Anthropocenica

Greening the Anthropocene

https://doi.org/10.21814/anthropocenica.4117

Orfeu Bertolami
Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto
Portugal
orfeu.bertolami@fc.up.pt
ORCID: 0000-0002-7672-0560

Abstract
The Anthropocene is a new phase in the development of the planet. The transformations on the Earth System that are already visible in terms of droughts, heat waves, dying oceans, unbreathable air, wildfires, among other disruptive events that are increased by impact of actions that led to the definition of the Anthropocene phase, call for a consistent action in all fronts of human activity. To address effectively the climate crisis requires structural changes in our societies to combat inequalities and asymmetries among the countries. It is increasingly evident that the deep changes that are needed in order to address these problems cannot be carried out in the context of the existing market economy. The crisis asks for a change in paradigm where the focuses are repairing the Earth System and its ecosystem components and endowing societies with means to combat inequalities and being more resilient and sustainable. Historical trends are analysed and local and global approaches are presented and discussed.

Keywords
Anthropocene; Earth System; Anthropocene Equation; Capitalocene; Green Anthropocene; Resilience Social Tax; Planetary Boundary Exchange Unit.

Resumo
O Antropoceno é uma nova fase no desenvolvimento do planeta. As transformações no Sistema Terrestre que já são visíveis em termos de secas, ondas de calor, oceanos moribundos, ar irrespirável, incêndios florestais, entre outros eventos disruptivos que são agravados pelo impacto das ações que levaram à definição da fase do Antropoceno, exigem uma atuação consistente em todas as frentes da atividade humana. Enfrentar efetivamente a crise climática requer mudanças estruturais nas nossas sociedades para combater as desigualdades e assimetrias entre os países. É cada vez mais evidente que as profundas mudanças necessárias para resolver esses problemas não podem ser realizadas no contexto da economia de mercado existente. A crise pede uma mudança de paradigma onde os focos sejam a reparação do Sistema Terrestre e seus componentes ecossistémicos e dotar as sociedades de meios para combater as desigualdades e serem mais resilientes e sustentáveis. Tendências históricas são analisadas e abordagens locais e globais são apresentadas e discutidas.

Palavras-chave
Antropoceno; Sistema Terrestre; Equação do Antropoceno; Capitaloceno; Antropoceno Verde; Resiliência Fiscal Social; Unidade de Troca de Limites Planetários.

Introduction

Evidence based on mitochondrial genetics suggest that between 50 and 100 thousand years ago humans were at the brink of extinction as its population decreased down to less than about 10000 individuals. A plausible explanation is the eruption of the Youngest Toba volcano around 75000 years ago where today is Lake Toba in Sumatra, Indonesia, which triggered a 10 years volcanic winter and possibly a 1000 years long cooling period. The extinction of other mammals has also been observed.

At about 40000 years, four human subspecies existed: *Homo floriensis* at Indonesia; Denisovans at Siberia and Asia; *Homo neanderthalensis* at Western Europe and Asia; *Homo sapiens*, worldwide. Unlike their primate ancestors they did not hyper-specialize themselves to live in any particular environment. Their unique mental skills, developed hundreds of thousands of years earlier, most likely when they left the relative safety of the trees and faced the savannas before them, allowed for the development of tools and networks of trustworthy individuals with whom they could hunt, gather food and materials, and protect their kin. Along with these skills they expanded their capability to communicate and create, word by word, a language and thus a symbolic representation of reality. This remarkable capability allowed humans to remain a single species who could adapt to any environment and somehow break free form the pressure of the natural evolution and converge to a single worldwide sapiens kind, who assimilated the genes and the cultural features from the other human subspecies (Harari, 2011; Arsuaga, 2021).

Sapiens were up to challenge to survive the last glaciation of the periodic glaciations that took place at the Pleistocene (2.6 million till BP). By 12000 years ago, Earth's orbital parameters and its main geological destabilizing forces (plate tectonics and volcano eruptions) have reached a relative equilibrium, allowing for a period of remarkable climatic stability, the Holocene, that started at about 11700 years ago. It is within the Holocene that the humans and the human civilizations greatly thrived and in which the agricultural (Neolitic) revolution took place, more or less simultaneously, throughout the whole planet at several sites about 10 thousand years ago.

From then on humans could choose to abandon their ancestral condition of hunter-gatherer and become a shaper of the environment according to their needs and will. It is likely from hereon that the division of labour started, the differentiation in social skills and capabilities to manipulate complex tools appeared, land ownership gave origin to the first inequalities (Rousseau,1999 [1755]), then to private property and finally to the city-states (Morgan, 1877; Engels, 1990 [1884]).

Human endeavours have evolved to become increasingly complex. Intensification of the division of labour and the growth of population multiplied manifold wealth and the very nature of the human activities. By 1500 human population reached about 500 millions. In Europe, nations, as if woke up from their indistinct obscurity, sailed across the globe in order to break free from their insulation and poverty, putting face to face civilizations that were completely unaware of each others existence. This material urge to achieve wealth from goods found and manufactured elsewhere gave origin to a cultural exchange. This led the need to understand new languages, new forms of government and thinking that has moved philosophy away from the dogmatic scholastics. And this, in turn, brought about new challenges in linguistic, logic (Bod, 2013) and mathematics of practical matters, most particularly for the calculation of financial interests (John Napier published his book on logarithms in 1614 and Jakob Bernoulli discovered the irrational constant, e=2.71281828459045235…, from the calculation of the compound interest in 1687), areas and volumes (a subject very keen to Greek mathematicians of the classical age) and, of course, for navigational purposes.

The publication of Galileo’s *Sidereus Nuncius* in 1610, has open a new avenue for humanity to understand Nature and its workings, and is still very much the tonic of a great deal of the human pursues. Galileo’s stargazing and the logics he used to reach conclusions from his observations, the scientific method has changed humankind for good. In 1687, the publication of Newton’s *Philosophiae Naturalis Principia Mathematica*, set up the basis upon which it was possible to understand the mathematical principles required to grasp the essence of an ever-changing world and generalize it to every particular branch of science. This crucial development had deep implications both for science and philosophy as it gave origin to the concept of a world that followed deterministically invariant laws whose understanding would allow for prediction and organization.

However, despite these remarkable conceptual achievements, at its roots, the world order remained essentially the same till late XVIII century. Wealth was still somewhat static and was thought to result from the conscientious stocking of exchangeable and valuable goods. Land ownership was a supreme form of wealth and working relations were, till late XVIII century generally based on a feudal order that locked the equilibrium of political power in the hands of king-clergy-nobility through ancestral rules and proceedings. By 1600, the rapid expansion of trade and wealth has led to the creation by merchants and nobles of some innovative forms of joint-stock companies such as the East India Company in England and the Dutch East India Company, whose main purpose was to finance expansion of trade and later the profitable trade of slaves from Africa to the flourishing colonies of the New World. Interestingly, somewhat earlier, eastern civilizations, China and Japan, have chosen to close themselves as in their judgment little could be gained otherwise.

The subsequent expansion of trade, commerce, and the swelling of once city-dwellers allowed for the accumulation of enough capital to be reinvested back into production and to acquire human labour creating a new form of production and economy, capitalism. In Britain, the transition to capitalism was boosted by the removal of common rights that people held over farmland and parish commons, the enclosures, leading to an exodus of workers to the urban areas that quickly become manufacturing centres. Similar developments took place in other parts of Northern Europe. Capital, technological advances (the steam engine of Thomas Newcomen appeared in 1712, the more development engine of James Watt in 1775; the general physical principles of functioning all thermal engines were understood by Sadi Carnot in 1824) and the concentration of abundant and cheap labour were the driving forces of the Industrial Revolution from 1760 to 1840 that inspired the so-called economic liberalism, a political and economic ideology based on the pillar concepts of market economy and private property of the means of production. Liberalism is still a strong moral and political philosophy and was brought about by the XVII-XVIII century Age of Enlightenment that sought to replace hereditary privilege, state religion, absolute monarchy and the divine right of kings by representative democracy and by the rule of law. This set of ideas gave origin to two fundamental historical developments, the American and the French Revolutions. The waves created by these revolutions and the sharp contrast between wealth created by capitalism and the material poverty it brought to the vast majority of the workers led to rebellion and revolutionary movements that swept Europe in the mid XIX century. The conflicting interest of capitalists and workers became evident and as well as the way the capitalist economy reshaped cultural, political and social institutions. The increasing accumulation of wealth allowed capitalists to control an increasing amount of labour, including women and children, and to acquire the technical means to create more capital to the point that the question was whether this evolution could be maintained, for how long and under which conditions. The limitation of raw materials was an obvious boundary, but that could be overcome through a widening of the range of sources. After writing with Frederick Engels the *Communist Manifesto* in 1848, Karl Marx published in 1867 the first volume of his *Das Kapital*, where the principles and the fate of the capitalist system at long term was analysed. His main conclusion was that by the very interest of its players, capital has the inevitable tendency to be accumulated without limit in the hand of fewer and fewer capitalists, who eventually would have the monopoly of wealth and the capability to sweep away competition and all political and social mechanisms to regulate their ambitions. This "principle of infinite accumulation" would prevent, according to Marx, any economic equilibrium at long term and would, of course, generalize poverty. Furthermore, the excessive accumulation of capital would curtail competition causing the bankruptcy of unsuccessful businesses, which would work against the very principles of the free market.

The first dooming prediction of Marx did not take place (the second one, poverty, is unquestionable till nowadays). According to liberal economists, the growth of *all* relevant economic variables, production, interests, profit, salaries, capital, and so on, is the natural evolution at advanced stages of economic development, which in turn, leads to a macroeconomic equilibrium. Furthermore, the market forces spontaneously cause inequalities to settle at acceptable levels. Even though, these explanations are hardly better than fairy tales, the fact that capitalism did not collapsed had still to be explained. An insightful solution for Marx's conundrum was put forward by Rosa Luxembourg (Luxembourg, (1951 [1913]), who remarked that through imperialism, in fact the first globalization that took place between 1870 till 1914, European powers greatly expanded the basis of the needed resources to feed their industries and to create new markets, postponing the collapse of the capitalism. Of course, this expansion gave origin to more tension, as the interests of the very powers that divided the "cake" in the XIX century could no longer be put aside, leading to the First World War. Unfortunately, the international political movement of socialist and labour parties embodied then by the Second International (1889-1916) could not prevent the political developments that trapped the world into that deadly conflict. The choice between either socialism or barbarism, as framed by Rosa Luxembourg, is indeed, quite suggestive. In fact, we may be facing a similar dichotomy nowadays in what concerns the mounting climate crisis resulting form the systematic aggressions to the Earth System and the impossibility of further expanding market economy without an inevitable collapse of human civilization (see also Mészáros, 2001). The solution of the current crisis urgently calls for a post-capitalist order.

Nevertheless, despite the terrible tow in lives and destruction, the causes and the economic conflicting interests of the First World War were not resolved and the world fell prey of the political deadlock of three antagonistic political forces: western colonial democracies, nazi-fascism and soviet communism. The Second World War was even more deadly and destructive and changed completely world's geopolitics. From the debris of destruction, two superpowers did emerge: United States, supreme representative of the free market economy and liberal ideology, and communist, state controlled economy, Soviet Union.

In fact, if from one hand, the state controlled economy of the Soviet Union was somewhat a result of Marx's planed economy ideas and some practical adaptations introduced during the pressing years of the Second World War, capitalist economy had by then moved substantially away from its pristine foundational ideas of a free market that could evolve flawlessly with no room for government intervention, to the point of being completely dependent on the regular input of the State capital into the economy. This Keynesian approach (Keynes, 1936) was crucial to rebuilt world's economy after the depression of 1929 and after the Second World War, becoming the prevailing economic doctrine till the rebirth of the liberalism in 1970s.

These two forms of economy, market economy and State planned economy, did mobilize, from 1950s onwards, a considerable amount of resources and labour and greatly accelerated the human activities to the point that changes on the upper crust of the Earth were driven from then on predominantly by the human intervention. This transformation has given origin to a new geological age, the Anthropocene (Crutzen & Stoermer, 2000). Thus, the world nowadays is physically and predominantly shaped by humanity, a world that after the second globalization of 1970s to 1980s, is intertwined by information so that economical and financial transactions do involve the whole planet. A fast changing world where the European Union experiment presents itself as a new economic block, China has emerged as a key global player, the military geopolitical influence of US and Russia is still very visible, but somewhat blurred in a world shattered by huge economical and social inequalities and multiple local interests, that have no coherence, and leave very little room for common ground and universal ideals.

Even though, economic developments do allow for creating huge amounts of wealth, ensuing transformations in politics and society do continuously erode rights and do not cease to generate inequalities. The world population is expected to climb to 9 thousand million in 2050, but the rampant problem of inequality and the seriousness of the climate crisis, suggest that living conditions for most of the populations are expected to deteriorate sharply. In fact, the signs have been visible for decades, but have been minimized for all major economical players. The conclusions of the IPCC Sixth Assessment Report 2021 (IPCC, 2021) are very clear and we mention just a few of them:

> It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred (p. 4);

> Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since the Fifth Assessment Report (AR5) (2014) (p. 8);

> Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level (p. 21).

These conclusions unequivocally suggest that in the next couple of decades, crucial measures will have to be implemented in order to halt the degradation of the environment and the uncontrolled destruction of ecosystems. It is foreseeable that without decisive action major ecological disasters, unstoppable suffering and generalized poverty will follow. The scale of the needed intervention is planet wide and proportional to the extension of the human interference on the Earth System. The world asks for a scientific utopia (Bertolami, 2018) designed to tackle the countless and multidisciplinary problems necessary to repair and revert the damage on the Earth System, avert inequalities and help humankind to built the necessary resilience to face the challenges ahead in order to built strategies for a sustainable future (Gonçalves & Bertolami, 2020; Henry, Rockström, & Stern, 2020).

In what follows we shall discuss the scientific issues associated with the Earth System and how to assess the extent of the impact of the human activity and relate it with the underlying economic issues.

Earth System and the Anthropocene Equation

Attempts to predict the evolution of the relationship between humankind and the environment at long term have been the purpose of well-known classical studies due to, for instance, Malthus (Malthus, 1798) and Pareto (Pareto, 1896-1897). In late 1960s, these issues and, in particular, how human population would evolve given the scarcity of raw materials was the object of detailed discussions of the so-called Club of Rome (Meadows, Meadows, Randers & Behrens, 1972). The impact of the human action on the environment has been the object of several proposals such as the I = PAT measure (Ehrlich & Holdren, 1971), the Kaya identity (Kaya & Yokoburi, 1997) and the well-developed Ecological Footprint proposed in the 1990’s (Rees & Wackernagel, 1994), which since 2003 is being carried out in a systematic way by the Global Footprint Network.

In these quantifications, it is clear that the human activities have a visible impact on the environment through the destruction of ecosystems, widespread pollution, extinction of species, immigration of populations and exhaustion of resources. Early warnings about the dangerous legacy of the economical development are well known (Carson, 1962; Liebmann, 1979), but it was only through the visionary work of James Lovelock (Lovelock, 1995). and subsequent studies by NASA (Liebmann, 1979) that it was understood the intertwined nature of the various Earth’s sub-systems and how they feedback each other through a complex network of interactions. In fact, the report of The Earth System Sciences Committee of NASA Advisory Council, published in January 1988, led by Christopher Bretherton, also known as the Bretherton report (National Research Council, 1988), defined what we call nowadays Earth System Science (see also Steffen et al., 2020).

The Earth System is defined as the planetary system that comprises the biosphere, including all living biota, and their interactions and feedbacks with the atmosphere, the cryosphere, the hydrosphere and the upper lithosphere. The state of the Earth System is established in terms of the so-called Planetary Boundaries (PB) (Steffen et. al., 2015): rate of biosphere loss, land system change, global fresh water use, biogeochemical flows (global Nitrogen and Phosphorus cycles), ocean acidification, atmospheric aerosol loading, stratospheric ozone depletion, climate change, chemical pollution, and some others. The optimal values of these parameters are set up in terms of their magnitude at the Holocene (indicated in green in Figure 1). Recent assessment led to the staggering conclusion that the impact on the climate is not the only evidence available of the destabilizing nature of the human activities (European Environment Agency, 2020). Actually, through quantification of the PB, it is shown that four of these parameters, the biosphere integrity and biogeochemical flow, climate change and land system charge have overshoot the safety boundaries as shown in Figure 1.

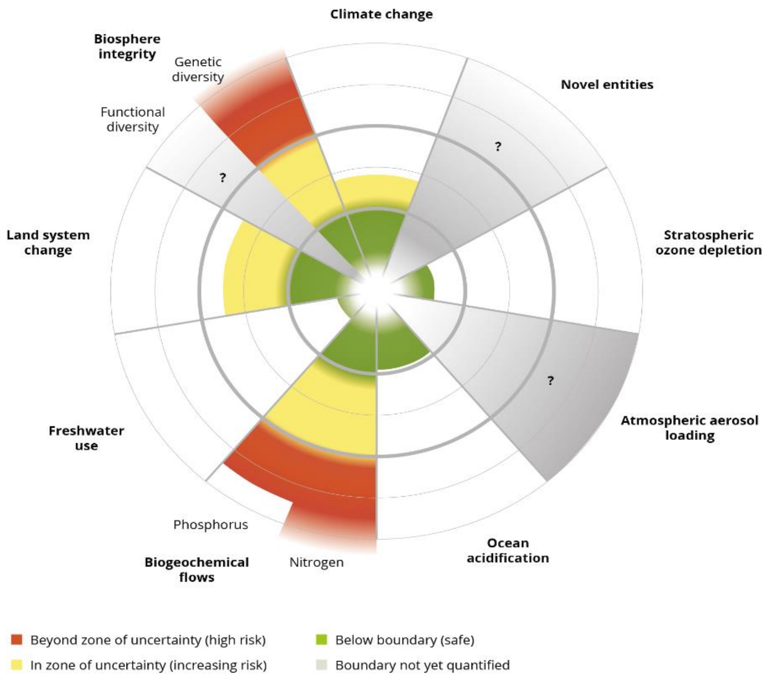

Figure 1. Depiction of the Planetary Boundaries of the Earth System. The safety zone (SOS – safe operating space) is shown in green. The yellow and red colours indicate an overshooting beyond the Holocene conditions. The biosphere loss and the biogeochemical flows show signs of an irreversible disruption.

To understand the evolution of the Earth System an evolution equation is required to determine the features that characterize the trajectories in the space of possible transitions and equilibrium configurations. This equation is generically called the Anthropocene equation and refers to evolution equation of the key physical quantity that describes the evolution of the system.

In a recent work, we have proposed that transformations among different equilibrium states of the Earth System are phase transitions that can be described thermodynamically according the Landau-Ginsburg theory of phase transitions [28] in terms of the free energy, F, of the system. It was found that natural causes lead to the transitions depicted in Figure 2, while the human intervention lead to a transition between the Holocene to the Anthropocene as shown in Figure 3. In Figures 2 and 3, $\psi = {(T - T_H)}/{T_H}$, where TH, is the average Holocene temperature.

The transformations that lead the Earth System to different equilibrium states are driven, in general, by natural causes (astronomical, geological, internal dynamics) as depicted in Figure 2; however, after 1950s, the Earth System has been driven by human causes as depicted in Figure 3. In fact, the human intervention has been destabilizing the Holocene conditions since the Industrial Revolution, but more acutely after 1950s.

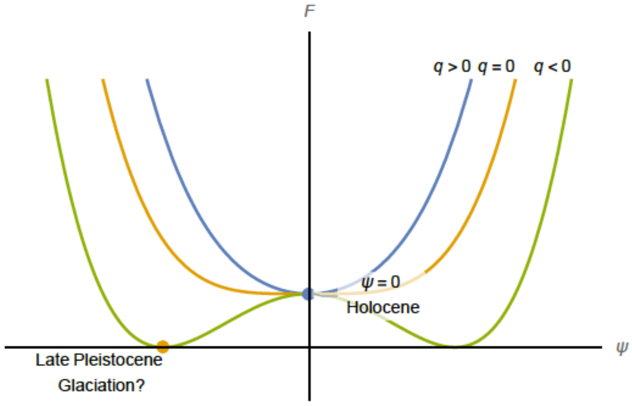

Figure 2: Minima associated to the Holecene, Late Pleistocene and hotter eras, in which the Earth System is driven by natural causes (astronomical, geophysical and due to internal dynamics).

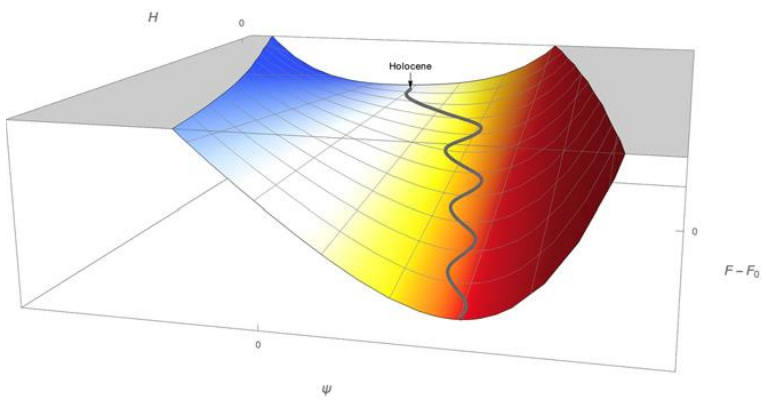

Figure 3: Transition through the Anthropocene driven by the human intervention, H, between the Holocene and a hotter new state of the Earth System, the Hothouse Earth, shown in red.

The developed model allows, based on available data, concluding that the features of the transition from the Holocene to a new hotter state, usually referred to as Hothouse Earth, can only be explained due to the human action (Bertolami, & Francisco, 2018), and the understanding of how does the Earth System evolve, can be achieved with the model through the obtained Anthropocene equation. More critically, our modeling allows for showing that the Hothouse Earth state is actually an attractor of trajectories in the Anthropocene (Bertolami & Francisco, 2019).

Our modeling also provides, in a natural way, an accounting system with which human action can be gauged (Barbosa, Bertolami & Francisco, 2020). In fact, the resulting accounting system can be easily matched to the one based on the PB (Meyer & Newman, 2018). Furthermore, it can be shown that the resulting accounting system is stable on a scale of about a year as interactions terms between different PB parameters is of order of 10% or so (Barbosa, Bertolami & Francisco; 2020).

Anthropocene versus Capitalocene

Our previous discussion established that the Anthropocene is a transitional period between the Holocene and the new hotter Hothouse Earth state. The implications of this transition are becoming increasingly visible in what concerns the climate change and its manifold implications: droughts, heat waves, dying oceans, unbreathable air, wildfires, irreversible destruction of ecosystems as mentioned above. (See Wallace-Wells, 2019 for a detailed discussion). Furthermore, as the clouds of the pandemic crisis, which on its own is a sort of rehearsal for the difficulties we shall be facing soon, dims, the pressure to get the economy back to its previous state and to resume the growth ideology is mounting. This is particularly alarming as from our previous discussion it is clear that the expansion of the market economy is not compatible with the recovery of the Earth System back to the Holocene conditions.

Furthermore, capitalism cannot survive without the crucial input of capital from the governments and its expansion as happened in the second globalization, but these will soon be blocked by the damage inflicted on the Earth System that is already back reacting on the economy itself. Indeed, the logic of considering the Earth System as an externality cannot be sustained for much longer. How can the internalization of the goods and services that the Earth System provide be achieved? This is a matter of heated debate. Taxation has been the most obvious solution and for this purpose it was created the "carbon social cost", that is, the cost of the damages for the environment and on the human health caused by one ton of carbon dioxide or the equivalent of other greenhouse gases with long term effects (methane, oxide of nitrogen, ozone, CFCs, etc). Even though its importance, settling a realistic estimate for the social cost of the carbon has been problematic, most particularly within the prevailing view that climate changes will manifest just in a distant future. For sure, this view has been changing, but the social cost of the carbon has been arbitrarily established given the political ideology and conditions. For instance, in the US, during Obama`s administration it varied from 30 to 50 dollars for 2010 to 2030. But in 2017, the Trump administration downgraded it from 1 to 6 dollars. The Biden administration evaluated it in 51 dollars, but it is believed that it might go up to 125 dollars. In Europe, similar variations have occurred in the various countries and due to changes in policy or ideology. Of course, the effectiveness of this tax depends on the voluntary adhesion of the countries and the way they convert the resulting capital into measures to mitigate the effect of the climate change and of the destruction of ecosystems. About 50 countries have already adopted the carbon social cost principle (see also Henry, Rockström & Stern, 2020 for an updated discussion).

In fact, in the context of the mainstream economical thinking, two conflicting views have emerged. In 2006, the Stern Report (Stern et al., 2006), commissioned by the British Government, presented the view that the damage caused by the climate change damage could be estimated to be of order of up two digits of GDP per year and defended a low discount rate (1 to 1.5% per annum) approach. The Review proposed that one percent of global GDP per annum would be required to be invested to avoid the worst effects of climate change. Subsequent estimates suggested that the investment should be doubled.

The Report has been criticised, by some of its assumptions, most particularly by adopting a low discounting rate. For instance, William Nordhaus (Nobel Prize of Economics in 2018) defended that the discount rate should be higher (4-5%) and somewhat closer to average capital rates in the market (Nordhaus, 2007). This perspective reveals the general assessment of economists that a lower value on consumption should be placed in the future rather than in the present. The main points of the argument are the following: people generally value consumption better at present; consumption levels are assumed to be higher in the future, so that the marginal utility of consumption (the rate of change of the utility of a good from the increase in consumption) will be lower; understanding consumption patterns in the future is harder; improvements in technology are expected to make it easier to tackle climate change in the future. Clearly, a strictly economic perspective does not give, in our opinion, the importance that the matter deserves and the urgency for consistent measures. It would be preferable to implement measures (and accumulate capital for that) now rather than in future, as advocated in the Stern Report. The capital could be used, for instance, to directly implement technology for *in loco* capture of greenhouse gases, cut the cost of renewable energy sources, relieve disasters caused be climate change, mitigate expected disasters, etc.

In fact, Nordhaus` DICE model (Dynamic Integrated Climate Economic model) (Nordhaus, 1992) is regarded from the point of view of neoclassical economics, as the way to integrate the carbon cycle, climate science, and to estimate the impacts in a framework that allows for weighing the costs and benefits of taking steps to slow climate change. In 2020, the model was rerun using updated climate and economic information by researchers of the Potsdam Institute for Climate Impact Research and found that the economically optimal climate goal was now less than 2ºC of global warming and not the 3.5ºC that was originally assumed by Nordhaus (Hänsel et al., 2020).

At microeconomic level, attaching into the final price to consumers the negative externalities would be an obvious solution for manufacturing and distribution of goods that harm the environment, cause unemployment and upset social harmony. But, of course, these principles can only work if, on a global scale, the damage cannot be exported, which, on its own, would require profound political and social reorganization, deep changes in the very principles of manufacturing and delivery of goods, and an urgent intensification of the principles of a circular economy.

Clearly, the logics of the existing market economy can only thrive through the continuous expansion of markets, resources and labour and the second globalization which took place in late 20th century, whose effects that we are still experiencing and that led to the Anthropocene, has reached limits beyond which no further expansion seems to be possible without inflicting even more irreversible damage to the functioning of the Earth System.

Actually, the very concept of Anthropocene has been contested on the grounds that it suggests a sharing with the whole humankind of the responsibility for having so dramatically affected the Earth System as, in fact, this responsibility is overwhelmingly due to the most developed countries of the North Hemisphere. The Capitalocene designation is alternatively suggested in order to stress this responsibility (Moore, 2016; Demos, 2012; Maldonado, 2018).

This view is actually relevant as there is an increasing consensus, even among mainstream economists, that the confidence on the ideal mechanics of the market is no more than an ideological legacy which can no longer address neither its own intrinsic failures nor bring about the changes the world needs right now. Indeed, research on data of three centuries concerning about 20 different countries (Piketty, 2013) has shown that inequality is an inevitable outcome of capitalism as the net rate of return to capital (r) historically exceeds the growth rate of output (g), that is $r > g$, meaning that as a rule, capital beats work, past beats the future, and inequality just grows – in fact, data extends now to about a hundred countries, see Word Inequality Database: https://wid.world. Mitigation of this intrinsic inequality would require, according to Thomas Piketty (Piketty, 2013), that governments worldwide should intervene to prevent inequality and create a global tax on capital.

This means that solutions for the unfolding climate crisis demand necessarily for a post-capitalist order where economic-environmental-social problems and associated vulnerabilities are addressed in an integrated fashion. We call this new paradigm, *Green Anthropocene*, in the context of which a new scientific utopia may arise, driven by the scientific and technical solutions for the climate crisis and the problem of inequality (Bertolami, 2018; Bertolami, 2015). In fact, the outcry for a vigorous set of changes has been intensified by a great number of social movements and has also been defended by quite influential authors (Mason, 2015; Piketty, 2021). Some emphasize (Žižek, 2020; Gonçalves & Bertolami, 2020) the lessons that can be drawn from the pandemic crisis and the way it exposed how hardships affected more harshly the vast majority of those that worldwide are at the basis of the income pyramid.

Greening the Anthropocene: global versus local

The above discussion has set the ground for the argument about the need for new strategies to tackle the climate crisis and to solve the problem of inequalities within societies. Naturally, addressing the latter will help the majority of those that are being and will be more severely affected by the former. Moreover, as the richest nations and their elite are those whose ecological footprint is the highest, smoothing inequalities is a necessary condition to address the climate crisis.

For sure, solutions cannot be just devised in the realm of economic measures that tend to affect trends at a long term, but instead they must have an immediate impact on the real world. To put it in simple terms, taxes for destroying the environment do not prevent destruction they just make the destruction slightly more expensive for its actors and for the consumers. Restoring the Earth System to its Holocene conditions is a task that cannot be left for the future generations. It must be addressed now.

As argued above the coupled nature of the problems, climate crisis and inequality, asks for a post-capitalist order as the expansive evolution of capitalism is no longer sustainable given the damage it has already caused to the Earth System and the climate crisis it created. Historically, the call for a post-capitalist society was essentially an ideological one, nowadays it is an absolute necessity given the seriousness of climate change crisis and the way it is coupled with the inequality problem. Of course, the required changes cannot be thought about without a relevant shift in policies and priorities whose political dimension concerns the very essence of the concept of freedom of choice. As Hannah Arendt put it: «(…) the pre-revolutionary *idea* of freedom but also the experience of being free coincided, or rather was intimately interwoven, with beginning something new, with metaphorically speaking, the birth of a new era» (Arendt, 2017 [1967], p. 67).

Indeed, the hypercapitalism of the last few decades has unleashed such a range of ethical and material problems, besides the climate crisis and the inequality problem, that solutions can only be found through profound changes involving a return, in a novel fashion, to the generous ideas of socialism and social reform (Mason, 2015; Žižek, 2020; Bertolami, 2018). For sure, the required changes cannot be a straightforward recall of old ideas, but instead a conscious and technically oriented set of social measures such as, for instance, universal basic income and inheritance (Mason, 2015) to flatten inequalities and to equip societies, emotionally and materially, with the needed resilience to face the unfolding climate crisis (Gonçalves & Bertolami, 2020). This discussion had become quite concrete due to the pandemic crisis, which showed the crucial role played by a robust welfare state as a provider of universal and high quality medical care. Countries, no matter how wealthy, performed poorly when their medical care assistance was predominantly private owned. This suggests that an international social tax should be created to foster overall resilience. We propose to call it *resilience social tax* (for a further discussion see Gonçalves & Bertolami, 2022, in preparation), designed to bring this crucial component into the logics of the economic cycle.

More general and encompassing answers to the issues we face are, by their scale and multilateral nature, necessarily global. They can tackle effectively the crises we have been discussing if and only if in alignment with a great number of nations. As is well known the various agreements involving the regulation of the use of protected areas, oceans and space, and, most particularly, the climate agreements, can only work if an extraordinary alignment of good will on an international scale exists and in consonance with economic interests. The examples are well known: the Montreal Protocol signed up in 1987 to halt the destruction of the ozone layer; the Kyoto Protocol signed in 1997 for reducing the greenhouse-gas emissions (the latter was rectified in Paris in 2015) whose purpose was keeping the global temperature rise below 1.5-2ºC above pre-industrial level till the end of the century.

An equally unlikely global agreement is required, for instance, for scaling up the idea of a shared property like a condominium as it involves the voluntary membership of sovereign states to share the responsibility of operating the Earth System under established conditions and to function within a new legal framework to be agreed upon (Magalhães et al., 2016; Common Home of Humanity, http://www.commonhomeofhumanity.org). Besides this obvious difficulty of an extraordinary alignment of sovereign nations, it is unlikely that an agreement of this nature will be achieved in the context of an economic system strongly based on fossil fuel and on practices of trade, tax and climate dumping. No changes on the nature of the private property and on the principles of sovereignty can be expected without deep changes in the underlying economic system.

On the other hand, many local proposals like, for instance, the Earth System Governance Project (ESGP) (https://www.earthsystemgovernance.org) launched in 2009 exist and have quite good chances to thrive. In fact, in 2015 ESGP has become part of a wide international research initiative, the Future Earth (https://futureearth.org), aiming to address long-term local challenges such as air pollution, contamination of waters, waste treatment, desertification and soil degeneration, all involving degradation of the operating conditions of the Earth System.

As an example of a completely different approach let us mention the proposal of boosting the recover of ecosystems through of a digital contract using the most recent *blockchain* techniques and the exchange of a new *cryptocurrency, the Planetary Boundary coin* (PBCoin) (Bertolami & Francisco, 2021).

A blockchain is a list of connected digital records. Each record is referred to as a block and each one is linked to the previous one through a cryptographic key, the *hash*. Blockchain technology is at the basis of the cryptocurrencies, the first one was the well-known Bitcoin. Nowadays, blockchain technology is widely used to trade financial assets, most particularly those associated with the cryptocurrencies. One of the key features of blockchains is the public nature of the information they store. Hence, any user whose computer is connected to a given blockchain network can access the information it storages. Moreover, any computer connected to a network has a copy of the blockchain, which is disseminated by the whole network. This universal ownership, which can be acquired voluntarily, makes blockchains a particularly useful tool for the governance (Massessi, 2019; Mitra, 2019; Blockshainhub Berlin, s.d.) of common goals such as restoring the Earth System.

The advantages of blockchain technology can be easily listed: it is accurate; interactions involve no charges; it is decentralised, and through the public key procedure it can make ownership safe proof; the whole technology of the procedure is most often open source. However, the existing blockchain technology has a huge environmental footprint and although it allows for users savings in the transactions, the proof of work in the case of some cryptocurrencies consumed vast amounts of computational power and energy.

Our proposal is that blockchain technology, free from the energy consumption problem can be used to setup a network of concerned communities with the PB parameters of their village, town, region, country or continent. The blockchain technology allows for implementing authentication procedures in a decentralised fashion without the need for a legitimising authority above a community of traders, transaction partners and ultimately citizens.

Of course, a crucial matter concerning the governance strategy we propose is its inception and how it can motivate partners to build up an initial community. We believe that on its onset, the main driver might be the idealism and the interest in averting a catastrophic state of the Earth System. This might be sufficient for setting up the first blocks and to attract the interest in an evolving chain. As the community starts actively exchanging means to restore ecosystems, either by the exchange of goods or means via the exchange of a PBCoin (see Figure 4 below), specially designed for this purpose, the dynamics of this process may generate further interest.

Indeed, the most relevant issue at hand is the demand for action to the Earth System in a time-scale short enough that it can mitigate the most destructive impacts of human activities. In this respect, a set of widespread local actions may be far more effective than long-term low-intensity ones resulting from international political compromise such as the needed for setting a global condominium or other forms of governance. A large number of sustained local actions can have a lasting and global effect. Furthermore, it is assumed that local actors can be progressively scaled up to engage into actions with wider spatial impact. Setting up the PBCoin and its exchange among the members of the network requires an initial set of blocks that details the functionality conditions for the initial communities.

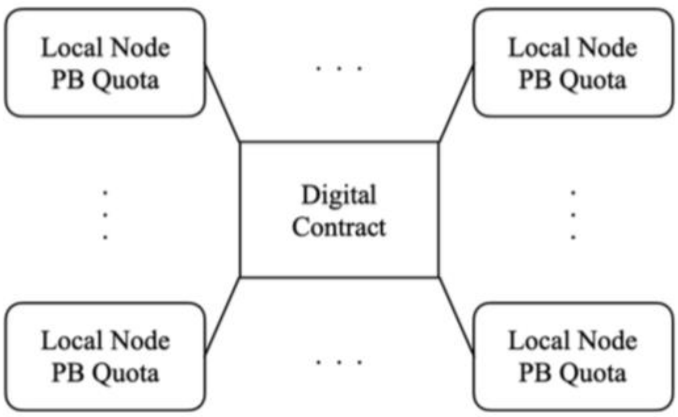

Figure 4: The Planetary Boundary Exchange Unit is established through a decentralized digital contract between the local nodes. Each participant must have its PB Quota evaluated in order to assign the initial amount of PBCoin (Bertolami & Francisco, 2021).

The inherent assumption of the digital contract (Figure 4) built into the blockchain is the requirement of updated information on the status of the PB within each participant's territory at regular time intervals. It is relevant to point out that there is already a considerable array of instruments, land-based and space-borne, to evaluate PB parameters and acquiring access to these capabilities may be in itself an initial motivation for communities to join in the Earth System Blockchain. In this respect, there is a great potential for development as the evaluation of strategies to restore the SOS conditions (see Figure 1) will ask for considerable technical expertise ranging from communication to algorithmic capabilities (including artificial intelligence) and skills, which members of the Earth System Blockchain will be keen to acquire and develop.

The proof of work of the members of the network should be consistent with technical requirements set up on the basis of physical models of the Earth System that are updated by the available data sources. A certain amount of PBCoin would be assigned to each member over a given period of time. This amount would have to be determined on the basis of a quota system that is motivated by those physical models and is transparent to the members of the community. As mentioned above, detailed knowledge of the interactions between PBs is required to make this validation meaningful.

Naturally, any restoring action should imply in a positive value assigning to a given member of the network an established PBCoin amount. A negative value implies that a given member of the network has effectively destroyed ecosystems and thus, it is contractually bound to restore ecosystems locally or elsewhere. Some of the members would have a surplus while others would have a deficit of PBCoin. This balance is calculated in relation to a quota, which in turn, is determined by the SOS of the Earth System (see Figure 1). This would naturally generate a market of ecosystem services and capital. Since actions to restore the ecosystems necessarily require real capital (land, manpower, machinery, seeds, etc.), an exchange rate between PBCoin and existing currencies will arise. This mechanism will generate the necessary incentive towards the generation of more PBCoin, which is only possible through the proof of work of ecosystem restoration. It is conceivable that the implementation of local operational and technical means to a community to measure the PB parameters and to join in the network may be rewarded with a PBCoin amount (see Figure 5).

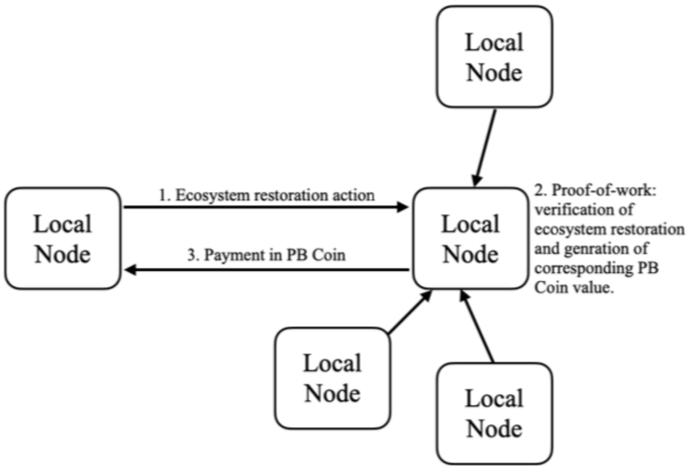

Figure 5: Sketch sequence of the transactions for a member of the network executing restoring actions on another node-member, with a set of third-nodes in the network validating the proof-of-work (Bertolami & Francisco, 2021).

The convertibility of PBCoin into conventional currencies and into PB quotas could ensure the key goal of our proposal, namely, internalising into the financial and economic chains the environmental damage caused by human activities. Once the network achieves a certain scale, this also provides incentive for others to join.

It is relevant to point out that the supply of PBCoin would be limited by the finite amount of physical resources of the planet. The only way to create more units would be to restore ecosystems and in this way expand the resources of the planet. This contrasts with the Bitcoin, the original cryptocurrency, which was created to have an asymptotically limited supply, by means of exponentially increasing computational requirements, as a way to protect savings against inaction. Still, cryptocurrencies, lacking both legal tender status and tangible value, are purely speculative assets. PBCoin would have a proxy tangible value as an ecosystem service.

Our proposal provides an example of local set of activities that can be scaled up to acquire a planetary dimension, not jeopardizing simultaneous global efforts to be implemented by international agreements and decisions. Being outside the prevailing framework of the economic players it has the potential to contribute to create an alternative to the existing attempts to fix the climate crisis with instruments that act predominantly within the logics of the hypercapitalist economy, like for instance the carbon social tax, which have no direct bearings neither on the climate crisis nor on the issue of inequalities. Empowering local communities with means to restore ecosystems endowing them to acquire PBCoin capital might be a step towards an alternative post-capitalist order.

Conclusions

From almost extinction to becoming the main force on the planet, humanity has shown a remarkable capability to face and to overcome unforeseeable hardships. In last few centuries, revolutions in science, industry and in the social order have changed historic trends that existed for millennia. The Scientific Revolution, in particular, has endowed us with a body of knowledge and methods that can be systematically used to analyse problems and to seek for their solutions. In fact, these tools were so effective that they engendered an ideology of optimistic, continuous and perpetual progress, economic, scientific and social. This Panglossian perspective that we live the best of the worlds, even though expressed through the well-known Voltaire's satire (Voltaire, 1759), is so entrenched that it had its defenders in evolutionary biology and even in contemporary cosmology with the so-called Anthropic Principle (see for instance Barrow & Tipler, 1986). for an extensive discussion), according to which the fundamental forces of Nature have been balanced so to allow for the presence of observers. The damage that human activities have caused to the Earth System has changed this benign view for good. Actually, to replace the Anthropic Principle we propose alternatively a new principle, the Cosmic Responsibility Principle, an ethical duty we should all embrace of preserving, at all levels, the biological ecosystems and all the species they harbour (Bertolami, 2010; Bertolami & Gomes, 2018).

The impact of the human action is nowadays visible everywhere on Earth and on the surrounding space around Earth. The ubiquity of the impact of humankind activities has implications on the state of the Earth System and is jeopardizing the long-term sustainability of human civilization. The impact of humanity comprises an incredible loss of biodiversity, an accelerated rate of destruction of ecosystems compromising climate stability and leading the Earth into a state that will not allow for the existence of the human societies as they are nowadays. This situation requires urgent measures of governance aiming to keep the operational conditions of the Earth System.

There is a wide consensus that the state of the Earth System can be well monitored by the control of the PB parameters and we have proposed that the use of blockchain technology, widely used for decentralised bureaucratic procedures and in crypto-currencies, can be a useful tool for the governance of the Earth System. We described a mechanism for decentralised global stewardship of the Earth System based on the blockchain concept and the design of a Planetary Boundary Exchange Unit (PBEU or PBCoin). We have also discussed how it can help to drive the Earth System away from the Hothouse Earth discussed in Refs. Steffen et al., 2018 and Bertolami & Francisco, 2019). We hope this can motivate the setting up of voluntary exchange mechanisms to progressively internalise the environmental costs into the economy and thus into the political options.

To draw and end to this discussion and to emphasize its *leitmotiv*, we should say that a robust set of changes are needed in order to address the unfolding climate crisis and the problem of social inequalities. As discussed, these are coupled problems. Their solution requires a scientific utopia that will lead us beyond the hypercapitalism of the Anthropocene. The defended changes must be driven by the tenets of political freedom, social opportunities, transparent guarantees, and protective security that can only be warrant by a collective ethical choice based on a principle of maximization of the common interest (Sen, 2012). History shows that without changing the precepts of the current economic paradigm, any utopia or sustainable equalitarian principle has little chances to go beyond the realm of the generous ideas.

References

Arendt, H. (2017 [1967]). The freedom to be free. *New England Review, 38*(2), pp. 56-69

Arsuaga, J. (2021). *Vida, a grande história, uma viagem pelo labirinto da evolução*. Trad.: Pedro Garcia Rosado. Temas & Debates.

Barbosa, M., Bertolami, O. & Francisco, F. (2020). Towards a Physically Motivated Planetary Accounting Framework. *The Anthropocene Review, 7*(3), pp. 191-207.

Barrow, J. D. & Tipler, F. J. (1986). *The Anthropic Cosmological Principle*. Oxford University Press.

Bertolami, O. (2010). Cosmological Thinking: cultural heritage and challenge. *Arxiv-Physics*. https://inspirehep.net/literature/845343.

Bertolami, O. (2015). *A tensão utópica*". (http://web.ist.utl.pt/orfeu.bertolami/Utopia_Bertolami.pdf).

Bertolami, O. (2018, June). Utopia: Utopian and Scientific. *SSRN*. http://dx.doi.org/10.2139/ssrn.3874980.

Bertolami, O. & Francisco, F. (2018). A physical framework for the Earth System, the Anthropocene Equation and the Great Acceleration. *Global Planet. Change 169*, pp. 66-69. https://doi.org/10.1016/j.gloplacha.2018.07.006.

Bertolami, O. & Francisco, F. (2019). A phase-space description of the Earth System in the Anthropocene, *EPL 127*(5), 59001. https://doi.org/10.1209/0295-5075/127/59001.

Bertolami, O. & Francisco, F. (2021). A Digital Contract for Earth System Restoration Mediated by a Planetary Boundary Exchange Unit. *The Anthropocene Review*. https//:doi.org/10.1177/2053019620987270.

Bertolami, O. & Gomes, C. (2018). A Origem do Universo. In Maria do Céu Patrão Neves e Maria da Graça Carvalho, *Ética Aplicada. Investigação Científica*, Edições 70. (http://web.ist.utl.pt/orfeu.bertolami/OrigemUniverso_2018f.pdf).

Blockshainhub Berlin (s.d.). *Crypto Governance*. https://blockchainhub.net/blockchain-governance

Bod, R. (2013). *A New History of the Humanities*. Oxford University.

Carson, R. (1962). *Silent Spring*. Houghton Mifflin

Crutzen, P.J. & Stoermer, E.F. (2000). The “Anthropocene”. *Global Change Newsletter, 41*, 17.

Demos, T. J. (2012). *Against the Anthropocene. Visual Culture and Environment Today*. Sterberg Press.

Engels, F. (1990 [1884]). The Origin of the Family, Private Property and the State. In: Karl Marx and Friedrich Engels, *Collected Works*, vol. 26, Engels: 1882-1889 (pp. 129-276), Lawrence & Wishart.

Ehrlich, P. & Holdren, J. (1971). Impact of population growth. *Science 171*, pp. 1212-1217.

European Environment Agency (2020) *Status of the nine planetary boundaries* (infographic). https://www.eea.europa.eu/soer/2020/soer-2020-visuals/status-of-the-nine-planetary-boundaries/view.

Gonçalves, C., & Bertolami, O. (2020, October 2). Anthropic Risks, Coronavirus Pandemic (COVID-19), Climate Change (& Other Disasters): An Attempt to Reach Public Perception. *SSRN*. http://dx.doi.org/10.2139/ssrn.3703878.

Gonçalves, C. & Bertolami, O. (2022). In preparation.

Hänsel, M., Drupp, M. Johansson, D., Nesje, F., Azar, C., Freeman, M., Groom, B. & Sterner, T. (2020). Climate economics support for the UN climate targets. *Nature Climate Change. 10*(8), pp. 781-789..1038/s41558-020-0833-x.

Harari, Y. (2011). *Sapiens, a Brief History of Humankind*. Vintage.

Henry, C., Rockström, J. & Stern, N., eds. (2020). *Standing up for a Sustainable World Voices of Change*. Edward Elgar.

IPCC (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf.

Kaya, K. & Yokoburi, Y. (1997). *Environment, energy, and economy: strategies for sustainability*. United Nations Univ. Press.

Keynes, J. M. (1936). *The General Theory of Employment, Interest and Money*. Palgrave MacMillan.

Liebmann, H. (1979). *Terra um Planeta Inabitável? Da antiguidade até os nossos dias toda a trajetória poluidora da humanidade*. Tradução: Flávio Meurer. Biblioteca do Exército.

Lovelock, J. (1995). *The Ages of Gaia: A Biography of Our Living Earth*. W.W.Norton.

Luxembourg, R. (1951 [1913]). *The Accumulation of Capital: A Contribution to an Economic Explanation of Imperialism*. Transl.: Agnes Schwarzschild. Routledge & Kegan Paul.

Magalhães, P., Steffen, W., Bosselmann, K., Aragão, A. & Soromelho-Marques, V. (2016). *The Safe Operating Space Treaty: A New Approach to Managing Our Use of the Earth System*. Cambridge Scholars Publishing.

Maldonado, M. A. (2018). *Antropoceno: La política en la era humana*. Taurus / Penguin Random House.

Malthus, T. (1798). *An Essay on the Principle of Population*. J. Johnson.

Mason, P. (2015). *PostCapitalism: A Guide to Our Future*. Allen Lane

Massessi D (2019, January 25). Blockchain governance in a nutshell. Coinmunks. https://medium.com/coinmonks/blockchain-governance-in-a-nutshell-67903c0d2ea8

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W., III. (1972). *Limits to growth*. Universe Books.

Mészáros, I. (2001). *Socialism or Barbarism - From the "American Century" to the Crossroads*. Monthly Review Press.

Meyer, K & Newman, P. (2018). The planetary accounting framework: A novel, quota-based approach to understanding the impacts of any scale of human activity in the context of the planetary boundaries. *Sustainable Earth 1*: 4. doi: 10.1186/s42055-018-0004-3.

Mitra, R. (2019, November 1). What is Blockchain Governance: Ultimate Beginner`s Guide. https://datawider.com/what-is-blockchain-governance-ultimate-beginners-guide

Moore, J. ed. (2016). *Anthropocene or Capitalocene? Nature, History, and the Crisis of Capitalism*. PM Press.

Morgan, L. (1877). *Ancient Society; or, Researches in the Lines of Human Progress from Savagery, Through Barbarism to Civilization*. MacMillan & Comp.

National Research Council. (1988). *Earth System Science: A Closer View*. The National Academies Press. https://doi.org/10.17226/19088.

Nordhaus, W. D. (2007). A Review of the Stern Review on the Economics of Climate. *Journal of Economic Literature 45*(3), pp. 686–702 (2007). doi:10.1257/jel.45.3.686.

Nordhaus, W. D. (1992). The “Dice” Model: Background and Structure of a Dynamic Integrated Climate-Economy Model of the Economics of Global Warming. Cowles Foundation Discussion Papers 1009, Cowles Foundation for Research in Economics, Yale University.

Pareto, V. (1896-1897). *Cours d`Economie politique professé à l`Université de Lausanne*. F. Rouge.

Piketty, T. (2013). *O Capital no século XXI*. Trad.: Sarah Adamopolous. Temas e Debates.

Piketty, T. (2021). *Pelo Socialismo!*. Trad.: Artur Lopes Cardoso. Temas e Debates.

Rees, W. & Wackernagel, M. (1994). Ecological footprints and appropriated carrying capacity: Measuring the natural capital requirements of the human economy. In A-M. Jansson, M. Hammer, C. Folke, and R. Costanza (Eds.). *Investing in natural capital: The ecological economics approach to sustainability*, pp. 362–390. Island Press.

Rousseau, J.-J. (1999 [1755]). *Discurso sobre a Origem e os Fundamentos da Desigualdade entre os Homens*. Trad.: Maria Ermantina Galvão. Martins Fontes.

Sen, A. (2012). *Sobre Ética e Economia*. Trad.: Pedro Elói Duarte. Edições Almedina.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Sustainability. Planetary boundaries: guiding human development on a changing planet. *Science, 347*(6223), 1259855. https://doi.org/10.1126/science.1259855

Steffen, W., Richardson, K., Rockström, J., Schellnhuber, H., Dube, O., Dutreuil, S., Lenton, T. & Lubchenco, J. (2020) The emergence and evolution of Earth System Science. *Nature Reviews. Earth & Environment*, *1*, pp. 54-63.

Steffen, W., Rockström, J., Richardson, K., Lenton, T. M., Folke, C., Liverman, D., Summerhayes, C. P., Barnosky, A. D., Cornell, S. E., Crucifix, M., Donges, J. F., Fetzer, I., Lade, S. J., Scheffer, M., Winkelmann, R., & Schellnhuber, H. J. (2018).

Trajectories of the Earth System in the Anthropocene. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(33), pp. 8252–8259. https://doi.org/10.1073/pnas.1810141115

Stern, N., Peters, S. Bakhshi, V., Bowen, A. Cameron, C. Catovsky, S., Crane, D., Cruickshank, S., Dietz, S. Edmonson, N., Garbett, S.-L., Hamid, L., Hoffman, G., Ingram, G., Jones, B. Patmore, N., Radcliffe, H., Sathiyarajah, R., Stock, M., Taylor, C., Vernon, T., Wanjie, H. & Zenghelis, D. (2006). Stern Review: The Economics of Climate Change. HM Treasury.https:/www.hm-treasury.gov.uk/stern_review_report.htm.

Voltaire (1759). *Candide, ou l`Optimisme*. Cramer, Marc-Michel Rey, Jean Nourse, Lambert, and others.

Wallace-Wells, D. (2019). *The Uninhabitable Earth. Life after Warming*. Tim Duggan Books

Žižek, S. (2020). *A Pandemia que Abalou o Mundo*. Trad.: João Moita. Relógio d`Água.

Acknowledgments
I am grateful to Carmen Diego Gonçalves and Sandra Sousa for the insightful comments and suggestions.