THE FUTURE OF SUSTAINABLE DEVELOPMENT

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Contents

Summary

Over the nineteenth and twentieth centuries, while human numbers increased 700 to 800%, global economic output grew 4000%. This article addresses the prospects for continuation of this progress.

To begin, the demographic transition that started in Europe during the 1800s, and spread to every other corner of the world during the twentieth century, is described. With human fertility falling dramatically in Africa, Asia, and Latin America, population growth rates are slowing and it appears likely that human numbers will stabilize, at a little less than half the current level, after 2050.

Next, agricultural development is assessed. Since 1960, crop output has increased more because of higher yields than because of agriculture's geographic expansion. The pace of yield growth has fallen since the peak of the Green Revolution, in the 1970s. Without renewed improvements in agricultural productivity, threats to biodiverse habitats and food-insecure populations could mount during the first half of the twenty-first century.

Sustainability concerns also relate to fossil fuels. Over time, humankind has moved from warmed rocks, to burning logs, to falling water, to conversion of burned wood or coal to steam, and on to refined oil products and electricity. Since 1860, worldwide production and the use of energy have increased some 25 times. The lion's share of this net increase, equivalent to more than 90% of current energy demand, comes from fossil fuels and hydroelectricity. While the environmental impact of each useful unit of energy has fallen, the total impact on the environment of the energy economy has risen. This trend will continue, as ever more refined and convenient forms of energy dominate end-uses.

While there are many energy resources that can produce energy in some usable form, how energy is consumed remains bound by the laws of thermodynamics. That is, we can consume energy primarily as heat or as work (mechanical energy). A sustainable pattern of energy production and use is one in which the conversion efficiency of the crude energy input rises, environmental impacts fall, and end-use efficiency continues to improve. The human race can never overcome the ultimate effects of thermodynamics. However, as long as the earth is an open system, which receives enormous supplies of solar radiation every day, some combination of this radiation along with energy stored in the earth's crust will provide for the energy needs of civilization. How countries make use of the two major sources of energy—the daily flow from the sun as well as the stock stored on the earth—will always depend on their relative endowments, technology, social institutions and prices.

Our fundamental conclusion is that substituting human capital for natural resources has allowed and will continue to allow environmental impediments to economic progress to be overcome. To cite but one example, producing 1 KWh of electricity from coal in 2000, creates about one-tenth of the total pollution that such output occasioned early in the twentieth century. The difference is primarily in the quality of the equipment used for converting coal to electricity and the ingenuity employed in such artifacts.

1. Introduction

For practically all of its existence as a species, humankind's survival, while not exactly tenuous, was far from assured. Even after the dawn of agriculture, some ten millennia ago, winning sustenance from the earth was a back-breaking endeavor, demanding nearly everyone's constant attention and effort. As expressed in God's condemnation of Adam as he was being expelled from the Garden of Eden, "cursed is the ground because of you; in toil you shall eat of it all the days of your life" (*Genesis*, Chapter 3, verse 17). Toiling humanity reproduced itself very slowly, the global population reaching one billion fewer than 200 years ago.

As the eighteenth century was drawing to a close, educated people pondered rates of demographic expansion that were, by historical standards, unprecedented. In Europe, life expectancies were rising and total fertility rates (TFRs)—that is, the number of births per adult woman—remained high. Annual population growth exceeded 0.5% year after year in a number of countries.

Moreover, technological innovation during the 1700s promised to change the material circumstances of life for the better. Thomas Savery had patented the world's first practical steam engine—a pump for removing water from mines—in 1698, and Thomas Newcomen came up with a newer design in 1712. But the major breakthroughs were made by James Watt, who patented the separate condenser in 1769 and the double-action principle in 1782. Together, these innovations greatly enhanced the energy efficiency of steam engines. Never before had it been worth the trouble to contemplate either industry's expansion beyond what wind and water power allowed or the elimination of farming's dependence on muscle power, provided by draft animals as well as people. After Watt, these prospects beckoned.

The Industrial Revolution did not get beyond the incipient stage until after the Napoleonic Wars. Likewise, the mechanization of farming was not to begin for several more decades. Nevertheless, the consequences of improved production possibilities obviously merited consideration. In 1798, Thomas Malthus published the first edition of *An Essay on the Principles of Population*, in which he argued that improved material circumstances always lead to an increase in human fertility. In particular, living standards better than those required for bare subsistence cause human numbers to increase exponentially. But since food supplies grow in a linear fashion, a demographic equilibrium characterized by bare subsistence, nothing more and nothing less, is eventually reached. If the population happens to exceed the equilibrium level, an opposite adjustment takes place, with mortality exceeding fertility, until living standards have risen to bare subsistence.

Although Malthus never abandoned the belief that human numbers press against what we now call carrying capacity, his views about population dynamics changed somewhat as time passed. In the second, and enlarged, edition of his *magnum opus*, he suggested that people would delay marriage and employ other means to limit procreation. This is, of course, an entirely different check on population growth from that described in the first edition, namely disease and starvation. In addition, such voluntary restraint is exercised only if people are motivated by a desire for self-improvement, which is a possibility not really considered in the first edition.

As D. Gale Johnson emphasizes, the desire for self-improvement has asserted itself in spectacular fashion during the two centuries since the first edition of *An Essay on the Principles of Population*. Because of this desire and the technological improvements it has unleashed, current life expectancies, infant mortality rates, and per-capita food consumption in China, India, and many other poor countries compare very favorably with corresponding indicators of the social wellbeing in industrialized nations during the nineteenth century. Utterly inconceivable from the perspective of Malthus and his contemporaries has been the 40-fold increase in the real value of global output since 1800 that has coincided with an expansion of the human population from 800 million to six billion.

The prospects for continuation of the unprecedented progress that humankind experienced during the eighteenth and nineteenth centuries are examined in this article. Given the profound breadth of this topic, certain issues are not addressed here. For one thing, no attention is paid to the availability of aluminum, copper, iron, and other metals. In an econometric study of inflation-adjusted prices from 1870 through 1998, Stephen Brown and Daniel Wolk demonstrate that these resources have been growing less, not more, scarce. Continuation of this trend depends on continued improvements in recycling technology as well as increased use of silicon and other abundant materials in various economic sectors. In addition, future supplies of timber ought to be ample, some forestry economists foreseeing no real price increases and others forecasting only modest growth. Finally, fishery depletion, which is an important global concern, is not examined in this article, because fish amounts to a small share of total food consumption.

Our focus, then, is on three issues. The first is demographic, in particular the changes in human numbers likely to be observed during the twenty-first century. Next, agricultural development is examined, both so that the potential dimensions of food insecurity can be identified and so that the threats to biological diversity associated with agriculture's encroachment on species-rich habitats can be clarified. After that, energy futures are described. Special attention is devoted here to the use of exhaustible fossil fuels, the combustion of which creates pollution and contributes to global warming.

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Biographical Sketches

Professor Douglas Southgate. A natural resource economist with a doctorate from the University of Wisconsin, Douglas Southgate is a Full Professor in the Department of Agricultural, Environmental, and Development Economics at Ohio State University, where he joined in 1980. His research focuses on tropical deforestation, watershed deterioration, and other environmental problems arising in developing countries. To date, he has published three books, three monographs, an edited volume, 20 chapters in edited volumes, as well as 32 articles in *Land Economics*, the *American Journal of Agricultural Economics*, *World Development*, *Ambio*, and other scholarly journals. Professor Southgate is best known for his analysis of government policies influencing the development of renewable natural resources in Latin America. In addition to reflecting his research, this work draws on his experience as a consultant for the Ford Foundation, the Inter-American Development Bank, the US Agency for International Development (USAID), and the World Bank, in 15 countries.

A member of *Phi Beta Kappa* and the American Economic Association, Professor Southgate served on the Tropical Ecosystems Directorate of the US Man and the Biosphere Program during the late 1980s, and held a Joint Career Corps assignment with USAID in Ecuador during the early 1990s. More recently, he has directed Ohio State University's Center for International Studies and Latin American Studies Program.

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Dr. Hertzmark has worked for governments, energy companies, financial institutions and international organizations in over 60 countries, to design and assess energy programs and projects, build institutional capacities for energy sector planning and regulation, identify sources of financing, conduct market studies, and price energy products. He has assisted clients in evaluating and financing refinery, LNG and power plant investments in North and South America, Asia, Europe, Africa and Russia, and has negotiated transactions for his clients. He has helped transitional economies establish frameworks for energy sector restructuring and privatization.

Dr. Hertzmark holds a Ph.D. in Natural Resource Economics. He is an Adjunct Professor of Economics at Georgetown University, where he teaches a course on the economics of oil and energy. Dr. Hertzmark has also taught courses on project analysis and energy development to the staff of the World Bank, the Asian Development Bank and the African Development Bank.