The Dasgupta Review:
Supplementary Notes on Investment in Conservation and Restoration, Family Planning, and Reproductive Health

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These supplementary notes to *The Economics of Biodiversity: The Dasgupta Review* (henceforth, *Review*) have been prompted by the virtual meetings I have had in recent weeks with colleagues in a wide range of institutions across the world. Their probings on the *Review* have been wide ranging. I had anticipated that, for no two people read a text in the same way – their expectations differ. In the present case, the reader's motivation for reading the *Review* matters. What the private citizen would like to find in it differs from what someone in a government department or an international agency or a private company seeks. I was aware of this diversity of demands when composing the *Review*. But the questions that have been put to me at the meetings have made me realise that there are themes that could be studied further usefully. This is what these notes are meant to do.

Background

The *Review* is global in its reach in two senses: First, it is not restricted to a particular group of countries or cultures; it instead constructs an economic grammar that can be adopted anywhere. Secondly, it offers a vocabulary that speaks to institutions everywhere (government, charities, households, firms, banks, and financial companies). Anyone can adopt the common grammar and choose the vocabulary that meets their motivation and reach.

The common grammar is built on a recognition that the biosphere is a tangled web of self-regenerative entities called 'ecosystems'. Processes governing ecosystems differ among one another both in speed and spread. Which is why even the decision to designate a patch of the environment as an ecosystem depends on the context - a hedgehog's gut is as much an ecosystem as the woodland in which the hedgehog resides. Biodiversity, by which is meant the diversity of life, is a characteristic of ecosystems. There is now a fair understanding of the sense in which it contributes positively to their productivity (*Review*, Ch. 2).[1]

Individual actors in ecosystems include organisms that, among other activities, pollinate, decompose, filter, transport, redistribute, scavenge, and fix gases. Nearly all organisms that help to produce those services are hidden from view (a gram of soil may contain as many as 10 billion bacterial cells), which is why they are almost always missing from popular discourses on the environment. But their activities enable ecosystems to maintain a genetic library, preserve and regenerate soil, fix nitrogen and carbon, recycle nutrients, control floods, mitigate

[1] Here, as in the *Review*, we use the terms Nature, the natural world, the biosphere, natural capital, and the environment synonymously.

droughts, filter pollutants, assimilate waste, pollinate crops, operate the hydrological cycle and maintain the gaseous composition of the atmosphere.

These are what ecologists call 'regulating and maintenance services'.[2] The processes that give rise to them are in large measure complementary to one another: degrading one severely can be expected to threaten the others (*Review*, Ch. 3). Regulating and maintenance services provide the basis on which we draw upon Nature's 'provisioning goods', such as food, timber, medicines, dyes, fibres, and fresh water. The *Review* shows that there is a tension between humanity's needs for these two classes of goods and services. Because private companies are in large measure unable to capture the returns from investment in regulating and maintenance services (they are in all too many cases non-excludable), they invest mostly in those forms of natural capital that are direct inputs for provisioning services (farms, plantations, housing, manufacture, and transportation), whose products *are* excludable. That has eroded Nature's regulating and maintenance services. Non-excludability is a reason the economics of biodiversity pays particular attention to 'externalities', which are the unaccounted consequences for others of our actions.

Because the biosphere is a tangled web of ecosystems, the *Review*, unlike the economics of global climate change, does not offer sharp formulae for policy, such as a social price for biomass. It does not even prescribe 'biomass offsetting markets'. The reason it does not is that a unit of biomass in a particular location in one ecosystem (e.g. a tropical rainforest) has widely different roles to play from a unit of biomass in another (e.g. in a grassland). The differences arises because the processes governing ecosystems are entangled with one another. Their entanglement is the reason ecosystems harbour what may be called 'natural externalities'. If biomass offsetting markets were introduced, brokers could profitably purchase units of biomass from ecologically productive places and offset them in ecologically unproductive places, making a profit. Further institutional mechanisms would then be needed to regulate such transactions. The *Review* speaks of ecosystems as the source of Nature's supply of goods and services; it does not build the economics of biodiversity on units of biomass.[3]

That the *Review* found it necessary to construct a common grammar for the economics of biodiversity is self-explanatory. Fires cannot be put out if fire fighters do not coordinate their tasks. If humanity is to face up to the emergency we have created by the enormous overshoot in the demands we have been making on the biosphere relative to its ability to meet them in a sustainable manner (see below), there needs to be coordination among agencies. The *Review* therefore urges not only national governments and central banks, but also international organisations such as the World Bank, IMF, and FAO to include estimates of the ecological consequences of their policies before advocating them.

Evidence is Always Model Dependent

[2] The classification of Nature's services in these Notes has been adapted from then one proposed by the pioneering Millennium Ecosystem Assessment (MA, 2005a-d).

[3] For brevity I am laying aside here 'cultural services' (places of beauty and tranquillity; sacred sites), which also compete with provisioning and maintenance services for our attention.

That government policies should be informed by evidence is a truism. What counts as evidence, though, is shaped by the model on whose backs the evidence has been drawn. Which means evidence is model dependent. Policy W may look good because it is backed by evidence, but if the underlying model does not include natural capital, it may be that W is in fact a socially bad policy. Likewise, it may be that policy X is not supported by the evidence that has been elucidated, but if the underlying model of economic development does not include natural capital, it may be that X is in fact a socially desirable policy.

Nor do mainstream models of economic development pay attention to 'reproductive externalities'. The *Review* (Chs. 7-9) identifies two classes of such externalities: (i) those that travel through the biosphere; (ii) those that travel across the social world.

A substantial literature has now unravelled the social embeddedness of our needs and wants. That is the source of the externalities in class (ii). Mainstream models of economic development and the income-expenditure models that governments use assume instead that people are egoists. The *Review* shows that our social embeddedness implies that policies which lead us to alter our choices - over the food we eat, the clothes we wear, the appliances we find useful, and the size of families we hope to create - may enhance our own well-being even in our own assessment (*Review*, Ch. 9). Reducing our demand for the biosphere's goods and services may be far less costly at the personal level than mainstream models of growth and development ask us to suppose.

Policy menus that are put forward without an assessment of the future impact on the biosphere of additional births (type (i) externalities) are at odds with the *Review*'s finding that family planning and reproductive health are central to the economics of biodiversity (*Review*, Ch. 7; see below). Policy Y may look good because it is backed by evidence, but if the underlying model does not include reproductive externalities, it may be that Y is in fact a socially bad policy. Likewise, it may be that policy Z is not supported by the evidence that has been collected, but if the underlying model of economic development does not include reproductive externalities, it may be that Z is in fact a socially desirable policy.

The place of biodiversity in our economies is largely missing in both academic writings and government reports on economic growth and development. The *Review* argues that the lacuna has resulted in both type-1 and type-2 errors in policy making.

The Impact Inequality

Changes in land-use accompanying the enormous expansion in the global demand for provisioning services over the past 70 years has diminished Nature's ability to supply regulating and maintenance services. The *Review* reports findings in the Earth sciences, ecology, and the social sciences, that the global demand for the biosphere's goods and services today far exceeds its ability to meet it on a sustainable basis (*Review*, Ch. 4).

The *Review* calls the gap between the demand humanity makes of the biosphere and the ability of the biosphere to meet that demand on a sustainable

basis, the *Impact Inequality*.[4] The *Review* decomposes the demand by taking global GDP to be a measure of human activities. Let N be global population and y per capita global GDP. Global GDP is thus Ny. But GDP is the market value of the final goods and services produced in a period of time (a year). So let α be a numerical measure of the efficiency with which the biosphere's supply of goods and services are transformed into marketable products. It follows that Ny/α is the aggregate demand for the biosphere's flow of goods and services.[5]

N, y, and α are *not* independent of one another. Policies that affect y may cause households to alter their reproductive goals, implying that future values of N would be affected; policies that affect α would be expected to influence y; and so on. The *Review* contains extensive discussions of these interlinkages.

To illustrate the biosphere's supply of goods and services, the *Review* assumes for simplicity that they can be aggregated into a numerical measure, labelled by G. (If the aggregation reads far fetched, the supply of each service should be read separately.) The biosphere is our global natural capital. Let S denote that stock, measured in terms of the biosphere's features such as biodiversity. (We should again imagine that S is a weighted sum of stocks of ecosystems. The weights would be accounting prices; see below in the text.) G is a function of S, the bigger the stock, the larger is G, at least in the biosphere that prevails today. We may then write $G = G(S)$. Because the biosphere is finite, G cannot exceed a finite limit. Armed with this notation, the Impact Inequality can be expressed as: [6]

$$Ny/\alpha > G(S) \tag{1}$$

By one (inevitably very crude) estimate, the ratio of demand to supply (i.e. $Ny/\alpha\, G(S)$) is today approximately 1.6, which provides the image that we need 1.6 Earths to meet our current demand (Wackernagel and Beyers, 2019). The demand overshoot has led to a staggering rise in the rate of biodiversity loss, among many other losses. As biodiversity writ-large is a global public good, continual biodiversity loss threatens us all.[7] As with fighting fires, humanity should be

[4] The Impact Inequality was introduced in Barrett et al. (2020).

[5] The decomposition of aggregate demand into N, y and α is due to Ehrlich and Holdren (1971). The biosphere's services are assumed to include assimilation of waste products (e.g. carbon absorption). The *Review* reinterprets pollution as the reverse of Nature conservation.

[6] If the aggregation exercises that have been assumed are not possible, the Impact Inequality would be a set of inequalities, one for each of Nature's goods and services. For example, Rockström et al. (2009) identified *nine* biophysical processes that are critical for Earth System functioning. The authors' proposal was to set quantitative boundaries for each, beyond which the Earth's Holocene state would be put at further risk, making the move to the Anthropocene firmer. The authors named the markers that may be used to check whether the processes are undergoing rapid change, 'planetary boundaries'. Their classification would give us nine expressions for comparing the net pressure on the biosphere' supply of goods and services.

[7] Current extinction rates of species in various orders are estimated to have risen to 100-1,000 times the average extinction rate over the past tens of millions of years (the 'background rate') of 0.1-1 per million species per year (expressed as E/MSY), and are continuing to rise. In absolute terms, 1,000 species are becoming extinct every year if 10 million is taken to be the number of species and 100 E/MSY the current extinction rate.

responding to the urgency created by the overshoot by designing institutions that speak to it. If 'sustainable development' has any meaning, it should as a minimum be read as a pattern of development in which the Impact Inequality is converted into an equality. Which is why it is a puzzle that designers of the UN's 17 Sustainable Development Goals - to be reached by year 2030 - didn't ask whether the goals, taken together, are sustainable. In the Annex to these Notes we borrow from the *Review* (Ch. 4, Box 4.3) to show that meeting them on a sustainable basis would require transformative changes in global institutions.

In the remainder of these Notes I highlight ways in which the variables on both sides of the Impact Inequality can be affected by public policy, and more generally by the design of institutions.

Causality

Mono-causal explanations are to be avoided in the social and ecological sciences. The Impact Inequality contains five variables: N, y, α, G, S. Each is a function of time, and each can be influenced by policy. Of them, N, α, and S are stocks, while y and G are flows.

y can be affected even in the short run, as can S (it doesn't take much time today to decapitate a forest), and the trajectory of N has been known to alter sharply under rapidly changing fertility behaviour and improved hygiene and medical facilities. It can take time to increase S (wetlands cannot be restored overnight), but as we see below, it can nevertheless be socially profitable to do so. And changes in institutions or technology (α) have an impact on y, N, and G with varied gestation lags.

The *Review* (Chs. 4* and 13*) presents a dynamic socio-ecological model in which all five are endogenous variables: *each influences the others over time and is in turn influenced by the others*. The model shows that mutual causation is the rule in socio-ecological systems. It is thus as wrong to insist that high consumption (read y) in industrial countries is the underlying cause of biodiversity loss as it is to claim that large population (N) is the underlying cause.[8]

Only a quantitative model can unearth the mutual influence among economic variables. Policies that are directed at y can be expected to have an effect on future N as households adjust their fertility targets. Likewise, policies directed at influencing fertility behaviour (future N) can be expected to have an effect on y. And its not hard to see why policies that bring about institutional changes and new technology (α) will have an effect on all the variables, even future values of α. The *Review* (Ch. 4*) presents a socio-ecological model that demonstrates such mutual influence.[9]

And yet, in public discourses on the environment the practice is all too often to avoid mentioning policies that would affect future values of N; the focus is instead on y, α, and the biosphere's ability to produce goods and services as

[8] Dasgupta and Ehrlich (2013) is an early statement of this particular instance of this perspective.

[9] A reduced form of the model in Chapter 4* of the *Review* is studied in Dasgupta et al. (2021) that demonstrates the mutual influence of N and y. The authors use the model to show that the UN's Sustainable Development Goals can be achieved by year 2030 only if the annual percentage rate of increase in α were to rise four-fold from what it has been over the past three decades.

expressed in *G*. The *Review* argues that there are no reasons for awarding *N* a different normative status from the others (*Review*, Chs. 7, 9).

Accounting Prices as Social Values

The *Review* points to various directions in which our institutions and practices need to change if private and collective incentives are to be brought into alignment with the common good. Formally, the problem faced by societies is to find ways to bring the prices individual agents face for goods and services in line with reasoned assessments of their social worth. The latter are called 'accounting prices'. The *Review* explores the many ways by which the two sets of prices can be brought into alignment with each other. It explains the logic underlying institutions involving payment for ecosystem services, and those administering taxes on the use of ecosystems and the services they offer, even restrictions over their use, such as protected zones. The *Review* also reports on the varied experiences communities have had with those institutions and practices (*Review*, Chs. 7-9).[10]

Like produced capital and human capital, ecosystems are capital assets. So the *Review* calls them 'natural capital'. The designation should be congenial to readers, for we are all asset managers, and we manage the assets we have access to in line with our motivations as best as we can (*Review*, Ch. 1). The *Review* catalogues the reasons market prices of natural capital are below, often far below, their accounting prices (environment and social 'externalities', and public subsidies for the use of natural capital are the subject of Ch. 7-9 in the *Review*). The gap between accounting prices and market prices is the reason even the best each of us is able to achieve with our portfolios has resulted in a massive collective failure to manage the global portfolio of all our assets. The analogy of each person in a crowd trying to keep balance on a hanging bridge and bringing it crashing down speaks to what will happen if the biosphere continues to be diminished.

One route to reducing the Impact Inequality is to find ways to increase α. And one way to do that is to remove environmental subsidies. The *Review* estimates that active global subsidies on the use of natural capital amounts today to some 4-6 trillion US dollars a year, or approximately 5-7 per cent of global GDP. The figure does not include the passive subsidies humanity pays itself to exploit global commons such as the high seas as a source of fish and a means of transportation and the atmosphere as a sink for carbon emissions. One of the *Review*'s recommendations is the creation of a transnational institution that would be given the task of monitoring, managing, and charging for the use of Nature's global public goods. The revenue could be used to pay for the protection of such global public goods as peatlands and tropical rainforests, which fall within national jurisdiction.

In contrast to market prices, accounting prices have a subjective element to them, which is why people differ in their valuation of Nature's resources. The

[10] Colleagues have asked whether accounting prices are meaningful in a world whose workings are highly non-linear and uncertain, even unknown. The *Review* assumes that even if the uncertainties are so confounding that the decision-maker is unable to arrive at subjective probabilities over states of nature, she is not paralysed into inaction. So long as she settles on a decision rule, she can arrive at her assessment of accounting prices. The accounting prices she reaches would be based on her decision rule.

forest patch that is sacred to one community may not be sacred to another. For people in the former community, use of the patch would be non-negotiable (*Review*, Ch. 12). But even the 'use-value' of natural capital is often contested among experts. That's because the models they use to estimate accounting prices can differ.[11]

Possible disagreements over accounting prices should, however, not deter us from rejecting market prices as measures of the worth of natural capital. It is better to compromise on a price for an ecosystem, so long as the compromise is on a positive value, than allow the price to be set at zero by default. The *Review* takes it that differences among citizens over accounting prices should be mediated by the political process, similar to the way differences among citizens over the allocation of private and public goods are mediated by the political process. The recent proposal by the UN Statistical Commission to establish a framework for Ecosystem Accounting should enable countries to coordinate as they prepare national balance sheets (*Review*, Ch. 13). National statistical offices could be charged with the responsibility of providing a first round of estimates of accounting prices with which to value assets, to be revised regularly to reflect an increased understanding of their implications for investment and consumption decisions (*Review*, Chs. 10-13). The *Review* shows that by 'sustainable development' we should mean a path of development along which 'inclusive wealth' - that is, the aggregate accounting value of produced, human, and natural capital – does not decline over time. Private companies construct their balance sheets, they don't rely entirely on income-expenditure accounts. National statistical offices (e.g. ONS in the UK) should be required to construct national balance sheets as an addition to national income and expenditure accounts.

Conservation and Restoration as Investment

Investment in Nature conservation and restoration is a way to increase S and thereby G.[12] However, the term 'investment' does not carry the same connotation to everyone. To the private investor it would be to hold the right portfolio. For reaching the right portfolio he will be guided by the prevailing stock market prices and his expectations of their movements over time. Because both price expectations and price realizations change, he periodically shifts assets in his portfolio, buying some while selling others.

In contrast, investment in a capital asset by a public decision-maker (the *Review* calls her the Citizen Investor) is the routing of public expenditure toward increasing the asset's stock (in quantity or quality, or both). Formally, for her investment in a capital asset is the accounting value of the change in its stock (in quantity or quality, or both) over a unit of time. We are talking of *net* investment, that is, investment net of depreciation.

The two senses of investment are of course related. Government policies, including its investment policies, influence the stock market prices private investors face and expect to face. It is no great simplification to think of the private

[11] The social cost of carbon provides a good example. Estimates vary from 10 US dollars per tonne to 100 US dollars per tonne.

[12] The G-function itself could be raised through bio-technology. GM-crops are an immediate example.

investor as a passive price taker, in contrast to the government investor, who chooses her investment portfolio with a view to shaping the economy's future.

It is a commonplace that investment is deferred consumption. But the matter is subtler. Providing additional food to undernourished people via, say, food guarantee schemes not only increases their current well-being, it enables them also to be more productive in the future and to live longer. Because their human capital increases, the additional food intake should count also as investment. Note though that food intake by the well-nourished does not alter their nutritional status, which means the intake is consumption, not investment.

Common-sense notions of investment carry with them a sense of robust activism. When a government invests in infrastructure, the picture drawn is of bulldozers levelling the ground and tarmac being laid by people in hard hats. But the notion of capital assets in the *Review* extends beyond produced capital to include human capital and natural capital. That training people to be teachers is investing in human capital is simple enough. To leave a forest unmolested may not sound much like investment, but it is an investment: it enables the forest to grow. To allow a fishery to re-stock is to invest in the fishery; and so on.

Investment in natural capital often involves simply *waiting* (*Review*, Chs. 10, 13). The problem is, the waiting can be long, as in the case of slow growing forests. More generally, the waiting can be long for degraded ecosystems to recover. If the rate at which the government uses to discount future public incomes exceeds ecosystem productivity, public decision makers would steer public expenditure away from conservation and restoration projects. They would say ecological investments have low economic returns. This is a common response of mainstream economists to environmentalists who ask them to shift investments toward Nature conservation and restoration projects.

There are two faults in the reasoning mainstream economists deploy, of which one is subsumed in the other. First, public decision-makers should value ecosystems in terms of their accounting prices, not market prices. Secondly, the rate of return on an asset is the algebraic sum of its productivity (or yield) and the capital gains it enjoys on the commodity selected as numeraire (e.g. income).[13] If the economy were on a balanced economic trajectory, spot (accounting) prices would be constant over time, which means there would be no capital gains or losses on assets.

Investment projects are routinely evaluated on the assumption that the flow of benefits and costs remains constant over their lifetime. This is bad practice at the best of times, but as the *Review* shows, it is especially bad practice when note is taken of the fact that the (spot) accounting price of natural capital relative to produced capital should be expected to be rising. It should be expected to be rising because produced capital is being accumulated in the contemporary world even as natural capital is decumulated. The growing gap in the Impact Inequality reflects that.

This has far reaching implications. Suppose, for example, the Citizen Investor believes that produced capital will continue to be accumulated in the

[13] An asset's yield is also called its own rate of return.

global economy even while natural capital continues to be decumulated. In that case, the accounting price of natural capital relative to produced capital will be expected to rise over time. And that would make Nature restoration and conservation projects look good even to the hard boiled economist. Including the capital gains ecosystems will enjoy makes a huge difference to project evaluation. We confirm that with pair of examples.

Imagine that, as is common practice, the public decision maker chooses produced capital as numeraire. Imagine also that the discount rate she uses to appraise projects is 3% a year. Thus, 3% a year is the rate at which she discounts marginal changes in consumption as expressed in units of produced capital. That's her 'social discount rate'. Suppose now that the prospects of reducing the Impact Inequality in the near future is negligible even if investment is steered vigorously toward Nature conservation and restoration projects.[14] The decision maker therefore expects the accounting price of natural capital relative to produced capital to increase over the years in the near future. Suppose she estimates the rate of increase to be 1% a year. Considers now a Nature restoration project that is expected to increase the flow of the biosphere's goods and services by B in social benefits, at a social cost in terms of foregone consumption of E every year. Viewed from the present, the project's net social benefit in year t would read as $[B(1.01)^t - E]/(1.03)^t$. The expression could be interpreted as saying that as against a discount rate of 3% a year for the project's running costs, the project's gross benefits B should be discounted at the lower rate of 2%.

To make the point more strikingly, suppose the economic trajectory the world is projected to follows over the next few years reflects business-as-usual. In that case, because of biospheric non-linearities the Impact Inequality would continue to increase at an even higher rate than it has in recent years. So then suppose the Citizen Investor expects the accounting price of natural capital relative to produced capital to increase at a rate of 5% a year. She now considers a Nature restoration project that is expected to increase the flow of the biosphere's goods and services by B in social benefits, at a social cost in terms of foregone consumption of E every year. Viewed from the present, the project's net social benefit in year t would read as $[B(1.05)^t - E]/(1.03)^t$. The expression could be interpreted as saying that as against a discount rate of 3% a year for the project's running costs, the project's gross benefits B should be discounted at the rate -2%. Practitioners are accustomed to using positive rates to discount future benefits and costs. *The Review shows that it can be that the benefits of conservation and restoration projects should be discounted at negative rates*. As negative rates of discount amplify future benefits, even slow growing forests would be found to be socially beneficial and so pass the cost-benefit test.

This is not to say that conservation and restoration *projects* should be discounted at a lower rate than investment in produced capital.[15] (Our example only pointed to the desirability of using a lower discount rate for the benefits B, not for the costs E.) For suppose there is a competing project that would produce

[14] Climate scientists, for example, tell us that mean global temperature will continue to rise for some time even if net emission of carbon was driven to zero immediately.
[15] This is frequently urged on governments by environmentalists.

a consumer good but would incur a recurrent cost involving the same set of inputs as the project we have just studied. If the government decision maker was to deploy two systems of accounts, there would be confusion. The recurring costs would have to be valued differently in the two projects. That could of course be done, but in practice it would lead to errors.

The figures I have used to illustrate movements of natural capital accounting prices are not fanciful. The *Review* (Ch. 2, Box 2.3) estimates that globally the own rate of return (or yield) on natural capital in the form of 'primary producers' is as a minimum some 19% a year.[16] In contrast, the long-run global yield (rent or dividend) on housing and equities has averaged around 5% a year. If we take that figure to be a proxy for the yield on produced capital *and* assume that the global economy has been managing its portfolio of assets in an efficient manner, then the capital gains on produced capital relative to natural capital would *as a minimum* equal the difference between the two figures (i.e. 14% a year). In short, we would expect the accounting price of primary producers relative to produced capital to be *declining* by 14% a year.

Patently the latter has not been happening in recent decades, nor is it happening today. Destruction of the world's rainforests and degradation of the soils, when taken together with global accumulation of produced capital (approximately 3% a year), points to rainforests above ground and the soils underground – which are important seats of primary producers – becoming *scarcer* relative to produced capital, not more abundant. Simple and crude as this calculation is, it demonstrates how far off we are from an efficient allocation of global assets. It points especially to the enormous imbalance we have created between produced and human capital on the one hand, and natural capital on the other.

Poverty and the Local Resource Base

The Impact Inequality doesn't speak only to the global scenario, it is highly relevant for local scenarios. The idea that trade would permit *all* regions to live beyond their sustainable 'footprint' on a sustainable basis suffers from an adding-up problem. If all regions were to live beyond their ecological means the Impact Inequality would be enlarged. Deep poverty in Sub-Saharan Africa, South America, and South Asia is not unrelated to the erosion of the local natural resource base. It is helpful to remind ourselves that rural communities in the world's poorest regions do very little trade with people in distant regions. They may not be autarkic, but they rely for the most part on raw materials (timber, fibres, mud, plants and animals for food) that are obtained from the local landscape. The economic historian Tony Wrigley has called them 'organic economies' (Wrigley, 2004).

Mainstream models of poverty alleviation and economic development ignore *ex cathedra* the links between households' reproductive goals, their

[16] Primary producers are organisms that obtain energy directly from the sun to produce their own food. They consist of plants, algae and many bacteria. Nearly all other organisms depend on them for their energy.

incomes, and their local landscape. The Impact Inquality points to their links. But it is formal models of rural economies that display the links sharply and trace them to underlying features of the economy being studied (Dasgupta, 1993). The *Review* draws on a sizeable literature in paleo-history, geography, and anthropology that traces the links between population, consumption, and the local ecology. It uncovers processes by which people in organic economies can get trapped in a deteriorating environment, and attempt to migrate when the situation becomes intolerable.

The purpose of foreign aid is in large measure poverty alleviation, but in practice the *direct* target is all too often provisioning services; that is, y and the provisioning component of G. That affects the regulating and maintenance components of G adversely. But as noted above, y is affected by policies that target the other variables in the Impact Inequality. So there are *indirect* means toward raising y. The emphasis the *Review* places on the need for investment in community-based family planning and reproductive health in sub-Saharan Africa (SSA) was not casual. It is certainly true that SSA cannot remotely be held responsible for the *global* overshoot in humanity's demand for the biosphere's goods and services. But the *Review* shows that unlike the rich West, who can depend on trade and so transform their own neighbourhood that it does not contribute to the biosphere's supply of provisioning services, the rural poor in SSA are unable to do that: the fraction of their income that is based on trade is negligible. If the demands they make on their local environment exceeds their local environment's ability to supply daily needs over a period of time, they face destitution. That's the Impact Inequality as confined to the local community.

Family Planning and Reproductive Health

In one set of population projections (UNPD, 2000), sub-Saharan Africa's population can be expected to rise to 3.8 billion in year 2100 from the current size of approximately 1.1 billion. The *Review* urges development practitioners to recognise that it is in the interest of people in sub-Saharan Africa that their governments give assistance to help bring about a fast fertility transition through investment in community based family planning and reproductive health programmes. A transition to replacement fertility rate in, say, 20 years' time rather than in 40 years' time would mean a massive lowering of their projected population size in 2070 and would reduce the pressure population size under current projections would inflict on the local environmental resource base in SSA.[17]

[17] Vollset et al. (2020) have offered global population projections for 2100 based on two assumptions that are notably different from UNPD (2019): (i) sharper declines in fertility rates in countries that have already undergone a fertility transition; (ii) earlier declines in the TFR in low income countries. The authors' forecast of global population in 2100 is 8.79 billion, with a 95% prediction interval of 6.8 to 11.8 billion. Their forecast for sub-Saharan Africa is an increase of approximately 2 billion from today's 1.1 billion, which is fewer by 700 million than the median projection of UNPD (2019). In fact, differences between the two sets of projections for global population become significant only after year 2070. Until then, there is less than 5% difference between the two. For example, the difference between the two projections for global population in year 2050 is 211 million. Of a median projection of 9.7 billion in UNPD (2019), that is negligible. The projections' closeness until 2070 matters far more than their differences for year 2100. As the Impact Inequality shows, Nature responds to the demands we make of it, it does not calculate rates of

Currently the EU to Africa Official Development Assistance (ODA) toward 'family planning and population services' is less than 1%. The World Bank also attaches low priority to it. Moreover, developing countries themselves relegate family planning to minor government departments. The introduction of family-planning related media messages is credited in part for the rise in contraceptive demand and use in countries where governments have taken family planning seriously. Between 2000 and 2019, total demand for family planning (which is the sum of contraceptive use and unmet need) among women of reproductive age rose from 48% to 61% in Malawi, and from 27% to 44% in Rwanda (UNPD, 2020). In contrast, little or no change in demand was observed in those countries, such as Nigeria and the Democratic Republic of Congo, where family planning programmes remain weak.

Over the years, female education has been seen by development experts as the surest route to women's empowerment, including, for example, choice over birth spacing. All governments recognise the importance of women's education for empowering women. And yet even today nearly 30% of women between 15-24 years of age in low income countries are illiterate (World Bank, 2019). Family planning programmes in contrast are affordable by governments even in low income countries (see below), they offer an easy and effective route to governments for empowering women – they are a low-hanging fruit - and yet they remain low on the development agenda. It is a paradox.[18]

By providing access to subsidised contraceptive commodities and services, family planning programmes were successful in accelerating fertility declines in East Asia and Latin America in the 1960s and 1980s. Cleland et al. (2006) estimated that promotion of family planning in countries with high birth rates had the potential at that time to avert more than 30% of all maternal deaths and nearly 10% of childhood deaths. The rationale for vigorously expanding the content and reach of such programmes today also lies in the more than 215 million women in developing, mainly low income countries who have reported they want to prevent pregnancy but are not using modern contraception. Among them over 150 million use no method of contraception and nearly 66 million rely on traditional methods (UNPD, 2020). The Guttmacher Institute (2019) estimated that there are nearly 111 million pregnancies in low and middle income countries annually that are unintended. The institute also estimated that if all unmet need for modern contraception were satisfied in developing countries, there would be a near 70% decline in unintended pregnancies, amounting to around 35 million a year. Meeting unmet need for contraception would reduce pregnancy related deaths by 70,000. Many unintended pregnancies end in abortion, a significant proportion of which are performed under unsafe conditions.

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change in demands, nor rates of change of rates of change in demands. If a few more planetary boundaries are breached by year 2070, differences in population projections for year 2100 will count for little.

[18] The significance of family planning programmes is reflected in the demographic histories of Bangladesh and Pakistan. In 1970 (i.e. before the partition of Pakistan into two states), the total fertility rate was high in both Bangladesh and Pakistan – 6.9 in Bangladesh and 6.6 in Pakistan – but by 2000 it had dropped to 3.2 in Bangladesh but was 5.0 in Pakistan (A. Dasgupta, 2020).

In addition to reducing unintended pregnancies, contraceptive-use among women enhances their own health and that of their children by spacing births and by providing greater opportunity for education. The Guttmacher Institute (2019) reported the estimate that more than 2.5 million babies in low and middle income countries die each year in the first month of life. Access to modern family planning is a means for women to have greater control over their lives and for improving the chance of having healthy babies. If the benefits of modern family planning are high, the costs are low. By one estimate (Guttmacher Institute, 2017), expanding and improving services to meet women's needs for modern contraception in developing countries would cost under US$2 a year per person.

None of this should involve command and control. Instead, it would involve expanded investment in information, community wide discussions, and the means for people to plan their own family size in an informed way. The *Review* stresses the need *community* based family planning because, as noted above, fertility behaviour is influenced not only by private desires and wants, they are also shaped by societal mores: preferences over family size are socially embedded. Reproductive behaviour is 'conformist' when the family size a household desires stays close to the average family size in the community or, more broadly, in the world households come into contact with (Dasgupta and Dasgupta, 2017). This feature of our preferences gives stimulus to fertility transitions when households have access to modern family planning and reproductive health services. The neglect of family planning and reproductive health in official aid from the European Union and in governments in SSA is indefensible.

Family planning and reproductive health have received scant attention in development economics even in the way their programmes are designed. Dasgupta and Dasgupta (2017) noted that desired family size is typically elicited from answers to the following question: "If you could go back to the time when you did not have any children and could choose exactly the number of children to have in your whole life, how many would that be?" The way the question is framed denies the social embeddedness of desired family size. Women are not asked what their desire would be if the prevailing fertility practices of others were different. In fact, there is no mention of the prevailing fertility rate. Since respondents are not invited to disclose their conditional desires, they very likely disclose their desired family size on the assumption that fertility will remain at its prevailing rate. A direct way to discover socially embedded preferences would be to reconstruct the questionnaires by asking a series of conditional questions, which we collapse here for convenience into one: "If you could go back to the time when you did not have any children and could choose exactly the number of children to have in your whole life, how many would that be, assuming everyone else in your community had *n* children over their whole life?"

Externalities and Rights

Socially embedded preferences harbour behavioural externalities that move through the social world. But additional births also give rise to externalities that are transmitted through the material world. Households may be deemed to have a right to their own fertility decisions, but if additional births accentuate the

Impact Inequality, future people would be adversely affected. That gives rise to tensions between externalities and rights (Dasgupta and Dasgupta, 2017).

Although the failure to protect property rights has traditionally been at the heart of the theory of externalities, the language of rights sits awkwardly there. We are speaking of fundamental rights, not rights that are assigned to people or organisations because they are instrumental in advancing the well-being of the people involved. But even fundamental rights need to be justified. As elsewhere in the economics of biodiversity, trade-offs have to be weighed if actions are to be judged. Rights short-circuit those complexities.

Rights are peremptory, which is why they are problematic. One way to overcome the problem is to place them in a hierarchy. That was the conclusion John Rawls famously reached when framing his principles of justice (Rawls, 1972). But if note is taken of adverse externalities accompanying a person's actions, it is by no means clear whose rights are to trump. This is why the language of rights sits awkwardly in the economics of biodiversity.

In recognisably exceptional circumstances governments resolve the dilemma by creating a hierarchy of rights. In the context of the COVID-19 pandemic, many governments have insisted that the right not to be infected by others and risk death trumps the individual right to do as we please when it comes to wearing face masks and keeping safe distance from our friends. Most people would seem to have accepted that allocation of rights.

A far more sensitive sphere where rights would seem to clash is reproduction. The 1994 International Conference on Population and Development reaffirmed the language of rights in the sphere of family planning and reproductive health, prompted by the infringement of women's reproductive rights in China and, for a brief period, in India. The Conference's conclusions read:

"Reproductive rights … rest on the recognition of the basic right of all couples and individuals to decide freely and responsibly the number, spacing, and timing of their children, and to have information and means to do so, and the right to attain the highest standards of sexual and reproductive health," (UNFPA, 1995)).

The qualifier 'responsibly' could be read as requiring couples to take into account the adverse environmental externalities their reproductive decisions may give rise to, but that probably would be a stretched reading. Certainly, writings affirming the UN declaration have interpreted the passage and its intent more narrowly. For example, the fundamental right of individuals "to decide freely and for themselves whether, when, and how many children to have" is central to the vision and goals of Family Planning 2020. It is also pivotal in the reproductive health indicators of the UN's Sustainable Development Goals (SDGs). In this vision, information and other services pertaining to family planning and reproductive health are rights, as is choosing one's family size regardless of whether one's ideal family size is anything from zero to eight. But it is not clear that the two sets of rights have the same force, nor is it clear how they are to be weighed against one another should a choice have to be made at the margin between them.

In a world where the Impact Inequality holds, and holds strongly, it may seem reasonable to insist on the rights of future generations when an appeal is

made to curb our impact on the biosphere. Sen (1982), for example, likened persistent pollutants to instruments of oppression: "Lasting pollution is a kind of calculable oppression of the future generation." But if additional births can be expected to contribute further to the discharge of persistent pollutants, why does a couple's reproductive rights trump the rights of future people not to be oppressed? That is the kind of ethical dilemma the language of reproductive rights misses. The *Review* does not offer a position on this contentious issue, but to avoid any discussion of these conflicting rights cannot be morally right.

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Annex

The Impact Inequality and the UN's Sustainable Development Goals

In September 2015 the United Nations General Assembly agreed on an agenda for sustainable development in member countries. Nations committed themselves to meeting 17 Sustainable Development Goals by year 2030. The SDGs involve 169 socio-economic targets. To measure progress in meeting those targets, it was proposed to track more than 240 socio-economic indicators over the coming years.

International agreement on the SDGs was a remarkable, even noble, achievement, for the Goals unpick features of lives that would enable us to live well. But there is a problem. The Goals are not accompanied by an examination of whether, assuming they are achieved, they are sustainable. In view of the fact that we are now in a situation where there is an ever growing Impact Inequality, sustainability should as a bare minimum require that the inequality is converted into an equality.

So then, how large is the current overshoot of Ny/α over G? The Global Footprint Network defines ecological footprint not as Ny/α but as the ratio of Ny/α to $G(S)$. The Global Footprint Network (see Wackernagel and Beyers, 2019) have estimated that the ratio from 1 in about 1970 to 1.7 is 2019, implying that it increased at an average annual rate of 1.1%.[19] That means the ratio increased at an average annual rate of 1.1%.[20] Moreover, global GDP at constant prices has increased since 1970 at an average annual rate of 3.4%.

We turn to the right-hand side of the Impact Inequality. Managi and Kumar (2018) estimated that the value of per capita global natural capital declined by 40% between 1992 and 2014 (Fig.l 4). That converts to an annual percentage rate of decline of 2.3%. But world population grew approximately at 1.1% in that period. Taken together it follows that the value of global natural capital declined at an annual rate of 1.2%. Because there are no estimates of the form of the G-function, we assume for simplicity that local variation is a good approximation,

[19] In other words, in the late 1960s the global ecological footprint was sustainable but it is not today. The Global Footprint Network (GFN) picturesquely interprets the figure 1.7 as the number of Earths needed to match humanity's demands of the bisophere's goods and services on a sustainable basis. GFN has recently reported that the figure fell to 1.6 in 2020 due to the impacts of the COVID-19 pandemic.

[20] GFN's estimates are based on data furnished by the United Nations Statistical Office. For an account of the methods that are deployed for estimating G, see Wackernagel and Beyers (2019). It should be noted that as an approximation they take G to be linear in S.

meaning that G is proportional to S. So, G can also be taken to have declined at an annual rate of 1.2%.[21]

The estimates for the annual percentage rates of change of Ny, G, and $[Ny/\alpha]/G$ enable us to calculate that α had been increasing at an annual percentage rate of 3.5% in the period 1992 to 2014. Suppose we want to reach Impact Equality in year 2030. That would require $[Ny/\alpha]/G$ to shrink from its current value of 1.7 to 1 in 10 years' time, implying that it must decline at an average annual rate of 5.4%. Assuming global GDP continues to grow at 3.4% annually and G continues to decline at 1.2% (i.e. business is assumed to continue as usual), how fast must α rise?

To calculate that, let us write as $g(X)$ the percentage rate of change of any variable X. We then have

$$g([Ny/\alpha]/G) = g(Ny) - g(\alpha) - g(G) \quad (2)$$

Equation (2) can be re-arranged as

$$g(\alpha) = g(Ny) - g([Ny/\alpha]/G) - g(G) \quad (3)$$

We now place the estimates of the terms on the right-hand side of equation (3) to obtain

$$g(\alpha) = 0.034 + 0.054 + 0.012 = 0.1 \quad (4)$$

In short, α must increase at an annual rate of 10%. As that is a huge hike from the historic rate of 3.5%, we consider a different scenario. Suppose global GDP was to remain constant in real terms from now to year 2030 and draconian steps were taken by us over our demands to limit the rate of deterioration of the biosphere to an annual 0.1%. What would be required rate of increase in α need to be? Using equation (3) we have $g(\alpha) = 0.054 + 0.001 = 5.5\%$. Even that is considerably larger than the 3.5% rate at which α has been increasing in recent decades.

[21] While Managi and Kumar (2018) base their work on the UN data base, the questions they ask differ from those asked by the GFN (Wackernagel and Beyers, 2019). Moreover, because the Managi-Kumar study includes fossil fuels and minerals, we must assume for our purposes of illustration that the percentage rate of global decline in the accounting value of sub-soil resources equalled the corresponding figure for ecological resources. Using data from different systems of measurement in the numerical calculation we conduct here is a price we have to pay for continual neglect of the economics of the biosphere in international organisations. GDP estimates have been refined continually over the decades by countless experts, whereas the human footprint on the biosphere remains of interest only to a handful of people.