books or scientific papers published mainly in the field of *phenomenological* econophysics for example [1-7].

This paper presents a new econophysics model and several econophysics considerations are made on the economic and financial effects that arise as a result of the application of measures to limit the spread of the COVID-19 pandemic worldwide. Such a model is necessary in order to avoid inappropriate or insufficiently substantiated decisions, which could lead to serious economic and financial crises in the case of the application of those decisions.

The new econophysics model is a combination of three other econophysics models, proposed and analyzed in our several previous works [1-6] namely the economic amplifier [1-5], the econophysics model of the Cobb-Douglas production function [3,4,8] and the econophysics model of the mixed economy that will be presented succinctly in following 2-4 sections. Such modeling removes any kind of ambiguities and gives the adopted model its own accuracy to the laws of physics, mathematics or chemistry, etc. which are exact sciences, they describe the immutable phenomena or laws of nature or physico-chemical or biological processes etc. [1-7].

2. The Economic Amplifier

The economic amplifier is one of the most important models within the *phenomenological* econophysics that underpins the shaping of numerous economic laws and processes, such as the process of development and economic growth [1,2], the modeling of the production function [2], the modeling of the mixed economy [5,7] etc.

Since the process of growth or economic development is essentially the amplification of the initial investments applied within a company (enterprise etc.), it is natural for this process to be shaped by a physical system that produces an amplification, such as the electronic amplifier in Electronics and Solid State Physics, which applied in the case of economic

processes is the economic amplifier (Figure 1.a,b). So, the model of economic amplifier (Figure 1.b) works by analogy with an electronic amplifier with solid state electronic devices (transistors or integrated analog circuits) (Figures 1.a and 2) analyzed in our previous papers [1-3].

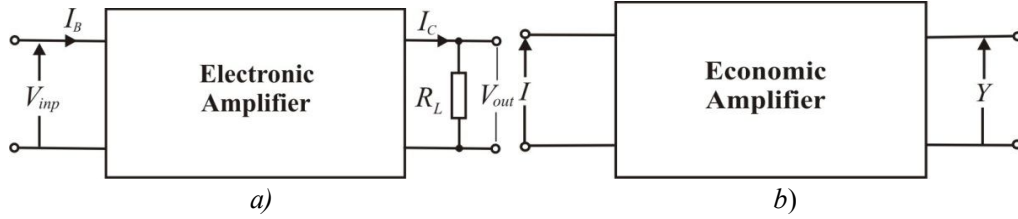


Figure 1.a) Simplified representation of an electronic amplifier with transistors or integrated circuits; b) The schematic representation of an economic amplifier.

Every electronic amplifier has an active element which is either a bipolar transistor (with $p-n$ junctions) or a field effect transistor (MOS type). In the modern electronic usually only analog integrated circuits are used as amplifiers, such analog integrated circuits having in their structure many bipolar or MOS transistors [2,9]. Since the operation of such integrated devices and circuits is described electronically by the principles governing the operation of a bipolar single or MOS transistor, the general principles of construction and operation of bipolar transistors with $p-n$ junctions will be presented below (Figures 2 and 3).

As we can see in Figure 3, the bipolar transistor is made of two $p-n$ junctions semiconductor created in a small single semiconductor crystal, first junction (emitter junction) being forward biased with V_{BE} voltage, and the second one (collector junction) being reverse biased with V_{CB} voltage, with:

$$|V_{CB}| \gg |V_{BE}|. \quad (1)$$

By proper biasing of the junctions, the transistor will be crossed by emitter, base and collector currents (I_E , I_B and I_C) which are in the following relation:

$$I_E = I_B + I_C \quad (2)$$

in which I_E represent the current due to injection of charge carriers from emitter region to base region where they are transferred into collector circuit as collector current I_C under the action of electric field of collector junction (Figures 2 and 3).

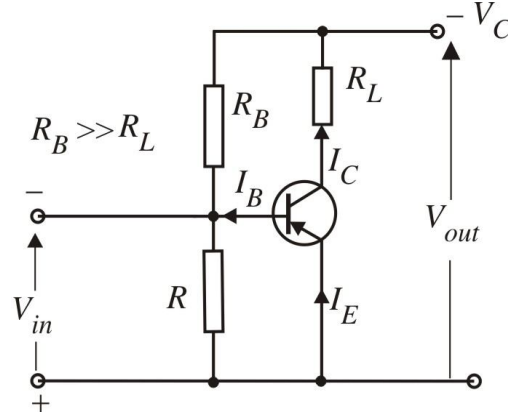


Figure 2. Structure of one stage electronic amplifier with a *p-n-p* transistor.

Due to inverse currents of minority carriers from collector and emitter regions, I_{CBO} and recombination current of charge carriers in the base region I_r , the base current I_B is much smaller than I_E or I_C :

$$I_B \ll I_C. \quad (3)$$

The amplification factor of the single stage transistor amplifier in Figures 2 and 1.a in the presence of only polarization bias voltages applied to the transistor is basically given by the direct current amplifier factor β of the bipolar transistor in common emitter configuration (EC), where emitter's electrode is **common** both for the input and output circuit (Figures 2 and 3):

$$B = \frac{I_{out}}{I_{in}} = \frac{I_C}{I_B}. \quad (4)$$

In equation (4), I_C represents the collector current at the output of the transistor from the amplifier with transistors or integrated circuits (Fig. 2), and I_B is the base current that is present in the input circuit [1,3]. In [1-3] is shown that similarly, an economic amplifier can be characterized by the amplification factor $\beta_{economic}$ given by [1-4]:

$$\beta_{ec} = \frac{Y}{I} \quad (5)$$

where Y is the aggregate income obtained on the basis of investments I from “the entry” of economic amplifier (Fig. 1.b) [1-4].

3. An Econophysics Model of Mixed Economy

As shown in our previous works [5,7], in most countries of the world there is a system of mixed economy in which, in addition to private companies and other economic operators in economic activities also

participates, the State, which coordinates, centralizes or participates directly in the economic process through its public sector. In view of this fact, a basic model of the mixed economy will be presented succinctly as follows, for which the equation of economic balance is [5,7]:

$$Y = C + I + G. \quad (6)$$

In the equation (6), Y represents the total macroeconomic income, i.e. GDP, C represents the total consumption, I represents total investments and G represents both governmental and public expenditures [9-10].

We can imagine an econophysics model for mixed economy by analogy with the physical structure of a bipolar transistor (Fig. 3), which is the active amplification device from an electronic amplifier as the one in Figure 2, which – as we've shown in our previous papers [5,7] – perfectly shapes the economic development phenomenon in a sustainable economy (in which there is economic growth based on investments I) the economic amplifier.

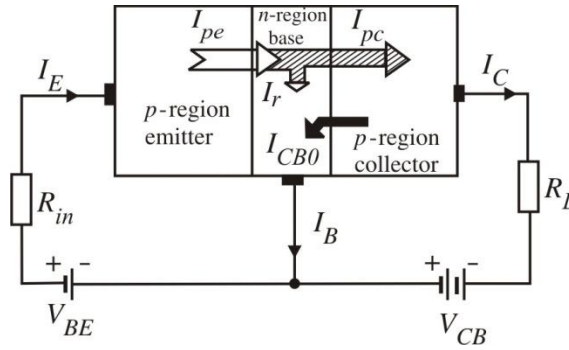


Figure 3. Schematic physical structure of a $p-n-p$ transistor.

In the transistor's structure shown in Figure 3, the p -regions that represent the emitter and, respectively, the collector of the bipolar transistor with $p-n$ junctions, are assimilated to the private sector of the country's market economy, while the n type intermediate region, referred to as the base of the transistor, represents the public sector, its participation and the degree of state intervention in the economy, being characterized by the value I_B of the base current that closes through input circuit of the electronic amplifier (Fig. 2) that shapes economic development through the associated economic amplifier. Thus, G factor of the economic equilibrium equation (6), showing the share of public and government expenditures is modeled by the I_B current in the case of the electronic amplifier (Figures 2 and 3) that shapes the economic amplifier, i.e. in the case of the econophysics

model of the mixed economy instead of I_B will be taken the G factor, so we can write:

$$I_B = G. \quad (7)$$

In equation (4) it is obvious that excessive increase of current I_B is unacceptable, because it leads to drastic decrease or even cancellation of the amplification factor β , i.e. the economic amplifier doesn't work and economy stagnating. For the proper operation of the electronic amplifier and, respectively, of the mixed economy model, it is essential that I_B and by default G to be as low as possible to get a reasonable value for the amplification factor $\beta = \beta_{el}$ and the default β_{ec} .

From Electronic Physics it is known that the current I_B is given, mainly, by the sum of the reverse current of electrons coming from the collector to the base, I_{CBO} (see Fig. 3) and the current I_r of recombination in the base of positive charge carriers injected from emitter as a result of application of entrance signals and normal bias voltages of the amplification device (transistor) (v. fig. 2) [9]:

$$I_B = I_r + I_{CBO}. \quad (8)$$

In equation (8) we see that for the reduction of the base circuit current I_B is necessary to significantly decrease the width of the base that has the effect of significant decrease the level of recombination current I_r , the current I_{CBO} having a constant and reduced value.

Correspondingly, as evidenced by the equation (8), decreasing the current I_B , respectively of the width of the base is equivalent to the significant reduction of public sector and state intervention in the economy, as well as the governmental expenditure (expressed by the term G from equation (6)).

As previously shown, for the proper operation of the transistor and a high value for the current amplification factor f , i.e. for β , the I_B current must be as small as possible, to represent a small fraction of the value of the I_C collector current i.e. [5,7].

$$I_B = \alpha_{el} I_C \quad (9)$$

where [5]:

$$0 > \alpha < 1 \text{ and } \alpha \neq 0; \alpha \neq 1.$$

A high I_C value also leads to U voltage amplification that can be obtained at the load resistance R_L terminals from the electronic amplifier output (Figures 1.a and 2), as well as to a high electrical power value:

$$P = UI \quad (9')$$

delivered at the amplifier output.

Replacing (9) in equation (5) and assimilating the output current I_C with the income Y of the economic amplifier results for β_{el} of the electronic amplifier [5]:

$$\beta_{el} = \frac{I_C}{I_B} = \frac{I_C}{\alpha_{el} I_C} = \frac{1}{\alpha_{el}} \quad (10)$$

and respectively (see eq. (7)):

$$G = I_B = \alpha_{el} I_C = \alpha_{ec} Y. \quad (11)$$

From equations (7), (10) and (11) we can also write an equation similar to the equation (10), i.e.:

$$\beta_{ec} = \frac{Y}{G} = \frac{Y}{\alpha_{ec} Y} = \frac{1}{\alpha_{ec}}. \quad (12)$$

Thus, the transistor's amplification can be increased by decreasing the base width as much as possible (consequently of the Government expenditure G and the public sector in the economy in the case of the econophysics model) which reduces the base current I_B mainly by drastically reducing recombination current I_r in the base region (see equation (8)).

4. Econophysics Approach and Model of the Cobb-Douglas Production Function

Production is one of the basic factors of the economy in all fields of activity in which goods and services are made, i.e. in agriculture, industry, digital technologies, automation, robotics etc.

Therefore, considering production as a sector of activity in which goods or services are made under the conditions of the existence of a certain technology it can be accepted that the results obtained (the amount of outputs) depend on the volume of the various inputs (resources) used. This bond between production and the factors that determine its' size is described by the **production function**. Such a function can be defined as a representation (table, graph, equation) from which the amount of achievements (outputs) is derived when using factors (inputs) following a certain way of working (technology, organization) [2-4].

Thus, the production of goods or services is the result of the harmonious and to a certain extent of the factors joining in that process such as capital, K , labor, L , investments, expenditure, technology and technical progress etc. Among them the decisive role lies first of the **capital** (both in liquid form and in the form materialized in means of production etc.) and then by the **labor**

force – *Labor* – concentered by the work and the number of employees who produce goods and services.

In accordance with the previous considerations, several types of production functions have been developed, particularly in the U.S.A., with reference first to agricultural production [2,3]. One such function was developed by C. W. Cobb and P. H. Douglas, who in 1928 showed by a formula the statistical dependence between national income (variable Y) and the main factors contributing to the realization of production, namely **work**, L (from Labor) and **capital**, K , invested in the production process, expressing the function of production in the form of [8]:

$$Q = g L^{\lambda} K^{\mu} \quad (13)$$

where [2]:

Q – means the production expressed in cash form (income: Y);

L – labor force used (number of employees);

K – capital in service (fixed capital volume);

g – the coefficient of proportionality;

λ – the coefficient of elasticity of production in relation to the work used;

μ – the coefficient of elasticity of production in relation to the capital in operation.

Generally, coefficients λ and μ have low values, close to 1. Initially the coefficients λ and μ were taken so as to result:

$$\lambda + \mu = 1 \quad (14)$$

and in a later version was taken:

$$\mu + \lambda \neq 1, \quad (15)$$

but so that the sum $\lambda + \mu$ does not differ – in value – too much from 1. Thus, at present, between the coefficients of elasticity λ and μ the following equations are considered: $\lambda + \mu < 1$; $\lambda + \mu = 1$ and $\lambda + \mu > 1$.

As shown in our previous papers [2-4], the Cobb-Douglas production function, expressed by the equation (13), can be modeled on the electrical power charged on the load resistance R_L of the economic amplifier in Figure 1. a (or/and Figure 2).

If the I_C represents the output current from the electronic amplifier, the power delivered to the output shall be given by (see (9)):

$$P_e = UI_C. \quad (16)$$

where $U = R_L I_C$ represents the voltage drop on the load resistance R_L (Figure 1. a or/and Figure 2).

For correlation with the economic amplifier model, the equation (13) for the Q production function will be matched with the equation (16), which expresses the (electrical) power charged to the load resistance R_L of the amplifier (see Figure 2) from where it is transferred outwards.

By identifying the variables that enter the two equations, it is that the I_C can be assimilated with the capital (investments) in operation, and the work force denoted in the Cobb-Douglas model with L , corresponding to the U factor of the electronic amplifier that shapes the economic amplifier. Also, the coefficient of proportionality g is equal to 1 (in the case of equation 16) and the elasticity coefficients, for power P_e are equal to 1 for both λ and μ .

It is obvious that by lowering the term L decreases the voltage U which in terms of the electronic amplifier shapes the economic amplifier which translates into a decrease in polarization voltages (bias voltages) or signals applied to the input of the amplifier or its output (see Figures 2 and 3).

Because it is an electronic amplifier, so an exact physical process, here the coefficients μ and λ are equal to 1, so they have constant values as in any model derived from the exact sciences; in actual cases, from production, investments etc., and these coefficients are generally subunits, having the characteristics of elasticity coefficients.

As, for each enterprise there is a volume of production Q , correlated with the labor force L and the capital in operation K , and in the case of the electronic amplifier, different levels of power P charged can be considered according to the current I (assimilated with investments) and the Voltage U on the load resistance R_L (assimilated to the work used), which is also found in the diversity of types of electronic power amplifiers (single stage, final, counter-time of different classes etc.) [2,3,9].

5. Impact of Coronavirus COVID-19 on World Economy – an Econophysics Approach and Model

The Covid-19 Coronavirus pandemic appeared suddenly, first in China in December 2019 and, in less than two months, spread to most countries, gaining great expansion mainly in Europe and the United States of America. Such an “explosion” or boom in the spread of that virus found the infected countries totally unprepared, without coronavirus protection materials and equipment or with a smaller number of physicians specialized in infectious diseases or hospitals with insufficient numbers of intensive care beds etc. etc.

Under the pressure of time and speed of propagation of the highly contagious COVID-19 coronavirus, governments and political-administrative

managements in the countries where the pandemic has been extended have taken the measures they considered necessary, but, as we mentioned at the beginning, some of these measures have proved inadequate, leading to some negative effects, namely to a decrease in economic development and to an increase in unemployment as a result of the cessation of production in several industrial sectors, tourism, trade etc., employees being sent to technical unemployment or real unemployment by the termination of employment contracts in bankrupt firms etc.

Admitting that such corrective measures have been or are justified to stop the sudden spread of coronavirus, the decrease in labor in bankrupt or endangered firms, is an obvious fact, with economic analysts stating that by the end of the first wave of coronavirus spread, there will be about 350 million new unemployed people in the world compared to those existing at the beginning of the COVID-19 pandemic.

As scientists say that from now on we will be able to have other “waves” of infection with coronaviruses that will coexist with previous types of viruses, it is advisable to take early action in order to limit the spread of coronaviruses, and their negative effects that can seriously affect the world economy. It is therefore necessary to rigorously analyze and model the characteristics of the coronavirus and their effects on economic growth, by using some models inspired by the exact sciences or natural sciences as shown before in this paper. In this respect, in this paper we will use the econophysics models analyzed in sections 2-4, in order to introduce a generalized econophysics model that combines the characteristics of three econophysics models based on the concept of economic amplifier proposed by us and analyzed in several works, in which that model was used to explain economic phenomena or processes [1-9].

First we will consider the model of the economic amplifier analyzed in sections 2 and 3, with an extension to the economic model for the mixed economy that now exists in most countries of the world (with the exception of socialist countries such as North Korea and Cuba or countries with totalitarian regimes). The main parameter by which this model is characterized is the economic amplification (development) factor defined by the equation (5) i.e.:

$$\beta_{ec} = \frac{Y}{I}. \quad (5')$$

This factor may be influenced by the change in the value of total income Y assimilated with GDP [1,2]. A decrease in the income Y leads to a decrease in the β_{ec} factor, thus to economic stagnation, which is to be avoided.

In the section 4 we examined the econophysics model of the Cobb-Douglas production function [1,2] expressed by the equation (13):

$$Q = gL^\lambda K^\mu. \quad (13')$$

in which:

L – means the work force used (number of employees in operation):

K – capital in operation;

Q – represents the production, expressed in the form of money, so at national level represents the total income $Y = \text{GDP}$.

It follows directly from this that the income Y (i.e. total production) will decrease if the total number of employees L decreases (as a result of restrictions on workplace travel, layoffs etc.) and as a result the factor – $\beta_{ec} = Y/I$ will decrease due to the decrease in the value of Y (see equation 5').

Returning to the econophysics model for the Q production function described by the Cobb-Douglas equation (13'), as shown in Section 4, the Q size is assimilated with the electric power:

$$P_e = UI \quad (17)$$

delivered as production Q by the economic amplifier (assimilated to the electronic amplifier), by the load resistance R_L from the amplifier output (Figure 1 and Figure 2), U the voltage at the R_L resistance terminals being assimilated to the L factor – which is the workforce – Labor, and I is the value of the output current I_c which is assimilated to the K – which represents the function capital used by the manufacturing unit modeled by the associated economic amplifier.

Finally, in order to complete the econophysics model on the spread and economic effects of the COVID-19 coronavirus, we will use the econophysics model for the mixed economy described by the equation (6) [5].

To limit the spread of COVID-19 coronavirus, large sums of money were spent on the purchase of protective equipment and materials, the building of hospitals, the payment of salaries for an increased number of physicians or other employees in the medical or protection field, the payment of unemployment or technical unemployed benefits, social benefits for medicines etc. As a result, the term G which represents government expenditure, from the equation of economic balance in the case of the mixed economy (which is specific to all countries) has greatly increased, leading to an increase in the I_B current in the case of the economic amplifier (see equation (7)) and thus to an increase in the factor α_{ec} (see equation (11)) and thus to a notable decrease in the economic growth factor:

$$\beta_{ec} = \frac{Y}{I} = \frac{1}{\alpha_{ec}} \quad (18)$$

(see equations (5'), (5,7), thus economic stagnation or even regression, which can only be avoided by avoiding a decrease in labor L and government spending G .

6. Conclusions

In December 2019 and early 2020, the COVID-19 coronavirus pandemic spread rapidly in most countries of the world.

COVID-19's aggressiveness and the rate of propagation of this virus has led most states to take insufficiently substantiated measures which, in addition to beneficial results, have also led to some negative effects, the most important being that of drastically reducing production activities in most economic sectors, increasing unemployment, local food crises and the marked deterioration of the world economy due in particular to the isolation of people at home, blocking borders and banning travel, blocking tourism and trade activities etc.

In order to understand the causes and consequences of such measures and to recommend solutions to limit the negative effects that have arisen as a result of hastily taken measures in most countries of the world, this paper proposes an econophysics model on the economic impact of the COVID-19 pandemic and ways of limiting effects that could adversely influence economic development.

The generalized econophysics model that is proposed and analyzed in this paper is a combination of three other econophysics models related to economic development, namely the economic amplifier model, the econophysics model of the Cobb-Douglas production function and the econophysics model of the mixed economy, all of which are proposed by us in our previous papers.

The analysis made in this paper shows that in order to limit the direct effects of the pandemic with COVID-19, and the effects of economic decline, it is necessary to adopt middle ways, that is to say, in addition to banning activities and manifestations involving large masses of people such as sporting events, grand and outdoor concerts, pilgrimages, religious gatherings, educational activities and the like, to continue public order activities, medical and protective activities, to encourage work at home – where possible – but also the direct productive activities, in particular agricultural or construction activities, as well as other activities in important productive or trade sectors but which are very well protected and endowed with corridors of disinfection and sanitary isolation as is done after the first wave of the COVID-19 pandemic has passed.

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