Budgeting nature for sustainability

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Our planet Earth is with limited physical boundaries. The carrying capacity of nature can be relaxed to a certain and, in many cases, illusionary extent, but there exists a budget line from nature to support sustainable human development. Respect for nature indicates that human beings must abide by living within the boundaries of nature and make a clear and observable budget for exploitation and utilisation of nature in the process of pursuing a sustainable future of our mankind.

1 A life community sharing nature

There are variations in nature, but overall our nature is in balance and has its own rules. Such balances and rules are the fundamentals of nature budgets. If some elements of nature go too far beyond the other elements' capacity, the system of nature will be in turbulence. The budget line might have an immediate impact on one element of the living system, but this impact will be transmitted to others, and finally the system of nature will be changed accordingly.

Physical nature constitutes the basis for living organisms. Key indicators include, among many others, temperature, water, oxygen, nitrogen, minerals and many different gases. Living organisms share the physical environment and provide the conditions for other members of the life community. When some elements of nature go extreme, the survival of some members of the life community will be in immediate danger, and

such impacts will be passed on to the others through the food chain or the change of the ecological environment.

One example is the change in atmospheric temperature. Some members of the life community are more sensitive than the others. Human beings with modern technology and equipment can survive in an environment higher than 40°C and lower than –30°C. Nevertheless, many other members cannot stand such extremes. As a result, some species may disappear, and biodiversity losses would occur. Such loss of biodiversity will finally impact the human species as human beings survive from food supply from the living environment.

As a result, scientific observation and research establish a cause-and-effect relationship with earth surface temperature increase, further with the rise in CO_2 concentrations in the atmosphere and, finally, the continued increase in emissions of other greenhouse gases. For the protection of biodiversity, earth surface temperature increase was proposed to be kept at 2°C as compared to pre-industrial levels in the United Nations climate change negotiations in 2007 in Bali, Indonesia. This was further elaborated and agreed upon as documented in the Copenhagen Accord in 2009, and enhanced efforts are indicated in the Paris Climate Agreement in 2015 to restrict global warming to 1.5°C. Such temperature target is translated into the amount of carbon dioxide emissions that the atmosphere can still absorb, and this amount is understood as the budgetary constraint for climate security.

Understandably, the human race can stand and survive a temperature rise higher than 2°C, but many other species cannot. The balance of the ecosystem is thus broken, and human survival will be negatively affected and the sustainability of human society will be in danger. When we talk about human development, no one is left behind. In a living community, all the members share the physical environment and resources, constitute the conditions for the living of the other members and thus must obey the same budget line of nature.

2. *Indicators and measurements of nature budgets*

The budget approach was originated from, and applied to, the protection of the climate. When the 2°C target was addressed at the Bali climate conference in 2007, climate policy researchers rushed to calculate the amount of emissions consistent with the target and its equity implications. With its entry to the World Trade Organisation in 2001, China's process of industrialisation and urbanisation had been accelerating, and in 2006

China's total emissions from fossil fuel combustion surpassed the United States, becoming the largest emitter in the world. In *per capita* terms, Chinese emissions were higher than the world average as well. However, China's level of development was still insufficient as compared to developed economies. As the U.S. and a few other Umbrella Group countries[1] rejected or withdrew from the Kyoto Protocol, many people believed that a cap on emissions would limit the rate of economic growth in developing countries.

As carbon stock accumulated in physical infrastructure through historical emissions in the industrialised countries, emissions in the past are considered a necessary part of the total emissions contributing to global warming. Therefore, the total amount of budget available for keeping temperature below 2 or 1.5°C should be calculated from the start of the industrial revolution up to 2100 at the endpoint of the 2°C target. This accumulative amount of carbon emissions contributing to a 2 or 1.5°C temperature increase was then considered the budget constraint (Pan 2008). However, the budget numbers calculated from different sources vary substantially. An earlier calculation from the research group at the Chinese Academy of Social Sciences gives an estimate of 1.2 trillion tons of emissions from 2005 onwards (Pan & Chen 2009), and the other from the German Advisory Council on Global Change gives a figure of 0.75 trillion between 2010 and 2050, with a 67% probability meeting the 2°C target (WBGU 2013: 75). Such a budgetary approach is further institutionalised in the Paris Climate Agreement as adopted in 2015, indicating a goal of carbon neutrality in the second half of this century, or by the middle of this century if 1.5°C target is pursued, and detailed in Nationally Determined Contributions by the developed and many developing country parties, including the U.S., E.U., Japan and China.

Carbon has been more and more strictly budgeted at the global, national and sub-national levels for climate security as a leading element of sustainability. For biodiversity protection, we need a budget approach, too. However, the budget arrangements for biodiversity may not be as easy and straightforward as the climate target. The reason is that our knowledge about biodiversity is limited. We know that some species have been distinguished while many more are endangered. But there are numerous species that we have no records of or only limited studies. The other difficulty

1 The U.S. did not ratify the Protocol. Other Umbrella Group countries, including Australia, Canada, and Japan, withdrew from the Kyoto Protocol during the negotiation of the post-2012 commitment.

is that the species in danger cannot be protected on their own. Should we protect the endangered species, the entire ecosystem would have to be put under strict protection. Therefore, the budgetary indicator is not the number of species or the size of population. Instead, it should be a spatial area where the protected species live together with others in the complete ecosystem. In this regard, it is the spatial area that should be budgeted and allocated for protection.

Then how can a budgetary framework for biodiversity protection be established? When we say a system in which man and nature are in harmony, what does this mean exactly? Harmony does not mean domination or monopoly by one; instead, it means sharing resources in a proportional manner. A combination of three basic interpretations can be obtained with budgetary implications. One refers to an exclusive domination of wilderness. That is, strictly protected areas for endangered species or specific ecological systems not allowing any human activities, and all wild species should be exempted from human interventions. Around 1119 A.C. in Song Dynasty, wild tigers roamed around in Shandong, now a densely populated coastal province of China. Population expansion has been encroaching the area where wild animals and primary ecosystems prevailed 900 years ago. Now we have set apart a proportion of protected land to maintain exclusively for wilderness. The second should be an area that allows co-existence. Arable land, plantations and planted forest areas are mainly for agricultural production, but the space is also open to species compatible with human activities. The third refers to urban, industrial and other human settlements in which human activities dominate.

To protect biodiversity and unique ecosystems, we need to have a budget for land for different purposes. Land for exclusive wilderness, agriculture and forest production, and urban and industrial use should be properly budgeted and enforced to ensure sustainability. The land budget for exclusive wildness should be systematic, covering all the important ecosystems where the well-known endangered and unknown living organisms interact within the life community and the physical environment. Currently, some 15% of land is under protection for nature. Evidently, this is not enough. Each year we have large areas of land flooded, and a large proportion of arable land is marginal. If flood retention areas and marginal land are exempted from human intervention, nature would be more resilient and friendly to our social and economic system. This accounts for some 10% to 15% of our land space. Urban and industrial land is highly concentrated, and the ratio is around 5% of the total land area. So roughly the budget for land uses can be estimated: exclusively for

nature at some 25% to 30%, agriculture and forest production at 65% to 70%, and urban and industrial at 5%.

Owing to the existence of a food-water-energy nexus, the water budget is as important as land budgetary constraints. If all the water resources are extracted for human activities, wild members of the life community would not have a chance to survive. This is particularly the case in arid and semi-arid regions where water is in shortage for human demand. For example, in northern China, underground water has been over-extracted for intensive farming, industrial usage, and urban expansion. Beijing's underground water table is some 20 m lower in 2019 as compared to the 1960 level. Among 2.86 billion m^3 of freshwater extracted in 2020, some 60% goes to domestic consumption, 10% to industrial, 11% to agricultural and 19% to environmental/ecological uses (BWB 2021). As almost 60% of freshwater supply in Beijing is budgeted to secure domestic consumption, only around 20% of extracted freshwater goes to agricultural and industrial production. This means that food supply must be highly reliant on other regions, and employment in the industrial sector must be limited as well. Therefore, such a budgetary arrangement requires substantial water and energy for food production and supply in Beijing where water deficit constitutes a challenge for ecosystem security and sustainability.

3. The rigidity of budget constraints

Can the budget of nature be relaxed? Technologies, market forces and investment can help in the short run, but in the longer run we have to face an increasing physical rigidity of the budget constraints.

Technological innovation has an impact on both resource-saving and acceleration of resource depletion. Take water shortage as an example. We have the technologies to dig deeper and deeper in order to extract underground water. Immediately water supply is increased. If water extraction is larger than natural replenishment, underground water reserves would be exhausted in the end. Extensive investment in long-distance water transfer helps relocate water resources spatially. If the distance is too far away, risk and uncertainty may result in unbearable costs in the long run. For mitigating water shortage in Northern China, a 1,432 km long water transfer canal was constructed, diverting water from Hanshui in the South all the way up to Beijing and Tianjin, with capacity totalling around 12 billion m^3 annually, with about 1.2 billion to Beijing and Tianjin respectively. In addition to risks associated with such a long canal, climate change is likely to change the weather pattern, and water availability for transfer

might be in question. Another example is the enlargement of urban space. Buildings can be constructed high into the sky, and underground space can be explored to provide more space for demand. Such technologies can relax the budgetary constraint of land surface to a certain extent, but, in addition to the limits for the application of such technologies, financial, social and environmental risks go up exponentially.

With efficiency-improving technologies, the budget of nature can be relaxed progressively, but the physical rigidity cannot be removed. For instance, regarding coal-fired power generation, super-super-critical technologies require only 270 grams of coal for 1 kWh electricity, which makes them some 30% more efficient than sub-critical technologies. But such improvement is unable to reduce coal consumption to zero. However, revolutionary technologies prove a zero fossil fuel consumption for energy supply. Renewable energy technologies, such as solar, wind, water and carbon-neutral biomass, produce energy but with no connection to fossil fuels and with zero-emission of carbon. Even so, there is also a budget line from nature: competition for solar radiation with regard to land surface use for agriculture, forest or photovoltaics.

4. A simple conclusion

Planetary boundaries are the ultimate budget line for resource use and consumption. Respect for nature requires human beings to understand, make and abide by a budget of nature for sustainability. The budgetary constraints from nature are highly rigid, and inappropriate or excessive budgeting for human demand will risk system failure and put our future in danger. Technological innovation and investments can help relax the budgetary constraints only to a limited extent and in the short run, but we have to be aware that some technologies can speed up the process of resource depletion and damage to nature. Even for the use of renewable resources, they are not exhaustible, but their supply is also subject to a budget of nature constraints. For sustainability, we do not only need a carbon budget for climate security but also a land budget for biodiversity and ecosystem safety and a water budget for water-food-energy nexus security.

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