"Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist."
Kenneth Boulding

BEYOND GROWTH
The *environment* key to survival in the 21st century

We have developed an economic system over the past two centuries dominated by exponential growth of world domestic product, GDP, and world population, writes **GEOFFREY P. GLASBY**. Calculating continuing growth rates of GDP and world population through the 20th and 21st centuries shows we have the potential to create between 8 and 26 times more wealth in the 21st century than in the rest of human history. The unprecedented increase in resource consumption that will occur in the next 90 years, compared to the preceding 10,000 years of human history, will result in a massive environmental deficit by 2100. We are on course now in 2008 to overwhelm the natural environment on which we depend for life on Earth, which will cause severe problems for the more populous world of the late 21st century. Vigorous steps are needed to curtail resource consumption, world GDP, population growth, and global greenhouse gas emissions to improve human prospects for the 21st century and beyond. Humanity must learn restraint to survive.

1820 is a key date in human history,[1] marking the beginning of a huge increase in world population from about one billion to just over 6.6 billion in 2007. This was accompanied by a 180-fold increase in world GDP, as a result of industrialization and large-scale use of fossil fuels. As a consequence, we are putting increasing stress on the environment and moving steadily away from the ideal of sustainable development as envisaged in the Brundtland Report.[2]

The early 21st century is a critical juncture in human history. There is now clear evidence the lifestyle of the developed world is unsustainable[3] and this trend will increase markedly over the coming decades, unless we make major changes in our consumption patterns and attitudes to the environment.[4] The central role of humanity in recent earth history has been recognised in a newly coined geological epoch, the "Anthropocene"[5] now divided into three phases.[6] The first, beginning between 8,000 and 5,000 years ago, was the result of long-term emissions of carbon dioxide (CO_2) and methane (CH_4) from forest clearance for agriculture and animal husbandry.[7] The second phase began with the industrial revolution through the invention of the steam engine in 1784.[8] The third phase began around 1950, and marks the period where human activities advanced from influencing the global environment in a few ways to dominating it in many ways.

The method

To calculate the impact of human population on the global environment, I list three parameters, world population, world per capita GDP and world GDP over the last 8,000 years. This period is subdivided as follows: a 5,000-year interval from 8000 B.C. to 3000 B.C., 500-year intervals for the period from 3000 B.C. to 1500 A.D. and then 50-year intervals for the period from 1500 to 2000 (Table 1). Data and methods are described and referenced in paper by J. Bradford DeLong, University of. California. Berkeley.[9] From these data, it's possible to calculate the growth rate of each of the parameters for each of the 5,000, 500 and 50-year intervals. Total wealth created in each interval can then be derived by calculating annual world GDP for each interval. This enables the growth rate of total wealth created to be calculated for the three phases of the Anthropocene.

To make similar calculations for the period from 2000 to 2100, it is assumed world population will grow from 6.272 billion in 2000 to a median peak value of 9.0 billion in 2070 and then slowly decline.[10] This corresponds to an average annual median world population growth rate of 0.3% during the 21st century. Increases in world GDP were calculated based on three scenarios: i) and ii) using Keynes' assumption that world GDP will naturally increase by factors of

four and eight per century,[11] and iii) assuming world per capita GDP will continue to grow at the annual rate experienced between 1950 and 2000 of 2.83%. This gives an overall growth rate for world GDP during the 21st century of 3.12% annually, and can be taken to represent the "business as usual" scenario.

Growth rates in world GDP based on these three scenarios can then be calculated to be 1.4% p.a., 2.1% p.a. and 3.1% p.a. for the entire century, respectively. Total wealth created from 2000 to 2049 and from 2050 to 2099 is found by summing the annual world GDP for each of these two periods based on these three scenarios (Table 1).

Initial analysis

Various methods have been devised to quantify adverse environmental impacts on a global scale. One involves the equation:

Environmental Impact = Population × GDP per capita × Environmental Impact per unit of GDP.

This equation provides a crude estimate of the global environmental impact of human activity for any period. The environmental impact per unit of GDP depends on many factors, like amount of waste produced per unit of economic activity, efficiency of economic activity and the production technologies used.[12] As this term is not easily quantifiable, I have defined Environmental Impact solely as total wealth created per unit of time, understanding this to be an approximation and the analysis therefore only semi-quantitative. Others have used a similar approach with some success.[13]

The past

The period from 8000 B.C. to 1500 A.D. covers the dawn of civilization to the beginning of the early modern period of European history.[14] For this period, DeLong assumed a constant world per capita GDP of US$115 (in constant 1990 US$).[9] This value is taken as a measure of per capita agricultural output in pre-indus-

Year	World Pop. (millions)	% increase per year	Per capita GDP ($)	% increase per year	World GDP ($US billions)	% increase per year	Total wealth ($US trillions)	% increase per 50 years
8000 BC	4.5		115		0.52			
8000–3000 BC	14	0.02%	115	0	1.6	0.02%	3.5	
3000–2501 BC	19	0.06%	115	0	2.2	0.06%	1.0	
2500–2001 BC	27	0.07%	115	0	3.1	0.07%	1.3	
2000–1501 BC	38	0.07%	115	0	4.4	0.07%	1.9	
1500–1001 BC	50	0.05%	115	0	5.7	0.05%	2.5	
1000–501 BC	100	0.14%	115	0	11.5	0.14%	4.2	
500–1 BC	170	0.11%	115	0	19.5	0.11%	8.1	
0–499 AD	195	0.03%	115	0	22.4	0.03%	10.7	
500–999 AD	265	0.06%	115	0	30.5	0.06%	12.7	
1000–1499 AD	425	0.09%	115	0	48.9	0.09%	20.0	
1500–1549 AD	481	0.25%	127	0.20%	61	0.45%	3	
1550–1599 AD	545	0.25%	140	0.20%	76	0.45%	3	25%
1600–1649 AD	545	0.00%	155	0.20%	85	0.20%	4	18%
1650–1699 AD	610	0.23%	172	0.21%	105	0.43%	5	17%
1700–1749 AD	720	0.33%	190	0.20%	137	0.53%	6	27%
1750–1799 AD	900	0.45%	210	0.20%	189	0.65%	8	34%
1800–1849 AD	1,200	0.58%	300	0.72%	360	1.30%	13	64%
1850–1899 AD	1,625	0.61%	679	1.65%	1,103	2.26%	31	137%
1900–1949 AD	2,516	0.88%	1,622	1.76%	4,082	2.65%	108	247%
1950–1999 AD	6,272	1.84%	6,539	2.83%	41,017	4.72%	847	684%
2000–2049 AD	7,258	0.29%	11,302	1.10%	82,033	1.40%	2,938	247%
2050–2099 AD	8,400	0.29%	19,532	1.10%	164,067	1.40%	5,877	100%
2000–2049 AD	7,258	0.29%	15,983	1.80%	116,013	2.10%	3,569	321%
2050–2099 AD	8,400	0.29%	39,064	1.80%	328,134	2.10%	10,095	183%
2000–2049 AD	7,258	0.29%	26,260	2.83%	190,594	3.12%	4,944	484%
2050–2099 AD	8,400	0.29%	105,432	2.83%	885,627	3.12%	22,972	365%

Table 1. *Data for the last 10,000 years on world population, world GDP and total wealth created in each time period. Increase in these for each 50-year period from 1500 is also shown along with projected increases to 2100 for annual percentage increases of 1.4%, 2.1% and 3.12%.*

trialized agricultural societies and reflects humanity's inevitable dependence on working the soil.

From 8000 B.C. to 3000 B.C., world population and GDP growth rates were 0.02% yearly. This figure can be considered the natural growth rate of the human population before civilization began. Total wealth created in this period was $3.48 trillion, representing 0.3% of total wealth created in the subsequent 5,000 years of our history.

From 3000 B.C. to 1500 A.D., world population and world GDP growth rates varied between 0.03 and 0.14% yearly, and total wealth created in this 4,500 year period was $62.3 trillion, equivalent to that created between 1500 and 1890 (Table 1). Growth rates in world population did not increase systematically in this period, reflecting humanity's vulnerability to the vagaries of life, war, famine, pestilence and death: the four horsemen of the apocalypse. Significantly, the highest growth rates (0.11–0.14% annually) occurred during the classical period and did not reach these levels again until the Renaissance. Although these growth rates were modest by future standards, it would be wrong to think man's impact on the environment was negligible in this period.[15,1]

From 1500 to 1750, world population increased by 0.2% annually and world GDP by 0.4% annually (Table 1). These growth rates were again modest by future standards with total wealth created in this period being $21 trillion. The period from 1750 to 1950 was marked by a steady rate of increase in world population, per capita GDP and world GDP through each 50-year interval in this period. World population and world GDP increased by 1.6 and 2.6 times respectively between 1750 and 1850 and by 2.1 and 11.3 times respectively, from 1850 to 1950. However, the increase rate of per capita GDP was lower between 1900 and 1950 than might have been expected, in extrapolating the rate from 1850 to 1900. This was probably the result of the two world wars. Total wealth created in these two periods was $21 trillion and $139 trillion, respectively.

From 1950 to 2000, world population and world GDP increased by 2.5 and 10.0 times respectively, far higher increases than anything ever seen before. Even allowing for the lower baseline in 1950 as a result of the two world wars, this was a period of unprecedented growth. Total wealth created in this 50-year period was $847 trillion, more than three times that created in the preceding 10,000 years.

The future

From this data we can calculate the increase in total wealth that will be created in the 21st century relative to total wealth created by humans during their entire history, based on growth rates in each of the three scenarios mentioned earlier. These assume world GDP will increase by 1.4% p.a., 2.1% p.a. or 3.1% annually, comparable with those of the last few decades. This leads us to conclude that in the 21st Century, we have the potential to create eight times, 13 times or 26 times more wealth than has been created in the entire human history to date, depending on whether we increase world GDP by factors of four, eight or 22 during this period. These calculations are a stark reminder of the power of exponential growth.

Raising living standards

John Maynard Keynes, preeminent economist of the 20th century, demonstrated that accumulation of capital along with technical change would lead to an increase in living standards in "progressive" countries of between four to eight times per century, based on the power of compound interest.[16] He dated the modern age as beginning in the sixteenth century with compounding capital and interest accumulation. Technical change on the necessary scale had to await the industrial revolution. Prior to this, living standards of the average person had largely been limited by agricultural output. Keynes was writing at the time of the Great Depression and saw this development as entirely benign, imagining a future quite different from the one we have chosen. He imagined we would work a 15-hour week, where the major problem would be how to occupy one's leisure.

As has been shown above, world GDP increased by 11 times between 1850 and 1950 and by 10 times between 1950 and 2000, supporting Keynes' view. Assuming no major wars and no major increases in population, Keynes believed the economic problem would be solved, or be close to a solution, within 100 years. Economic growth rates achieved since 1850 might suggest, for the developed world at least, that we have unlocked the secret of increasing wealth on an exponential basis.

The future imperfect

We now live in a world of intense global competition, characterized by maximizing use of assets and capital mobility. The principal aim of economic activity is to maximize growth rates to create wealth, thereby implicitly increasing human well-being. In advanced countries, this is achieved by creating demand (or increasing consumption). Growth is considered critical because it can alleviate material scarcity, increase employment and eliminate poverty. Yet one of the

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paradoxes of this emphasis on growth based on intense economic competition is the widening wealth gulf between the richest and poorest both within and between countries. The idea economic growth leads to environmental degradation and inequalities in wealth was clearly demonstrated by Daly.[17] Later, Gorgescu-Roegen argued we live off low entropy capital.[18] As a result, consumption of resources leads to an increase in entropy in the global system which I interpret as environmental degradation.[19]

In economics, everything must have a value (or price) and be quantifiable. The natural world is considered to have no value, except in the sense it contributes to human well-being. However this view is easily open to question if we consider how we would survive in Antarctica, or on Mars, without resources from the naturally inhabitable world. This observation clearly shows an ecologically healthy natural world is necessary for survival of the human race on this planet.

It has been argued that far from being without value, the natural world, or in other words the world's ecosystem services and natural capital, actually contribute more to human welfare (US$16–54 trillion) than does global GDP (US$18 trillion).[20] This remarkable conclusion comes at a time when we are putting great stress on the natural environment and when authoritative predictions show this stress will increase markedly over the course of this 21st century and beyond. It shows beyond doubt that we must put great emphasis on maintenance of our ecological support systems, if we consider the long-term well-being of the world's people to be our major priority. This goal may be considered to be analogous to sustainable development.

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Speeding to collapse

Exponential growth in world population and GDP through the 20th century and into the 21st century, as earlier described, are unsustainable, even over the next 50 years. Back in 1991 Goodland and others observed that anything remotely resembling the magnitude of a 5–10-fold increase in global economic activity over the next 50 years as proposed in the Brundtland report would simply speed today's long-run unsustainability to collapse of the global ecosystem.[21] About the same time the Ehrlichs also found the planet could not support a quintupling of economic activity even for a short time.[22]

Our potential to create between eight and 26 times more wealth in the 21st Century than was created in the preceding 10,000 years of human history suggests we are far removed from the transition to sustainability within two generations as argued a decade ago by the National Research Council.[23] Instead, we are on course to overwhelm within this century the natural environment on which we depend for our tenure on this planet. In these circumstances, it seems quite possible there will be a sharp decline in world population to more sustainable levels in the next few decades. Exponential growth rates for world population and world GDP calculated here, particularly from 1950 onwards, clearly show the concept of sustainable development is a chimera, meaningless in the context of our time.

Atmospheric CO_2 and economic growth

James Lovelock has reminded us that life on Earth depends on the Earth being a dynamic planet with an equitable temperature regime and a regulated atmosphere.[24] Carbon dioxide (CO_2) has formed around 0.028% of the earth's atmosphere (280 parts per million by volume or ppm) for most of the last 8,000 years. Prior to 1850 it varied naturally by around 3% of this amount but from 1850 to 1950 it rose by 5% and from 1950 to 2000 by 18% to reach 369 ppm. Significantly, the current rising trend in atmospheric CO_2 concentration began around 1780, about 40 years before the turning point in increased world population,[25] probably the result of forest clearance for agriculture in the New World. Initially the average annual increase in atmospheric CO_2 for the period from 1750 to 1950 was only 0.06% but this increased markedly to 0.34% annually for the period 1950–2000. It increased further to 0.56% or 2.1 ppm annually in the period 2001–2007 with CO_2 now at 383 ppm and rising.[26] If atmospheric CO_2 concentration were to increase at this rate for the rest of this century, it would attain a value of 577 ppm by 2100.

The influence of atmospheric CO_2 on the earth's surface temperature has been known since the late nineteenth century.[27] As CO_2 levels have risen in the last few decades the consequences for a more energetic climate and rising sea-level from a warming earth have become increasingly apparent. In response, the United Nations and the international science community have undertaken a series of reviews through the Intergovernmental Panel on Climate Change (IPCC)[28] to document evidence and likely future consequences. In its most recent 2007 report, the IPCC Fourth Assessment concluded: "Most of the observed increase in globally averaged temperatures since the

mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations." It also stated: "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level."[29]

The IPCC estimates CO_2 levels to rise to more than 600 ppm by 2100, with average global temperature rise ranging between 1.8 and 4.0°C above 1990 levels, depending on the particular CO_2 emissions scenario we follow.[30] Even the lowest of these is 2.4°C above pre-industrial average global temperature and above the 2°C threshold for "dangerous climate change," referred to in the 2005 Exeter meeting on that topic, the dangers arising from more powerful cyclones, floods, droughts and rising sea level from melting ice as well as pressures on marine and terrestrial ecosystems, from higher temperatures and more acidic oceans. These unwanted consequences of our rising wealth are plainly factors to consider in considering the future.

If atmospheric CO_2 concentrations should attain values of more than 600 ppm by 2100 as projected by the IPCC, they will be well outside the envelope of greenhouse gas concentrations that have accompanied human evolution. Although the resulting temperatures may be tolerable in some places, the increased warmth will disturb the energy balance of both the atmosphere and oceans with markedly detrimental effects[31] and significantly affect the Earth's carrying capacity for an advanced industrial population critically dependent on agricultural production to feed itself.

In spite of the gravity of the situation, there appears to be no consensus on the need to reduce economic growth in order to reduce CO_2 concentrations in the atmosphere in the future.

This will have severe consequences at a time when the human population will be at its highest level ever and economic activity well outside the limits required for sustainable development of the environment. Lord Rees in 2006 urged adoption of a programme similar to the Manhattan or Apollo projects to reduce the impacts of global greenhouse gas emissions.[32] In spite of the gravity of the situation, there appears to be no consensus on the need to reduce economic growth in order to reduce CO_2 concentrations in the atmosphere in the future.

Prospects for societal collapse

Jared Diamond[33] recently drew attention to historical examples of societal collapse over the last four millenia. Are such collapses conceivable for a modern society? Two basic causes can be considered:

- natural catastrophes like earthquakes or volcanic eruptions. These may destroy local communities but rarely a society.
- environmental degradation of forests and soils (in some cases enhanced by regional climate change). This is a more substantive threat, as has been shown for example on Easter Island, the Anasazi and Maya societies of North America and the Norse colony in Greenland.

In considering the fate of future societies, Diamond identified four additional pressures: global climate change, build-up of toxic chemicals in the environment, energy shortages and complete utilization of the Earth's photosynthetic activity by humans. In each of the historical societal collapses, the fundamental problem was that population growth outstripped available resources as foreseen by Thomas Malthus in 1798. However these examples had little effect on global population. Modern society is global in its domain and seems to require continuing economic growth to be sustainable. It's therefore possible to foresee a third cause for societal collapse:

- over-dependence on centralized power supplies or communications technologies in a globalized world.

Future environmental impacts

Global environmental impact has previously been defined as total wealth created in a given time multiplied by the environmental impact per unit of GDP. This is hard to gauge and is assumed to be directly proportional to GDP. On this basis, it can be calculated from data given in Table 1 that the global environmental impact will be roughly 7, 12 and 27 times greater in 2100 than in 2000 based on assumptions about global GDP growth as described earlier.

But the values calculated are only average values. Global environmental impact will be greatest in fragile environments where population growth has been the greatest. Some regions will be able to minimize environmental degradation by importing environmentally sensitive products from elsewhere, thereby exporting environmental degradation to other countries. Yet environmental degradation will increase overall. It will be most marked on local- and regional-scales and cause knock-on effects. As one region becomes subject to severe environmental degradation, part of the population will migrate to more favoured regions, exacerbating environmental problems there.[34]

Thus it's likely most fragile areas of the Earth's surface will be severely degraded by 2100. This view is supported by Diamond, who says he has never met anyone who seriously argues the world could support 12 times its current impact, yet this is what we can expect in 2100. Yet the problem is already with us, for the Secretariat of the Convention on Biological Diversity recently reported global demand for resources now exceeds by 20% the biological capacity of the Earth to renew them. Back in 1960, mankind used only about one half of the Earth's biocapacity.[35]

Global climate change will amplify existing hazards and play a major role in determining the magnitudes of environmental impacts. German insurance company, Munich Re, has shown weather-related natural catastrophes, like windstorms, floods, severe weather events, heat waves and forest fires, have a disproportionate effect on insurance pay-outs, which have increased almost ten-fold since the 1960s. Even small shifts in mean atmospheric temperatures can lead to dramatic increases in the probabilities of exceeding critical threshold values.[36]

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Environmental consequences of future global climate change have been assessed and summarised most recently in the Synthesis Report of the IPCC Fourth Assessment.[37] Regarding ecosystems, their first three points are:

- "The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g. flooding, drought, wildfire, insects, ocean acidification) and other global change drivers (e.g. land-use change, pollution, fragmentation of natural systems, over-exploitation of resources)."
- "Over the course of this century, net carbon uptake by terrestrial ecosystems is likely to peak before mid-century and then weaken or even reverse, thus amplifying climate change."
- "Approximately 20 to 30% of plant and animal species assessed so far are likely to be at increased risk of extinction if global average temperature exceed 1.5 to 2.5°C."

On industry, settlements and society they make two points:

- "The most vulnerable industries, settlements and societies are generally those in coastal and river flood plains, those whose economies are closely linked with climate-sensitive resources and those in areas prone to extreme weather events, especially where rapid urbanisation is occurring."
- "Poor communities can be especially vulnerable, in particular those concentrated in high-risk areas."

The report also warns of consequences for food, water and health, and for abrupt irreversible changes. "Partial loss of ice sheets on polar land and/or thermal expansion of seawater over very long time scales could imply metres of sea-level rise, major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands." If a temperature rise of 1.9–4.6°C (relative to pre-industrial) by 2100 is sustained, the IPCC says, rapid sea-level rise on century time scales cannot be excluded. Recent measurements of the volume of the Antarctic ice-sheet,[38] show it's shrinking faster than expected, but the causes are not yet well-known enough to make reliable future projections. These new observations are disturbing. It's also increasingly obvious that international agreements, like the Kyoto Protocol have yet to become effective in reducing atmospheric CO_2 emissions.[39] Although the energy intensity (energy consumed per unit of GDP) has decreased substantially since 1990, global CO_2 emissions continue to rise, combining the effects of growth of global per capita income and increase in world population.[40]

Other gases amplify warming

Other warming gases, apart from fossil fuels, also contribute to global warming. For example, the 1997 fires in Indonesia, associated with the largest El Niño event on record, released between 0.8 and 2.6 Gt of C into the atmosphere, between 13 and 40% of global carbon emissions for the year. Around 74% came from burning peat and the rest from burning vegetation.[41]

Thawing permafrost along lake margins in northern Siberia has increased methane emissions, CH_4, in the region by 58% between 1974 and 2000.[42] Methane liberated in this region during 2003 and 2004 was about 0.004 Gt yr^{-1}, about 10% of the total contribution of CH_4 to the atmosphere from all natural sources.[43] Although this amount is tiny, the region is estimated to hold about 500 Gt C in permafrost which makes it a potential risk for increased methane discharge with continued global warming. Another risk lies in destabilization of some of the 500–2,000 Gt of methane hydrate beneath the ocean floor.[44] These examples emphasize the amplification of global warming from sources of greenhouse gases other than fossil fuels.

It's clear from these observations there will be no single factor involved in environmental collapse of human societies but a number of factors will converge to produce major impacts locally and regionally which will then knock-on to other areas. Once a critical stage is reached, societal collapses could be quite rapid and complete within a few decades. This process has been eloquently described by Ray Pierrehumbert as a catastrophe in slow motion. [45].

Options for the future

As a species, we have come to assume we are in control of our destiny. Yet the current phase of our history from 1820 began less than two centuries ago. The Roman and British Empires both lasted far longer than this but both have now gone. Collapse of the Roman Empire, followed by the Dark Ages which lasted from about 500 to 1000 AD, was marked by frequent warfare and the virtual disappearance of urban life. In the long sweep of history, humanity has been accustomed to living in an under-populated world where the world's resources were there for the taking. Our mindset has not yet adjusted to thinking in terms of restraint.

In considering our future prospects, Desmond Morris summed up our predicament succinctly:[46]:

> No matter how extraordinary our achievements may be, we nonetheless remain animals and subject to all the rules of biology. If we ignore these rules and, for instance, over-populate and pollute the planet, we will not be protected by some supernatural force. We will become extinct just as easily as any other species.

The projected growth rates in world population, world GDP, total wealth created and atmospheric CO_2 concentrations in the 21st century presented here are sufficiently alarming to demand action. Several courses of action can be taken to move towards a more sustainable world.

What to do

Firstly, it's vital to reduce population growth rate. One child families should become the norm. The increase in world population is a major driving force in increasing consumption and in degrading the environment. Secondly, affluent countries must reduce consumption and move towards more modest lifestyles. Maximizing growth rates by creating demand exacerbates the problem. Finally, major efforts must be made to reduce greenhouse gas emissions. As Stern has noted, costs of mitigating global climate change will be an order of magnitude less than costs of coping with the consequences.[47]

Projected growth rates in world population, world GDP, total wealth created and atmospheric CO_2 concentrations in the 21st Century presented here are sufficiently alarming to demand action

As our society faces this challenge, world spending on armaments is approaching US$1,200 billion dollar a year.[48] Armed conflict killed up to 187 million people in the 20th century.[49] This approach to solving political problems is an anachronism. The survival of modern society requires a global consensus on a scale beyond anything previously attempted.

Conclusions

The analysis presented here shows we have developed an economic system over the past two centuries dominated by exponential growth of both world population and world GDP. If high growth rates persist for the rest of this century the natural environment on which we depend for our sustenance will be destroyed. In these circumstances, a sharp decline in world population seems inevitable. Major environmental impacts are likely to occur rapidly on a human time-scale, probably as a series of shocks. To minimize risks, we must reduce over-population, over-consumption and greenhouse-gas emissions now. Our goal is not to achieve sustainable development, as that's no longer possible, but to minimize the effects of demonstrably unsustainable development.

The 21st century must therefore become the century of the environment when we come to terms with

the environmental excesses of the industrial revolution and its aftermath, mass consumption in richer countries and mass poverty in poorer countries. This means putting the environment at the centre of national and international decision-making. To achieve these objectives, the human race must achieve a greater unity of purpose than ever before. For this, inspired political leadership is needed.

We have now unlocked the secret of increasing wealth on an exponential basis but seem incapable of stopping it. We need an economist of Keynes' ability to show us how to end this exponential growth without causing massive deflation of the global economy and the chaos this would undoubtedly cause.

"Civilization occurs by geological consent, subject to change without notice." — Will Durrant

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