GLOBAL DEVELOPMENT AND ENVIRONMENT INSTITUTE

WORKING PAPER NO. 13-03

Population, Resources, and Energy in the Global Economy: A Vindication of Herman Daly's Vision

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February 2013

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Abstract

Herman Daly pioneered the concept of environmental macroeconomics. He famously argued that we have moved from an "empty world" of resource abundance to a "full world" of energy and resource limits. His insights, however, have generally been rejected or ignored by most mainstream economic analysts, who argue that resource shortages are remediable through market flexibility and substitution, posing no threat to long-term exponential economic growth.

In the absence of immediate crisis, standard economics has been able to maintain this "optimistic" stance, dismissing population, resource, and energy limits. But developments during the first decade of the twenty-first century indicate that it will be Daly's view, rather than that of the mainstream, that will be most important in shaping economic development in the coming century.

As Daly foresaw, an energy economy based on high efficiency and renewable fuels cannot pursue the exponential growth path characteristic of the fossil-fuel dependent economy of the twentieth century. The issues involved go well beyond the energy sector of the economy. Population growth and food supply also become critical. There are many interactions between the agricultural and energy systems; in addition to energy intensification in agriculture, demands for biofuels put pressure on the limited supply of agricultural land. Recent price spikes in food, fuels, and minerals indicate the tremendous stresses placed on the global ecosystem by the combination of population and economic growth in China, India, and elsewhere. They also raise major issues of equity, as high prices for energy and food impact the poor disproportionately. Similar problems affect ecological systems such as forests and fisheries on a global scale.

It will not be possible to adjust to such stresses simply through market flexibility. It is already evident that large-scale government intervention will be needed to respond to climate change. In this context, an activist environmental macroeconomics will be required to balance the requirements of equity and ecosystem sustainability. Either through planned adjustment or through crisis, it will be necessary to shift away from a macroeconomics of indefinite growth towards stabilization of population and reduction of resource throughput, as Daly has long advocated.

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Jonathan M. Harris

Introduction

Herman Daly pioneered the concept of environmental macroeconomics (Daly, 1973, 1991a and b, 1996). He famously argued that we have moved from an "empty world" of resource abundance to a "full world" of energy and resource limits.[1] His insights, however, have generally been rejected or ignored by most mainstream economic analysts. From the point of view of neoclassical economic analysis, resource shortages are remediable through market flexibility and substitution, posing no threat to long-term exponential economic growth. In the absence of immediate crisis, standard economics has been able to maintain this "optimistic" stance, dismissing population, resource, and energy limits. But developments during the first decade of the twenty-first century indicate that it will be Daly's view, rather than that of the mainstream, that will be most important in shaping economic development in the coming century.

A review of global trends in the areas of population, food supply, non-renewable and renewable resources, and environmental impacts including global climate change indicate that the situation has changed significantly during the first decade of the twenty-first century. Evidence of resource shortages and environmental impacts that was contentious prior to the year 2000 has become unarguable. From the point of view of the debate among economists, this is most significantly reflected in price trends. During the debate over resource limits during the second half of the twentieth century, the trump card of the neoclassical position has always been the contention that prices for food, non-renewable resources, and energy were generally stable or falling. This, it was argued, indicated that substitution, innovation, and resource discovery were overcoming the limits foreseen by Daly – and that this process might continue indefinitely. Projecting declining price trends into the future was never justifiable, and it is now evident that these price trends have decisively reversed.

The most obvious and urgent environmental limit is climate change. Some analysts from a standard economics background, such as Nicholas Stern (2007), have come to realize that climate change requires profound changes in global economic growth patterns. The full implications of a transition away from fossil fuel dependence, though, have yet to be explored. As Daly foresaw, an energy economy based on high efficiency and renewable fuels cannot pursue the exponential growth path characteristic of the fossil-fuel dependent economy of the twentieth century.

The issues involved go well beyond the energy sector of the economy. Population growth and food supply also become critical. There are many interactions between the agricultural and energy systems; in addition to energy intensification in agriculture, demands for

[1] See Daly and Farley, 2011, Chapter 7: "From Empty World to Full World".

biofuels put pressure on the limited supply of agricultural land. Recent price spikes in food, fuels, and minerals indicate the tremendous stresses placed on the global ecosystem by the combination of population and economic growth in China, India, and elsewhere. They also raise major issues of equity, as high prices for energy and food impact the poor disproportionately.

It will not be possible to adjust to such stresses simply through market flexibility. It is already evident that large-scale government intervention will be needed to respond to climate change. Similar problems affect ecological systems such as forests and fisheries on a global scale. In this context, an activist environmental macroeconomics will be required to balance the requirements of equity and ecosystem sustainability. Either through planned adjustment or through crisis, it will be necessary to shift away from a macroeconomics of indefinite growth towards stabilization of population and reduction of resource throughput, as Daly has long advocated.

A significant literature has already developed around the concept of development without growth, or at least without growth in what Daly identified as "throughput" – resource and energy input and waste output (Victor, 2008, 2010; Jackson, 2009; Heinberg 2007, 2011; Harris, 2007, 2009, 2013a and b). The task of accomplishing this shift, while preserving the reasonable expectations of the developing world for better conditions of life, will be immense. Standard economic theory may provide some insight into necessary tools, such as carbon trading, but it is the broader framework of Daly's ecological theory that provides the essential context for real solutions.

Population and Food Supply

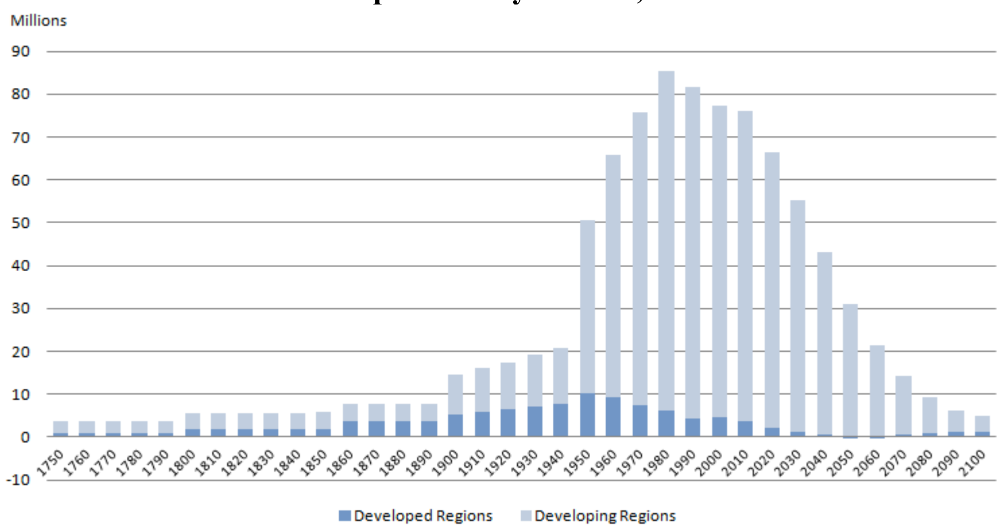
A favorite argument of those who contest the "full world" concept has been that population problems are in effect taking care of themselves. With falling rates of fertility and population growth, world population will stabilize, according to this view, at manageable levels. Recent evidence on population growth shows this assertion to be questionable.

While population growth rates are indeed falling, the growth in total population means that the average annual increase has barely changed since reaching a maximum in the 1990s. According to the U.N.'s median population projection, the net annual increase will decline in coming decades, but will not have stabilized by 2050 (Figure 1). This implies a net addition of 2-3 billion people above the current global population of 7 billion before stabilization. Further, the fastest addition to population is occurring in those areas that can least support it: Sub-Saharan Africa and poorer parts of Asia and the Middle East. In Sub-Saharan Africa, population is projected to at least double before stabilization (see Table 1 – in the "medium" and "high" projection population continues to grow after 2050).

This population picture presents two types of problems, both of which were not a major factor during the period of exponential population and economic growth. First is the very real issue of carrying capacity, as global population reaches levels that strain food and other essential life support systems (See Figure 2). The other is the social problem of supporting a growing cohort of elderly people, an unavoidable result of population stabilization.

Slower population stabilization will make the first problem more acute, while faster stabilization will accentuate the second problem. In either case, as global population stabilizes, economic systems must adapt both to the greater food and resource requirements of larger populations and to their environmental and social impacts. This poses unprecedented challenges for macroeconomic policy, which has traditionally been oriented towards continuing exponential growth. The new realities of population will therefore demand new approaches to economic analysis and policy.

Figure 1: Net Annual Increase in Population by Decade, 1750-2100



Sources: Population Division of the Department of Economic and Social Affairs of the United Nations, *World Population Prospects: The 2010 Revision*, http://esa.un.org/unpd/wpp/index.htm, Medium Variant; Repetto, 1991.

Table 1: Projected Population Growth for Major World Regions

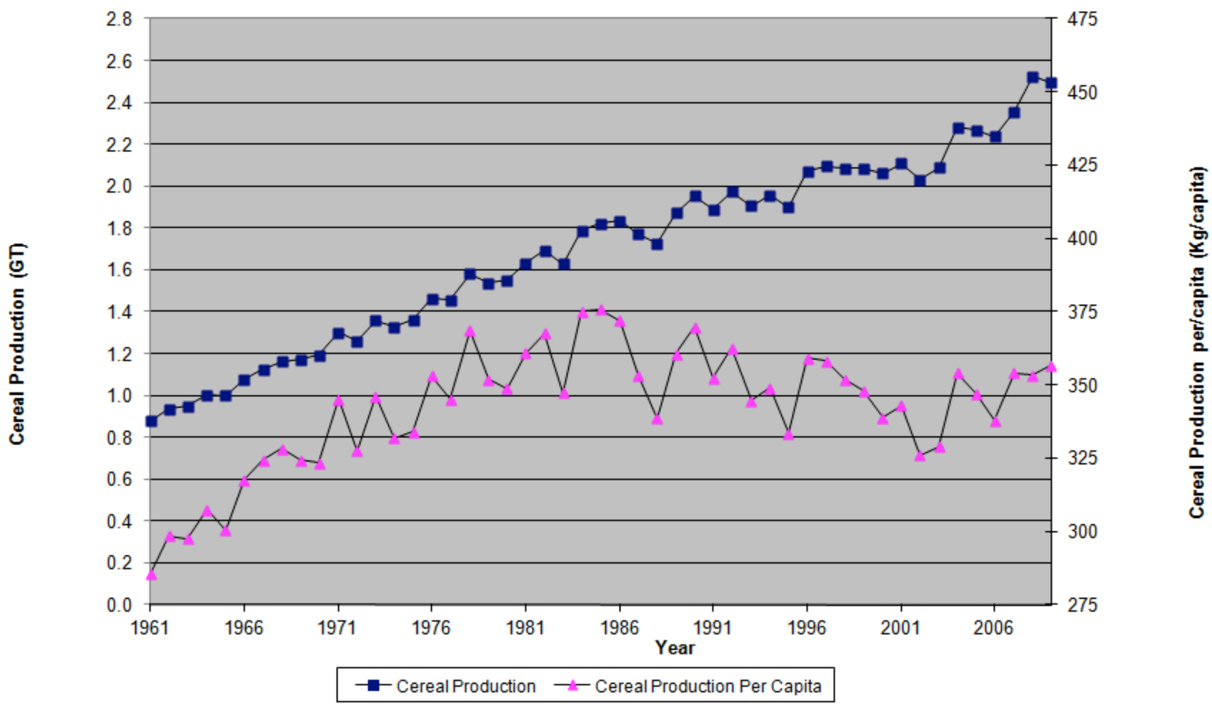
		2050 population Projections (millions)		
Regions	***2010 Population (millions)***	***Low fertility***	***Medium fertility***	***High fertility***
Africa	**1,022**	**1,932**	**2,192**	**2,470**
Asia	**4,164**	**4,458**	**5,142**	**5,898**
Latin America and Caribbean	**590**	**646**	**751**	**869**
Europe	**738**	**632**	**719**	**814**
Northern America	**345**	**396**	**447**	**501**
Oceania	**37**	**49**	**55**	**62**
More developed regions	**1,236**	**1,158**	**1,312**	**1,478**
Less developed regions	**5,660**	**6,955**	**7,994**	**9,136**
World	**6,896**	**8,112**	**9,306**	**10,614**

Source: Population Division of the Department of Economic and Social Affairs of the United Nations, *World Population Prospects: The 2010 Revision*, http://esa.un.org/unpd/wpp/index.htm

The first challenge posed by population growth is providing sufficient food. As Figure 2 shows, growth in grain production has barely kept up with population growth since the 1980s. So long as grain and other food prices remained stable, economist could argue that this slowdown was not evidence of resource constraints. Greater demand pressing on limited supply would lead to increased prices, and until recently food prices were stable or declining. But with the onset of the "food crisis" in 2008, these price trends reversed to give a dramatic spike in food prices. Food prices again touched all-time highs in 2011, falling back slightly in the first half of 2012 (Figure 3).[2]

Increased food prices are partly attributable to a growing "global middle class" with higher demands for meat and other luxury food products, and partly to demand for biofuels, which compete with food crops for limited arable land. The steady increase in land in cultivation from the 1950s to the 1980s, which helped to accommodate growing world food demand, has since slowed almost to a halt[3]. It appears that a higher price world food regime is a permanent change, not a temporary spike.

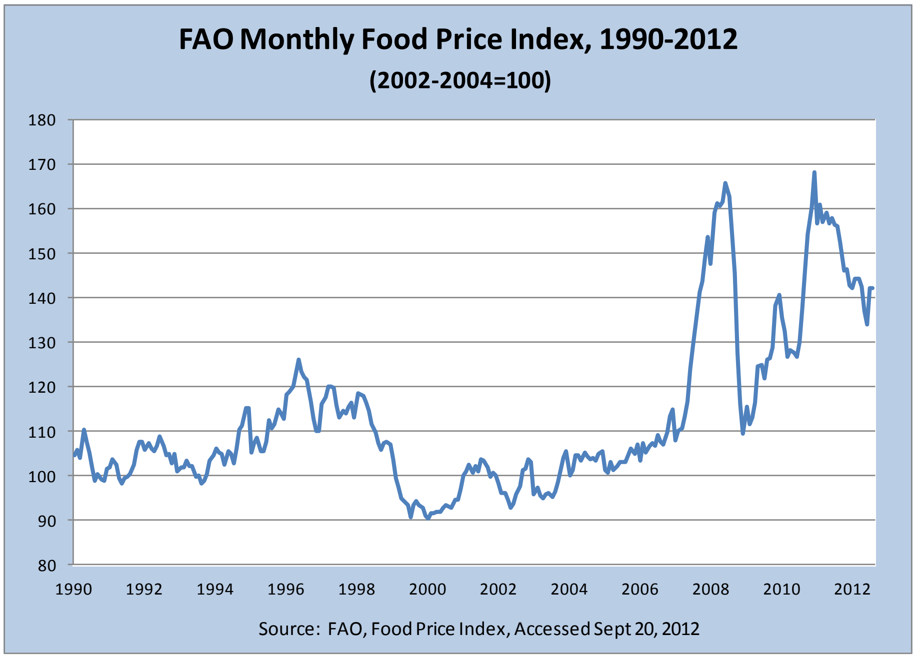
Figure 2: Absolute and Per Capita Grain Supplies, 1950 to 2010



Source: For world total cereal production FAO, 2011 http://faostat.fao.org/
Population Source: World Bank 2011 -- http://data.worldbank.org/indicator/SP.POP.TOTL

[2] http://www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/
[3] See Harris 2006, Chapter 11, and http://faostat3.fao.org/ for data on arable land area.

Figure 3: Food Prices, 1990-2012



Source: http://faostat.fao.org/

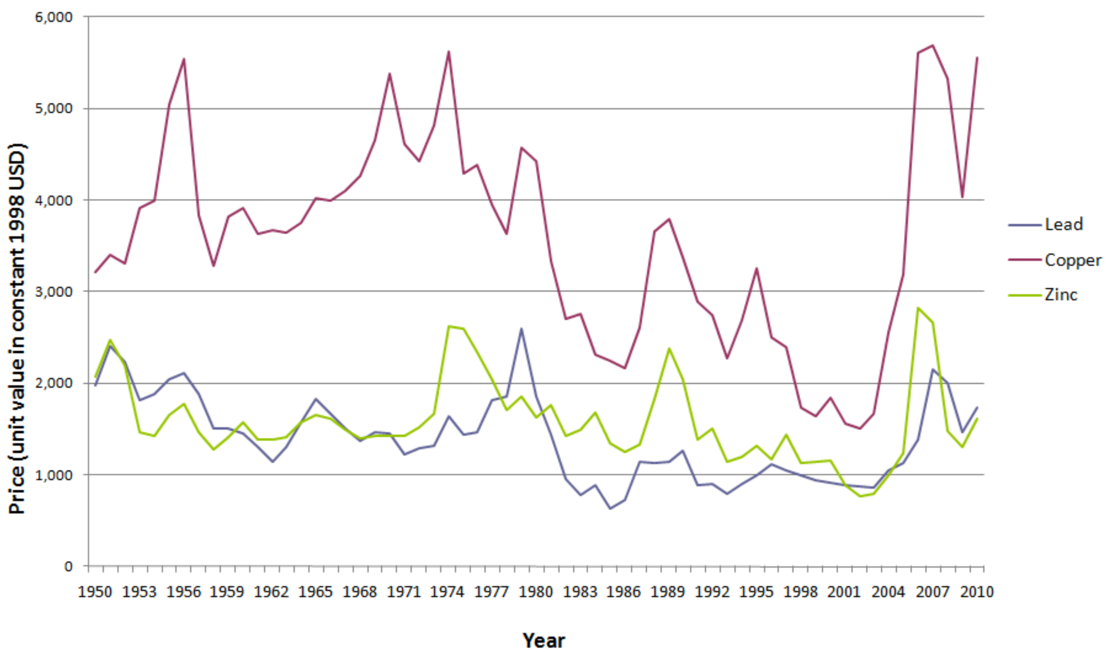
Non-Renewable Resources

The prices of non-renewable resources have also shown a recent uptrend that reverses a long-standing pattern of stable or declining prices (See Figure 3). There have been previous periods, for example the mid-1970s and the late 1980's, when price spikes led to some speculation that the long-term declining trend was over, but these previous price increases proved temporary. This may yet be the case with the current price spikes for many minerals, but there are indications that this time the trend is more permanent.

A major factor in increasing prices for non-renewable resources is the rapidly growing demand from fast-developing nations including China, India, and Brazil. An increasing price trend for non-renewables is, of course, consistent with fundamental exhaustible resource theory as first set forth by Hotelling in the 1930's (Hotelling, 1931).[4] The theory, however, can be confounded by long periods and high discount rates: if exhaustion of a resource is not foreseen within the medium-term future, potential future shortages will not be reflected in current prices. Rising prices indicate that future shortages have begun to enter the consciousness of today's commodity traders. This does not mean imminent exhaustion of the entire resource, but rather a shift to more expensive extraction of lower-grade ores[5]. These rising extraction costs are in turn associated with higher current or projected energy prices. Both higher extraction costs for energy resources themselves (Figure 4), and the increased use of energy in lower-grade resource extraction, contribute to this trend.

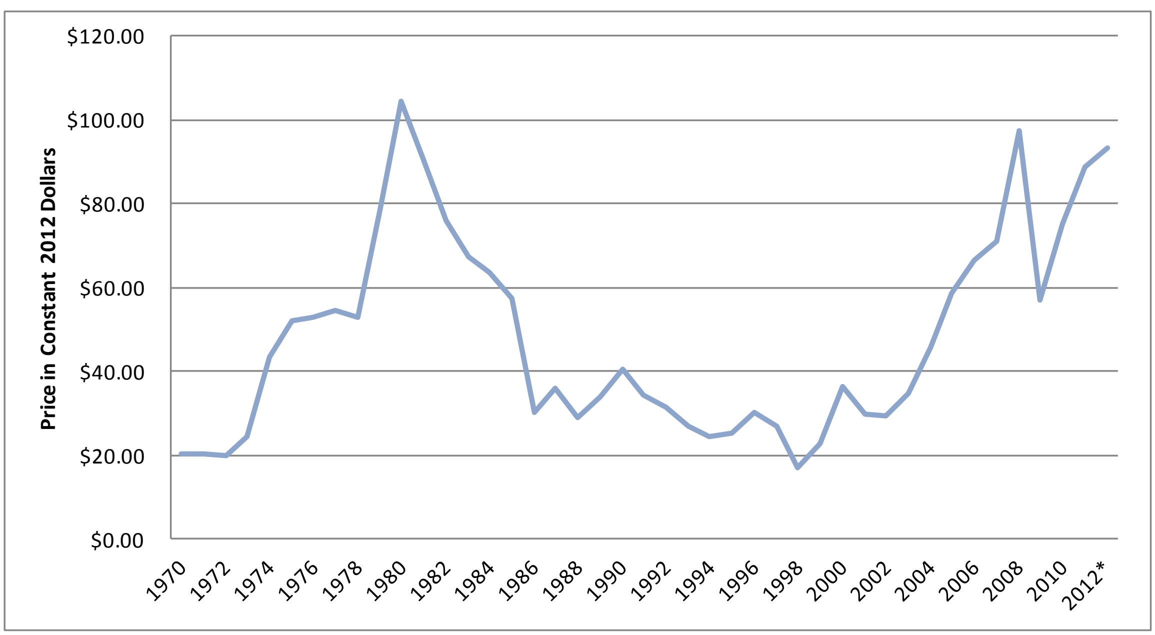
[4] See Harris, 2006, Chapters 5and 12, for an exposition of the theory of non-renewable resources.
[5] See Heinberg, 2011, Chapter 3: "Earth's Limits: Why Growth Won't Return".

Figure 3: Price Trends for Selected Minerals (Price per ton)



Source: USGS, available at: http://minerals.usgs.gov/ds/2005/140/

Figure 4: Oil Prices, 1990-2012



Sources: Data from Energy Information Administration http://www.eia.gov and http://inflationdata.com

Ecosystems and Renewable Resources

Ecologists identify a number of major areas in which current economic activities are systematically undermining the planet's long-term carrying capacity. These include:

- Erosion and degradation of topsoil; topsoil losses worldwide are currently estimated at 24 billion tons annually, with nearly 11% of the world's vegetated land suffering moderate to extreme degradation.[6]
- Overuse and pollution of fresh water supplies -- a problem in virtually every country, reaching critical levels in China, India, and parts of the former Soviet Union.[7]
- Loss of biodiversity, with more species driven to extinction every year than at any time in the preceding 65 million years of planetary history.[8]
- Extreme climate fluctuations resulting in heat waves, drought, flooding, and disruption of water supplies.
- Collapse of fisheries and other overexploited ecosystems, with associated irreversible effects due to changes in species balance and invasive species.

A recent article in *Nature* suggests that these trends are approaching a "tipping point" leading to an irreversible "planetary-scale transition".[9] This transition to a less diverse, less productive planetary ecosystem will have profound effects for human well-being.[10] The prospect of ecological collapse should also have a major effect on principles of economic analysis. Economists have basically ignored macro-level ecological impacts, which are difficult to capture as "externalities". They can only adequately be addressed by considering Daly's principle of limits to economic scale. Clearly, this issue has now moved beyond a theoretical consideration for the future, and is a pressing immediate concern.

The broader ecosystem changes and their impact on human well-being can be difficult to quantify, but we can see a well-defined example of the phenomenon in fisheries. Many of the world's major fisheries have passed their peak sustainable yield, and are now in decline (Table 2). The global wild fish catch appears to have peaked around 1995 and has been stable or slightly declining for the past 15 years (Figure 5). Expansion of aquaculture production has enabled overall output to keep up with population growth, but per-capita catch has not increased since about 1970.[11] And of course many forms of aquaculture have significant environment problems, implying that this increase cannot continue indefinitely.

Fisheries thus provide a case study in approaching and reaching carrying capacity. It is possible that better fisheries management could prevent fishery collapse, but the essence of good fishery management is to limit catch to a level at or below sustainable yield. Even a global institution of good fishery practices (consistent with an economic principle of maximizing net

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6 Ehrlich, Ehrlich and Daily, 2003

7 Postel, 2003

8 Hooper et al., 2012.

9 Barnosky et al., 2012

10 Millennium Ecosystem Assessment, 2005a, 2005b; Cardinale et al., 2012

11 See Harris, 2006, Chapter 14, Figure 14-7; per capita catch has remained at about 16 kg per capita since 1970, after doubling from 8 kg/cap between 1950 and 1970.

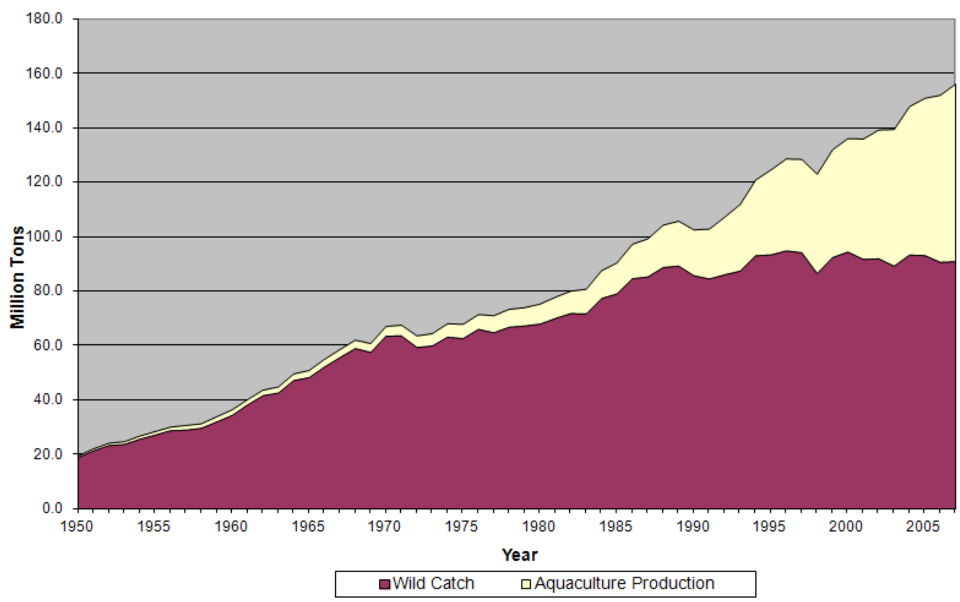
social benefit) cannot expand fishery output much beyond current levels. For fisheries, as well as for an increasing number of ecosystems including inland water, forest and wetland biomes, human demand is now clearly pressing up against carrying capacity on both regional and global scales. This suggests that Daly's concept of a "biocentric optimum" taking into account ecosystem capacity, rather than an "anthropocentric optimum" based on marginal costs and benefits, is essential for effective management of human/ecosystem interactions.[12]

Table 2: Declining Major Fisheries

Ocean Area	*Estimated Annual Potential (million tons)*	*Year Potential Reached*	*Decline from Peak Yield*
East Central Atlantic	4	1984	-22%
Northwest Atlantic	4	1971	-38%
Southeast Atlantic	3	1978	-53%
West Central Atlantic	2	1987	-28%
East Central Pacific	3	1988	-13%
Northeast Pacific	4	1990	-12%
Southwest Pacific	1	1991	-13%
Antarctic	0.2	1980	unavailable
World	82	1999	unavailable

Sources: FAO, The State of World Fisheries and Agriculture, 1997; McGinn, *Safeguarding the Health of Oceans,* Worldwatch Institute 1999.

Figure 5: Wild Fish Catch and Aquaculture Production.



Source: U.N. Food and Agriculture Organization (FAO), FAOSTAT Statistical Database, at http://www.fao.org/fishery/statistics/software/fishstat/en, updated February 2011.

[12] Daly, 1996, Chapter 2.

Energy and Climate

In the ecological perspective championed by Daly, energy and the entropic limits on energy use have a special importance, following the principles set out in Nicholas Georgescu-Roegen's fundamental work on energy and the economic process.[13] The entropy principle points to three essential limits on energy use: the planetary supply of non-renewable energy resources, the solar flux, and the ability of the ecosphere to absorb the wastes produced by energy consumption.

The first of these has received much attention in the recent debate over "peak oil". Estimates of "ultimately recoverable" oil vary widely. Worldwide cumulative oil consumption is now about 1.1 billion barrels, and some analysts believe that there is only about another 1 trillion barrels of extractable oil remaining. If this is true, we are at or close to a global peak, given well-established patterns of "peak oil" for individual nations such as the U.S. More optimistic estimates of ultimately recoverable oil, including natural gas liquids and "unconventional" sources, would extend the period until the peak for at least several decades.[14]

As noted in Figure 4, there has been a clear increasing trend in the price of oil. This is unlikely to be reversed. Even if the more optimistic estimates of ultimately recoverable oil prove true, the extension of the peak is dependent on the recovery of oil from unconventional sources such as shale and very deep water, which is generally higher-cost. Thus regardless of the resolution of the peak oil debate, we are likely to have entered a regime of higher oil prices, especially given continuing rapid demand increases from developing economies (see Figure 6).

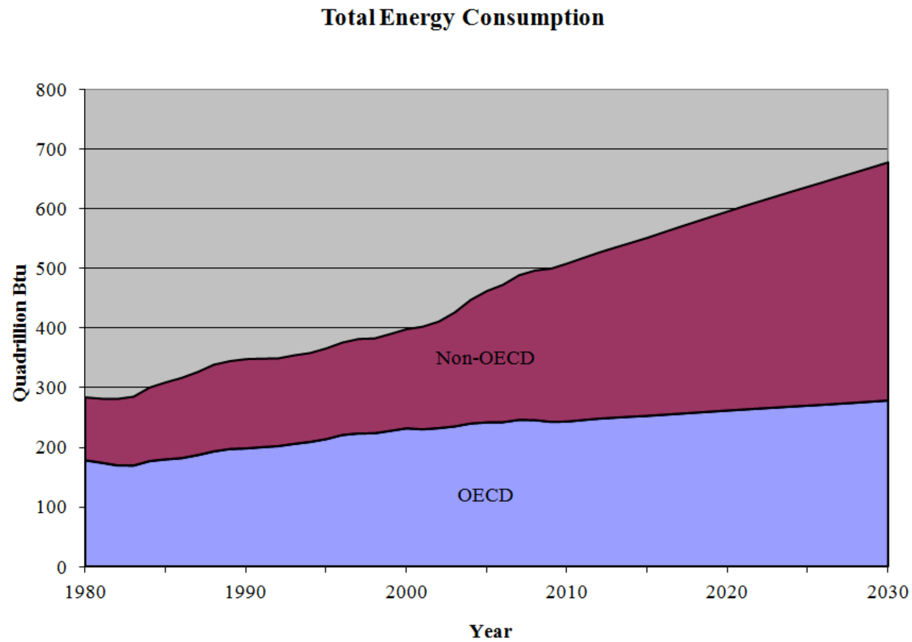
The more binding constraint on energy use has to do with its waste products, in particular carbon dioxide. The lifetime of fossil fuels could in theory be extended significantly by increased reliance on coal and its derivatives. But of course coal, along with some kinds of unconventional oil, represents the dirtiest of fossil fuels. As Figure 7 shows, carbon emissions from fossil fuel use have risen steadily, with no sign of stabilization, let alone reduction. Despite numerous warnings from scientists, global economic growth remains tied to fossil fuels. Given the highly unequal distribution of per capita consumption and per capita emissions (Figures 6 and 7), there is certain to be further significant demand growth from the developing world in coming decades.

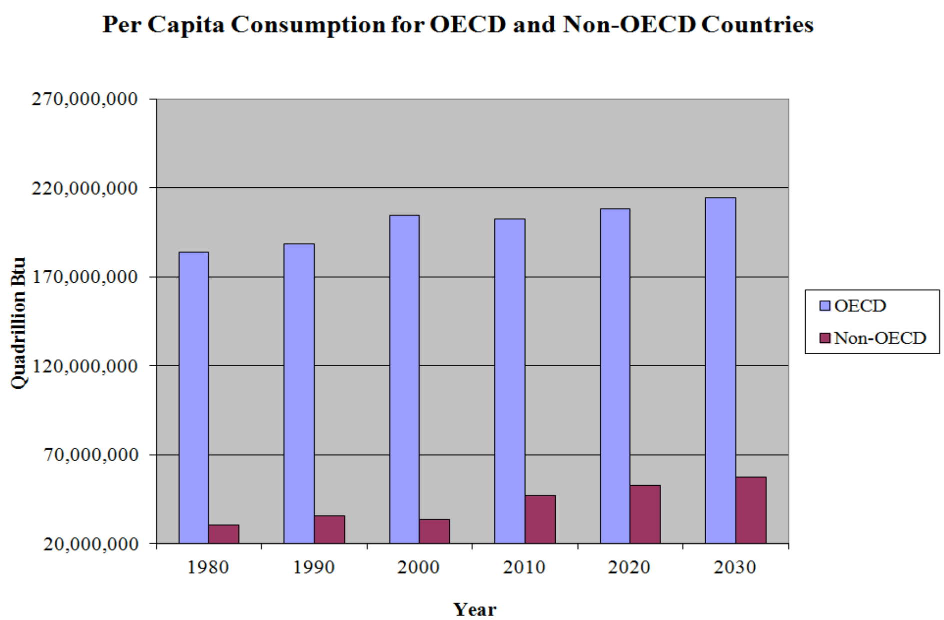
Despite numerous warnings from scientists, little has been done to internalize the true costs of carbon or to slow emissions growth. There is a huge disconnect between "business as usual" and the recommendations of scientific groups such as the Intergovernmental Panel on Climate Change (IPCC). The IPCC has called for stabilization of carbon *accumulations* at no more than 450-550 parts per million, which requires drastic reduction in carbon *emissions* (Figure 8). Many scientists believe that even these targets are insufficient to keep warming below 2˚C. Even at 2˚C there is a possibility of catastrophic consequences such as destabilization of the Greenland ice sheet, causing up to seven meters of sea-level rise.[15] Two scientific models including deep-sea warming have indicated that CO_2 emissions must fall to

[13] Georgescu-Roegen, 1971.
[14] Hall and Klitgaard, 2012, Chapter 15; Deffeyes, 2001, 2005; Heinberg 2007; Campbell, 1998, 2005.
[15] Hansen et al., 2007.

near zero by the mid-twenty first century to prevent temperature increases in the range of 4˚C (7˚F) by 2100.[16] Any carbon reductions even approaching these recommendations obviously imply major changes in patterns of global economic growth – again suggesting the essential role of Daly's concept of entropic limits.

Figure 6: World Energy Consumption Projections, Total and Per Capita

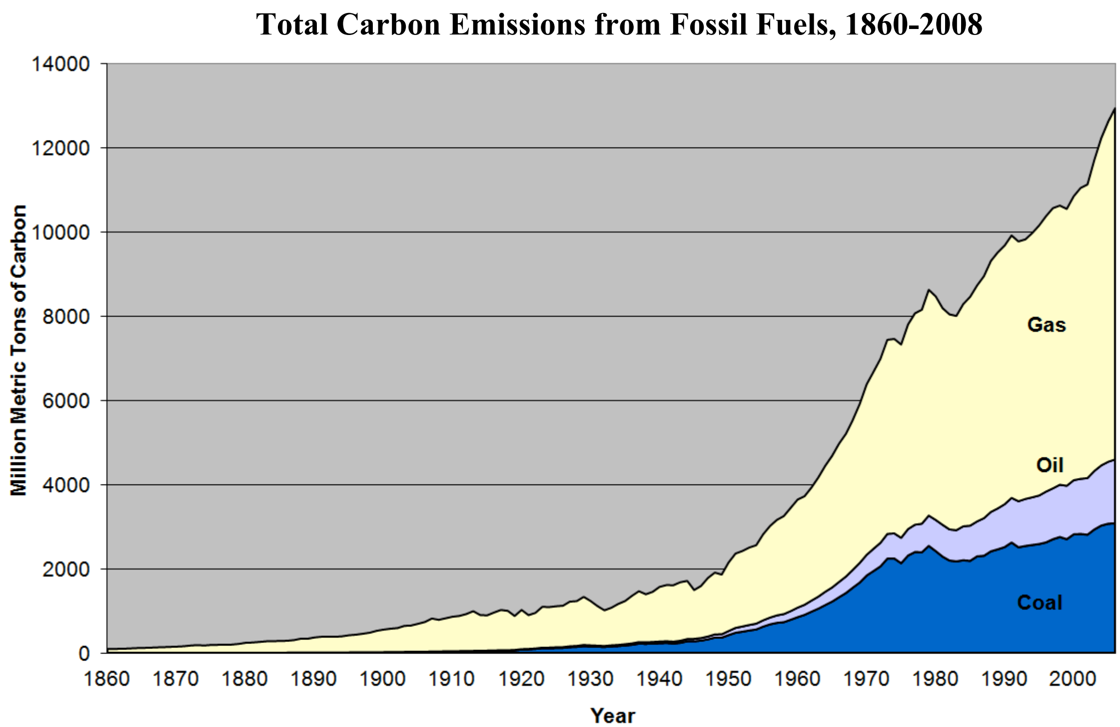




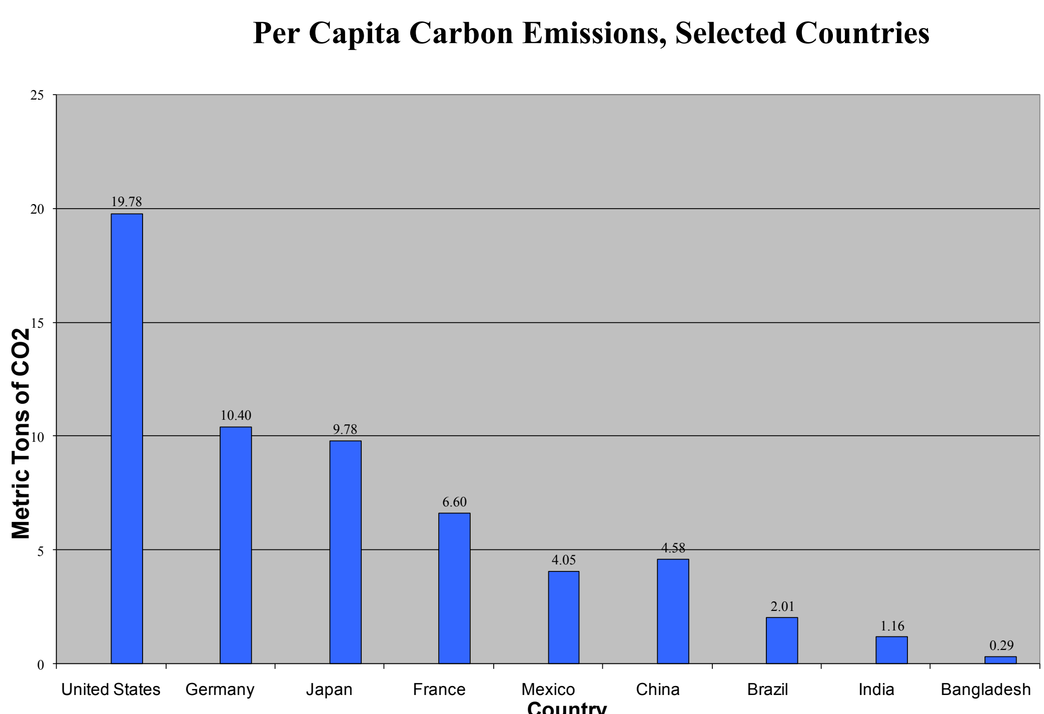
Source: accessed at: http://www.eia.doe.gov/oiaf/ieo/ieorefcase.html

[16] See Harris and Goodwin eds., 2009, Chapter 4 (Baer et al., "The Right to Development in a Climate-Constrained World" and Chapter 8 (Harris, Ecological Macroeconomics: Consumption, Investment, and Climate Change); Schmittner et al., 2008; Matthews and Caldeira, 2008.

Figure 7: Global Carbon Emissions from Fossil Fuel Consumption, Total and Per Capita in Selected Countries

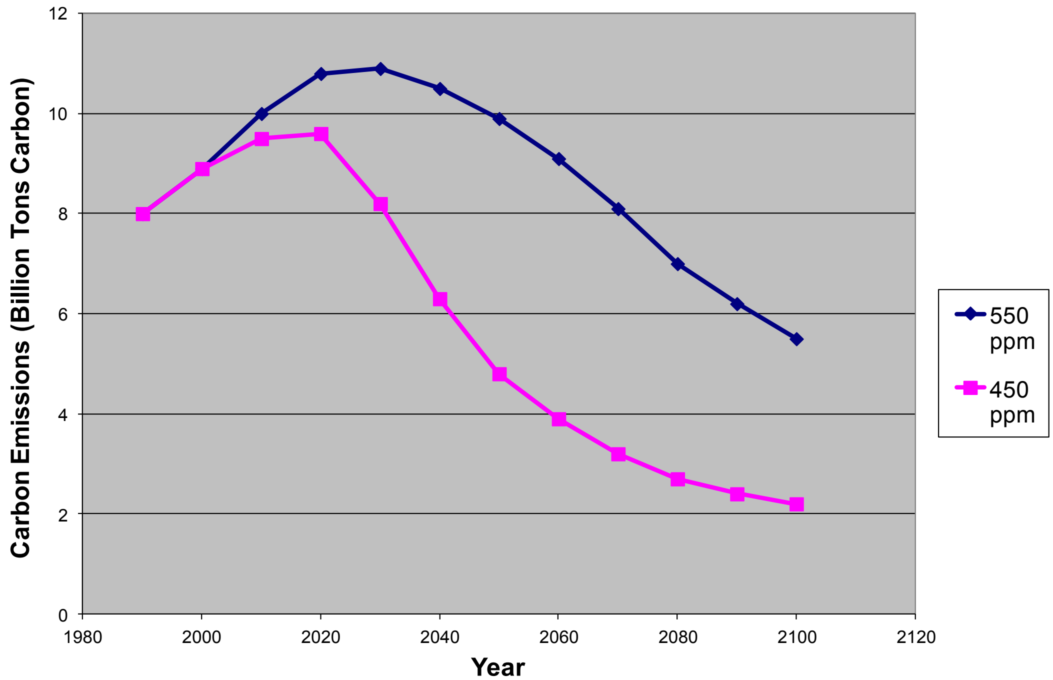


Source: http://cdiac.ornl.gov/trends/emis/glo.html accessed July 2011



Source: International Energy Annual 2008 update

Figure 8: Carbon Emissions Projections for Climate Stabilization



Source: Adapted from IPCC, *Climate Change 2001: The Scientific Basis*, http://www.ipcc.ch/

An entropic perspective implies a massive transition away from fossil fuel dependence, with the use of fossil fuels strictly limited and a far more efficient economic system powered directly or indirectly from the flux of solar energy. One economic interpretation of this would be a strategy of "decoupling" economic growth from energy use. In theory, economic growth could continue while energy use is reduced through greater efficiency, and carbon emissions further reduced by a transition to renewable energy sources. To a very limited degree, this is already occurring: economic systems are becoming somewhat more energy-efficient, and renewable power sources such as wind and solar are experiencing rapid growth.[17]

Theorists advocating "prosperity without growth" argue that such "decoupling has practical limits (Jackson 2009; Victor 2009; Hall and Klitgaard 2012). The deeply-rooted dependence of current economies on fossil fuels offers opportunities for decoupling, but would require fundamental changes in the nature of growth – and in terms of energy and resource throughput, and end or reversal of growth – in order to achieve the kinds of carbon reduction targets suggested by the IPCC and other scientists. Decoupling is certainly needed, involving massive investment in energy efficiency and renewable supply systems, but these theorists suggest that reduced consumption and lifestyle changes are also essential, at least for the currently developed economies.

[17] See Harris 2006, Chapters 13 and 17, for data on reduced energy intensity in industrial economies and expansion of renewable energy sources.

Macroeconomic Theory Perspectives

In his essay, "Elements of Environmental Macroeconomics," Daly suggests that the main requirement for macroeconomics to adapt to real-world limits is to adopt a macroeconomic goal of *optimal economic scale* to accompany goals of full employment, price level stability, and distributive justice (Daly, 1996, Chapter 2). This would certainly represent a major shift away from the current structure of mainstream macroeconomics. Distributive justice does not rank high among standard macroeconomic goals, and any concept of scale is completely absent. What would it mean for macroeconomics to start, at last, to take Daly's proposition seriously?

One approach to answering this question is to modify macroeconomic growth models. There appears to be no reason why standard economic models, such as the Solow growth model, cannot be adjusted to take into account resource constraints. Interestingly, Solow himself has recently commented:

> "There is no reason at all why capitalism could not survive with slow or even no growth. I think it's perfectly possible that economic growth cannot go on at its current rate forever … it is possible that the US and Europe will find that…either continued growth will be too destructive to the environment and they are too dependent on scarce natural resources, or that they would rather use increasing productivity in the form of leisure . . . . There is nothing intrinsic in the system that says it cannot exist happily in a stationary state."[18]

Without an assumption of steady technological progress, Solow-type growth models converge to a steady-state of constant output per worker (Solow, 1970). It is the assumption of technological progress that causes the model to exhibit continual growth in per capita income. Adding a resource constraint to Solow-type growth models can offset the effects of technological progress, leading to convergence to a steady-state of output per worker. If population also stabilizes to a zero rate of growth, this will give an overall steady-state equilibrium.[19]

An alternative approach is to offset the effects of technological progress with a decreased input of labor time per worker (a shorter work day and/or work week). This approach is central to the model present by Victor (2008). This corresponds to Solow's suggestion above that increased productivity be taken in the form of leisure. This also harks back to speculation by J.S. Mill (1994 [1848]) that satiation of material needs would lead to a cessation of economic growth – an outcome that Mill viewed as desirable.

There is thus no formal reason why macroeconomic models need to reflect an assumption of perpetual economic growth. This assumption, however, is deeply embedded in most approaches to macroeconomics, whether at the professional or textbook level. In practical terms, the main reason for this nearly universal acceptance of the necessity of economic growth has to

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[18] Robert Solow, quoted in Steven Stoll, "Fear of Fallowing: The Specter of a No-Growth World" Harper's Magazine, March 2008.

[19] See Cleveland, 2003, for an exposition of resource constraints in standard models of economic growth and review of relevant literature.

do with the need to maintain employment. In real-life experience, whenever economic growth falters or temporarily reverses, as in a recession[20], unemployment rises. The solution to unemployment is therefore widely seen as a resumption of economic growth. But this is a result of a perspective based on experience with current institutions and accepted economic policies.

In the current situation of a seriously depressed economy, Keynesian expansionary policies to promote a recovery may be essential, as advocated by Krugman (2012). But in the longer term, full employment does not necessarily depend on continued exponential growth. Full employment is possible in a steady-state economy, but it requires different institutions from those that prevail in current market economies (Victor, 2009). The barriers to achieving well-being without economic growth, at least in advanced economies, are therefore political and institutional rather than economic.

A central issue for economic theory is whether more traditional Keynesian economic policies can be combined with a theory of resource and environmental limits to adapt to new realities. I have argued elsewhere that a "green Keynesianism" is possible, and indeed essential, for adaptation of economies to carbon constraints and environmental sustainability (Harris 2007, 2009, 2013a, 2013b). Specifically, I suggest that:

> There is a close complementarity between new Keynesian and ecological perspectives. While older Keynesian analysis was oriented towards promoting growth, a true Keynesian analysis of the relationship between investment and consumption does not depend on a growth orientation. What this analysis has in common with an ecological perspective is the rejection of market optimality assumed in classical models. Moving away from the neoclassical goal of inter-temporal utility maximization allows for different, pluralistic economic goals: full employment, provision of basic needs, social and infrastructure investment, and income equity. These goals are compatible with environmental preservation and resource sustainability, whereas indefinite growth is not. But they require a revitalization of the sphere of social investment, seriously neglected (indeed often omitted completely) in standard models.[21]
>
> There is a good precedent for this approach in Keynes' own writings. In "Economic Possibilities for our Grandchildren" Keynes envisioned an end to economic growth. He suggested that a different structure of economic incentives and values would be appropriate for a world in which material economic growth had ceased. In his essay on "The End of Laissez-Faire" he also recognized the importance of social direction of investment in achieving what he anticipated to be a better economic system: "I believe that some coordinated act of intelligent judgement is required as to the scale on which it is desirable that the community as a whole should save …and whether the present organization of the investment market distributes savings along the most nationally productive channels. I do not think that these matters should be left entirely to the

[20] A recession is defined as "a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales." See http://www.nber.org/cycles.html

[21] Harris, 2013a, also at http://www.ase.tufts.edu/gdae/publications/working_papers/index.html

chances of private judgement and private profits, as they are at present."[22] Keynes also famously proclaimed that "The outstanding faults of the economic society in which we live are its failure to provide for full employment and its arbitrary and inequitable distribution of wealth and incomes"[23] – a statement that seems to have particular contemporary resonance.[24]

Daly, like Keynes, recognizes the importance of orienting theory and policy towards goals of social investment and economic justice. Mainstream economic theory has moved far from this perspective. This is what makes mainstream theory an unreliable guide to responding to today's problems. The assumption of a self-regulating, self-adjusting economic equilibrium makes it essentially impossible to respond to problems like the need for a major energy transition or adjustment to a society with a stabilized population and a higher proportion of elderly. The Keynesian perspective transforms problems into solutions: massive investment in a clean-energy transition, or in health and elder care services, generate employment and so appear not as net costs but as net benefits to society.

From the point of view of the developing world, an end to growth hardly seems like an encouraging prospect. But very different growth paths are possible. Investment in energy efficiency, renewable energy systems, clean water, basic health care, primary and secondary education, forest conservation and sustainable resource use, etc., provide extensive possibilities for generation of employment without damaging the environment. In the long term, the growth of resource "throughput" must end, but in the medium term a better goal is "convergence", with declining use in the global North, based on efficiency and lifestyle change rather than deprivation, and modestly increasing use in the global South.

Scientists have told us in no uncertain terms that unless we adapt our economic systems to planetary limits we face catastrophe before the end of the twenty-first century (Barnosky, 2012; Hooper, 2012; Matthews and Caldeira, 2008; Schmittner et al., 2008). It is up to economists to respond, and there are plenty of options available in the microeconomic and macroeconomic toolkits if we choose to use them.

Neo-classical economics, despite its tunnel vision on many of the "big" questions, may be effective in determining efficient solutions once better goals are identified. Keynesian economics provides avenues for infrastructure investment and employment generation that can be redirected to "green" ends. The school of ecological economics inspired by Daly provides new forms of analysis more specifically appropriate for ecosystem functions and resource limits (see e.g. Costanza and Farber 2002; Costanza et al., 2004; Malghan 2010). By building on this rich legacy, the discipline of economics can contribute to, rather than retard, the process of finding solutions to the twenty-first century challenges of population, environment, development, and well-being

[22] See Keynes (1963 [1930]), "The End of Laissez Faire" and "Economic Possibilities for Our Grandchildren".
[23] See Keynes (1964 [1936]), Chapter 24, "Concluding Notes on the Social Philosophy towards which the General Theory Might Lead."
[24] See Harris, 2013b, for further discussion of the specific potential of "Green Keynesianism".

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