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Energy Transitions, Environmental History and Collective Action: Notes from the History of Economic Thought for the Current Debate

PRELIMINARY 1ST DRAFT - PLEASE DO NOT CITE *

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1. As a way of introduction

It is by now well-known and documented that human activity can impact on the earth eco-system both positively and negatively. In particular, in recent decades one of the most salient preoccupations highlighted by environmental studies are the effects of demographic pressure on climate (see, among others, Diamond, 2005; Tainter, 1988; Lander, 2021).

Any species whose population grows *persistently* and occupies or conquers different biomes inevitably has predatory impacts. The concern on demographic pressures goes back well into human history. And this is not less true for the *Homo Sapiens* who had always brought about significant impacts on the living conditions on the planet. In fact, the problems created by demographic pressures and energy depletion date back to more than 20 thousand years ago, when most of the population were hunter-gatherers (Hamilton *et al*, 2016).

As hunter-gatherers started to deplete vegetable and animal sources of energy for their own mobility somewhat between 15,000 to 11,000 years ago, the energy constraint set the limit for further expansion. Under stretched conditions for provisioning their food populations started to modify their techniques of production thus giving rise to organised agriculture and settlements[1]. According to Danish economist Ester Boserup (1965) demographic pressures bring about operational changes in the way food is produced, by developing new and more intensive techniques for the use of land, thus increasing both labour productivity per land and production of food per capita.[2] Contrary to Malthus's (1798 [1803]) popular thesis, it is *not* that intensification of land use (or the use of marginal lands, paraphrasing Ricardo, 1815) will lead to a lower rate of food growth relatively to population growth; rather it is the increase in population that will lead to the intensification of agriculture thus raising productivity and food

* This is a work in progress and it must be taken as a *preliminary outline* of the paper; so the ideas discussed here are all subject to further research and review.

[1] For the active role of the state managing and controlling nomadic populations in 15th cent. China, see Lander (2021).

[2] This implies the existence of a well rooted culture among the population that allows them to best deploy their tools and knowledge.

per capita thanks to better organisation of workers and technical use of the land. This is a radical inversion of the causal mechanism put forward by Malthus and the classical school (though not, to a certain extent, by Adam Smith). Thus, new techniques, intensification of the use of land, innovation in agricultural production and better use of soil (e.g., fallow system), domestication of animals and plants, all led to what we normally refer to the Agricultural Revolution of roughly 10 thousand or so years ago. The domestication of certain varieties of plants and animals was the *technical solution* to the environmental restrictions that most hunter-gatherers were facing.

Estimates put the total world population before the Agricultural Revolution in 8,000 BCE at 5 million people (Population Reference Bureau, PRB 2022)[3]. As environmental historians have documented, the agricultural revolution had a severe impact on ecosystems such as deforestation due to overgrazing and widespread desertification. Biodiversity was severely dwarfed. While there is no denial that this transition came at a cost in environmental terms, the magnitude of transformation in place meant a paramount change in the energy produced and consumed for the purposes of feeding, dressing, warming and making tools, increasing from a daily 5,000 kilocalories (*Kcals*) during the period of the hunter-gatherers to an average of 30,000 *Kcals* in advanced agricultural societies such as the Roman empire.[4] Moving forward, by1800, i.e., 10 thousand years after the agricultural revolution, the population had passed the mark of 1 billion people (PRB, *id*).

The second most important energy transition since dominance of *Homo Sapiens* took place more recently, during the Industrial Revolution of the 18th and 19th centuries. Transformation in energy production meant an unprecedented and radical leap forward in the way populations feed themselves, consume, communicate, etc.

Until then, humanity relied on wood from trees for the purposes of cooking, warming, constructing ships (e.g., 2,000 trees needed per ship for the Royal Navy, check source), building houses (according to Vaclav Smil, urbanised areas in tempered zones required 20 to 30 times their sizes in forest areas to satisfy their energy needs), melting metals, etc. Obtaining wood required occupying extensive areas of land with trees which meant reducing the crop planted area and/or moving to less fertile lands. The increased demand for wood (due to increase in population during the 16th and 17th cent in Europe) drove food prices upwards significantly (source: *Britannica*, History of Europe). Forests for wood extraction in England were around 5% to 7% of the territory and so they had to rely on the Baltic and New England for energy source. This certainly entailed an environmental constraint.

It was in this context that the combination of coal with the steam engine created the conditions for a structural transformation with the industrial revolution. The use of coal grew exponentially while the use of wood and animals as a source of energy (horses, donkeys, etc) gradually decreased. The revolution of the coal and the steam transformed transportation with railways and steamships, as well as launched the British textile industry into the world market. In late 19th cent/early 20th cent, simultaneously with the growing use of another fossil fuel, petroleum (or oil), agriculture was also industrialized through the incorporation of machines

[3] https://www.prb.org/articles/how-many-people-have-ever-lived-on-earth/

[4] One calorie is the measure unit to represent the amount of heat needed to raise the temperature of 1 cm^3 of water by 1°C. One *Kcal* (1,000 calories) is the amount of heat required to raise the temperature of 1 kg of water by 1°C.

such as tractors and harvesters and the application of fertilizers, herbicides, fungicides, and insecticides. Since then, developed economies have not lacked food and forests occupy larger areas than they did in the 19th century. As Tony Wrigley has estimated, without coal the humanity would have needed to cut all the trees of the world to produce the iron and steel required by the 19th century railways. The upshot of this mammoth transformation in energy production, transportation and consumption, can be appreciated by noting that, after 200 years since the industrial revolution, the world population reached 7.7 billion people (PRB, *id.*) – a remarkable increase in a really very short time span in historical terms.

Certainly, energy production based on fossil fuels do have restrictions. Unlike theories and hypotheses that have stressed that oil depletion would be the limit to growth (Club of Rome, 1972), or rooted ideas of orthodox flavour highlighting "relative scarcities" (Jevons, 1865, 1871), the actual restriction which the still-dominant fossil fuel resources-based energy production faces is that it creates greenhouse gases (GHG) in the atmosphere (water vapour, CO_2, methane, ozone and nitrous oxide) thus making the earth getting warmer and warmer.[5] Using standard economics terminology, global warming could be regarded as being a negative externality; however, as its name indicates, it is a global phenomenon and so any meaningful intervention to mitigate this would require a global perspective going beyond the standard economic tools to deal with such a "market imperfection".

At the same time, since the onset of the industrial revolution, notwithstanding the great divergence from 1820 on (Pomeranz, 2000), present-day world inhabitants have reached unimaginable levels of consumption, well-being, health services, life expectancy in such a remarkably short period of time (for illustrations and figures on all these, see Pinker, 2018). Ruling out natural catastrophes (although they have indeed played a decisive role in the shaping of the world humanity, such as volcanic eruptions, epidemics, floods; see Brooke, 2014; Ellenblum, 2012), the social changes brought about in the last 150-200 years look irreversible. Indeed, it is practically impossible to reduce the world population; the current estimate is that there will be 10 billion people by 2050 (PRB, *id.*). Also, it is socially and politically unfeasible – especially in developing countries – to reduce consumption drastically so that the use of fossil fuels falls in any significant magnitude as the main source of energy. Who, after all, would be willing to refrain using the smart phones, internet, Apps, or call an Uber ride? Further, and perhaps even more importantly, checking the use of energy for transportation, networks, infrastructure, heating and cooling, among many other key activities may lead to drastic reductions in *productivity* – that would seriously impinge on the prospects not only of human well-being but also (contrary to what many may otherwise think) for the environment itself. This does not mean greener forms of energy production should not be encouraged. Far from that. But given these provisional hypotheses on the demand side, then it will have to be the supply side of energy production which will have to undergo significant changes in order to generate the energy necessary to meet with the increasing demand in the decades to come. As Tainter (1988) and other authors have argued, there is a decisive space governments and states to actively participate in this transition.

One of the aims of this paper is to examine the role of the state in the relation between environment, social production (and social surplus), and technology. Indeed this crucial

[5] A GHG is any gas in the atmosphere that absorbs and re-emits heat, thus keeping the atmosphere warmer. As of 2020 83% of all primary energy produced has its origin in fossil fuels. In 2000 it was 87%; (Vaclav Smil, Nov. 2021).

relationship shaping the current debate on energy transition is *not* independent of the state: the state needs production and surplus to collect taxes, expand their range of power, intervene in the economy; as such it is another agent that has influence on the environment – governments not only can intervene in and regulate the energy sector, governments do need energy production to guarantee its own existence, presence, dominance against potential rivals, and in turn to come back to continuing their intervention and so on, in an undefined cycle as many environmental historians have documented. A fall in productivity, therefore, would mean, for example, less surplus from which government can collect taxes and thus the possibility to intervene in energy sector (e.g., by promoting green energy source, by financing green energy, etc) would be hindered if not totally obstructed. But the fall in productivity, even independently of its impact on the state finance, would bring dire consequences for the economies, for the population and for the environment. A further complication to this picture is the global governance necessary to tackle a global phenomenon (climate change).

Thus, global warming is the current restriction that fossil fuels-based energy faces. This paper does *not* deal with the technical aspects involved in the energy transition towards greener sources that is in the public agenda (COP26, etc.)[6] and that might eventually help reduce the global warming and its implications (floods, increase in sea levels, etc). Our concern here is to start thinking about the role and efficiency of state intervention as a big agent that both is affected and affects the environment.

As a first attempt to address this aim, in the following section we introduce a simple version of the Lotka-Volterra prey-predator model which enables us to illustrate some of the interactions and dependences of the variables that interest us here, i.e., economic growth and natural resources. This very simple framework will allow us to examine some of these dynamics through the lenses of different approaches in the history of economic thought, in particular, Boserup, Smith and Malthus. Then we try to introduce the state in such a framework which may help us to discuss the role of the state in the relationship between economic growth and natural resources.

2. Natural resources, economic growth, and the prey-predator model (Lotka-Volterra; Goodwin; Weber; etc)

We introduce the Prey-predator model to discuss the relation and impacts between the "prey" (natural resources) and the "predator" (GDP per capita). The basic prey-predator model is given by the following system of differential equations.

$$\dot{x} = x(a - bY) \qquad a, b > 0 \qquad (1)$$

$$\dot{y} = y(-c + dX) \qquad c, d > 0 \qquad (2)$$

[6] While governments across the world during Cop26 agreed on paper that greener ways of producing energy should replace fossil-fuel based sources in 45% by 2030, reality is much gloomier. According to Vaslav Smil, to achieve these goals would mean to replace **5% per year** of fossil fuel-based primary energy production with greener sources (intermittent sources like wind, solar, etc) until 2030. As mentioned above, the world has only replaced 4% of fossil fuel-based energy production with greener ways in 20 years, between 2000 and 2020, i.e, **0.2% per year**. Realistically speaking, energy expert Vaslav Smil argues that the energy transition will take several decades to come to fruition and replace the current energy matrix.

Where **X**: natural resources (level); $\dot{\boldsymbol{x}}$**:** natural resources (change in time); ***a***: natural growth rate of *X* when there are no predators (*Y=0*); ***b***: impact on growth of X of the density of predators (*Y>0*); **Y**: GDP per capita; $\dot{\boldsymbol{y}}$**:** GDP per capita (change in time); **c**: natural rate of decay (*Y* does not "eat" *X*); **d**: depletion rate of *X* by *Y* (i.e, growth of *Y* is dependent on the density of *X*).

As can be easily seen from (2), GDP per capita growth does depend on the use natural resources. At the same time, the level of per capita GDP affects positively the growth of the variable (more on this below). On the other hand, equation (1) relates the dependence of the natural resources on the dynamic of GDP per capita. In absence of the latter natural resources will be preserved and will grow at a natural rate, *a*. Another way to see these relations is to re-write the model slightly different, expressing the *growth rates* of the variables explicitly on the LHS, thus:

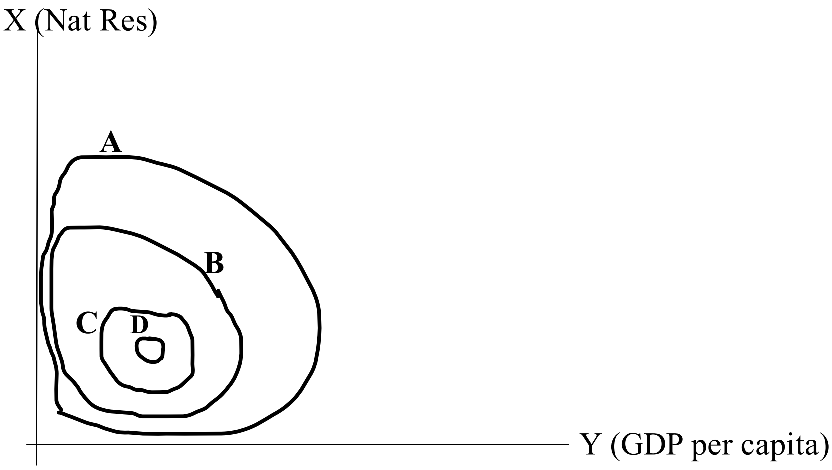
$$\frac{\dot{X}}{X} = (a - bY) \qquad (3)$$

$$\frac{\dot{Y}}{Y} = (-c + dX) \qquad (4)$$

This system of differential equations admits, assuming some initial positive value for both variables at t=0 (i.e., $X_{(t=0)}$ and $Y_{(t=0)}$), a stable solution around the critical point for both variables when both growth rates of X and Y reach zero. These critical values are X*=d/c and Y*=a/b.

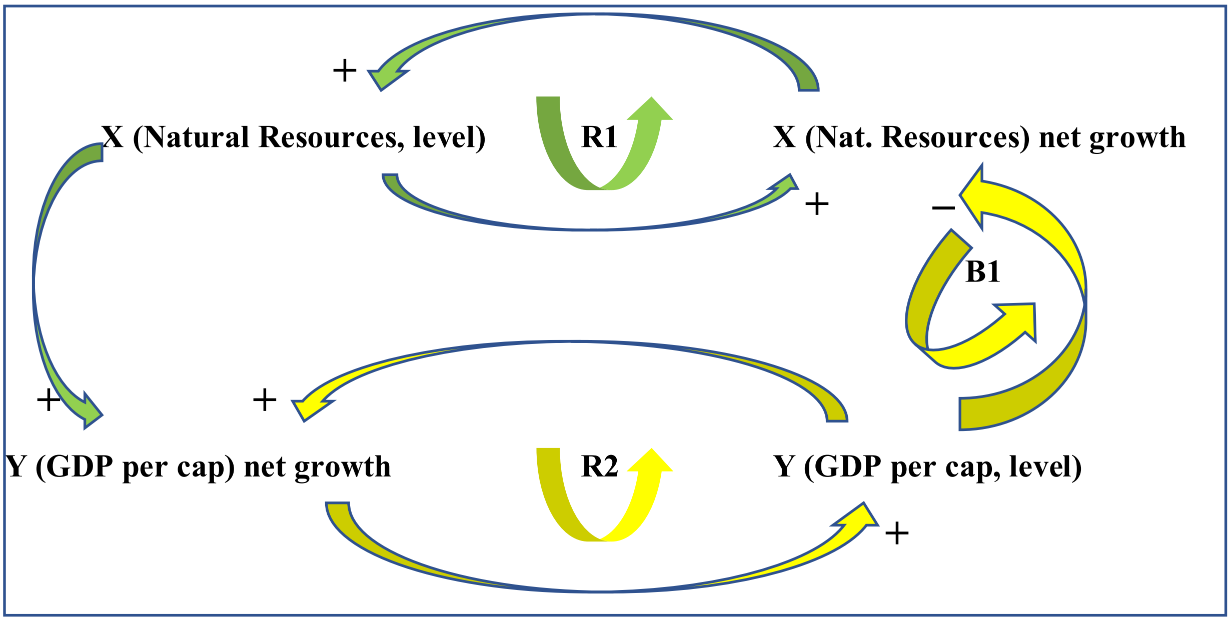
It can be easily shown that, given some initial values for the variables, if GDP per capita is greater than a/b then this will negatively affect natural resource growth which, in turn at the following period, will negatively affect GDP per capita, and thus the equilibrium will be restored around the critical values. This dynamic is replicated in an infinite cycle whose period can be rigorously determined[7]. For different initial values of the variables the following phase diagram depicts this dynamic.

[7] In this simple model (assuming certain initial values of the variables), the period for the cycle is given by $T = \frac{2\pi}{\sqrt{ac}}$



For example, locus D is plotted for certain initial values of X and Y (e.g., $X_{(t=0)}$=100 and $Y_{(t=0)}$=80); locus C, in turn, is plotted for initial values of the variables greater than 100 and 80 respectively; then locus B for even greater initial values, and so on. Thus, given the initial values the dynamic of the model indicates that the values will oscillate around the critical values for X and Y.

The following diagram (based on Weber, 2005) further illustrates the dependence of each variable on one another.



The above diagram shows the interdependency of the variables and the reinforcing (R1, R2) and balancing (B1) loops.

The stock of natural resources is dependent on the net growth of natural resources. But at the same time, the net growth of natural resources depends on their density positively (e.g. reforestation contributes to better soils, increase of biodiversity, etc.), as can be seen from both the upper green arrows. In this paper we use "natural resource" in a loose way to capture all production inputs associated with the natural environment.

The green arrow connecting the natural resources and GDP net growth is also positive, because the greater the availability of natural resources, the higher the potential for the GDP to grow. This positive effect is captured by coefficient d in the model, which can be taken as indicating some notion of *productivity* of the natural resources on the GDP growth. Then, increases in productivity will entail better use of the natural resources thus allowing for GDP growth.

The yellow arrows depict the other reinforcing loop, R2: GDP depends on its own growth. In a simple macroeconomic model, if growth declines, then future plans for investments, for example, will fall thus contributing to a drop in the level of GDP; then demand for investment being reduced will entail a lower "depletion" of natural resources. But, at the same time, if for any reason GDP grows (e.g. public expansionary fiscal policy) then the increase in demand will entail an increase in the use of the natural resources.

The balancing loop B1 indicates the depredatory behaviour of GDP on the growth of natural resources. In the model this is captured by the coefficient b. It is precisely this balancing force that will create oscillations in the model around the critical points.

Both this diagram and the phase graph above may help us bring in salient economic interpretations we find in the history of economic though and that are relevant, at least for some aspects, on the current debate around the impact of human activity on the earth eco-system, i.e., on climate and so on climate change.

a) Malthus (and Ricardo)

As is well known, Thomas Malthus followed the insights from B. Franklin on the relationship between growing populations and limited resources. Thus, in chapter 2 Malthus wrote that "[t]he ultimate check to population appears to be a want of food, arising necessarily from the different ratios according to which population and good increase" (p. 12). It is broadly known that this "law" entailed a very pessimistic view of Malthus and many other scholars of the time. Such a view was rooted in the conventional wisdom of the time that all natural resources (land) were already under cultivation and that any increase in their production would entail decreasing rates of products, which would not be enough to feed the increasing population; thus eventually leading either to positive checks (famine, wars, etc) or preventive checks (delay in marriage, etc). This implies a zero-sum relationship between population and resources.

The model depicted above may capture this dynamic. On the one hand the coefficient b in the model implies that increases GDP per capita (when population increases) would mean to use "more prey" but since all good lands (prey) are occupied, then marginal lands would be put in use and then the increase in food would be not enough to feed the new population. Then with the use of marginal (or distant land) the natural resources would be affected, thus providing declining levels in food provision. Then, according to Malthus, due to checks population would diminish, GDP would come bac to the "natural" equilibrium as so would the level of use of the natural resources. This process of a *gradual* equilibration process around the natural levels of use of natural resources and production can also be envisaged through the phase graph above, for example in terms of locus B – the economy is always orbiting around the critical values of Y and X, which in Malthus are the natural levels.

Further, since productivity in land use cannot be enhanced in Malthus's theory then there is no way to think of modify the coefficient *d* in the model, relating the natural resources and the food production growth.

b) *Smith and Boserup*

To a certain extent differently from Malthus, in Adam Smith we find a rather more optimistic view of the development of the system, even when the industrialisation had not yet been spread at the time of his writing, in the second half of the 18th century. For Smith, unlike Malthus, the division of labour *and* the extent of new markets would actually allow for an increase in output per capita and eventually an increase in the general well-being. Provided energy supplies remain stable (the industrial revolution brought with it a drastic transformation in energy production by coal) the division of labour would allow for the "skill and dexterity" of labour to be more efficiently used in the social production thus allowing for real growth per capita. Whilst we will not discuss here Smith's references to "natural" prices, "natural" values, or any other reference to "natural" that may sound somewhat compatible with the general approach shared with Malthus, what we want to highlight here is the fact that, for Smith there was room for real increase of food as population grows. In terms of our simple model, a better organisation thanks to the division of labour and the skill, dexterity and adaptation of workers to the working environment the product per capita would rise and therefore this would mean an increase of *productivity* which is captured in the coefficient *d*. An increase in this coefficient would mean that the same GDP growth could be achieved with *less* natural resources employed, what is exactly the same as thinking of small real increase in GDP growth using some more quantity of the natural resources. This increase in productivity would also allow to employ the natural resources more efficiently. At the same time, changes in the variables may move their critical values of equilibrium departing from certain initial conditions, which may turn the system unstable. One way to envisage this is to think that we shift from one locus closer to origin to another locus far from it; for example from locus D to locus C, or from locus C to locus B, etc., from our phase graph above.

Another economist who departed – more radically – from Malthus and Ricardo *on the specific issue relating population and subsistence*, is Ester Boserup. For her the fact that in the 18th cent England all lands were occupied and that recourse to marginal lands would give decreasing rate of food product did not mean that the same hypothesis could be wisely applied to the rest of the world, especially in the developing countries. Thus for example Boserup writes (1965, p. 14, emphasis added):

> Malthus thought that the increase of population to a level beyond the carrying capacity of the land must lead to the elimination of the surplus population either by direct starvation or by other positive checks which in his opinion could be traced back to the insufficiency of food supplies as the basic cause. The new version of Malthusian theory is based on the idea that the increase of population leads to *the destruction of the land*; and that people, in order to avoid starvation,

move to other land which is then destroyed in its turn. The neo-Malthusians collect all the evidence on the misuse of land and paint a picture of the world as a place where growing populations are pressing against a food potential which not only is incapable of increase but even gradually reduced by action of these growing populations. It is not to be denied that the food potential of the world has been narrowed down by populations, who did not know how to match their growing numbers by more intensive land use without spoiling the land for a time or forever. But nevertheless, the neo-Malthusian theories referred to above are misleading, because they tend to neglect the evidence we have of *growing populations which managed to change their methods of production in such a way as to preserve and improve the fertility of their land*.

In terms of our simple model it is worth noting, that what Boserup is referring to here, when she writes that in the Malthusian model moving to another land would imply a further destruction of that land, can be captured in our framework by the balancing loop B1 of the diagram. Indeed, decreasing productivity applied to marginal lands would make the latter even worse off for future crops or pasture, and so product per capita would eventually fall.

Picking on this last insight we may relate it to the fact that growing economies (predator) are impinging on the environment (prey). In Boserup and Smith counteracting forces such as better use of soils, division of labour and extension of the market would balance the negative effects, thus allowing for real increases in per capita GDP and well-being. However, once we want to use this framework to sketch a rough dynamic between the human activity and climate change/disruption in the ecosystem we have to realise that this problem cannot be circumscribed to a plot of land, or certain acres of forest, etc. In other words, this is a global problem. Many would immediately say that it will require global action and coordination to tackle this. We agree. But before that we think that a first attempt in that direction could be to discuss possibilities through which the state can take on active role into this framework.

3. State and collective action: some first thoughts

Given the above framework we may ask how the state could be brought into the dynamics illustrated and examine its potential role, if only conjecturally. If we think of the "prey" variable (natural resources) as reflecting some notion of ecosystem/climate we may relate this to the problem of greenhouse gases and global warming. As GDP per capita continues to grow and since the core of the energy sources are fossil fuels, then the "depredatory" effect given by b indicates the effect that economic expansion may have on the environment.

To be clear, a priori this does not mean that the Malthusian sustainability crisis is operating. It could be the case that, after cycles of "Schumpeterian" growth the locus depicted in the phase graph move outwards, thus indicating "jumps" in the capital accumulation process. But, even if the latter is the case, the "depredatory" effect of growth on climate would continue to be so because of the still heavy reliance on fossil fuel-based energy. In other words, it is the assumption (introduced above in the Smith sub-section) that energy sources would remain stable the key factor conditioning the sustainability of the whole economic process. In other words, market economies have always taken for granted that energy sources are more or less stable in terms of access and use. However, current challenges brought with climate change and greenhouse emission may lead us to drop this assumption. At this juncture one way to address this issue is to reflect on how the state could step in this dynamic.

The state is not such an "exogenous" player in the modern economy. Like in pre-modern times, the state is a key player in the economic process. To begin with, the state is much concerned about the economy and surplus generation as it has to collect taxes to cover for administration, bureaucracy, public companies, army, etc. At the same time, the state acts as an environmental agent, in that its direct action in the process will influence the ecosystem. For example, infrastructure such as canals, harbours, electricity network, gas pipelines are all key sectors which are underlying the economic activity. If economic growth is to be kept sustainably one way to think about this transition is to put at the fore of the debate the intrinsically necessary role of the state in this transformation.

To begin to think about this complex issue, and this outline paper is just a first attempt, using the above framework one can think that the state may be brought in as another branch in the relationship between economic growth and natural resources (environment) which on the one hand needs of economic growth and surplus to sustain the state itself, and on the other can influence the impact on climate and environment. Such a key role in this framework would entail an increase in the level of complexity and management of the state. As many historians of collapses of societies have noted, the key relationship between the state and the energy sector is a key one. And so for example Tainter (1988, p. 91) notes:

> Energy flow and socio-political organization are opposite sides of an equation. Neither can exist, in a human group, without the other, *nor can either undergo substantial change without altering both the opposite member and the balance of the equation*.

Modern society is far more complex than the pre-industrial society; having left the Malthusian fear of not feeding the world, societies now enjoy a myriad of services, artefacts, transports, connections, etc. This increase in complexity, as Tainter explains, implies that a higher level of bureaucracy, transport, centralisation, communications are required and so "all this complexity is dependent upon energy flow at a scale vastly greater than characterizing small groups of self-sufficient foragers or agriculturalists" (pp. 91-2).

On top of this key relation between state and energy is that the increase in complexity will entail an increase in the costs per capita to maintain the socio-political organisation. The more complex the organisation, the higher the costs will be. This must be taken into account when we think of the incorporation of the state in this framework to mitigate the impact of economic growth on climate change (to diminish the coefficient b of the model). In other words, as societies get more and more complex, in a context of global warming it is clear that states will have to pay for higher costs, in the aggregate, in order to intervene. In fact, at the level of industry or sectors, increase in complexity with intervention of the state or collective action may lead to a reduction on average costs – think for example the advantages of transport networks in cities vis-à-vis costs of transportation in rural areas. On the other hand, an increase on the administration and intervention of a more complex society at the macro level may increase.

For Tainter and other scholars who hold the thesis that an endogenous, Malthusian process is underway towards collapse (Diamond, 2005), the increased costs of complexity that the socio-political organisation must cover are due to some law of diminishing returns of investment in complexity and so doomed to failure. For Tainter this may be one of the reason fo why societies collapse. Tainter says:

> In many crucial spheres, continued investment in sociopolitical complexity reaches a point where the benefits of such investment begin to decline, at first gradually, then with *accelerated force*. Thus, not only must a population allocate greater and greater amounts of resources to maintaining an evolving society, but after a certain point, higher amounts of investment will yield smaller increments of return. (p. 92, emphasis added)

A priori, however, we believe this is open to other interpretations. It could be the case that a technical revolution in energy production can lead to mitigating climate change in the long run and so the investment in social complexity should not be seen through the lenses of marginal productivity.

Another issue worth exploring is the fact that, since climate change is a global issue, we will need to rethink about the fact that it is not one state that can intervene but there might be more than one. This entails state competition – if one state is not able to mitigate the negative impacts of growth on the environment, this does not mean that another one will follow the same faith. Because of this permanent state competition, single states -since the very formation of empires and then modern states – have to factor in what other states may or may not do also on this pressing issue of climate change.

Natural catastrophes are also another key element in shaping the human world and as such they must be incorporated into the discussion (see Brooke, 2014; Ellenblum, 2012).

(work in progress…)

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