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Reconciling Growth and the Environment

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Abstract

Macroeconomic theory and policy are strongly based on the assumption that economic growth is a fundamental goal. The environmental realities of the twenty-first century compel a reassessment of macro theory in terms of the impact of current growth patterns on planetary ecosystems.

This paper examines the macroeconomic impacts of growth in terms of several major areas of conflict between economic demands and ecosystem capacities:

- (1) energy use and fossil fuel dependence
- (2) greenhouse gas emissions and climate change
- (3) transportation systems and automobile use
- (4) food systems and agricultural productivity
- (5) water, forests, and fisheries
- (6) toxic chemicals and wastes

Implications for macroeconomic theory include a modification of the goal of increasing consumption, and a distinction between the consumption of necessities and luxuries. In addition, macro theory needs to address the issue of how to achieve a stable, full-employment economy in the absence of continual growth. The role of social investment and the provision of public goods needs to be recognized. The concept of a 'long-term growth path' should be modified to take account of the specific impact of investment choices that affect long-term economic structure, and the concept of GDP needs to be broadened to a multidimensional measure of well-being.

Macroeconomic policy implications include a shift in tax burden from income, capital, and labor to energy, materials, and waste flows, an increase in public investment, and new global institutions to regulate capital flows and transfer funds to developing nations.

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Reconciling Growth and the Environment

I. Introduction

There are good reasons why the word 'sustainability' has become popular. It emphasizes a subject that had become too nearly forgotten in economic theory, as well as in much economic behavior (including both corporate behavior and public policy): that is, the subject of the future, especially when considered in a long-term, generational perspective. Sustainability is about the possibility that the things we value in the present will continue to exist in the future. In this paper we will assess the usefulness, even the viability, of contemporary mainstream economic theory against the criterion of whether this theory contributes to the understanding and promotion of sustainability in economic systems.

Macroeconomic theory and policy are strongly based on the assumption that economic growth is good. Keynesian and neoclassical perspectives, as well as their many current variants, all accept growth as the goal, while differing over the best means to achieve that goal. However, throughout the development of economics there have been sub-currents challenging the possibility and/or desirability of continual and unlimited growth.

Two lines of thought have suggested limits or significant modifications to economic growth. One tradition is that of J.S. Mill, whose 'stationary state' represented a desirable goal of adequate consumption combined with continued cultural development. His heirs include Keynes himself (see e.g. Keynes, 1930), as well as recent advocates of 'sustainable consumption', including the small but persistent voluntary simplicity movement (see Durning, 1992). The other tradition is the Malthusian view of physical constraints on population and economic growth. In recent years Herman Daly (1991, 1996) has revived the concept of the steady state as an alternative to unlimited economic growth, advocating the concept of sustainable macroeconomic scale.

Mainstream economics has not been seriously influenced by the perspective of either Mill or Malthus. Current macroeconomic theory reflects the past two and a half centuries' experience of economic growth. The affluence of modern industrialized countries, as they are currently organized, depends on an economic development package that includes:

- (1) higher per capita purchasing power, resulting from
- (2) higher output per worker, achieved by
- (3) accumulation of capital equipment, as well as
- (4) technological and institutional innovations, along with
- (5) increased energy use and material inputs, supported by
- (6) a consumerist culture that assures that the goods produced will be purchased.

The promise of globalization is to extend this package to the presently less developed countries, leading to continual growth in living standards, consumption, and GDP. But a strong environmental critique maintains that we cannot continue with the fifth piece of

the package – increased energy use and material inputs – without ecological catastrophe. In this view, current use of materials and generation of wastes is already straining or exceeding the planet's carrying capacity. It is therefore not physically possible for the global South, with still-growing population, to imitate the consumption patterns of the North, any more than it is possible for the North to continue indefinitely increasing output and consumption.

If this environmental critique is well grounded, then the nature of economic growth in the twenty-first century will be fundamentally different from the resource-intensive growth of the previous two centuries. Economic systems will have to satisfy demands for higher living standards for a larger global population while adapting to inescapable environmental constraints. This would not necessarily mean an end to economic growth, but will require a significant reorganization and reconceptualization of growth that must include some combination of much greater efficiency in resource use, stronger environmental protection, and a shift in the composition of consumption from material goods to services.

There is evidence that all three of these trends are in fact occurring in currently developed economies. This leads some economists to believe that the environmental critique is overstated. One argument claims that markets will adapt to ecological limits, without any necessity to deviate from the present growth-dependent course. Such a process of adjustment would, to be sure, require informed government intervention to correct the failure of markets to reflect environmental costs. Microeconomic incentives would have to be changed through higher prices reflecting scarcer resources or internalized environmental costs. The case for this kind of intervention is well established in standard economic theory.

The case for the more radical position of the environmental critics is based on a different assessment of the scale of the problems. If indeed the impact of economic growth on major ecological systems is potentially catastrophic, then more drastic changes are needed in theory and policy, not only at the micro but also at the macroeconomic level.

In this paper we will examine the macroeconomic impacts of growth in terms of several major areas of conflict between economic demands and ecosystem capacities:

- (1) energy use and fossil fuel dependence
- (2) greenhouse gas emissions and climate change
- (3) transportation systems and automobile use
- (4) food systems and agricultural productivity
- (5) water, forests, and fisheries
- (6) toxic chemicals and wastes

In all of these areas a strong case can be made that current patterns of growth are unsustainable. In each area the problems of limits, overuse, and degradation of resources imply a reassessment of macroeconomic growth goals, a reorientation of policies at both

the macro and micro levels, and a rethinking of basic economic theory to accommodate revised goals and policies.²

II. Energy Use and Fossil Fuels

Energy has a unique role in all economic systems, and its importance increases in advanced industrial systems with high energy use. The centrality of energy as the essential input to productive processes has always been emphasized by theorists in the ecological economics school (see e.g. Georgescu-Roegen 1971, Odum and Odum 1976, Peet 1992, Daly 1991b). However, energy has no special standing in most macroeconomic theory. Economic growth is seen as dependent on inputs of capital and labor, with energy rarely specified as an independent variable. Thus standard growth models have no limits or constraints related to the availability of energy. This is a serious oversight.

World consumption of fossil fuels (oil, coal, and natural gas) quadrupled during the second half of the twentieth century, from about 2 billion tons of oil-equivalent in 1950 to close to 8 billion tons by 2000. The use of fossil fuels represents about 85% of commercial energy use, while hydroelectric and nuclear account for 7% and 6% respectively. Solar, wind, geothermal, and biomass account together for less than 1%. Projections for future energy use during the first two decades of the twenty-first century show a 59% global increase, with energy use in the developing world more than doubling over 1999 levels (U.S. Department of Energy, 2001). Unless there are dramatic changes in current energy price structures, the great bulk of this additional energy use will also come from fossil fuels.

The 2002 World Summit on Sustainable Development considered, but failed to adopt, a goal of supplying 15% of the world's energy needs from renewable sources by 2010. Even if a target in this range were achieved, fossil fuel use would still be about 30% higher than present levels by 2020. This projection presents grave problems. Even leaving aside issues of atmospheric carbon emissions and global climate change (to which we will return shortly), issues of ground-level pollution associated with fossil fuels are significant, especially in urban areas of developing nations. For oil, in particular, there are also questions of reserve limits. While overall fossil fuel reserves are adequate to meet projected needs for at least two more decades, a number of analysts project a peaking of world oil production between 2010 and 2030 (Campbell and Laherrère, 1998; MacKenzie 1996). The heavy concentration of oil reserves in the Middle East implies an unhealthy import dependence for major consuming nations, with attendant economic vulnerability to cartels or disruption of supply. This is especially true for the United States, which now imports well over half its oil supplies.

² The case that the world has reached, or will soon reach, environmental limits, has been made by Goodland (1992) and Daly (1992), among others. We seek here to review and update this assessment, and to examine its particular significance for macroeconomic theory.

So long as cheap and abundant fossil fuels provided the basis for economic growth, and environmental considerations played a minor role, economic growth models could afford to neglect energy as a specific input. But the approach that worked for twentieth century growth modelers is inadequate for the twenty-first century. The critical dependence of global economic growth on energy supplies, the centrality of fossil fuels to the global energy system, and the dominant role of oil among fossil fuels, are determining factors shaping economic growth. While a transition to more renewable energy sources is possible, and indeed essential, such a transition will not come about without major policy changes at the macro level. Macroeconomic theory and models of economic growth must reflect the unique role of energy, as well as the natural limits on all of the major energy sources on which the world now relies.

III. Greenhouse Gas Emissions and Climate Change

Beyond the issues around fossil fuels that were just mentioned, the greatest environmental danger they pose is that of atmospheric carbon emissions which cause global climate change. The 2001 report of the Intergovernmental Panel on Climate Change provides a comprehensive review of the evidence on human-induced climate change. Atmospheric concentrations of carbon dioxide have risen 31% above pre-industrial levels, reaching a level not exceeded during the past 420,000 years, and probably not during the past 20 million years. Global surface temperatures have risen for the past four decades, with a total increase over the twentieth century of about 0.6° C. Snow and ice cover have decreased, global average sea level has risen, and 'there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities' (IPCC, 2001a). For the twenty-first century, the IPCC projects a global surface temperature increase of 1.4 to 5.8° C (2.5 to 10° F).

The main driver of continued climate change is the carbon dioxide emissions associated with fossil fuel use. Current global carbon emissions are about 6.2 billion tons per year, and this figure will increase with increased consumption of fossil fuels. Despite efforts under the Kyoto protocol to stabilize emissions, they have grown significantly above 1990 levels. Moreover, the stabilization of global emissions at the Kyoto target levels would not be enough to prevent continued and growing atmospheric accumulations of carbon. In order to stabilize the accumulated level of atmospheric carbon, it will ultimately be necessary to cut carbon emissions by 70-80% from present levels. Even if and when this is achieved, effects such as increased ice melting, rising sea levels, and surface temperature increases will continue for hundreds of years (IPCC, 2001a).

It is thus apparent that human economic activity has already had major, irreversible effects on planetary ecology through induced climate change, with a prospect of extremely severe continued impacts during the twenty-first century even under the most optimistic scenarios. Details in these scenarios include reduction in crop yields especially in tropical and sub-tropical regions, an increased incidence of extreme weather events, increased inland flooding, massive disruption of water systems, decreased water availability in water-scarce regions, an increase in vector-borne diseases, extensive

damage to coastal ecosystems, and inundation of low-lying areas. The entire nation of Bangladesh, with 133 million people (projected to increase to 200 million by 2050) is especially at risk of inundation, as are the Netherlands, island nations, low-lying cities such as New Orleans and Miami, and tens of millions more people in coastal areas worldwide (IPCC, 2001b; Population Reference Bureau, 2002). All these impacts will be further magnified if positive feedback effects accelerate warming, disrupt ocean circulation, or cause collapse of the West Antarctic or Greenland ice sheets.

The massive potential impact of global climate change raises a fundamental question about economic growth. The essential assumption underlying growth models is that human well-being will be increased by economic growth. Overall, despite great social inequalities and extensive environmental damage, this has been true during the twentieth century. But the projected climate change scenarios raise the possibility that conditions for the current generation of children, and for future generations, will be significantly worse in important respects. The loss of ocean-front property in the U.S. will be painful for those affected, but pales to insignificance in comparison to the devastating loss of homes and lives in store for millions of people in Bangladesh and other low-lying countries. Malaria and other tropical diseases – long a major force against economic development – will infest a much larger portion of the planet. Existing crises in access to clean fresh water (see below), and related issues of health and military conflict, will accelerate.

If human economic activity results in the replacement of a relatively benign planetary climate with one that is more hostile to human well-being as well as to ecosystem diversity, it is difficult to argue that greater economic production will provide an adequate compensation. This is especially so if ever-greater portions of every nation's wealth must be diverted to activities that do not advance well-being beyond its present state, but simply try to make up for what is being lost or destroyed.

Can we hope that these worst scenarios will not be realized? It may be possible that, with an effective policy transition to the promotion of non-carbon fuels, and the reduction of other greenhouse gases, the effects of climate change might be limited, and the general presumption of increasing well-being resulting from economic growth would be affirmed. But this more optimistic outcome is strongly dependent on the nature of economic growth. And the nature of economic growth will be determined by macroeconomic policies that affect carbon dependence. In contrast to the economic development patterns of the twentieth century, when it was possible to view macroeconomic goals in terms of the promotion of stable growth, the challenge of climate change implies that macroeconomic policies must be judged not on whether they promote growth, but on what kind of qualitative change in economic systems they achieve.

IV. Transportation Systems and Automobile Use

The major contributor to global warming is the burning of fossil fuels, and the largest single use for fossil fuels is in transportation. The car culture that has been pioneered by the United States, and is rapidly extending worldwide, is the most significant cause of the relentless increase in global transportation fuel consumption.

As of 2000, four fifths of the world's 520 million automobiles were in industrial countries. In the United States, there were three vehicles for every four people. In Western Europe and Japan, the ratio was about one for every two people (Brown, 2001). Even if the industrialized countries can be considered to be approaching saturation in automobile use, there is enormous upward elasticity in the demand for cars throughout the developing world. In Brazil, there is about one car for every ten people, and in China and India less than one for every 100 people. The Chinese government has recently moved to unleash this potential demand by altering policies that favored bicycle transport to policies that encourage cars while banning bicycles from many urban roadways.

The car culture is not just about cars. It determines the mix of public and private transportation options, affecting how materials are shipped as well as the way the individuals travel. It enters our daily lives in the form of pollution, congestion, traffic accidents and parking. Behind these experiences are the materials and energy that go into making cars, the energy used to run them, and the physical space that cars take away from other uses. On a global scale, in addition to the contribution to global warming, loss of cropland to road networks is also an important issue.

In the U.S., an estimated 61,000 square miles are devoted to roads and parking lots. For every five cars added to the U.S. fleet, an area the size of a football field is paved – and croplands are often the first choice for roads because they are on flat, well-drained soils (Brown, 2001). The U.S. is a relatively land-abundant country with no domestic food shortage. The competition for land between cars and food can be much more critical in land-short developing nations with much higher population densities.

“If China were one day to achieve the Japanese automobile ownership rate of one car for every two people, it would have a fleet of 640 million cars, compared with only 13 million today . . . Assuming 0.02 hectares of paved land per vehicle in China, as in Europe and Japan, a fleet of 640 million cars would require paving nearly 13 million hectares of land, most of which would likely be cropland. This figure is over one half of China's 23 million hectares of rice land . . . While India has only a third the land area of China, it too has over a billion people, and an automobile fleet of 8 million. Its fast-growing villages and cities are also encroaching onto cropland. A country that is projected to add another half-billion people by 2050 cannot afford to cover large areas of cropland with asphalt for roads and parking lots . . . There is not enough land in China, India, and other densely populated countries like Indonesia, Bangladesh, Pakistan, Iran, Egypt, and Mexico to support

automobile-centered transportation systems and to feed their people. The competition between cars and crops for land is becoming a competition between the rich and the poor, between those who can afford to buy automobiles and those who struggle to buy enough food. Governments that subsidize an automobile industry with revenues collected from the entire population are, in effect, taxing the poor to support the cars of the wealthy” (Brown, 2001).

The model of consumption that encourages this path is the middle-class car culture of the developed nations. This model cannot be replicated in the developing world without disastrous impacts on the environment and perhaps also on food production.

This does not mean, of course, that the existing automobile-centered systems of the U.S., Europe, and Japan are sustainable while those planned for the developing world are not. The significant contribution of the transportation sector in the industrialized nations to global carbon emissions means that these countries are in no position to preach to developing nations about the need for restraint. The envisioned development of ‘hyper-cars’ getting 80-100 miles to the gallon, and the use of advanced fuel-cell technologies, could significantly reduce emissions problems. But these technologies are, under optimistic projections, 12-15 years away from realization, and during the intervening period many millions of current-technology vehicles will be added to the world’s automobile fleet. And of course more efficient automotive technology cannot solve the problem of land use conflicts in densely populated countries.

The transition to a more environmentally-friendly transportation system in developed nations will be a huge challenge, requiring substantial social investment as well as modification of the consumption-oriented ethos which is presently driving continued increases in traffic congestion and in emissions. Macroeconomic issues of social investment and infrastructure, as well as social goals and values, are crucial to determining the future of transportation networks and land use.

V. Food Systems and Agricultural Productivity

Between 2000 and 2020 an average of over 70 million people a year will be added to the world’s population. To feed these additional people at the current world average consumption rate of 350 kg/cap of grain would require about 25 million additional tons of grain each year, a cumulative increase of 25% over present production levels.³ The actual increase required, however, is likely to be much larger than this, because, as incomes rise, there is a well-documented tendency for people to shift to more meat-intensive diets, which require significantly more grain use as animal feed. This in turn

³ These grain figures include direct consumption and indirect consumption (grain used as animal feed). They use the U.N. Food and Agriculture Organization system including unmilled rice, and are therefore higher than estimates, such as those of the U.S. Department of Agriculture, which use milled rice. Grain output supplies about 50% of global calorie consumption and uses about 50% of world agricultural land, so it can be used as an (imperfect, but easily quantifiable) proxy for total food production.

requires more land, water, and input use. The International Food Policy Research Institute, for example, estimates a cumulative global increase in grain demand of 35% between 1997 and 2020, with a 49% increase in the developing world (Rosegrant et al., 2001).

How much of a strain will this increased food demand impose on world agricultural production systems? Increases in the range of 40% clearly cannot be met by expanding cropland. There has been little expansion in global cropland since the 1980s, and most additional land theoretically available for cropping is in forested tropical areas, generally poorly suited for agriculture and involving significant ecological costs to convert. Moreover, housing as well as transportation systems and other infrastructure for growing populations create pressures on croplands. For all these reasons, there is general agreement that the great bulk of the projected demand increase must be met through increasing yields.

But worldwide yield growth from agriculture is slowing. Rates of growth in yields averaged 3% per year in the 1960s, and about 2% in the 1970s and 1980s. During the decade of the 1990s world yield growth rates were only 1.3% per year. This trend reflects diminishing returns from the Green Revolution. Rapid rates of increase in yields were obtained from grain varieties that were bred to accept large quantities of fertilizer and irrigation water, converting much of these inputs to grain for consumption rather than to the leaves and stalk of the plant. The requirement for high input use has resulted in significant environmental problems of fertilizer runoff and water pollution and overdraft. By 2000, the benefits of the Green Revolution technologies had been largely exploited, leaving little room for additional yield growth from these input-intensive techniques.

Current grain yields average a little over 2 metric tons per hectare in developing nations (excluding China), as compared to 3.7 metric tons per hectare in developed nations. To accommodate a 40% increase in grain demand, average global yields would have to rise to about 4 metric tons per hectare, assuming a modest increase in land use (Harris, 1996 and 1999). Doubling grain yields in the developing world in a 20 year period would require rates of growth in yields in excess of 3% per year – well above current trends. For this reason, almost all projections for global food supply and demand envision the developing world importing much larger quantities of grain. The International Food Policy Research Institute reports that ‘cereal production in the developing world will not keep pace with demand, and net cereal imports by developing countries will almost double between 1995 and 2020 to 192 million tons in order to fill the gap between production and demand. Net meat imports by developing countries will increase eightfold during this period to 6.6 million tons.’ (Pinstrup-Andersen et al., 1999, p. 5).

Does this indicate a Malthusian outcome, with increasing danger of food shortfalls and famine? Not in the classic sense, since global export capacity will probably be adequate to meet the demand. It does, however, raise several troubling possibilities. One relates to the special case of China, which has had rapid success in raising yields to over 4 metric tons per hectare. However China’s population is still projected to increase by nearly 200 million (Population Reference Bureau, 2002), cropland loss to urban and industrial uses

continues, erosion is a serious problem, water overdraft is severe, and pollution from fertilizer runoff is widespread. Should China fall significantly short of self-sufficiency in grains, its entry into the world market as a major importer could raise prices, creating great hardship for import-dependent but poorer nations, especially in Africa. In addition, the experience of China indicates that environmental problems resulting from the push to raise agricultural yields can be enormous.

Africa is closer to a genuine Malthusian crisis. With the world's most rapid population growth, Africa is projected to double in population before 2050, even taking into account the increased death rate from AIDS (Population Reference Bureau, 2002). Water constraints are extreme, with only 4% of cropland irrigated, and yields in Africa have barely increased in the past several decades, averaging only slightly over one ton per hectare. Much cropland and grazing land is being lost due to degradation, while deforestation is bringing ever more marginal land into production (Paarlberg, 1996).

The true neo-Malthusian threat in the twenty-first century is not that we will run out of food, but that agroecosystems will suffer such high environmental costs that water supplies and soil quality will be seriously degraded, leading to even greater dependence on artificial inputs and accelerating damage to future sustainability, especially in the developing world. Many environmental problems associated with agricultural production are long-term in nature: the effects of soil erosion and water overdraft, for example, may not affect productivity significantly for decades, but will eventually have devastating impacts when the topsoil is lost or the aquifer runs dry. In the short-term, however, the negative effects are usually masked by increases in agricultural productivity from additional inputs. This means that farmers have few market incentives to conserve resources for the longer-term future, since the immediate economic incentives promote more intensive production and resource use.

During the period 1950-2000 global agricultural production nearly tripled, running steadily ahead of population growth. We are already experiencing a shift from that experience of rapid growth in per capita food production to a situation of slower growth and tightening environmental constraints. This suggests that the concept of carrying capacity is relevant in analyzing the combined effects of population and economic growth. Carrying capacity is a relatively straightforward concept in population biology, and clearly applies to analyses of, for example, grazing stocks or fisheries. Economists have generally rejected it as inapplicable to human economic growth, essentially because technological progress allows escape from resource constraints – or at least enormous elasticity in extending those constraints. But in the area of global agricultural production it appears that we are already stretching the limits of biophysical production systems.

The introduction of carrying capacity constraints into economic theory would fundamentally change the role of technology in growth models. In most such models, technology appears as an inexhaustible source of increased production, raising the productivity of capital and labor in a secular fashion without limit. But with significant environmental constraints it seems that we must at least ask the question, 'What kind of technology?' Some technologies will worsen environmental problems, directly or

through unforeseen consequences (as in the case of impacts on ecosystems and genetic diversity). The market does not necessarily supply incentives for the development of environmentally friendly technologies. Thus, rather than simply seeking to provide stable conditions for economic growth, macroeconomic policy needs to be concerned with the direction of growth. In agriculture, this could imply moving subsidies from technologies that encourage overproduction and high input use to those that promote conservation and ecological technologies – a different approach from the standard economic recommendation for elimination of subsidies and free trade in agricultural commodities.

VI. Water, Forests, and Fisheries

“[H]umanity has entered the endgame in its traditional, historical relationship with the natural world.”

– James Gustave Speth, Dean of the Yale School of Forestry and Environmental Studies (Speth, 2002, p. 19).

The meaning of Speth's statement is especially evident in relation to renewable resources such as water, wood and food harvested from the oceans. History provides many examples of local catastrophes for peoples who exceeded the local limits of such resources. Humanity is now, for the first time, encountering on a global scale the limits placed by the natural ecosystems of the planet on the availability of renewable resources.

At present about one third of the world's population lives in countries suffering from moderate to high water stress, and in less than twenty-five years this figure is projected to be two thirds of the world's population (United Nations Environmental Programme 2002). The global supply of fresh water is fixed, with an annual freshwater runoff of about 47,000 cubic kilometers per year, or 7,000 cubic meters per capita (Gleick, 2000). The portion of global runoff that is stable and available for human use (i.e. excluding floods and remote areas) is significantly less. Since the available total can be increased only marginally through dam or river diversion projects, per capita availability falls steadily as population increases. Uneven regional distribution of water means that global per capita figures do not accurately indicate the frequency of regional water stress (less than 2,000 cubic meters per capita) and water scarcity (less than 1,000 meters per capita). All major areas of irrigated agriculture currently suffer from groundwater overdraft, often with severe impacts including restriction of urban water supplies, land subsidence, and salt-water intrusion into aquifers.

Similar, though less easily quantifiable, limits exist for the sustainable yields available from the world's forests and fisheries. Current patterns of forest loss in developing countries – about 13 million hectares annually, equal to 0.65% of forested area per year, or 6.5% per decade – arise from a combination of wood and firewood demand plus conversion to (often short-lived) agricultural uses. On the positive side, forested area in developed countries is increasing, as is plantation forest area worldwide. In theory, improved forest management practices and increased reliance on plantation forests and

recycling of wood products should make it possible to prevent excessive demands on natural forests. But such improved practices are a long way from reality, and demand for wood, which has grown steadily over the past forty years, is projected to continue to increase from 3.28 billion cubic meters in 1999 to about 4.35 billion cubic meters in 2015 (Brown, 2001; FAO, 2000a, 2001).

Overexploitation of ocean fisheries is a worldwide problem, with 11 of the 15 major fishing areas and over 60% of major fish species either fully exploited or in decline (McGinn, 1999, FAO, 2000b). Here also better management practices could reduce excessive pressures, but achievement of sustainable harvesting, especially in international waters, is extremely difficult. The global harvest of wild fish appears to have peaked around 90 million tons in the 1990s, and growth in fish consumption is now coming primarily from aquaculture. Aquaculture, however, is encountering serious environmental problems of physical and biological/genetic pollution. Per capita fish harvest, including both wild and cultivated, has barely increased since the late 1980s, and FAO projections envision little future increase in wild harvest, with expansion of aquaculture being essential to any increase in per capita consumption (Gardner, 2000; FAO 2000b).

VII. Toxic Chemicals and Wastes

As economic systems grow, their 'throughput' of energy and materials tends to increase.⁴ This net effect results from two opposing trends. One is the increase in per capita consumption of output. The other is 'dematerialization' – decreasing material use per unit of output (Ackerman, 2001; Wernick et al, 1996). In general, while intensity of materials use tends to decline with technological progress, this has been outweighed by increasing per capita consumption, leading to long term national and global increases in materials use (Gardner and Sampat, 1998). This raises questions of possible resource and environmental constraints. The original Limits to Growth report in 1972 (Meadows et al., 1972) focused on issues of exhaustion of mineral resources, but for most resources this prospect is still fairly distant due to technological progress, resource substitution, and discovery of new reserves. More recent discussion, including the 1992 update *Beyond the Limits* (Meadows et al., 1992), has focused on environmental impacts associated with expanded resource recovery and disposal. This is of greatest concern when the products and byproducts of resource throughput are toxic to humans or damaging to ecosystems.

By the late 1990s global output of chemical products for industry and agriculture totaled over \$1.3 trillion. Chemical industry production is projected to grow slightly faster than gross world product through 2020 (McGinn, 2002; OECD, 2001). Only about 10% of approximately 72,000 industrial chemicals have been thoroughly screened for toxicity, and only 2% have been tested to determine if they are carcinogens, teratogens, or mutagens (Miller, 1998). Chemicals in widespread use that are known to be both highly toxic and long-lived include halogenated hydrocarbons, dioxins and furans, and heavy

⁴ The term "throughput", introduced by Herman Daly, denotes both the input of materials and output of wastes resulting from the use of energy and resources by economic systems.

metals such as lead, mercury, cobalt, and cadmium (McGinn, 2002). As global production increases, especially in the developing world, the threats posed by the known and unknown dangers of toxic emissions and wastes intensify.

The 2001 Convention on Persistent Organic Pollutants seeks to ban 10 of the most damaging chemicals – but even if the POP convention succeeds, this addresses only a small portion of the global toxics problem. Persistent lead and mercury pollution are widespread throughout the world, despite recent reductions in emissions. Stockpiles of toxic wastes exist in almost all developed and developing nations, often with little regulation or adequate techniques for disposal. Common products such as PVC plastics, whose production, use, and disposal involve a range of toxic emissions, are expanding in use with little attention to problems of immediate toxicity or of long-term disposal. One of the most troubling problems is the migration of toxic chemicals from agriculture, industry and transportation into aquifers – another source of stress on the world's potable fresh water. This virtually irreversible problem is becoming evident both in industrial areas and in increasing nitrate and pesticide pollution of groundwater in agricultural areas (Sampat, 2001).

The use of toxic materials appears inextricably integrated into current production systems. A massive shift to 'industrial ecology' systems, involving extensive recycling and substitution of environmentally benign materials, could significantly reduce the long-term pollution and health problems associated with toxic emissions and wastes, but such a shift is not now on the horizon. In effect, there is a race between the spread of 'greener' technologies and rapid industrial growth using current technologies. In this context, economic growth is both a promise and a threat. The outcome will be determined by institutional and policy factors; there is no guarantee that economic growth in itself will improve, rather than worsen, the situation.

VIII. Implications for Macroeconomic Theory

The major areas of economic/environmental conflict that we have reviewed offer ample evidence that the nature of economic growth will have to change, and that there are real global limits on energy and resource use. This argument is not new (see e.g. Goodland, 1992; Daly, 1992) nor is our presentation of the issues either unique or comprehensive (see e.g. Brown, 2001b). But our review of these major areas indicates that the problems have grown worse over the last decade, and cannot be expected to ameliorate in coming decades without drastic policy action. This has – or should have – significant implications for macroeconomic theory and policy.

The first essential area for reorientation of macroeconomic thinking is with respect to the goal of increasing consumption. Macroeconomic theory is implicitly or explicitly oriented towards achieving this goal, either through raising current consumption or through greater investment, which makes possible higher future consumption (see e.g. Goodwin et al., 1997). No distinction is made between consumption of essentials and luxuries, nor is much attention paid to the distribution of consumption expenditures. In a

standard macroeconomic perspective, a rising tide lifts all boats, and the object of macroeconomic policy is to keep the tide rising. The picture of environmental limits that we have sketched implies a much more critical view of increasing consumption. Growth in consumption is not necessarily undesirable, but needs to be weighed against its negative effects on resources and environmental services.

In this perspective, it is clear that growth of consumption in developing nations must be viewed differently from growth of consumption in the developed world. For the developed countries a good case can be made that current material consumption is sufficient (or perhaps excessive). For these countries, J.S. Mill's 'stationary state', with continued development in cultural and intellectual areas but not in material consumption, may be a relevant model. Here the problem should be to assure the sustainability of current living standards, and to improve equity, but not to promote a continued rising tide. This clearly poses a major challenge for macroeconomic theory, since we currently have no theory that indicates how to achieve a stable, full-employment economy in the absence of continual growth.

For the developing world, increased material consumption is essential, but a distinction needs to be drawn between consumption of basic needs, health services, and education, and a broad range of consumer products such as the automobile. The former need to be promoted, while the latter must be evaluated in terms of environmental feasibility and the availability of more sustainable alternatives. This, of course, raises questions about the unregulated provision of consumer goods through the market – a basic assumption in standard macroeconomic models. The importance of social investment, social provision of goods and services, and the regulation or redirection of market-based production, all need to be recognized in macroeconomic theory.

On the production side, standard macroeconomics assumes an aggregate production function based on supplies of labor and capital, with output determined by total factor productivity. These supply factors determine the basic pattern of economic growth, while demand fluctuations explain deviations from the long-term trend (see e.g. Solow 1997). Our survey of resource and environmental issues indicates that this generally accepted approach is fundamentally wrong. In every case where there is serious conflict between economic growth and the environment, the important issue is what kind of production takes place, and whether the direction of growth is compatible with environmental limits. This implies that there is no inevitable long-term growth trend – everything depends on which technological path is chosen. This choice is partly market-driven, but is also a product of conscious social and economic policy. Automobile transport, for example, is dependent on infrastructure investment in road systems as well as energy tax policy and strategic choices regarding oil supply.

Thus we cannot say that there is 'a' path of economic development over time. There are many paths; the choice of path and the issue of economic fluctuations around the path are both issues of macroeconomic policy. This, of course, has been true in the past, especially regarding social policy and the provision of goods such as education and health care – among the Western economies, there are clearly different path choices

between, say, the U.S. and the Swedish models. In the future, the environmental aspects of these macroeconomic choices will be paramount – regarding fuel use, land use, water systems, industrial ecology, and natural resource use. Economic growth and its measurement will look very different depending on which choices are made.

The fallacious concept of a unique ‘natural’ growth path for the economy is reflected in the one-dimensional output measure of GNP/GDP. While critiques of GNP/GDP as a measure of well-being are extensive (see Tinbergen and Hueting, 1992; Harris, 1997; England 1997), no single alternative measure has emerged. This is not surprising, since the essence of the critiques concerns the reductionist nature of standard national income measures. There is no simple way to include the many dimensions of human well-being and ecosystem sustainability that are omitted or distorted in standard GDP accounts. Very broad measures such as Daly and Cobb’s Index of Sustainable Economic Welfare (ISEW) or the Genuine Progress Indicator (GPI) are conceptually valuable, but difficult to use for analysis because of the many value judgments they necessarily embody (Daly and Cobb, 1994, Cobb et al., 2000). This poses a dilemma for the reform of macroeconomic analysis. Shall we continue to use a measuring rod that we know to be faulty, or abandon it when no other well-defined measurement concept is in sight?

Two major approaches have been taken to resolving this dilemma. One is to adopt a partial system of correcting existing accounts for resource and environmental depreciation (see e.g. Hamilton and Clemens 1997). Another is to employ satellite accounts measuring environmental factors in physical terms, an approach now systematized by the U.N. (United Nations, 2000). Either or both may have significant implications for the formulation of macroeconomic and trade policies especially when natural resource sectors are a significant portion of output, as they are in many developing economies (El Serafy 1997). In general, it will be necessary to escape the trap of measuring and thinking about all macroeconomic problems in terms of GDP – even though the existing alternative measurement systems are necessarily incomplete. Awareness of the multiple dimensions of human well-being and ecosystem health will broaden macroeconomic goals beyond the narrow objective of increasing measured GDP.

IX. Implications for Macroeconomic Policy

Standard macroeconomic policy tools can be reoriented to respond to environmental goals. One widely discussed approach is tax shifting to promote a ‘greener’ economic growth path. The most widely discussed example is a carbon tax, but other ‘green’ taxes include taxes on virgin raw materials or on waste flows. The use of such a tax at the microeconomic level is based on a simple Pigouvian analysis of internalizing external costs. When employed on a large scale, the macroeconomic issues involved include whether or not the taxes are designed to be revenue-neutral and whether there is a ‘double dividend’ of environmental and economic benefit from recycling green tax revenues to reduce taxes on capital and labor. There is an extensive literature on this debate (see e.g. Bovenberg, 1999). There is also some experience with environmental taxes in practice, especially in Europe (Roodman, 2000). One important issue relates to the equity

implications of environmental taxes. If implemented on a large scale, the impacts are potentially quite regressive unless offset with progressive systems of tax rebates.

Without a wholesale shift to environmental taxes, especially in the area of carbon-based energy sources, it is unlikely that any major transition away from current resource-using economic paths will occur. Even with significant technological progress in energy efficiency and renewable sources, the market mechanism places a significant roadblock in the way of an energy transition. So long as fossil fuels remain cheap, any successful effort to conserve or reduce demand for carbon-based fuels will tend to lower their price further, causing significant "leakage" from any carbon reduction policy. In effect, the fact that some consumers use less fossil fuels will simply encourage others to use more, through the market signal of lower price. Only a macro-level, and ideally global, system of carbon taxes or the equivalent can avoid this problem.

Another major area of environmental macroeconomic policy is social investment and the provision of public goods. In a standard Keynesian view, social spending can serve the function of maintaining full employment. From a narrow perspective, the nature of the spending is not important, only its amount and employment multiplier effects. But in a broader view, public expenditure is not merely filling a gap in aggregate demand. It is compensating for the failure of private markets to take adequate account of future social needs. This rationale, especially regarding educational and health, has always been central to the political success of Keynesian policies of public expenditure. It is not just the employment effects, but also the perceived social benefit from government investment in these areas, that makes them politically feasible. Economic theory has generally taken the narrower view, and with the decline of Keynesian theory within the mainstream of economic thought, both kinds of benefits from social investment have been downgraded in favor of goods supplied through the private market. But as Thurow and others have pointed out, this ignores the fundamental need for social investment – a need that has grown more, not less, pressing in modern economies (Thurow, 1997, Chapter 13, "Democracy versus the Market").

The massive investments required on a global scale to respond to environmental problems introduce a new dimension to the discussion of government provision of public goods. Funds must be raised and spent both at the national and international levels. Proposals for new mechanisms such as the Tobin tax, as well as new institutions for transfer of environmental investment funds to developing nations, have the potential to reshape the global macroeconomic environment (ul Haq et al., 1996, Kaul et al., 1999). Joseph Stiglitz, former World Bank chief economist and recent Nobel laureate, has made an eloquent appeal for reform of current international financial institutions, arguing that their narrowly conservative policies have done major damage to the developing world (Stiglitz, 2002. See also Streeten, this volume). Both from the point of view of traditional macroeconomic concerns – employment, price stability, and economic stabilization – and in terms of new environmental imperatives, a new approach is clearly needed.

The twenty-first century will see continued population and economic growth, including unprecedented growth in the developing world. This growth could lead to a global system that is even more inequitable, unstable, and environmentally unsound. Or it could be mediated and directed towards a more stable global system, with moderated consumption, environmentally-oriented technology, and more equitable distribution. It is folly to leave this choice of outcomes to undirected market forces. The needed response must come through intelligent macroeconomic policy, drawing on the best of earlier Keynesian theory while adapting to the new realities of environmental constraints on human economic activity.

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