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ENVIRONMENTAL ESSAY

Limits to Growth? – A Perspective on the Perpetual Debate

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ABSTRACT

The publication of the Club of Rome's report *Limits to Growth* in 1972 sparked an intense and polarised debated which has remained very much alive in the subsequent three decades. The task of resolving the existence of any limits to economic growth has become the ultimate goal of much of the science and socio-political economics that address issues of sustainability. Although the advancement of technology and scientific understanding has undeniably altered the terms and parameters of the limits debate, it has also unveiled new fears, and a growing realisation of our capacity to curtail and diminish the future welfare of mankind. There is strong evidence that although we appear to have alleviated many of the earlier concerns of resource depletion, the threat of other physical limits to growth are as prevalent as they ever have been, particularly with respect to the production of waste materials. Moreover, it is increasingly likely that despite theoretical arguments which describe the potential of technology and human ingenuity, real-world complications, uncertainty and basic human aspirations will have a major role in shaping the future pattern of environmental degradation, and human welfare.

Keywords: economic growth; limits paradigm; resource supply; environmental degradation; technocentrism; globalisation

1. INTRODUCTION

> Now more than six billion people fill the world. The great majority are very poor; nearly one billion exist on the edge of starvation. All are struggling to raise the quality of their lives any way they can. That unfortunately includes the conversion of the surviving remnants of the natural environment. Half

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> of the great tropical forests have been cleared. The last frontiers of the world are effectively gone. Species of plants and animals are disappearing a hundred or more times faster than before the coming of humanity, and as many as half may be gone by the end of this century. An Armageddon is approaching at the beginning of the third millennium. But it is not the cosmic war and fiery collapse of mankind foretold in the sacred scripture. It is the wreckage of the planet by an exuberantly plentiful and ingenious humanity.
>
> Edward O. Wilson (2002) *The future of life*

> Children born today – in both the industrialised world and developing countries – will live longer, and be healthier, they will get more food, a better education, a higher standard of living, and more leisure time and far more possibilities – without the global environment being destroyed. And that is a beautiful world.
>
> Bjørn Lomborg (2001) *The Skeptical Environmentalist*

It is scarcely possible to believe that these two quotes, both from highly influential individuals, can be describing the same planet. Certainly they cannot both be true, yet both proponents are adamant that their viewpoint is correct. Many politicians, economists and scientists alike consider the continued apparent failure of a number of doomsayers, starting with Thomas Malthus in the 18th Century, to foretell the impending boundaries of continued economic growth (e.g. Ehrlich, 1968; Meadows, Meadows, Randers, & Behrens, 1972), as clear evidence that such boundaries do not exist. Consequently the majority of us march arrogantly forward, armed with a supreme confidence that any limitations brought about by the plundering of natural resources and the production of waste materials can easily be swept aside by the ingenuity of man (Simon, 1981, 1996). During the past century we have dramatically increased our average life expectancy, reduced infant mortality, improved literacy rates, and generally increased the overall ‘wealth’ of the human population (Lomborg, 2001). Why then, do many of us find ourselves still battling with these same deep-seated fears? Are we really destined for the “beautiful world” as described by Bjørn Lomborg, or do we remain as vulnerable as ever to the impending “Armageddon” threatened by Edward Wilson?

This essay seeks to provide a short reflection of how the debate on limits to economic growth (taken to include all physical dimensions of the economy; materials, human bodies and artefacts) has progressed in recent years.

I conclude by emphasizing that the discussion is still very much of the highest relevance to environmental science and humanity at large.

1.1. Historical Background

The most famous expression of the existence of limits to economic growth in recent times was the Club of Rome's report *Limits to Growth* (Meadows et al., 1972), which highlighted the interdependency of population growth, economics and the deterioration of the natural environment. Despite the many similarities with the major theses of earlier classical economics, the report challenged the intellectual foundations of the dominant neoclassical school of economics, and was consequently met with vigorous criticism (Beckerman, 1974; Nordhaus, 1973). The report's conclusions, which stated that continued resource depletion and pollution emission set absolute and imminent limits to economic growth, undermined the popular belief that technological progress and the market mechanism effectively marginalised concerns of resource scarcity and environmental degradation (Beckerman, 1974, 1992). This polarised debate has remained very much alive in the intervening three decades, and its resolution has become the ultimate goal of much of the science and socio-political economics that address issues of sustainability. However, despite this attention, the complex links between the different aspects of ecological, economic, social, and political systems remain poorly understood.

2. BIOPHYSICAL LIMITS: THEIR EXISTENCE AND RELEVANCE IN TODAY'S GLOBAL ECONOMY

The foundation of biophysical limits to growth is the materials balance principle as defined by the first two laws of thermodynamics, and was introduced to economics around the time of *Limits to Growth* (Boulding, 1966; Daly, 1980, see also Daly, 1987; Georgescu-Roegen, 1971). The first law of thermodynamics defines economic growth as a process of transformation rather than production in stating that matter can neither be created nor destroyed. The second law or 'entropy law' has been defined by Georgescu-Roegen as the 'taproot of economic scarcity' (Georgescu-Roegen, 1979), in so far as it states that all conversions of energy-matter are less than 100% efficient and serve to increase the entropy (unavailable energy) of an isolated system (e.g. the Earth). More recently there has been continued debate regarding the relative isolation of the earth system – in particular the existence of practically infinite amounts of solar energy – and therefore the relative importance of the second law to economic growth (e.g. Ayres, 1998). However, there are a number of practical social, political and economic limitations which prevent us from rapidly shifting away from non-renewable energy sources towards a more direct harnessing of solar energy. Furthermore, it is altogether possible that existing levels of economic activity are capable of precipitating changes in the environment (e.g. biodiversity loss) which cannot be reversed despite potentially vast future increases in available energy. Therefore, although the Earth may be considered a theoretically 'open' system with respect to available (solar) energy, serious practical limitations are likely to prevent us from harnessing this resource within timescales meaningful to the current limits debate. Consequently, the materials balance principle remains of clear relevance to sustainable development, and for many very practical purposes it serves to re-define the economy as linear rather than circular, and emphasises that matter cannot be rearranged indefinitely.

The two most immediate and popular implications of the materials balance principle with respect to biophysical limits to growth are the possibilities of finite sources (resource supply) and finite sinks (waste assimilation) (Daly, 1987; Meadows et al., 1972; Meadows, Meadows, & Randers, 1992).

2.1. Economic Limitation Through Resource Depletion

The resource whose limitation is perhaps the most threatening to the global economy, as well as being the most apparent to its countless participants, is the global food supply. I explicitly consider food as a resource because its production involves a number of factors which in practical terms can be considered to be both finite and susceptible to depletion – e.g. soil and freshwater. The potential of the earth to feed the projected extra 2–5 billion people within the next 50 years is the source of considerable controversy despite the fact that a number of global carrying capacity estimates far exceed predicted population growth rates (e.g. Cohen, 1995; Simon & Kahn, 1984).

Overall demand for cereal crops is expected to increase by 60% by 2025 (Harris, 1996). Cereals comprise some 70% of dietary protein and calories in developing countries (Harris, 1996), and as such are taken as an indicator of gross food availability. Despite significant projected increases in both the extensive and intensive margins of agriculture (Matthews & Hammond, 1999; Tilman et al., 2001), grain production is only expected to increase by 40% by 2020 (Matthews & Hammond, 1999), and global per capita food production has been falling for some time (FAO, 2004). This consequent shortfall is largely due to diminishing returns on agricultural productivity; a phenomenon particularly prevalent in developing countries (FAO, 2001a; Harris, 1996). Observations of severe soil erosion and degradation due to intensive agriculture (Daily, 1995; Pimentel et al., 1995), in addition to decreases in per capita availability of fresh water (Jackson et al., 2001), cast serious doubt on claims that this shortfall can be compensated by increased yield through further intensification of fertiliser, chemicals and irrigation schemes (e.g. Lomborg, 2001). Aside from any concerns of the potential environmental and opportunity costs of such actions, many growth optimists fail to acknowledge serious real world complications which limit the spread of knowledge and technology, and thereby also limit the potential for increased crop yields. Bjørn Lomborg (2001) states that with respect to soil erosion, ''*it is possible to maintain the content and composition of soil indefinitely under proper agricultural management*'', despite having earlier acknowledged that ''*poor peasants who cannot afford to think of tomorrow consequently overexploit their land today*''. More than 800 million people are critically undernourished today (FAO, 2001b), income disparity is increasing and most countries are not on track to meet the UN goals for human development by 2015 (UNDP, 2001).

With respect to energy, humanity is presently dependent on coal, oil and gas for 80% of its supply (Lomborg, 2001). Estimates of reserve size are uncertain at best, with oil considered to be in the shortest supply, and estimates of the peak in global production are as early as 2007–2019 (Mackenzie, 2000). Coal is considerably more abundant with depletion estimates ranging between 200 and 1500 years (e.g. Craig, Vaughan, & Skinner, 1996; Lovejoy, 1996a). Although the potential capacity from renewable energy resources is enormous, the practicality of a near-term global shift away from dependence on fossil fuels is particularly overshadowed by the fact that the two most populous countries of the world, China and India, are 80% and 70% dependent on coal respectively (Lovejoy, 1996a, 1996b). Moreover, recent statistics only show this dependence increasing with a 28% rise in Chinese coal consumption during 2002 (BP, 2003). Reserve estimates of non-energy materials are more variable, although few resources are expected to be limiting within the next 300 years (Craig et al., 1996; Lomborg, 2001).

The theoretical finitude of the basic resources discussed above formed the basis of the systems model in *Limits to Growth* (Meadows et al., 1972, 1992). The validity of a number of these claims has subsequently been diminished by continued observations of non-diminishing reserve sizes for a number of basic resources. In particular with regard to energy supplies, the mainstream belief of environmental scientists no longer supports the concern that global reserves are rapidly diminishing (Holdren, 2002). Moreover, a number of academics have challenged the practical relevance of resource depletion to economic growth by arguing for the importance of positive economic and social feedbacks in response to scarcity – crucially the market mechanism and the ability of humans to provide technological improvements or substitutes (Beckerman, 1974, 1992; Scott & Pearse, 1992; Vincent & Panayotou, 1997). In light of our potential for increased efficiency in resource capture, production and recycling, some technocentrists have even advocated that the very concept of finitude is meaningless, and furthermore that the only meaningful measure of scarcity is the cost of a good (Simon, 1980).

Supported by such arguments, and embodied by the belief that the ultimate resource is really the human mind and its ingenuity (Simon, 1981, 1996), many people uphold that resource endowment limits can easily be breached or expanded (e.g. Exxon Mobil, 2002; Lomborg, 2001); and indeed, much of the available evidence seems to be in their favour. Since the start of industrial extraction the development in reserve size of most energy and mineral resources has far outpaced demand. For example the predicted number of available years-of-consumption in global oil supply (reserve size divided by annual production) has roughly quadrupled in the last 60 years (Lomborg, 2001). Furthermore, there have been notable increases in the efficiency of resource extraction and exploitation. Between 1980 and 1995 there was a 19% reduction in energy use per dollar of GDP in America, the world's largest economy (Battles & Burns, 1998). Moreover, some researchers have argued that the incorporation of theoretically vast increases in solar energy into recycling models could turn much existing industrial and agricultural waste into a viable future resource supply (e.g. Ayres, 1998, 1999). Even when faced with real-term shortages many consider that the price mechanism will force the development of effective substitutes as absolute scarcity becomes evident – e.g. communication satellites instead of copper cables (Simon, 1996), shale oil instead of existing fossil fuels (Craig et al., 1996), and intensive plantations instead of primary forest for timber (Matthews & Hammond, 1999).

The response of advocates of the limits thesis to the above claims is not to nullify the value of technology and human ingenuity, but to argue that a critical set of natural resources exists that cannot be substituted and should act only as complements to man made and human capital (Costanza & Daly, 1992; Daly, 1987; Dasgupta, 1995; England, 2000). Advocates of this position have identified the supply of natural capital and ecosystem services provided by the environment as being finite as well as both irreplaceable, and extremely valuable (e.g. Costanza et al., 1997). However, despite the intuitive validity of this claim, identification, quantification, and valuation of such a critical set of natural resources is fraught with difficulty, thus reducing its operational and political importance. As I discuss below, much of the potential value of technology and human ingenuity is frequently undercut or stifled by real-world political and socio-economic complications.

2.2. Economic Limitation Through the Production of Waste

In light of the above observations of increased technological efficiency in resource extraction and use, many proponents of the limits paradigm perceive that the true limit to economic growth will come from increasing amounts of waste or pollution – too much *use* rather than too little supply (Booth, 1998; Daly, 1980; Ehrlich & Ehrlich, 1978; Mikesell, 1995). Herman Daly (Daly, 1980, 1987) was one of the first to formalise this proposal, and stated following the second (entropy) law of thermodynamics, that economic activity cannot avoid producing high entropy waste material, which under continued growth would lead to unavoidable environmental degradation. Environmental degradation has the capacity to feedback on both economic activity itself by incurring any obligatory abatement costs, as well as on the resilience or threshold capacity of natural ecosystem functions and life support services which are essential to human welfare. The list of causes of environmental degradation is vast, but can be roughly grouped into effects on climate, bio-geochemical cycles, and biodiversity.

The spectre of climate change following anthropogenic greenhouse gas emissions has produced considerable concern over the future capacity and functioning of the planet, following unequivocal reports of human-driven changes in many climatic variables (IPCC, 2001a). Predicted climate alterations over the 21st century are expected to have net negative effects on human welfare and economic opportunity (IPCC, 2001b). In particular developing countries situated in tropics and sub-tropics are likely to experience decreased crop yields with only nominal amounts of climate change due to increases in severe drought and flood events (IPCC, 2001b, 2001c). According to Munich Re, the world's largest reinsurer the cost of climate change is growing two to three times faster than the global economy which pays for it, and could run to more than $300bn by 2050 (Marshall & Lynas, 2003). Following the disruption of the carbon cycle, the second most prominent human-induced alteration of global bio-geochemical cycles is in the nitrogen cycle. Humans presently fix more nitrogen than all natural systems combined (Vitousek, Mooney, Lubchenco, & Melillo, 1997), with concomitant effects on acid rain, water contamination, crop damage, and negative effects on marine aquaculture and biodiversity (Matthews & Hammond, 1999; Vitousek et al., 1997).

Aside from carbon dioxide and nitrogen-based compounds, humans emit some 70,000 other synthetic chemicals into the natural environment (Myers, 1995), with largely unknown consequences for human welfare and economic growth. However, perhaps the most worrying and lasting consequence of economic activity is that of biodiversity loss (Wilson, 2001). The economic benefits of conserving wild nature and global biodiversity are very difficult to quantify but available data suggests that the benefit:cost ratio is at least 100:1 (or in other words these data would have to be out by more than a factor of 100 for environmental conservation not to make economic sense, Balmford et al., 2002), whilst the annual value of freely obtained ecosystem services and natural capital to the global economy is roughly double the gross annual GNP (Costanza et al., 1997). However, despite these clear benefits some of the earth's most productive ecosystems have declined by 1–3% per year since the Rio Convention on Biological Diversity in 1992 (Balmford et al., 2002), whilst some individual ecosystems have declined by as much as 6% per year (Gardner, Côté, Gill, Grant, & Watkinson, 2003). In the case of individual biological species our understanding is even less certain, but recent extinction rates are 100–1000 times their pre-human levels in well known taxonomic groups, with predicted increases of an additional order of magnitude during the next century (Pimm, Russell, Gittleman, & Brooks, 1995). It is important to remember that that the global environment is made up of many highly interdependent components, and our impacts upon one aspect can have strong negative repercussions elsewhere. For example recent research has predicted that in addition to the effect of other stressors, human-induced climate change is likely to commit a further 15 and 37% of species to eventual extinction (Thomas et al., 2004).

Despite the above catalogue of threats, some politicians and academics consider economic activity and the attainment of wealth to be far less a cause of environmental degradation, but a *prerequisite* for environmental quality (and hence continued growth) (e.g. Beckerman, 1992; Stokey, 1998; Vincent & Panayotou, 1997). This belief is founded in the observation that due to improvements in technical efficiency, pollution abatement technology and environmental awareness, environmental quality is eventually a decreasing function of income (Grossman & Krueger, 1995; Stokey, 1998). This relationship has been termed the Environmental Kuznet's Curve (EKC), and perhaps the most famous example is the observed decrease in SO_2 and smoke concentrations in London during the last century (e.g. Lomborg, 2001). However, as noted by Arrow et al. (1995), economic development is not a panacea for environmental quality. This fact stems primarily from the large spatial and temporal scales across which many pollutants operate, making it very difficult to elucidate negative feedback effects (Rothman, 1998; Stern, Common, & Barbier, 1996). Secondly many pollution problems are cumulative and/or irreversible in nature and any subsequent increases in wealth are irrelevant in the face of irreparable damage. In fact some recent research suggests that economically advanced countries can actually have higher rates of biodiversity loss – undeniably the most irreversible consequence of economic activity (Naidoo & Adamowicz, 2001). Finally, despite increases in environmental regulation, benefits derived from pollution abatement can be offset in developed countries simply by increases in scale. This, together with the transferability of many pollution costs to the industry-intensive developing world (Chapman, Agras, & Suri, 1999), helps account for the fact that despite popular indicators, material through-flow is in fact *increasing* in most industrial economies (Matthews, 2000). Such arguments against the validity of EKCs also serve to expose the overly simplistic assumption of a vicious circle relationship between poverty and environmental degradation. Whilst it is clear that poverty can promote overexploitation of the environment, all too frequently it is the process of wealth acquisition and economic development itself which promotes waste production and environmental degradation (Duraiappah, 1998).

Although it is clear from the above discussion that economic activity has the potential to cause severe environmental degradation, it is far more difficult to prove based on our current understanding whether this provides an absolute limit to *growth*. Many, if not most neo-classical economists maintain an unfaltering belief in the sanctity of economic value (meant here in the popular sense to mean simply price) as a true measure of welfare. However, public goods and environmental externalities are endemic in most economies (Ayres & Kneese, 1969), a situation which has led to a universal over-exploitation and degradation of shared resources – the 'tragedy of the commons' (Hardin, 1968). The founding principle of the field of environmental economics is that the environmental consequences of economic activity can in theory be valued, and hence incorporated into future private and public cost-benefit analyses. Despite the fact that only a negligible proportion of the global economy has incorporated such a comprehensive accounting of environmental costs and benefits, growth optimists may argue that this presents a way of promoting sustained future development: another example of man's ingenuity. However, this assumption is seemingly oblivious to the serious inadequacies in valuation techniques and other failings of the market system (Perman, Ma, McGilvray, & Common, 1999; Willinger, 1999). Whilst market incentives are able to make considerable progress towards limiting environmental degradation, such inadequacies preclude their ability to fully compensate for the negative effects of economic activity, and thus sustain continued growth. In the real world, calls for a constraint on growth, or a fundamental shift towards a new growth model (e.g. Hawken, Lovins, & Lovins, 2000) are largely ignored until the economy suffers a direct and negative feedback (IMF, 2000). However, the existing world economic view includes very little, if any precaution. Irrespective of their possible future existence, the fact that few serious negative feedbacks from environmental degradation are yet prevalent in the major economies of the world (aided by the fact that globalisation allows the exportation of any industrial activity which involves negative environmental impacts), prevents any serious present recognition of absolute limits to growth, and hence a possible pre-emption of an impending environmental disaster.

3. REAL-WORLD COMPLICATIONS

It can be seen from the above discussion that resolution of the limits to growth debate is far from imminent. However, many arguments remain grounded in little empirical evidence, instead being more commonly dominated by theoretical possibilities or eventualities, logic, and semantics. Some practical complications to this debate have already been mentioned. However, a number of further factors which are endemic to the economic system need to be emphasised in so far as they can serve to exacerbate any physical constraints on economic growth.

As mentioned above, the ability of technological progress in industry, business and agriculture to sustain continued economic growth is frequently overwhelmed by the absolute scale of the human population increase. The importance of this point is frequently overlooked by many, and repeatedly by Bjørn Lomborg in *The Skeptical Environmentalist*. In one example Lomborg notes that the average fuel efficiency of cars in America has increased by 60% between 1973 and 2000. He fails to note in the same discussion however that the *number* of cars has increased by 200% between 1970 and 2000 (BTS, 2001), resulting in a net increase in carbon dioxide emissions (although technological advances have prevented similar increases other vehicle emissions such as nitrogen oxide). With respect to food production Lomborg notes that the number of starving people in sub-Saharan Africa dropped by 5% between 1970 and 1996. However, the overall population size roughly doubled during the same time period. Even to keep the numbers of starving people non-increasing the percentage would have to have dropped by more than half (Pimm & Harvey, 2001). In addition to an overwhelming trust in the ability of new technology to alleviate limits, many growth optimists hold a similar faith in the ability of the market mechanism to ensure that individual resources are never driven to extinction: i.e. demand for scarce commodities rapidly diminishes as the price escalates upwards. However, human material aspirations frequently serve to contradict this principle and allow for resource extinction in a very real (as opposed to commercial) sense – as in the desire of Japanese consumers for rare fish, where a single southern bluefin recently sold for $178,000 (Reynolds, Dulvy, & Roberts, 2002). More than anything else these examples indicate that market principles, technological development, and human ingenuity frequently fail to compensate for the relentless increase in both the material aspirations, and sheer number, of people.

In addition to the overbearing scale of growth in human numbers and material aspirations, there is a growing appreciation that the socio-economic system itself has a number of *internal* constraints or feedbacks which pose a serious threat to future growth. One such example is the effect of climate change, itself a direct consequence of economic activity, on poverty. In 1997 the then World Bank President, James Wolfensohn stated that "*continued global warming is in nobody's interest, but the simple facts of the matter are that developing countries will suffer the most damage, and their poor will be at an even greater disadvantage*" (United Nations General Assembly, June 1997). It does not take much further imagination to appreciate how increasing global poverty may seriously hinder future global economic development. Indeed, Michael Moore, the President of the World Trade Organisation in 2002 even went so far as to say that "*poverty in all its forms is the greatest single threat to peace, security, democracy, human rights and the environment*" (WTO Conference, Mexico, 2002). In recognising the link between poverty and global security (international war, as well as terrorism) it can quickly be seen by everyone that even when only considering aggregate (rather than equable) growth, poverty represents a major threat to sustained economic growth. This interconnectedness of climate change, poverty and global security has been devastatingly re-emphasised in a recent high-profile report from the US Department for Defence, which predicts that abrupt climate change could bring the planet to the edge of anarchy as countries develop a nuclear threat to defend and secure dwindling food, water and energy supplies (Townsend & Harris, 2004). The implications of this message for future human economic prosperity could not be clearer. Moreover, it hardly needs to be emphasised that the Pentagon is no radical environmental pressure group.

Given the complex but highly important practical relationship between poverty and inequality with global economic activity, it is perhaps surprising that they are rarely considered when debating physical and economic limits to growth. As I have discussed above, one of the fundamental arguments of technocentric optimists such as Julian Simon and Bjørn Lomborg is that human ingenuity can alleviate concerns about limits through technological advances. However, in addition to other complications, the practical implications of political geography and income inequality severely restrict this option. How can an impoverished people remove obstacles to economic progress via new technology if the initial capital required is beyond their means? As Sandersson and Johnston (1980) put it, does Simon expect "capital to drop like a manna from heaven whenever the labour force grows?". Poverty aside, many social and political factors exist to prevent mutual benefit from *existing* technology never mind any future theoretical advances (e.g. patenting and intellectual property rights, see also Davis, 1980; Weitzman, 1998). This reality seems invisible to those who consider that "innovations . . . regardless of where they originate are carried around the world to be used wherever they are most advantageous" (Scott & Pearse, 1992) (if "advantageous" was swapped for "profitable" this statement sounds less ridiculous). Reality seems once again absent when Simon (1996) equates *population* directly with *productivity*, an assumption that appears at odds with many empirical observations. In a country already impoverished due to a history of colonisation, war, and international debt, continued population growth can only serve to increase the level of poverty in a capital starved nation. This same escalation of poverty serves to further restrict a countries economic potential – a classic example of which can be seen in Namibia, where 26% of the agricultural work force has been lost to the poverty related disease AIDS since 1985 (FAO, 2001a; UNFPA, 2002). Technocentric challenges to the limits to growth position, although often logical and supported by (frequently selective) empirical evidence are underlain by many such theoretical assumptions, and examples of real-world violations are commonplace.

A number of ideological alternatives have been proposed to help restructure the global political and economic framework away from the current system which exacerbates the rich-poor divide (see Stiglitz, 2002), and towards one which seeks to increase general prosperity through levelling the power of nations and multinational companies (one of the most persuasive examples of which is presented by George Monbiot in *The Age of Consent*, 2003). However, to be successful such alternatives require nothing short of a global revolution, and as for the successful dissemination of green technologies, they are confronted with the reality of strong resistance from a small number of powerful economic forces which benefit from maintaining the status quo.

4. CONCLUSION

Although the advancement of technology and scientific understanding has undeniably altered the terms and parameters of the limits debate, it has also unveiled new fears and a growing realisation of our capacity to curtail and diminish the future welfare of mankind. There is strong evidence that although we appear to have alleviated many of the earlier concerns of resource depletion, the threat of other physical limits to growth are as prevalent as they ever have been, particularly with respect to the production of waste materials. Moreover, it is increasingly likely that despite theoretical arguments which describe the potential of technology and human ingenuity, real-world complications, uncertainty and basic human aspirations will have a major role in shaping the future pattern of environmental degradation, and human welfare. A recent review of the subject describes technology as being "*a double edged sword for the environment*" and concluded that we do not yet possess enough scientific information to properly inform the policy making process about the projected interaction of technology dependent industries (e.g. energy and agriculture) with the environment (Grübler, Nakicenovic, & Nordhaus, 2002).

As was seen above, overall global economic growth has persisted despite severe environmental degradation in many areas. However, the fact that such degradation can have negative intra and inter-generational equity effects, in addition to affecting non-human life forms is abhorrent to many, and therefore cannot symbolise growth of human welfare in what many would consider to be the truest sense. (Daly, 1987; Hirsch, 1977). To lack consideration of such aspects of welfare surely serves to make the search for progress less meaningful (Booth, 1998; MacKellar, 1996), and perhaps turns economics, as Paul and Anne Ehrlich (1978) put it, into '*the gallop of a headless horse*'.

In resolving the apparent paradox of the two predictions of Edward Wilson and Bjørn Lomborg, we would do well to consider the possibility that both sets of data are largely correct. It is unquestionable that humanity has made astonishing progress. However, these facts do not make Wilson's predictions wrong but can be easily explained by the concept of over-shoot: that we are able to exceed the carrying capacity of the world, thus enabling existing populations to live longer, whilst also depleting out natural capital for future generations (or impoverished existing ones) (Hawken et al., 2000), or stated another way "*the ability to accelerate a car that is low on gasoline does not prove that the tank is full*".

The issue of limits remains unresolved, uncertain, complex and controversial. Two key factors are frequently absent from the technocentric perspective; (1) the importance of precaution in the face of ignorance about the effects of our activity on the global environment and (2) the importance of real-world complications such as poverty, human material aspirations, and the existing asymmetry of political and economic power, in determining the potential of human ingenuity and technological progress to alleviate limits. In the face of technocratic optimism we would do well to remember that Galileo's observation that the Earth is not at the centre of the universe took 359 years to be accepted by the Catholic Church. Stubborn adherence to established paradigms could be our downfall.

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