10.3197/whpjps.63887831800450

RESEARCH ARTICLE

The role of medicine for the alleviation of resource scarcity: Towards a 'Consumption and Production Medicine' framework

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Abstract

Despite technological progress, humanity suffers from (at least) two ills: it operates beyond planetary biophysical limits and continues to face unmet needs. This paper explores the intersection of medicine, economic wellbeing and ecological sustainability in the context of global resource scarcity. A conceptual classification of resource use – reasonable, wasteful, and negative externality-induced – is introduced to better understand the consumption and production forces shaping resource scarcity. Then I explore how medicine focused on prevention and reversal can reduce resource scarcity: by shifting consumption patterns toward healthier and more sustainable lifestyles, it both augments the human and non-human resource base of the economy and reduces demand for resource-intensive and environmentally damaging uses. Thus, it is concluded that Preventive and Reversive Medicine is a powerful (albeit unacknowledged) extant technology that simultaneously reduces resource scarcity and increases well-being and, critically, contributes to the disassociation of human well-being from environmental impact. The (wanted) side-effect of this process is more leeway for the global economy to provide a good life to all within planetary limits. This, I suggest, is essentially the 'Consumption and Production Medicine' that humanity needs.

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Keywords
Lifestyle medicine, preventive medicine, reversive medicine, population health, resource scarcity, negative externalities, environmental externalities, production and consumption, SDG12, sustainability, planetary boundaries, ecological footprint.

Resource scarcity continues to be a major obstacle to the achievement of a good life for all

Medicine's main moral obligation is, broadly speaking, to reduce physical suffering (Hofmann, 2024).[2] Sometimes physical suffering stems from, or is concurrent with, economic suffering, i.e., having a smaller income than needed to have a 'good life'.[3] Sometimes, though, physical suffering may stem from lifestyle choices enabled by a larger income, as is the case with non-communicable diseases (NCDs).

A 'good life' could be defined as a comfortable but not wasteful life in the Aristotelian sense (Lianos, 2016) or as a life compatible with the 'ultimate end' of economic activity, a term encompassing material comfort but also moral and ecological soundness (Daly, 1980). Notwithstanding the difficulty of defining the content of a good life, especially in terms of produced goods, there are estimates of the amount of additional production that would bring all living people within an acceptable definition of a good life. Some suggest that global production would need to be five to ten times bigger than today (World Commission on Environment and Development, 1987; Roser, 2021). Others find that a decent life for all could be possible if the efficiency of transforming the planet's resources into (produced goods and then) human/social wellbeing, were increased by two to six times (O'Neill et al., 2018); this is essentially tantamount to suggesting that

2 The term 'medicine' is used in the text in an expansive way. It comprises the knowledge and tools that can be used to promote health of individuals and populations. The term 'preventive and reversive medicine' that will be used later does not specifically refer to an established specialty but is used to underscore that the primary goal of the use of medicine should be prevention and reversal rather than treatment of symptoms. An established specialty that gets closer to this goal is probably 'Lifestyle Medicine', mentioned later in the text.

3 The terms 'good life' (εὐδαιμονία), 'decent life', and 'wellbeing' are used interchangeably in the text, mainly as reminders that consumption of produced goods and services does not automatically translate into a 'good life'. To define the product mix of the global economy that could best promote good life or wellbeing or a meaningful life (serving Daly's 'ultimate end') is beyond the scope of this paper.

global production should increase by two to six times, under the current technical efficiency of the economy.[4]

A major obstacle for further growth of global production is the scarcity of resources, i.e., not having enough resources relative to needs. Resources can be thought of as elements that can be used either directly (such as clean air) or indirectly (as inputs of production of goods and services) in the 'wellbeing' function of individuals and societies.[5] There are two transformations that take place between usable resources and a 'good life': first, resources are transformed by the economic system into products and services; then, products and services have to be transformed into well-being, the latter being similar to what Daly defined as 'ultimate end'.[6]

In this paper I attempt to provide a working framework for the imbalance between finite means and increasing global needs, and how prevention- and reversal-focused medicine can beneficially affect them – the central idea is that wellbeing is constrained by resource scarcity, i.e., the short supply of (services from) resources relative to needs.

That resource scarcity exists is one of the least debated topics in economics; in fact, it is the reason for the existence of economics: the discipline of allocating

4 It should be noted that many scholars typically acknowledge (a) the additional needs created by an expanding population, and (b) the incompatibility of increasing global output with sustainability; these observations increase the severity of the scarcity problem that will be discussed below.

5 The mainstream economic terms for resources are 'factors of production' or 'production inputs' that are used to produce material goods and services. Nevertheless, some resources increase wellbeing without being purposefully produced or exploited by the economic system (such as the beauty of unspoiled natural landscapes, biodiversity, sea breeze, clean air, clean spring waters, human relationships, peaceful societies, solitude and privacy, free space, etc.). It is not my purpose to provide a strict definition of resources here, but to use the term in a way that makes sense to most disciplines. For stricter definitions of resources and resource scarcity in economics and ecological economics, see Jones, 2018; Haddad and Solomon, 2023.

6 The concept of resources may be better understood in terms of the services (per period) that they provide, as will be illustrated in Figure 3. For example, a hectare of forest provides carbon sequestration services, flood control services, recreation services, etc.; a manager provides managerial services; a delivery truck provides transportation services for goods; a building provides shelter and functional services; and so on. However, in the text, the word 'resources' will be sometimes used instead of 'services from resources' for the sake of simplicity. For example, when we say 'resources are wasted or degraded' this means that we waste the services that could be delivered by these resources.

scarce resources to their best uses. Scarcity is broadly manifested in the price of goods. If resources were abundant, the price of 'a good life' would be such that every person could afford it. Since prehistoric times resource scarcity has arguably led to misery, wars, conflicts, migration, and colonies. With many parts of the world and population segments within rich countries lagging behind both in terms of per capita income and in various well-being indices (Jansen et al., 2024) it is not easy to support the opposite statement; i.e., that resources are plentiful.

On the other hand, it is also reasonable to believe that resources are not scarce in a definitive, permanent way. Faced with scarcity, human ingenuity seems to have augmented the effective supply of resources (resource services) so that more needs could be catered for. For example, after WWII humanity has experienced a large period of continuous growth of production volume, coupled with large increases in per capita incomes and wellbeing indices for almost everyone on the planet. Extreme poverty is now rarer, the diseases and outcomes associated with poverty (infectious diseases, maternal and child mortality, etc.) are rarer, people are more educated, and life has arguably become more comfortable for almost everyone, despite the global population increasing from 2.3 bn to more than 8. It could be reasonably expected that human ingenuity can make the global economy grow even more, until the remaining economic suffering is eradicated and everyone lives a good life.

The flaw in this belief is that it assumes the ability of the economic system to replicate the growth rate of the past; it does not take into account the negative externalities (negative impacts) of production and consumption incurred so far, or the natural (biophysical) limits within which the economic system is functioning (Costanza et al., 2015). Both of these effects reduce the ability of the economic system to deliver increasing output at the rates seen in the past. In other words, it could be that previous output growth has taken place at the expense of further growth, leaving the current population with resources that are fewer and/or of lesser quality.

Further, there is a more important flaw in the belief that growth of output has led to the reduction of economic suffering. It can be argued that the reduction of economic suffering and the increase in the people being able to afford a good life since the post-WWII period has been a *by-product* of growth, not a deliberate achievement of the economic system. As it is structured, the economic system is rather good at allocating resources to a global product mix that is useful for those who can pay, not to those farthest away from a good life. Collective values such as sustainability and justice are not well represented in the market; thus they are under-represented in the ensuing product mix. This may be why expenditure in beauty and personal care products in the US alone (around $100 bn in 2024, (Statista, n.d.)) is larger than the financing gap for education- and health- related SDGs combined (Sachs, 2019). The economic system is not good by design at purposefully achieving a 'good life', as the allocation of resources to uses that (i) can be backed by income, and (ii) are based on individual (not social) preferences takes principal position over the allocation of resources to uses that serve ecological sustainability and justice. In terms of Daly's ends-means spectrum (see Kalimeris, 2018 for a discussion), the economic system arguably fails by conception, design and measurement to allocate human-made intermediate means (resources such as technology, knowledge, human effort and, critically, our social capital and institutions) to the best mix of intermediate ends (health, education, sustainable infrastructure) that would efficiently serve the ultimate end.

However, all these human-made means are ultimately dependent on the ultimate means: the finite stock of low-entropy matter-energy provided by the planet's natural processes. Our current production and consumption patterns, particularly those that can be characterised as 'wasteful' or 'negative-externality induced' (see below), often prioritise the expansion of intermediate means and consumption without sufficient regard for their impact on the ultimate means, i.e., on the planet into which our economic system grows within and from which it feeds. In a sense, the economy is akin to a foetus, within a womb, that grows by poisoning both its mother and the amniotic fluid. This prioritisation deficit leads to a distortion of the identity and purpose of the economic system, exacerbating resource scarcity and environmental degradation, as exemplified by the transgressions of planetary boundaries discussed below.

Indeed, a large body of literature suggests that (a) the planet (our 'ultimate' resource) is for years beyond its capacity to absorb the economy's waste and regenerate natural resources at the rate needed (even with large deficits in attaining basic 'good life' elements such as universal access to healthy food, health care and education) and (b) that the impacts of previous growth to the environment, public health and future wellbeing are vast, expensive and difficult to reverse; climate change, sea level rise, plastic and chemical pollution, biodiversity loss and the increased risk for pandemics are cases in point (Lebreton and Andrady, 2019; UNEP and ILRI, 2020; Dasgupta, 2021; Keesing and Ostfeld, 2021; Ripple et al., 2022; Grandey et al., 2024; Ling, 2024; Schlesier et al., 2024; Symeonides et al., 2024; Luby et al., 2024; Zhu et al., 2025; Hyman et al., 2025). Thus the conditions in which the economy operates now are not as favourable as they used to be. In other words, achieving 'good lives' for all may not be as feasible as it once was. But, importantly, the current state of the planet endangers not only the rate of further growth of production, but the existence of humanity itself (Ehrlich and Harte, 2015; Barnosky et al., 2016; Bradshaw et al., 2021; Cafaro, 2022; Ceballos and Ehrlich, 2023).

The literature on planetary boundaries provides a comprehensive quantification of the negative externalities of current production and consumption. It indicates that humanity has entered a region of risk for irreversible negative outcomes: six out of nine planetary boundaries have been transgressed so far and a seventh boundary (ocean acidification) is about to be transgressed (Richardson et al., 2023). For two of the transgressed boundaries, we do not have the knowledge yet to either quantify the risks (the chemical pollution – 'novel entities' boundaries) or to measure humanity's exact impact (the 'biosphere integrity' boundary). Importantly, a transgressed boundary amplifies the impacts of human activity on other boundaries (Lade et al., 2020; Villarrubia-Gómez et al., 2024).

If we consider the whole planet as one resource, the planetary boundaries literature shows that the planet (our most essential resource) cannot sustainably provide for the *current* needs of humanity for production and waste absorption; and this is so despite many countries' shortcomings in various economic and social wellbeing goals (Fanning et al., 2022). At the same time, a world of *ad libitum* increasing human population *de facto* reduces the feasibility of achieving 'good lives for all'; thus there is a trade-off between per person wellbeing and human numbers (Daily et al., 1994; Ferguson, 2005; Pimentel et al., 2010; Lianos and Pseiridis, 2016; Dasgupta et al., 2021). Indeed, human population numbers seem to be a defining factor of the transgression rate, even in countries (such as China and India) with modest per capita incomes and per capita transgression rates (Tian et al., 2024). The transgression rate can be seen as an estimate of the intensity of resource scarcity, and both per capita consumption and population make scarcity more intense, *ceteris paribus*.

The ecological footprint literature provides similar information for the global but also the country level. This literature, examining a sub-area of planetary boundaries, compares land ('biocapacity') that is available for food, settlements, wood, and absorption of CO_2 (only) to the resource use ('footprint') caused by an economy's consumption or production each year.[7] When available biocapacity is smaller than the footprint (needs), then an ecological deficit ('overshoot') ensues. The size of the overshoot can be again taken to be an estimate of the intensity of scarcity.[8] It can be seen that since 1961, the earliest year for which ecological footprint accounting data exist, the scale of global economic production increased dramatically, which went hand in hand with an increasing intensity of overshoot and augmentation of ecological scarcity: in 1961, human needs were just 73% of biocapacity, but the needs rose to 125% in 1991 and 174% in 2021 (calculated with data in Dworatzek et al., 2024). For the world as a whole, forty per cent of global production and consumption is currently over what would be required for ecological balance, a metric that could be taken to measure the debt to future generations (Lianos and Pseiridis, 2021). And this debt to the future is steadily increasing.

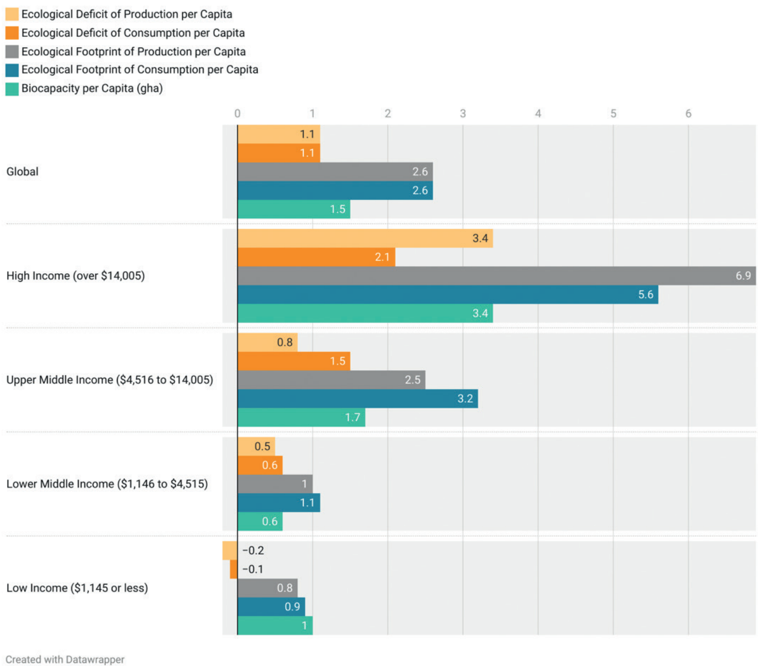
An ecological deficit means that each year's production and consumption leave the world, countries and individuals with fewer (e.g. forests) and/or degraded resources (e.g. soil and biodiversity) each year. And this happens despite (or side by side with) technological advances that supposedly reduce the per capita ecological impact of consumption and production and/or increase biocapacity. As shown in Figure 1, only the low-income countries still, as a group, consume and produce within their means, but these are also the countries that are most in need to increase their level of consumption so that they, too, achieve a good life.

7 Biocapacity and footprints are measured in a standardised artificial metric called 'global hectare'. A global hectare is a hectare of average global productivity. A country with lower-than-average productivity 'owns' fewer global hectares than its geographical area. Also, the footprints are measured in required hectares of global average productivity, not in the country's productivity. At the country level, the ecological footprint of consumption will be larger than that of production in countries that consume a lot of foreign biocapacity embedded in imports; it will be smaller than that of production in countries exporting more biocapacity than they import – see Figure 1 and its note. Of course, a country can have a deficit in both consumption and production.

8 As the market does not cater to the needs of those without income to support purchases, both a planetary boundary transgression rate and the ecological overshoot rate underestimate the actual chasm between needs and means.

As mentioned above, this type of scarcity is exacerbated when population increases. The country ecological footprint accounts show that this is the case with 90% of countries and the planet as a whole. At the global level, although between 1961 and 2023 global biocapacity has increased by 22% (arguably due to technological progress and increases in technical efficiency), the increase of population size resulted in a 54% reduction of global *per capita* biocapacity. In all but one of the low-income countries that I studied, the per capita biocapacity diminished dramatically within the same years (e.g. in DR Congo from 14 to 1.9 global hectares, an 86% loss; in Central African Republic from 22.1 to 6.6 global hectares, a 70% loss), leaving each person with fewer ecological resources to cover their (desired to increase) needs.[9]

Figure 1. Resources (biocapacity) vs needs (either for consumption or for production), and intensity of scarcity (ecological deficit) in 2023 (per person, in global hectares)



9 The list of 176 countries studied (those with quality flag + or ++) are provided in the Appendix.

Notes: The figure shows the ecological resources (biocapacity), needs (for consumption and production), and impacts (ecological deficit) in 176 countries (98% of the global population) classified along the four World Bank income groups. Income groups refer to the 2023 calendar year. Values are per person, in global hectares for 2023. If the per person biocapacity is smaller than the footprint, then a country (or the planet) is in overshoot. The global footprint of production equals that of consumption as at the global level there is no trade of biocapacity embedded in products. Thus the global consumption footprint equals the global production one. The low-income countries as a group still have a per person footprint of consumption smaller than their per person biocapacity thus present a small (but declining) ecological surplus of consumption. The high- and middle- income country groups are in overshoot. The high-income countries are net exporters of (overshooted) biocapacity, while the middle and low income groups are net importers. Compiled by the author with data from Dworatzek et al., 2024. Download link: https://www.datawrapper.de/_/9isfn/?v=4

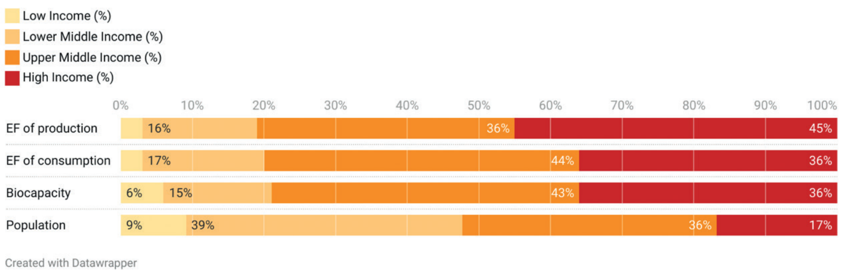
That all but one low-income countries have witnessed a decrease in per capita biocapacity[10] and most (15 of 26) are already in ecological deficit, shows that even countries with materially deprived individuals can produce and consume beyond available ecological means. Further, contrary to the global trend of increasing total biocapacity (+22% between 1961 and 2023), many countries across all per-capita income levels[11] experience a *total* biocapacity decrease as well. This, coupled with the unequal share of global biocapacity that low-income countries and lower-middle income countries own compared to their population (which makes up almost half of the global population, see Figure 2), makes a weak case for achieving peaceful and 'good' lives for all.

10 The only exception among low-income countries is *South* Soudan (for which data exist since 2012, when former Sudan was split into South Soudan and Soudan) where the per capita biocapacity has increased 1% between 2012–2023. During the same years, Soudan's per capita biocapacity decreased 18%. Among the 21 low-income countries with data since 1961, the decrease in per capita biocapacity ranged from 52% (DR Korea) to 87% (DR Congo).

11 Countries include Antigua and Barbuda, Barbados, Bolivia, Brazil, Central African Republic, Colombia, Congo, Costa Rica, Cyprus, DR Congo, Ecuador, El Salvador, Eritrea, Gabon, Gambia, Grenada, Guadeloupe, Guyana, Iceland, Japan, Liberia, Mauritania, Mongolia, New Zealand, Nicaragua, Panama, Paraguay, Samoa, Somalia, Suriname, Trinidad and Tobago.

A large body of the literature attributes the inability of the current economic system to provide good lives to all to an overconsumption focus of the wealthiest which is to the detriment of the poorest (Wiedmann et al., 2020; Kallis et al., 2025). On the other hand, individuals in the less affluent fifty per cent of the global population already live beyond some of their allocated (i.e., per person) planetary boundaries (Tian et al., 2024). It is therefore difficult to imagine the level of material consumption that could provide good lives to the current global population without creating overshoot or further transcending planetary boundaries.[12] The trade-off between wellbeing and population size make this exercise even more difficult in the face of the continuous increase of the global population (Lianos and Pseiridis, 2016; Samways 2022).

Figure 2. Share of global population, biocapacity, and ecological footprint (EF) among countries of different income levels, 2023



Notes: Low-income countries and lower-middle income countries have a share of global biocapacity that is smaller than their share of global population. Compiled by the author with data from Dworatzek et al., 2024 on 176 countries (98% of the global population) classified along the four World Bank income groups. Graph download link: https://www.datawrapper.de/_/k0F8Q/?v=6

Both perspectives (planetary boundaries and ecological footprint) show that the global economy does not serve well the good life objective, either for current or future generations. Besides degrading resources and putting humanity's future at risk, the negative impacts of global production and consumption (mis)allocate resources to uses that do not increase wellbeing; that is, instead of

12 In fact, describing a lifestyle that, if adopted by all 8 billlion humans, would keep the impact of production and consumption within the boundaries would be an interesting topic for future research.

resources being entirely used to increase humanity's wellbeing, some of them are diverted to managing damages instead. The volume of misplaced resources has been found to represent a considerable portion of production and also to result in considerably reduced subsequent volumes of production (Lianos and Pseiridis, 2021; Bilal and Känzig, 2024; Kotz et al., 2024), with both effects antagonising the positive effects of technological progress on the objective of 'good life for all'. To use a metaphor, suppose the global economy produces only bricks; many of them are used to repair damage created by how humanity produces and consumes. Therefore, the bricks left to build additional houses are limited. But also, fewer bricks can be produced each year due to resources getting fewer and fewer. These may be two reasons why it seems to be difficult to provide a good life to all either by the market or even through policies (Sachs et al., 2024).

The components of economic scarcity: resources and needs

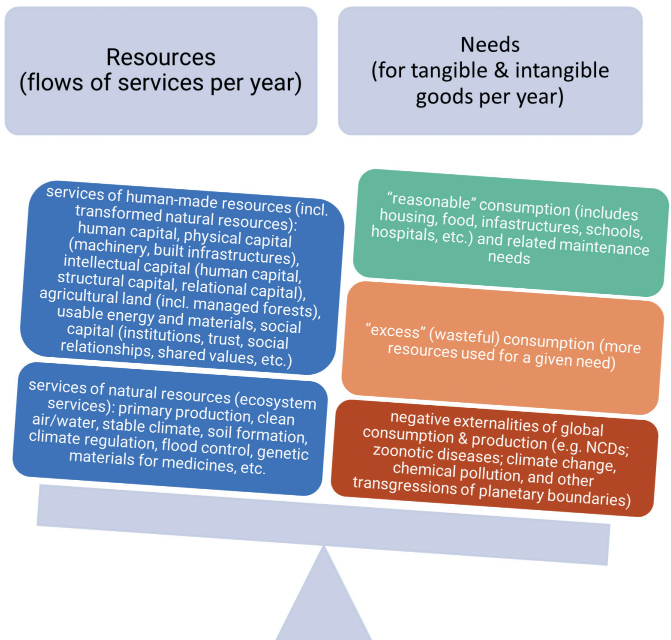
The above discussion outlines the constraints that the increasing intensity of resource scarcity puts on future wellbeing for all countries. Given resource scarcity, meaningful interventions to help ease humanity's problems should either be able to (a) increase wellbeing without augmenting resource scarcity or (b) reduce wasteful consumption and the negative impacts of the economic system so that some resources are freed from unnecessary or non-meaningful uses.

Figure 3 provides a graphical representation of resource scarcity with the use of a scale. The scale is tilted to signify that available resources (left) are not enough to meet the current needs of humanity in terms of production volume (right). The working hypothesis is that the consumption of resource services, either embodied in goods through production or in their natural form (as the air we breathe) satisfies human needs.[13]

13 As the global GDP is measured in constant prices, it can be used to compare the volume of production through the years. Economists usually assume that more needs are fulfilled with a higher GDP. However, the degree to which human needs are covered can be summarised, and arguably in a more meaningful way, with various other indices of wellbeing (see Jansen et al. 2024 for an overview), but figuring the right part of the scale as the global production volume (not value) is satisfactory for our purpose here.

Available quantities of resources can be split into two groups: human-made resources (which comprise transformed natural resources, such as usable energy and metals) and natural resources. Resources are measured as flows of services per year. Needs, in the right part of the scale, for our purposes here, can be classified into three types (Type 1, 2, and 3) according to the necessity satisfied with the consumption of products and services. This classification provides, I believe, a simple but holistic conceptual framework for the demand side of the economy which also helps consider negative externalities and overconsumption. Metaphorically, T1 consumption can be seen to represent the 'health of nations' while T2 and T3 can be seen to represent the 'illth of nations' (Daly, 2019; Merz et al., 2023).

Figure 3. Types of resources and types of consumption



Note: The graph provides a simple classification of resources and needs. Negative externalities are the environmental impacts (e.g. pollution) created by production or consumption but not borne by the producer or consumer responsible for their creation thus not reflected in market prices. Examples of the three types of consumption are provided in Figure 4.

T1. Reasonable consumption: what is necessary for a 'good life'. This type of consumption includes food, shelter and also development and maintenance of infrastructure (roads, schools, hospitals, machinery, networks of utilities, etc.) in good working condition. These needs are also called 'basic' or 'essential' needs (Haddad and Solomon, 2023). This type of consumption represents technically efficient transformation of resources into output and eventually into what we define as a good life. Production is technically efficient if a given amount of output (or wellbeing) is produced with the lowest possible amounts of inputs (resources). If production is not technically efficient, then some resources are wasted, thus some part of the volume of consumption falls within T2 consumption, see below. Reasonable consumption cannot be zero; its size depends on the per person consumption that humanity believes is acceptable, the size of the global population (as, by definition, per capita consumption equals global consumption divided by the population), and the available technology for transformation of resources (into output) into wellbeing.[14]

T2. Excess (wasteful) consumption: using more resources than needed to satisfy a given need, or producing less than maximum output with given resources. This type of consumption reflects inefficient use of global resources, i.e., wasted resources. It could be zero, but this depends on how humanity defines 'reasonable' and 'excess', how it defines the 'good life', and also on the availability of technology to all producers so that they can indeed be efficient producers. Consumption of goods and services that does not increase well-being belongs here. Goods that cannot be produced for all at the quantity enjoyed by a few, owing to their prohibitively high resource requirements and the degradation of nature they will

14 For an interesting discussion on the efficiency of this transformation see Hickel and Sullivan, 2024.

cause if they are to be universally scaled, could be included in this category (they could be called 'elitist goods').[15]

T3. Negative externality-induced consumption: resource consumption used to deal with (prevent, manage, mitigate, or offset) the negative externalities created by how we produce and consume. By definition, the market prices of goods incurring negative externalities do not reflect their full cost to society; thus individuals, societies, and governments bear these costs either concurrently or at a later stage. Market prices usually reflect only private (internal) costs to the producer or consumer, and not the (external) costs to the whole society. Taxes applied to such goods aim to make producers or consumers assume ('internalise') these external costs.

Indicative examples of the three consumption types are provided in Figure 3. Generally speaking, T3 consumption represents 'symptom-level' interventions, or an expanded version of what has been described as 'disease care' in Campbell

15 I refrain from describing those as 'luxury goods', as the latter are defined based on individuals' income elasticity of demand and not on the availability of resources to produce these versions for the global population without considerably increasing the environmental impact of production. It is reasonable to expect that the global economy has the resources (materials, human capital, factories, energy, ecosystem services) to replace many types of 'non-luxury' items produced annually with luxury ones (e.g. replace all non-designer apparel items with designer ones), without considerably degrading the state of the planet. And there might be better versions of necessities, not considered luxuries by people, which, if produced for all, might not increase resource use nor the impacts of the product category. But for some goods (luxuries or necessities regardless) it is unreasonable to expect that the global economy has the required resources to scale production for all without creating considerable additional harm to the planet. One example is the composite good named 'lifestyle of the richest 10%'; it cannot be scaled for all without causing considerable additional harm to the environment (see Tian et al 2024); in this sense, living like the top 10% can be described as elitist, as it cannot be consumed by all at the level consumed by the 10%, thus essentially precluding others from living it. Other examples of elitist goods could be organic meat, milk and eggs, and wild-caught fish; air travel for non-essential purposes; excessive housing, hotels in exclusive natural settings, yacht vacations, etc. These are for sure luxury goods for some; but, for others, they may be necessities. What is important is that they are impossible to produce for all at the quantity consumed by the 'elite' consumers with the existing resources (or without further harming the environment to create the amount of resources needed). To convey this impossibility of global scaling along with the inherent injustice that this consumption creates, I use the term 'elitist goods'; of course, alternative terms such as 'unsustainable-at-scale goods' or 'resource-prohibitive goods' might more aptly describe the same concept.

and Disla (2020). The disease is the production and consumption pattern of the global economy (Merz et al., 2023), which for one euro of additional private benefit may incur costs (including environmental, human health, societal costs) exceeding one euro. This kind of consumption should be minimal. It cannot be zero with today's technology, as almost any type and level of consumption creates negative impacts. It could be minimal, though, at the level corresponding to a global production mix that supports T1 consumption with the least negative impacts. For example, a diet change towards plant-rich diets with minimally processed foods will reduce both the resources needed for food production (agricultural land, fertilisers, usable energy, etc.) and the resources needed for the treatment of the inadvertent side-effects of food production and consumption (climate change, pollution, nitrogen runoff, diabetes, heart diseases, zoonotic diseases, etc.).[16] It will also reduce the resources needed for providing health care during natural disasters (Rifkin, 2023). As summarised by the WHO,

> What we eat and drink has an impact on both our health and the climate. This is because the production of food can lead to greenhouse gas emissions; this is referred to as the climate footprint of food. Meat, especially beef and lamb, has a high climate impact. Overall, a diet that is predominantly plant based and low in salt, saturated fats and added sugars is recommended as part of a healthy lifestyle. Such diets are widely associated with a lower risk of premature mortality and offer protection against NCDs. (WHO, 2022)

16 Plant based diets consistently feature among the changes that need to be done if food security and poverty elimination is to be sustainably achieved for the projected population in 2050 and beyond, see e.g. Gerten et al., 2020; Hickel and Sullivan, 2024. Gerten et al., 2020 quantify the necessary reduction of animal products in protein calorie terms instead of total animal calorie terms, among other major changes that should be made in production. Using FAO data, I calculate that their suggestion of 3.125% of total calories from animal protein represents a global 40% reduction compared to what is consumed today. The necessary reductions range from 33% for Asia to over 60% for North America, Europe, and Australia and New Zealand. Africa is the only continent below this figure by 30% (see Supplementary Table 1).

Figure 4. Examples of the three types of consumption that use resources

T1 - reasonable consumption (for a "good life")
• food, shelter, insurance, transportation, etc.
• provision of public goods (education, health care, urban planning, etc.)
• maintenance of public and private infrastructure (schools, hospitals, roads, housing, machinery, knowledge, etc.)
• treatment of negative externalities of reasonable consumption and associated research
T2 - wasteful (excess) consumption
• consumption as a public display of wealth (conspicuous consumption)
• "elitist" goods (e.g. free-range/organic meat/eggs/milk/fish) - see footnote
• devices or apparel designed to be non-repairable or have a short life (planned obsolescence)
• technically inefficient (wasteful) production (including use of virgin plastic, aluminum, fibers, and other recyclable materials)
• wasted food by households, food losses in production that could be avoided with current technology
• bringing water to boiling temperature without the pot lid on; using conventional pots instead of pressure cookers; consuming gasoline in idling mode
• overcooling spaces (setting temperatures below comfortable levels), cooling unoccupied rooms, or running A/C units with open windows or poor insulation
• most single-use plastic items; many cosmetics and personal care products
• some gifts; some collections (watches, jewellery, cars, houses, etc.); potlatches
• consumption of excess calories (more than needed for optimal health)
• unneeded or ineffective dietary supplements and medical procedures
• trashing usable items of footware, clothing, cosmetics, homeware, hardware
• corruption, bribes, wars, conflicts, defense, lobbying for harmful production/consumption paradigms
• research for marketing wasteful consumption; marketing of wasteful consumption
T3 - negative externality-induced consumption
• rebuilding infrastructure destroyed by climate change-induced natural disasters
• building more expensive infrastructure (including health systems) to enhance resilience to climate change impacts
• medications, equipment, and treatments for NCDs and zoonoses
• treatment of infertility and other diseases caused by exposure to environmental chemicals
• carbon capture and storage plants
• contraptions to remove plastics from the oceans; beach cleaning initiatives
• research on the treatment of negative externalities of T2 (e.g. smoking, NCDs) but also T3 consumption
• research on alternatives to harmful products (e.g. for BPA replacements)

Created with Datawrapper

Notes: The examples are indicative and are given to provide a starting point for discussion. The list reflects the author's personal ideas rather than definitive facts. What should be classified into each category is an issue open to discussion and research. Download link: https://www.datawrapper.de/_/8WNUg/?v=3

A note on technology and technological progress

Some global resources are used in research aiming to create new knowledge and/or embed knowledge into new resources, products, services, and/or production processes or even invent new markets (e.g. the market for children's cosmetics and make-up products). All these 'new' or 'improved' elements of the economy can be accommodated under the umbrella term of 'technological progress'. Since prehistoric times, technological progress has helped increase the productivity of resources and create new ones, thereby helping to reduce the amount of resources needed for all types of consumption. Nevertheless, despite scientific progress and technological change, it seems we have achieved neither a good life for every person on this planet, nor a no-impacts global production, nor a perfectly circular global production that only feeds on recycled materials. In fact, we are planets apart from these three goals.

Technological progress is the outcome of a research process, itself using resource services, and producing waste and other negative externalities (Tomlinson et al., 2024). Research serving Type 2 consumption may well represent wasteful consumption to some degree, depending on whether humanity believes that the objective served by this research is worth the (real opportunity) cost of not using the same resource services to cover basic (T1) needs. Research on children's makeup or on creating hyper-palatable foods and advertising them to children, or aiming to improve performance of wasteful products (e.g. for heatproof plastic linings for paper single-use cups) arguably resembles more to wasteful consumption than socially meaningful, essential-needs consumption of resources.

Regardless of what humanity believes constitutes wasteful consumption, some research is exclusively carried out to treat the negative externalities of consumption and production (Type 3 consumption). A few examples appear in Figure 4. If the negative externalities of consumption and production (emissions of greenhouse gases, the use of plastics and harmful chemicals, the existence of NCDs, etc.) are to any degree avoidable, then research to 'treat' their negative effects is also avoidable to some degree. Ideally, technological progress could lead to absolute decoupling i.e., an increase in production and wellbeing would happen together with a decrease in associated negative impacts – but evidence indicates it does not (Bithas and Kalimeris, 2022).

It follows that there are two benefits in the avoidance of these two types (T2 and T3) of research:

- First, fewer resources will be needed for a given level of wellbeing. Thus, humanity could live equally well by using fewer resources, or could increase the well-being of its members with the same quantity of resources. Currently, humanity both uses resources for research related to T2 consumption and for research on problems related to negative externalities (e.g. NCDs, climate change); it would make more sense to use the same research resources to minimise wasteful consumption and negative externalities in the first place.

- Secondly, the negative externalities to the environment and health generated by this research itself can be avoided. The research process *per se* may create negative externalities, the effects of which are difficult to quantify or even know. For example, many new chemicals for T2 and T3 uses (e.g. single-use objects, BPA replacements) are being created and disposed into the environment for research purposes – we may never know how they affect human or planetary health, especially if they do not make it into mass production.

The severity of ecological problems that humanity faces today can be seen as a manifestation of technological change that has been too weak and/or too unfocused to bring outcomes meaningful for sustainable human welfare. As mentioned above, the global economy has entered into ecological overshoot since 1970 (Dworatzek et al., 2024). At the same time, technological progress has enabled a feeble increase in global biocapacity (i.e., in resources). As mentioned above, between 1961 and 2023 global biocapacity (the resources part) has increased by a mere 22%; but the global annual ecological footprint (the needs part) has increased by 195%. Had technological change been properly focused, the increase in global biocapacity would have counteracted the increased impact of economic activity on nature, and the global economy would not be in overshoot. Similar reasoning can be applied to planetary boundaries. Therefore, even though technological progress is considered by many as a panacea to humanity's ills (see Rees 2023), the extent of its potential should be judged by whether it helps the resources vs needs balance to tilt towards the left. So far, it has not.

Treating resource scarcity with (consumption and production) medicine

The literature on planetary sustainability points to an ailing consumption and production pattern of the global economy. It can be (and has been) fairly said that the current global 'lifestyle' is unsustainable and that the goals of sustainability and good life under the business-as-usual scenario are in conflict.

In this context, there seems to be an untapped potential of medicine towards both these two goals which has recently come to be acknowledged (Hughes, 2024). Most medical specialties (cardiology, endocrinology, oncology, gastroenterology, geriatrics, etc.) have a preventive component alongside the other two (medication and procedures). However, prevention and reversal of disease remain largely neglected in medical practice, primarily due to inadequate nutrition education for doctors and misaligned incentive structures that favour treatment over prevention (Devries et al., 2014, 2017)[17]. A recently established specialty, Lifestyle Medicine, which can be administered by almost all specialties, stands out as the sole specialty that actively promotes reversal, rather than management, of disease (Lippman et al., 2024).[18]

The diseases and conditions that can be prevented or reversed by preventive and reversive medicine (PRM henceforth) are both diseases associated with poverty (infectious diseases, maternal and infant diseases) and diseases that are usually associated with rising incomes, as are usually the non-communicable diseases (NCDs). The latter are also called 'lifestyle diseases', 'Western diseases', or 'diseases of affluence' (Campbell et al., 1992); they are chronic and degenerative, are usually considered non-reversible, and their occurrence is rising: in 2050 among the ten major causes of healthy life years (or Disability-Adjusted Life Years (DALYs)) lost, the eight will be from NCDs (vs only three in the top ten in 1990, see Figure 5). Importantly, PRM can also prevent infectious diseases and improve the outcomes of their treatment (Rahmati et al., 2023; Papadaki et al., 2024). Similarly, PRM can also speed recovery from injuries and surgeries.

17 It is interesting that while Medicare covers participation in an 'intensive cardiac rehabilitation programme' aimed to reverse heart disease since 2010 (Centers for Medicare & Medicaid Services (cms.gov), 2010), this option has not yet become the standard mode of 'treatment' in the US.

18 The history of lifestyle medicine dates back to ancient years, but its modern form as an official medical specialty is quite recent. In the US, Lifestyle Medicine (LM) is 'a medical specialty that uses therapeutic lifestyle interventions as a primary modality to treat chronic conditions including, but not limited to, cardiovascular diseases, type 2 diabetes, and obesity. LM-certified clinicians are trained to apply evidence-based, whole-person, prescriptive lifestyle change to treat and, when used intensively, *often reverse* such conditions. Applying the six pillars of lifestyle medicine – a whole-food, plant-predominant eating pattern, physical activity, restorative sleep, stress management, avoidance of risky substances and positive social connections – also provides *effective prevention* for these conditions' (emphasis added).

As will be elaborated below, preventive and reversive medicine has a unique potential to positively affect both sides of the scarcity balance: (a) resource availability and (b) humanity's needs for resources, especially (but not exclusively) the ones used for reasonable consumption and externality-induced consumption. The main pathway through which PRM reduces resource scarcity is through voluntary changes in the preferences and then consumption basket of individuals, especially regarding food (Campbell, 2021), which increase the health and wellbeing of individuals but are also socially beneficial locally and globally (Pseiridis, 2012; WHO, 2022; Becker and Fanzo, 2023). Table 1 provides a summary.

Table 1. The effects of preventive and reversive medicine (PRM) on the determinants of economic scarcity (resources and needs)

Availability of resources: PRM increases resource quantity and quality	**Demands on resources: PRM reduces needs**
Effect of PRM on Human Capital: Healthier children miss fewer schooling days and grow up as healthier and more productive adults (WHO, 2021; O'Donnell, 2024). Healthier working age people miss fewer workdays (fewer DALYs lost) and while at work they can be undistracted by physical discomfort or disability (Stephens and Toohey, 2018; Springmann et al., 2018; Tan et al., 2022; Rojanasarot et al., 2023; Glick et al., 2023; O'Donnell, 2024; Pinna Pintor et al., 2024; Golombek et al., 2025, 2025). A healthier elderly population is more productive, offering care and mentoring services for the young, household work, emotional support, etc., and even if this work is not counted in the official GDP, it increases the labour participation and productivity of their family members.	**Effect of PRM on Reasonable Consumption (T1)** Fewer resources would be needed for reasonable consumption – mainly for food, transport, healthcare unrelated to negative externalities (Springmann et al., 2018, 2021; Springmann, 2020, 2024; Musicus et al., 2022). Hence a smaller part of resources needs to be used for healthcare, long-term care, and related medical research. **Effect of PRM on excess consumption (T2)** A healthy diet minimizes the need for (effective and ineffective) nutritional supplements (see e.g. Abdelhamid et al. 2020). **Effect of PRM on consumption induced by negative externalities (T3)** Healthier behaviours tend to create fewer negative impacts on both individual health and the environment (Springmann et al., 2018).

On the other hand, a larger timespan lived in frail health drains financial and emotional resources out of families and the economic system and reduces the accounted productivity of those caring for the elderly, especially of female family members who are typically (and informally) burdened with their care (Swinkels et al., 2019; Xiong et al., 2020).[19] **Effect of PRM on the Environment:** Healthier behaviours tend to be less resource intensive (Behrens et al., 2017; Musicus et al., 2022). Healthier behaviours reduce environmental impacts and this in turn reduces the loss of non-human resources (soil fertility, buildings, roads, etc.) incurred by them.	**(a) Health:** Healthier behaviours (especially whole food plant based diets) result in less disease and disability (2018 Physical Activity Guidelines Advisory Committee, 2018; Campbell, 2021; Springmann, 2024). A healthier workforce and a healthier aging require fewer visits, medications, procedures, hospitalisations, research funding, and long-term care (Scarborough et al., 2011; Hallström et al., 2017; Bodai et al., 2018; Morton, 2018; Li et al., 2020; Edington et al., 2020; Livingston et al., 2021; Ahmann et al., 2024). PRM increases the ratio of life years lived in good health (Li et al., 2020) and thus reduces the timespan that health care and long-term care related to aging is needed. Healthier diets reduce the risk of new zoonoses and pandemics (UNEP and ILRI, 2020). **(b) Environment:** Healthier behaviours (especially whole food plant based diets) create fewer negative environmental impacts such as climate change, pollution, ocean acidification, water and soil contamination, sea level rise, etc. (Springmann et al., 2016, 2018; Brand et al., 2021; Li et al., 2024; Conrad et al., 2024; Springmann, 2024) thus require fewer resources for the management of these impacts.

19 PRM helps decrease the health cost of aging and reduce the excess demand for formal and informal long-term care. This is especially important in economies with aging populations in which the public cost of health care and official long-term care as a percentage of GDP is expected to rise (European Commission, 2024; Nektarios et al. 2025).

Bottom line	**Bottom line**
A healthier population (ceteris paribus) is tantamount to increased quantity and quality of human and non-human resources.	A healthier population (ceteris paribus) needs fewer resources to cover its needs.

Notes: The table presents information about available and required quantities of resource services, assuming today's technology. The monetary savings (e.g. reduction of the private and public health care costs) arising from the application of PRM are not the focus of this paper, but are briefly discussed in the concluding section. Ceteris paribus: all other things constant. Human capital can be seen as the ability of humans to be productive due to their knowledge, experience, skills, and health.

PRM versus taxes for the common good 'health'

The literature on shifting toward socially beneficial consumption behaviours advocates the adjustment of market prices through taxation, so that they convey clearer signals to consumers and businesses. Taxes have been effectively used for years for tobacco (Yurekli et al., 2016; Delipalla et al., 2022); they can be used to correct market prices for foods, too (Mozaffarian et al., 2014; Springmann et al., 2018; Springmann and Freund, 2022).[20]

Taxes may be effective, but need careful planning to bring permanent changes in the behaviour of consumers and producers (Wright et al., 2017; Burton et al., 2024; Banerjee, 2025). They may also exacerbate inequalities if they are applied on essential goods (Fremstad and Paul, 2019). Generally, taxes work by making the previous consumption bundle of an individual more expensive. Following a tax, cheaper items may be substituted for expensive items in a person's bundle. This change in behaviour does not necessarily reflect a change in preferences, i.e., in what the person finds desirable. If a person's income increases, they may revert to their previous consumption level. Taxes may also meet opposition by the public and incumbent companies on the grounds of personal freedom that is reduced by taxes. This opposition can be weakened by investing in public

20 There are a few, if any, examples of taxes aiming for the wider adoption of a whole-food, predominantly plant-based diet.

awareness: governments have in many instances stepped up to reduce the consumption of goods or promote behaviours that are deemed undesirable for the common good (e.g. infant formula feeding, smoking, unprotected sex, drunk driving) when market forces cannot deliver socially desirable results. Therefore, under proper information, the public can be made aware that some personal choices burden financially all taxpayers and that the less fortunate should also have the personal freedom to live a good life, but do not, because the personal freedom of some intensifies resource scarcity and raises the price of the 'good life'.

Fortunately, PRM can bring permanent changes in consumer preferences without the practical and political problems of taxation. Incumbent producers have no choice but to respond to a (PRM-induced) redefined expression of personal freedom of consumers by altering their product mix or line of business; thus, the transition to a different lifestyle may not be as difficult as it seems, see below.

Further, the application of PRM does not exacerbate inequalities but rather reduces them as it makes a healthy life – an essential good – more affordable. In terms of DALYs (i.e., years of full health lost due to death, disability, or ill health), low-income countries, despite a lower prevalence of NCDs, face a larger total burden of disease than rich countries (see Figure 6) on top of few per capita resources. The use of PRM can help low-income countries make better use of their scarce resources and prevent the rising NCD prevalence that comes with increasing incomes.

Preventive and reversive medicine can also reduce unequal health outcomes that are nurtured by gender and other types of discrimination. For example, females are more exposed to cleaning chemicals than males, either as professional cleaners or as own-house cleaners, as they spend more time on housework than males. The dietary component of PRM can help minimise the exposure to dangerous chemicals and also protect from the adverse effects of chemicals.[21] Further, as NCDs often require care work which is mostly provided by (unpaid) female family members (Swinkels et al., 2019; Xiong et al., 2020), the decrease in NCD prevalence and severity that is achieved by PRM will help reduce this unequal burden, too.

21 I am grateful to Eleni Prifti for pointing this out.

In sum, PRM may be the most efficient and cost-effective use of medical knowledge to reduce the years lived with disease and disability and the environmental impacts of production and consumption at the same time. Its beneficial effects come mainly through the change in the current food consumption paradigm, which is responsible for a large part of humanity's negative environmental impacts and for a considerable part of the resource use (and monetary cost) of NCDs. Therefore, PRM can be seen as a tool (or as a readily available technology) enhancing the ability of the global economic system to provide a good life to all without an increase in the scale of global production. In a sense, PRM could be the *sine qua non* technology to genuinely decouple human flourishing from environmental degradation.

The transition to an economy of real 'health care' may not be as difficult as it might seem

There is a widespread belief that if demand for a sector's output declines, then this will reduce the earnings of those (employees, business owners, and shareholders) remunerated by this sector. This is far from true: following a short period of disequilibrium created by reduced demand, a new equilibrium occurs where the resources (including human capital) that have been made redundant will soon find themselves earning similar real incomes in the same or another sector. In fact, this re-equilibration process is rather the norm: the economy is always in a constant process of 'creative destruction' spurred by never-ending innovations, as described by Schumpeter (1943). The application of PRM will be one of innumerable innovations that have spurred a round of creative destruction in the economy (e.g. personal computers, digital photography, unleaded gasoline). Maybe a difference with other innovations will be that the innovation introduced with PRM is essentially available for use to all, safe, affordable and beneficial to the whole society and the environment; and it also helps increase the wellbeing enjoyed on the same or even reduced income and quantity of resources.

During this process of re-equilibration, the medical system will continue providing medical services – but more emphasis will be given to prevention rather than management of disease; researchers investigating novel chemicals may find themselves researching ways to undo the negative effects of novel chemicals that have been produced so far; researchers investigating medications for NCDs and supplements may investigate medications for other diseases (for sure, there is no scarcity of under-serviced diseases); behavioural researchers who work on creating addictive unhealthy foods may work on educating the public and enabling the permanent adoption of healthier lifestyles; advertisers may use their skill to advertise healthier behaviours, whole plant foods, and PRM-compatible products instead of the consumption of unhealthy foods, resource-intensive foods, or products that increase chemical exposures; workers in the animal agriculture sector will find themselves employed in the plant foods sectors; restaurants may transform their menu, and so on. It can be argued that there will be no actual losers from the adoption of PRM principles and a lower-resource-use economy in the long-term as the cost of the 'good life' will correspond to lower work effort than today.

The pressures from industry, politicians and even academia and international organisations supposedly serving the greater good to maintain the current state of affairs has always been strong (Campbell and Disla, 2020; Behrens and Hayek, 2024), but the financial benefits (avoided expenditures and/or tax revenues) to society from the application of PRM are so large that those involved in declining sectors or lines of business could be compensated for their temporary losses and still the net benefit to society would be positive (Broeks et al., 2020). This means that the enablers (medical doctors, public health professionals, hospitals, NGOs, schools, municipalities, etc.) could also be financially rewarded with part of the benefits so that more enablers join. A proper mix of incentives (taxes, subsidies, and rewards) could bring about a large self-financed positive change. Thus, sharing the benefits with the temporary losers and the enablers is a necessary part of the change as it could create a virtuous circle of acceptance and promotion of a new, socially beneficial, paradigm of consumption and production.

Concluding remarks: preventive and reversive medicine as 'consumption and production medicine'

We live in a resource-scarce world. Resource scarcity is continuously enlarged by the increasing per capita consumption of an increasing population, and the way that the economy uses its scarce resources. The current production and consumption paradigm seems unable to provide good lives for all currently; and it is highly doubtful whether all can achieve good lives without further jeopardising the environment and the future of humanity.

This paper attempted to provide a simple conceptual framework about the potential of preventive and reversive medicine (PRM) to affect both the resource side of the economy and the production/consumption side: in short, PRM can (a) augment the resource base of the global economy and (b) change consumption behaviours and the global production composition in a meaningful (for wellbeing) and sustainable way. In a way, PRM can be seen as a 'sustainability technology' that is readily available. There are, however, a few other benefits worth a brief mention.

First, PRM is also important in managing the consequences of the increasing average age of the global population: PRM can allow more productive, active, gracious and dignified aging by increasing the years lived in good health. This will benefit the tax and pension systems as elderly can be productive and/or remain at work if they wish; it will also benefit families who are struggling with the burden of care for their sick elderly which leaves less time and fewer other resources for them and their young.

Secondly, besides the obvious wellbeing benefits accruing to individuals treated with PRM versus the alternative route of just managing NCDs, the resource savings due to PRM allow more leeway for achieving 'a good life' for all members of the global population – especially low-income countries and communities facing financing gaps in the provision of basic health services. Thus, humanity can distance itself from making the 'good life' an elitist good obtainable by only the few who can afford the management-focused treatment of NCDs be they in high-income countries or in lower-income ones.

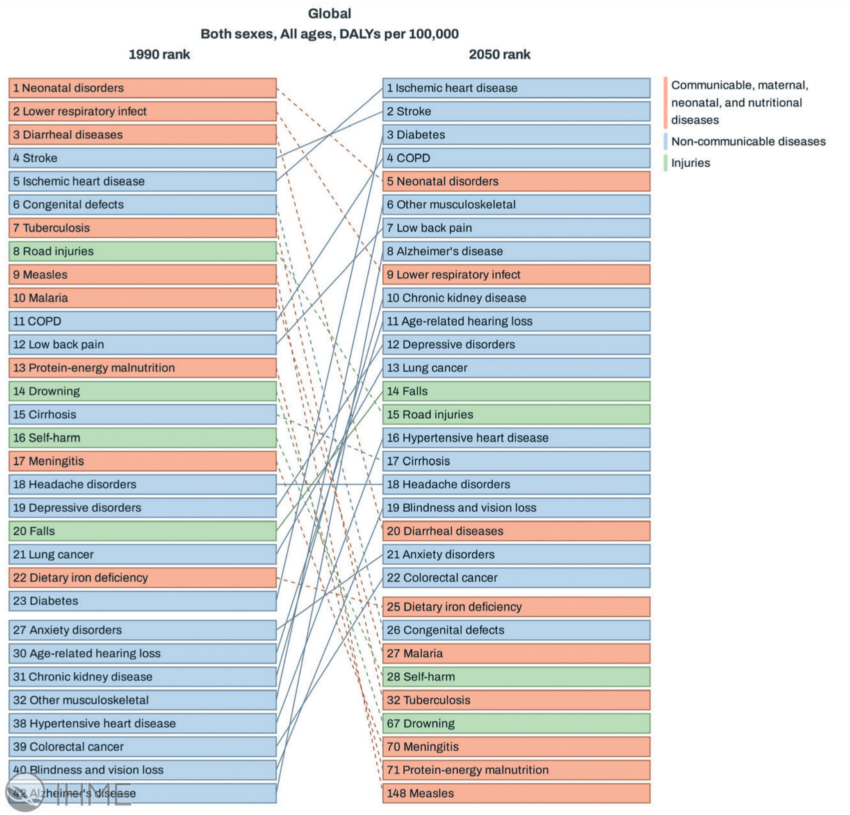
All is not rosy, though. While potential resource savings achieved through PRM may be considerable, the associated monetary savings could be used to increase the consumption of goods with higher environmental impacts (what is described as the 'rebound effect' (Polimeni et al., 2008)). Therefore, the application of PRM should be complemented with price motives. If prices reflect the full cost or benefit to society, consumers can be enabled into more sustainable choices. Like any concerned citizen, health professionals and policymakers should promote and support appropriate taxes and subsidies on goods and behaviours (and also regulatory frameworks) that actually decrease total resource use in the economy.

In summary, medicine focused at prevention and reversal, used in clinical practice or in public health settings, is in a unique position to help transform the consumption pattern, the associated production pattern, and the values of society to their most sustainable (low-resource use and low-impact) versions. Therefore, it is time to view preventive and reversive medicine (PRM) as the 'Consumption and Production Medicine' that humanity needs, and administer it in mega doses to humans, governments, and institutions.

> I will apply dietetic [i.e., consumption and production] measures for the benefit of the sick according to my ability and judgment; I will keep them from **harm and injustice**.
>
> *Excerpt from Hippocratic oath, ~400 BCE. (text in brackets and emphasis added)*

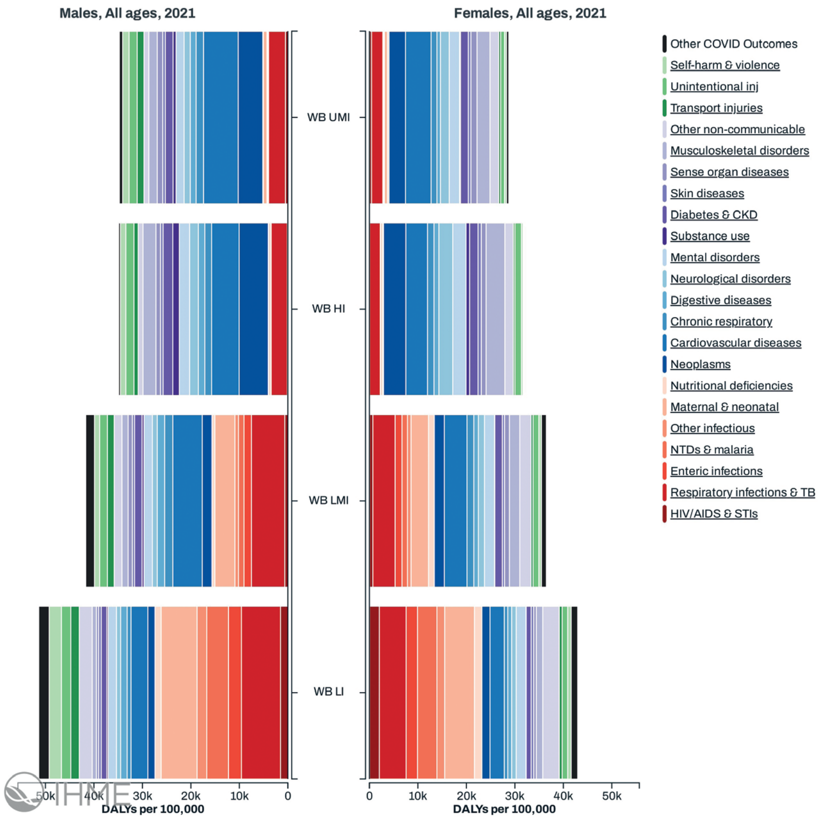
Appendix: supplementary graphs and tables

Figure 5. Projections for 2050 for main causes of DALYs lost per 100,000, all ages



Note: Figure created by author with the IHME GBD Foresight Visualization tool (https://vizhub.healthdata.org/gbd-foresight, 26 Nov. 2024).

Figure 6. DALYs lost per 100,000 by World Bank income group, all ages



Notes: Despite a lower prevalence of NCDs in low-income countries, the DALYs lost from all health causes are higher. Low-income countries have to tackle additional, albeit avoidable costs, with their limited resources. Figure created by author with the IHME GBD Compare Data tool (http://vizhub.healthdata.org/gbd-compare, 26 Nov. 2024).

Supplementary Table 1. Quantification of change in animal protein suggested by Gerten et al. using FAO Food Balances data for 2022

	Australia & New Zealand	**Northern America**	**Europe**	**South America**	**World**	**Asia**	**Africa**
Calories from all sources (FAO)	3,417	3,881	3,471	3,111	2,985	2,944	2,567
Protein from animal sources (g) (FAO)	74.0	81.9	68.1	56.3	38.1	34.3	15.5
Protein from animal sources (calories) – not provided by FAO; calculated	296.0	327.7	272.4	225.2	152.4	137.2	61.9
Calories from animal protein that should be consumed according to Gerten et al. (3.125% of total calories)	106.8	121.3	108.5	97.2	93.3	92.0	80.2
Necessary change in animal protein calories	–63.9%	–63.0%	–60.2%	–56.8%	–38.8%	–32.9%	29.6%

	Australia & New Zealand	**Northern America**	**Europe**	**South America**	**World**	**Asia**	**Africa**
Calories from animal protein as % of total calories (instead of 3.125%)	8.7%	8.4%	7.9%	7.2%	5.1%	4.7%	2.4%

Values in rows 2 and 3 are per person per day and come from FAO Food Balance Sheets for 2022, accessed 7 April 2025 (FAOSTAT, 2024). Conversion of protein grams to calories: 1 g of protein yields 4 calories. Regions listed based on last row, from largest to smallest percentage. This table does not imply that the amounts of calories per person per day are adequate or nutritious, but shows the order of magnitude of the changes in the consumption pattern that would make food supply conform to the 3.125% target set in Gerten et al. or similar ones.

Supplementary Table 2. Countries used in Graphs 1 and 2

	High income	**Upper-middle income**	**Lower-middle income**	**Low income**
1	Antigua and Barbuda	Albania	Angola	Afghanistan
2	Australia	Algeria	Bangladesh	Burkina Faso
3	Austria	Argentina	Benin	Burundi
4	Bahamas	Armenia	Bhutan	Central African Republic
5	Bahrain	Azerbaijan	Bolivia	Chad
6	Barbados	Belarus	Cabo Verde	Congo, Democratic Republic of

	High income	Upper-middle income	Lower-middle income	Low income
7	Belgium	Belize	Cambodia	Eritrea
8	Brunei Darussalam	Bosnia and Herzegovina	Cameroon	Ethiopia
9	Bulgaria	Botswana	Comoros	Gambia
10	Chile	Brazil	Congo	Guinea-Bissau
11	Croatia	China	Côte d'Ivoire	Korea, Democratic People's Republic of
12	Cyprus	Colombia	Djibouti	Liberia
13	Czech Republic	Costa Rica	Egypt	Madagascar
14	Denmark	Cuba	Eswatini	Malawi
15	Estonia	Dominica	Ghana	Mali
16	Finland	Dominican Republic	Guinea	Mozambique
17	France	Ecuador	Haiti	Niger
18	French Polynesia	El Salvador	Honduras	Rwanda
19	Germany	Equatorial Guinea	India	Sierra Leone
20	Greece	Fiji	Jordan	Somalia
21	Guyana	Gabon	Kenya	South Sudan
22	Hungary	Georgia	Kyrgyzstan	Syrian Arab Republic
23	Iceland	Grenada	Lao People's Democratic Republic	Togo
24	Ireland	Guatemala	Lebanon	Uganda
25	Israel	Indonesia	Lesotho	Yemen
26	Italy	Iran, Islamic Republic of	Mauritania	

	High income	**Upper-middle income**	**Lower-middle income**	**Low income**
27	Japan	Iraq	Morocco	
28	Korea, Republic of	Jamaica	Myanmar	
29	Kuwait	Kazakhstan	Nepal	
30	Latvia	Libyan Arab Jamahiriya	Nicaragua	
31	Lithuania	Malaysia	Nigeria	
32	Luxembourg	Mauritius	Pakistan	
33	Malta	Mexico	Papua New Guinea	
34	Netherlands	Mongolia	Philippines	
35	New Zealand	Montenegro	Samoa	
36	Norway	Namibia	Sao Tome and Principe	
37	Oman	Paraguay	Senegal	
38	Panama	Peru	Solomon Islands	
39	Poland	Republic of Moldova	Sri Lanka	
40	Portugal	Republic of North Macedonia	Tajikistan	
41	Qatar	Saint Lucia	Tanzania, United Republic of	
42	Romania	Serbia	Timor-Leste	
43	Russian Federation	South Africa	Tunisia	
44	Saudi Arabia	Suriname	Uzbekistan	
45	Singapore	Thailand	Vanuatu	
46	Slovakia	Tonga	Viet Nam	

	High income	Upper-middle income	Lower-middle income	Low income
47	Slovenia	Turkiye	Zambia	
48	Spain	Turkmenistan	Zimbabwe	
49	Sweden			
50	Switzerland			
51	Trinidad and Tobago			
52	United Arab Emirates			
53	United Kingdom			
54	United States of America			
55	Uruguay			

Acknowledgements

I would like to thank Eleni Prifti, Theodore Lianos, T. Colin Campbell, Panos Kalimeris, Asimina Christoforou, Frank Götmark, Nandita Bajaj, Stan Becker and David Samways, the Editor, for useful discussions on ideas presented here. I am also grateful to the anonymous referees for their valuable contribution in improving this paper. Errors are mine.

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