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Abstract

The sustainable development paradigm has failed. Ecological overshoot is accelerating and breaching the intergenerational equity criterion which requires humanity to live within safe planetary ecological limits. The equity gap between rich and poor also continues to grow wider breaching the intra-generational equity criterion.

This paper argues that the failure of the sustainable development paradigm is due to it being subsumed into the economic paradigm - a paradigm so disconnected from reality that it simply cannot address the sustainability problem. This is grounded in a failure to understand the fundamental contradiction between ecological imperatives and economic imperatives.

An overview of the way the world works ecologically followed by a brief presentation of the human evolutionary journey provides the context for the discussion. Based on this, economics is generically defined as 'the way an animal species organises itself to obtain the necessary low entropy from it environment for it wellbeing'.

This is followed by an evaluation of the sustainable development construct and how it is addressed through the lenses of environmental and ecological economics. This leads to the conclusion that the economic system as currently designed is simply unable to deal with the sustainability problem.

An analysis of the financial system and its role in the problem is then presented and leads to the conclusion it is the inevitable structural driver of ecological overshoot and increasing inequity. An examination of the origins of economic thought and the assumptions it is based on throws some light on why the economic system fails humanity.

The final section considers how humanity might allocate the absolutely scarce resources of the planet so as to maximise the welfare of humanity while ensuring the very long term sustainability of the human enterprise.

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Introduction

The sustainable development paradigm has failed. The two internationally agreed necessary criteria for a sustainable human presence on the planet – inter- and intra-generational equity – have both been massively breached in the 25 years since they were proclaimed by the World Commission on Environment and Development (WCED, 1987). Ecological overshoot is accelerating (WWF, 2012) and breaches the intergenerational equity criterion which requires humanity to live within safe ecological limits. The equity gap between rich and poor also continues to grow wider (Milanovic, 2011) breaching the intra-generational equity criterion.

In spite of this, the sustainable development paradigm remains as humanity's response to the sustainability emergency which can be best described as a 'perfect storm' of rapidly converging global crises that threaten the survival of human civilisation (Dunlop, 2006).

These crises include: climate change (likely dangerous); sea level rise (possibly metres this century); ocean acidification; the sixth major extinction event (ecological life support systems are in decline); the peaking of oil and other key resource production; loss of soils; fresh water supplies; forest and fisheries; ongoing poverty and inequity (widening gaps) for a large proportion of humanity; and most recently the global financial crisis. Humanity is running the planet as if it were a business in liquidation.

The fatal flaw with the sustainable development paradigm is the failure to understand the fundamental contradiction between ecological imperatives and economic imperatives. Instead, living within ecological limits and relying on economic growth to drive development were seen as compatible objectives so long as the economy dematerialised by at least the same rate as it grew (WCED, 1987).

It is in this context that the sustainability discourse (a concern for the very long term welfare of humanity) was largely subsumed into the economic paradigm through the 'sustainable development' construct. The promise of economics is to allocate scarce resources so as to maximise the welfare of society. The evidence is that economics has failed its promise to humanity in at least two ways.

First, there is a massive and exponentially increasing over-allocation of the planet's scarce resources into the global economic system resulting in ecological overshoot and the breaching of the intergenerational equity criterion. Human survival will almost certainly require a massive reduction in the material and energy throughput of the global economy.

Second, there is a massive under-allocation of the world's resources to the vast majority of humanity who live in poverty while there is a corresponding massive over-allocation of resources to the wealthy minority of humanity. This highly divergent allocation of resources transgresses the sustainability criterion of intra-generational equity. The welfare of humanity would be greatly enhanced through a convergence of access to resources towards a similar level for all people so as to achieve intra-generational equity.

In addition, the global financial system is in a precarious state and should the financial system collapse the world would surely be thrown into a state of chaos (Friedman, 2009; Gilding, 2011). Supply lines of essentials could cease to flow almost immediately with potentially life-threatening consequences for much of humanity.

Understanding and addressing this failure of economics is arguably the most important research problem that humanity has to solve if economic, social and ecological collapse is to be avoided and the human enterprise is to be viable into the indefinite future.

Aim

The aim of this paper is to provide the "Missing the Point" online sustainability conference with food for thought that challenges and questions many of the assumptions and received wisdoms in both the sustainability and economic fields. In the spirit of Herman Daly (2005, 102) who said if "choosing between tackling a political impossibility and a biophysical impossibility, I would judge the latter to be the more impossible", this paper attempts to sketch a solution to the sustainability problem that is physically possible in the hope it can be realised politically. There is obviously no point in developing politically palatable 'solutions' that are physically impossible.

The argument presented here is that the design of the economic system is in fact the systemic structural root and driver of both key dimensions of the sustainability issue and the breaching of the two sustainability criteria. Both problems will inevitably continue to rapidly worsen unless the economic system is transformed or abandoned so as to remove the structural drivers that give rise to ecological overshoot and increasing inequity.

The theoretical world of economics is a fantastic unreal world where thermodynamic and ecological laws do not apply, where humans have perfect knowledge of everything that's going to happen in the economic realm, and where there is no absolute scarcity of resources thanks to the principle of infinite substitution.

Organising the world on the basis of what Keynes described as theoretical nonsense (Nadeau, 2006, 112) did not matter much when the scale of the human economic enterprise was trivial in comparison to the ecological system in which it is embedded. However, as the global physical scale of the economic enterprise grows exponentially it eventually overwhelms the capacity of the planet's ecosystems to sustain it. This is the essence of the sustainability problem.

The paper will begin with an overview of the way the world works ecologically, the dependencies of humanity on the ecological world for our survival and the disruption to ecological integrity that the human economic enterprise is causing. It will generically define economics as 'the way an animal species organises itself to obtain the necessary low entropy from it environment for it wellbeing'.

The evolutionary journey of humanity culminating in the sustainability problem is then presented to contextualise the problem. This is followed by an examination of the sustainable development construct and how it is addressed through the lenses of environmental and ecological economics. This leads to the conclusion that the economic system as currently designed is simply unable to deal with the sustainability problem.

An analysis of the financial system and its role in the problem is then presented and concludes it is the inevitable structural driver of ecological overshoot and increasing inequity. An examination the origins of economic thought and the assumptions it is based on then throws some light on why the economic system fails humanity.

The final section considers how humanity might allocate the absolutely scarce resources of the planet so as to maximise the welfare of humanity while ensuring the very long term sustainability of the human enterprise.

How the World Works Ecologically

The natural order of the universe is that energy and matter dissipate or run down or break down or cool down of their own accord. The fundamental law of the universe that describes this reality is the 2nd Law of Thermodynamics – order spontaneously dissipates and degrades into disorder or chaos. The entropy or disorder of the universe is understood to be increasing.

About 3.8 billion years ago something remarkable happened on Earth. A self catalysing loop of chemical reactions started somewhere in the ocean. Drawing energy and matter from the surrounding environment this loop of reactions sustained itself and became the first spark of life (Kauffman, 1993). It was the distant ancestor of every species of living thing that has ever existed and evolved into the whole web of life on Earth.

Life seems to defy the 2nd Law of Thermodynamics in that it takes dissipated matter and energy from the environment and concentrates and organises and structures it into living organisms. Living organisms are technically known as dissipative structures in thermodynamics because their order and structure is created by the energy that flows and dissipates through them (Johnson, 1988). Thus, life appeared to reverse the entropic flow of the universe by creating order out of chaos (see Kauffman, 1993).

But life does not actually defy the 2nd Law. What happens is that a localised pool of order is created at the expense of even greater disorder in the surrounding environment so that the system as a whole moves to an overall state of increased disorder in the process (Georgescu-Roegen, 1971, 74). In general the order created by life on the Earth is created at the expense of the increasing disorder of the Sun as it slowly burns up.

Life (through photosynthesis) produces a localised reversal of the entropic flow, organising, structuring and concentrating matter and energy, thereby imbuing it with the quality of low entropy which may be loosely translated as 'usefulness'. Through the eons of time this has created the complex dynamic world that we know today, including its atmosphere, soils and the web of life.

Solar energy is captured by plants and a fraction of that energy cascades into the herbivores that eat the plants and in turn a fraction of that energy cascades into the carnivores that eat the herbivores. Woven together, these organisms make up ecosystems that are kept going by the solar energy cascading and dissipating though them.

Without life, the Earth would be barren and run down like Mars. Life has transformed the Earth's early atmosphere of methane, ammonia and water vapour to the current mix of nitrogen and oxygen with traces of greenhouse gasses that keep the planet some 30 degrees Celsius warmer than it would otherwise be. Billions of tons of matter that make up the biogeochemical cycles of the planet continually flow through the web of life and keep it going.

However, there is a safe operating space that this system operates within and recent research shows that humanity is exceeding some of the biophysical boundaries that define this space (Rockström, 2009).

Economics – How Society's Organise to Obtain Low Entropy
In order to survive, each animal species goes about obtaining low entropy matter and energy from its supporting environment. How any animal species goes about this can be thought of as its economic activity (Eldredge, 1995). For most species, the evolutionary wisdom of how to do this is imprinted in their genes. Over and above genetic transmission, humans rely primarily on the transmission of knowledge across generations to survive. Each culture develops its worldview or mythology (a story that makes sense of reality) through which its way of organising the relationships of its members (its social system) and its way of extracting low entropy or usefulness from the environment (its economic system) is passed from one generation to the next.

This ability to conceptualise and to transmit learned knowledge from one generation to the next differentiates humans from other animal species and has conferred an adaptive advantage on humans. Innovations such as the control of fire, tools, clothing and shelter have allowed humans, originally a tropical animal, to occupy some of the coldest regions of the planet. But just as a culture's worldview is its primary means of survival, it can also lead to its demise if it leads to behaviours at odds with how the world works ecologically.

The ability to conceptualise and to transmit learned knowledge across generations has also enabled humans to invent their way around nature's limits or negative feedback loops. This is humanity's Achilles Heel in that can allow humans to overstep the carrying capacity of the supporting environment temporarily, and if this goes far enough before being brought in check it could destabilise the whole web of life as would be the case if a runaway greenhouse effect was triggered (Guterl, 2012).

In the course of the human evolutionary journey, the mode of economic organisation has evolved from hunting and gathering to agriculture to industrial to financial. In the period humans lived by hunting and gathering (of course some do still to this day) they were little different from any other animal species in their relationship with the broader web of life. Their numbers ebbed and flowed in response to the availability of food in their surrounding environments. In times of increased scarcity either their numbers declined or they migrated to greener pastures.

Then about 10 000 years ago a new mode of organization emerged - agriculture. Agriculture heralded the beginning of settlement and civilization. While hunting and gathering resulted in fairly minimal ecological impacts, agriculture involved quite significant interventions in, and disruptions of, ecological processes and systems. Indeed, Tainter (1990) has identified over 20 civilisations that have collapsed over the past 10 000 years, very often as a result of agriculture undermining itself and the surrounding ecosystems. In many cases agriculture has degraded the landscape through salinisation (e.g. the 'fertile crescent' cradle of civilization surrounding the Tigris and Euphrates rivers), soil and nutrient loss (e.g. overproduction in the 'granary of Rome' in northern Africa), and denudation of the surrounding landscape (e.g. the surrounds of eastern Mediterranean). While significant, these collapses were fairly localized and the civilization in question either migrated to be absorbed elsewhere or it disappeared if there was nowhere else to go.

The most profound shift in how humanity organized itself began a little over two centuries ago in the 18th century. Depending on the perspective, this shift is known as the Industrial

Revolution, the Great Transformation (Polanyi, 1971), the Economic Revolution (Heilbroner, 1980) or the Ecological Transition (Bennett, 1976).

For Polanyi (1971), the Great Transformation was the transition from a society where people met their needs through social relations, to an economy where people met their needs through economic relations. This involved huge dislocations in life including the enclosure of the commons which forced people to earn money in order to meet their needs.

Heilbroner's Economic Revolution was the emergence of the market system (as opposed to markets) as "a mechanism for sustaining and maintaining an entire society" (Heilbroner, 1980, 25). As Heilbroner explains, until the seventeenth century, the market system could not even be conceived "for the thoroughly sound reason that Land, Labor, and Capital – the basic agents of production which the market system allocates - did not yet exist" (Heilbroner, 1980, 25). Even the idea of gain for gains sake is a modern one - a concept Heilbroner points out was even foreign to the 17th century Britain of Sir William Petty who recorded men would only labour when necessary, preferring leisure to labour (Heilbroner, 1980, 22).

Bennett's (1976) Ecological Transition emphasised the transition from societies where the only source of power was muscle power to the unleashing of unimaginably vast sources of fossilised energy. Without this vast source of energy it would not have been possible for humanity to transform the face of the planet in the ecologically unsustainable way it has. Indeed, it would not even be physically possible for the human population to grow to the present 7 billion. Smil (2002) showed that about 2.5 billion people alive today could simply not exist without the doubling of the planet's nitrogen cycle that has occurred through the production of nitrogen fertilisers made from fossil fuels. There is simply not enough biologically available nitrogen in the natural nitrogen cycle to make the protein of more than about 4 billion people.

The human capacity to invent a way around nature's limits is central to the sustainability story for it allows humans to temporarily far exceed the supportive capacity of their surrounding environment (or as is the present case, planet) in ways that other species cannot. Tainter (1990) postulated that the human strategy for getting around natures limits is to move to ever higher levels of social and technological complexity and increased food production. The problem with this strategy is that each increase in complexity requires a disproportionately greater per capita flow of resources to sustain that greater level of complexity.

The 'security' of increased food production also allows population to increase further multiplying the demand for resources to eventually unsustainable levels resulting in collapse. The sustainability lesson from Tainter is to avoid the strategy of increasing complexity. The collapse of any ecological subsystem is simply a return to increased simplicity and increased resilience (Gunderson and Holling, 2001). It suggests that in designing a sustainable society, simplicity may be a key design criterion to reduce per capita resource flows to sustainable levels.

The simple sustainability lesson from thermodynamics is that nature produces an essentially fixed rate of flow of low entropy matter and energy that spontaneously degrades with time. Humans, like all animal species, require a flow of low entropy to live. To use a mechanistic analogy, the biosphere is like a self-organising factory where the only input from the outside is sunlight. This factory is the web of life comprising all living things. It produces the conditions for its continuance and its plants produce a continuous flow of low entropy matter containing embodied energy by which it (each species and the whole) continuously reproduces itself.

Over the eons of time this low entropy flow has very slowly accumulated into two kinds of stocks of low entropy: non-living, non- renewable stocks such as fossil fuels and mineral deposits; and, the living, renewable stocks such as soils, forests, fisheries and ecosystems that generate the low entropy flows such as wood, fish, fresh water, air, climate and other ecosystem services on which humanity depends for its existence. In economic language these stocks can be thought of as capital (or natural capital) and the flows as income.

The modern industrial economy fuelled by fossilised energy, has allowed humanity to harvest exponentially growing quantities of low entropy sourced from all over the planet thereby allowing the human population to expand far beyond what would be possible in the absence of such fossilised energy. The sustainable flow was passed in the 1980s (WWF, 2012) and since then the only way to keep growing the flow is by liquidating the stocks of natural capital. Returning to our factory analogy, humanity's exponentially growing demand for low entropy reached the point in the 1980s where we started to dismantle the factory itself in the quest for more low entropy.

The key point here is that all economic activity uses up or dissipates natural capital. If the economic system consumes natural capital from the biosphere more quickly than it can be regenerated, this is by definition, unsustainable. A fundamental condition for sustainability is that the economic system consumes natural capital from the biosphere no more quickly than it can be regenerated by natural processes that are essentially ecological.

Now that we have started to understand the way the world works as an ecological system and from a thermodynamic perspective, the discussion turns to the sustainability problem.

The Sustainability Problem

The sustainability problem has a long history that can be traced back to Plato (Glacken, 1967) and in more recent times was addressed in a significant number of publications from the late 1940s (Vogt, 1948; Osborn, 1948; Osborn, 1953; Brown, 1954; Sears, 1956; Carson, 1962; Boulding, 1966; Ehrlich, 1968; Georgescu-Roegen, 1971) culminating in Limits to Growth published in 1972 (Meadows, et.al., 1974). These were all concerned about the impacts of human economic activities on the ecological or environmental sustainability of the human enterprise.

The origins of the ‘sustainable development’ construct can be traced back to the very first international sustainable development conference - the United Nations Conference on the Human Environment, held in Stockholm in 1972.

The position put forward by the Conference was that economic growth was essential if development was to take place in the less developed parts of the world. It was argued this development need not clash with environmental protection. The key to achieving this was an integrated planning approach to resolve conflicts between environmental and developmental objectives. Such an approach would make it possible to achieve both environmental and developmental objectives. Indeed, development was also seen as necessary to fund environmental management and improve environmental quality (UN, 1973).

Although economic growth had received some attention as a source of environmental pressures in the *Report of the United Nations Conference on the Human Environment*, the Stockholm Conference rejected the 'no growth' philosophy as being "absolutely unacceptable" (UN, 1973, 46).

In essence, this seminal discourse of sustainable development remained unchanged 15 years later in the 1987 publication *Our Common Future*, better known as the Brundtland Report which served to bring the concept of sustainable development to public awareness around the world. It served an urgent notice to the world that immediate decisive political action needed to be taken "to begin managing environmental resources to ensure both sustainable human progress and human survival (WCED, 1987, 1).

The twin objectives of the Brundtland Report were the elimination of absolute poverty in the Third World and overcoming the problems of environmental degradation and resource depletion more generally. The elimination of poverty was afforded the highest priority (WCED, 1987).

According to Brundtland, "a relatively rapid rise in per capita incomes in the Third World", coupled with growth in the industrialised world to revitalise the world economy, is essential to overcome poverty. It called for "a new era of economic growth - growth that is forceful and at the same time socially and environmentally sustainable" as the means to achieving sustainable development (WCED, 1987, xii). Growth rates of 5% in the developing nations and 3%-4% in the developed nations were advocated (WCED, 1987, 50-51).

Although committed to a policy of economic growth, Brundtland recognised the reality of ecological limits and acknowledged economic growth as the major factor contributing to the problems of environmental degradation and resource depletion. In order to reconcile this contradiction, the Report has the qualification that this "requires a change in the content of growth, to make it less material- and energy-intensive in its impact" (WCED, 1987, 52). Dematerialisation of the economy through increased economic efficiency was seen as the key to achieving sustainable development.

The Brundtland Report triggered an international response with most governments around the world placing sustainable development squarely on their policy agendas. It also triggered a flurry of academic activity including the formation in 1989 of the International Society for Ecological Economics (Costanza, 1989), an upsurge of interest in environmental economics and the generation of a vast sustainability literature dominated by Brundtland's sustainable development construct.

By the time of the 1992 United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro (also known as the Earth Summit) the sustainable development construct was well entrenched and remains at the core of the sustainability discourse to this day. However, the recent failure of the 2012 Rio +20 UNCED conference appears to mark the end of any international political commitment to the sustainability imperative. Rather, global financial instability and a weak global economy now hold centre stage.

Unpacking the Sustainability Concept
The Brundtland Report defined sustainable development as

> *development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987, 43).*

This well-known definition defines the generally accepted twin objectives of sustainable development. In more formal language, these objectives are intergenerational equity and intra-generational equity - that is, equity of access to resources both between and within generations. Dovers makes the observation that intergenerational equity is the fundamental objective:

> *If we do not place a value on the needs of future generations, then sustainability is not an issue (Dovers, 1990, 3).*

The second objective of intra-generational equity derives from the first as Brundtland points out:

> *Even the narrow notion of physical sustainability implies a concern for social equity between generations, a concern that must logically be extended to equity within each generation (WCED, 1987, 43).*

While there is widespread general agreement that these are the necessary conditions for sustainability, there is little agreement on how intergenerational equity is to be achieved. Basically there are two competing views, an economically based view and a physically based (ecological) view known respectively as the 'weak' and 'strong' sustainability models (Daly, 1991, 250). What differentiates these two models is the extent to which financial and human-made capital can substitute for natural capital. This subtle difference reflects a fundamental paradigmatic divide. This question of capital substitutability is the critical question in the sustainability debate.

Natural capital (the factor of production called 'land' in economics) consists of renewable and non-renewable resources. The renewable form is living and active and includes biodiversity, species, habitats and ecosystems. If put under too much pressure it may become non-renewable. It spontaneously produces a finite rate of flow of goods and services (that can be thought of as the interest from natural capital). The renewable form is more than just resources - its primary value is life-support. The non- renewable form is passive and consists primarily of fossil and mineral deposits. Stocks are finite and flow rates are a matter of policy. In contrast, human-made capital consists of financial capital (i.e. money or debt), manufactured capital (i.e. machines, buildings, tools, etc. made by humans from natural capital using human capital), and human capital (i.e. people's labour, skills, knowledge and culture).

The weak sustainability model argues that natural capital can be substituted for by financial, manufactured and human capital (it is a central tenet of economics that all forms of capital are more or less substitutes for one another). Therefore, natural capital is not a limiting factor and can continue to be liquidated and transformed into other forms of capital through the economic process. This view argues that the welfare of future generations is assured so long as the total stock of the various forms of capital does not diminish. This view reflects mainstream economic thought (Daly, 1991, 250) including environmental economics. This approach sees no limits to economic growth.

The strong sustainability model argues that there is limited substitutability between natural and human-made capital - that these two forms of capital are largely complementary and that natural capital stocks are the limiting factor and must therefore be maintained. The following example clearly illustrates the different views.

The annual fish catch is currently limited by the natural capital of fish populations in the sea and no longer by the man-made capital of fishing boats. Weak sustainability would suggest that the lack of fish can be dealt with by building more fishing boats. Strong sustainability recognises that more fishing boats are useless if there are too few fish in the ocean and insists that catches must be limited to ensure maintenance of adequate fish populations for tomorrow's fishers (Daly, 2005, 103).

Proponents of strong sustainability also point out that manufactured capital is made from natural capital. As Korten (2006) explains "without these natural systems, none of the other forms of wealth, including human labour and technology, can exist”. They point out that there is no substitute for the life-support functions of natural capital and even if there was, why try and artificially produce it at great cost when natural capital produces it spontaneously at no economic cost. This view reflects modern ecological economic thought. This perspective understands there are physical limits to growth and calls for a steady state economy in physical terms.

While the weak sustainability model may have made sense in the past era of an 'empty world' when the scale of the human enterprise was trivial, it no longer appears to make sense as the basis for ensuring the welfare of future generations in a 'full world' where the scale of the human enterprise already far exceeds the biophysical carrying capacity of the planet.

The discussion now delves deeper into to the environmental and ecological economic perspectives of the sustainability problem.

Environmental Economics

As we have seen, economists, including some environmental economists ascribe to a weak sustainability perspective and see no absolute physical limits to economic activity. In addition to the general substitutability of different forms of capital they hold to a theory of infinite substitutability of resources. They argue that when in a market based economy, as a particular resource becomes increasingly scarce, a combination of human ingenuity, technological innovation and market forces (rising prices) will always lead to a substitute resource being found.

The environmental economic school of thought sees environmental problems, including unsustainability generally, as cases of market failure. Because air and water and other environmental factors are unpriced or underpriced, they get over-used resulting in environmental problems. The way to fix the market failure is to ‘get the prices right’ on those things that are unpriced or underpriced and then, according to the theory the market will solve the problem. The outcome of this correction of market failure is economic efficiency. There appears to be a tacit understanding amongst environmental economists that this equates to sustainability.

Those environmental economists that accept the reality of biophysical limits (as did Brundland) advocate the dematerialisation of the economy. This idea has become central to the sustainable development discourse because it is the only possible way to continue to have economic growth while not increasing the environmental and ecological impact of the economy on the planet. Dematerialisation works so long as the economy dematerialises by at least the same rate as it grows to that impacts remain constant or decrease. This idea is appealing to economists because increased economic efficiency is also seen as the key means by which dematerialisation is achieved.

Evaluating the Environmental Economic Perspective
The essence of the environmental economic approach is that the pursuit of efficiency will result in a sustainable world by getting the prices right so as to internalise any externalities and to also achieve dematerialisation of the economy. In order to evaluate the validity of this perspective the matter of getting the prices right will be considered first.

Markets (and neoclassical economic theory) only work in a world of relative scarcity. Relative scarcity simply means the scarcity of one resource relative to another resource. In economics, price is the ratio of the scarcity of one resource relative to the scarcity of another. In the economists' theoretical world of relative scarcity, there may be some specific resources that do run out, but overall there is no general scarcity because, as a resource gets close to running out, market forces will force its price to rise and this incentive plus human ingenuity will lead to a substitute resource being found.

This is fine for resources for which there are substitutes. However, there are resources without substitutes such as ecological systems or the life-support functions they perform. These and even the total stock of low entropy produced by life are finite in their availability. In other words, these and arguably the whole spectrum of natural capital produced by nature are absolutely scarce. Since resource prices reflect the relative scarcity of different resource types and not their absolute scarcity (Baumgartner et.al., 2006, Lawn, 2010) markets cannot rationally allocate absolutely scarce resources. In other words, it's not possible to get the prices right for absolutely scarce resources. Since the primary focus of sustainability is on the non-substitutable living resources that are by their nature absolutely scarce this begs the question of whether it is possible in principle to 'get the prices right' in regard to the sustainability problem.

A further problem to be considered is how a one-dimensional value (price) can be used to solve a multi-dimensional sustainability problem involving the interaction of countless factors given the complexity of the ecological world. Price would need to reflect a multitude of relevant physical and ecological variables at the very least. To assume that the interaction of supply and demand in the market which reflects the subjective desires of ecologically illiterate consumers can provide this information in a single variable is a very long bow to draw. Furthermore, mathematicians point out that it is simply not possible to solve such multiple variable problems on the basis of a single variable (Keen, 2009, pers.comm.). Even this brief analysis throws grave doubt on the idea that sustainable outcomes can be achieved simply by getting the prices right.

The next consideration is the argument that economic growth can be sustainable so long as efficiency gains allow the economy to dematerialise by at least the same rate as it grows. One problem with this idea is the Jevons (or Rebound) Effect. Jevons observed that when technology improves the efficiency with which a resource is used, there is a tendency to use even more of the resource (Alcott, 2008). A hypothetical example often used is that of a nation's car fleet where fuel efficiency is suddenly doubled, thus halving fuel use. Fuel becomes cheaper and so many more people drive leading to even more fuel being used than previously. A similar argument (the shadow rebound effect) is where the savings from efficiency gains are spent on other things that more than offset those gains through increased resource consumption or ecological impacts.

There is a stronger argument - that dematerialisation is mathematically absurd. Economic growth of x% per annum is an exponential function. The mathematics of decoupling requires that efficiency gains increase exponentially through time at the same rate as economic growth so that there is no resultant increase in the material throughput of the economy (Sanders, 1993).

To illustrate this, consider economic growth of 5% per annum and decoupling (efficiency gains) also proceeding at 5% per annum, such that the overall impact remains constant. It follows that both economic growth and efficiency gains will double approximately every 13 years. Thus, things will be twice as efficient in 13 years, four times as efficient in 26 years, 8 times as efficient in 39 years, 16 times as efficient in 52 years and 32 times as efficient in 104 years, ... etc.

In other words, this would require accelerating returns to efficiency which is at odds with the reality of diminishing returns (Sanders, 1993). In the real world (as opposed to the imaginary world of economic thought) it becomes harder and harder to achieve efficiency gains through time, not easier and easier as the flawed economic logic of dematerialisation demands.

There are a couple of further considerations which throw even greater doubt on the sustainability of a society organised on the basis of conventional economic logic. One is what one might call the aggregation problem. While it is economically rational for the individual to maximise and have high levels of consumption, it becomes ecologically irrational if billions of people do the same thing. This insight is in direct conflict with the 'harmony of interests' - one of the fundamental tenets of economics that sees individuals pursuing their own self-interest leading, as if by an invisible hand, to the maximising of the welfare of society.

Another is the phenomenon of discounting which has the effect of biasing values away from future generations towards the present generation. Markets are inherently biased to maximising present day values due to the phenomenon of discounting. Discounting exists because we have interest rates and essentially, the discount rate equals the interest rate. If the interest rate is 10% then $100 invested today is worth $110 in one year's time. Conversely, $110 worth of value in one year's time is considered to be worth only $100 in present value terms. Even at low discount rates, values 30 years into the future have almost no value in present day terms. In other words, markets place almost no value in the values of the next generation, let alone, the values of future generations. This is the opposite of sustainability, which is primarily about the values of future generations.

How markets deal with the issue of time is to define an 'optimal depletion path' for all resources. This path is the one that maximises present values. This perverse logic is such that it is economically rational to harvest (say) whales as fast as possible to maximise returns (as opposed to a 'sustainable' rate of harvest) until it becomes uneconomic because of scarcity and then to invest the proceeds in harvesting something else (say forests), and so on (Princen, 2010, 93). Eventually, there is nothing left to harvest and future generations are deprived of these things. The philosophical position of conventional economists is the assumption that the future will take care of itself - that rising prices, resource substitution, technological progress and human ingenuity will solve the resource scarcity problems of future generations.

Ecological Economics

Ecological economics is grounded in a systems view of reality that rests on thermodynamic and ecological foundations. Ecological economists understand that sustainability requires humanity to live within the biophysical carrying capacity of the planet in keeping with the strong sustainability principle of non-declining natural capital over time. To achieve this outcome they propose the following approach. First, impose a sustainability constraint to limit the annual global supply of natural capital to the sustainable level in order to meet the intergenerational equity criterion. Then ensure an equitable (not equal) distribution of money amongst the world's population in order to meet the intra-generational equity criterion. Finally, let the market efficiently allocate this constrained supply of natural capital within these prior constraints Daly, 1992).

Evaluating the Ecological Economic Perspective

On the face of it, this approach appears to have a sound logic. However, there is a problem if the physical amount of resources within the sustainability constraint is inadequate to meet the material necessities of 7 billion people for food, shelter, infrastructure, etc. In such situations of absolute scarcity the market operates on the basis of exclusion. Prices rise until sufficient of the population is excluded and then the market clears at that high price. One could argue that this is not a problem if purchasing power is equitably distributed. However, in this case those who get in first will get the resources and many will miss out again. The only way to avoid this inequitable outcome is by rationing.

Reflecting back on the limitations of a market based approach covered in the previous section on evaluating the environmental economic approach to sustainability it is becoming increasingly clear that the economic system as we know it is simply unable to deal with the sustainability problem.

The Role of the Financial System in the Sustainability Problem

Some ecological economists have added a further dimension to the understanding of the sustainability problem by drawing attention to the role of the financial system in the global financial crisis. Martinez-Alier (2009) explains the global financial crisis as a mountain of debt that has grown exponentially and now vastly exceeds the real wealth it lays claim to. To the extent that the debt cannot be realised, its value is greatly depreciated. Daly and Green (2009) ask:

> *What allowed symbolic financial assets to become so disconnected from underlying real assets? First, our economy is based on fiat money (paper money issued by governments) that has value by convention but isn't backed by any physical wealth. Second, our fractional reserve banking system allows pyramiding of bank money (demand deposits) on top of the fiat government-issued currency (Daly and Green, 2009, 7).*

In seeking to explain the global financial crisis, former World Bank economist Daly (Daly and Green, 2009) turned to the work of Frederick Soddy. Soddy was the 1921 winner of the Nobel Prize for chemistry, who turned his talents to economics; a field he felt lacked a connection to biophysical reality. His 1926 book *Wealth, Virtual Wealth and Debt: The Solution of the Economic Paradox* is one of the foundations of ecological economic thought which is grounded in a thermodynamic view of reality. Quoting (Daly and Green, 2009, 6):

> *Soddy wrote that real wealth was subject to the inescapable law of thermodynamics and would rot, rust or wear out with age, while money and debt [virtual wealth] – as accounting devices invented by humans - were subject only to the laws of mathematics. Rather than decaying, virtual wealth, in the form of debt compounding at the rate of interest, actually grows without bounds.*

Under the system of fractional reserve banking which has been in place for the past 3 centuries all money comes into existence as interest-bearing debt. Consequently, the money supply grows exponentially in a debt-based monetary system. According to Blain (1987) the historical record shows the United States money supply has grown at around 6% compounding based on the empirical data. Fractional reserve banking locks the economy into exponential growth in order that the interest on debt can be paid – otherwise the economy collapses. Essentially the fractional reserve or debt money design of financial system is a pyramid scheme.

Virtual wealth can be obtained by physically working to produce things (e.g. factories, farms or services) or by investing which now constitutes the bulk of 'economic' activity. Investment may be either in the production of real (i.e. physical) wealth or in the production of virtual wealth. Today the bulk of investment is directed at the latter.

Soddy used a 9 inch ball of gold to illustrate the logical absurdity of a system based on investing virtual wealth in the production of more virtual wealth. If the gold is converted to money and lent at 5% compounding interest, in 1070 years' time "our 9 inch ball of gold, … would arise legal claims to a golden ball equal in size to the earth, and weighing four times as much" (Soddy, 1926, 107).

Soddy observed:

> *The ruling passion of the age is to convert wealth into debt in order to derive a permanent future income from it - to convert wealth that perishes into debt that endures, debt that does not rot, costs nothing to maintain, and brings in perennial interest (Daly, 1996, 178)*

> *As a result of this confusion between wealth and debt we are invited to contemplate a millennium where people live on the interest of their mutual indebtedness (Soddy, 1926, 89)*

These insights illustrate profoundly the fundamental disconnection between economic and physical reality. The next section will show how the abstraction of virtual wealth can help to explain the real world issues of ecological overshoot and increasing inequity.

Explaining Ecological Overshoot and the Liquidation of Natural Capital

Our new understanding of the concept of virtual wealth can explain why the planet's natural capital is being liquidated. Money (i.e. debt-based money) is not wealth but virtual wealth which is a claim on real wealth. Real wealth is derived from the natural capital of the planet. In the simplest analysis the root of the sustainability problem is the design of the financial system which structurally locks the world's money supply into growing exponentially. This amounts to an exponentially growing set of claims (virtual wealth or money) on a finite (and now rapidly diminishing) pool of natural capital (i.e. the source of real wealth). In other words, the combined purchasing power of humanity is growing exponentially.

The world's now globalised market system facilitates the accelerating flow of natural capital from the environment though the economy to the consumer with purchasing power. The level of demand being exercised by humanity exceeded the planet's carrying capacity in the 1980s and is now 1.5 times the planet's carrying capacity (WWF, 2012). The planet's natural capital stocks are being liquidated in order to meet the escalating demand that the exponential growth of virtual wealth requires.

Explaining the Growing Equity Gap

David Korten (2006) identifies two dimensions to the economic system, the real economy which produces real wealth and the virtual (or financial) economy which produces virtual wealth. In the modern world people live by obtaining virtual wealth (i.e. money or debt) which they use to purchase real wealth which Korten (2006) defines as "those things that have actual utilitarian or artistic value: food, land, energy, knowledge, technology, forests, beauty, and much else."

Korten points out that the production system engages almost everyone one way or another in producing the world's goods. However, it is the financial system that determines who gets what of the global production pie. Those who do all the hard physical work receive a pittance of a few dollars a day on which to subsist while the investors take the vast bulk.

Although virtual wealth is an abstraction, its power is that it is a claim on real wealth (Daly, 2009,6). As Soddy (1926, 137) explains, the holder of virtual wealth is owed real wealth! Korten (2006, 68) describes virtual wealth as:

> *an accounting chit that has value only because by social convention people are willing to accept it in exchange for things of real value. Money, however, bestows enormous power and advantage on those with the power to create and allocate it in societies in which access to almost everything of real value requires money.*

The reason for the ever growing gap between rich and poor now becomes clear. Simply stated, the rich are able to grow their virtual wealth exponentially at compounding interest while the only means the poor have is to labour, and the low levels of virtual wealth they earn is expended in subsistence with no surplus to invest. Consequently, the rich can become rich at an accelerating rate while the poor have little opportunity to do anything but subsist. As Korten describes the situation:

> *The wealthy "have enjoyed rapid growth in their financial assets throughout the period of deepening environmental decline, thus bestowing on them claims against a growing proportion of the real wealth of planet and society, and creating an illusion that we are all growing richer, when the opposite is true. Take just one key indicator: the combined market capitalization - financial asset value - of the shares traded in the world's major share markets grew from $0.8 trillion in 1977 to $22.6 trillion in 2003. This represents and enormous increase in the buying power of the ruling class relative to the rest of society. It creates an illusion that economic policies are increasing the real wealth of society, when in fact they are depleting it" (Korten, 2006, 68).*

Another aspect to this is that private sector loans are only created for those projects that can be expected to generate a sufficient rate of return. Since the purpose behind most loans is to make money; the nature of the actual investment is incidental. This means that a great deal of production does not serve human welfare as meeting the basic needs of 80% of humanity is simply not profitable. Rather most investment is directed to meeting the wants of the already wealthy.

Thus, it is clear that the current design of financial system also structurally locks humanity into breaching the intra-generational equity criterion for sustainability.

This section has argued that the economic system is simply not able to address the sustainability problem. Furthermore, it has argued that the design of the financial system is in fact the systemic structural root and driver of both key dimensions of the sustainability issue. It has shown a disconnection between key elements of the economic view of reality and the way the world works. The next section helps to understand the failure of economics both generally, but also in the face of the sustainability problem.

The Dubious Foundations of Economic Thought

The origins of modern political and economic thought lie in a Deist worldview that God had created a mechanical clockwork universe that operated according to his rational natural laws. It was widely held by many philosophers of the time that human thought and behaviour were largely determined by natural laws similar to laws of motion Newton had discovered (Nadeau, 2006).

Adam Smith, the founding father of economics, in keeping with the Deist thinking of his time, believed that God's natural economic laws ensured the society as a whole moved along a preordained path of continual improvement irrespective of the disparate activities of the individuals making up society.

The only way Adam Smith could make sense of this was to invent a *deus ex machina* (literally "god from the machine") which is a device used to explain away the unexplainable. In this case he came up with idea of the invisible hand as the means to explain how people pursuing their own self-interest serve the greater interests of society (Nadeau, 2006). Adam Smith published his *Inquiry into the Wealth of Nations* in 1776. A century later, the founders of modern neoclassical economics Walras, Jevons, Edgeworth and Pareto, who collaborated quite closely, were also influenced by this Deist view of God's natural laws.

They sought to transform economics into a rigorous scientific discipline by aligning it with physics. They reasoned that there were parallels between the natural laws of physics and the natural laws of economics. They drew on the work of one of the best known and most widely regarded physicists of his time called Helmholtz. Helmholtz was grappling with the inability of Newtonian mechanics to deal with heat, electricity and light hypothesized the existence of a protean field of energy that could unify these phenomena in 1847. However, this theory was eventually abandoned because it could not be tested scientifically (Nadeau, 2006,103). In spite of this:

> *The strategy used by the economists was as simple as it was absurd - they took ... [Helmholtz's equations] ... and changed the names of the variables. Utility was substituted for energy, the sum of utility for potential energy, and expenditure for kinetic energy" (Nadeau, 2006, 104).*

These equations based on failed physics equations remain the theoretical foundations of neoclassical economics to this day. Little wonder that JM Keynes wrote to his colleague John Hicks saying "I shall hope to convince you some day that Walras' theory and all the others along these lines are little better than nonsense" (Nadeau, 2006, 112).

The conceptual basis of neoclassical economics continues to be recognised as being weak, even by a significant number of economics Nobel Laureates including: Joseph Stiglitz, George Akerlof, Daniel Kahneman, Robert Aumeann, Thomas Schelling, Amartya Sen and Wassily Leontief (Hall et.al., 2006).

For example, in his Presidential address to the American Economic Association in 1971, Leontief aired his concern that economics had taken a wrong turn. He said:

> *Page after page of professional economic journals are filled with mathematical formulas leading the reader from sets of more or less plausible but entirely arbitrary assumptions to precisely stated but irrelevant theoretical conclusions (Leontief, 1982, 104).*

Elaborating in a letter to *Science* he found the basic models of economics "unable to advance in any perceptible way a systematic understanding of the operation of a real economic system" (Leontief, 1982, 107).

This brief review of economic thought strongly suggests a total disconnection from reality, ironically resulting from the endeavours of its founding fathers to ground economics in physics.

The reality is that this 'nonsense' as Keynes described it, remains the foundation of modern economic theory and serves as the rationale for relying on the market as the key organising principle of society. Perhaps it would make more sense, as Al Gore (1992) suggests, to "make the rescue of the environment the central organizing principle for civilization."

The final section will now look at how humanity could allocate the planet's absolutely scarce resources to maximise the welfare of humanity while ensuring the long term sustainability of the human enterprise and consider some elements of the transition to this new sustainable mode of human organisation.

Toward a new Economic System Grounded in Reality

Three broad objectives need to be addressed in order to allocate absolutely scarce resources sustainably. Resource allocation needs to be within ecological limits (intergenerational equity), it needs to be equitable (intra-generational equity) and it needs to be technically or ecologically efficient (i.e. provide maximum human benefit from a given quantum of resources).

Since, as discussed, this problem is not amenable to market based solutions the challenge falls to the institutions of governance and because the problem is global in scale, some degree of global governance is implied. Governance at what is currently the national scale will need to be both politically and economically democratic (to meet the intra-generational equity criterion). So what might the sustainability institutions look like in this context?

One thing the previous analysis makes clear is the disconnection between the virtual money/ price system and the real physical system. This effectively means that economics cannot serve as the mechanism to direct what happens in the physical world. This means that economic analysis and practice must actually be conducted in terms of the physical dimensions and not the monetary dimensions of the economy. The following suggestions adopt this direct physical approach.

Towards Intergenerational Equity
The institution to ensure intergenerational equity will need to establish a global system for determining and monitoring the physical natural capital stocks and flows of energy and materials that are available to humanity on a sustainable basis. On the basis of this information it would be possible to establish a system of physical accounts for each form of critical natural capital. This would enable annual physical capital budget constraints to be set for each form of critical natural capital. These physical capital budget constraints could then be allocated on an equitable per capita basis to each continent or country or jurisdiction (Sanders, 2003; Harris, Lenzen and Sanders, 2005). If each jurisdiction around the world abided by its physical budget constraints, then in principle the world would be operating on a sustainable basis.

In order to operate within these physical budget constraints jurisdictions would need to identify current forms and modes of production that can be abandoned or greatly reduced with little or no impact on the well-being of the people. Policies would be needed to set energy and material descent pathways and targets; establish targets for the phase out of fossil fuels; introduce a shorter working week; and introduce rationing for critical resource factors such as water and petrol.

While these measures may appear drastic, the sustainability emergency demands emergency responses if civilisation is to survive. Consider global warming, just one of the factors in the perfect storm of rapidly converging crises that constitute the emergency. At the time of writing, the Arctic sea ice has already passed the record minimum of 2007 with three weeks of melt still remaining. If the resulting release of methane is sufficiently large and rapid, it could trigger a runaway greenhouse effect that may destroy much of the web of life (Guterl, 2012).

Towards Intra-generational Equity
The second requirement for allocating absolutely scarce resources sustainably is equitable access to the capped critical natural capital physical budgets. Addressing current inequities will require significant redistribution of access to the world's resources to meet the intra-generational equity criterion for sustainability. In the short term, a Global Marshall Plan (Gore, 1992; Brown, 2008) may be required to facilitate the redistribution and ensure the needs of the neediest are met.

Within jurisdictions, it will be important that the citizenry decide in broad terms how the relatively small annual pool of resources should be used through a democratic process. Obviously priority will be given to the highest needs and would probably reflect Maslow's (1943) hierarchy. Food needs would need to be assured first, then shelter and then perhaps essential infrastructure. It may be that the pool of resources is so constrained that needs beyond these may not be able to be met. This could provide a strong social incentive to produce fewer children and reduce population over time since standard of living will be inversely proportional to population size given a non-increasing annual pool of resources.

As the discussion on virtual wealth made clear, sustainability demands that the financial system be redesigned so it no longer drives ecological overshoot and inequity. One often suggested reform of the financial system is to shift from a fractional reserve system to a 100% reserve financial system (Daly and Green, 2009). This has no expansionary imperative which also means the economy can be contracted without collapsing. Under such a system, the state could fund the physical infrastructural transformation of the economy to a solar energy basis while significantly contracting the scale of the physical economy. It could also be used to fund a Global Marshall Plan.

Ideally, the financial system and the powers of credit creation should be vested in the public sector under a system of very strict prudential supervision oriented to sustainability considerations. The privilege of credit creation and seigniorage (the windfall profit from creating credit) should solely rest within the public sector for the public benefit. Investment should be directed to meeting the needs of humanity in the most technically efficient way as sustainability requires that resources are directed to meeting needs and not to growing virtual wealth.

Technical (or Ecological) Efficiency

The third requirement for allocating absolutely scarce resources sustainably is technical or ecological efficiency which means that the maximum human benefit is derived from a given quantum of resources. Since the earlier analysis suggests the market cannot do the job, the responsibility for achieving technical or ecological efficiency must also be borne by democratic systems of governance.

This institution would conduct physical technical efficiency analyses for the spectrum of products and their associated modes of production. Highest priority would be given to meeting basic needs of food, shelter and energy and then working progressively up Maslow's (1943) hierarchy of needs. The initial focus would be on the industrial system of production (as opposed to local production within community).

The proposed framework of physical accounts referred to earlier would provide the informational basis for these and similar analyses to identify the most appropriate technologies for achieving maximum reductions in both throughput and ecological impact. Through the use of input-output tables it will be possible to untangle the complex interconnections of embodied matter, embodied energy and embodied water to identify or design the most efficient approaches in terms of these factors collectively (or synergistically). Once the most efficient modes of production are identified, the system of governance would facilitate the production of the selected form of energy, materials, goods and services by the specified modes of production. It is conceivable that every citizen will be required to contribute (say) one day of labour a fortnight into this system of production in return for a fair ration of the product.

Some may take ideological exception to the idea of the system of governance allocating resources in this way. As a rejoinder, they should note that the current spectrum of products (the production of which is rendering the planet incapable of supporting humanity) is produced by a system where the plutocracy (wealthy) decide what is to be produced and how it is to be produced. These two approaches are differentiated by their respective objectives. The plutocracy seeks to increase their virtual wealth behind the convenient mythological cloak that pursuing their self interest will maximise the welfare of society thanks to the agency of the 'invisible hand'. The objective of this democratic approach is to maximise the wellbeing of all members of society while keeping the human enterprise sustainable.

Conclusion
This paper has shown that the failure of the sustainable development paradigm is due to it being subsumed into the economic paradigm - a paradigm so disconnected from reality that it simply cannot address the sustainability problem.

An evaluation of the sustainable development construct as it is seen through the lenses of environmental and ecological economics leads to the conclusion that the economic system as currently designed is simply unable to deal with the sustainability problem. An analysis of the financial system and its role in the problem leads to the conclusion it is the inevitable structural driver of both ecological overshoot and increasing inequity. Sustainability therefore demands that the current design of economic and financial systems is abandoned.

Finally, an alternative approach as to how humanity might allocate the absolutely scarce resources of the planet so as to maximise the welfare of humanity while ensuring the very long term sustainability of the human enterprise was presented.

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