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Article 1

Economic Growth in the Anthropocene

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Abstract

The explosion of global economic activity following the Second World War coincides with a new geological time, the Anthropocene, where humans are the main factor in the broader Earth system. A feature of this coincidence is the decumulation of *natural capital* (wetlands, grasslands, biomes such as the oceans and soils, etc.). To better understand this decumulation and its relation to broader human economic activity, I here focus on the maintenance and regulating services that undergird natural capital (climate regulation, decomposition of waste, nitrogen fixation, etc.). From this focus, I propose a model relating human ecological footprint and stocks of natural capital. I close by offering some policy proposals to regulate this relationship going forward.

Keywords: exhaustible resources and economic development, environment and development, sustainability.

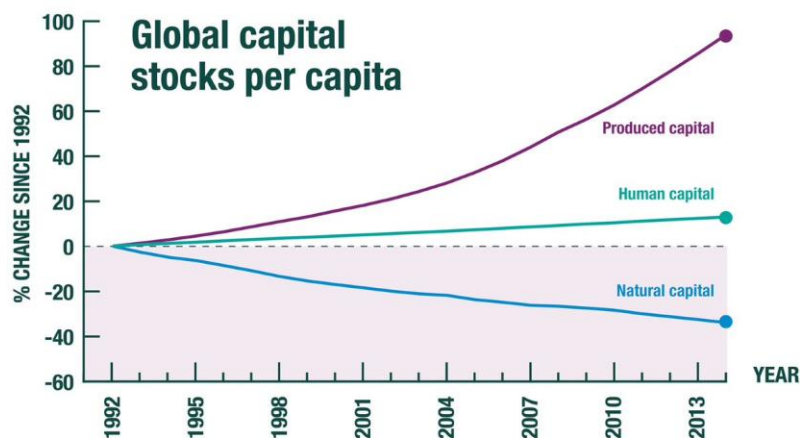
Some Global Economic Statistics, 1950–2020

Since 1950, nearly all aspects of the global economy have radically changed: Global GDP has increased more than 15-fold to over \$120 trillion PPP. Per-capita global GDP has increased more than 5-fold to some \$20,000 PPP. Population has increased more than 3-fold from 2.5 to 8 billion. Life expectancy at birth has increased from 46 to 72 years. And the proportion of people in extreme poverty has declined from more than 60% to less than 10%.

These statistics reflect a rare intersection between economics and the Earth sciences, for Earth scientists have dubbed 1950 as being the year we entered the Anthropocene—a geological time where human activity has been the primary factor that affects the Earth system.¹ The growth of the global economy during this period *is* the story of the Anthropocene: the economy now looms large against the Earth system.

The enormous success reflected in these statistics has been achieved by an accumulation of *produced capital* (roads, buildings, ports, and machines) and *human capital* (health, education, skills, and character). But it has been accompanied by the decumulation of *natural capital* (wetlands, grasslands, mangroves, coral reefs, woodlands, forests, lakes, and such biomes as the atmosphere, the oceans, the soils, and subsoil resources). For example, the rate of species extinction is estimated today to be 100 to 1000 times the background rate of extinction, which is some 0.1 to 1 species per million per year. At this elevated rate, some 1 million species of a total of 8 to 20 million species will be extinct in the next 100 years. By one UN estimate, in the period 1992 to 2014, the global stock of produced capital per capita doubled and human capital per capita increased by some 20%, but natural capital per capita declined by 40%.

Figure 1. Global Capital Stocks Per Capita, 1992–2014



Source: Managi and Kumar 2018.

¹ There are debates about the beginning of the Anthropocene, but in 2019 the Anthropocene Working Group of the International Commission on Stratigraphy made a formal proposal with the mid-twentieth century as the start date.

Growth and development economics and the economics of poverty need to account for the decrease in natural capital. Yet GDP, as a flow, does not record depreciation of capital, so cannot serve as the measure. Economics should instead look to the principles of asset management, and the measure we should ideally deploy is *inclusive wealth* (the accounting value of produced capital, human capital, and natural capital), which is a stock.

We should be measuring the (inclusive) wealth of nations, not the GDP of nations. That's because inclusive wealth corresponds to well-being across the generations—if one increases, so does the other. Measuring inclusive wealth, however, is only an ideal; it is not achievable: there will be far too many forms of natural capital whose accounting prices will fall within, at best, wide ranges. But the inclusive-wealth approach is invaluable because it tells us what to approximate. We thus avoid the temptation of proposing ad hoc measures, such as the UN's Human Development Index. In what follows, I focus on one component of inclusive wealth: natural capital.

Nature's Goods and Services

The biosphere is a self-regenerative asset, supplying us with a variety of goods and services. Ecologists have offered a two-way classification of nature's goods and services: Provisioning goods include food, water, timber, fibers, pharmaceutical products, and nonliving material. Regulating and maintenance services include climate regulation, decomposition of waste, nitrogen fixation, air and water purification, soil regeneration, pollination, and so forth.

We have increasingly drawn on nature's regulating and maintenance services to provide ourselves with provisioning goods, by mining, quarrying, and otherwise transforming the landscape (e.g., forests cleared for agriculture and plantations; grasslands transformed into pastureland). There is thus an inevitable tension between provisioning goods on the one hand and regulating and maintenance services on the other. But regulating and maintenance services are fundamental, without them there would be no provisioning goods.

It is important to note that when we economists talk of substitution possibilities between different types of natural capital, we have provisioning goods in mind. In contrast, regulating and maintenance services are *complementary*, which sets bounds on the extent to which human ingenuity can be exercised to transform natural capital into produced and human capital. Nature is not a house of cards, of course; she is resilient, but we humans are so powerful that we could convert her into one if we so chose.

One way to identify the difference between provisioning goods on the one hand and regulating and maintenance services on the other is to recognize that the biosphere is a dynamical system (i.e., of differential equations). Provisioning goods are stocks (the state variables), which are recursively mapped from one period to the next. The forms of the functions that constitute the mapping are the regulating and maintenance services.

The global demand of maintenance and regulating services made by the human economy has in recent decades outstripped nature's ability to supply them on a sustainable basis. The most widely known example is the global demand for carbon regulation, which exceeds the biosphere's ability to meet that demand on a sustainable basis. "Net-zero" is an expression of the desire to bring the two into equality. Turning to the aggregate level, the global demand for maintenance and regulating services today exceeds nature's ability to meet that demand on a sustainable basis by a factor of 1.7 (this estimate employs land-use changes

to estimate changes in the flow of those services). That’s why people say we need 1.7 Earths to meet human demands!

Global Impact Inequality

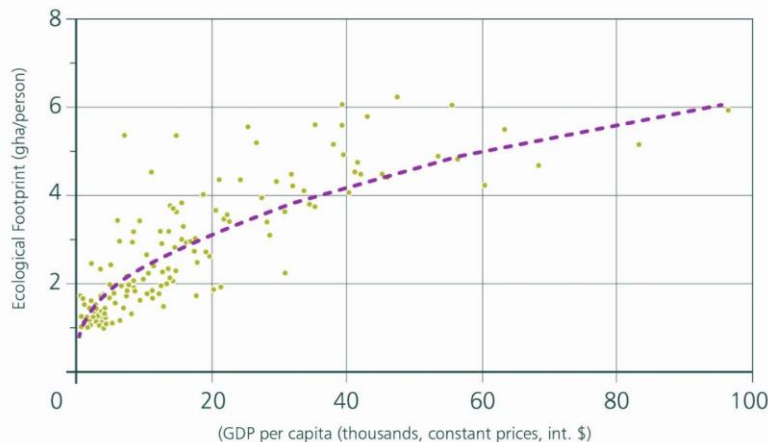
We can model the current imbalance between the demand for and the supply of maintenance and regulating services—the global impact inequality. Let N stand for the global population, y the per capita global GDP, and α the efficiency with which the biosphere’s maintenance and regulating services are converted into global GDP. We can thus interpret Ny/α as a measure of humanity’s ecological footprint. Let G stand for nature’s regeneration rate, which we can think of as the (annual) rate at which nature supplies us with maintenance and regulating services, expressed as a scalar aggregate. And finally let S stand for the biosphere, measured as a stock of natural capital. $G(S)$ is thus the ability of the biosphere to supply goods and services sustainably. (Note: We could equally base $G(S)$ in terms of provisioning goods.) Thus, our model of the global impact inequality can be expressed as

$$Ny/\alpha > G(S)$$

As G is bounded, Ny/α is bounded. It should be noted that α reflects both technology and institutions. Sustainable development will require that the impact inequality be close. You can do that by reducing Ny , increasing α , increasing $G(S)$, or some combination of those three. But α cannot be increased indefinitely, for to do so would require that humanity can asymptotically free itself at the margin from nature.²

But there are problems within problems:

Figure 2. Ecological Footprint and Income



Ecological footprint is measured in global hectares (gha), a unit that “represents a rate of biological regeneration equal to that of a world-average biologically productive hectare” (Lin et al. 2018, 3). Source: Dasgupta 2021, fig. 4.10.

² I have expressed the impact inequality in terms of scalar measures. In principle there would be a relationship between demand and supply of each regulating and maintenance services. An example of a vector of inequalities are the planetary boundaries.

The concavity of the function means that redistribution of wealth from the rich to the poor puts a strain on the biosphere, that is, average income would have to be lowered if the total footprint is to remain the same.

A Sample of Global Policies

“Pay for what we use”—so the *New York Times* very perceptively summarized the main policy proposal from *The Dasgupta Review*, my 2021 report for the UK government (Grossman et al. 2023). If we did, then the system of prices people face would be so different from what it is today that technological change would display a very different character. New technologies would be far less rapacious of nature.

In my report, I suggested several more specific policies: We should enforce charges for the use of oceans (transportation of goods, pleasure cruises, mining, fishing, and polluting) through an international agency. Crude estimates suggest humanity could raise billions and billions of dollars annually. The revenue could in part be used to pay nations that house tropical rainforests for protecting them (akin to payment for ecosystem services that are in play within national boundaries). But I have been assured by those who understand global politics that the world does not have the appetite for such an institutional change. Finally, we should invest in family planning and reproductive health, especially in sub-Saharan Africa, where the growing population projection to 2100 entails poverty traps. Unfortunately, global decision makers do not want to talk about population.

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