SUSTAINABLE PRODUCTION AND CONSUMPTION

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ABSTRACT

The second half of the last century showed real progress with food production outpacing population growth in many regions. Since 1984, however, world grain output has fallen behind demographic growth not because of a sudden spurt in population growth but rather the economic curbs on production in major grain producing areas of the world. Increased food production depends on multiple factors and one of the challenges of the new century is to foster a better understanding of the patterns and driving forces of production and consumption. Ending hunger is a far more complex problem than dealing just with food production or population growth, a trap into which overenthusiastic single interest groups have been too readily drawn.

PERSPECTIVE

The landmark UN Conference on Environment and Development (1992) recognised that current global patterns of production and consumption of many items are not sustainable. Overconsumption occurred in the economically affluent countries of the North and underconsumption in less developed countries of the South where poverty and lack of infrastructure impaired the capacity to look after people and natural environments. Since then much has been done to devise policies that mitigate the adverse effects of both types of consumption.

Consumption means different things to different groups. Economists define it by the generation of utility, and anthropologists and sociologists by its social meanings. I will concentrate on the Statement of the Royal Society and the National Academy of Sciences that consumption is of concern to the extent that 'it makes the transformed materials or energy less available for future use, or negatively impacts biophysical systems in such a way as to threaten human health, welfare or other things people value'. Put in another way sustainable consumption aims to achieve a balance between production, use, and renewal of the resource base and it therefore lies at the heart of the concept of sustainable development.

Sustainable development (which everyone seems to want) was coined as a concept in the 1970s and given prominence by the Brundtland Commission in 1989. Chris Patten in his Reith Lecture quoted sustainable development as 'living here as though we were intending to stay for good, not just visiting for the weekend'. Sustainable consumption is central to sustainable development but it is not a vote-winner. It is favoured neither by more developed countries because it is seen to threaten lifestyles, competitiveness and profitability, nor by less developed countries because it is seen as a device to suppress them

from realising their legitimate aspirations. We need to examine questions about whether sustainable consumption is visionary or illusory, a solution to future demands or a pipe-dream limited by the impracticability of changing personal lifestyles and habits.

Analysis of trends during the period from 1950 to the early 1990s show that world population has more than doubled (2.2 times), food as measured by grain production has increased almost three-fold (2.7 times), energy output by more than four-fold (4.4 times), and the economic performance by more than five-fold (5.1 times). The Boston: Stockholm Environmental Institute has predicted that over the next 50 years the growth rates of consumption could continue well beyond that of population if we assume 'business as usual'. Lifestyles of affluent countries in Europe and North America have become a model for new consumers in China, India, Brazil, Mexico, Russia and SE Asia among several other leading nations. This can be observed in the trends reported for selected items by region. The prospect of 'business as usual' is therefore hardly an option and the drivers of consumption need to be understood.

DRIVERS OF CONSUMPTION

Population growth has been identified as a driver of overconsumption and the enemy of sustainable development. Two examples, however, show that this explanation is too simplistic. In the UK the emissions of carbon dioxide are more than double those of Bangladesh. Yet the annual population growth in the UK is only 118,000 compared to 2.4m in Bangladesh. The second concerns the richest 20% of the world's population that has raised its per capita consumption of meat and timber two-fold, its car ownership four-fold and its use of plastics five-fold since 1950. The poorest 20% have raised their consumption hardly at all. Population size, however, does matter as can be seen with the example of China. If China increased its consumption of beef from 4 kg per person pa to match that of the USA's 45 kg, and if the additional beef came from feedlots, it would absorb the equivalent of the entire USA grain harvest (343m tonnes). Already meat intake in China has increased by 105% during the 1990s and it has become the world's biggest meat consumer. When China matches the USA for cars and oil consumption it will need 80 m barrels of oil per day (current global output is about 65 m barrels).

The world's population currently numbers 6bn people and the figure continues to grow by more than 80 million people each year, or around 220,000 each day. The growth rate itself has actually declined since 1970, from about 2% to about 1.5% today. However, because this rate is applied to a much larger population today than in 1970 the added yearly increments are larger. If the population continues to grow at the present rate then it will have doubled by the year 2050. More than 90% of the world's population growth is occurring in less developed countries in Asia, Africa and Latin America where the rates of natural increase vary from 1.4% in Asia to 2.6% in Africa.

A further concern is population momentum, the tendency for any population with a high proportion of young people to continue to grow even after the birth rate has declined to two children per family - the fertility level where each couple replaces itself in the population. Because of past population growth, an unusually large number of young people are just

entering the child-bearing years. However, we have noted that population growth can no longer be seen as the only driver of consumption. Consumption is determined and influenced by numerous interactive factors that include population growth and size, technology choices, economic activity, human behaviour, social values, institutions and policies. For this reason addressing the negative effects of overconsumption is complex.

HOW WILL SCIENCE AND TECHNOLOGY HELP?

What are the possibilities of moving towards a strategy of sustainable consumption and what would it involve? Two principles have been identified by UNEP (2001) around which to build a framework for a transition towards sustainable consumption. Dematerialisation can be achieved by increased efficiency in resource productivity, novel ways of production, improved tracking of materials and energy in industrial and consumption processes, and cost internalization to increase economic efficiency. Optimisation involves creating different consumption patterns by government actions and investment; conscious consumption by consumers who choose and use more wisely because of the availability of better information; and appropriate consumption because of a deeper debate about whether the quality of life in civic, cultural and religious terms is increased or decreased by consumption behaviour.

Science and technology have an important part to play for, as Francis Bacon observed in the 16th century - 'he that will not apply new remedies must expect new evils, for time is the great innovator'. An evidence-based approach to the problem is where scientists can contribute by analysing and making sense of the available evidence. Above all, scientists can identify new technologies and fundamental breakthroughs that might offer new options to existing and anticipated problems. The Royal Society, the UK's premier Academy of Science, recently convened a meeting on Sustainability for this purpose and key opportunities were identified in seven main areas by its research alumni.

The Clean Energy Group concluded that the public perception of the risks associated with nuclear power and its waste products was the crucial factor affecting this energy source but no one could envisage how continued growth and consumption could be achieved without it. The public seemed increasingly concerned with small probability high-risk events and it was unclear whether the way forward was to provide the public with more information of attempt to explain that there are risks in all activities. The importance of generating power from biomass sources, including landfill gas, was stressed as a topic with great potential for expansion. Landfill is still the dominant waste disposal route in the UK and 80% of the population lives within 2 km of a landfill site. However, tensions exist between securing a diversity of energy supply (oil, gas, nuclear, solar, wave, tidal and biological renewables), enhancing competitiveness, and meeting the targets of reduction in CO2 emissions of 60% by 2050 in the UK and methods of CO2 sequestration need special attention.

Controlling Pollution identified the value of modern analytical techniques including the environmental scanning electron microscope (ESEM) to measure pollution from nanoparticles. New information was available about the electronic structure of atoms at the surface and in the particle interior. The difficulty in understanding the toxicological effect of cocktails of chemicals was highlighted and the problem of the release of persistent chemicals

with lifetimes in excess of 1000 years. 'Green chemistry' has grown considerably and aims to reduce the environmental risk associated with chemicals by minimising, or preferably eliminating the inherent hazard of the chemical. It was also suggested that fluid mechanics could address a number of the issues around sewage sludge and dispersal of particles.

Food technology suffered from the public perception that it placed profit above consumer well-being. In order to address this problem, sustainability needed to be integrated into traditional science. Technology-based programmes were essential to show graduates how they could make a difference if they become involved. The lack of information about the dispersal of pollen from GM crops onto adjacent crops indicated that research about interactions at the whole plant level, as opposed to the molecular level, was deficient.

Information technology focused on the importance of ensuring the validity of information on the World Wide Web and in databases. The learned societies had a role to provide valid information, but governments should control such electronic information. Information and communication technologies were available to improve food security, identify environmental degradation, develop educational programmes, and support the outcome of clinical treatments in deprived areas. In Chennai, India, the M S Swaminathan Research Foundation has set up over 30 internet centres to provide access to information on the internet to villagers to improve food security. Other examples include SciDev.net involving the prestigious scientific journals, Nature and Science.

The Group on Biodiversity recognised that existing advisory organizations were important but they failed to concentrate on reaching a scientific consensus and some have become politicised. Less developed nations were increasingly aware of the value of biodiversity as indicated by the number that had signed up to the Convention on Biodiversity. Alternative value systems should be assessed alongside conventional systems familiar to workers in nations of the North.

Renewable resources present a great opportunity for science and technology but the adoption of alternatives such as the hydrogen economy provide many challenges not least in how to store hydrogen in tanks with the danger of explosion, or in solid materials where release is limited by the diffusion rate. The extent to which oil could be replaced by ethanol from fermenting plants was discussed; it would take the entire corn production of the USA to produce enough ethanol to replace oil in transport.

The Healthcare Group concluded that the issues were mainly economic rather than scientific in nature. The greatest number of people would benefit from less exciting solutions than those offered by high technology. Rehydration therapy saved more lives than the more advanced drugs. Increased longevity would increase the difficulty of achieving sustainable healthcare. Decisions about the provision of infrastructure and the distribution of resources in less developed countries were susceptible to systematic enquiry and the treatment of AIDS in South Africa was a case in point.

There was little doubt that steady incremental progress is the most likely form of improvement in sustainability. Strategies using science and technology need to be fully applied in striving toward global sustainability, but they will clearly not be enough.

Empowering women throughout the world, seeking means to raise their status, and alleviating poverty are among the most important actions to be taken to achieve sustainable development. Microcredit provision is another.

OTHER STRATEGIES

Leapfrogging

An objective of sustainable consumption is to decouple economic growth and the depletion of the environment and natural resources by the adoption of scientific and technological advances. For materials, the per capita usage in the USA of all industrial minerals, metals and forestry products has shown an S-shaped pattern of growth in the last century with fewer materials being used for a unit of production (dematerialisation). Steel consumption pc has either remained constant or more usually has decreased as the income of each person has increased. An office building needing 100,000 tons of steel 30 years ago can now be built with one third as much because of better steel and smarter design. Within the EU manufacturers will be required to recycle 85% of a vehicle's weight by 2005 rising to 95% by 2015. Many of these achievements are due to the ingenuity of engineers concerned with production, fabrication of useful artefacts and their distribution to the consumer. The Fraunhofer Institute of Systems and Innovation Research has demonstrated that energy intensity declines with time and that nations in economic transition should aim to leapfrog to a level of efficiency enjoyed by more developed countries, learning from their mistakes and gaining from their technological development.

For food, biotechnology has demonstrated a capacity to be part of the solution to increase productivity on the same land. This has become crucially important because the available amount of land on which to grow crops is decreasing, and the damaging environmental impact of intensive methods of food production demonstrates that changes are demanded. Professor Peter Raven, reportedly the world's leading botanist, emphasised in this year's Presidential Address to the American Association for the Advancement of Science that today's yields have been achieved only because we manufacture increasingly toxic pesticides with which we now douse our agricultural lands at the rate of 3m metric tonnes per year, and poison the environment with the nitrogen we fix (our output now exceeds the total derived from natural processes). We also cultivate or graze most of the world's available arable land and rangeland, and harvest two-third's of the world's fisheries beyond sustainability. Over the past 50 years we have lost about one fifth of the world's topsoil, a fifth of its agricultural land, a third of its forests and seen a dramatic increase in the loss of biodiversity.

Food production today is sufficient to feed everyone in the world and if the world's supply of food had been evenly distributed in 1994 it would have provided an adequate diet of about 2350 calories per day for 6.4 billion people, more than the actual world population. Nonetheless, about 800 million people remain food insecure because food redistribution is impractical and prohibitively expensive. A shift towards more sustainable consumption so far as food is concerned means production methods that do not cause irreversible environmental damage, that decrease chemical burdens on the environment and people,

reduce waste by improved storage properties and recycling, and give better quality of food for humans and feed for livestock by the judicious application of genetics.

Some promising options have emerged in recent years from our expanding knowledge of plant (and non-human animal) genomes. The first sequence of the genome of a plant, the modest little flowering brassica, Arabidopsis thaliana, revealed both the striking conservation of genetic mechanisms that underpin cellular processes of living organisms and the intriguing differences between plants and other organisms. While this knowledge will allow the rational transfer of relevant genes, the early examples of transgenic plants attracted severe criticism from the general public and sections of the scientific community alike because the genes adopted were heavily biased towards the interests of multinational industries rather than the benefits of consumers and those with greatest needs. Hence, the first generation of input trait control systems from which the seed and agrochemical industries had most to gain included transgenic maize and cotton engineered to tolerate herbicides (71% of the total transgenic area in 1999) so that chemical sprays could eliminate competitive weeds, the property of agrochemical firms. A more promising development was insect resistance (22%) because it reduced the chemical burden on the environment, a striking example of dematerialisation.

Second generation traits have proved of greater interest because they address the processing of food and better storage properties with less food spoilage and wastage. Third generation traits are even more interesting because they are designed for the food and pharmaceutical retail sector and will offer benefits to consumers through crops fortified with micronutrients including iron and vitamins, cholesterol-reducing grains, edible vaccines, anti-cancer vegetables as well as increased productivity. Among these, the Golden Rice project has produced transgenic rice that expresses enhanced levels of provitamin A (beta-carotene) in the grain to fortify diets based on the major staple foods of South Asia such as rice and wheat to combat blindness in children induced by vitamin A-deficiency. Acceptance of these third generation plants is expected to largely influence the future success of this technology and will provide further examples of optimisation so far as sustainable production and consumption are concerned.

Combating hunger by increased food production in a sustainable manner involves many interacting factors; the spread of new knowledge and improved education, local innovations by farmers themselves, improvements in infrastructure, and by no means least, national and international policies relating to trade, food prices, exchange rates and access to markets. The range of factors is a sombre reminder that ending hunger is a far more complex problem than dealing just with population or food production, a trap into which overenthusiastic single interest groups can be too readily drawn. The decline in crop yield increases since the Green Revolution presents another challenge for less developed countries. Optimistic speculations circulate about organic methods of farming but yields are too low to put much organic material back into the land and manure from livestock tends to be burned for fuel rather than invested in soil management. Organic cereals in the UK currently account for only 0.6% of the arable area and contrary to popular belief organic pesticides still leave residues so that organic food is not pesticide-free. Moreover, if organic food is exposed to disease such as fungi there is a risk of mycotoxin contamination of which aflotoxin is a potent liver carcinogen. Retail chains, some supermarkets and organic-breeding institutes

have funded work on soil-management methods to improve plant resistance against pests and disease and the production of pest-tolerant seeds, but it is important to acknowledge that relatively little investment has been made into research on organic technologies. Other options include integrated crop management because it is designed to avoid pest problems and reduce the need for agrochemicals.

Returning to transgenic technology, while it is expensive and requires a high initial investment, in the last six years the global area of transgenic crops has increased by over 50% with soybean contributing the most followed by maize, cotton, rape, potato, squash and papaya. Many millions of hectares (48m) of commercially produced transgenic crops have been grown and the global market for transgenic crop products has increased from $75m in 1995 to more than $3bn in 2000. The fact that China, South Africa, Mexico, Spain, France, Portugal, Rumania and Ukraine are starting to grow commercial transgenic crops indicates the widespread significance attached to this technology. Serious concerns persist, however, as reflected in the negative decisions of European consumers about GM crops partly because of scant information about the dispersion of pollen in the field and the risk of cross-pollination of GM crops with crop varieties destined for non-GM, GM-free or organic niche markets, and partly because of the difficulty of obtaining reliable information about long-term effects of GM crop products on human health and the environment. Even China changed its position on GM food crops because of the doubts expressed in Europe. For these reasons the US General Accounting Office's (GAO) recent report to Congress is significant - that GM foods pose no greater health risk than conventional foods. The report also says that the FDA should validate the accuracy of food safety data from companies more frequently. Therefore, leapfrogging into new technologies may be advocated as an important strategy for sustainability particularly in developing countries but challenging questions remain about optimisation regarding consumer confidence, public perception and acceptability of new technologies.

Centres of excellence

Two examples from Europe will illustrate the difference between a society that demands change and one where technology needs to be used.

In the Netherlands, the region of Twente was a major textile centre that went into decline in the second half of the last century. In 1964, a new science-based Technical University was created to become a center of excellence. It has increased to about 8000 students and academics, and has produced a remarkable culture for knowledge transfer that has led to a revitalised industry. University starter schemes encouraged the formation of spin-off companies within Twente and since 1985 the success rate measured as companies still existing has been about 70%. The emphasis has been on a mix of engineering projects that include environmental, chemical and medical engineering frequently based on biotechnology.

Comparisons of the situation in 1970 and today demonstrate a new entrepreneurial climate compared with the former classical academic attitude, a multidisciplinary rather than a monodisciplinary economy, a significant impact of R&D companies on the local economy, and a key role of government incentives for the establishment of start-up companies. This

example emphasises the impact of a society that demands change - an example of 'market-pull'.

My second example is Cambridge where we find a classical example of technology- push derived from one of the oldest and most distinguished Universities in the world. It has created a dynamic regional development based upon the excellence of its science.

The University of Cambridge has about 22,000 students, staff and academics and an income of about £400m pa. There has been a steady growth in the flow of knowledge into industry not only locally but also internationally. The Cambridge Phenomenon is a 176,000 ha area around the city known as The Greater Cambridge Technopole that consists of 1500 high tech companies with 44,000 employees in multidisciplinary companies. 'Technology push' from a top quality science environment has produced socio-economic change with 120 inventions disclosed each year and 5 spin-off companies. Numerous myths have to be dispelled but get it right and the inventors, their universities, industry and society will all benefit. Yet there are challenges that we cannot afford to ignore.

CHALLENGES

A reality check

Is there too much emphasis on biotechnology? Much was made of the promise of biotechnology in 2000, 'the year of the genome'. Public biotechnology companies reviewed by Nature Biotechnology for 2001 revealed that despite the downturn in the economy it was business as usual. Of the 440 companies reviewed the majority generated $5-50m (196) and in general the distribution of earnings was skewed towards the small to medium sized enterprises. Fourteen companies generated revenues of $500m or more but their combined income was less than that of the single Pharma company, GlaxoSmithKline.

All top ten companies earned over $500m in 2001, eight were based in the USA, and consolidation continued to be the characteristic of the biotechnology sector with 25 companies carrying out some merger or acquisition activity during the year. Monsanto, the agribiotechnology company, displaced Amgen from its top position by revenue. Of the 440 companies reviewed fifteen went public and there were 13 mergers, 12 acquisitions, 6 name changes and 17 delistings. Nonetheless, the biotechnology industry remained firmly in the red making a total loss of $5.3bn for the year. The financial hemorrhaging decelerated during 2001 from 30% in 2000 to 9% in 2001. Just 74 companies were profitable (17%) generating a profit of $3.9bn compared with the remaining companies that produced a loss of $9.3bn. The UK emerged as one of the more mature regions for biotechnology after the USA, with 7 of the 14 businesses that made a profit outside the USA being located in the UK. Recent scandals and stock market failures, however, have started to take their toll; two-thirds of the value of biotech stocks has been lost in the past two years and charges of insider trading against the former CEO of ImClone have shaken investor confidence.

A serious source of concern relates to the process of due diligence that ensures the scientific claims are firmly based and the personnel and infrastructure of new companies are capable

of supporting an apparently promising lead. The technique of publicly reporting new findings just before a renewed round of funding without prior publication in peer-reviewed journals has raised undue expectations among an unsuspecting public and damaged the confidence of the market in new scientific claims.

The message is that biotechnology, and plant biotechnology in particular, will have much to offer for socio-economic development but the lead-time for research and development, the susceptibility of financiers to inappropriate advice from professional consultants, the fear of venture capitalists that they may be left behind, and a reliance on publication by press release rather than rigorous peer-review have compromised the prospects of several ventures. When Dolly the sheep was born she was a symbol of the new technology of cloning. Now she stands by as the company involved in her creation, PPL Therapaeutics, struggles for further funding by announcing GM pigs suitable for the development of organ transplants for humans. Trumpeting this success by press release has only reinforced scepticism among the scientific community that keeping stock prices up has become more important than scientific rigour.

Public perception

Biotechnology as a mechanism to introduce socio-economic change must inevitably face the challenge posed by public concern about modern genetics and where it is leading us. Alex Mauron of the University of Geneva Medical School has been deeply involved in the Swiss debate on genetic engineering and in a recent article in Science entitled 'Is the Genome the Secular Equivalent of the Soul' he observed that the emergence of 'genomic metaphysics' was not surprising. The idea that the genome is the secular equivalent of the soul has taken hold not only among some scientists but many journalists and cartoonists, one of the groups most instrumental in steering public opinion. Genes have given biology a basic unit in the same way as the physicist's atom. Genocentrists speak of the genome as the 'Book of Life' and the 'Holy Grail' and it should not be surprising, therefore, that the following statements have become common currency in the media - 'Genetics is the stuff of life and we meddle with it at our peril'. 'Genetic engineering is like nuclear power because it can be used for good, but in the wrong hands it can cause devastation'. 'Once released there is no going back to a GM-free environment'. Furthermore, with the conflation of two almost sacrosanct icons - genomics and food - it is unsurprising that there has been so much fuss about GM crops.

Ethical issues

Advances arising from the science of genomes raise familiar ethical questions that include the following - are they safe, fair, natural, needed, accessible and who should own them. The adoption of the fruits of the new biology depends on getting the science right but also on how we address these ethical questions. Ethical resources exist within the religious and humanitarian traditions to explore our relationship with nature, our responsibilities of stewardship, how we view the good life offered by wealth creation and consumption, and how we view our relationship with each other and with the underprivileged in terms of justice and equity.

For example, no evidence has been produced that GM crops are unsafe for human health though difficult questions still remain about their effects on the environment. Concerning fairness, it should not be assumed that what works in the USA will work elsewhere. Certain multinational companies attempted to force its GM products into Europe shortly after a genetically modified hormone that increases milk yield in cattle, bovine somatotropin, had been rejected. The reason for rejection was the failure to demonstrate need, a fundamental stepping-stone towards successful innovation. It also followed the time of the 'mad cow' disease crisis when government assurances that beef was safe turned out to be false. The lesson to be learned was that biotechnology companies, like any other company, require a functional corporate memory if they are to succeed in a global market.

New technologies need regulation and in some instances legislation. In the UK the government has set up three Commissions that act as watchdogs - Human Genetics, Agriculture Biotechnology and Environment, and Food Safety. The UK's Nuffield Council on Bioethics (2000), an independent group of scientists, philosophers, lawyers, consumers and theologians, concluded that the large-scale introduction of genetically-modified crops (GM crops) is a moral imperative on the basis of the ethic - to each according to need. A moral duty exists to feed people in poor countries, to establish appropriate regulatory safeguards for human health and environmental safety, and to ensure that benefits accrue to poor farmers, in particular where GM technology might produce more employment income for those who needed it most urgently. Given the huge reductions in pesticide use demonstrated with GM cotton, given the benefits to soil microbial diversity resulting from the low till/no till practices possible with GM crops, and given the potential health benefits of third generation GM crops, who will be held responsible for the damage sustained from the non-use of GM crops that lead to unsustainable and dangerous practices?

Concerning the question of whether an advance is natural or not, there is a serious problem of defining what is natural today. Many plant and animal species bear little resemblance to their origins having been the subject of generations of selective breeding. Monsanto's pledge that they will not use genes from humans or animals in products intended for food or animal consumption, or that it will never sell a product into which a known allergen has been introduced, is helpful but sadly it is too late. The damage has been done and most would agree that winning Europe round will take years and the wider repercussions in second and third world countries continue to reverberate. Rather than seeking ways to change the public, institutions need to change and become more transparent and responsible in the promotion of innovation and the regulation of risk if socio-economic benefits are to be realised.

One of the institutions that has been challenged recently is the system of intellectual property protection. Benefits have accrued to society over the years from the protection of intellectual property through the patent system. Questions are now being asked about whether the patenting of DNA sequences has achieved its goals. A recent study of the Nuffield Council on Bioethics concluded that many patents assert rights over DNA sequences that are of doubtful validity, and that such rights should become the exception rather than the norm, and only if they meet the criteria of novelty, inventiveness and usefulness. The Council recommended that the granting of patents which assert rights over DNA sequences as research tools should be discouraged, and the protection of DNA

sequences for gene replacement therapy to alleviate the effects of a gene mutation should be disallowed because the treatment is obvious. If novel DNA sequences for the production of new medicines are to be patented the claims should be narrowly interpreted and only apply to the protein described in the submission.

An impediment for creating a culture of intellectual property protection in second and third world countries is the prohibitive expense of protecting intellectual property in major potential IPR centres such as the United States Patent and Trademark Office, the European Patent Office and the Japan Patent Office. A central fund could be structured to help support important inventions by bright young scientists in less developed countries through agencies such as the World Bank, the International Monetary Fund, Rockefeller Foundation and others. This would provide another signal to young scientists that there is a serious will to adopt biotechnology for socio-economic change.

FORCES FOR CHANGE

Forces for change in the way we use the earth's resources and produce food and feed for consumption have come in many forms and without change the fate of the peoples of the less developed economies especially looks grim. For food production, the Nuffield Council on Bioethics (2000) has concluded that the large-scale introduction of genetically-modified crops (GM crops) is a moral imperative on the basis of the ethic - to each according to need. A moral duty exists to feed people in poor countries, to establish appropriate regulatory safeguards for human health and environmental safety, and to ensure that benefits accrue to poor farmers, in particular where GM technology might produce more employment income for those who need it most urgently. A year-long study by seven academies published under the auspices of The Royal Society, the UK's Academy of Science, the US National Academy of Sciences, the Third World Academy of Sciences and Academies in Brazil, China, Mexico and India (2000) concluded that transgenic crops can be used to produce foods that are more nutritious, stable in storage and in principle health-promoting bringing benefits to consumers in both industrialised and developing nations. For example, reduced harvest and post-harvest losses would save China the equivalent of a diet adequate for an estimated 75 million people. The seven Academies recommended that multinational private corporations and research institutions should share GM technology with scientists for use in hunger alleviation and to enhance food security in less developed countries.

Another force for change has been highlighted by the UK's Global Environmental Change Programme, namely, the need for better indicators of economic progress based on secure scientific information. Gross National Product (GNP) as an economic indicator fails to account for the net value of changes in externalities such as the environment-resource base so that consumers are rarely presented with the true costs. Several attempts have been made to deal with externalities. One of these is the Index of Sustainable Economic Welfare (ISEW) that estimated that in the UK the GNP per capita was 230% greater in real terms in 1990 compared to 1950. In terms of the ISEW the difference was only 3%. The largest negative effects came from the depletion of non-renewable resources, long-term environmental damage and ozone depletion. The possibility exists to replace GNP with Net

National Product (NNP), a more realistic indicator of the true cost of production that takes into account the impact of externalities such as environmental costs.

Fiscal instruments can also be useful to bring about change in consumption patterns but when translated into policy they require rigorous assessment of their effectiveness. In this respect subsidies serve many useful purposes and overcome deficiencies in the marketplace, support the disadvantaged and promote environmentally-friendly technologies. However, 'perverse subsidies' as depicted by Myers exert adverse effects on the economy and the environment. The global ocean fisheries catch costs about $100bn to bring to the dockside where it is sold for $80bn leaving a shortfall of $20bn made up by government subsidies. The result is a depletion of major fishstocks, bankruptcy of businesses and sizeable unemployment. This example points to a need for greater sophistication in economic management and control if overconsumption is to be avoided.

UNDERSTANDING THE CONSUMER'S BEHAVIOUR

Even with better information about the real costs of overconsumption, Princen (1997) has argued that insatiability is axiomatic and reduced consumption in the use of land, materials and energy will only happen through scarcity or the impositions of external authority. People continue with their current lifestyle because material consumption is an integral part of meeting social needs and the pursuit of happiness. The epidemic proportions of obesity show that even when high-quality scientific and public information advises us about the health risks, knowledge alone is insufficient to alter consumption. One conclusion is that we have evolved excellent physiological mechanisms to defend against body weight loss in times of scarcity, but only weak mechanisms to defend against body weight gain in times of affluence.

If the lessons form evolutionary psychology are correct much of our behaviour as economic consumers derives from our nature as biological animals attempting to maximise our opportunities for genetic success. Jackson (2000) points out that we position ourselves as advantageously as possible both with respect to our sexual competitors and in relation to the opposite sex so that 'conspicuous consumption' advertises our wealth and attractiveness relative to those around us. Dawkins (2001) argues that sustainability does not come naturally to the human species as the tendency to accumulate material goods for positional reasons appears to occupy a critical place in our evolved strategies for genetic success. Or as Ridley (1994) puts it 'animals and plants invented sex to fend off parasitic infections. Now look where it has got us. Men want BMWs, power and money in order to pair-bind with women who are blonde, youthful and narrow-waisted'.

Evolutionary psychology suggests that modern society is ill-suited to defend the integrity of the environment or to enhance well-being. Behaviour in an environment of prosperity therefore seeks to counter excess consumption by slimming aids which cost the First World $40bn, a sum similar to extra required by less developed countries to eliminate malnutrition by improved agriculture. Others have suggested that religious or spiritual beliefs evolved precisely to provide a balancing mechanism at the super-social or planetary level, though yet others consider that religious fervour is there to anaesthetise a doomed civilisation and to

paralyse people from taking appropriate remedial action. Nevertheless, studies show that people do develop resource-limiting behaviour and can display a remarkable capacity for rapid change. The unacceptability of smoking in public places is one example of how quickly habits can change. Perhaps the future emphasis should be on the scientific understanding of the public rather than the public understanding of science if we are to take sustainable consumption seriously.

COMMENT

In conclusion, we can see that opportunities and rewards exist for those committed to sustainable consumption as a strategy for the future. The eco-opportunities presented to industry by the world market for energy efficiency, recycling, waste management and pollution control has been estimated to be more than £600 bn pa, strong competition for the global aerospace, car and chemical industries. Cornucopians, therefore, would claim that technology-fixes will resolve impending crises (Smil, 2000). Catastrophists on the other hand question whether the fixes will deliver in time because the 850m long-established consumers in rich nations are already being joined by an even larger number of new consumers in 20 developing and transition nations who possess 22% of the global fleet of cars and contribute significantly to the increase in CO2 emissions. A message for today is that time is not on the side of business people and policy makers who are only just beginning to think about sustainable consumption as a strategy.

The future is notoriously difficult to predict but futures can be invented. Sustainable consumption is a future option waiting to be adopted. Science and technology have a crucial part to play but reducing overconsumption in nations of the North and dealing with underconsumption in the South will not be resolved by science and technology alone. Creating a sustainable future demands interdisciplinary studies that elicit a deeper understanding of environmental quality, social equity, economic development and the determinants of consumer behaviour.

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