

## Original Paper

# Oscillating Economic Sphere: Sustainable Limits of the Biosphere in the Face of Climate Change

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### **Abstract**

*This paper proposes a new geometric model to facilitate the understanding of the complex interaction between the economic system and the limits of the biosphere. The concept of the oscillating economic sphere is based on a central parameter of the economy, the Gross Domestic Product (GDP). In the model a hypothetical sphere was built, in which its radius ( $r_e$ ) corresponds to the world GDP (economic sphere), and another hypothetical sphere with radius ( $r_b$ ) is also introduced to represent the size of the biosphere (sphere of life), on this geometric construction, these spheres are concentric ( $r_b > r_e$ ). Therefore, an expansion of the economic sphere will occupy the biosphere, since the fundamentals of economy predict unlimited growth of GDP. Thus we will have a limit to be reached because the biophysical forces oppose this expansion, creating harmful environmental effects such as climate change.*

### **Keywords**

*economy, climate change, biosphere, oscillating sphere, sustainability, cooperation*

### **1. Introduction**

The challenges presented by the environment generate debates and scenarios on future directions of the civilizing process. Several scientific articles discuss the limits of economic growth and the tolerable

limits of the biosphere (Meadows et al., 1992; Wackernagel et al., 2002; Haberl et al., 2007; Rockstrom et al., 2009a; Rockstrom, 2009b; Running, 2012; Biermann, 2012; Steffen et al., 2015; Smith et al., 2016; Tian et al., 2016). Authors like Rockstrom J. et al. (Haberl et al., 2007; Rockstrom et al., 2009a) identified some processes as the planetary boundaries. Among them, climate change is the most impactful for society, environment and biodiversity (Hansen et al., 2008; IPCC, 2013; Trenberth et al., 2015; Matless, 2016; Seddon et al., 2016).

The Earth's environment experienced long period (age) of stability in the last 12,000 years, known to geologists as the period "Holocene", in which the planet was able to attenuate smoothly external and internal disturbances of the biosphere. Since the industrial revolution, the intensive use of fossil fuels, industrialization, and the expansion of agriculture, population growth and increased consumption of natural resources are threatening the stability hitherto experienced by the planet. In view of this finding, Crutzen and Stoermer (Crutzen & Stoermer, 2000; Crutzen, 2002) propose a new concept for this period of major changes since the industrial revolution, the "Anthropocene". This term suggests that human society as whole is changing a geological variable, the "climate". The result can be irreversible and, in some cases, these sudden changes in the environment could lead to serious changes in the biosphere, making it difficult to human survival.

The Stern (2006) report already simulated and accounted for the losses that the world economic system would suffer from global climate change. These changes were also highlighted in the Intergovernmental Panel on Climate Change (IPCC) report in early 2007 (IPCC, 2013). The publication of this report has produced an international discussion about such changes on scientific, economic and political level and it was featured in the mainstream media. The issue was discussed in major international economic forums and seemed to be one of the factors that could influence the economic direction of the XXI century. However, since the economic crisis (Campello et al., 2010; Uslaner, 2010) on 2008/2009, this scenario was modified, with decreased perception of environmental problems, as the focus shifted to the economy and its crisis. The environment has become a secondary issue and international climate agreements have faced failures since then. To exemplify, we can mention the attempts of a new climate agreement to replace the Kyoto one (Kutney, 2014; Helm, 2012).

The twenty-first century will have as a central challenge the understanding of the complex relationships between environmental and energetic issues and their consequences for the global economic system, bringing important questionings to the intricate geopolitical relations between nations. Economic, environmental and energy crises are intrinsically related to each other, and have no separate solutions (Georgescu-Roegen, 1995; Sthel, Tostes, & Tavares, 2013; Grubb, 2014; Cambridge Econometrics, 2016), that is, they must be treated with a systemic view. In an effort to understand the complex environmental issues that permeate modern society, Sthel and Tostes proposed in 2012/2013 a simple geometric model entitled "Sustainable Complex Triangular Cells" (SCTC) (Sthel & Tostes, 2012; Sthel et al., 2013) for easy viewing of important concepts, using geometry. The model proposes to represent the area of a triangle as the individual ecological footprint and the letter E is placed in each of its

vertices, representing the three crises of today (economic, energy and environmental), which have no separate solutions. Now the authors offer a new geometric model: the “Oscillating Economic Sphere” (OES), with the purpose to facilitate the understanding of complex environmental issues, considering that the current choices may cause extremely damaging impacts for future generations. Therefore, the limits of the biosphere are being discussed facing the expansion of the economic system that, forty years ago, seemed unlimited. From there on, the civilizational conflict between society and environment unfolds. The geometric model of the oscillating sphere will use the concept of anthrosphere (human domain) (Quilley, 2001; Marzluff et al., 2008), adopting only the economic aspect of human society. This will be represented in the model by a hypothetical sphere with radius ( $r_e$ ). This sphere is the world economy, defined as the sum of the GDP (Gross Domestic Product) of all countries. Another hypothetical sphere with radius ( $r_b$ ) will be used to represent the approximate size (~ 20 Km) of the Biosphere (Vernadsky, 1998; Bridgewater, 2002; Common & Stagl, 2005; National Geographic, 2017), where all planetary life is inserted between the ocean depths up to the top of the troposphere, its size is less than 0.4% of the Earth’s radius (6400 km). These spheres are concentric, and the global economic sphere is contained inside the biosphere ( $r_b > r_e$ ). The model will represent the conflict between the tendencies of unlimited economic growth (expansion of the economic sphere) and the biophysical forces opposed to this trend that are a response of the biosphere.

The  $r_b$  and  $r_e$  rays have different units. The  $r_b$  is the extension of the biosphere (units in Km) while  $r_e$  is the GDP value of all countries (units in dollars). What seems inconsistent, because these variables do not have the same units and are juxtaposed because by geometric construction the rays are collinear. The interaction between these variables presents here only a symbolic character (geometric model) to facilitate the visualization of the conflict between economic growth (GDP) x biosphere. An example can illustrate this assertion in Brazil, in the case of deforestation in the southern Amazon forest (rich in biodiversity, climate control and large carbon stock). Where large-scale economic activities with agriculture (soybeans) and livestock rising have greatly expanded Brazilian GDP. As consequence, this forest has been violently deforested and burned, which reduces the Brazilian Amazonian biosphere extension. These environmental impacts are reported in several scientific studies (Vieira et al., 2008; Fearnside et al., 2009; Costa & Pires, 2010; Aldrich et al., 2012; Coe et al., 2013; Balch, 2014; Berenguer et al., 2014; Godar et al., 2014; Ferreira et al., 2014; Lapola et al., 2014; Gibbs et al., 2015; Khanna et al., 2017; Chambers & Artaxo, 2017).

So if we consider all global environmental aggressions (all countries) that are produced to maintain world GDP growth, we will have a consequence of reducing the extent of the global biosphere ( $r_b$ ). Therefore, these variables are used in a comparative way to facilitate the perception of the reduction of the global biosphere ( $r_b$ ) that is linked to the growth of economic activities, GDP ( $r_e$ ). The use of geometry facilitates the perception of complex environmental issues by non-scientific public, and can be used for environmental education. The objective of this study was to evaluate one of the planetary boundaries, i.e., “Climate Change”. Aware of the importance of other limits discussed by Rockstrom et

al. (2009a) and Rockstrom et al. (2009b), when there is a great economic growth.

## 2. Planetary Boundaries and Global Change

The planetary boundaries are more visible in the XXI century and can compromise dramatically the sustainability of life. Rockstrom et al. (2009a) claim:

*“We have found nine such processes for which we believe it is necessary to define planetary boundaries: Climate change; rate biodiversity loss: interference with the nitrogen and phosphorous cycles; stratospheric ozone depletion; ocean acidification; global fresh-water use; change in land use; chemical pollution; atmosphere aerosol loading”.*

Three of these processes have transgressed the planetary boundaries. They are: climate change, changes in the nitrogen cycle, and biodiversity loss. The social impact depended on the resilience of affected societies. The proposed concept of “planetary boundaries” lays the foundation for shifting our approach to governance and management away from the essentially sectorial analysis of limits to growth. The planetary boundaries ensure that major environmental changes caused by humans on a global scale are avoided. Lenton et al. (2008) reported large-scale phenomena, such as the collapse of the thermohaline circulation of the Atlantic, the drastic reduction of the Amazon rainforest, and the melting of the ice sheet of Greenland. Barry et al. (2013) reported that the scientific concept of tipping points and political implications have attracted the interest of the international scientific area. On terrestrial biosphere, tipping points involve attributes of ecosystems (Barnosky et al., 2012), such as species abundance or carbon sequestration, as a non-linear and potentially irreversible response to a loss of habitat and a severe environmental impact.

The anthropocene started, as suggested Crutzen and Stoermer, during the Industrial Revolution, with a dramatic increase in air pollution, which has led to serious environmental problems. They report that:

*“The rapid expansion of mankind in numbers and per capita exploitation of Earth’s resources has continued apace. During the past three centuries, the human population has increased tenfold to more than 6 billion and is expected to reach 10 billion in this century. Fossil-fuel burning and agriculture have caused substantial increases in the concentrations of ‘greenhouse’ gases”.*

The industrial revolution introduced sudden changes in man’s relationship with nature. The large-scale expansion of energy and natural resources consumption has led many authors to question this unlimited economic development model, which has led to dangerous global changes. According to Steffen et al. (2007):

*“We use the term global change to mean both the biophysical and the socioeconomic changes that are altering the structure and the functioning of the Earth System. Global change includes alterations in a wide range of global-scale phenomena: land use and land cover, urbanisation, globalisation, coastal ecosystems, atmospheric composition, riverine flow, nitrogen cycle, carbon cycle, physical climate, marine food chains, biological diversity, population, economy, resource use, energy, transport, communication, and so on. Interactions and linkages between the various changes listed above are also*

*part of global change and are just as important as the individual changes themselves. Many components of global change do not occur in linear fashion but rather show strong nonlinearities”.*

Global changes will certainly be one of the great conflicts of the twenty-first century (society x nature). How to maintain the technological achievements that brought comfort and convenience to human activities without affecting so dramatically the climate? We emphasize the conference on climate change that was held in Copenhagen in 2009 (UNCCC, 2009). “This included the long-term goal of limiting the maximum global average temperature increase to no more than 2 °C above pre-industrial levels”. Global mean temperature increases up to 2 °C are likely to allow adaptation to climate change (Huntingford et al., 2012; Rogelj et al., 2013; Victor & Kennel, 2014; Tollefson, 2015) for many human systems at globally acceptable economics, social and environmental costs. Increases greater than 2 °C could result in an increasingly costly adaptation, considerable impacts that exceed the adaptive capacity of many systems and an increasing and unacceptable high risk in what regards large scale irreversible effects; drought and flooding are the best examples of extreme events, which generate multiple effects like: food and water shortage, loss of cultivated areas, devastation of urbanized areas in the coastal zones, migration of the populations, regional conflicts and political instability in some of the most “volatile” regions of the world. On December 12, 2015, 195 member countries of the United Nations Framework Convention on Climate Change (UNFCCC) met to conduct the Conference of the Parties (COP21) (UN, 2015; Tollefson & Weiss, 2015). The agreement stipulates that the signatory countries must act to ensure that the planet’s average temperature does not reach 2 °C above pre-industrial levels (Fawcett et al., 2015), seeking to limit the temperature (Hulme, 2016) rise to 1.5 °C. Rich countries have pledged to spend \$ 100 billion a year in developing countries between 2020 and 2025. The agreement also provides that, from 2023, the countries will meet every 5 years to negotiate the extension of emissions cuts.

### 3. Economic Oscillating Sphere: Sustainable Biosphere Limits

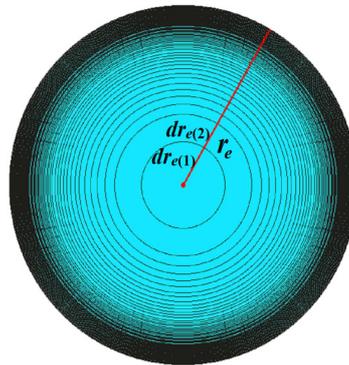
#### 3.1 The Economic Sphere

Several planetary limits pointed out by several authors can lead to extremely harmful tipping points, this century. The consequences are not fully known, but certainly impact drastically the sustainability of the planet. Facing the serious situation, we propose in this paper a simple geometric model that can make it easier to understand (display) these complex environmental issues that challenge human society in the twenty-first century. We will use the concept of anthroposphere (human domain) in which we only evaluate the economic aspect of anthroposphere, i.e., the global economic sphere. We define the radius  $r_e$  of this sphere as the world/annual GDP, i.e., the sum of annual  $GDP_i$  of all  $N$  countries of the world, where  $GDP_i$  is the annual GDP of  $i$ -th country. We symbolize  $GDP_i$  as a line segment of  $dr_{e(i)}$  radius ( $GDP_i = dr_{e(i)}$ ). The world / annual GDP of  $N$  countries are given by:

$$r_e = \sum_{i=1}^N dr_{e(i)} \quad (1)$$

The radius sector  $dr_{e(i)}$  is proportional to the value of annual  $GDP_i$  of individual countries. Then, the

largest  $dr_{e(i)}$  represent countries with highest annual  $GDP_i$ . Figure 1 illustrates geometric representation of  $GDP_i$ , where  $dr_{e(1)} \geq dr_{e(i)}$  for  $I > 1$ .



**Figure 1. Geometric Representation of  $GDP_i$  of the World Countries**

Countries with the biggest  $GDP_i$  would be closer to the geometric center of the economic sphere. In this case, the United States would occupy the center. Other countries would be placed sequentially in decreasing order of their  $GDP_i$  in relation to the United States. Thus, the poorest countries are arranged in the rim of the economic sphere. This distribution rule of  $dr_c$  along the radius  $r_c$  reproduces the economic status of today’s nations: central countries (rich) and peripheral countries (poor).

This model can also be employed with other major economic indicators, for example, country’s energy consumption, which  $dr_c$  is considered proportional to the power consumption of each country. Another important indicator that could be applied to the model is the *per capita* income of the countries, so that  $dr_c$  is proportional to the *per capita* income of each country. These new indicators will clearly change the rules of distribution of countries along the radius  $r_c$ . The United States, for example, have the highest world  $GDP_i$ , but do not have the highest per capita income.

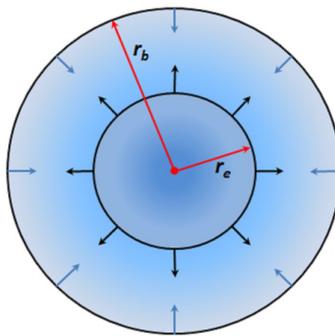
Another important indicator is the carbon footprint, that is, the  $CO_2$  equivalent emissions/year (Gt) of each country, that could, also, be disposed within the “carbon sphere”, by using a geometrical representation similar to the proposed for other indicators. Countries with the largest  $GDP_i$  have, in general, the largest emissions of  $CO_2$ /year, mainly due to the degree of industrialization and intensive fossil fuel consumption.

**4. Biosphere x Economic Sphere**

The term “biosphere” was coined by the geologist Eduard Suess in 1875 (Suess, 1875), which he defined as: “The place on Earth’s surface where life dwells. Our biosphere is the global sum of all ecosystems. It can also be called the zone of life on Earth, a closed (energetic flux of solar and cosmic radiation and practically no loss of terrestrial mass) and self-regulating system. From the broadest biological point of view, the biosphere is the global ecological system integrating all living beings and their relationships, including their interaction with the elements of the lithosphere, hydrosphere and

atmosphere”.

In the proposed geometric model, we have ( $r_b > r_e$ ) where  $r_b$  is the radius of the biosphere,  $r_e$  is the radius of the economic sphere and the spheres are concentric. We can then conclude that all growth in economic sphere (world GDP) will result in a reduction of free volume of the biosphere (Figure 2). The dynamics of the biosphere is based on ecosystem feedback loops, which are channels where the nutrients are always recycled, living organisms are open systems and generate waste that will be used by other organisms (life cycle). Therefore, the fundamental pattern of life is a network pattern, where there is a predominance of relations between the ecological community organizations, which are non-linear and involves many feedback loops. Levin (1998, 2005, 2006) and Anand et al. (2010) indicate that ecosystems are complex, adaptive systems and Keller (2005) proposes that the biosphere is the result of a self-organization process with a serious implication for the management of the biosphere itself, as it is necessary to preserve the services of these ecosystems. The man is extremely dependent on this preservation.



**Figure 2. Biosphere and the Growth of the Economic Sphere**

The interactions of men with natural systems generate highly complex patterns. According to Liu et al. (2007):

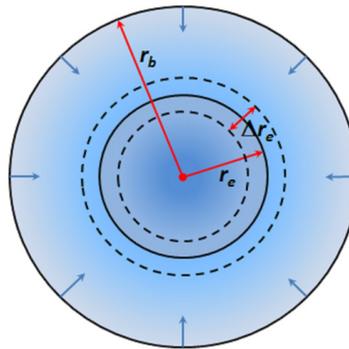
*“The complexity of coupling between human and natural system has always been present since the dawn of human society. Therefore, from the first hominids to the appearance of the genus homo, a set of complex interactions with the biophysical environment of the planet has always existed”.*

The interactions of economic activities with natural ecosystems are dynamic and complex processes. According to Limburg et al. (2002):

*“Ecological and economic systems share many characteristics. Both are complex networks of component parts linked by dynamic processes. Both contain interacting biotic and abiotic components, and are open to exchanges across their boundaries. Just what constitutes an ecosystem is somewhat arbitrary, and depends on how the system boundaries are drawn by the observer. Similarly, economic systems have boundaries that expand and contract”.*

The geometric model of concentric spheres ( $r_b > r_e$ ) represents the dynamic process of economic growth and its cycles of expansion and contraction of the world economy. The growth of the radius  $r_e$

indicates a worldwide economic expansion and the reduction of  $r_e$  indicate a contraction of world economy. Therefore, the global economic sphere ( $r_e$ ) oscillates around an average position of the sphere limited by  $r_e$  radius. The amplitude variation ( $r_e$ ) shows the variation of global GDP over the years (Figure 3), and the direction indicates if there is an economic expansion or contraction. There is a tension within the limits of the economic sphere (expansion and contraction cycles), for the biosphere, through biophysical effects (Smith et al., 2016; Bisaro & Hinkel, 2016; Fenichel et al., 2016), tends to resist to exceed its limits. If there is an increase in global average temperature above 2 °C, for example, it can generate extreme weather events, which would dramatically reduce the global GDP. That is, it results in a sharp contraction of the economic sphere. This negative variation (economic degrowth) could lead to very serious economic and social crises.



**Figure 3. The Global Oscillating Economic Sphere around an Average Position Value of World GDP**

Currently, we have a perception that this oscillation will not depend only on economic parameters, but also on systematic assessments of the environmental impacts caused by climate change. In the attempt to balance the tensions between these radiuses, we could move forward in conceptual terms and reach a new human development paradigm. To achieve it, we have to define the concept of GDP; thus environmental costs must be internalized in order to guarantee a socio-environmental sustainability, setting a new economic paradigm that takes into account the improvement in income distribution, quality of life and environmental sustainability (Costanza et al., 2014; Coyle, 2016). Nowadays, with the development of the Internet, there is a tendency to connect everything to everyone in a large efficient global network that generates goods and services at increasingly lower costs, leading to a range of collaborative access to common goods. Another important aspect to be pointed out is the rising of the hybrid economy (composed by a market economy and by a share-based economy) (Heinrichs, 2013; Richardson, 2015; Martin, 2016). It may be understood as a consequence of the massive internet usage, enhancing the human cooperative behavior. Then, the following question must be answered: Would such trend contribute to environmental sustainability?

The model of the oscillating sphere proposed here helps to visualize geometrically the conflict between

the economic sphere and the biosphere as the biophysical forces will act to modulate the amplitude of the economic radius  $r_e$ . A geometric representation facilitates the perception of this conflict. In the future, facing exceeding dangerous tipping points, can we maintain the activities of the economic sphere or would a great sphere contraction lead to a collapse of civilization? The biosphere will not negotiate with the man exceeding the biophysical limits. Thus, it would be better if there was a rapid negotiation between us in order to avoid that these limits are reached.

Recently we had an example in the American economy that can illustrate this discussion. US GDP<sub>i</sub> has declined 2.9% in the first quarter of 2014 according to data from US Department of Commerce (Bureau of Economic Analysis) (BEA, 2015), shown in Figure 4. Part of this decline has been computed to the harsh winter of 2014, which reduced economic activity (The Washington Post, 2015; Daily Mail, 2015) from January to March. The bad weather caused factories to shut down, reduced the construction of buildings, the movement of trains, trucks, airplanes, and even moved away consumers from trade. Several scientific articles (Duarte et al., 2012; Cohen et al., 2013; Palmer, 2014; Screen, 2014) reports that the global warming is influencing the generation of these harsh winters in the US in recent years, indicating that the loss of ice in the Arctic may be the cause of this phenomenon. This is an example of drop in GDP<sub>i</sub> in the richest nation on earth, that is, small contraction of the economic sphere, in this case restricted to one country. Such falls can occur and impact wider parts of the world, generating large contractions of the economic sphere, with a sharp fall of world GDP (Biosphere limits are exceeded).

The distribution model of countries individualized GDP<sub>i</sub> disposed as segment  $dr_e$  took us to a geometric construction where the countries closest to the sphere center (core countries) have larger GDP<sub>i</sub> and countries on the periphery of the sphere (peripheral countries) have minor GDP<sub>i</sub>. The destruction caused by hurricanes is higher in poorer countries (peripheral) than in rich countries (central). The geometric construction of the model illustrated in Figures 1 and 2 facilitates the visualization (perception) of this fact, because the contractions of the economic sphere are primarily felt in the periphery. In the last decade, extreme events occurred in peripheral countries (most vulnerable to climate change), causing serious socio-economic impacts. Several authors' point (Mendelsohn et al., 2012; Kang & Elsner, 2012; Emanuel, 2013; Noy, 2016) that, probably, tropical cyclones in the past decade have been intensified by the Pacific Ocean warming due to climate change. Examples are the cyclone Nagris (Rao et al., 2013; The Guardian, 2016) that hit Myanmar, killing more than 130.000 people in 2008, leaving behind a devastated economy and Haiyan drilling (The Guardian, 2016; Schiermeier, 2016), which reached the Philippines, killing over 5000 people in 2013.

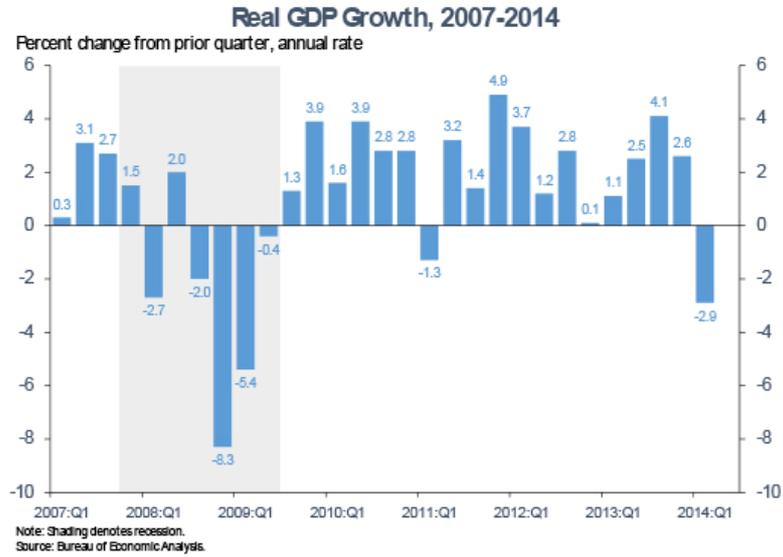


Figure 4. Change in US GDP<sub>t</sub> from 2007 to 2014

Another example of extreme event (climate change) in peripheral country was the drought in Syria from 2007 to 2010. In a recent article, Kelley et al. (2015) reported the event as a possible trigger for the start of the Civil War in this country in 2011. This event has amplified a serious problem to core countries today: the significant increase in the number of refugees (Wendle, 2015) in the countries of Europe. We assess this as a positive feedback effect, since climate change is generated by greenhouse gases emitted in greater amounts by the central countries. Climate changes caused the terrible drought in Syria (periphery), which led to civil war and possibly the increase in the number of refugees that economically impact the core countries. This may be nominated as a boomerang effect (positive feedback), which can also be viewed by the sphere model, as countries are represented by continuous spherical shells. That is, the core countries are connected to the peripherals, as evidenced in this episode of civil war in Syria. The conflict economy-environment will be a strong presence in the history of the XXI Century.

**5. Competition or Cooperation: Economic and Environmental Challenges**

Is it possible to propose the construction of a more harmonious relationship between the economy and the environment, with a control of the amplitude of the oscillation of the economic sphere, still contemplating the economic growth? Using a material (economic) point of view and, supposedly, still within the current competitive economic paradigm, a seemingly convincing answer to the question would be yes. This would be possible with the use of sustainable technologies, seeking a low-carbon economy in order to offset the biophysical effects, which try to restrain the economic sphere. Or, in an actually feasible way, we would have to change the paradigm for a new era of human cooperation, with profound changes in the capitalist centered-economic model and attempt to build a low-carbon economy.

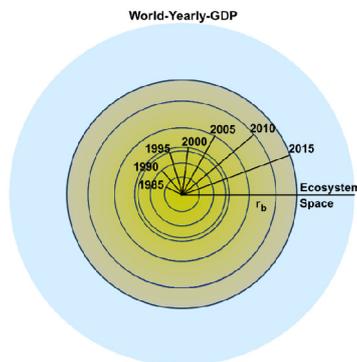
Emphasizing: within the capitalist economic model (competition), such negotiation would be extremely difficult, because it conflicts with the unlimited growth paradigms. But if we continue looting natural resources on a large scale, certainly we will reach soon the tipping points. Would it not be more convenient to anticipate measures to ensure a condition of minimum sustainability? This will certainly involve quite complex international negotiation, because it will require a redefinition of paradigmatic pillars of the capitalist system. However, this reset will only be achieved with a new more systemic view, where intense human cooperation (natural resources sharing) is maximized, in addition to an intensive use of low-carbon technology.

Martin Nowak (2012) states that: “*I believe that climate change will force us to enter a new chapter of cooperation*” in his book “Super-Cooperators” and presents several works on the importance of cooperation in the success achieved by certain earlier societies (Fehr & Fischbacher, 2004; Pennisi, 2009; Nowak et al., 2010; Nowak, 2012a; Nowak, 2012b; Mcloone, 2012; Rand & Nowak, 2013). Wilson (2012), in his book “The Social Conquest of Earth” comments that cooperation was the factor responsible for leading us (*Homo sapiens*) to be a successful species in the complex evolutionary game. Today, the radius  $r_e$  represents the economic growth, based on the concept of the macroeconomic variable GDP, which grows sustained by a linear production system, generating a high entropy (waste and pollutants). This has reduced the free volume of the biosphere and has interfered in the occurrence of natural cycles that are essential for the maintenance of planetary life. Can we avoid the disruption of these cycles? We will use mechanisms already employed by our ancestors that anthropologists call “cultural damping” (Kuhn & Stiner, 2006; Barkow, 2006; National Geographic, 2015), which is a behavior of an organized group with a cultural tradition, which serves as a guarantee for obtaining natural resources, increasing the chance of survival of the species in the challenging game of natural selection; in short, a cooperative group (Levin, 2006; Boyd & Richerson, 2009; Zhang et al., 2011; Richerson et al., 2016). This damping is natural to our species. We are already using it when we try to organize international cooperation meetings (Keohane & Victor, 2016), limiting emissions of greenhouse gases, as recently occurred in COP21. That is, we use collective intelligence to try to minimize the advance of climate change.

## 6. Applications of the Oscillating Economic Sphere (OES)

We present the world GDP variation for each five-year span starting from 1985. In addition, the increase in global CO<sub>2</sub> emissions since 1985, the stabilization trend from 2012 on and the variation on global CO<sub>2</sub> since 1976 is also introduced. The possibility of applying the sphere model to global indicators such as CO<sub>2</sub> emissions indicates the versatility of application of this model.

a) Variation of the total world GDP (1985-2015) and countries GDP<sub>*i*</sub> (2013-2015)—World Bank (2016) Figure 5 shows the annual global GDP between the years 1985 and 2015. The economic sphere is expanding since 1985 and has occupied the living space of ecosystems (Biosphere). Which can be easily viewed using the geometric model.



**Figure 5. World GDP Change from 1985 to 2015**

### **b) Change in global CO<sub>2</sub> emissions (Gt)/year between 1985 and 2015—IEA (2016a)**

The IEA (International Energy Agency) recently published reports (IEA, 2016b; IEA, 2016c) which claim that, between 2013 and 2015, global CO<sub>2</sub> emissions stabilized at around 32 Gt/year, as shown in Figure 6 and Figure 7. Using the sphere model to illustrate global CO<sub>2</sub> emissions (Gt)/year, we can notice a decrease in CO<sub>2</sub> emissions from 1980 to 1983, during the oil crisis, and in 2009, during the global economic crisis. These facts indicate the direct coupling of the economy with global emissions. However, in 2015 the global GDP increased about 3% (Figure 6) whereas there was a stabilization of global emissions. For the first time, in 40 years, the IEA notes this effect on global emissions into a global economic growth scenario, denoting a historical decoupling of these parameters. This fact is computed mainly to the efforts of some countries like China, the United States and European Union countries to reduce greenhouse gas emissions in the energy sector. This reduction was due to the increased use of renewable energy (wind and solar) in Europe and China and the search for energy efficiency by the United States (IEA, 2016b; IEA, 2016c). Smith et al. (2016) and Tian et al. (2016) published in 2016 articles discussing the limits of the biosphere and the economic costs of the increase in greenhouse gas emissions for different sectors of human activities. The articles indicated that the growth of greenhouse gas emissions, mainly CO<sub>2</sub> (which grew 40% in relation to the industrial era values), can generate climate impacts that would affect severely the global economy. To ensure that the increase in global average temperature does not reach the 2 °C, the large-scale deployment of “Negative Emissions Technologies” (NETs) is required. Despite the results of the stability of emissions obtained between the years 2013-2015, accompanied by economic growth, the concentrations of atmospheric greenhouse gases still remain high, and heavy use of NETs is needed throughout the XXI century. Is it possible to achieve this target set by the COP21 agreement in the current economic model? The facts show that it is possible to reduce CO<sub>2</sub> emissions if there is political will from the part of the major emitters of carbon. International cooperation is one of the paths that can strengthen these initiatives. Would we be already using the cultural damping mechanism?

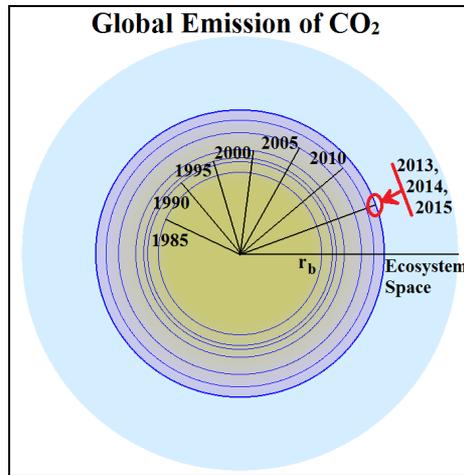


Figure 6. Changes in Global CO<sub>2</sub> Emissions(Gt)/Year between 1985-2015

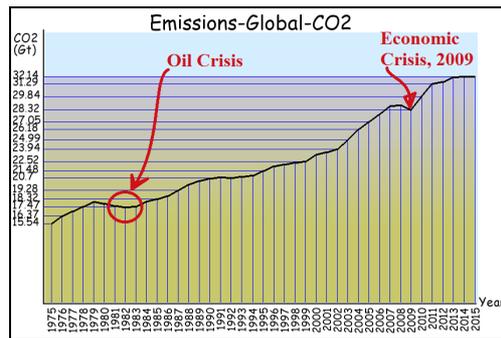


Figure 7. Changes in Global CO<sub>2</sub> Emissions(Gt)/Year between 1975-2015

**7. Conclusion**

The geometric model of the oscillating economic sphere presents itself as a facilitator for the perception of complex environmental problems and their correlation to the current model of the economy. The fall of the US GDP<sub>i</sub> in the winter of 2014 was presented as an example of application of the model. We discussed the possibility of reaching tipping points, which could cause a huge decrease of global GDP, producing a severe global economic crisis, with impacts not yet measured by human society. Biophysical forces that govern the biosphere do not sit at the tables of human negotiations, just act. The environmental deleterious effects appear abruptly to be solved by us, humans, as occurred with hurricanes in peripheral countries and with the civil war in Syria, which led to a refugee crisis in Europe. We need to achieve a strong global cooperation (Wendle, 2015; Rand & Nowak, 2013; Nowak, 2012b; Mcloone, 2012; Wilson, 2012; Keohane & Victor, 2016) in order to maximize our collective intelligence through cultural damping mechanism to tackle climate change.

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