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Confronting the Transitory Nature of Industrial Society

Jörg Friedrichs

Abstract

This paper relies on a combination of neo-Malthusian, institutionalist, and rational choice arguments to pinpoint and explain humanity's collective failure to confront the transitory nature of industrial society. In the first section I show that in the long run industrial society is incompatible with planetary limits, focussing on scarce energy resources and climate change as the most obvious cases in point. In the second section I show how existing knowledge regimes do not adequately reflect this predicament, examining the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) as examples. In the third section I show that, despite the inescapability of the human predicament and the honest efforts of countless individuals, we are still left with insoluble moral dilemmas related to ethical discounting and collective action problems. Because people know this "in their bones", I conclude on a pessimistic – or rather: realistic – note, namely that the collective failure of humankind to confront the transitory nature of industrial society is overdetermined.

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Confronting the Transitory Nature of Industrial Society

Jörg Friedrichs

There is a mean little story, attributed to Bertrand Russell, about a turkey on a farm who concluded from being fed every morning that food was nothing to worry about.[1] The turkey became fatter and fatter, but was unpleasantly surprised on the morning of Thanksgiving Day when instead of being fed the farmer came and chopped his head off.[2]

The turkey in our story falls prey to what David Hume has identified as the problem of induction.[3] From a strictly logical viewpoint, it is impossible to compellingly infer universal laws, or incontrovertibly predict future events, from observed regularities. But this assumes a linear

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[1] Thanks for comments to Kerstin Friedrichs, Jessica Jewell, Martin Kraus, Avner Offer, Kristian Krieger, and Jerry Ravetz.

[2] The story is common lore, but the original source seems to be Russell 1912: 97-98.

[3] Hume [1748] 2000: §4.1.20-27; §4.2.28-32.

worldview like that of the turkey. At least potentially, humans are fortunately able to act a bit more smartly than the turkey in our story and take a systemic perspective instead.

In this paper I contend that an animal endowed with higher intelligence could, in principle, overcome the inductivist fallacy and make predictions about its fate. An animal that understood the logic of the farm instead of just worrying about mealtime, would also understand that there is a day of final reckoning. A systemic perspective would allow the animal to grasp its predicament and warn the others. Nevertheless, this does not mean that the animals on the farm could rescue themselves. I argue that humans are in a similar position. On a finite planet, the fact that there have been sufficient resources in the past does not mean there will be in the future. If we question the comfortable habit of extrapolating the future from the past, and instead study humanity's existential predicament, then we can indeed make predictions about our collective fate. Nevertheless, there is precious little we can do to escape our trajectory towards "overshoot and collapse". Because this is so, many people prefer denial and self-deception to an unvarnished realization of the human predicament.

This paper relies on a combination of neo-Malthusian, institutionalist, and rational choice arguments to pinpoint and explain humanity's collective failure to confront the transitory nature of industrial society. In the first section I show that in the long run industrial society is incompatible with planetary limits, focussing on scarce energy resources and climate change as the most obvious cases in point. In the second section I show how existing knowledge regimes do not adequately reflect this predicament, examining the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) as examples. In the third section I show that, despite the inescapability of the human predicament and the honest efforts of countless individuals, we are still left with insoluble moral dilemmas related to ethi-

cal discounting and collective action problems. Because people know this "in their bones", I conclude on a pessimistic – or rather: realistic – note, namely that the collective failure of humankind to confront the transitory nature of industrial society is overdetermined.

1. The Human Predicament

Industrial society will pass away. This is as sure as the fact that we must die. Short of a miraculous technological breakthrough, industrial society cannot outlast the availability of finite energy resources such as oil, gas, coal, and uranium. The spectre of catastrophic climate change indicates that it may become unviable even before the resource base is exhausted.[4]

The reason is simple: in a world where material resources are finite and environmental sinks have limited capacity to absorb emissions, the extractive and polluting intensity of industrial society is not sustainable. Once vital resources have been depleted, world population cannot continue – as it does today – exceeding the "carrying capacity" of the planet. In the meantime, industrial society is already testing the absorptive capacity of the atmosphere.

Accordingly, even a steady state without further economic growth is unsustainable. But industrial society as we know it is premised on growth. Without the expectation of growth, credit markets must break down and sustained investment becomes impossible.

[4] Eastin *et al.* 2010.

However, if world economic output grew by 3% per annum, it would double after 23 years and quadruple after 46 years. This means that, other things being equal, humanity would consume 16 times more resources and emit 16 times more pollutants a century from now.

If you believe that resource intensity and pollution can be reduced by 50% due to technological progress, a century from now the world economy would still consume 8 times as many resources and emit 8 times as many pollutants as today. Although demographics is moving away from the historical pattern of exponential growth, world population is projected to grow from 6.9 Billion (2010) to 9.15 Billion (2050).[5] Now imagine a world of 9.15 Billion people where the global economy was 8 or 16 times larger than it is now.

The planet would hardly be able to yield sufficient food and energy resources, and to absorb the carbon and other emissions generated. And yet, industrial society depends on the wasteful use of finite energy resources, as well as the capacity of the environment to absorb anthropogenic pollutants and waste products. In short, the problem with industrial society in a finite world is that it depletes natural resources and strains environmental sinks.

Limits to Growth

None of this is new. The basic argument was made first by Thomas Malthus in 1798, who showed that exponential population growth is unsustainable because the increase of food production cannot keep pace with it.[6] This is axiomatically true insofar as population growth is

[5] Data retrieved from http://esa.un.org/unpp/index.asp, 23 August 2010.

[6] Malthus 1926 [1798].

inherently exponential while the growth in food production is at best linear. Nevertheless, over the last two centuries this simple fact has been obfuscated by two factors.[7]

First, mobility and trade made it possible to shift the territorial frame of reference for "carrying capacity" from the local to the national, international, and ultimately global level. For example, Europeans were able to move to "under-populated" landmasses such as America, and to import raw materials and foodstuffs from colonies and developing countries.

Second, it turned out that industrial inputs such as fuel and fertilizer can intensify agricultural output. As long as such inputs are abundantly available, food production can keep pace with population growth and even increase exponentially. The problem, however, is that fertilizers and land machines depend on a limited resource base that is not replenished.

From a normative viewpoint, the first factor is often deplored while the second one is deemed unproblematic. Colonialism and exploitation are criticized, while agricultural progress is cherished. From an ecological standpoint, however, the opposite is true. Mobility and trade allow for a permanent extension of carrying capacity up to a hard limit, while industrialization allows human populations to temporarily "overshoot" carrying capacity. The problem with overshoot is that it must lead to serious decline or even collapse later on.

In 1972, a group of researchers around Denis Meadows adopted the Malthusian framework to the entire world society and applied the method of computer-driven system dynamics to examine the earth as a whole. In their book *The Limits to Growth* and in its two updates, they

[7] Catton 1980.

have compellingly demonstrated that exponential growth in a finite world is impossible in the long run.[8] For a while, growth appears to defy systemic limits but only until the effects kick in. But in the long run, as resource depletion and/or pollution touch their physical limits, an abrupt decline or indeed collapse of industrial society is the only way for the world system to return to equilibrium. The delay between overshoot and collapse is due to the fact that there is a delay between anthropogenic causes (depletion of fuel, unsustainable carbon emissions, etc.) and systemic effects (energy scarcity, climate change, etc.). Hence, the prediction of Meadows *et al.* is a systemic pattern of exponential growth, overshoot, and collapse.

Contrary to what the detractors assume, *The Limits to Growth* did not envision an imminent crisis. It predicted exponential growth and overshoot until about 2010, followed by collapse between 2020 and 2050.[9] Up until now, the model seems to be on track.[10] The expected end-result is a contraction of world population to the level of 1980 by 2100. Shockingly, this would mean the reduction of world population by a billion people or more. However it would not happen by starvation alone, as other demographic factors such as pandemics and declining life expectancy driven by failing healthcare systems would also take their toll.

The Limits to Growth can be criticized because its models are based on projections. But the results of the *The Ecological Footprint Atlas 2009*, which relies on meticulous data collection, are hardly more encouraging. According to the Global Footprint Network, the planet would have to be 1.4 times its size to sustain current levels of material consumption.[11] Prima facie, this does not sound particularly alarming as a relatively mild abatement of lifestyle in the af-

[8] Meadows *et al.* 1972; 1992; 2004

[9] See the "standard run" model in Meadows *et al.* 1972: 124.

[10] Turner 2008.

[11] Ewing *et al.* 2009.

fluent world (for example less material consumption, or a change of dietary habits) would make it possible for the planet to revert to more moderate levels of material consumption.

The crunch, however, is the constraint on food production posed by the biological productivity of the earth. The metric of the Global Footprint Network is based on the assumption that non-renewable resources such as fossil fuel and mineral inputs are available at present levels to prop up the 'bioproductivity' of the earth.[12] Take the unsustainable use of fossil fuel and mineral inputs away, and feeding the current world population would become virtually impossible. With declining access to such vital inputs and simultaneous population increase (plus climate change), the situation is doomed to become increasingly unsustainable.

As mentioned, it is possible for industrial societies to "overshoot" and keep growing for a limited period of time. In the long run, however, no society, and much less the human race as a whole, can live beyond their limits without incurring bankruptcy. It is true that, in the past, technological innovation has significantly expanded the constraints within with industrial society has been able to operate. But no matter how recklessly we tap into the resources of the earth crust, this increment on global carrying capacity can be only temporary.

From the perspective of a society facing some specific resource limit, industrialism offers progressive solutions. From a planetary perspective, however, it only makes a bad situation worse.[13] Overshoot cannot continue indefinitely on a global level. Even in the unlikely event that another energy revolution gives a new lease of life to industrial society, the vicious cycle would only turn one loop further. Short of a miraculous breakthrough such as nuclear fusion

[12] Personal communication from the Project Manager of the Global Footprint Network, 15 March 2010.

[13] Dilworth 2010.

technology, any energy revolution would again be based on a finite resource. When the last vital resource is depleted or environmental sinks reach their limits, collapse would only become more abysmal due to a higher population level and a lower carrying capacity.

Rays of Hope?

None of this is to deny that the pace of overshoot is constrained by a number of circumstances. Economic growth is periodically thrown back by crises such as the credit crunch of 2008/9. Resource depletion and pollution are mitigated by technological innovation and political regulation, which can reduce resource intensity and environmental damage. In industrialized countries, population growth has been slowed down and sometimes even reversed by socioeconomic and socio-cultural change. In China, it was halted by political intervention. Population is now growing less quickly in a number of developing countries, including Iran. As a result, world population is unlikely to continue growing significantly after 2050.

But alas, none of this abrogates the unsustainability of industrial society. Economic crises so far have not altered the basic pattern of economic growth. The beneficial effects of technological innovation on pollutant emission have been more than offset by growth of economic output.[14] Political regulation can certainly help protecting the environment. But many measures, such as carbon sequestration and other clean coal technologies, reduce efficiency and thus lead to faster resource depletion. It is good news that world population will stop growing significantly after 2050, but this will happen only after increasing by another third.[15]

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[14] Dosi and Grazzi 2009.

[15] Calculation based http://esa.un.org/unpp/index.asp, retrieved 23 August 2010.

It is true that in some industrialized countries the economy has already stopped growing in real terms, *i.e.* net of inflation and the imaginary effects of asset and real estate bubbles. Even in "post-industrial" societies, however, there is broad consensus that real growth would be desperately needed because otherwise unemployment increases and financial markets are unstable. Meanwhile, real economic growth is now mostly taking place in the developing world. China, for example, "requires" at least 8% growth per annum to maintain social stability. As a result, the world economy keeps growing in nominal and in real terms.[16]

Optimists set their hopes in improved resource efficiency and an increasingly immaterial service economy. These are beautiful ideas, but unfortunately there is little to indicate that production can be sufficiently "decoupled" from resource use. Moreover, our "post-industrial" service economies rely on the importation of industrial goods from rapidly industrializing countries such as China. Since there are thermodynamic limits to possible gains in efficiency, the economy of the entire world would have to become almost ethereal for economic growth to become sustainable in the long run.[17] And even then there would remain practical limits to unlimited growth, such as the finite capacity of humans to cope with rapid innovation.[18]

Similarly, renewable energy is a highly appealing idea. But even if you count hydropower in (which is odd because installations such as the Three Gorges Dam are not what is usually associated with "green" energy), it can hardly supply much more than 20 per cent of the energy that is currently available. Renewable energy cannot sustain a consumer society.[19]

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[16] International Monetary Fund 2010: 2.

[17] Jackson 2009: 67-86. Note that key sectors of the service economy, such as health care and information technology, heavily rely on an energy-intensive industrial basis: pharmaceutical industry, computer industry, etc.

[18] Newman and Dale 2008.

[19] Trainer 2007.

Due to deep ideological rifts, "Malthusians" and "Cornucopians" will never agree. But if we pierce through the fog of ideological debates, then it appears that the Malthusians are right: infinite growth on a finite planet is impossible. Nevertheless, the truth of this statement matters little because the two opposing camps speak incommensurable discourses.[20]

Peak Energy and Climate Change

Ultimately it is impossible to know for certain when overshoot will be followed by collapse, and which of many possible bottlenecks will put industrial society over the edge. Industrial society relies on a variety of sources and sinks, not all of which are fully substitutable or expendable. The two most commonly recognized challenges to continued industrial growth are the spectres of energy scarcity and climate change. The jury is still out if either of the two will bite first, or if energy scarcity and climate change are going to bite together.[21]

Peak energy is related to the assumption that cheap energy with high calorific value will soon become scarce. For several generations, the backbone resource of industrial society has been oil. Now peak oil theorists predict a rapidly accelerating decline of world oil production.[22] If they are right, oil is not able to meet the projected needs of the world economy. Gas may provide a temporary substitute, but the other available surrogates are not appealing. Coal is abundant and cheap, but it does not have high calorific value. Uranium has high calorific value, but it is not abundant – and nuclear power is not cheap. Renewable energy is abundant

[20] Dryzek 2005: 26-71.

[21] Homer-Dixon 2009; see also Bardi 2009.

[22] Aleklett *et al.* 2010; on the implications see Korowicz 2010; Friedrichs 2010a.

in theory, but it is not cheap and does not provide high calorific value. None of the surrogates for oil, either alone or in combination, is compatible with high rates of economic growth.[23] Only fusion technology would solve the problem, but it is not going to be available. In short, oil and gas can hardly be replaced as the backbone resources of industrial society.

If peak energy is the most immediate resource constraint, then the most commonly accepted constraint on a sink is climate change. After a first wave of global thinking in the 1960s/70s, most environmentalists chose to act locally. As a result of their laudable efforts, air and water in industrial countries became cleaner and many endangered species have survived. The strategy was to divert part of the wealth generated by economic growth to repair the worst effects of pollution. Unfortunately, however, this did not address the fundamental problem that exponential growth generates emissions that cannot be absorbed by finite environmental sinks. The chicken is now coming to roost with climate change. Local gains from environmentalism are endangered by the effects of climate change: higher temperatures, rising sea levels, extreme weather events, desertification, famines, etc. As a result, industrial society may become unviable even before the exhaustion of its resource base.[24]

As indicated, peak energy and climate change are only the most likely candidates for plunging industrial society into agony. Moreover, various assumptions can be made on their sequencing. The worst-case scenario is a pincer movement with peak oil causing a shift to more carbon-intensive technologies, thus accelerating climate change. As a result the carrying capacity of the earth would be reduced. The ensuing crisis would be accompanied not only by the demise of industrial capitalism but also by other forms of doom and gloom.

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[23] Heinberg 2007, 2009.

[24] Eastin *et al.* 2010.

2. Knowledge Regimes

Having identified peak energy and climate change as the two most immediate challenges to industrial society, let us now examine the related knowledge regimes. Both regimes heavily rely on scientific expert knowledge, and in either case expertise is embodied in an authoritative international institution. Epistemic authority on energy supply is concentrated at the International Energy Agency (IEA), while scientific expertise on climate change is embodied in the Intergovernmental Panel on Climate Change (IPCC). Analysing the way by which scientific and popular discourse has been structured in line with, and in opposition to, these authoritative international institutions will help us understand exactly how such knowledge regimes are, or are not, able to adequately address the underlying global problems.

Peak energy and climate change are not normal scientific issues. There is considerable dispute with regard to the basic underlying facts and the values to be promoted or defended. As with other incalculable risks inherent to late modernity, it is easy to agree in principle that important issues are at stake and that the precautionary principle mandates action in the face of "low probability high impact" events.[25] But everything else is hotly contested.

The concept of post-normal science has been proposed for precisely this kind of situation, where "facts are uncertain, values in dispute, stakes high and decisions urgent".[26] In such situations, the issues at stake are too existential and too political to be left to experts. In post-normal science, debates over uncertainty go beyond technicalities and include radical doubt

[25] On risk society see Beck 1992, 1999, 2009.

[26] Ravetz 2004: 349.

and ethical contestation.[27] The scientific peer community is therefore informally extended to include decision makers, interested citizens, media pundits, and others.

As we shall see, mainstream energy science conforms to post-normal science only to a very limited extent. The economists and statisticians at the IEA have mostly left the issue of peak oil to mavericks at the fringes or outside mainstream scientific discourse. As a consequence, the potentially pressing issue of peak energy is hardly on the public agenda. Climate science, by contrast, has fully embraced post-normal science. But even though the IPCC has been uniquely successful in placing climate change on the public agenda, the inherent ambiguities of post-normal science have plunged climate science into a profound legitimacy crisis. Scientists are damned if they do and doomed if they don't engage in post-normal science.

Energy Supply and the IEA

International epistemic authority on energy scarcity is concentrated in the Paris-based International Energy Agency. Since its foundation in 1974, the IEA has slowly developed into the "global energy policy advisor" par excellence.[28] It has become "an agency for compiling data and making forecasts on energy markets", the hallmark of which is the collection of statistical data and the yearly publication of the authoritative *World Energy Outlook*.[29]

[27] Funtowicz and Ravetz 1993.

[28] Van de Graaf and Lesage 2009: 314.

[29] Noreng 2006: 48.

None of this was preordained. The original *raison d'être* of the IEA was to serve as an insurance regime against major oil supply disruptions.[30] Its mandate was to make rich oil consuming countries less vulnerable to supply disruptions such as the crisis of 1973-74, and to prepare them for the expected risk of a chronic undersupply. This was formulated by US Secretary of State Henry Kissinger in a 1973 address to the Pilgrim Society in London.

> "[W]e must bear in mind the deeper causes of the energy crisis: it is not simply a product of the Arab-Israeli war; it is the inevitable consequence of the explosive growth of world-wide demand outrunning the incentives for supply. The Middle East war made a chronic crisis acute, but a crisis was coming in any event. Even when pre-war production levels are resumed, the problem of matching the level of oil that the world produces to the level which it consumes will remain."[31]

On Kissinger's initiative, the International Energy Agency was established in 1974 as a counter-cartel to the club of oil exporting countries, OPEC. According to its bylaws, the most immediate task was to establish and manage an emergency response mechanism. Member states were obliged to hold the equivalent of a few months of net oil imports as an emergency stockpile. In case of a major oil supply disruption, defined as a shortfall of supply of 7% or more, the IEA Secretariat would have the authority to declare an emergency. Member states would then be obliged to share their supplies and implement demand-restraint measures.[32]

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[30] Willrich and Conant 1977; Keohane 1984: 217-240; Scott 1995; Bamberger 2004; Van de Graaf and Lesage 2009; Colgan 2009; Kohl 2010.

[31] Kissinger 1973.

[32] Since the 1980s, the requirement of physically transferring oil supplies to undersupplied member states has practically been replaced by an obligation to release oil stockpiles to keep prices from skyrocketing.

Since its creation, the IEA has been largely dormant in its capacity as an insurance regime. There has not been a single event that would have met the Agency's definition of a major oil supply disruption (shortfall of supply of 7% or more).[33] The IEA has acted only twice, on a voluntary basis, to inject additional oil from stockpiles into the market through coordinated action: 1991 in response to the Gulf War, and 2005 in response to Hurricane Katrina.

Like a fire department, the IEA must always be on standby in case there is an emergency. Although it has never been tested as an insurance regime, the IEA is a sizeable international bureaucracy. According to its website, the Agency has "a staff of 200 enthusiastic professionals".[34] Precisely because the IEA has been dormant as an international fire fighter, this staff had to be employed in some other useful way. For that purpose, the statutes of the IEA mention a few other goals in addition to the emergency response mechanism. The most important ones are monitoring the oil market and reducing the dependency on imported oil.[35] In other words, the IEA should have evolved in two complementary ways. First, it should have monitored international markets to keep the oil flowing. Second, it should have worked on ways to reduce the unsustainable oil dependency of industrial countries.

The Agency has eagerly embraced the former path, while neglecting the latter. This is an unfortunate failure of policy foresight. Insofar as the key task of the IEA was the strategic governance of energy scarcity as a long-term risk, it would have been mandatory for the Agency

[33] The largest event was the 1979 Iranian revolution, with a 5.6% shortfall. The next largest ones were the 1973 oil crisis and the 1991 Gulf War, with a 4.3% shortfall each (International Energy Agency 2007).

[34] http://www.iea.org/about/job.htm, retrieved on 4 February 2010.

[35] *Agreement on an International Energy Program* (http://www.iea.org/about/docs/IEP.PDF, retrieved on 15 March 2010); for the details see Van de Graaf and Lesage 2009; Colgan 2009.

to develop into an expert watchdog to monitor the availability of oil and prepare for a soft-landing after peak energy. However, this did not happen for a number of reasons.

First, the IEA was never really meant to question the presumption that oil is abundant. By placing its faith in markets, the Agency followed the preferences of its member-state principals. It is true that, since the 1990s, some members have been busy "greening" the IEA.[36] But no country has urged the IEA to seriously investigate the risks inherent in peak energy.

Second, the IEA is formally attached to the Paris-based club of industrialized countries, the Organization for Economic Cooperation and Development (OECD).[37] The institutional culture of the OECD has always been characterized by a firm belief in the capacity of markets to safeguard economic development, and this was bound to rub off on the IEA.

Third (and closely related), the IEA has been dominated by economists. As in the case of the OECD, most staff members are economists and/or public servants, usually with a background in economics. There are also a few lawyers. But engineers, geologists and other energy experts are a – slowly increasing – minority. The ascendancy of economists has been consequential.[38] For most economists it is axiomatic that in an effectively functioning market supply will always meet demand. Accordingly the IEA has mostly extrapolated trends in energy demand, assuming that future demand will be met via the market mechanism.

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[36] Kohl 2010: 211-216.

[37] In 1973 most net-importers of oil, including the USA after the peak of its oil production in 1970, were industrialized countries. Therefore, the OECD was attractive as an institutional hub for the IEA.

[38] Ravetz 1995.

The result is paradoxical. Originally, the whole point of setting up the IEA was that oil supply cannot be taken for granted. Oil markets can be disrupted, not only for political reasons but also by physical scarcity. Logically, it would have been a small step from trying to manage geopolitical risks (such as the 1973 oil crisis) to considering the geological limits to the future supply of oil and other vital energy resources (peak energy). Paradoxically, however, the idea of limited resources became anathema to the very watchdog of oil supply disruptions.[39]

In principle, the issue of energy scarcity would have been a good candidate for post-normal science. Energy science is a field where "facts are uncertain; values in dispute; stakes high; and decisions urgent".[40] Data on energy reserves are notoriously uncertain. Insofar as the industrial way of life is at stake, energy is deeply intertwined with fundamental values. Concomitant to peak energy, people all over the world are bound to face ineluctable choices.

Nevertheless, what we observe is a bifurcation between official normal science, and unofficial abnormal science. On one hand the economists at the IEA and its national counterparts such as the US Energy Information Administration (EIA), in unison with engineers and geologists working for the industry, maintain the trappings of objectivity and value-neutrality. On the other hand, whistleblowers and dissidents fill a parallel world in the "blogosphere" where polemics and eschatological thinking loom large. The wider public tends to avoid the topic altogether. The moment of truth is thus further postponed.

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[39] In the 1998 *World Energy Outlook*, and then again in the 2008 WEO, the IEA looked more carefully into the physical availability of energy resources. In both cases, there are rumours that in the following year there was backlash from member state principals and particularly the US (Macalister 2009; Badal 2010). And even in the 2008 WEO, the IEA made geologically unsubstantiated assumptions about supply following demand (Aleklett *et al*. 2010, criticizing International Energy Agency 2008; see also International Energy Agency 2009).

[40] Ravetz 2004: 349.

Climate Change and the IPCC

The case of climate change is strikingly different from energy supply. Here, we can observe post-normal science in action.[41] Mainstream climate scientists have colluded ever since the 1980s with the United Nations to translate their scientific expert views into political action.[42] Especially the Intergovernmental Panel on Climate Change, which was established in 1988, has been instrumental to this end.[43] Ever since the run-up to the UN Framework Convention on Climate Change (UNFCC), which was concluded at the 1992 Earth Summit in Rio, the IPCC has acted as a strategic link between the science and the politics of climate change.

Based on scientific expertise, the IPCC has collated four assessment reports (1990; 1995; 2001; 2007) that have significantly shaped public debates and international negotiations. With increasing levels of confidence, the assessment reports have suggested that current levels of emissions are unsustainable. From this, decision makers have derived prescriptions on what ought to be done to get emissions back on track to a sustainable level.

After the *First Assessment Report* of 1990, which set the stage for the Earth Summit in Rio, the *Second Assessment* of 1995 found that "the balance of evidence suggests a discernible human influence on climate change".[44] This emboldened the European Union to push for

[41] See Hulme 2009: 72-108.

[42] For a concise history of climate science see Hulme 2009: 35-108.

[43] Agrawala 1998; Bolin 2007. The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer has often been seen as a success story that should be, and indeed has been, emulated in the case of climate change; see Litfin 1994; Canan and Reichman 2002.

[44] Intergovernmental Panel on Climate Change 1995: 22.

quantified emission targets in the negotiations leading up to the 1997 Kyoto Protocol. Other key international players such as the United States and Japan were mildly sympathetic at the time, but showed themselves less convinced by the scientific expertise.

The *Third Assessment Report* of 2001 concluded more boldly that "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations".[45] While this did not prevent the US administration of George W. Bush from boycotting the Kyoto Protocol, it played an important role in galvanizing international collaboration to control climate change. The EU ratified the Kyoto Protocol in 2002. After the accession of Russia and Japan, the Protocol entered into force in 2005.

The *Fourth Assessment Report* of 2007 concluded on an even more alarmist note: "Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations".[46] The expression "very likely" corresponds to a confidence level of at least 90%.[47] Nevertheless, the path from scientific expertise to political action has not been straightforward, as shown by the abject failure of the Copenhagen Climate Summit in December 2009.

Climate science has behaved exactly like the proponents of post-normal science predict.[48] First, the peer community was extended. It includes decision makers, *e.g.* when the IPCC's *Summaries for Policymakers* are "approved" line-by-line at plenary sessions of national dele-

[45] Intergovernmental Panel on Climate Change 2001: 61.

[46] Intergovernmental Panel on Climate Change 2007: 5.

[47] Ibid.: 27.

[48] Funtowicz and Ravetz 1993.

gates.[49] To the extent that climate change has become an issue of mass politics, media pundits and civil society have also become enmeshed in the extended peer community.[50] Second, the reporting of uncertainty has become far more than a technicality. For its assessment reports, the IPCC has been relying on expert consensus not only to create but also to estimate the levels of confidence by which its findings are stated to be true.

Presumably to compensate for this bent to post-normal science, the IPCC is eager to maintain the veneer of standard science in a variety of ways. It relies on a painstaking procedure of scientific peer review; its confidence levels are associated with numerical values such as "90% certain";[51] and it is reluctant to translate its findings into specific policy prescriptions.

This amounts to a double bind by post-normal science and standard scientific values, which has placed climate science in a difficult situation. On one hand, extending the peer community has intensified public debate. On the other hand, the public does not forgive any dilution of scientific rigor with regard to "inconvenient truths". This imposes upon scientists a balancing act in which they must invoke scientific objectivity to maintain authority, while being forced by the circumstances to engage in "stealth issue advocacy" to be relevant.[52] Thus, they are torn between the need to keep a posture of scientific objectivity and the practical push to make political interventions in the context of post-normal science.

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[49] Agrawala 1998; Saloranta 2001.

[50] Bäckstrand 2003.

[51] Although the adopted procedure combines "hard science" with a considerable dose of "fuzzy logic", the IPCC attributes percentage values to its confidence levels. This is reminiscent of statistical techniques and suggests scientific objectivity. See Saloranta 2001; Swart *et al.* 2009.

[52] Pielke 2007.

Whether or not there is a greenhouse effect, mainstream climate scientists sit in a glass house where throwing stones becomes exceedingly dangerous to their expert authority. A few isolated cases of compromised integrity (emails leaked from the University of East Anglia) and one or two cases of overconfidence slipped into the 2007 *Assessment Report* (such as the melting of Himalayan glaciers) have been enough to discredit climate science.

Another case in point is the commitment to the fact-value distinction on one hand, while trying to influence policy decisions on the other. Science typically prides itself of factual knowledge, which is assumed to have objective validity regardless of political values. Thus, climate experts claim to be able to reconstruct and, to some extent, predict climate change; but they hasten to submit that they are unable to answer the question of how much climate change is tolerable to human society, or what exactly ought to be done. However, this is not enough for decision makers who need specific policy prescriptions to bolster their policy choices. Climate scientists oblige by offering decision makers focal points for political agreement. For example, discussions became much simpler after consensus had been reached on 2° Celsius as the highest tolerable increase of global temperature. This fairly arbitrary target was not actively promoted by climate scientists, but they put a good face on the matter when it was falsely attributed to their expertise. Now they are paying the price, because association with the arbitrary 2° Celsius target undermines their credibility.[53]

The collusion of climate scientists with political decision makers has created a serious problem to the reputation of their science. The problem is that the public sphere is an echo chamber of sorts. In periods of "climate panic", such as 2008 and 2009, alarmist climate science

[53] Knaggård 2009.

gets a lot of attention from civil society and political decision makers. However, such attention cycles usually do not last for more than a couple of years. After that, the public turns back to its cognitive and emotional biases against "negative" worldviews.[54]

Overall, the case of climate change shows the limitations of post-normal science. Even where expert knowledge is available and shared by an extended peer community, it does not necessarily translate into action. From a political viewpoint, this is not particularly surprising. First, there are serious distributional issues and multiple paths of action that might be compatible with various strands of expert knowledge. Second, to some extent it has always been an illusion that climate science is driving climate policy. From the start, government and civil society in different countries have drawn selectively on science to legitimize contrasting viewpoints and policies. Thus, Germany and other European countries have embraced the "climate consensus" while the USA under George W. Bush was nearly impermeable.[55]

In short, post-normal science is a fair description of the trajectory of climate science. But it has hardly contributed to tackling the problem of climate change. On the contrary, it may carry the seeds of its own destruction. Authority continues to be ascribed to normal, specialist science. Extending the peer community and thus diluting rigorous standards does not guarantee either more democratic processes or more desirable outcomes, but it does undermine scientific authority. The authority of scientific expertise is seriously endangered because "climate sceptics" are able to expose the political nature of the informal alliance between the scientific mainstream and promoters of vigorous action to control climate change.[56]

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[54] See my remarks on denial and self deception at the end of Section 3.

[55] Grundmann 2007.

[56] McGaurr 2009.

The Role of Social Science

For good and for ill, natural science sometimes acts as a catalyst for public awareness and political action (as in the case of climate science). Social science, by contrast, more often than not plays a sedative role. We have seen this in the case of energy science, where mainstream economists have simply defined the problem away.[57] The most glaring case in point is their staunch belief in a price mechanism that invariably translates demand into supply. If a resource becomes more expensive, more of it will be produced – period. This axiomatic assumption is incompatible with the idea that there are physical limits to industrial growth.[58]

Even social scientific fields explicitly dedicated to environmental issues have a poor record when it comes to preparing us for the demise of industrial society. Thus, environmental sociology develops policy suggestions for mainstream environmental policy rather than addressing the fundamental unsustainability of industrial society. Similarly, the literature on ecological modernization pretends that industrial society can be made environmentally viable by incremental reforms and ignores the fact that the world is hopelessly in overshoot.[59]

What is worst, social science has been complicit in subverting the notion of sustainability. Originally, sustainability is about finding socio-political and socioeconomic ways of life that

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[57] Following pioneers such as Karl William Kapp, Nicholas Georgescu-Roegen and E.F. Schumacher, proponents of ecological economics such as Herman Daly, Kenneth Boulding, Robert Costanza, H.T. Odum and David Pimentel have not been able to pose a significant challenge to mainstream economics.

[58] Another problem is that investment for research and development is bound to be scarce in times of economic crisis. Therefore, without timely political intervention markets are incapable of adequately responding to peak energy by developing innovative technologies for post-fossil industrialism. See Hirsch *et al.* 2005.

[59] For a survey, see Warner 2010.

are viable in the long term because they do not overstrain sources or sinks. This is a vague regulative ideal that leaves many questions open, but it does imply that political and economic considerations ought to be subordinated to more fundamental ecological concerns.

Unfortunately, however, the 1987 Brundtland report introduced the notion of sustainable development. The idea of sustainable development is based on the optimistic assumption that ecological sustainability and socioeconomic development go together rather than contradicting each other.[60] This has induced social scientists to claim that sustainability has three pillars: environmental, economic, and social.[61] The practical implication is that, insofar as any significant loss of economic or social achievements is anathema to markets and citizens, suggestions for ecological sustainability that are not palatable to markets and societies must be seen as incompatible with the imperative of economic and social sustainability. Thus, the idea of sustainable development has turned the original idea of sustainability on its head.

Some scholars unsatisfied with the system-stabilizing role of social science have gone post-positivist. They have developed sophisticated accounts of how industrial society engages in collective self-delusion.[62] Even empirically minded scholars, such as the author of this paper, are unable to give much guidance on how the impasse could be overcome. What they can do, and what some of them have done, is help us better understand the human predicament.[63] For example, social science can help us elucidate the moral dilemmas that make it so difficult for people to acknowledge, let alone address, the transitory nature of industrial society.

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[60] World Commission on Environment and Development 1987.

[61] Littig and Grießler 2005; for an ambitious (and upbeat) attempt by a physicist-turned-development-economist to translate this into practice, see Munasinghe 2009.

[62] See Blühdorn 2010 for a survey.

[63] While problems are in search of possible solutions, predicaments place us between rocks and hard places.

3. Moral Dilemmas

As we have seen in Section 1, the transitory nature of industrial society is an inescapable fact of life. As we have seen in Section 2, existing knowledge regimes are inadequate to confront the human predicament. In the present section I argue that, despite the inescapability of the human predicament and the honest efforts of countless individuals, we are still left with insoluble moral dilemmas related to ethical discounting and collective action problems. Because people know this "in their bones", they engage in collective denial and self deception.

Ethical Discounting

Warnings against unsustainable behaviour are habitually countered by exhortations to focus on the here and now. Thus, John Maynard Keynes famously muttered that the long run is "a misleading guide to current affairs. In the long run we are all dead".[64] The implicit argument is that, no matter how true they are, long-term considerations are futile because our life happens today and not in some distant future. We should therefore not unnecessarily worry about the future and instead put our focus on the events of the day.

Economists have developed a fancy way of expressing the hidden rationality of such thinking: "discounting the future". For the sake of the argument, let us assume you know that the roof of your house is not going to withstand next winter. How much would you pay *now* to repair your roof and thus prevent the expense of $10,000 *next year*? If we assume that interest rates

[64] Keynes 1923: 80.

are at 5%, then it would not be economically rational to pay more than $9,524 now.[65] Otherwise, you could bring the money to a bank and would have the $10,000 a year from now.

In the hypothetical case just mentioned, you would be discounting the future by a factor of 5%. Now let us assume you wanted to prevent an anticipated loss of $10,000 forty years from now. Again, we assume that your discount rate is 5%. If you do the maths properly, then you should not pay more than $1,420.[66] That is less than 15% of the expected damage.

So much for (highly simplified) economic theory. In real life humans discount the future even more radically, and their behaviour is frequently "time inconsistent".[67] Thus, some smokers prefer the risk of a miserable death in twenty years to abandoning their habit today. Others decide today that they will quit tomorrow, but when tomorrow comes they decide they will quit the day after, and so on. The longer the time frame and the more uncertain the chains connecting causes and effects, the more easily future damage is accepted for the sake of instant gratification and the more likely preventive action is to be procrastinated.[68]

This is particularly true about politicians, who are justly concerned about (re)election. In short: radically discounting the future may be irresponsible, but it is incontrovertibly human.

The other form of ethical discounting, apart from temporal discounting, is social discounting. Humans discount their fellow human beings according to real or perceived proximity. Most people are willing to support close relatives in need, while their willingness to help distant

[65] $9524 \times 1.05 = 10000$

[66] $1420 \times 1.05^{40} = 10000$

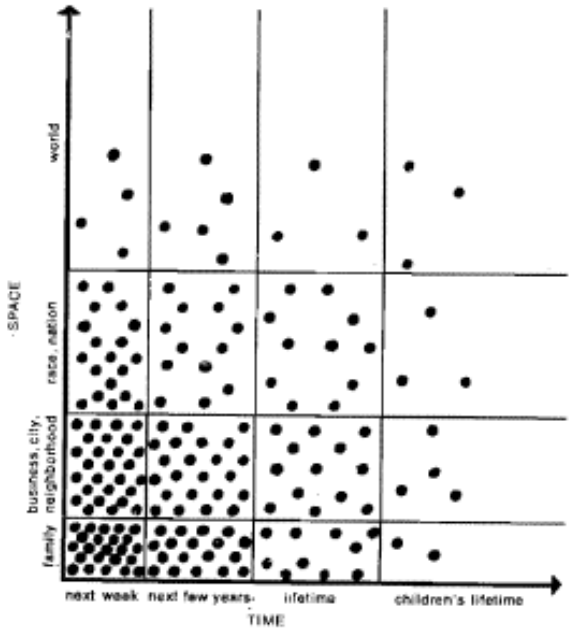
[67] Strotz 1955; Offer 2006: 39-74.

[68] Akerlof 1991.

strangers is severely limited. Citizens grudgingly accept that a considerable part of their income is taxed for social redistribution, but they would not accept more than a marginal amount of money to be spent on development aid (unless the recipients are brought closer to them by means of heartbreaking human interest stories about starving children; then these distant strangers become, at least temporarily, redefined as fellow humans in need).

The combined effect of both kinds of ethical discounting is summarized in Figure 1.[69]

Figure 1 HUMAN PERSPECTIVES



Although the perspectives of the world's people vary in space and in time, every human concern falls somewhere on the space-time graph. The majority of the world's people are concerned with matters that affect only family or friends over a short period of time. Others look farther ahead in time or over a larger area—a city or a nation. Only a very few people have a global perspective that extends far into the future.

[69] Source: Meadows *et al.* 1972: 19.

Climate change and peak energy are exactly the sort of situations where you would expect ethical discounting to occur. First, there is considerable delay between cause and effect. We can emit CO_2 now, but the effects will be felt by later generations;[70] we can deplete oil now, but scarcity will occur in the future. Second, the links between anthropogenic causes and systemic effects are extremely complicated. Even 30 years of climate science have not conclusively rebutted climate change deniers; and peak energy is obfuscated by terribly poor data. Third, there is also a huge disconnect between local action and distant effects. Even if we do not stop climate change, the worst effects can be assumed to happen in remote developing countries; people in rich industrial countries may assume that they would be better placed to survive skyrocketing energy prices than people in poor developing countries.

Collective Action Problems

Even if there was consensus that action is needed to prevent catastrophic events, there would be collective action problems.[71] Oil reserves can be seen as a "global commons". Similarly, the prevention or mitigation of climate change can be seen as a global public good: if it succeeds, all will benefit and nobody is left behind.[72] Unfortunately, however, collective action to preserve the global commons, or global public goods, does not come easy.[73]

At various levels of agency, collective action is made difficult by social traps such as the free rider problem and the prisoner's dilemma. It is enormously tempting from the viewpoint of individual countries or citizens to continue business as usual while hoping that others will

[70] Stern (2007: 663) is entirely unrealistic in assuming a "pure rate of time preference" as low as 0.1%.

[71] Olson 1965; Hardin 1982.

[72] Stern 2007.

[73] Levin 2010.

invest in climate change mitigation. By the same token, it doesn't make much difference for my own future access to scarce energy resources if I conserve energy, unless all others conserve energy too. Similarly, it is a perfectly rational strategy for national governments to call for a global climate deal while hammering out a growth package for the domestic economy. Because all actors are individually subject to the prisoner's dilemma and tempted to free-ride, cooperation at the collective level is unlikely to occur (and fragile when it does).

In a competitive environment profit is private, while negative externalities are collectively shared. In such a context where individual actors maximize their private utility regardless of the social consequences, public goods like a sustainable climate or the future availability of energy are in jeopardy. A famous illustrative example is the so-called "tragedy of the commons", where communal grazing land is understood as a public good ruined by a scramble for dwindling resources.[74] At least in theory, there are three possible solutions to such problems: centralized political control, regulation via the market, and societal self-governance.

The effectiveness of centralized political control is contested. On the one hand, many people agree that there is a need for binding international agreements, *e.g.* to limit carbon emissions. The distinguished British sociologist Anthony Giddens explicitly calls for a more political approach to climate change.[75] On the other hand, given the inherent weakness of international consensus, only few people truly believe in the practical feasibility of top-down governmental solutions to global problems such as peak energy and climate change.

[74] Hardin 1968.

[75] Giddens 2009.

It is more en vogue to hope for market-based schemes to incentivize actors to behave in a more desirable manner. Thus, some authors set their hope in voluntary schemes such as carbon offsetting and corporate social responsibility.[76] Others hope that people will voluntarily switch from cheap fossil fuels to more expensive renewable energy. These are appealing workarounds to reduce emissions in a more market-friendly fashion, but they cannot solve all problems. While carbon offsetting and corporate social responsibility work only in niche markets, there are not many "ethical consumers" willing to pay a premium price on their energy bills. Other instruments such as emissions trading or carbon taxes lead to serious market distortions and rely on coercion. To work on a global scale, they would presuppose a binding international agreement which, for various reasons, is not forthcoming.[77]

Much has been made of the fact that traditional societies and local communities sometimes develop institutional mechanisms to overcome the tragedy of the commons.[78] While this is undoubtedly the case, unfortunately it is hardly applicable to global problems such as peak energy or climate change. The crux is that industrial society at the transnational level lacks the social capital that is sometimes present in traditional societies and local communities.

Another serious collective action problem connected to peak energy and climate change is the lack of credible leadership. With a credible leader, it is sometimes possible to establish institutional devices to overcome collective action problems. For example, after World War II international free trade was re-established under the hegemonic leadership of the USA.[79]

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[76] Newell and Paterson 2010

[77] Another fundamental problem is that, unlike communal grazing land, a sustainable climate is not easily amenable to privatization. A commons can be privatized by "enclosure", but the atmosphere cannot.

[78] Ostrom 1990; see also Poteete *et al.* 2010.

[79] Gilpin 1987; see also Kindleberger 1973.

Once established, institutions can develop a life of their own and stabilize situations even in the absence of leadership.[80] In the cases of peak energy and climate change, however, the most credible candidates for global leadership (the USA and China) are part of the problem rather than part of the solution.[81] It is therefore hardly surprising that, as we have seen, international organizations such as the IEA and the IPCC have not made a big difference.

Denial and Self-Deception

Ultimately, people know "in their bones" that existential predicaments such as peak energy and climate change cannot be solved. The following represents a popular philosophy on how to deal with such intractable problems: "If we can do something to solve a problem, we will perhaps do it. If there is nothing we can do, we should try to forget the problem".

Peak energy and climate change are not just intractable – they are escalating problems. Escalating problems are problems that have an inherent tendency to spiral out of control. Since there is a tolerance limit to how much people or groups can take, any strategy to deal with such problems within the framework of the status quo is bound to break down at some point. When an intractable problem escalates, breakdown must happen regardless of whether or not people admit the problem because, sooner or later, the tolerance limit will be reached.

In such cases, myopic individuals and groups have a strong incentive to engage in denial and self-deception because it reduces their suffering at any given point in time. While the problem itself is beyond their control, the social and psychological cost of acknowledging it can

[80] Keohane 1984.

[81] As the history of the Kyoto Protocol has shown, the EU is not a credible candidate for climate leadership.

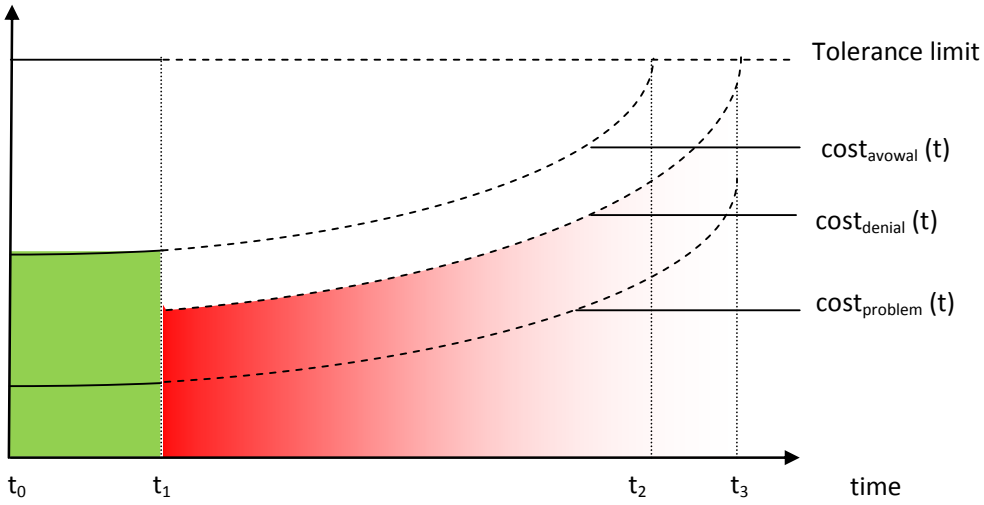
be avoided by deceiving oneself and pretending the problem did not exist. From this crypto-utilitarian viewpoint, denial and self-deception are social and psychological mechanisms to minimize harm when an escalating, intractable problem cannot be solved.[82]

To make this more tangible, let us assume that a couple have a problem of escalating debts. They both agree that their prodigal lifestyle is not negotiable. As a consequence, there is no solution to their problem. As long as they acknowledge the problem, they incur the social and psychological cost of avowal on top of the cost of the problem. Not only do they have to service their debt, but they also must acknowledge the uncomfortable fact that they are living beyond their means. At some point (t_1), they silently agree to stop talking about their escalating debts. They then feel much better. Their debts keep rising, but instead of lamenting their problem they are now able to keep it under the carpet. Initially, this seems to work very well indeed. But over time there is more and more fallout from their skyrocketing debts, and at some point (t_2) the entire house of cards is doomed to break down.

Figure 2 expresses this pattern of "fatalist denial" in more abstract terms. There is an escalating problem bound to break down when the total cost resulting from the situation hits the tolerance limit. Because acknowledging a problem comes with painful social and psychological cost, the total cost resulting from the situation is lower when people are in denial than when they acknowledge their problem. In other words, denial is expedient because it minimizes pain. It is therefore attractive for people to enter denial at an early stage of the escalation (t_1). Without denial, the tolerance limit would be reached at t_2. With denial, however, the tolerance limit is reached only at t_3. Thus, denial reduces cost and buys time.

[82] Friedrichs 2010b. See also Dyke 1614; Goleman 1985; Jopling 1996; Cohen 2001; Zerubavel 2006.

Figure 2: Fatalist Denial



This is exactly what happens in the case of peak energy and climate change. Public debate about limits to growth started in the early 1970s and culminated during the Carter administration, when there was a public enquiry into the issue.[83] During the 1980s, the debate ushered into denial with President Reagan solemnly declaring: "There are no limits to growth when men and women are free to follow their dreams."[84] But who knows? Maybe we have since then already passed the point of no return (t_2). How would markets and investors react to public acknowledgement that energy supply is declining for good?[85]

The issue of climate change is also increasingly beleaguered by denial and self-deception.[86] As long as there was a remote possibility for an international deal to be reached, there was a critical mass of people ready to support vigorous action. After the breakdown of the 2009

[83] Meadows *et al.* 1972; Mesarovic and Pestel 1974; Council on Environmental Quality 1980.

[84] Ronald Reagan, second inaugural address, 21 January 1985.

[85] See Korowicz 2010.

[86] On climate change denial see Norgaard 2011, 2006a, 2006b; Hamilton 2010: 95-133.

Copenhagen summit, however, decision makers and the public have lost confidence that climate change is a tractable problem. Since people tend to operate under the implicit assumption that lamenting intractable problems is pointless, "climate sceptics" have been emboldened and climate change denial is back with a vengeance.[87]

Despite the short-term benefit of reducing discomfort, there is a risk that fatalist denial may lead to long-term disadvantages. First, the cumulative cost of denial $[\int_{t_1}^{t_3} cost_{denial}(t)]$ can easily become greater than the cumulative cost of avowal $[\int_{t_1}^{t_2} cost_{avowal}\,(t)]$. Second, fatalist denial leaves people in a greater mess than avowal. For example: the later the breakdown of industrial society occurs, the worse climate change is going to be and the fewer resources will be left in the ground. Third, even intractable problems can be mitigated. But when people are in denial, they conceal from themselves essential information such as their cost functions and tolerance limit. As a consequence, they are unable to exploit the potential for mitigation.

Despite the negative long-term effects, there is a twisted kind of rationality to denial and self-deception. Both are rational insofar as people mostly focus on the short term.[88] When in denial or deceiving themselves, people follow what they see as their best interest by trying to minimize harm and maximize subjective well-being. Acknowledging a problem can lead to negative emotions such as fear and helplessness, or social conflict about the attribution of blame and responsibility. Both individually and in groups, people therefore have a predisposition to minimize such immediate cost by engaging in denial and self-deception, rather than

[87] See also Friedrichs 2010b: Section 7, 8.

[88] See the subsection on "ethical discounting".

seeking long-term solutions while relentlessly sticking to the truth. Such behaviour may be short-sighted and morally dubious, but it is by no means irrational.

Conclusion

Industrial society is transitory, presumably with a hard landing ahead. However, it is unable to overcome, or even confront, this predicament. The transitory nature of industrial society has been, and is still, ignored by most people including ecologically sensitive individuals.

Despite their intelligence, it seems that most people act the inductivist turkey caricaturized at the beginning of this article. They are not consciously aware of the problem – and even if they were, they would not be willing or able to take adequate action. There is no appropriate strategic governance of long-term risks to provide, to the extent possible, a "soft landing" when industrial society enters its terminal decline. On the contrary, current policies and political discourse are paradoxically geared towards "sustaining the unsustainable".[89]

There are many reasons why, even against better knowledge, industrial society is neither able nor willing to confront its transitory nature. Overall, it seems that our collective failure to confront the limits to our own social model is causally overdetermined. This becomes apparent if we apply counterfactual thinking. An event is causally overdetermined when there is no single causal factor which would prevent it from happening. In fact, there is not a single problem the solution of which would lead the planet on a path to ecological sustainability.

[89] Blühdorn 2010.

If our collective failure to confront the transitory nature of industrial society is so much over-determined, then why revolt against it? Why bother as an academic, if persuading people of the limits to growth is as impossible as persuading turkeys to vote for Christmas?

Well, it may be part of our job as intellectuals to get to the bottom of things. It may simply not be acceptable for us to join the public in their practice of denial and self-deception. Although this posture may have consequences for our moral conduct as citizens, it does not imply that there is a human solution to the human predicament.[90] Maybe there is no solution.[91] The problems of industrial society are enormously wicked, and few of our fellow turkeys are likely to give up denial and self deception. Perhaps the best we can do, as moral individuals, is to honestly acknowledge the situation. This may sound weary to some, and I encourage those who are more hopeful to prove me wrong by taking vigorous action.[92]

[90] For the long-term prospects, see Greer 2008, 2009.

[91] As a Christian, I look forward to the moment when God will "destroy those who destroy the earth", send "a new heaven and a new earth", and thus "make all things new" (*Revelation* 11:18; 21:1; 21:5).

[92] For an inspirational cornucopian statement, see Nordhaus and Shellenberger 2009. For a call to frugality and deliberate "de-growth", see Jackson 2009.

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