Macroeconomics and the Environment

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A GDAE Teaching Module on Social and Environmental Issues in Economics

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NOTE – terms denoted in **bold face** are defined in the **KEY TERMS AND CONCEPTS** section at the end of the module.

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1. INTRODUCTION

Economics is the study of how people manage their resources to meet their needs and enhance their well-being. While **microeconomics** emphasizes the economic activities and interactions of individuals and particular organizations (such as businesses, households, community groups, nonprofits, and government agencies), **macroeconomics** looks at how all these activities join together to create an overall economic environment at the national—and often the global—level.

Traditional macroeconomic goals include full employment, low inflation, and economic growth. While macroeconomic analysis has usually not taken the environment into account to any significant degree, this is changing due to the expanding scale of human economic activities. Macroeconomic objectives are increasingly seen as embedded in a much larger picture that includes the environment, resource supplies and limits, and flows of wastes and pollution.

2. THE CIRCULAR FLOW MODEL & THE NATURAL ENVIRONMENT

2.1 The Economic System and the Environment

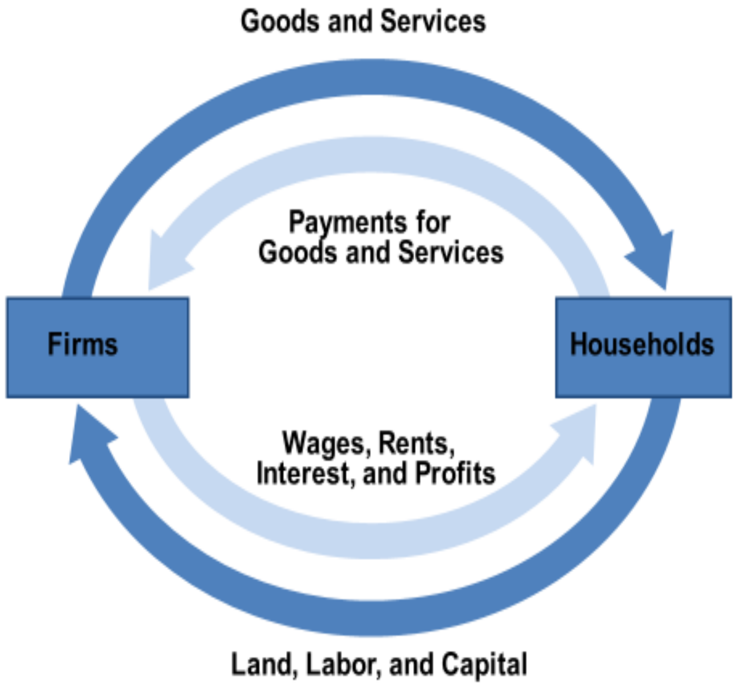
A basic building block of economic theory is the **standard circular flow model** of an economic system. As illustrated in Figure 1, this model shows the exchange of goods, services, and factors of production between two types of economic actors: households and firms.

When a good or service is purchased, two kinds of flows occur: the good moves from a firm to a household and a corresponding payment moves from a household to a firm. Similarly, when firms purchase factors of production (such as labor and capital), a payment of money for the use of these factors accompanies the flow of factor services from households to firms.[1] These transactions are symbolized on the graph above by the arrows going in both directions – from firms to households and vice versa.

In the usual version of this model, however, the environment and the natural resources which make economic production possible are not evident. Yet natural resources are essential to production: agriculture requires productive soils; industry requires fuels, water, and minerals; consumers need drinking water; and many environmental resources, such as beaches and forests, are in high demand.

[1] Of course, some economic transactions also occur between different firms, rather than between households and firms.

Figure 1. *The Standard Circular Flow Model*



The only indication of the natural environment in Figure 1 is the presence of “land” as a factor of production. Land is one of the three traditional inputs into economic production processes, along with labor and capital.

"Land" is the term often used by economists to represent all natural resources used in economic production, including soils, water, forests, species, minerals, and fossil fuels. The first thinkers who studied economics during the eighteenth and nineteenth centuries recognized the importance of land in productive processes, and emphasized the existence of natural resource constraints on economic growth. Later, in the second half of the 19th century, economists focused increasingly on the two other factors of production, capital and labor, which were essential for the growth of the industrial sector as rapid industrialization became the major economic phenomenon of these times.

Only recently, with increased awareness of environmental and resource issues, have economists once again focused on the topic of “land,” but now often use the updated term **natural capital**. Natural capital includes all natural resources as well as the environment. Using the term natural capital emphasizes the importance of these natural factors to the production process. It also indicates that what we ordinarily call "capital" is really **manufactured (or produced) capital**. Both types of capital are essential to the productive process, and both contribute to society's wealth.

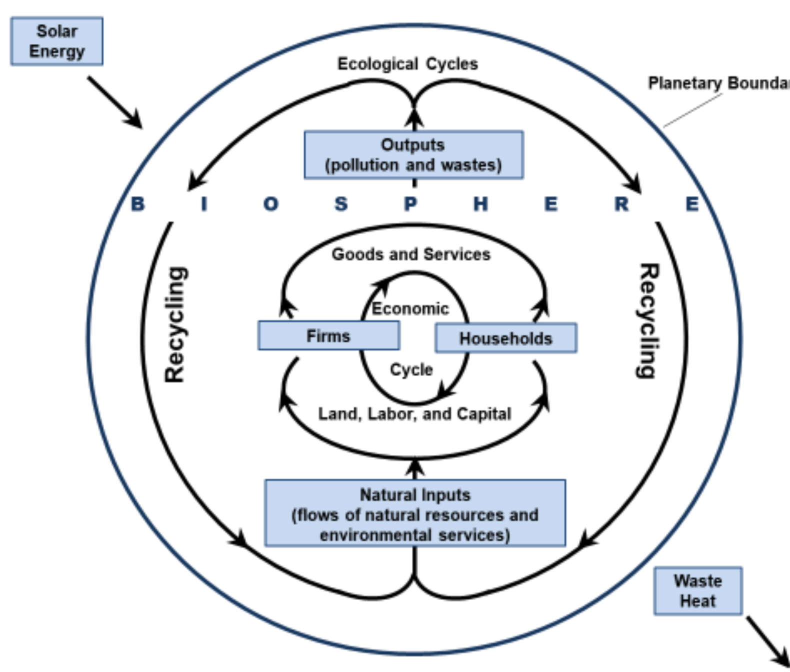
2.2 Linking the Economic System and the Natural Environment

Returning to the circular flow model from Figure 1, let's consider whether the simple diagram deals adequately with natural capital. First note that the circular flow model appears to be self-contained. But where do the inputs for production ultimately come from? Natural capital does not come from our two economic actors, firms and households. Instead it must be obtained from outside the system. Further, the model does not reflect the fact that the availability of natural capital depends on how resources are managed and on the scale of economic activity. Even the maintenance of the other two factors of production – labor and manufactured capital – require inputs of natural capital, such as food so that people can work productively, and raw materials for building and equipment.

In addition to the need to consider natural capital inputs, we also need to take account of output from the economy into the environment, in the form of wastes and pollution. This requires a different, broader circular flow model. A revised circular flow model is shown in Figure 2. We now see the economic system embedded in the environment, with natural capital as the ultimate input and wastes and pollution as the ultimate output. The revised model also reflects the fact that the earth itself is not a closed system and exchanges flows of energy with outer space - the energy flows it receives from the sun and the flows it releases into space (heat loss).

This expanded model also takes into account the fact that some of the wastes and pollution rejected in the biosphere are recycled naturally through biological and geophysical processes. For instance, wetlands play an essential role in purifying polluted waters. Some wastes are also recycled through the industrial system itself (including some paper, glass, and metals) and reinjected again into the production process as raw material.

***Figure 2**. The Circular Flow Linked to the Environment*



What does this new and expanded picture of the circular flow model imply for economic theory? There are at least two major implications:

1. The recognition that natural capital provides essential inputs into economic processes implies that human well-being is ultimately dependent on natural capital. Attempts to measure well-being should therefore consider the available quantity and quality of natural capital.
2. Economic activity may be limited by both the availability of natural capital and the ability of the environment to assimilate wastes and pollution.

This means that we need to do some rethinking of standard economic concepts such as gross domestic product and economic growth. If we take the revised circular flow model into account, we must update the standard ways of measuring economic well-being, and also consider whether there are limits to long-term economic growth, and whether it is possible to change the nature of economic activity to make it more compatible with resource limitations and to avoid overloading natural systems with pollution, such as excessive carbon emissions that cause climate change.

3. REDEFINING NATIONAL INCOME AND WELL-BEING

3.1 Limitations of GDP

Economists have traditionally measured the economic output of a society using **gross domestic product (GDP)**[2]. While it is widely recognized that GDP does not measure human well-being, both economists and policy makers often assume that an increase in GDP corresponds to an increase in welfare. Some of the common critiques of standard national accounting measures such as GDP include:

- ***Volunteer work is not accounted for.*** Standard measures don't count the benefits of volunteer work, even though such work can contribute to well-being as much as economic production.
- ***Unpaid household production and informal economic activity is not included.*** While standard accounting measures include the paid labor from such household activities as childcare, housekeeping and gardening, these services are not counted when they are unpaid, or when wages are paid "under the table" through the **informal economy**.
- ***No consideration is made for changes in leisure time.*** A nation's GDP will rise if total work hours increase, but no accounting is made for the loss of leisure time.
- **Defensive expenditures** ***are included.*** Defensive expenditures are those needed to counteract problems. An example is expenditures on police protection. If police expenditures increase to counter a rise in crime levels, the increased spending raises GDP,

[2] Economists have also measured economic activity using gross national product (GNP). The difference between GNP and GDP depends on whether the basis of the measurement includes income received by residents of a country from either domestic or foreign production (for GNP) income from all production within a country's physical borders (for GDP). GDP replaced GNP as the primary measure of productivity in the United States in 1991.

but no consideration is made for the negative impacts of higher crime rates. Another example is pollution cleanup expenses.

- ***The distribution of income is not considered.*** Two nations with the same GDP per capita may have significantly different income distributions and, consequently, different levels of overall well-being.
- ***Non-economic contributors to well-being are excluded.*** GDP does not consider the health of a nation's citizens, education levels, political participation, or other social and political factors that may affect well-being levels.

In our study of environmental issues, we must add another major criticism of standard accounting measures—they fail to account for environmental degradation and resource depletion. If a nation cuts down its forests, depletes its soil fertility, and pollutes its water supplies, this surely makes the nation poorer in some very real sense. But national income accounts will merely record the market value of the timber, agricultural produce, and industrial output as positive contributions to GDP, without taking account of the environmental damage.

There have been numerous efforts to develop "greener" accounting measures. Interest in inclusion of the environment in national accounting began in the 1970s and 1980s, when several European countries began to estimate physical accounts for natural resources such as forests, water, and land resources. In 1993 the United Nations published a comprehensive handbook on environmental accounting, which was revised in 2003, and again in 2014.

The U.N.'s 2014 System of Environmental-Economic Accounting (SEEA) report describes three basic approaches to environmental accounting:

1. Measuring the physical flows of materials and energy
2. Measuring the stock of environmental assets
3. Measuring economic activity related to the environment.

While many countries have adopted one or more of these accounts to some extent, no country has fully implemented the SEEA recommendations. Note that the SEEA framework seeks to integrate environmental accounting into existing methods of national accounting, typically using supplementary accounting tables

Economists have devised a number of various national accounting measures that aim to either revise or replace GDP. We can broadly classify these measures into three categories:

1. Approaches that adjust traditional accounting measures to account for resource depletion and environmental degradation, measured in monetary units
2. Approaches that provide an alternative or supplement to traditional accounting measures, but are still measured in monetary units
3. Approaches that provide an alternative or supplement to traditional accounting measures, measured in one or more non-monetary units.

3.2 Green GDP Measures

GDP measures the marketed economic production in a society. But as noted above, GDP fails to account for the resource depletion and environmental degradation associated with economic production. **Green GDP** approaches estimate these damages in monetary units, and then deduct this amount from GDP.[3]

National accounting estimates already recognize that economic production is associated with the degradation of resources – machines, equipment, and infrastructure wear out over time, requiring repair and eventual replacement. This process of wearing out, repairing, and replacing capital is taken into account by measuring the **depreciation** of manufactured capital. If we subtract an estimate of manufactured capital depreciation from GDP, we obtain **net domestic product** (NDP). For example, in 2017 the depreciation of manufactured capital amounted to about 17% of GDP in the United States.

Green GDP simply extends this same logic to natural capital, subtracting both the value of the depreciation of fixed capital and the depreciation of natural capital from the GDP to obtain this new measure. Economic production uses up nonrenewable natural resources such as coal, oil, and minerals. Renewable natural resources such as productive soils, forests, and fisheries can also be depleted or damaged through over-use. The wastes emitted from production processes pollute air, water, and land. Despite the obvious importance of this kind of depreciation, it has not been accounted for in standard measures of NDP or net investment.

One of the earliest attempts to incorporate the environment into national accounting estimated the monetary value of the depreciation of three types of natural capital in Indonesia from 1971-1984: oil, forests, and soil.[4] Despite only considering three resources, the annual value of natural capital depreciation averaged about 20% of GDP. Yet a study in Sweden which included the value of depreciation of soils, recreation values, metal ores, and water quality, based on data from the 1990s, produced estimates of only 1-2 percent of GDP.[5]

The most ambitious attempt at measuring Green GDP was in China in the mid-2000s. The measurement of Green GDP was sanctioned by Chinese President Hu Jintao in 2004 to foster a "scientific concept of development," with data collection in 31 provinces and municipalities. Results published in 2006 indicated that national damages from pollution amounted to 3% of GDP. However, these results were clearly on the conservative side, and implied that a more complete assessment might conclude that Green GDP growth rates were actually negative (i.e., that natural capital depreciation was greater than the growth of traditional GDP), at least in some provinces.[6]

Due to political pressure from officials in provinces with high pollution, China's Green GDP project was officially cancelled in 2009, but in early 2015 China's Ministry of Environmental Protection announced that it would undertake "Green GDP 2.0," with a new methodology and data

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[3] We use the most common definition of Green GDP here. A different definition of Green GDP seeks to measure the positive economic value of ecosystem services and public goods that are not included in GDP (see Boyd, 2007). Some researchers also use the term Green GDP to refer more broadly to various other approaches that incorporate environmental factors into national accounting.

[4] Repetto et al., 1989.

[5] Skånberg, 2001.

[6] Rauch and Chi, 2010.

collection in several pilot cities starting in 2016. Beginning in 2018, India's government plans to undertake a five-year analysis to calculate Green GDP for each state in the nation with the goal of generating an increased understanding of environmental well-being to promote better informed policy making. If successful, this will be the most comprehensive accounting of Green GDP at the national level.

3.3 Adjusted Net Savings

An approach that similarly starts with a traditional national accounting metric and makes adjustments to account for the environment is the **Adjusted Net Saving (ANS)** measure developed by the World Bank. The objective of ANS is to "measure the true rate of savings in an economy after taking into account investment in **human capital**, depletion of natural resources, and damage caused by pollution."[7] A country with a consistently negative rate of ANS would thus be considered on an unsustainable path.

(Human capital, another form of capital that has garnered growing interest among economists, represents the competence, skills and abilities of the labor force that allow them to be economically productive.)

Instead of starting with GDP, ANS starts with a country's rate of gross saving, which essentially equals total income minus all consumption expenditures. The steps taken to calculate ANS are shown in Figure 3.[8] These steps are:

1. Using the standard calculation of net domestic product, ANS first deducts the depreciation of manufactured (or fixed) capital against gross saving, to obtain net saving.
2. ANS considers education expenditures as an investment in a country's future. So these expenditures are added to net saving.
3. Depletion of natural resources is considered a disinvestment, and thus a deduction. The ANS data include monetary values for the depletion of energy, mineral, and forest resources.
4. The final deduction is for pollution damages. ANS makes deductions for pollution from particulate matter and carbon dioxide.

A higher value of ANS, measured as a percentage of Gross National Income, indicates that a nation is saving more for the future. Notice that an ANS rate may be negative due to excessive manufactured capital depreciation, depletion of resources, or pollution. In other words, a nation's positive investments in manufactured capital can be more than offset by the depletion of its productive resources.

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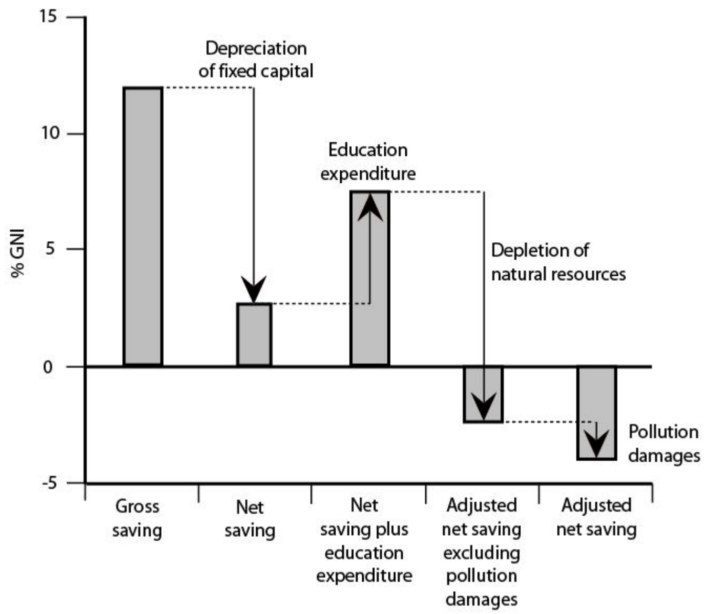
[7] http://data.worldbank.org/data-catalog/environmental-accounting

[8] Note that ANS is calculated by the World Bank as a percentage of Gross National Income (GNI). GNI is the domestic and foreign output by residents of a country, and is normally relatively similar to GDP.

Figure 3. *Calculating Adjusted Net Saving*



The World Bank has calculated ANS rates for most countries of the world. Table 1 shows the results for selected countries in 2016. For most countries, the environmental adjustments are relatively minor. For example, we see that the ANS rates of France and the United States are primarily a result of their respective net national saving rates and education expenditures.[9] But the environmental adjustments can be quite significant in some countries.

Table 1. *Adjusted Net Saving Rates, Selected Countries, Percent of GNI, 2016*

Country	Gross National Saving	Fixed Capital Deprec -iation	Education Expendi-ture	Energy Depletion	Mineral Deple-tion	Net Forest Deple-tion	Carbon Damage	Particulate Matter Damage	ANS
Chile	20.8	13.8	4.6	0.0	5.2	0.0	1.1	0.1	5.1
China	46.2	21.3	1.8	0.4	0.3	0.0	3.1	0.4	22.4
Congo, Dem. Rep.	12.6	1.1	2.1	0.3	9.8	13.4	0.5	1.9	-12.4
France	20.3	17.7	4.9	0.0	0.0	0.0	0.4	0.0	7.1
India	30.6	12.5	3.1	0.5	0.2	0.3	3.6	1.0	15.5
Indonesia	33.3	17.0	3.3	0.9	0.4	0.0	1.8	0.5	16.0
Russia	26.1	12.6	3.6	5.6	0.5	0.0	4.0	0.3	6.7
Saudi Arabia	26.8	9.3	7.2	9.2	0.0	0.0	3.1	0.2	12.2
Uganda	20.2	15.4	2.0	0.0	0.0	15.4	0.8	1.4	-10.8
United States	17.8	15.4	4.8	0.1	0.1	0.0	0.9	0.1	6.1

Source: World Bank, World Development Indicators database.

[9] The evaluation of carbon damages is controversial; the World Bank uses a relatively low estimate for the damages per ton of carbon emitted to the atmosphere. A higher estimate, advocated by some environmental economists, would lead to a more significant reduction in adjusted net savings.

Energy depletion is a significant deduction in Russia and Saudi Arabia. Mineral depletion significantly lowers the ANS rates in Chile and the Democratic Republic of Congo. Forest depletion exceeds 10% of GNI in the Democratic Republic of Congo and Uganda (see Box 1 for more on deforestation). Based on traditional saving measures, countries such as Chile and Uganda appear to be investing somewhat heavily in their future. But once we account for the depletion of natural capital, their savings rates are significantly lower. Both the Democratic Republic of Congo and Uganda have positive savings rates according to traditional measures, but negative ANS rates.

BOX 1: DEFORESTATION IN INDONESIA AND CHINA

The dollar valuation of natural capital in adjusted net savings accounts is controversial. Ecological values may not be fully taken into account. The World Bank, for example, indicates a "zero" estimate for net forest depletion in Indonesia (Table 1). But primary forest loss in Indonesia is a serious problem. According to a recent report, "the large majority of palm oil production occurs in just two countries, Malaysia and Indonesia, where huge swaths of tropical forests and peatlands (carbon-rich swamps) are being cleared to make way for oil palm plantations, releasing carbon into the atmosphere to drive global warming while shrinking habitats for a multitude of endangered species." So how can net forest loss be zero? Since destroyed tropical forest in Indonesia is frequently replaced by oil palm plantations, the land may be counted as still technically under forest cover. But this completely misses the vast ecological damage involved.

Similarly, in the case of China, there has been substantial reforestation based on mono-species plantations, in what environmentalists call "green deserts" because they don't provide for the kind of habitat needed for biodiversity. Meanwhile, primary forests are continuing to be depleted in China, which is also evaluated as having zero net forest depletion by the World Bank measure.

Sources: Union of Concerned Scientists, Drivers of Deforestation: Palm Oil https://www.ucsusa.org/global-warming/stop-deforestation/drivers-of-deforestation-2016-palm-oil#.W-C19XmouUk; Jon Luoma, China's Reforestation Programs: Big Success or Just an Illusion?" Yale Environment 360, https://e360.yale.edu/features/chinas_reforestation_programs_big_success_or_just_an_illusion

3.4 Genuine Progress Indicator

Green GDP and ANS adjust traditional national accounting measures to incorporate natural capital depreciation and environmental damage. But just like GDP, neither of these alternatives purport to measure social welfare. Some other approaches to greening the national accounts start essentially from scratch to create a measure of social welfare. Perhaps the most ambitious attempt to-date to design a replacement to GDP is the **Genuine Progress Indicator (GPI)**.[10]

One critique of GDP, as noted above, is that it includes all economic activity, including defensive expenditures, as a positive contribution to welfare. For example, all expenditures by the U.S. government Superfund for cleaning up toxic waste sites are contributions to GDP. The medical costs of treating diseases caused by air or water pollution are similarly added to GDP. By this

[10] An earlier version of the GPI was called the Index of Sustainable Economic Welfare (ISEW).

logic, the more pollution damage and resulting cleanup expense a nation experiences, the better off it is. Clearly this is irrational. Thus, the GPI differentiates:

> …between economic activity that diminishes both natural and social capital and activity that enhances such capital. [The GPI is] designed to measure sustainable economic welfare rather than economic activity alone. In particular, if GPI is stable or increasing in a given year the implication is that stocks of natural and social capital on which all goods and services flows depend will be at least as great for the next generation while if GPI is falling it implies that the economic system is eroding those stocks and limiting the next generation's prospects.[11]

Like the previous measures discussed in this module, the GPI is measured in monetary units. The starting point of the GPI is personal consumption, based on the rationale that it is consumption that directly contributes to current welfare. Next, personal consumption is adjusted to reflect the degree of economic inequality in a society. Then monetary estimates of goods and services that contribute to social well-being are added. These positive factors include:

- The value of unpaid household labor
- The external benefits society receives from higher education
- The service value of public infrastructure such as highways
- The value of volunteer work

Finally, the GPI deducts the monetary value of factors that reduce social welfare, including:

- The value of commuting and lost leisure time
- Damages from crime
- Climate change damages
- Damages from air, water, and noise pollution
- The depletion of natural resources

The GPI has been estimated for many countries, including Chile, China, Germany, India, Thailand, and the United States. GPI estimates have also been compiled for several sub-national regions, including the U.S. states of Maryland, Hawaii, Colorado, Vermont, and Utah. As we might expect considering all the adjustments above, the GPI may significantly differ from GDP in terms of magnitude and trends.

This is demonstrated in Figure 4, which shows the trends in real GDP and real GPI per capita aggregated across 17 countries from the 1950s to the mid-2000s. While both GDP per capita and GPI per capita both approximately doubled in real terms from the 1950s to the 1970s, we see that since then GPI has leveled off while GDP has continued to increase. The authors of this analysis conclude that "although GDP growth is increasing benefits, they are being outweighed by rising inequality of income and increases in costs."[12] The most recent version of GPI (termed GPI 2.0) aims to provide an updated, consistent and precise framework for measuring GPI.[13] The trend of stable or declining GPI appears to continue using GPI 2.0 for the years 2012-2014 (Figure 5).

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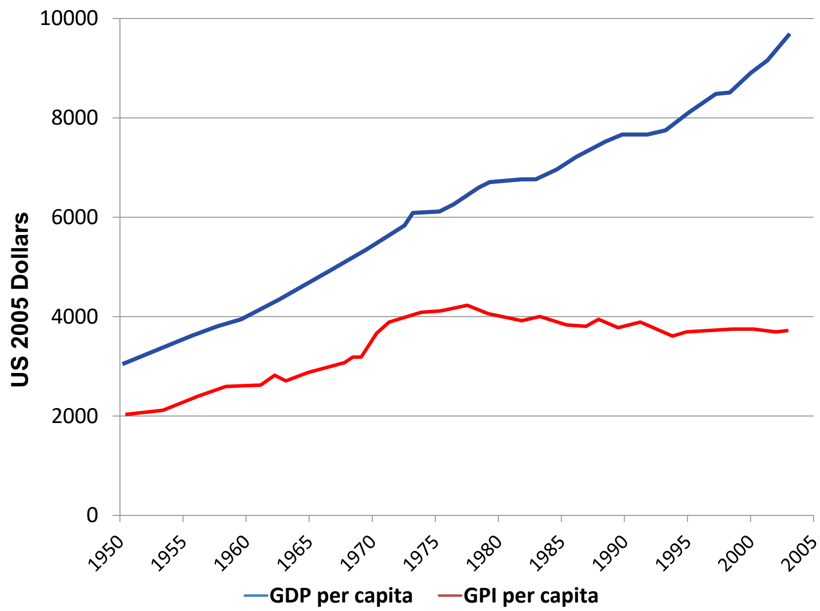
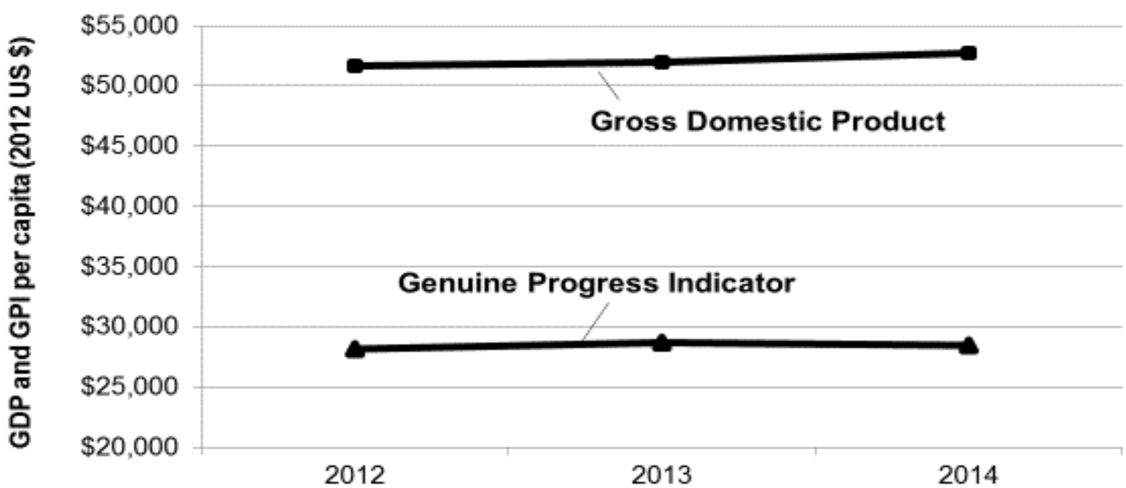
[11] Talberth, Cobb, & Slattery, 2007, p. 1-2.
[12] Kubiszewski et al., 2013, p.66.
[13] Talberth and Weisdorf, 2017.

Figure 4. *GDP and GPI per Capita, Aggregate of 17 Countries*



Source: Kubiszewski et al., 2013.

Figure 5. *GPI vs. GDP per capita 2012-2014*



Source: Talberth and Weisdorf, 2017.

Like Green GDP and ANS, the GPI requires converting various environmental factors into a single metric—dollars. This raises numerous questions about the assumptions necessary to convert everything into dollars. We may also question whether disparate environmental resources and natural capital can be directly compared using a common unit. Other approaches to measuring national well-being have been developed that avoid the use of a monetary metric. We consider one of these next.

3.5 Better Life Index

Recognizing the limitations of GDP and the need to develop indicators that incorporate social and environmental factors, in 2008 French President Nicolas Sarkozy created the Commission on the Measurement of Economic Performance and Social Progress. The Commission included Nobel Prize-winning economists Joseph Stiglitz and Amartya Sen. The Commission's report, published in 2009, concluded that it is necessary to shift from an emphasis on measuring economic production to measuring well-being.[14] It also distinguished between current well-being and sustainability, recognizing that the sustainability of current well-being depends upon the levels of capital (natural, physical, human, and social) passed on to future generations.

Largely in response to this report, the Organization for Economic Cooperation and Development (OECD)[15] launched the Better Life Initiative. First published in 2011 and revised most recently in 2017, their report, "How's Life?" describes the construction of the **Better Life Index (BLI)**. The report recognizes that well-being is a complex function of numerous variables. While material living conditions are important for well-being, so is quality of life and environmental sustainability. Further, the distribution of well-being across a society is important. The report argues that we need "better policies for better lives":

> Better policies need to be based on sound evidence and a broad focus: Not only on people's income and financial conditions, but also on their health, their competencies, on the quality of the environment, where they live and work, their overall life satisfaction. Not only on the total amount of the goods and services, but also on equality and the conditions of those at the bottom of the ladder. Not only on the conditions "here and now" but also those in other parts of the world and those that are likely to prevail in the future. In summary, we need to focus on well-being and progress.[16]

The BLI considers well-being to be a function of 11 dimensions, including income, housing conditions, health status, work-life balance, education, environmental quality, and **subjective well-being**. For each dimension, one or more statistical indicators provide empirical information about a country's performance on that dimension. For example, in the 2017 "How's Life?" report the environmental quality dimension is measured based on data on two variables: particulate matter concentrations and people's satisfaction with their water quality.

The results for each dimension are standardized across countries resulting in a score from 0-10. While the results for each of the 11 dimensions can remain disaggregated, they can also be combined to produce an overall well-being index. But how do we assign weights to the various dimensions? One basic approach is to simply weigh each of the 11 dimensions equally. But it may be possible that some dimensions contribute more to well-being than others.

The BLI reports make no specific recommendations for weighing the different dimensions. An interesting feature of the BLI is that a website allows users to select their own weights for each of the 11 dimensions. The OECD has been assembling user input data to determine what is most important in different nations. Based on almost 22,000 responses from the United States (as of

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[14] Stiglitz, Sen, & Fitoussi, 2009.

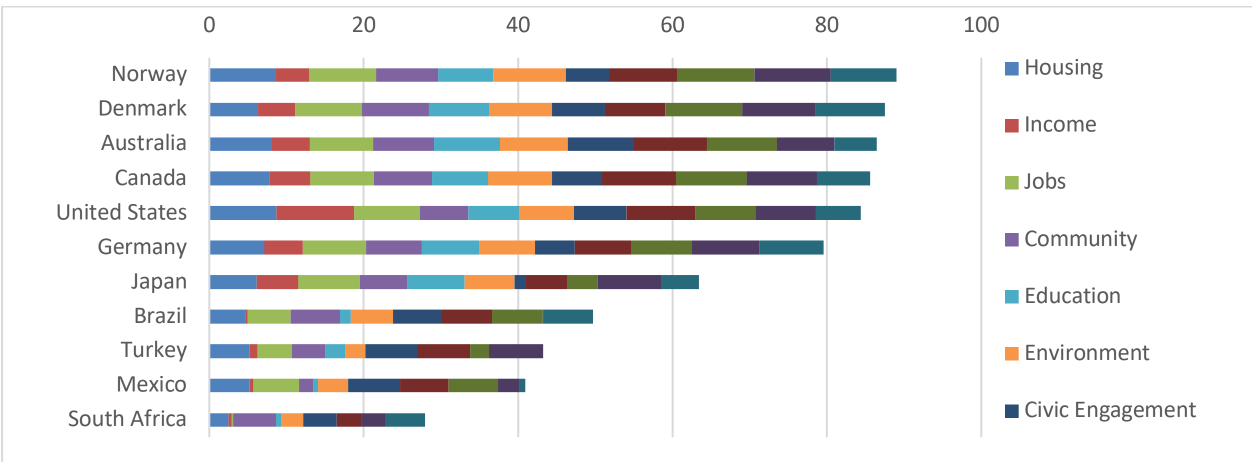
[15] The OECD is a group of the world's more developed nations, now including some developing nations such as Mexico.

[16] OECD, 2011, p. 3.

mid 2018) life satisfaction is ranked the most important dimension, with health #2, environmental quality #5, and income #7. In France the most important dimension is health, in Brazil it is education, and in Australia it is work-life balance.

The BLI has been measured for 38 nations. Even for the OECD nations, some results have to be estimated because of a lack of consistent data. Improving the standardization of data collection and reporting is one of the objectives of the Better Life Initiative. Based on equal weighting of each dimension, Norway, Australia and Denmark are the top three countries. The United States ranks 7th, performing well in terms of housing and income but ranking lower in terms of health, work-life balance, and civic engagement. An equal weighing of each dimension reduces the importance of income relative to most other national accounting approaches, such as the GPI and Green GDP. As far as the environmental rankings, the best scores are found in Iceland and Norway while pollution is ranked worst, among the countries evaluated, in Russia, Turkey, and Korea.

Figure 6. *Better Life Index, Selected Countries*



Source: OECD Better Life Index website, http://www.oecdbetterlifeindex.org/

While the main focus of BLI is not on environment and resource issues, its measures of environmental quality could be expanded or given greater weight in future.

3.6 "Happiness" Indicators

There have been a number of efforts to create indices that directly elicit people's well-being, or happiness, as a means of evaluating a society.

In 2012, the United Nations Sustainable Development Solutions Network published the first World Happiness Report, ranking 156 countries by their happiness levels. This report is based primarily on data from the Gallup World Poll, which includes a number of measures of self-reported well-being, where individuals state how satisfied they are overall with their lives on a scale of 0 to 10. In 2018 the Nordic countries scored highest in happiness rankings, with Finland coming in first followed by Norway and Denmark; while Syria, Tanzania and Burundi ranked lowest.

The Happy Planet Index (HPI), developed and calculated by the British New Economics Foundation, is perhaps the most novel attempt to devise an entirely new approach to measuring national welfare in the context of environmental sustainability. The Happy Planet Index is calculated on a national scale based on four factors:

1. Self-reported wellbeing (based on Gallup World Poll life satisfaction data)
2. Life expectancy
3. Inequality of outcomes (based on the distribution in each country's life expectancy and wellbeing data)
4. **Ecological footprint**, which is the average impact that each resident of a country places on the environment, calculated in global hectares per person.

The HPI has been calculated for 151 countries, using a combined measure of well-being and life expectancy divided by ecological footprint. The countries with the highest HPI scores are those whose citizens tend to be rather happy and long-lived but have a relatively modest ecological footprint, including Costa Rica, Vietnam, Belize, and Panama. One interesting aspect of the HPI is that a country's ranking tends to be unrelated to its gross domestic product (GDP). For example, the United States ranks 108th, only slightly better than Afghanistan (110th) and Syria (113th).

The interpretation and policy implications of the HPI are unclear. For example, India and Iraq have a higher HPI score than Germany or France. Does this imply that India and Iraq are more desirable to live in, or more ecologically sustainable, than Germany or France? Probably not. Another issue is whether a country's policies can affect happiness levels, which may be more a construction of inherent social and cultural factors rather than policy choices. Despite its limitations, the HPI has received attention as an alternative or supplement to GDP, especially in Europe.

Perhaps the best example of nationwide adoption of an alternative index as a primary well-being indicator over GDP comes from the country of Bhutan. Since 2008, the government of Bhutan has used Gross National Happiness (GNH) to measure their country's success and to inform policy making. This indicator is calculated based on factors including sustainable and equitable socio-economic development, environmental conservation, preservation and promotion of culture, and good governance. Bhutan, for example, has achieved net neutrality in carbon emissions through hydropower and forest cover, though this status could be threatened by business-as-usual economic development.

Other regions of the world including Seattle, Washington, Vermont, and Victoria, British Columbia have adopted measures of GNH modeled on the Bhutan indicator, but these have all been done on a much smaller scale.

3.7 Environmental Asset Accounts

The final green accounting measure we consider is **environmental asset accounts** (or **natural resource accounts**). These accounts are prepared by first defining various natural capital categories, such as timber resources, mineral resources, agricultural land, and groundwater. The accounts may have different degrees of aggregation. For example, the account for mineral resources might include a separate account for each mineral, or be further disaggregated based on mineral quality, degree of accessibility, or location. The units for each account would vary, based on the physical characteristics of the resource in question. So mineral accounts might be measured in tons, forest accounts in hectares of forest cover or board-feet of timber, groundwater accounts in acre-feet of water, and so on.

Environmental asset accounts can also be expressed in monetary units. In most cases, this simply involves multiplying a physical quantity by the market price per unit. For example, if a society has a standing timber stock of 500,000 board-feet of lumber and the market price is $5.00 per board-foot, then the asset value of their timber is $2.5 million.

Environmental asset accounts in monetary terms offer the benefit of comparability, both among different types of natural capital and to traditional economic aggregates such as GDP. But the benefits of many types of natural capital, such as endangered species and nutrient cycling, are difficult to measure in monetary terms. Monetary estimates may also be misleading – if prices for a particular resource rise, the monetary value of that resource could increase even if the physical stock decreases. Thus, policy makers could get the wrong impression about the status of the physical resource.

Several countries have started to maintain environmental asset accounts, including the United Kingdom, Australia, Canada, Denmark, Norway, and Sweden.

3.8 The Future of Alternative Indicators

While the need for alternative indicators is becoming increasingly evident and accepted, no single preferred approach has emerged. It remains to be seen whether each country will rely upon their own chosen approach, or if one or more indicators will become universally accepted. An important research objective is to develop consistent methods for measuring different variables, such as measuring carbon emissions and administering surveys to collect subjective data. The measurement of a broader range of environmental impacts, such as biodiversity and ecosystem services, also requires further research.

4. ECONOMIC GROWTH AND ENVIRONMENTAL IMPACTS

4.1 Defining Ecosystem Limits

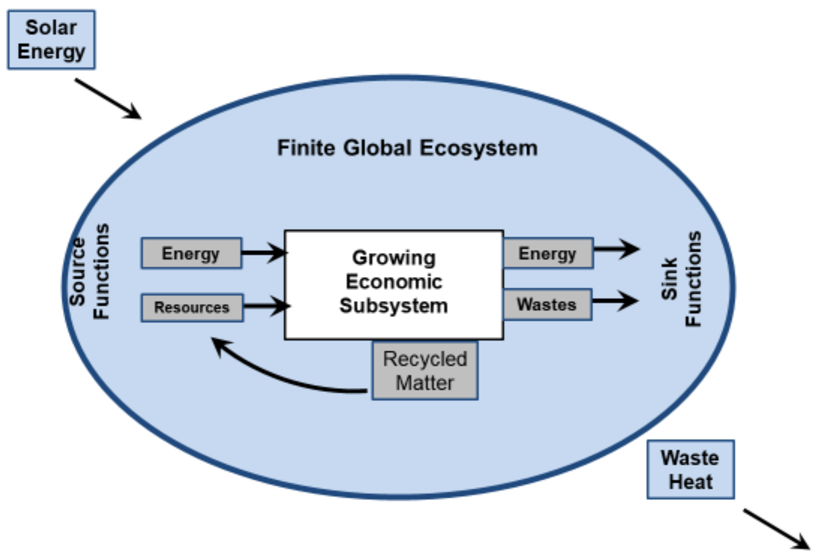
The complete circular flow model in Figure 2 shows us that natural capital can provide an ultimate constraint on economic activity in two ways:

- through limits on the supply of natural resources into productive processes;
- through limits on the ability of natural systems to assimilate waste products.

In the past, some civilizations have reached the limits of the ecosystems on which they relied; a well-known example is the collapse of the Easter Island civilization due to the depletion of their forest and food resources.

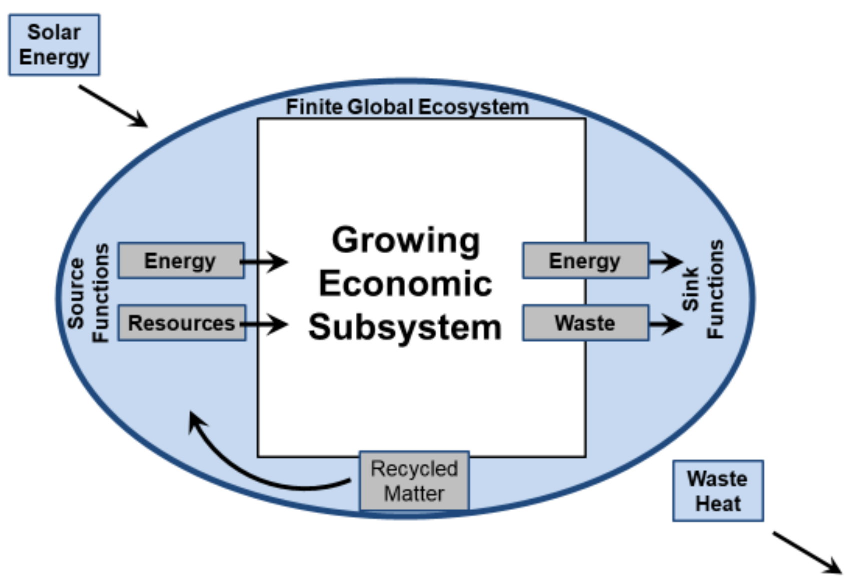
Today, there are more and more signs that the biosphere as a whole is affected in its regulation of biological and geophysical processes by the current scale of human activities. In traditional macroeconomics, economic growth is always considered desirable. But as we have moved from a relatively "empty world" in which human activity was small relative to overall planetary processes to a relatively "full world" in which human activity dominates the planet, an exclusive emphasis on economic growth could produce serious, and possibly irreversible, ecological damage, leading some researchers to question whether the current scale of human activities is sustainable (Figures 7 & 8).

Figure 7. *Empty World (Economy Small Relative to Global Ecosystem)*



Source: Goodland, Daly, and El Serafy, 1992, p. 5.

Figure 8. *Full World (Economy Large Relative to Global Ecosystem)*

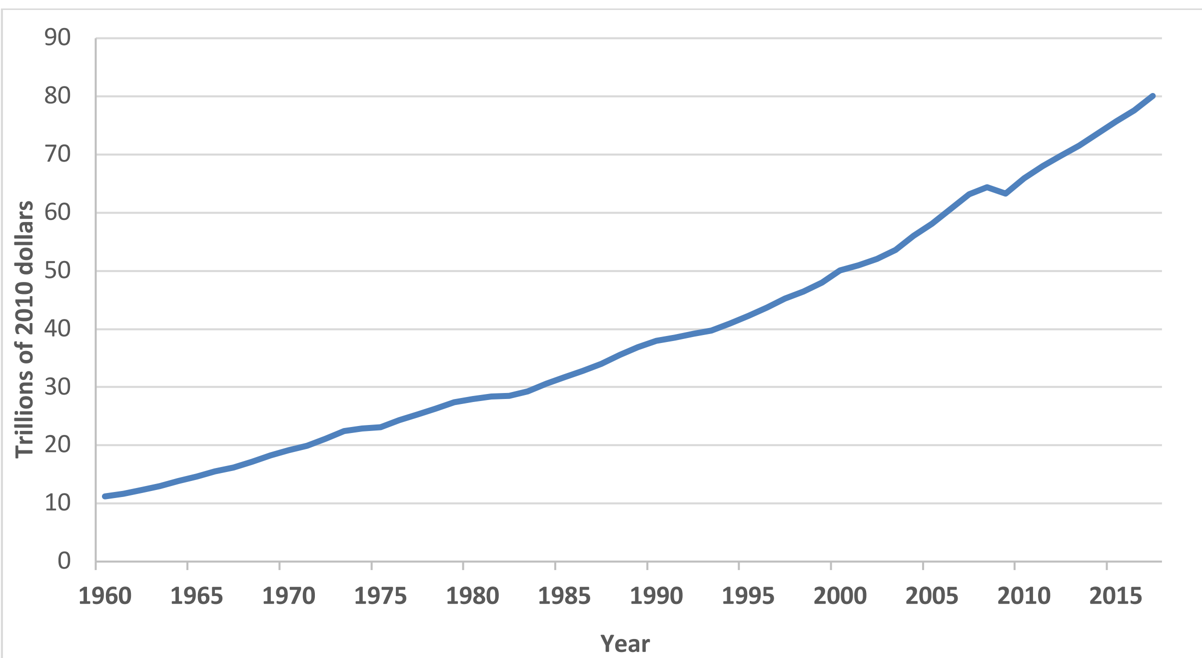


Source: Goodland, Daly, and El Serafy, 1992, p. 5.

Kenneth Boulding was among the first economists to address the necessity of a shift in the way the economic system functions, from what he called the "cowboy" economy to the "spaceship" economy. In the former case nature appears endless, and in this situation economic growth can occur without significant negative environmental consequences. Boulding argued in the 1960s that the natural world is not endless but limited, and that economic behavior must change accordingly. He suggested that the earth is best viewed as a finite spaceship – a lifeboat – on which humankind is embarked, and which must be piloted in a wise and not wasteful way.[17]

How close are we now to ecological limits? Clearly the global economy has expanded in recent decades, as shown in Figure 9. The chart shows the growth of gross world product (GWP, the sum of GDP for all nations) from 1960 to 2017, after an adjustment for inflation. We see that GWP has increased by a factor of nearly seven during this time period, with an average real annual growth rate of about 3.5%.

Figure 9. *Real Gross World Product, 1960-2017*



Source: World Bank, World Development Indicators database.

Even if global growth slows to an annual rate of about 2.5%, as the OECD projects,[18] this still means that the global economy will double every 30 years and that the world economy will be about eight times larger than it is now by the end of the 21st century. While the demands on natural resources and the generation of wastes need not increase by the same factor, this still implies a significant increase in the use of natural capital. And while recycling can reduce ecological impacts, there are limits to the effectiveness of recycling – see Box 2.

[17] Boulding, 1966.
[18] http://www.oecd.org/eco/outlook/lookingto2060.htm

BOX 2: ENTROPY AND THE LIMITS OF RECYCLING

The full world circular flow model (Figure 2) shows resources can be recycled, but there is a limit to the amount of usable material or energy that can be recycled, based on fundamental laws of thermodynamics. Economist Nicholas Georgescu-Roegen was the first to look at how the laws of thermodynamics apply to the field of economics and limit the potential for economic growth on a finite planet. His work focused on the issue of **entropy**.[19]

This concept measures the amount of available energy in a system – somewhat confusingly, *low* entropy indicates a large amount of available energy, while *high* entropy indicates little available energy. The Second Law of Thermodynamics states that entropy increases in all physical processes. For example, a lump of coal has low entropy (available energy), which can be used to do work when the coal is burned, but once the coal is burned the remaining ashes and the waste heat released have high entropy, meaning that they have no more capacity to do work. The same thing is true of all industrial processes, such as the production of plastics from oil: petroleum, when extracted from the earth, has a low level of entropy, which then increases, for example as it is processed to make plastics like those used in a disposable water bottles. That entropy is then increased further when that water bottle is recycled and processed to be made into something else of a lower grade, like plastic fibers for carpet. With each step, more energy is dispersed, making the material less usable.

In the case of Earth's planetary system, all economic processes are ultimately limited by the availability of low entropy, which comes from two sources: stocks of low-entropy fossil fuels and geothermal energy in the earth itself, and the flow of solar energy. The limits are not only on the input side, in terms of availability of energy, but also on the output side, in terms of accumulation of high-entropy wastes. The economic system will ultimately have to adapt to these limits imposed by the law of increasing entropy.

4.2 Measuring Planetary Limits

Ecologists have developed three main approaches for assessing the overall scale of human economic activity relative to the planetary carrying capacity. The first approach is based on the fact that all animal life on earth depends on green plants, which capture solar energy through photosynthesis. Without green plants, humans and all other animals would die of starvation since animals cannot produce food directly from the physical environment. The total capacity of plants to convert solar energy to usable energy is the **net primary production (NPP)** of photosynthesis. In principle, global NPP represents an ultimate constraint on the availability of energy into the food chain.

[19] Georgescu-Roegen, 1971.

Several estimates are available regarding how much of global NPP is utilized by humans – the **human appropriation of net primary productivity (HANPP).** The results suggest that humans are using 20%-30% of global NPP, and that HANPP has approximately doubled in the last century.[20] Thus humans could theoretically appropriate a greater share of NPP as the global economy expands without necessarily approaching absolute limits, although some of NPP must be used to support other species and human impact has already significantly reduced the NPP available to maintain species biodiversity. Research results conclude that HANPP grows more slowly than GDP or population. In addition, humans can use NPP more efficiently, for example by better management of irrigation water, soils, and fertilizers. On the other hand, the HANPP measure fails to account for all the environmental impacts of human economic activity. Thus, "when interpreting HANPP results in the context of sustainability, it is important to use complementary resource-use indicators to obtain a comprehensive picture."[21]

The second approach for assessing the relationship between human economic activity and natural capital is the **ecological footprint (EF)** measure. The premise of this approach is to convert all human impacts into equivalent units of biologically productive land area. In other words, a person's ecological footprint is the amount of land required to support his or her lifestyle, considering both the resources required to support one's consumption and to adequately assimilate one's wastes back into the environment.

Some impacts convert easily to land-area footprints. For example, demand for meat converts to pasture area needed to raise livestock. Other impacts are more difficult to translate to land-area equivalents. For instance, carbon dioxide emissions from burning fossil fuels are accounted for in the EF approach based on the area of vegetation that would be required to absorb the carbon emitted. Calculation of a country's ecological footprint requires data on more than 100 factors, including demand for food products, timber, energy, industrial machinery, office supplies, and vehicles.

Ecological footprints have been estimated for most nations. Comparing a nation's ecological footprint to its land area (adjusted for its ecological productivity, or its **biocapacity**) provides information on whether it is living within its ecological limits. The EF for each country is calculated on a per-capita basis, as is each country's biocapacity. An EF above a country's biocapacity suggests that it is on an unsustainable path.

The ecological footprint measure can be used to calculate how many earths would be required to provide the resources and assimilate the wastes if everyone on the planet lived with the lifestyle of the average person in each country. For example, if everyone on earth had a resource-use lifestyle similar to the average person in Norway, 3.6 earths would be required. Of course, we only have one earth available, so the conclusion is that though Norway ranks highly in other indicators, it would not be sustainable for everyone on the planet to live like the average Norwegian. In order to achieve global sustainability, everyone would need to have the environmental impacts of the average person in a country such as Honduras, which has an average per-capita income of only $5,000.

[20] Haberl et al., 2014.
[21] Ibid., p. 382.

Table 2 compares ecological footprints for a handful of selected countries, and indicates the "number of earths" required for everyone to have a lifestyle similar to that country. The EF results for the world suggest that the current global impacts are unsustainable.

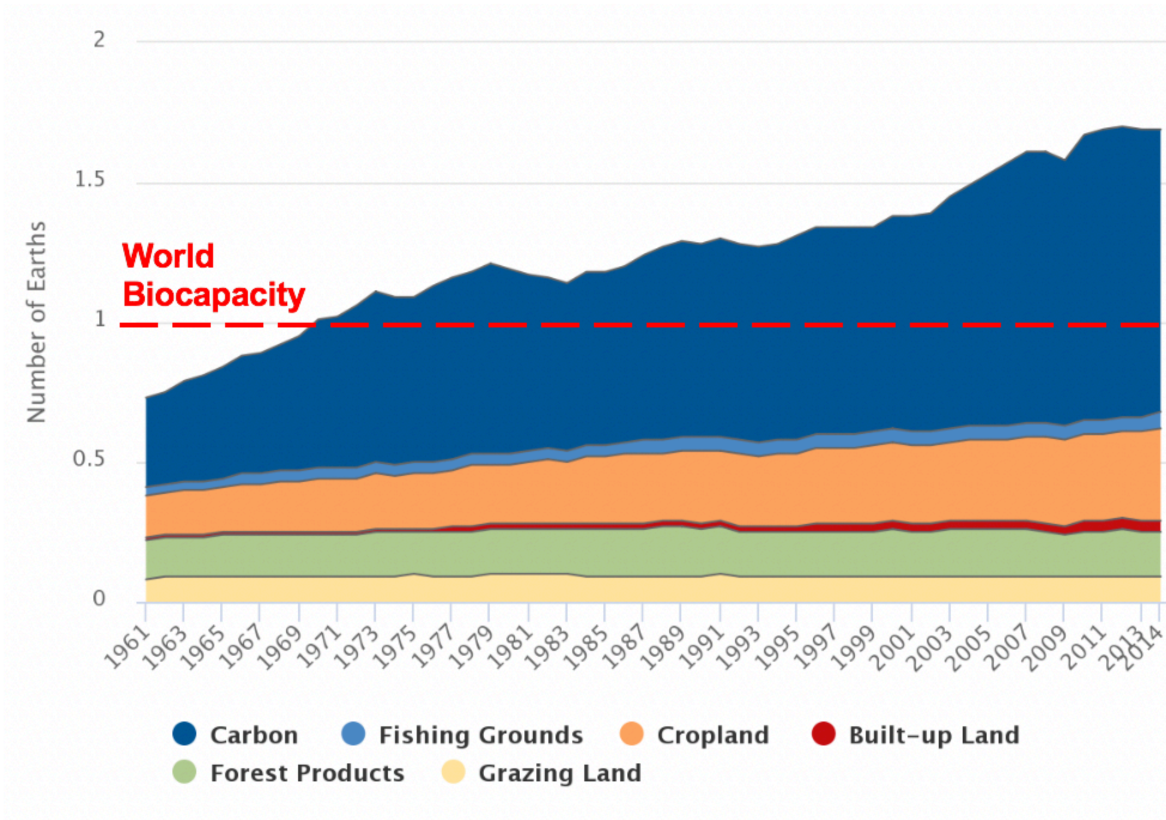
Table 2. *Ecological Footprint Data, Selected Countries, 2014*

Country	Ecological Footprint (hectares per person)	Biocapacity (hectares per person)	Number of Earths Required
Brazil	3.1	8.9	1.8
China	3.7	1.0	2.2
France	4.7	2.7	2.8
Honduras	1.7	1.7	1
India	1.1	0.5	0.7
Kenya	1.0	0.5	0.6
Mexico	2.6	1.2	1.5
Norway	6.0	7.4	3.6
Russia	5.6	6.9	3.3
U.A.E.	9.8	0.6	5.8
United States	8.4	3.6	5.0
Philippines	1.1	0,6	0.7
WORLD	**2.8**	**1.7**	**1.7**

Source: Global Footprint Network, 2018.
Note: U.A.E. stands for United Arab Emirates

Figure 10 provides more information about the global EF. The total EF surpassed total earth biocapacity around 1970, and has been rising ever since (with a brief reduction during the 2008 recession). Comparing Figure 10 to Figure 9, we see that while global economic output has increased by a factor of seven since 1960, global EF has increased by a factor of about two during the same time period. Thus EF does not increase at the same rate as economic production.

Figure 10. *Global Ecological Footprint, 1961-2014*



Source: Global Footprint Network. 2018. National Footprint Accounts.

Currently about 60% of the world's ecological footprint is due to emissions of carbon dioxide (the gas most responsible for human-induced climate change), 20% is due to growing crops, and 10% is due to harvesting forest products. According to this measure the world could return to an environmental footprint no larger than its biocapacity if global carbon emissions were reduced approximately 69%. This could be misleading, however: even with drastic reduction in carbon emissions, climate change would continue as more carbon accumulates in the atmosphere. We would need net carbon emissions of zero to stop atmospheric accumulation (and maybe below zero, absorbing carbon from the air, to undo existing damage). In addition, reducing carbon alone would not necessarily halt damage to forests, fisheries, croplands, and water systems (see Box 3 for more discussion of the economic and ecological impacts of climate change).

BOX 3: THE GROWING COSTS OF CLIMATE CHANGE

Recent research has virtually eliminated any doubts that human activities are affecting the earth's climate. Emissions of various greenhouse gases, particularly carbon dioxide, trap heat near the earth's surface, leading not only to a general warming trend but to sea-level rise, ecological disruption, and an increase in severe weather events, such as hurricanes, floods, and droughts.[22] As of 2017, human induced warming had already reached approximately 1°C above pre-industrial levels, with warming projected to reach 3°C by 2100.[23]

In 2006 the British government commissioned a comprehensive report, known as the Stern Review, to examine the economic impacts of climate change itself, as well as the economics of stabilizing greenhouse gases in the atmosphere. The Stern Review estimated the global costs of climate change in the twenty-first century as between 5 percent and 20 percent of global GDP. The report also concluded that the most severe effects of climate change could be avoided at a cost of only about 1 percent of GDP.[24]

A more recent report focused only on the United States calculated average losses due to both weather events and pollution related health consequences in the last decade (2006-2016) to be to $240 billion a year, with projected annual costs of $360 billion a year over the next decade.[25] The current $240 billion value is equivalent to 1.2% of US GDP, and is recognized to be a conservative estimate, as it does not include longer term consequences of extreme weather events like decreased agricultural yields, or deaths or health related costs of heat waves.[26] This number also does not reflect the fact that impacts will be felt unevenly, even within a single country. For example, in 2017 Puerto Rico and the US Virgin Islands sustained approximately $90 billion in economic damages due to a single hurricane, which is equivalent to almost an entire year's GDP for these territories[27].

The impacts of climate change—including coastal flooding, agricultural yield reductions, spreading of tropical diseases, and water shortages—are poised to fall disproportionately on developing countries. While rich countries could, to some extent, be able to adapt to many of the effects of climate change, most developing countries lack the financial and technical resources to do so. Thus, climate change is likely to exacerbate global inequalities and further impede economic development in poorer countries.

The **Planetary Boundaries** Approach, first developed by the Stockholm Resilience Center in 2009, is a third method of evaluating the earth's limits and current capacity, using nine earth system processes. These include:

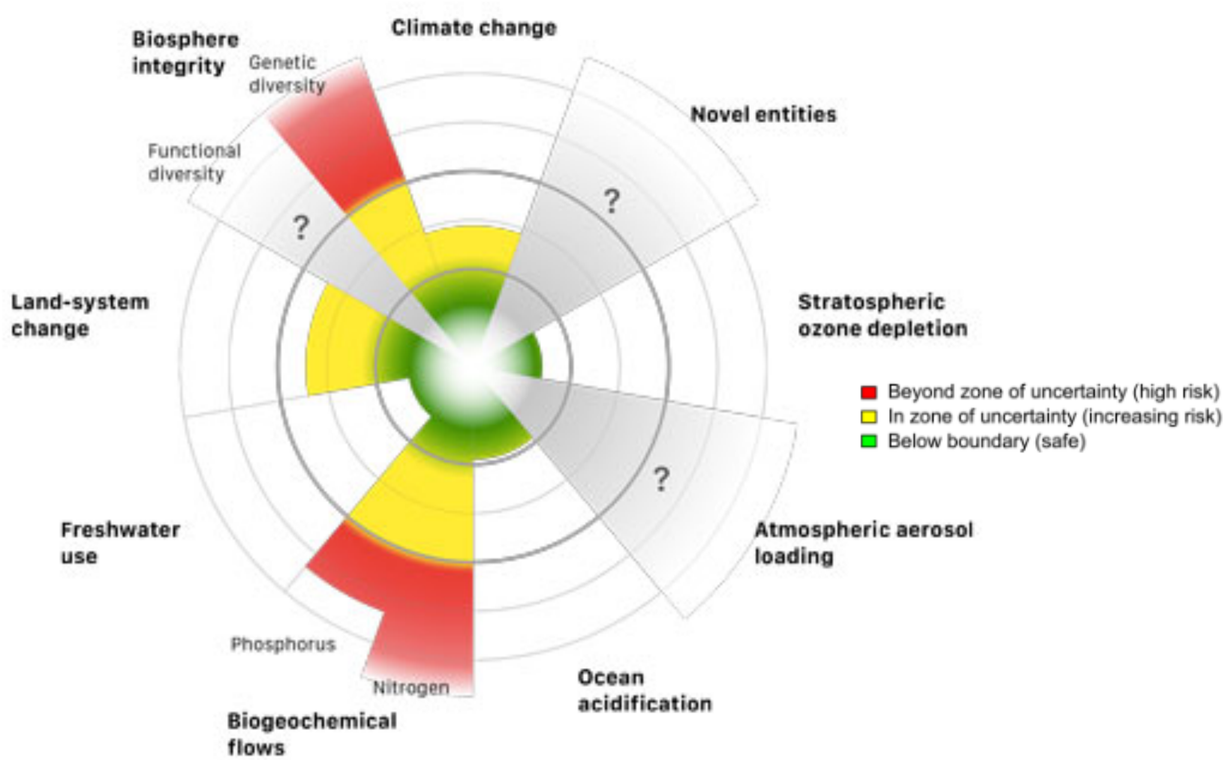
[22] IPCC, 2014.
[23] IPCC, 2018.
[24] Stern, 2006.
[25] Watson, McCarthy, & Hisas, 2017.
[26] Ibid.
[27] NOAA, 2018.

1. Stratospheric ozone depletion
2. Loss of biosphere integrity (biodiversity loss and extinctions)
3. Chemical pollution and the release of novel entities
4. Climate change
5. Ocean acidification
6. Freshwater consumption and the global hydrological cycle
7. Land system change
8. Nitrogen and phosphorus flows to the biosphere and oceans
9. Atmospheric aerosol loading

For each earth system processes an environmental boundary is determined, designating at what point we move from a safe operating space into a zone of uncertainty or high risk. Figure 11 shows the boundaries for each process relative to current levels. Due to the complex nature of some of these systems, and the high level of uncertainty related to how critical they are to maintaining current ecosystem function, planetary boundaries have not been quantified for three of these categories: atmospheric aerosol loading, chemical pollution and the release of novel entities, and functional diversity (a sub category of biodiversity).

Figure 11 shows that as of 2015, two boundaries—nitrogen and phosphorous flows, and loss of biosphere integrity— have already been crossed; while two others—climate change, and land system change— are in the zone of uncertainty or increasing risk.

Figure 11. *Planetary Boundaries*



Source: Steffen et al., 2015.

In addition to global level calculations, planetary boundaries can also be calculated on a regional scale. These regional calculations are important since while some systems are operating within a safe scale on the global level, there are regions that are already in the high-risk area. For example, while freshwater use is well within boundaries on a planetary scale, there are many regions where fresh water consumption is already in the high-risk zone, including much of the Middle East, Eastern and Southern Asia, Southern Europe and parts the South Western United States.

4.2 Population, Affluence, and Technology

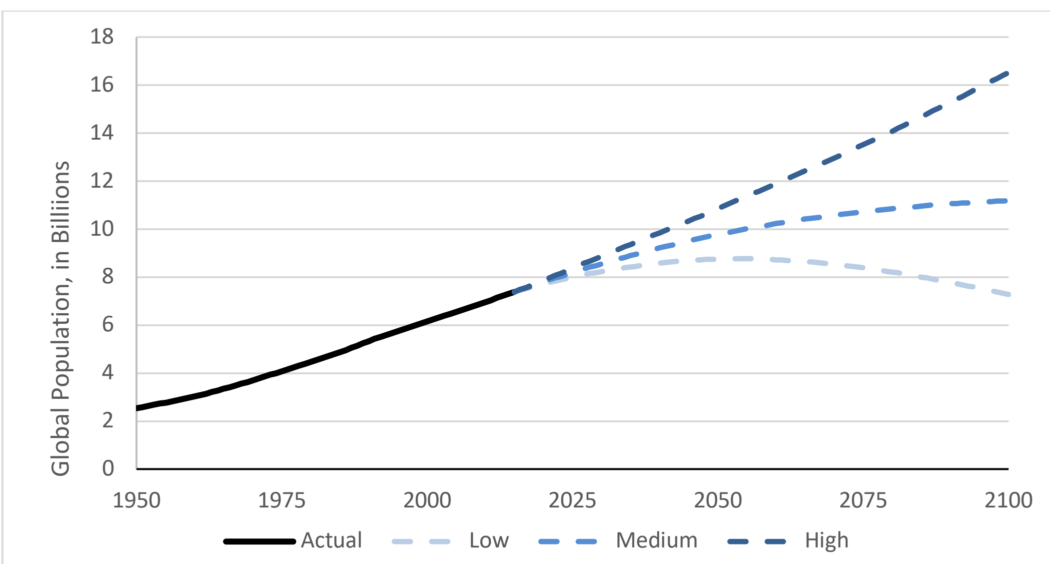
As we have seen above, environmental impacts increase as economic output grows, although at a somewhat slower rate. A simple equation has been proposed to define environmental impacts as a function of three variables:

$$I = P * A * T$$ (called the **"IPAT" equation**)

where I is environmental impact, P is population, A is a measure of affluence (for example, income per capita), and T represents technology (or in other words, the environmental impact per unit of income). Let's consider each of these variables in more detail in order to estimate how environmental impacts may change in the future.

Population: Global population has increased significantly in recent decades, from 3 billion in 1960 to 5 billion in 1987, and to 7.6 billion in 2018. Current population projections by the United Nations, shown in Figure 12, estimate that under a "medium variant" scenario the global population will continue to increase during the 21st century but at a slower rate, reaching 11 billion around 2100. The UN's low variant projection, assuming faster reduction in fertility rates, shows the global population peaking at around 8.7 billion around 2050, and then declining back to around 7 billion by 2100.

Figure 12. Actual and Projected World Population, 1950-2100



Source: United Nations, 2018.

Affluence: As mentioned earlier, global affluence is expected to increase for the foreseeable future. According to the OECD, potential real annual gross world product is estimated to increase at an average annual rate of 3.1% from 2018-2030, and then 2.2% per year from 2031-2060.[28] In general, increasing affluence is associated with increases in environmental impacts, such as transitioning from a plant-based to a meat-based diet as incomes rise (see Box 4).

BOX 4: AFFLUENCE AND CHANGING DIETS

Although there are a number of activities associated with growing affluence that will put a strain on the environment (e.g. increased purchase of individual vehicles, growing utility use, purchase of more consumer electronics), there is one consumption activity experiencing rapid growth that is especially detrimental: the transition to a meat based diet.

Increasing consumption of meat and other animal products leads to a larger environmental footprint, and puts a strain on many of the earth system processes evaluated above (fresh water consumption, land use change, biodiversity loss, flows of nitrogen and phosphorus) to the point that some researchers have found that switching to an animal product free diet is the largest single way that individuals can reduce their environmental impact[1].

Despite the recognized negative environmental impacts, increasing incomes and urbanization are resulting in changing diets worldwide, with developing and recently developed countries experiencing the greatest growth in meat consumption. For example, in East Asia per capita meat consumption increased by a factor of 4.3 between the mid 1960's to the late 1900s and is expected to continue to increase to a factor of 6.7 by 2030.[29]

If instead of continuing on this trajectory we transitioned from the current (2010) diet balance to an animal product free diet on a global scale, the amount of land required for agriculture would be reduced by 76%, while CO2 emissions would decrease by 6.6 billion metric tons per year.[30]

Thus, with population and affluence expected to increase steadily over the next several decades, technology becomes the only variable that has the potential to reduce environmental impacts. The relationship between technology and environmental impacts can go in both directions. Numerous inventions, such as automobiles, electricity, and airplanes, have resulted in significant increases in environmental impacts. Other technological innovations, such as electric vehicles, solar energy, and efficient buildings, may offer the possibility of reduced impacts.

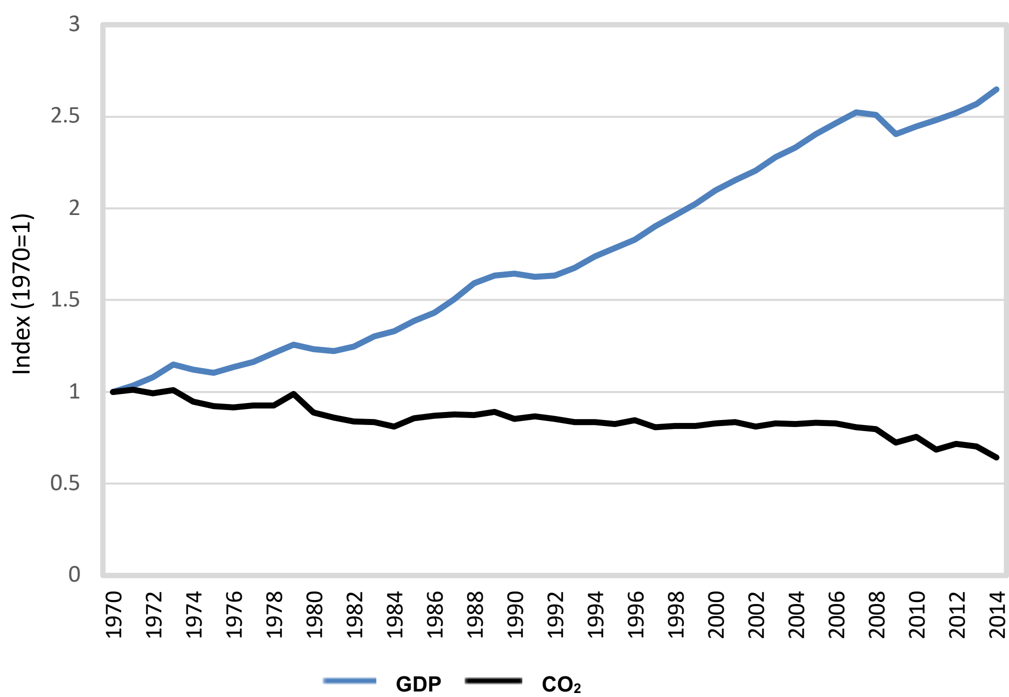
Overall, the data suggest that technology has generally worked to dampen the impact of increases in both population and affluence. Global environmental impacts, as measured using the ecological footprint metric (Figure 10), have not increased as rapidly as affluence (world economic output, Figure 9) or population (Figure 12). Nonetheless, the fact that global environmental impacts are

[28] OECD, 2018.
[29] World Health Organization, 2003.
[30] Poore & Nemecek, 2018.

increasing indicates that technology is not currently advancing rapidly enough, or in the appropriate ways, to achieve a sustainable world in the near future.

Is it possible to achieve economic growth while reducing environmental impacts? An example of **decoupling** of economic growth from emissions growth is shown in Figure 13, which presents GDP and carbon dioxide emissions in the United Kingdom over the last several decades. We see that the UK economy has expanded by a factor of about 2.6 since 1970, but that CO_2 emissions have declined by over 35%.

Figure 13. *Decoupling in the United Kingdom, Real GDP vs. CO_2 Emissions, 1970-2014*



Source: World Bank, World Development Indicators

Unfortunately, the situation in the United Kingdom, which was able to take advantage of new discoveries of natural gas to reduce coal consumption, cannot be easily replicated elsewhere. At the global level, we see little evidence of decoupling in the case of carbon emissions. Since 1970 world economic output has increased by a factor of 3.8 while global carbon emissions have increased by a factor of 2.4.

A 2011 report by the United Nations looks at the extent of global decoupling across a range of resources including fossil fuels, minerals, and wood.[31] The results suggest that a certain amount of decoupling has occurred in recent decades "spontaneously," rather than a direct result of policy intervention. This decoupling reflects an increase in the efficiency of production arising from

[31] UNEP, 2011a.

technological improvements. However, some resource extraction growth rates exceed recent global GDP growth rates. For example, extraction of iron ore, copper, and zinc grew faster than global GDP over the period 1990-2007.[32]

The UN report found that achieving sufficient decoupling will require ambitious policies. According to a business-as-usual scenario, global resource use is projected to triple by 2050. Attempts to avoid this increase in resource use would have profound implications for developed and developing countries. In developed countries, resource use would need to decline by a factor of 3 to 5 to allow enough resource availability so that developing countries could improve their living standards. Even then, the more advanced developing nations would need to reduce their resource use by 10-20 percent in order to permit some increase in resource use by the poorest countries. Decoupling at the global level:

> ...is only conceivable if it is accepted that sustainability-oriented innovations can result in radical technological and system change. Taken as a whole, this would be a scenario of tough restraint that would require unprecedented levels of innovation....Most politicians are likely to regard this scenario as too restrictive in terms of developmental goals such as reducing poverty and providing for the material comfort of a rapidly expanding middle class.[33]

5. CREATING A GREEN ECONOMY

5.1 Macroeconomic Theory and the Environment

Macroeconomics has traditionally focused on topics such as employment, the stability and growth rate of real GDP, and government spending. Until recently, macroeconomics has paid little attention to environmental issues. Instead, environmental concerns were generally considered a topic for microeconomics. But in 1991 economist Herman Daly argued for the creation of an environmental macroeconomics. Daly stated that the primary objective of environmental macroeconomics should be to address the question of the optimal scale for the economy:

> The message of microeconomics is to expand the scale of the activity in question up to the point where marginal costs equal marginal benefits, a condition which defines the optimal scale. All of microeconomics is an extended variation of this theme.
>
> When we move to macroeconomics, however, we never again hear about optimal scale. There is apparently no optimal scale for the macro economy. There are no cost and benefit functions defined for growth in scale of the economy as a whole. It just doesn't matter how many people there are, or how much they each consume, as long as the proportions and relative prices are right! But if every micro activity has an optimal scale then why does not the aggregate of all micro activities have an optimal scale?[34]

In the years since Daly's article, some theoretical and applied macroeconomic research has focused

[32] Jackson, 2009.
[33] Ibid., p. 30, 32.
[34] Daly, 1991, p. 259.

on environmental concerns. For example, a 2000 paper presented a proposal for integrating environmental constraints into traditional macroeconomic models. The proposal stated that macroeconomic outcomes should comply with an environmental equilibrium. At this equilibrium:

> the rate at which the economy is using environmental services is exactly equal to the natural environment's ability to support them. If we are thinking about the exploitation of a renewable resource (such as timber) then the rate at which it is being harvested equals the rate of replenishment. In the case of the emission of pollutants, the aggregate rate of emission must exactly equal the rate at which the environment is able to absorb and assimilate those emissions without net diminution of its future assimilative capacity.[35]

To remain within the environmental equilibrium, it may not always be acceptable to expand the macroeconomy using fiscal and monetary policy. In fact, if the economy is pushing environmental or resource limits, then expansionary fiscal policy, for example, may need to be offset with contractionary monetary policy.

Other macroeconomic research takes a broader view of environmental issues. A 2013 paper advocates for "**Green Keynesianism**."[36] Standard Keynesian macroeconomics asserts that prolonged recessions, such as the Great Depression, can be caused by a drop in aggregate demand below the productive capacity of the economy. Writing in the 1930s, John Maynard Keynes maintained that there was no assurance that a depressed economy would automatically adjust back to a full-employment equilibrium. The solution, according to Keynes, was for the government to stimulate the economy to offset the lack of aggregate demand, using either monetary or fiscal policy. Keynesian ideas had a significant influence on macroeconomic policy in developed nations for about 30 years after World War II, until falling out of favor somewhat starting in the 1970s.

The aftermath of the 2007-08 global financial crisis saw a renewed interest in Keynesian economics, with many nations undertaking ambitious government stimulus programs. Many of these programs had a significant "green" component, as shown in Table 3. We see, for example, that government investments in clean energy and other environmental measures comprised about one-third of the stimulus spending in China. In South Korea, most of the stimulus money went toward green investments. The stimulus spending of the United States, approaching $1 trillion, included about a 12% allocation toward such programs as tax breaks for investments in renewable energy and energy efficiency, funding public projects such as high-speed rail, and providing cash grants to supplement privately-funded projects.

While green stimulus spending has declined as the global economy has recovered, the Green Keynesian proposal would fundamentally integrate environmental goals with Keynesian macroeconomic policies on a broader basis. Green Keynesianism would distinguish between "macroeconomic aggregates that we wish to limit [namely energy-intensive consumption and investment], and those that we wish to encourage [investment in natural, human, and energy-conserving manufactured capital, and consumption of low-energy services]."[37] Green Keynesian policies could include: clean energy public investments such as efficient public transit and green buildings, tighter efficiency standards, increased public research and development spending, a **carbon tax** or **cap and trade permit system**, and preferential credit for clean energy investments.

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[35] Heyes, 2000, p. 7.
[36] Harris, 2013.
[37] Harris, 2013. p. 6.

Table 3. Green Stimulus Spending by Country, Post-Financial Crisis

Country	Total Stimulus Spending (billion US$)	Green Stimulus Spending (billion US$)	Green Stimulus Spending as a Percent of Total
Australia	44	9	21%
Canada	32	3	9%
China	649	218	34%
European Union	39	25	64%
France	34	6	18%
Germany	105	14	13%
Japan	640	36	6%
South Korea	76	60	79%
United Kingdom	34	4	11%
United States	977	117	12%

Note: The European Union stimulus spending is separate from the stimulus spending by each individual European country.
Source: Bernard et al., 2009.

5.2 The Green Economy and Growth

Economists have different conceptions of what exactly a "green economy" implies for economic growth in the long run. Specifically, does a green economy continue to grow in a traditional economic sense (i.e., growth in GDP) or does it seek to reduce or even halt further economic growth?

In 2008 the United Nations Environment Programme (UNEP) launched its Green Economy Initiative, UNEP defines a **green economy** as:

> one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive. [38]

UNEP has developed a complex model to analyze the economic and environmental impacts of directing investments to promote a transition to a green economy.[39] They consider a green scenario where 2 percent of global GDP is invested in various ways to promote sustainability, including energy efficiency, renewable energy, waste management, infrastructure improvements, agricultural production methods, and water management. They compare the results of this green economy scenario to a business-as-usual (BAU) scenario where investment rates follow existing trends.

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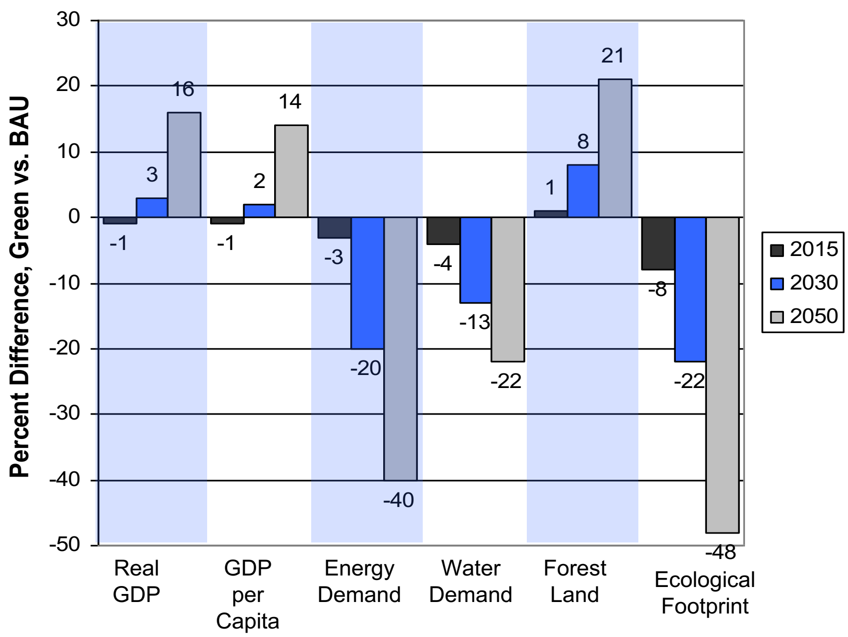
[38] http://www.unep.org/greeneconomy/AboutGEI/WhatisGEI/tabid/29784/Default.aspx
[39] UNEP, 2011b.

The results are shown in Figure 14. In the short-term (2015), the green economy scenario results in about 1 percent lower real GDP and lower GDP per capita. But in the longer term the green economy shows substantially better economic performance than the BAU scenario. By 2050 real GDP in the green economy scenario is 16 percent higher than in the BAU scenario. The environmental differences between the two scenarios are initially small, but become dramatic over the following decades. By 2050 global energy demand is 40 percent lower in green economy scenario, and the ecological footprint is 48 percent lower.

Figure 14. *Environmental and Economic Projections, Green Economy Scenario versus Business-As-Usual*



Source: UNEP, 2011b

Green investments are also relatively job-intensive, particularly in the agricultural, forestry, and transport sectors. In the energy sector, employment would initially decline as jobs related to fossil fuel use decline, but in the long run (after about 2030) net employment rises, primarily as a result of the creation of millions of jobs related to energy efficiency.

The UNEP model finds that investments in the green economy particularly benefit the world's poorest. The poor disproportionately depend upon natural resources for their livelihood. So investments in natural capital, including water resources, sustainable agriculture, and forests increase incomes while also improving the environment. Investments in natural capital also foster ecotourism, which offers another way to increase incomes in developing countries.

In the energy sector, investment in renewable energy can also benefit the world's poor. There are about 1 billion people in the world who lack access to electricity. Given the lack of an existing distribution grid in many poor regions, small-scale off-grid solar is currently more cost-effective than electricity generated using traditional fossil fuels. Many lower-income countries are in regions of the world with high, and as yet undeveloped, solar potential (See Box 5 below).

BOX 5: THE GROWING POTENTIAL OF RENEWABLE ENERGY

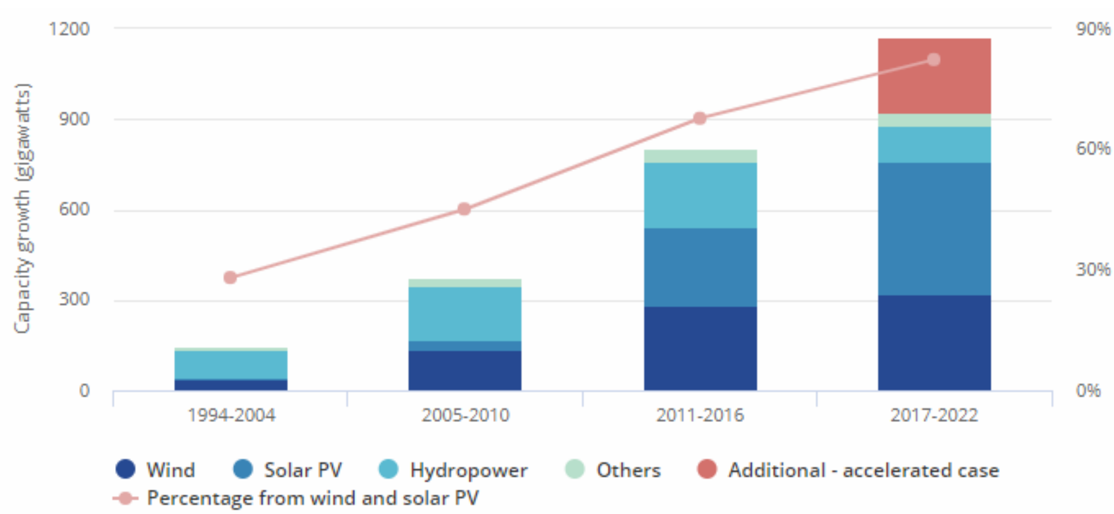
One of the strategies countries can take to move towards a green economy is to transition away from fossil fuels as their primary source of energy towards renewable sources including wind, solar, and hydropower. The combination of decreasing costs of renewable energy technologies combined with supportive government policies has led to a rapid increase in renewable energy generation across the globe.

In 2016 renewables accounted for nearly two-thirds of new net electricity capacity additions, with solar photovoltaics (PV) leading this expansion. Worldwide, solar PV capacity increased by 50% in 2016, with China accounting for almost half of this expansion. Solar PV installation is also increasing rapidly in developing regions, including sub-Saharan Africa and Asia, where off-grid household or mini-grid solutions are bringing electricity to millions of new customers.

Although the amount of energy generated by these installations represent only a small share of global PV production, there are large positive socio-economic impacts associated with providing electricity to previously unserved regions. Globally, renewable electricity generation capacity is projected to continue to increase, accounting for 30% of total power generation by 2022, as shown in Figure 15.

Source: International Energy Agency, 2017. Renewables 2017: Analysis and Forecasts to 2022. www.iea.org/publications/renewables2017/

Figure 15. *Renewable electricity capacity by technology*

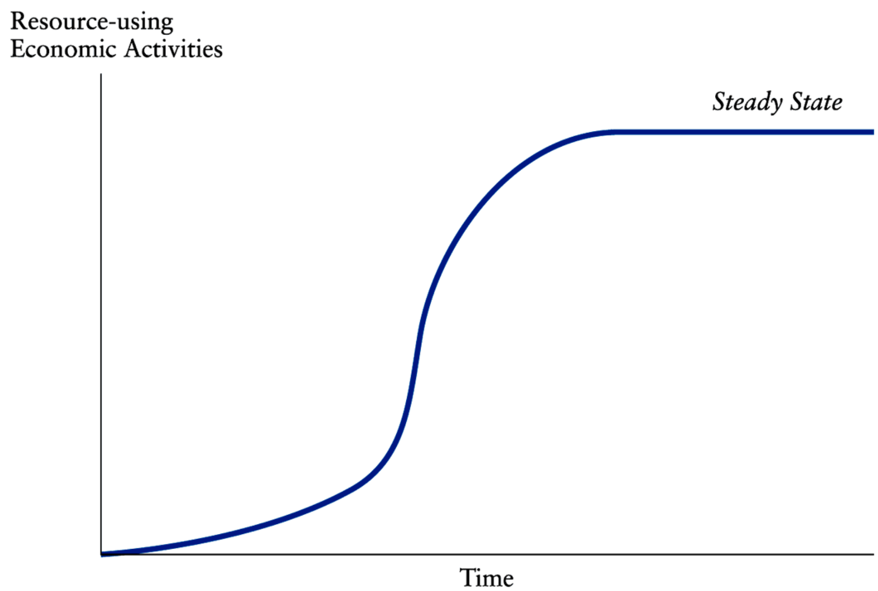


Source: International Energy Agency, 2017. Renewables 2017: Analysis and Forecasts to 2022. www.iea.org/publications/renewable2017.

While UNEP sees a green economy as compatible with growth, other economists envision a green economy as one that incorporates greater recognition of the limits of macroeconomic scale, as discussed earlier. According to this view, economic activity that relies heavily on natural resources, raw materials, and fossil fuels cannot grow indefinitely. Because the planetary ecosystem has certain limits, there must be some corresponding limits to the overall level of resource use and goods output. Economist Herman Daly, mentioned previously, has argued for the long-term necessity of reaching a plateau – a **steady state economy** in terms of the consumption of material and energy resources.[40]

This concept differs significantly from the standard view of economic growth, in which GDP increases indefinitely on an exponential growth path – for example, 3 percent GDP growth per year. In a steady state economy, national and global economic systems must eventually follow what is called a **logistic growth** pattern in which economic activity approaches some maximum, at least in terms of resource consumption, as shown in Figure 16.

Figure 16. *The Transition to a Steady State Economy*

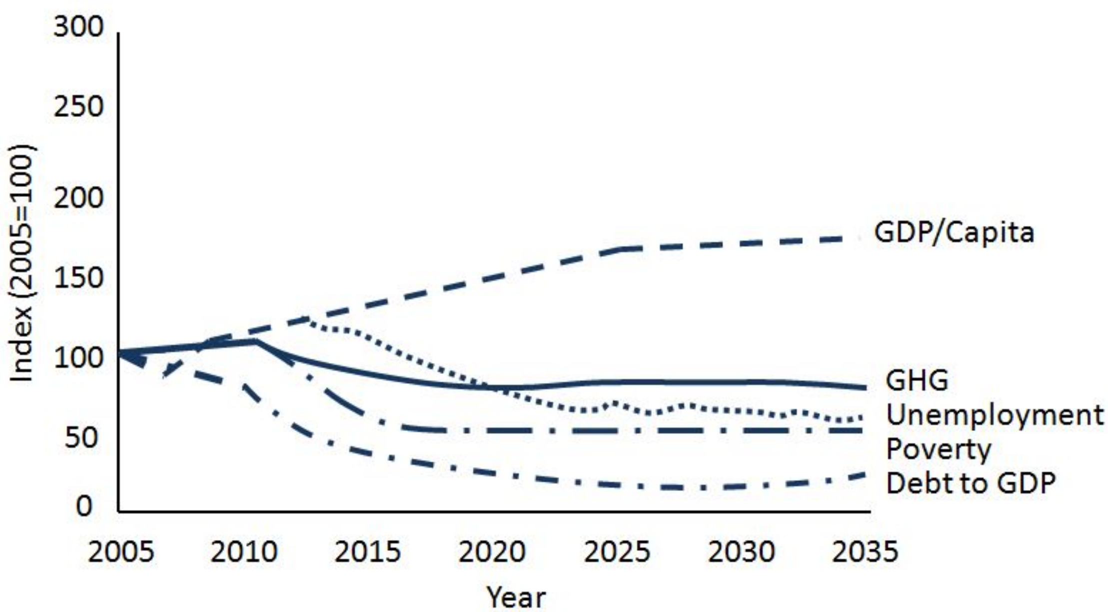


In Daly's vision of a steady state economy the stock of manufactured capital is kept constant. In order to minimize the use of natural resources, products are long-lasting and recycled whenever possible. In principle, the steady state economy does not imply that GDP remains constant. Economic activities that involve no resource consumption or are environmentally neutral or environmentally friendly, could grow indefinitely. Such activities could include services, arts, communication, and education. Once basic needs are met and moderate levels of consumption achieved, economic development could be increasingly oriented toward these kinds of low-impact activities.

[40] See Daly 1993, 1996.

Economist Peter Victor has developed a model that depicts a potential transition to a steady-state economy, applied to the country of Canada.[41] His model presents "socio-eco-environmental" paths that offer desirable social and environmental outcomes without requiring economic growth. In the scenario presented in Figure 17 the Canadian government is assumed to introduce a tax on greenhouse gas (GHG) emissions, creating incentives to switch from high GHG sources of energy to lower ones, making energy in general more expensive and encouraging conservation and efficiency. The revenues from the GHG tax are used to reduce other taxes, so that the net effect on government revenues is zero.

Figure 17. *The Transition to a No Growth Economy, Canada*



Source: Adapted from Victor, 2008.

In this scenario, GDP per capita stabilizes after 2025, and GHG emissions decrease by 22% by 2035. Poverty levels as well as unemployment decrease significantly, and fiscal balance is reached, with a steady decrease in the debt to GDP ratio. A shorter work week allows for full employment, with less growth in material consumption but more spending on health care and education. Thus the model shows that the stabilization of economic output can be consistent with full employment, virtual elimination of poverty, more leisure, considerable reduction in GHG emissions, and fiscal balance.

[41] Victor, 2008.

5.3 Policies for a Green Economy

Regardless of one's vision of a green economy, significant policy changes at the national and international levels will be necessary to foster a transition. The policy recommendations from UNEP's Green Economy Initiative include:

- *Use taxes and other market-based instruments to internalize* ***negative externalities****.*[42] Pricing pollution promotes more efficient resource use and encourages innovation. Well-designed taxes or permit systems can also be net job creators. For example, a German tax on fossil fuels and electricity, introduced in 1999 and slowly phased in over several years, used the revenues to reduce the costs of hiring employees by lowering firms' required social security contributions. The tax was estimated to have created 250,000 full-time equivalent jobs while also reducing carbon emissions. As of 2017, the use of environmentally related taxes was still limited on a global scale, representing only 5.2% of total tax revenue in OECD countries.[43]
- *Decrease government spending that depletes natural capital.* A 2015 report by the International Monetary Fund estimates that global fossil fuel subsidies amount to about $5 trillion per year, or more than 6% of gross world product.[44] The report concludes that "the fiscal, environmental, and welfare impacts of energy subsidy reform are potentially enormous" – government revenues could increase by about $3 trillion and global economic welfare could increase by nearly $2 trillion. Subsidy reforms should be phased in slowly to reduce negative economic impacts, and be supplemented with policies to protect the poor. In Indonesia, for example, reductions in energy subsidies in 2005 and 2008 were implemented along with cash transfers to low-income households.
- *Efficiency and technology standards can sometimes be more cost-effective and easier to administer than market-based instruments*. Developing countries often lack the institutions for complex tax and tradable permits systems. Technology standards are easier to enforce, and can ensure a rapid transition to the best available technologies. The challenge is to set appropriate standards, and adjust them as new technologies become available. Standards for government procurement have been demonstrated to be an effective way to jump-start the demand for environmentally-friendly goods and services.
- *Temporary support measures are needed to ensure an employment transition for affected workers.* UNEP's analysis (Figure 14) indicates that in the short-term the transition to a green economy will cause a slight decline in GDP. Training will be needed to provide displaced workers with the skills to gain new jobs in the green economy. In many cases workers will remain employed in their current jobs, but through skill enhancement they can learn to do their jobs in new ways. Construction workers will still build houses, but construction techniques can incorporate better insulation, solar photovoltaic systems, and more efficient lighting.
- *International environmental governance needs to be strengthened*. Even with the potential economic benefits of green economy policies, individual nations remain

[42] In economic terminology, an externality is an impact of economic activity such as pollution, which is not valued in the economic system unless policymakers "internalize" it, for example with a pollution tax.
[43] OECD, 2017
[44] Coady et al., 2015.

hesitant to act alone. Strong international agreements create a level playing field and are the only effective way to deal with global environmental issues such as climate change and ozone depletion.

While some of these recommended policies will require major changes in current political institutions, others, such as reducing harmful subsidies or increasing efficiency standards, can be relatively easily and quickly implemented. The transition to a green economy will be a major issue confronting all economic policymakers in the coming decades.

The transition to a green, sustainable economy will require a sustained commitment. In 2017 the OECD published a Green Growth Indicator Report, evaluating how the OECD and G20 countries[45] have progressed since 1990. The findings indicate that overall, countries have achieved only a partial decoupling of emissions from economic growth, with CO_2 emissions continuing to increase, though at a lower rate than GDP. Risks of ecosystem degradation, biodiversity loss, and negative health impacts from poor air quality remain high.[46]

On an individual country scale, the UK and Denmark were some of the countries that made the greatest progress towards a green economy. Since 1990, the UK has cut carbon emissions by 42%, while the economy has grown by two-thirds. As of 2016, 47% of electricity used in the UK came from low carbon sources, recycling had increased 4 times over 2010 levels, and 430,000 were employed in the low carbon sector.[47] Denmark, a leader in environmental technologies and innovation, ranked highest in the use of environmental taxation, with these tax revenues contributing around 4% of their GDP.

The challenge is to maintain and extend such efforts across all countries through bold initiatives, long-term thinking, and international cooperation. Policies that promote greener economies are a positive development, but have yet to change the fundamental course of macroeconomic growth either in developed or developing economies towards sustainable goals.

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[45] The G20 is a group of 19 countries plus the European Union that collectively account for around 85% of gross world product.
[46] OECD 2017
[47] https://www.gov.uk/government/publications/clean-growth-strategy

KEY TERMS AND CONCEPTS

Adjusted Net Saving (ANS): a national accounting measure developed by the World Bank which aims to measure how much a country is actually saving for its future.

Better Life Index (BLI): an index developed by the OECD to measure national welfare using 11 well-being dimensions.

Biocapacity: the capacity of a natural environment to provide resources and assimilate wastes.

Cap and trade permit system: a system that allows firms to emit a certain amount of pollution based on the number of permits they obtain, while the government controls the overall level of permits.

Carbon tax: a per-unit tax on goods and services based on the quantity of carbon emitted during the production or consumption process.

Decoupling: breaking the correlation between increased economic activity and similar increases in envrionmental impacts.

Defensive expenditures: expenditures made to reduce negative impacts in economic systems, such as crime or exposure to an environmental contaminant.

Depreciation: the reduction in value of a capital stock over time due to wearing out or exploitation.

Ecological footprint (EF): a methodology that seeks to convert all human impacts into equivalent units of biologically productive land area.

Economics: the study of how people use their resources to meet their needs and enhance their well-being.

Entropy: A measure of the unavailability of the energy in a system; high entropy indicates little available energy, low entropy indicates significant available energy.

Environmental asset accounts (also natural resource accounts): national accounts that track the level of natural resources and environmental impacts in specific categories, maintained in either physical or monetary units.

Genuine Progress Indicator (GPI): a national accounting measure that includes the monetary value of goods and services that contribute to well-being and deducts impacts that detract from well-being.

Green economy: according to the United Nations Environment Programme, an economy which is low carbon, resource efficient and socially inclusive.

Green GDP: a national accounting approach that deducts the monetary value of environmental damages and natural capital depreciation from GDP.

Green Keynesianism: the incorporation of environmental sustainability objectives into traditional Keynesian macroeconomics.

Gross domestic product (GDP): the total market value of all final goods and services produced within a national border in one year.

Human appropriation of net primary productivity (HANPP): the portion of NPP used for human activities.

Human capital: the competence, skills and abilities of the labor force that allow them to produce economic value

Informal Economy (or Informal Sector): the part of an economy that is neither taxed nor monitored by any form of government. Unlike the formal economy, these activities are not included in a country's GDP.

IPAT equation: an equation that defines environmental impacts as a function of population, affluence, and technology.

Logistic growth: an S-shaped growth curve tending towards an upper limit.

Macroeconomics: the study of how the economic activities of individual actors join together to create an overall economic environment at the national—and often the global—level.

Manufactured (or produced) capital: productive resources produced by humans such as factories, roads, and computers.

Microeconomics: the study of the economic activities and interactions of individuals and particular organizations (such as businesses, households, community groups, nonprofits, and government agencies).

Natural capital: the available endowment of land and resources including air, water, soil, forests, fisheries, minerals, and ecological life-support systems.

Negative externality: negative impacts of a market transaction affecting those not involved in the transaction.

Net domestic product: gross domestic product minus the value of depreciation of manufactured, produced, capital.

Net primary production (NPP): the biomass energy directly produced by photosynthesis.

Planetary Boundaries: A quantification of the limits of key earth system processes, beyond which humanity risks triggering non-linear, abrupt environmental change.

Standard circular flow model: a diagram that illustrates the flow of capital and money between households and businesses.

Steady state economy: an economy that maintains a constant level of manufactured and natural capital by limiting resource-using economic activity.

Subjective well-being: people's overall rating of their well-being, as determined using surveys.

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DISCUSSION QUESTIONS

1) Do you think the revised circular flow model in Figure 2 is sufficient? Can you think of any further revisions to make it more accurate or more inclusive of environmental factors?

2) List one advantage and one disadvantage of each of the national accounting measures discussed in Section 2. Which of the measures do you prefer? Why?

3) Do you think the ecological footprint approach provides a roughly accurate measure of a country's overall environmental impacts?

4) Are you optimistic or pessimistic regarding the potential of technology to solve environmental problems?

5) Do you think that economic growth and environmental sustainability are compatible?

6) How would you define "the green economy"?