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Limits to Growth: human economy and planetary boundaries

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Abstract

The idea of physical limits to human economic systems is advanced by physical scientists and ecological economists, as well as appealing to the common sense proposition that unending growth in physical processes such as material extraction and waste disposal will ultimately be inconsistent with any finite entity, even one as large as the Earth. Yet growth remains the central aim of business and government almost everywhere. This paper examines the history of the idea of economic growth and the many influences and interests that supported – and still support – its enshrinement as the principal aim of human societies. These include the apparatus of propaganda in favour of corporate interests; the emphasis on international trade; the funding of environmental denial; and, underlying all these, the corporate requirement for profit to continue to increase. The dominance of these influences has serious consequences for the natural world while growth has failed to solve the problems of poverty.

Keywords:

Limits to Growth; propaganda; consumerism; environmental denial; planetary boundaries.

The authors of *The Limits to Growth* (Meadows et al., 1972) were not the first to draw attention to physical limits on the expansion of the human economic system, but they enjoyed substantial attention, especially in the 1970s, and brought the concept into mainstream thinking. The project came out of the concerns of the founding members of the Club of Rome and drew on the discipline of systems analysis being developed at the Massachusetts Institute of Technology (MIT).

The Club of Rome, founded by Italian industrialist Aurelio Peccei and Scottish scientist Alexander King, brought together a select group of prominent, mostly wealthy individuals who wanted to address what they called the *problematique*, translated as "the predicament of mankind". Peccei saw post-war economic and industrial advance as a double-edged sword and described himself as "perplexed and worried by the orderless torrential character of this precipitous human progress" (Barney, 1982, p.607). Soon after it was founded in 1968, the Club commissioned the Limits to Growth project at MIT with researchers Donella Meadows, Dennis Meadows, Jørgen Randers and William Behrens.

The MIT team identified five major aspects of this predicament: accelerating industrialisation, rapid population growth, extensive malnutrition, depletion of non-renewable resources, and environmental decline. They formulated this question: how could growing populations, locked into ever-expanding industrialisation, avoid immense environmental degradation, exhaustion of the resources on which everything depends, and the social chaos that would be likely to follow decline or collapse? To answer this question, they devised World3, a computer program that combined extensive data about the many interacting aspects of the economy and the environment, with different scenarios about changes that might be made. These scenarios ranged from business as usual (the standard run), through several combinations that assumed extremely advanced technology, to scenarios where both population and physical throughput were stabilised. The standard run led to collapse around the middle of the current century. Even massive technological advance could not avert this outcome, but there were scenarios that could: those that stabilised population and wound back the scale and rate of material extraction and waste.

The book remains the best-selling environmental book ever published, but its reception in the political and economic mainstream was mixed. In the early years, both US President Carter and Prime Minister Trudeau of Canada took it

seriously and launched parallel studies (Barney et al., 1981; Barney, 1982; Voyer and Murphy, 1984). From the beginning, however, most economists ridiculed the idea that human economic systems have physical limits (Beckerman, 1972; Economist, 1972; Nordhaus, 1973; Solow, 1973), an attitude which came to prevail. One characterised the World3 computer program as "Garbage in, garbage out". Robert Gillette (1972), who reported for *Science* at the launch of the book, noted that the "assumption of inevitable economic growth" constitutes "the very foundation" of the economics profession – which may help to explain the intensity of the assault from economists.

In recent years, several researchers (Hall and Day, 2009; Turner, 2014) have compared the Meadows projections with what has actually happened. The correlation between the standard run (business as usual) and real world trends over the intervening years is extremely close. Hall and Day (2009) could not find "any model made by economists that is accurate over such a long time span". Given that the projections up to 2010 have proven accurate, it would seem wise to question the pursuit of business as usual.

Unprecedented Growth since 1950

Growth, of both economies and populations, was indeed "torrential" in the years after the end of World War II, especially the first three decades. The world's population increased from just over 2.5 billion in 1950 to almost 4 billion in 1975.[1] In the same period, world GDP more than doubled. Thus, by 1975, the base of both the economic system and human numbers was already immense and doubling times were short. By the 1990s, annual increase in world GDP has been estimated to approximate the entire global output of 1900, about one trillion in 1990 US dollars (DeLong, 1998).[2] Although economists like to argue that humans have been exploiting their resources and pursuing economic growth since the Stone Age (Solow, 1974; Beckerman, 1972), there has never been anything like the twentieth century.

Australian climate scientist Will Steffen and colleagues have shown just how unusual it was, in the sets of exponential graphs known as "The Great

1. It is estimated to have exceeded 7.5 billion during 2016.
2. DeLong uses several methods. Estimated annual additions for the 1990s vary from half the entire economy of 1900 to the entire 1900 economy.

Acceleration" (Steffen, Broadgate, et al., 2015). The graphs start at the year 1750 and run to 2010; the disjunction around 1950 is clear in all of them. Figure 1 shows the economic aspects of the growth boom. Despite the financial crisis of 2007–2008, the continuation of this trajectory is sought, to the maximum extent possible, by governments and international organisations.

Socio-economic trends

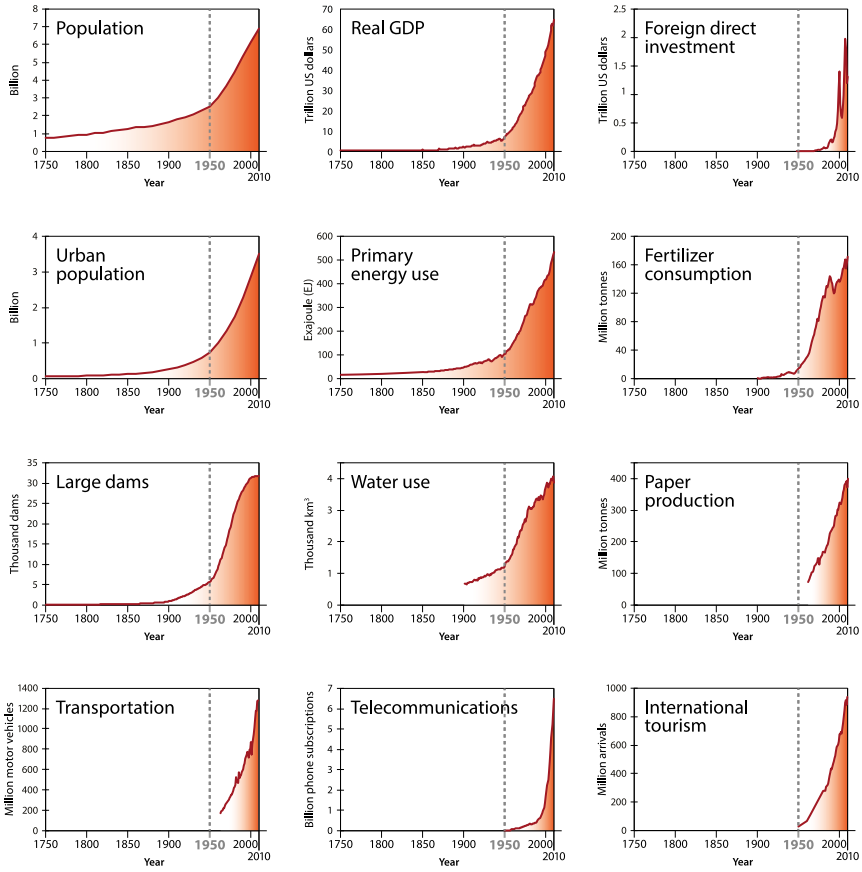

Figure 1. The Great Acceleration, social and economic aspects, courtesy Will Steffen.

The economists' intense attack on *Limits to Growth* reflects the rift between the core assumptions of mainstream economics and those of the physical sciences. Basic economics textbooks depict a standard model where the circular flow between production and consumption has no natural context: producers and consumers are seen to function without any reference to the physical world of resources and wastes. Ecological economists, on the other hand, and most physical scientists, accept Nature as the essential foundation of the human economy; in this framework, production requires resource inputs from the physical world and sinks where its wastes can be absorbed: depletion and pollution are inescapable.

In mainstream economics, economic growth is understood to be the result of two factors: capital and labour. This picture was developed while energy and resources were plentiful; economists could ignore the physical basis of economic activity, including the role of energy. Physical scientists, on the other hand, regard energy as the "master resource", since no other commodity can be produced without it (Cleveland, 1991; Zencey, 2013).[3] One of the ecological economists, Kenneth Boulding, warned in 1966 that the "cowboy" economy (which had commanded the limitless resources of an "empty world") was over; humanity faced a new situation which he called "spaceship Earth", a world that was rapidly filling up. Odd as it may seem, economics has yet to fully acknowledge that energy is just as essential to production as are labour and capital, even though the massive economic growth since 1950 has depended on it.

Economic growth as a corporate goal: inventing consumerism

Notions of limits to economic growth threaten many powerful groups that depend on continually rising profits and the expansion of the physical economy.

3. By the 1950s, empirical studies had shown that capital and labour could explain only one seventh of observed economic growth in the US. There was no clear candidate for the rather large missing ingredient, although "technical progress" was often assumed to provide the best explanation (Ayres and Ayres, 2009, p.11). Later, Robert Ayres (a physicist) and Benjamin Warr identified the missing factor as energy – or, more exactly, as the increasing efficiency with which energy and raw materials are converted into useful work. In this explanation, technological improvement plays a part, but Ayres and Ayres (2009, pp.9–18) stress that: "labour and capital *extract* energy; they don't *make* it". Thus energy is a *prerequisite* for, not a *product* of economic activity.

One of the crucial innovations of capitalism[4] was the system of accumulation, where production surpluses are largely devoted to expansion of the enterprise. Growth is indispensable to such a system, and the corporations that emerged around 1900 were determined to maintain it. The immense productive powers developed over the nineteenth century had met the basic needs of most of the US population by the early twentieth century and the captains of industry feared that the system had triggered a permanent crisis of overproduction. The American capitalist economy confronted the plenty it had created as a threat to its very existence.

A consumer solution, however, was simultaneously emerging. Edward Bernays[5] (2005), one of the pioneers of the public relations industry, pointed out in 1928 that mass production can only be profitable if it ensures steady or increasing demand, which, he suggested, could be accomplished "through advertising and propaganda". Although the practice of inciting consumption has earlier roots (Higgs, 2014, pp.68–69), the first major surge of mass consumption was promoted in America in the 1920s. A "new economic gospel of consumption" was urged (Cowdrick, 1927); new needs could be created, with advertising enlisted to "augment and accelerate" the process (Hunnicutt, 1996). People could be encouraged to give up thrift, value goods over free time and, with ever-increasing aspirations, they would always be chasing a receding goal. Just before the Wall Street Crash, President Herbert Hoover's Committee on Recent Economic Changes (1929) welcomed the "grand... expansibility of human wants and desires", celebrated an "almost insatiable appetite for goods and services", and foresaw "new wants that make way endlessly for newer wants, as fast as they are satisfied". People were encouraged to board an escalator of desire (a stairway to heaven, perhaps) and progressively ascend towards the luxuries of the affluent.

Although the Great Depression interrupted this process, it resumed after World War II with an intensity stimulated by corporate advertisers using debt facilities and the new medium of television. As retail analyst, Victor Lebow, put it in 1955:

4. With the partial exception of Cuba, socialist and communist economies have been just as dedicated to industrialisation and economic growth as their capitalist rivals. Eastern Europe and the former Soviet Union were even more severely polluted than the West, as is China today; although a state-controlled economy, China is hardly "socialist" (Higgs, 2014, pp.5–7, 11–13).

5. Nephew of Sigmund Freud.

> Our enormously productive economy demands that we make consumption our way of life... that we seek our spiritual satisfaction, our ego satisfaction, in consumption. … We need things consumed, burned up, replaced and discarded at an ever accelerating rate (Kettles, 2008, p.47).

Vance Packard (1959) described the advertising men of this new era, putting "sizzle into their messages by stirring up our status consciousness", making what were once luxuries into the "necessities of all classes". Sold as status symbols perhaps, it was endless material objects that were being consumed.

The prospect of ever-extendable consumer desire, characterised as "progress", promised a new way forward for modern manufacture, a means to perpetuate economic growth. Progress required the endless replacement of old needs with new, old products with new. Notions of meeting everyone's needs with an adequate level of production did not feature. In this sense, the twentieth century capitalist era unleashed desire with its complex individual peculiarities and set it loose in the marketplace of material goods, supplanting basic survival needs as the purpose and driver of economic growth. Up to now, there has been little change in this strategy. As we run up against the limits of material production, nothing could be more inimical to finding solutions.

Economic growth as policy goal: the idea takes over

In the reports of the IMF, World Bank, Organisation for Economic Co-operation and Development (OECD) and G20, and in the speeches of our politicians, economic growth is seen as imperative, and it may seem that government – and international – economic policy has always embraced this view. However, Australian economist H W Arndt (1978) demonstrated that the idea of economic growth as a policy objective appeared quite abruptly in the 1950s – as did the idea of "development". Governments pursued neither material development nor economic growth during the first half of the twentieth century, academic economists rarely discussed it, and neither businessmen nor politicians thought governments had any role in promoting it (Arndt, 1978).

At his inauguration in 1949, President Harry Truman signalled a departure from this position[6], announcing the intention of the US to extend modern industrial production to every corner of the earth: "More than half the people of the world are living in conditions approaching misery…. Greater production is the key to prosperity and peace.... [and will require] a wider and more vigorous application of modern scientific and technical knowledge" (Truman 1949).

Soon afterwards, a new field of economics emerged, defining the well-being of the world's people in terms of economic growth and the exploitation of resources. The new "development economists" echoed Truman's vision of technology as the engine of human progress, and stressed capital accumulation as the central facilitator. Energy did not play any role in their theories. Walt Rostow (1960) held that "the age of high mass-consumption" is the ultimate stage of progress. W Arthur Lewis (1954) argued that traditional cultures and subsistence livelihoods must be swept away and replaced by the industrial money economy, a necessary and inevitable process.

"We are interested", Lewis wrote, "not in the people in general, but only in the 10 per cent of them with the largest incomes.... The central fact of economic development is that the distribution of incomes is altered in favour of the saving class". In this respect, the development economists adopted a "trickle down" approach to solving the misery Truman lamented. Lewis focussed on consolidating the wealth of the rich, who would instigate an economic "take-off"; at a later stage, he believed, the resulting economic growth would reach the poor. In recent times, neoliberal ideology embraced the same idea, with its claim that cutting taxes for the wealthy leads them to invest and therefore benefit everyone. Neither the expectations of the development economists nor the claims of the neoliberals are supported by empirical evidence. In both cases, wealth has "trickled up" (Higgs, 2014, pp.119–123).

Quest for the bigger pie

Several imperatives underpinned the new scramble for economic growth in the post-war world. After the Great Depression, full employment was regarded as an essential policy objective and economic expansion was believed to be the only practical way to achieve such a goal. In the "developing" world too, where national

6. See Hickel (2017, pp.7–9) for an account of how this came to be included in the inaugural address.

liberation movements had to be accommodated or neutralised, growth was preferred to redistribution of land or resources. Although growth has increased the numbers of the middle class in some developing countries, especially China, and despite persistent claims that economic growth has "lifted millions out of poverty", the reality is not so rosy. More than half the world's people still live in poverty, without reliable material security, even if the definitions used by the rich world's institutions tend to obscure the fact. Prosperity is concentrated among a privileged minority (Higgs, 2014, pp.105–162; Hickel, 2017).

The so-called "bigger pie" was promoted as the obvious solution to all social problems – debt, unemployment, poverty, and even the environmental damage involved in baking it. It still remains the primary strategy for the institutions of the OECD world, whether businesses, national governments, or the international bodies allied to business. In these forums, no-one asks where we are to find the ever less accessible ingredients for this ever more gargantuan pie.

Post-war theories of economic growth harboured two key assumptions – and continue to do so. Firstly, economic growth is regarded as an inevitable stage of human civilisation, a natural and linear progression from more "primitive" social forms. Secondly, economic growth is seen as a process of indefinite duration, with no limits in space or time. On a graph, it is a curve which continues upward forever, permanently exponential. Such beliefs are a form of magical thinking. They ignore problems of resource scarcity, especially that of energy, they ignore waste and they ignore the destruction of the natural world in which everything is based.

Arndt's fears that the limits critique would end the pursuit of economic growth were groundless; in fact, the influence of such ideas waned as neoliberalism increasingly monopolised the economic discourse, and began to dominate government policy from around 1980 when Ronald Reagan was elected as US President, and Margaret Thatcher had just settled into Downing Street.

Naturalising the "free market"

Neither natural nor inevitable, the so-called free market has received massive advocacy for more than a century – in order to create, retain and extend public acceptance. The roots of this process lie back in the early decades of the twentieth century, just as the modern corporation was emerging (Higgs, 2014, pp.167–169).

By the 1920s, with Edward Bernays in the lead, public relations (PR) began to gain ground as a career path. As Bernays (2005, pp.37–38) explained in 1928, with a candour rarely heard these days:

> The conscious and intelligent manipulation of the organised habits and opinions of the masses is an important element in democratic society. Those who manipulate this unseen mechanism of society constitute an invisible government which is the true ruling power of our country. … It is they who pull the wires which control the public mind.

Bernays described himself as a "propaganda specialist" or a "public relations counsel". He and his colleagues were anxious to offer their services to corporations and were instrumental in founding an entire industry that has since operated along these lines, selling not only commodities but also opinions on a great range of social, political, economic, and environmental issues.

One early PR man, Ivy Lee, simply made up facts to suit the purpose (Higgs, 2014, p.170), a precursor of the "alternative facts" which have become more palpable than ever since 2016. Later, with the advent of Bernays, PR centred on the careful construction of image: for example the idea that corporations exist to serve, rather than turn a profit; the displacement of the term "big business" with a new enemy, Big Government; the denigration of public servants and politicians as "fat cats" while CEOs were depicted as models of generosity; and the replacement of terms like capitalism, laissez faire and private enterprise with the sanitised expression "free enterprise" (Higgs, 2014, pp.175–178).

The work of hired propaganda specialists was augmented by that of think tanks later in the twentieth century. Just a handful of these institutions predate 1970; but by 2015, their number was estimated at almost 7,000 (McGann, 2017). Funded by corporations that prefer to avoid regulation (for example tobacco, asbestos, chemicals, fossil fuels, mining, car manufacturers), business-friendly activists set out to "litter the world" with "free enterprise" think tanks (Cockett, 1995, p.307). In the US, the family foundations where fortunes of corporate leaders are often held also chipped in handsomely (Higgs, 2014, p.90, pp.191–192).

These ferociously proliferating think tanks have disseminated industry propaganda as "independent research" ever since. Most are tax-exempt and vociferous claims

to independence disguise their political ties. One think tank operative, however, told researcher Georgina Murray (2006) that it would be naive to imagine that think tanks are established "by Santa Claus or the tooth fairy". Rather, as Irving Kristol (1977) admitted, they are always intended to "shape or reshape the climate of public opinion". Think tank staff enjoy immense influence in the media of the English-speaking world, where they are depicted as scholars on a equal footing with peer-reviewed academics and have also been recruited into governments. Heritage, American Enterprise Institute and Hoover supplied 150 of Reagan's staff – and numerous Heritage operatives were "borrowed" by George W Bush. In the UK, the Thatcher government owed much to the Institute of Economic Affairs and the Centre for Policy Studies (Higgs 2014, pp.96–98, 214–215).

Think tanks promoted the bogus standard of "balance" in place of impartiality and accuracy, as they pursued "equal time" in media and educational institutions. Analysis of the US prestige press between 1988 and 2002, showed that "balanced" reporting successfully obscured the scientific consensus on global warming by giving equal, or even greater, space to those who denied that climate change was occurring (Boykoff and Boykoff, 2004). This trend is symptomatic of multiple efforts to undermine any science that threatens polluting industries (Higgs, 2014, pp.211–238) and demonstrates the efficacy of "balance" as a tool of obfuscation.

The drive for "free trade"

By the early 1980s, neoliberal ideology was established as the economic creed of the governments of the UK, US and Australia and had begun to penetrate international institutions. When assisting developing countries, the IMF now insisted on Structural Adjustment Programs which required strict market policies in exchange for its help. These programs were rarely in the interests of the citizens of these countries: privatisation, deregulation, balanced budgets, abolition of welfare measures and removing barriers to foreign investment usually disadvantaged the poor.

By 1986, the General Agreement on Tariffs and Trade (GATT), founded in 1948, had attracted 108 member countries and slashed tariffs by 75 per cent. Like "free enterprise", free trade is not so much about freedom, but about abolishing rules for corporations and substituting rules for governments and citizens. Already, under the GATT arrangements, rules relating to environment, health or working conditions were excluded as not "trade-related". The World Trade

Organisation, fiercely pursued by corporate lobbyists, was finally established in 1995, and followed the same blueprint. Dispute panels of both entities were run by corporate lawyers or economists with no input from environmental experts.

Under the trade regime of the GATT-WTO system, trade has priority over environmental, health, and social justice considerations, regardless of the wishes of a government and the people it represents. To enforce trade obligations, the rules penalise countries if they choose to assess risk and protect citizens or environment under their own standards. For example, it is regarded as irrelevant if fish are caught with collateral slaughter of dolphins, or if residues of pesticide or growth promoting hormones exceed local limits. The burden of proof is reversed, so that citizens must prove commodities are unsafe rather than manufacturers having to show they are safe.

Although the GATT concentrated on removing tariffs on actual goods, the WTO and subsequent multi-party agreements such as the North American Free Trade Agreement, moved to abolish restrictions on capital flows, making it nearly impossible to prevent stampedes of capital in and out of countries on speculative errands. Overall, economic goals gained precedence over all other priorities. By the new century, business priorities were entrenched in public discourse, government policy, and international institutions (Higgs, 2014, pp.246–254). Economic growth was established almost everywhere as the only way to solve any problem. Environmental protection and social justice, both national and worldwide, were now deemed to depend on it.

Approaching the planetary boundaries: four major problems

Over the twentieth century, physical production increased twenty-fold and human population quadrupled. The consequences continue to cascade through the natural and human world, literally liquidating life on earth. Although the roots of this post-war growth lie deep in our history, it was not until about 1950 that the scale of the human project began to outgrow planet Earth decisively. It might not have mattered so very greatly at other points in history, but frantic attempts to restart the growth curve of the past 70 years and to enshrine economic growth as the central element in government policy are now in conflict with physical reality.

Figure 1 showed the economic aspects of the growth boom. Figure 2 shows the corresponding physical changes in the natural world. From the 1960s onwards,

scientists such as Rachel Carson sounded alarm about various problems associated with growth, but this was not the case in governments, bureaucracies and public debate, where economic growth was gradually being entrenched as the central objective of collective human effort. The transition to service economies in developed countries has not moderated the global trajectory of either economic or natural impacts, since our consumption continues to increase, with even greater quantities of far cheaper material objects imported from the countries that now conduct manufacture.

Earth system trends

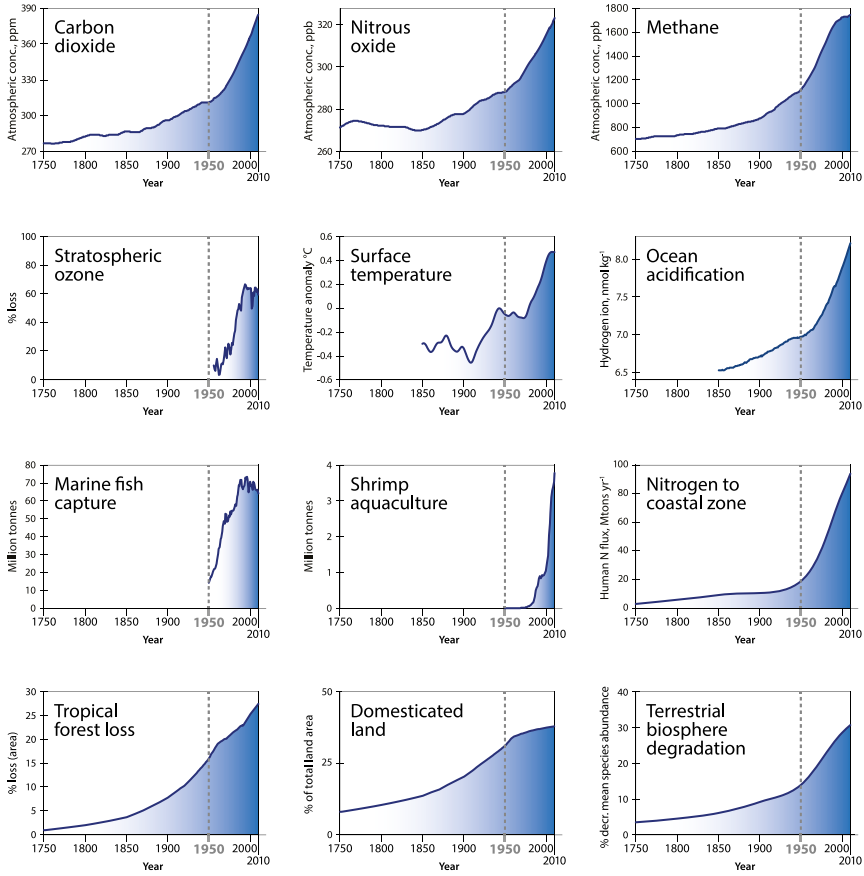

Figure 2. The Great Acceleration, impacts on Nature, courtesy Will Steffen.

The concept of planetary boundaries has been developed by a team led by Johan Rockström of the Stockholm Resilience Centre and Will Steffen from the Australian National University. It is a work in progress and the exact extent to which we are breaching these boundaries is still being quantified; the teams' most recent paper (Steffen, Richardson, et al., 2015) argued that two problems are already extremely dangerous and two others are well on the way.

Biodiversity

The boundaries team argues that the most serious problem is loss of biodiversity.[7] We are losing species 100 to 1,000 times faster than the background rate through geological time and the world lost something like 50 per cent of all its mammals, birds, fish, amphibians and reptiles in the forty years following 1970. This research refers to numbers of animals, not species, but smaller populations are increasingly vulnerable (Ceballos et al., 2015; WWF, 2014).

Trade plays a crucial role in obscuring the location of the ecological damage embodied in consumer products. It allows the people who consume most of the goods to transfer the damage involved to the generally much poorer people who host the extraction of the materials they are made from and the factories where they are made. Manfred Lenzen and his team (2012) estimated that some 30 per cent of extinctions are related to trade. The website shipmap.org gives a graphic picture of the immense scale of trade by sea; trade by air is also extensive. My own country, Australia, occupies an unusual position for a developed country. Mainly through agriculture – and to some extent mining – we sustain more ecological damage on behalf of others than we export through consuming products made elsewhere. Consumption in the US, Japan and Europe, however, transfers significant ecological damage, especially to countries in Africa and South-East Asia.

Disruption of biogeochemical cycles

For Steffen and colleagues the second most immediate danger lies in the impact of fertilisers: the nitrogen and phosphorous cycles are radically disrupted. In Nature, most nitrogen was inert in our atmosphere (though mobilised by bacteria

7. Most serious in the sense of most well advanced. Many scientists argue that non-human species and ecosystems have intrinsic value, a view I share; but even if one rejects this view, humans nonetheless depend on the fabric of life on earth for survival – for food, clean water, pollination and numerous other ecosystem services as well as for novel substances, including drugs (see Crist, Mora and Engelman, 2017).

and leguminous plants). Mainly through making fertiliser, nitrogen is now flooding through our rivers, groundwater and continental shelves, causing algal blooms and dead zones where fish, molluscs and aquatic insects may die, sometimes in large numbers.[8] In the case of the other widely dispersed fertiliser, phosphorous, there is an added danger – phosphate rock is a resource in decline, with grim implications for agriculture (Cordell and White, 2014). Phosphorous is an element, one of the indispensable building blocks of DNA, and no market on earth will be able to manifest a substitute, though it could be recovered from human waste.

Land use changes

Land use change is in the "amber zone", close to crossing the boundary into extreme danger; it is also implicated in the threat to biodiversity. Humans are still clearing millions of hectares of vegetation every year and draining wetlands. Tropical forests of Asia and Africa are being replaced by palm oil plantations, also expanding in Latin America, where clearing already provides cattle pasture, soybean and sugar cane. Oil palm plantations involve the death of immense numbers of individual animals and the annihilation of vast tracts of tropical forest. In China and South Korea, wetlands that support migrating birds are being drained and transformed into ports. Growing populations, in both rich and poor countries, contribute to this pressure (Crist, Mora and Engelman, 2017).

Global warming

Also in the amber zone is global warming. We are well on the way to a very hot planet and, to remain below the 2°C target, we require technologies which do not yet exist for extracting carbon from the atmosphere. Even if the commitments made in Paris are all honoured, it will already be 2°C hotter than pre-industrial times[9] by 2050 and at least 2.7°C hotter by 2100. The aspirational 1.5°C target is likely to be reached by the early 2030s (Watson et al., 2016).

This situation is better than the likelihood of 4°C which applied before Paris, but there is no guarantee that we will limit the damage to 2.7°C. Even if we do, that temperature will reduce crop yields, make many places unliveable, melt the

8. Humans now produce more reactive nitrogen than natural processes do. Excess nitrogen involves hazards in addition to eutrophication: the greenhouse gas nitrous oxide (N_2O) is released during fertiliser application; nitrate may also leach into groundwater and contaminate drinking supplies.
9. Usually defined as pre-1870.

glaciers that supply water to billions in Asia and South America, destroy coral reefs and many other species, and produce significant – even catastrophic – sea level rise. James Hansen and his team (2015) regard 2°C as already posing a dangerous sea level threat, as much as 3m this century. The Greenland icesheet is melting at an accelerating rate. Not considered likely a decade ago, the entire coast of West Antarctica is dotted with ice shelves that are shrinking or collapsing as warm seawater intrudes underneath. Glaciers are speeding up as a result; Pine Island glacier is considered to be melting irreversibly, as is Thwaites and other adjacent glaciers (Rignot et al., 2014). It is expected to take several centuries before really catastrophic sea level rise occurs, but Hansen et al. (2016), as well as many glaciologists, warn that the melting of the polar icesheets involves non-linear processes of disintegration, so the timing is unknown and may be far quicker than assumed.

Pollution

Alongside these four major crises (species loss; disruption of the biogeochemical cycles; land clearing; and global warming), Steffen's team is also aiming to quantify how close we are to being overwhelmed by pollution and novel substances. This aspect of their project is ongoing, but we do know that there are more than 5 trillion plastic fragments in the ocean, so prevalent that 90 per cent of sea birds are now ingesting them, while deep sea creatures are eating micro-plastic fibres disgorged by our washing machines (Eriksen et al., 2015; Taylor et al., 2016). And we do know that the ocean is acidifying.

Conclusion

As the historian Dipesh Chakrabarty (2009) noted, what is new about the pursuit of the study of history in the twenty-first century is the need to address the intersection between natural history and human history. The key to this collision is the concept of scale, an insight brought to prominence by the ecological economists. Herman Daly and his colleagues perceived that the scale of the human project in relation to the scale of the planet had reached an unsustainable ratio. Especially since World War II, the human project has altered – and continues to alter – the actual physical condition of the earth.

While deniers of ecological crisis like to argue that notions of human impacts on the geophysical scale are laughable, this attitude reveals an ignorance of natural

history. It is scientifically uncontested that humble cyanobacteria microscopically producing oxygen over two or three eons created an oxygen-rich atmosphere suitable for complex life, including ours. If algae can have planetary impacts – expressed very slowly, but unquestionably a geophysical force – big animals such as humans are obviously in a position to change the planet rather faster.

Herman Daly's ten-point program (2008) is an excellent example of the sweeping changes ecological economists consider necessary, most of them totally unacceptable to corporate capitalism. His policy summary includes ecological tax reform; limitations on unequal income distribution; the re-regulation of international commerce; the downgrading of the IMF, World Bank, and WTO; the abolition of fractional reserve banking; stabilisation of the population; and the transfer of the remaining commons to public trust. Under the current economic system, there seems little to no chance that any of these measures would be adopted by governments that exist at the pleasure of market forces.

And yet, structural change is indispensable. Some propose a transition to socialism, others hope to tame the capitalist economy and establish a steady state economy. Both options seem equally hard to imagine in the neoliberal era. However, to hijack Margaret Thatcher's famous expression, "there is no alternative".

We need a different kind of economy, one designed to meet needs rather than create them; we need to abandon the consumer path to human advancement and the reduction of our choices to monetary terms. The consumer template for the human future has outworn its usefulness. Stimulating consumption in the interests of growth and chasing economies of scale was, perhaps, suitable for the "empty world". In the "full world" (and getting fuller) we need redistributive justice within and between countries and a plan for the rich world to reduce its material demands to allow space for the rest of the world to reach material security.

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