THE CYBERNETIC SYSTEM OF THE GLOBAL ECONOMY WITH INFLUENCES OF CLIMATE CHANGE ON THE EVOLUTION OF IT

Emil SCARLAT

Bucharest University of Economic Studies, Romania
emilscarlat@ymail.com

Delia BĂLĂCIAN

Bucharest University of Economic Studies, Romania
delia.balacian@gmail.com

Abstract. *The present paper proposes a model of global economy which takes into account the effects of climate change on the evolution of it. The economic processes are developed based on the characteristic of the complex adaptive systems, specifically on the definition of the national economy cybernetic system. Additionally, a strong point of reference is the Dynamic Integrated Model of Climate and Economy (DICE), modelled and developed by William Nordhaus and many collaborators, co-authors and researchers in economics and related fields, having a generous support from Yale University. The instrument used for developing the presented stock – flow diagram is Stella 9.0. The objective of studying the relations between entities and variables in this model is that of understanding how our choices of consumption, our wellbeing and our governmental policies act in the economic system of the world. Day by day, the state of the climate is changing and its effects become more and more visible. The globalization phenomenon has accelerated the pace of change and societies worldwide struggle to adapt in order to survive. Therefore, the difficulty to predict future possible outcomes of policies and behaviours is increasing.*

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1. Introduction

The global economy is characterized by complex economic processes, accelerated flows of information and technology, increasingly broad cultural exchanges and a dynamic that is difficult to predict. Moreover, all these components are tied to the phenomenon of globalization, which strongly influences all the links between the countries involved, but especially the ones referring to climate change. Climate disasters are often caused by extreme phenomena (hurricanes, floods, natural fires, etc.) which tend to have a higher frequency in the last period. Unfortunately, the effects of climate changes target a good part of, if not all of the sectors within an open economy: the evolution of gross domestic product is influenced, as well as of the investments, the levels of exports and imports are affected in a positive way, the population consumption fluctuates and the contribution of taxes to the national budget changes. Therefore, modelling a system composed of representative variables for all of these elements results in complex interdependencies that are difficult to quantify and predict. For this reason, the modelling of the economic system and the climate system started on separate paths. Then, the research community came with initiatives aimed at integrating climate-specific modules into the global economy. In addition, the complexity of the systems imposes limitations for each model and the clear hypotheses that present the framework of the model.

1.1. Climate Change

The effects of long-term climate change and under normal, unmodified conditions include changes in temperatures, weather and land use [1], [2].

First of all, it is expected that the heating will be more pronounced on the surface of the earth than on the surface of the water and in the area of the poles. It is expected for long-term heating to increase, adding more greenhouse gas emissions to the already accumulated volume. Also, the heating is more accentuated during the winter than in the summer and at night than during the day. In general, climate models developed by specialists confirm these trends.

Secondly, it is expected that in some areas there will be intensified rainfall and in others less. In this regard, climate models do not reach a common conclusion because geographical positioning has a strong influence: subtropical areas will become drier and areas with higher latitude will have increased humidity, which means that in the south hemisphere rainfall will occur more often over the seas; in temperate areas, winters will have high humidity and summers will be drier. In any case, changes in precipitation tend to become more significant over time, but the possibility of a reverse evolution is not excluded. As it warms, precipitation tends to become more intense, with considerable rainfall between periods of drought. Moreover, the storms will become more intense all over the globe and the maximum wind speed is likely to increase, but there is no indication that their frequency will be higher or that their formation area will increase [2].

Thirdly, sea level will increase because heated water increases its volume. Although this phenomenon cannot be observed in everyday life, it exists, and in the context where the ocean has an average depth of three kilometres, a water expansion of 0.01% causes a sea level rise of 30 centimetres [2]. During the 21st century, the sea level will increase with a height between 10 and 33 centimetres due to the thermal expansion. To this is added the increase of 4 - 23 centimetres caused by the melting of glaciers.

The effects of climate change cover a wide range of diverse implications, which are manifested locally, nationally and globally. These consequences vary in nature and include: economic (climate impacts agriculture and changes are required from entrepreneurs, who need to rethink processes in the food industry, redefine the functioning of the national and international trade, but also of public administration), demographic (population migration to more economically advantageous areas and offering a higher standard of living, which can cause destabilization of economic centres and abandonment of unpopular geographical areas), sociological (the need to inform people about the changes occurred, finding ways to attract them towards a sustainable responsible living and getting them accustomed to certain restrictions) and others. However, the biggest risk that leaders face is the safety of citizens, which is questioned in case of changing the climatic conditions of a certain area, as explained in the previous paragraphs.

1.2. The phenomenon of globalization

Globalization is a term with wide coverage which refers to the process by which many communities, from all areas of the world, develop connections and thus have similar experiences from an economic, social, political and cultural point of view. In other words, the phenomenon of globalization describes the interaction and integration of entities within the population, companies and governments belonging to different countries. On one hand, international trade and investments are the main tools for controlling the phenomenon of globalization, being supported by information technology. On the other hand, globalization has effects on the environment, the culture of a people, the political systems of the countries involved and on the economic development, implicitly, on the prosperity of the citizens and their standard of living.

The phenomenon of globalization has not brought benefits for everyone. The evolution of the industrial technologies, the fragmentation of the industries and the economic policies of the governors are contributing factors to the differences between those who benefit from globalization and those affected by this process. Many relevant examples can be found in the field of production, especially of technological products. One such case is Apple computers, which, although considered to be American products, they are mainly tested and manufactured in China, and in the United States only the final assembly of Macintosh products takes place. Then, General Motors and Ford, American car brands, are only partially assembled in the United States, and subassemblies are imported from Mexico, Germany, Brazil, Argentina, and other countries [3]. Thus, there is a segmentation of jobs between countries based on their economic activities.

Globalization has considerable advantages for some of the world's countries. It supports capitalism and encourages consumption among the population by intensifying international trade activities. Through them, economic, cultural and technological exchanges are carried out. Economic exchanges involve trade in goods, products originating in each country or region, but more importantly, trade in raw materials such as natural gas, crude oil, gold, diamonds, precious stones, minerals and so on. The latter are, in fact, natural resources with high strategy value because they are found in a limited quantity, smaller or larger, and cannot be obtained by technological processes, but only extracted and used as efficiently as possible.

Cultural exchanges refer to the transfer of innovative ideas, specialized knowledge and the talent each individual has. The effects of globalization, of the existence of a continuous exchange between countries at all social levels, can be observed when the person changes his/her residence in another country due to changing the place of work or to the desire to form a family nucleus in a stable, convenient place for both partners.

Technological exchanges may have the same strategic importance as economic ones, with the difference that they consist of information and data flows, which facilitate the emergence of innovations in each country. Through the migration of the labour force, accentuated by globalization, there is also an exchange of ideas, of knowledge accumulated by the respective professionals.

2. Redefining the Complex Adaptive System of the National Economy

The model designed in this paper presents the global economy as a complex adaptive system, to which are added representative variables for the climate state. It is considered that the latter is influenced by regulations and measures adopted from an economic point of view, such as carbon tax, subsidies for "green" technologies or penalizing agents that exceed the level of emissions allowed.

The development of the global economy system started from the description of the national economy [4], which comprises six interdependent subsystems and which, as well unite other subsystems. These subsystems of the national economy are: the household system, the business sector, the government (public) sector and the external sector. The climate is represented here by means of representative variables, which can be further developed based on in-depth knowledge of the geophysical mechanisms between climate, atmosphere, land surface and oceans.

3. The Model of the Global Economy with Climate Influences

The household system links to the market of goods and services through the consumption function, implicitly through per capita consumption. The consumption is influenced by every individual's preference, actually represented by the elasticity of the marginal utility of consumption (α) and social time preference parameter (ρ).

Social welfare is considered representative for households as it captures the standard of living of the population and thus it can be observed the connection between the lifestyle of an individual and the effects of his consumption choices, which have an impact on the climate. Specifically, a better standard of living implies a comfortable income for the individual, which will lead to more sustainable choices because the consumer has the opportunity to choose from a wider range of goods and services.

By means of the optimal utility method of economic growth theory, social welfare is defined as the present value of consumption per capita, under the effect of population weight [5].

Figure 1. The Model of Global Economy with Climate Change Influences

$$W = \sum_{t=1}^{Tmax} U[c_t, L_t] R_t \quad (1)$$

Equation (1) presents the method of calculating social welfare (W), where c is per capita consumption, L is population and R is the discounted value rate.

Further, U [] can be defined according to the equation:

$$U[[c_t, L_t]] = L_t [c_t^{1-\alpha} / (1 - \alpha)] \quad (2)$$

where α is the elasticity of the marginal utility of consumption, which is constant and describes the change between different generations. If α is zero, then consumption levels between different generations can be replaced on a large scale. If α is greater than zero, the consumption levels between the different generations are not gradually replaced [5].

R_t , the discounted rate, can be estimated by the formula:

$$R_t = (1 + \rho)^{-1} \quad (3)$$

where ρ represents the preference for social time, which gives different weights to different generations through (3). If the value of ρ is small, then the future utility is more important than the present one. If ρ is zero, then utilities between different generations are equally important.

At present, modelling climate protection involves a real discussion about the value of this parameter ρ because determining its value implies the ethics that the economist has in relation to this subject. This is also the case when determining whether a person's future consumption levels are as important as those present, a topic discussed by Nordhaus and Stern [5].

In 2007, Nordhaus argued that the value of ρ should be 0.015 to estimate the practical experiments, while Stern claimed that ρ should be 0.001, supporting the idea that future levels of consumption are as important as the present. This value is close to zero, which allows the future utility to be updated and thus estimating the impact of climate change on the welfare of the present can be overestimated [5].

Another essential element that we must analyse in the context of climate change is the *global population*, more precisely the growth rate of the inhabitants of planet Earth. The equation for the global population level at any given time is:

$$Population_t = Population_{t-1} * (Birth Rate_{t-1} - Death Rate_{t-1})$$

In March 2020 there are 7.8 billion people worldwide, the birth rate has been steadily declining since the 1990s (in 2017 the rate of new-borns is 1.85% worldwide [6]), as well as the mortality rate (in 2017, this rate is 0.75% [7]). The evolution of the population influences the economy by generating government expenditures for ensuring shelter and basic care, by changing the consumption trend and the level of taxes to the local and national budgets, while being closely monitored so as future generations benefit of proper care: the benefit of a pension, the existence of medical insurance, the existence of institutions dedicated to the care of the elderly, etc.

Moreover, the population influences a very important strategic sector for the economy of any country: *the energy sector* [8]. The rate of energy consumption of the population, but also the type of energy it encourages, have direct effects on climate change by generating greenhouse gas emissions, especially those of carbon dioxide.

The model includes a rate of energy consumption, calculated in relation to the population at that time. It does not take into account the different forms of production of each type of energy, but it can be developed in future research based on solid information about the ways in which the emissions of harmful gases are generated to the climate. For example, France mostly uses low-emission nuclear power, as opposed to burning fossil fuels, widely used in China or the United States, which is a major contributor to the amount of greenhouse gas emissions. precisely 31% of global fossil fuel consumption is attributed to the Chinese population [9]. Hence, it is given a rate of energy consumption based on the population and the global consumption. This value can be given as an input in the model by analysing historical data of the countries. The consumption of energy per capita is another variable which results from the multiplication of a given starting value (an average value from past decades, a value from a reference year, etc.) and the energy consumption rate.

The global economy is represented by the gross domestic product per capita, which in turn is influenced by a rate of GDP evolution, given as an exogenous variable in the model, previously determined.

The effects of climate change are highlighted by the amount of greenhouse gas emissions from the atmosphere and the temperature they add to the present value. The model highlights the factors that contribute to the accumulation of emissions (global GDP per capita, the amount of emissions already accumulated, energy consumption per capita), but also a variable with control role. The emission control rate (ECR) represents the effect of the measures taken from an administrative point of view, influencing the evolution of the economy in the long term. In other words, it is an "indicator" of policies adopted by world leaders to improve the effects of climate change. The parameter σ (sigma) represents the ratio of emissions generated per dollar of GDP value. Both mentioned parameters are adjustable. Thus, the equation by which we estimate the quantity of emissions is the following [5], [8], [10]:

$$\text{Level of Emissions}_t = \sigma * (1 - ECR) * GDP_t \quad (4)$$

It is expected that σ will decrease with time based on the current tendency to continually optimize the efficiency of the economy, implicitly that of the industry, by which we will generate less harmful emissions for every dollar produced in goods and/or services. This approach is highly likely to happen because we have made significant progress in the past. Then, the emission control rate takes values from 0 to 1, where zero means that the adopted policy is one that does nothing to reduce emissions and one signifies the adoption of a policy where the efforts to reduce emissions are maximum. It is worth mentioning that in the latter case ($ECR = 1$) the result of the above equation is zero, meaning that there would be no harmful emissions at all, not even those from the burning of fossil fuels [10]. This is a parameter that lends itself to modeling in the form of increasing function, assuming that over time, governments will be more inclined to adopt more responsible and stricter policies towards climate change.

4. Conclusion

Globalization influences our daily lives more than we imagined. It may seem surprising, but every aspect of our lives is influenced by this continuous process by which goods of all kinds (food, furniture, medicines, clothing, tools, tools, etc.), information (news, ideologies, theories, innovations, software, etc.), data (financial, geographical, demographic, etc.), even masses of people are moving and communicating with the external environment. Certainly, the Internet has facilitated these exchanges and together marked the beginning of a new era, one with great benefits, but also with hurtful costs caused by greedy and irresponsible human actions.

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