THE CHALLENGE AHEAD

NON-LINEAR INTERACTIONS IN CURRENT SOCIETAL DYNAMICS

G·STIC GLOBAL SUSTAINABLE TECHNOLOGY & INNOVATION CONFERENCES

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This publication represents the views, opinions and assessments of the authors of the publication and in no way represents the views or opinions of the Global Sustainable Technology and Innovation Conference Series (G-STIC) and its partners. The extract of the publication, summarizing some of the major socio-economic and natural resources trends from the point of view of the authors, is reproduced here as an example of the complex and deep changes that currently affect every person, community and country in the world and that form the backdrop of the integrated and innovative technological solutions G-STIC is identifying as needed to make progress in the achievements of the SDGs. These technological transitions can not be viewed nor implemented in a vacuum and need to take into consideration major trends in the changing socio-economic and natural environments. Hence the reproduction of the "taking stock" chapter of "The World in 2050: Transformations to Achieve the Sustainable Development Goals" serves as an example of a concise, informative description of our current day world in which the technological transformations, supported by STI roadmaps for the SDGs, take place.

THE CHALLENGE AHEAD: NON-LINEAR INTERACTIONS IN CURRENT SOCIETAL DYNAMICS

Be aware of the change of a lifetime ... *(the Lion King)*

Excerpt of a report prepared by The World in 2050: *"Transformations to Achieve the Sustainable Development Goals"*.

The World in 2050 (TWI2050) was launched by the International Institute for Applied System Analysis (IIASA), the Sustainable Development Solutions Network (SDSN), and the Stockholm Resilience Centre (SRC) with a clear purpose to provide scientific foundations for the 2030 Agenda. This global research initiative endeavors to demonstrate how it is possible to meet the objectives of sustainable development within planetary boundaries, ensuring prosperity, social inclusion, and good governance for all.

TWI2050 **(www.TWI2050.org)** brings together more than 150 participants, including leading policymakers, analysts, modeling and analytical teams from 60 organizations around the world, to collaborate in developing pathways toward sustainable futures and policy frameworks for implementing the SDGs and (more importantly!) achieving the needed transformational change.

The TWI2050 report "*Transformations to Achieve the Sustainable Development Goals*" was released in July 2018 on the occasion of the United Nations 2018 Session of the High-Level Political Forum. This report, which has been coordinated by IIASA, is based on the voluntary and collaborative effort of more than 60 authors from about 20 institutes, and some 100 independent experts from academia, business, government, intergovernmental and non-governmental organizations from all regions of the world. In addition to examining the current trends and dynamics that promote and jeopardize the achievement of the SDGs, this report presents the TWI2050 framework: the integrated pathways which harness the synergies and multiple benefits of the SDGs as well as the approaches to achieving a sustainability transformation.

TWI2050 identifies six exemplary transformations which will allow achieving the SDGs and long-term sustainability in 2050 and beyond:

I Human capacity and demography;
II Consumption and production;
III Decarbonization and energy;
IV Food, biosphere, and water;
V Smart cities;
VI Digital revolution.

Pages 35 to 49 of the TWI2050 report's Chapter 2 "*The Challenge Ahead: Non-Linear Interactions in Societal Dynamics*" examine the current socio-economic, technological and environmental trends and dynamics. In the excerpt reproduced here, some text related to later sections of the full publication have been deleted. These deleted sections are marked with [....].

The reasons for publishing these pages in the current stand-alone format are multifold:

1. The 2030 Agenda, adopted by the United Nations in September 2015, positioned Science, Technology, and Innovation (STI) as key means of Implementing the SDGs and launched the UN Technology Facilitation Mechanism (TFM). Under this mechanism, a guidebook on STI roadmaps for the SDGs is prepared by the UN, the World Bank, and other partners, and a program has been launched to help countries develop STI roadmaps for the SDGs. Such roadmaps should take the form of forward-looking policy frameworks, action plans and/or strategies with sector-specific deep-dive approaches and a countrywide scope involving all levels of government. The diagram below depicts the crucial steps of this roadmapping exercise. The present excerpt of the TWI 2050 report's Chapter 2 is directly relevant as a possible backdrop to steps 2, 3 and 4 of any such roadmapping exercise.
2. Taking action to achieve the SDGs is a complex multidimensional process. Without significant technological, economic and societal changes – as this excerpt from the TWI2050 publication argues so well – it will just not be possible to achieve the SDGs. There are many signs that we are currently involved in major transformations of the global societal order. In the form of narratives, this excerpt reviews some of the major trends in population, institutions, global governance, democracy, urbanization, technology, etc. These trends, and others, need to be considered if one is serious about making progress towards achieving the SDGs.

3. Even broader evidence shows that profound changes are happening in all sectors and segments of society, all over the world. We are in transition – and that is a fact. Without a good understanding of the pervasiveness of this transition, we are like a ship sailing without a compass. Written in simple terms, the current publication helps us understand some of the different levels and directions from which change is coming and where we might be heading. Having this overview in the back of our minds will assist us in making wiser and more sustainable choices and decisions.
4. G-STIC, the Global Sustainable Technology & Innovation Conference Series **(www.gstic.org)** recognizes that achieving the SDGs by 2030 is just not possible with our current development models. G-STIC, therefore, aims to accelerate the development, dissemination, and deployment of innovative and integrated technology solutions that can enable the achievement of the SDGs. The review of major current trends, as summarized in the first TWI2050 publication, strongly endorses the need for transformational change and transitioning to new development patterns that are socio-economically and environmentally sound. Hence, this review provides an example of vital background information captains of industry and public authorities in charge of major investments need to keep in mind.

PROCESS FLOW OF SIX KEY STEPS AND THREE LEVELS IN THE DEVELOPMENT OF STI FOR SDG ROADMAPS

Source: TFM draft, A Guidebook on Development of STI for SDGs Roadmaps. April 2019

Let us all be aware of the change of a lifetime – and help the global society steer the change in a sustainable direction. We hope you enjoy the reading.

Signed:
Prof. Nebojsa Nakicenovic, Deputy Director General, IIASA and Former Professor of Energy Economics, TU Wien
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IF YOU ARE INTERESTED TO LEARN MORE ABOUT TWI 2050:

- Please visit **www.TWI2050.org.**
- Please read TWI2050 - The World in 2050 (2018). Transformations to Achieve the Sustainable Development Goals. Report prepared by the World in 2050 initiative. Published by the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria. Available at: pure**.iiasa.ac.at/15347** and **www.TWI2050.org.**

IF YOU ARE INTERESTED IN THE GLOBAL SUSTAINABLE TECHNOLOGY AND INNOVATION CONFERENCE SERIES:

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IF YOU ARE INTERESTED TO LEARN MORE ABOUT THE TECHNOLOGY FACILITATION MECHANISM, THE UNITED NATIONS INTER-AGENCY TASK TEAM ON SCIENCE, TECHNOLOGY AND INNOVATION FOR THE SDGS, AND STI ROADMAPS FOR THE SDGS:

- Please visit **sustainabledevelopment.un.org/tfm**

If you wish to learn more about the societal changes that are impacting our everyday life, please look out for Prof. Sander van der Leeuw's new publication **"Social Sustainability, Past and Future: undoing unintended consequences for the Earth's survival."** This book will be published in the autumn of 2019 by Cambridge University Press in Open Access.

We thank TWI2050 Executive Director Prof. Nebojsa Nakicenovic, Prof. Sander Van der Leeuw and all authors involved in developing the TWI 2050 report's Chapter 2 for granting permission to reproduce it in this publication.

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In the words of the authors:

We have highlighted a selection of domains in societal dynamics where there are substantive chances for quantum non-linear change. **The selection is of course arbitrary. We could have taken different themes and looked at them from different perspectives.** They all concern the current or near-future state of long-term trends that are the cumulative result of earlier events and processes. But underlying, long-term path-dependent second-order dynamics are the drivers behind the trends involved.

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1. INTRODUCTION

One of the assumptions of the Sustainable Development Goals (SDGs) is that achieving the vision underpinning the SDGs will be possible on the foundations of our current global socioeconomic system and its natural environment. This chapter places some question marks behind that assumption. There are many signs that we are currently involved, worldwide, in a major transformation of the global societal world order: the shifting of the political structure from the long-standing Euro-American to an East-Asian center of gravity; the rapidly emerging self-confidence of Islam as a global force; the emergence of Africa as a developing continent, etc.

Other issues also provide warning signs of potentially complicating developments, such as the ever-increasing wealth discrepancy in many countries that might trigger social tensions; growing insecurity around the provision of basic environmental services such as food and water, which may lead to (inter-) national conflicts; emerging identity-related populist tendencies that are in contrast with the wave of globalization that we have seen over the last half century.

Moreover, the current Information and Communication Technology (ICT) revolution has, and will continue to have, a major (and accelerating) impact on these issues by fuzzing the distinction between signal and noise, undermining our societies' alignment around certain existing worldviews and values, as well as transforming human communication.

In this chapter, we will signal, in the form of narratives, some of the tendencies that might emerge. We acknowledge that looking into the future is fraught with difficulties and uncertainties, but it clearly is relevant to include these emerging trends in any considerations relative to the future of our planet and our societies

But beyond these individual trends, a much larger danger emerges: the possibility that due to the interaction between several of these destabilizing trends, the whole of our societal organization is thrown into disarray. We conclude that, rather than, as is usual, deal with developments in each domain separately, we need to consider them together, in a holistic manner if we are to become aware of such interactions.

[...]

We will conclude the chapter with arguing that by adopting a strategy of designing for change (rather than changing when in trouble) we could greatly improve our chances of achieving the SDGs.

1.1 PLACING SOCIETY AT THE CORE

After many years in which sustainability issues were principally the domain of the natural and life sciences, the social science community is getting seriously involved. Hence, sustainability is now viewed as a socio-environmental challenge, and much research is dedicated to the immediate relationship between societal and environmental dynamics. But we must go further and finally acknowledge that the real sustainability challenge is societal, not environmental. Societies define and shape what they consider their environments, what they see as the main challenges in the environment, and what kind of solutions they can try and offer. If humanity is to re-equilibrate with the environment, that will have to come from changes in mindsets, societal structures and human behavior.

Hence, placing society at the center of the sustainability debate is the next quantum jump that we have to implement in our thinking. This is reflected in the structure of this paper: from people via institutions, technology, values and economics to natural resources. But, of course, there are many human societies on Earth, and these have different ways of perceiving and dealing with their environments. Each has developed over long stretches of time in a path-dependent co-evolution between perceptions, ideas, values, institutions and ways to interact with the environment. The socio-cultural diversity of human societies is profound and is an important aspect of socio-environmental relations. Yet, as the SDGs have been adopted as global goals, to be implemented by each country at the national level, we must try to discuss them at the global level as well as at that of the cultures involved.

[...]

1.2 FROM HERE TO THE FUTURE … OR BACK?

To project into the future is, of course, fraught with difficulties. When life was slower, it did not matter so much as we had time for regular reassessments that could keep our systems functioning under changing circumstances. But with the acceleration of everything - innovation, communication, transportation, technology, etc., - that is no longer the case, and we must learn how to improve projections.

This can be done in two ways. Either one extrapolates from the present to the future, or one determines what kind of future is plausible and desirable (Bai et al., 2016) and then constructs a roadmap from the present to the desired future.

Whereas future(s) arrived at by taking the present as the point of departure are constrained by present-day thinking and existing trends, the second approach does enable us to conceive "out-of-the-box" futures, but it is more difficult to see how these could be realized.

The SDG approach is inevitably a hybrid attempt to link these two ways of conceiving the future. On the one hand, it projects a fundamentally different (sustainable) future, to be implemented differentially across countries, while on the other it assumes continued "progress" from the present to that future or futures. It takes the present as point of departure and yet focuses on arriving at a very different future (or set of futures). In doing so, it not only limits the range of visions that may be conceived for our future to those that can be extrapolated from our present, but it also ignores the possibility that fundamentally disturbing dynamics might unfold between the present and 2030, c.q. 2050, which could completely change the societal contexts in which the SDGs would be implemented.

[…]

In the next section, we will therefore touch upon some major ongoing long-term trends that are likely to trigger events that will require fundamental decisions about the pathways we may take to achieve the SDGs.

2. A CRITICAL EXAMINATION OF SOME CURRENT TRENDS

We have chosen to examine, at the global scale, some major current trends in demography, economics, finance, society and politics. Although each of these trends in itself has potential to trigger major tipping points for our current world system, the importance of this examination is the fact that these dynamics are likely to interact, thereby creating an uncontrollable development that may change the world so much that 2030 and 2050 will be presenting a very different context from the present. In that process the rapid evolution of ICT is a crucial factor, with consequences for almost all aspects of our current world order. But it is important to emphasize that the underlying trends are not new – in some instances they go back centuries, in others 50 or more years. They have gained so much momentum that changing them will be very difficult. So, the major challenge we face is to understand such interactions and identify mechanisms that could orient them towards the future we want.

2.1 PEOPLE

2.1.1 GLOBAL DEMOGRAPHY AND HEALTH

Figure 2.1 compares several recent population projections by the United Nations (UN) (probabilistic) and International Institute for Applied Systems Analysis (IIASA) (Shared Socioeconomic Pathways) to the end of the century illustrating the uncertainties in projecting so far into the future. Some scenarios based on rapid development show a peak of world population into the future, but noticeably not before 2050. Some others implementing a stalled development result in a continuous increase. This figure poses a fundamental question: will the current global population explosion continue, or not?

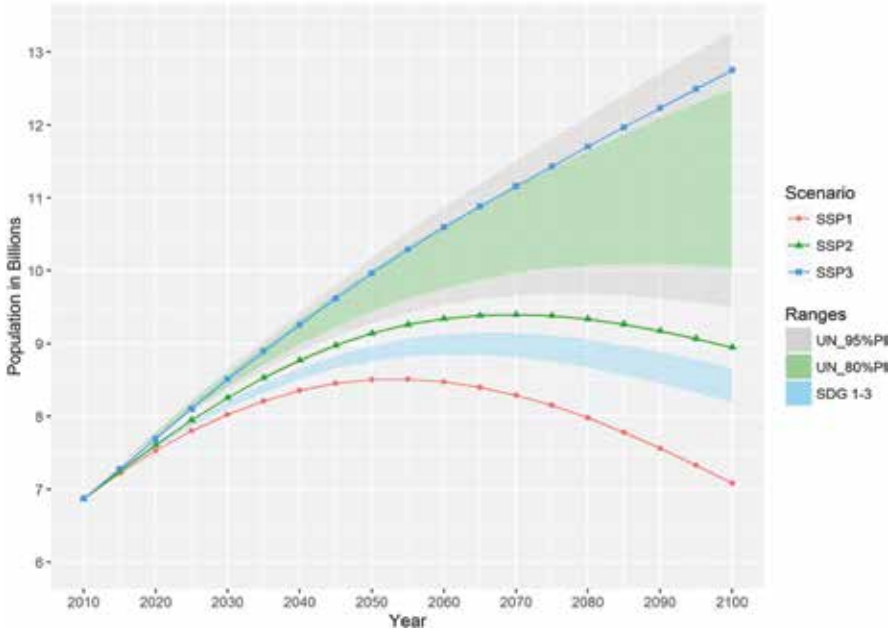

Figure 2.1. Future world population growth as projected according to the three SSP scenarios, and the probabilistic ranges given by the UN population projections. Source: Abel et al. (2016).

It appears that with growing wealth in the developing world, the crude birth rate will go down as life expectancy increases. A crucial question is, however, whether growth in wealth and decrease in birth rate will manifest themselves at more or less the same rates or not? Another question is how these processes will play out in different parts of the world. No one knows, but it is clear that 200 years of industrial economy have created important demographic discrepancies that may impact on global sustainability. Figure 2.2 shows that the increase in projected world population is uneven; the Near East and Africa show major increases, Europe is projected to slightly decrease. Figure 2.3 shows how life expectancy at birth is also very unevenly distributed in ways that are similar to that of wealth.

Currently, in a number of developed countries, aging and a low birth rate combine to cause decreasing numbers of inhabitants of working age: Japan, China and Germany are examples. Others still have an expanding population due, for example, to important immigration (the US, Canada, Australia) but in a general political climate in which immigration is increasingly subject to xenophobia, those fluxes may well decrease. That will have an impact on the nature and size of their economies. On the supply side people will be replaced by automation, leading to unemployment, and this might negatively affect the demand side.

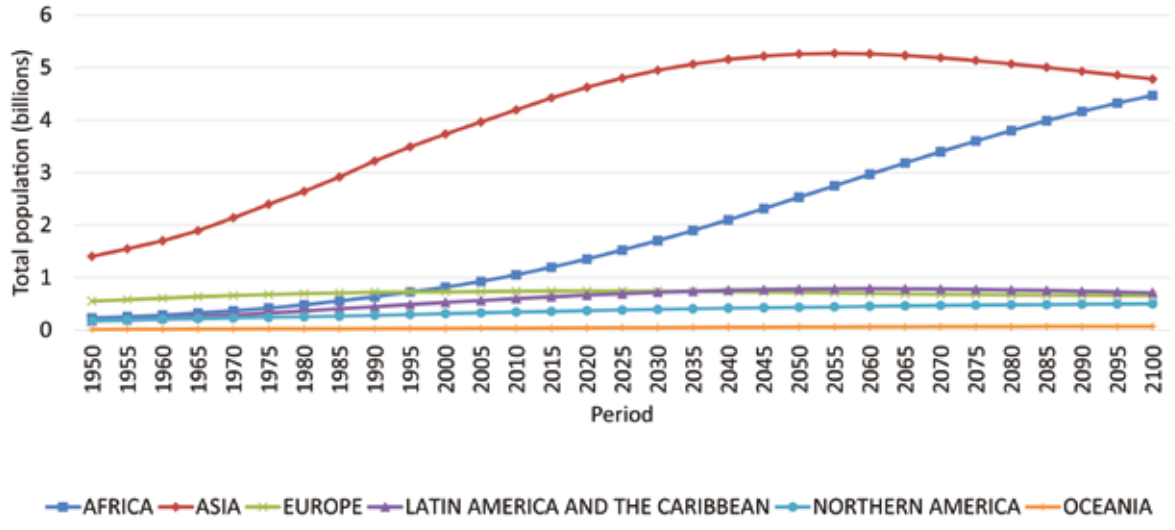

Figure 2.2. Population growth is very uneven. Population by region: estimates, 1950-2015, and medium-variant projection, 2015-2100. Source: UNDESA (2017).

The opposite is the case for South East Asia and Africa, where birthrates are still higher and the working-age population will be growing for some time. There, economies will continue to grow, and one of the interesting questions that raises is whether this will also entail a shift in global power balance towards these continents.

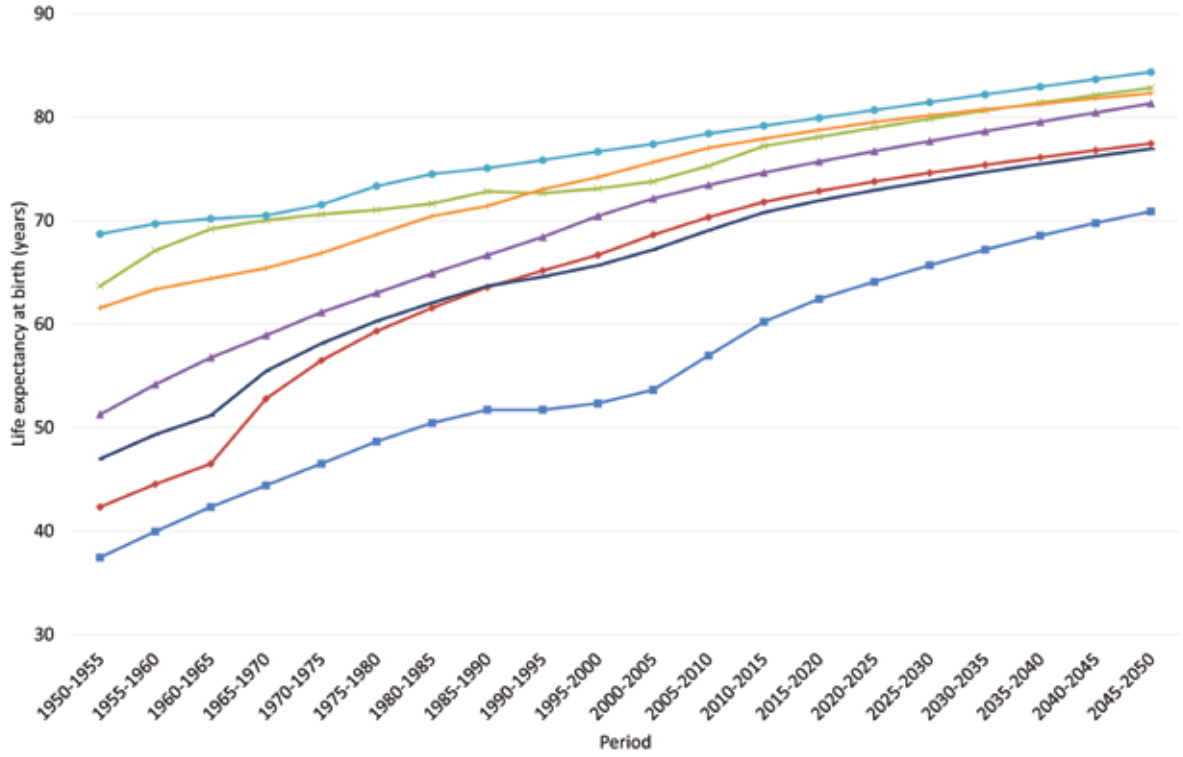

Figure 2.3. Life expectancy at birth (years) by region: estimates 1975-2015 and projections 2015-2050.. Source: UNDESA (2017).

That will in part depend on whether, and in how far, they will be able to develop their technologies and economies, as well as their institutions and legal systems. China has shown, over the past few decades, how this can be done.

Another fundamental characteristic of the current world, but with ancient origins, is the occurrence of large-scale migrations. Current research indicates that on a global scale, migration has not recently increased substantively, but at local and regional scales it has shifted demographics. According to the United Nations, during 2005-2050 the net number of international migrants to more developed regions is projected to be 98 million (UNDESA, 2017). Such regional migration is likely to further accelerate in the foreseeable future due to, for instance, climate change, sea level rise, and food and water availability. But there may also be increasing pressure towards migration for societal reasons, such as warfare, failing states, populism, ethnic cleansing or criminal violence. The counterpart may be a defensive reaction in developed countries, fed by local populism and identity issues, which creates more barriers to migration and globalization, as is now happening in Southern Europe and the United States.

We may therefore anticipate major cultural, social and economic challenges in the developed world as well as in the developing world wherever state control is not willing or able to prevent mass migration.

2.2 INSTITUTIONS

2.2.1 GLOBALIZATION AND CONFLICT

For five centuries the European (and later the Western) socioeconomic system has spread across the world. Initially this occurred through trade (1500-1800), then (1800-1945) through agricultural and mineral resource exploitation under military and administrative control, and since the Second World War (WWII) in the form of economic colonization. But since WWII, a counter-trend is also visible, in which ex-colonies gain independence, find their economic footing, and gain self-confidence in part through learning from developed countries. Now the Euro-American sphere is coming under increasing political and economic pressure. The rise in importance of the BRICS (Brazil, Russia, India, China and South Africa) countries is a sign of this trend, which is bound to be a source of uncertainty while the world searches for a new political organization.

An important underlying trend is that a reduction in the dimensionality of metrics (and awareness) of human wellbeing has emerged. Different cultures and populations now interact principally around the dimension 'wealth' when they judge themselves, compare among each other and transact exchanges. This has increased the emphasis on productivity and growth and has led to the over-consumption of natural and social capital in many regions. Other dimensions such as religion, community solidarity, art, culture, have decreased in importance as primary drivers of decision-making except among focused subsets of societies whose interaction creates 'hotspots'.

Current populist movements find their origins at least in part in the need to re-appropriate those multidimensional communal value sets, as was finely analyzed by Polanyi (1944) and members of his school in anthropology (Munck, 2005; Graeber, 2001). Elites have been able to make the transition towards a globalized society, whereas a very large majority of citizens worldwide has been left behind, focused on their local community and thus resistant to the reduction of the dimensionality sphere of their identity. This has shaped two 'deep' (second-order) fields of tension. Globalism poses a threat to the future of governance because it disenfranchises the vast majority and empowers a technocratic elite. But it also stimulates the emergence of identity issues, which are creating fields of tension between nations. Both trends are increasing the risk of (inter)national conflicts.

2.2.2 OUR GLOBAL GOVERNANCE SYSTEM

The Treaty of Westphalia in 1648 and the Congress of Vienna in 1815 laid the foundations for the organization of the European nation-states and the philosophy that shaped it, based on sovereignty (the freedom of national governments to act as they see fit in their territories without outside interference), and a balance of power between states. That order collapsed in the 20th century when individual states pushed the system out of balance, leading to the two world wars and the collapse of several major empires (Haass, 2017; Kissinger, 2014).

After WWII, all efforts were directed at re-establishing stability, by creating a series of global institutions such as the UN and its agencies. This led to a more or less stable geopolitical order for another 40 years, thanks to the balance of power between the North Atlantic Treaty Organization (NATO) and the Warsaw Pact. But with the collapse of the Union of Soviet Socialist Republics (USSR), this order fell apart, both between states and within them. As the US military completely dominated the globe, competition shifted to the economic sphere; nations focused on internal economic development and increasing economic interdependence through closer trading relationships. Economic frictions were negotiated through the General Agreement on Tariffs and Trade (GATT), at the World Trade Organization (WTO), and by means of bilateral trade agreements.

With growing interdependency between nations that was the result of growing trade flows, the relationship between domestic and international dynamics came to the fore, recently eroding the sovereignty that was the basis of the bipolar post-WWII system and creating an unstable multipolar one. Regional 'hotspots' emerged across the world, where competition between regional players led to (potentially explosive) tensions of mixed economic, nationalist, religious, ethnic and tribal nature.

These trends seem for the moment on an ascendant path. We cannot, between now and 2030 or 2050, count on a global web of stable governments and have to envisage that the political world may look very different by that time.

2.2.3 DEMOCRACY AND ITS VALUES UNDER PRESSURE

The governance system of most developed countries is, since WWII, democratic. Individuals delegate their political power to an elected elite that makes decisions for a limited amount of time. This system works as long as internal tensions in societies can be worked through by discussion, debate or vote.

In most developed countries, *there seems to have been a connection between the adequate functioning of the democratic system and the rise of the consumer society*, leading to huge increases in use of raw materials, energy and human capital in the countries concerned, and our current sustainability challenges.

Currently, as material and social stresses increase, mainstream media and long-standing political parties are losing power, as is clear from the recent Brexit referendum, as well as elections in Europe and the United States of America. The vacuum has been filled by populist organizations that find their base in social networks and undermine the democratic system in four different ways: 1) accelerating the decline of political parties and other institutional forms of engagement, 2) weakening the legislative branches, 3) reducing a sense of social cohesion and 4) undermining democratic state competence. In some instances, this has led to hybrid democratic regimes which keep the trappings of democracy, including seemingly free elections, under leaders who control the election process, the media and the scope of permissible debate. This is currently a highly debated issue [...].

Underpinning this process is the loss of alignment around sets of values more or less shared by people in the developed countries. The recent multiplication of sources of information enables subgroups in society to focus on a narrow set of sources for their information, leading to different conceptions of 'truth', 'signal' and 'information' and fracturing the overall alignment of societies ("people live in different bubbles").

2.2.4 THE DE-CONSTRUCTION OF COMMUNITIES

In his '*Great Transformation*' (1944) Polanyi distinguished between 1) "markets" as auxiliary tools to ease exchange of goods serving to maintain *social* relations - and 2) "market societies", in which the society becomes subject to the laws of the market, *subordinating the dynamics of society to the economic dynamics of the market's "invisible hand*". As part of the Industrial Revolution (roughly from the 1830's to the 1850's), a fundamental transformation between these two approaches seems to have occurred in the UK, which then spread across the world as part of globalization. A financial, unidimensional economic logic was progressively dis-embedded from the wider, multidimensional, socio-cultural logic and grew in importance to the detriment of the latter (Ussher et al., 2018; Frieden, 2006; Graeber, 2001; Polanyi, 1944). Munck (2005) has posited that globalization is at the root of the destruction of social communities because it undermines the multidimensional value spectra that keep communities together. People need to both belong to a group, and to distinguish themselves as individuals within that group. In order to enable that, a community needs to have many conceptual- and value dimensions. Such values are social creations shaped in the social networks that constitute the context of individuals.

Whether one agrees with these arguments or not, the destruction of many communities, in the process of migration, urbanization and rural abandonment, agricultural efficiency-related reorganization and so forth, is a fact, leading to an erosion of the structures at the base of our societies.

2.2.5 URBANIZATION

Urbanization is a global phenomenon that has rapidly accelerated and spread across the world. The relative longevity of the built infrastructure may explain why urbanization has so far been the most persistent societal dynamic known to mankind. Fossil energy enabled the explosive global urbanization of the last century. Urbanization is therefore often seen as a major stabilizing trend for the future. But most of the predictions about urbanization, and in particular that by 2050, 68% of the world's population is projected to be urban (UNDESA, 2018), and possibly about 80-90% by 2100, are based on a linear extrapolation of the current dynamics. We are actually dealing with a complex and highly vulnerable system with many nonlinearities and unintended consequences, and hence, such a linear scenario is not appropriate. Food and water security challenges may well force populations to disperse from their highly concentrated agglomerations. The ICT revolution may undermine the need for spatial concentration of information and material processing that drove the need to live in cities. Climate change will exert pressure to increase transport costs and to reduce the use of bulk transportation, so that we may have to develop economies that are more regional, more local. Together such dynamics may very well upset the business-as-usual scenario for urbanization. In order to deal with that, cities may have to change their policies from "changing under pressure" to "designing for change".

2.3 TECHNOLOGY

All the above structural, long-term ongoing developments are likely to be impacted, over the next decennia, by the rapid developments of technology that have emerged from the Industrial Revolution and the lifting of the energy constraints on innovation. These are commonly summarized as the Nano-, Bio-, Information- and Communication (NBIC) technologies. The first two of these are still in experimental stages and it is therefore difficult to outline their potential impact on society. As far as we can see at the moment, the *devolution of information processing and communication to electronic systems is the most important driver to have a transformative impact on the near-term global future of our societies.* It drives a transition that we will not be able to cope with by simply becoming more resilient while remaining organized as we have been. The acceleration of information processing, driven by increasing interactivity, communication between more and more people in possession of more and more complex and effective tools for thought and action is causing unintended consequences of actions and decisions in a dynamic that is beyond our control. We have no sense at all of how to deal with the second-order changes this may be triggering.

2.3.1 DIS-EMBEDDING INFORMATION

The ICT revolution is nothing new. It is the culmination of a process of knowledge acquisition that began when humans 'bent their minds around' the challenge of creating artifacts. It accelerated under the impact of the Industrial Revolution, which put virtually unlimited quantities of relatively cheap energy at societies' disposal. Thus, lifting the energy constraint on innovation set in motion an explosive development in technology and knowledge acquisition (and thus information processing) of all kinds, improving overall health, wealth and resource use wherever the social conditions were favorable, and notably favoring education.

Until the 1860s, matter, energy and information were embedded in each other, mostly being transmitted in language, in the form of artifacts, but also in the structure of customs and organizations. Writing was a major step in dis-embedding information by substantiating symbols with informational meaning onto a material substrate, and thus facilitating communication beyond immediate interaction, and beyond unity in time and space. Printing popularized this means of communication.

With the telegraph and telephone, *transmitting* information became possible in the form of pure (electrical) energy, reducing the cost of communication hugely. But this electrification did not extend to the *processing* of information.

Due to the territorial limitations of national governance, the increasing efficiency of information processing has enabled – and been driven by – the growth of the large multi-national corporations. It now spreads over much of the globe, accelerating the creation of a global *extraction-to-waste economy* (Steffen et al., 2015) contributing to an increase in wealth differentials, exponential growth of cities, dependency on the fossil energy industry, globalization and the consumption society. It also reduces the chances that outsiders can become insiders.

But as part of that trend, the global information processing network will itself become more accident-prone and sensitive to minor disturbances because of its growing interconnectivity (Helbing, 2013).

2.3.2 ELECTRONIC INFORMATION PROCESSING

At the root of the current tipping point is the fact that, presently, information is *not only transmitted*, but also *processed* in digital form, enabling the semi-independent processing of information by machines, reducing the time and energy involved in information processing to (near) zero, and accelerating second-order change in information processing into a nearly exponential one. Coupled with a very rapidly accelerating algorithmic software evolution, the acceleration is such that societal information processing is no longer able to deal with it.[1] This has important social consequences. The people directly engaged in informatics have an enhanced opportunity to accelerate invention. But this group is proportionately getting smaller as the technology becomes more complex, whereas those outside that small community are left behind. That is profoundly affecting our societies' general capability to absorb change.

2.3.3 CHANGING RELATIONSHIPS BETWEEN SOCIETY AND SPACE

During the last 200 years, the acceleration of our means of transportation (cars, airplanes) has reduced time needed for going to places and increased the frequency of displacements. The ICT revolution has accelerated interaction further by enabling anyone to share any information immediately across the world.

1 As roughly calculated by Friedman (2016), technological innovation generations last some 5-6 years, while changing behavior in society to fully exploit these technical advances takes up to 15 years.

This has implications for the relationship between humans and space, as the transformation of 'spaces' into 'places' (locations 'created by human experience', cf. Tuan (1977)) is deliberately disabled. That could ultimately undermine our current reliance on spatially defined administrative entities such as municipalities, provinces, states and nations. Territoriality is not a 'natural' state of affairs, but one created over time by specific historical circumstances.

As people become increasingly 'place-less', will other, non-territorial modes of organization emerge? An experiment with such a novel organization is currently being carried out in Estonia, which accepts applications for e-residency from anywhere in the world. Were others to follow that example, location would no longer define the laws and statutes governing a person or firm's transactions, but the organization that guarantees the transactions would do so, wherever in the world it might be established.

2.3.4 THE IMPACT OF ICT ON TIME MANAGEMENT

Central to the evolution of the relationship between the individual perception of time and its societal management are external, mechanical devices enabling an "objective" measurement of time. Since the age of sundials and hourglasses, larger and larger communities have delegated their time management to mechanical devices of increasing precision, so as to manage the explosion of interactions involved in their growth.

A dynamic relationship between the size of the flow of information processed and time perception seems to be confirmed by everyday experience: when an individual is very busy (processes a lot of information), time seems to be 'flying', whereas when information processing falls below a certain level, time is perceived to move very slowly. If such a relationship exists, then the growing volume of information processed would seem to relate to an increasing subdivision of temporal intervals in societal time management. Would this come to a point that only closer integration between people and computers can deal with societal time management?

2.3.5 LOSS OF CONTROL OVER INFORMATION PROCESSING

The ICT revolution is progressively transforming "information processing without *central* control" into "information processing without *any* control". Until now there have always been nodes that controlled information processing to some extent, whether through enforcement, institutionalization, incentives or otherwise. Each node involved only a limited number of people (subscribers to a daily, or listeners to a radio station), and there were barriers to the flow of information between them (spatial isolation, differences in culture, identity, administrative organization, finance or other). That enabled each node to maintain its culture, align its members on certain values, procedures and institutions. The reduction in information - processing space/time that culminated in the internet, is removing these barriers, generating an explosive increase in horizontal information processing at all levels of society across the globe. This has made it much more difficult for societies to maintain their own identities. On the one hand, ideas and values now move very easily from society to society, while on the other the risk of social fragmentation has increased, as ideas within a society get increasingly differentiated.

2.3.6 'FUZZING' THE BOUNDARY BETWEEN INFORMATION AND NOISE

One important consequence of this loss of control over information processing involves the status of 'information' itself. Numerous internet sites now proclaim to provide 'news' but launch egregious 'information' that has little relationship with commonly experienced realities. Deliberately or by default 'factoids' are presented as 'facts' *according to the worldview of the presenter*. Though that is nothing new – the rumor mill has always, in every society, had this effect – in the internet age it is much more difficult to find out how information has emerged, and what its relationship to the realm of phenomena is. *This undermines in many societies the distinction between signal and noise and the alignment of people around shared sets of values*. Over time this could fundamentally affect the existence of all social institutions because it obfuscates the boundaries between the institutional structure of our societal interactions and the surrounding stochastic chaos. Individuals would lose their alignment and compass, feeling lost and immobilized by indecision.

2.3.7 BIG DATA AND INDIVIDUATION

The capability to collect, store and process 'Big Data' in great detail is transforming our understanding of societal phenomena. Traditionally, in social science, conclusions were based on statistical generalizations around limited samples. We can now enhance resolution to deal with individuals separately, improving our understanding of many societal dynamics at the cost of hugely increasing the need for processing power. This is one of the trends driving High-Performance Computing.

In practice, this trend also enabled a major concentration of information processing, and thus political and financial power, in the hands of a very small group of corporations that use the data in completely opaque ways. Governments have difficulty limiting negative effects, protecting privacy, ensuring full transparency and thus re-establishing eroding trust. This field of tension is potentially a very destabilizing side of the 'Big Data' revolution.

2.3.8 AUTOMATION AND ARTIFICIAL INTELLIGENCE

Relatively recent advances in information processing have also enabled the automation of increasingly complex mechanical tasks. In the last thirty years, robots were specifically designed to perform relatively simple, monotonously repetitive tasks. But that, too, is changing. Very recently the combination of 'Big Data' with 'Cloud Storage' has laid the foundations for the development of contemporary artificial intelligence (AI) based on Machine Learning (ML). It programs the computer to recognize and identify patterns by analyzing very large numbers of data through approaches in which initial approximations of meaning are tested and refined many times until they come close to correct understanding (cf. 'fuzzy sets') (Zadeh, 1975). Such reflexive learning based on analysis of very large datasets enabled computing to conquer important new domains of information processing, including non-routine and relatively complex analytical tasks for example. It enables an ICT-based system to operate and adapt to changing circumstances with reduced or even without human control, as in the case of the self-driving car.

But AI is shifting from '*narrow*' (sets of specific applications for discrete problems) to 'general' (multi- and cross-domain 'broad spectrum' applications). As this shift proceeds, human-machine teaming will grow in importance. This opens the road to employment opportunities that are not likely to disappear in the next few years. But filling these slots requires high levels of education and training people in the specific skills required.

2.3.9 EXPLODING CONNECTIVITY AMONG 'TOOLS FOR THOUGHT AND ACTION'

The 'Big Data' revolution has exponentially inflated the volume of information that we can gather and process. But it also engendered an even more rapid increase in the connectivity between different signals and dimensions of the information processed. The ubiquitous availability of information from across the globe, and improvements in ways to search for, and identify, complementary components has accelerated this process further, enabling an important shift in the nature of innovation, from reliance on originating innovations (which open up a completely new technology) towards reliance on recombinant innovations (Strumsky and Lobo, 2015; Brynjolfsson and McAfee, 2011). A next step in this process is the development of the internet of things, connecting many of our everyday tools to each other so that they can interact, with or without human intervention.

2.3.10 ICT AND EDUCATION

Information technology is increasingly penetrating all aspects of our life and confronting all citizens whether they like it or not. It is currently applied for identity management by capturing biometrical data. According to the company Smartmatic (2018), the employment of their biometric technology helped to reduce the citizen registration time of Haitians from three months to a few days. Through the possession of an identification card, citizens are for example allowed to vote (Smartmatic, 2018).

In Denmark, a Central Person Registration System is in place (Lifeindenmark.dk, 2018). Anyone who stays longer in the country than 3 months, or 6 months if EU/EEA citizen or from the Nordic countries, is obliged to register with the municipal authorities to receive their personal CPR number. It gives access to a range of services such as social security, handling taxes, open a bank account, conclude a phone contract, among others (Lifeindenmark.dk, 2018). However, strong cyber security needs to be provided, to protect from potentially damaging cyber-attacks.

In the absence of increased, universal, "data-literacy" developments such as these will rapidly lead to major societal challenges. Retrieved data needs to be critically assessed to understand who provided the data, which method was used and what it conveys when embedded in a wider context. Our current education systems are not up to the task – relatively few people are educated to the necessary level, creating a very small elite in control of information, and many forms of education are themselves sub-optimal.

The transformation of education through the digital revolution takes many forms. Online education platforms such as Coursera (2018), or Khan Academy (2018) have become an established part of the education system and have allowed a larger public to engage and access information. Virtual reality simulation courses from i.e., Labster ApS (Labster, 2018), which allow students to learn a laboratory method before physically entering the laboratory, are currently in development.

Citizen science is another, complementary, new development, using technological innovations to engage the wider population in research. For example, the European Commission's Joint Research Centre encouraged citizens to report invasive alien species in their region by using a specifically developed app (Galiay, 2018; Tsiamis et al., 2017). In the United States, the Environmental Protection Agency (EPA) developed a toolbox with low-cost sensors for citizen scientists, among others, to collect local data on air quality, to help interpret it, as well as to compare it with data collected by regulatory stations (EPA, 2018).

But viewed overall, most educational institutions at all levels still practice teaching approaches that were developed many years (in some cases centuries) ago. Moreover, we need not only to focus on moving capacity building in technological research forward, but also to invest research time and money on discussing and reflecting how we will control such developments in ways to *maximize societal benefits* (Tegmark, 2015).

2.4 ECONOMY

In many ways, the economy is both the best- and the worst- studied of the socio-environmental interactions. The best studied because there is a wealth of data available, but the worst studied because many formal macro-economic models used to explain observed patterns are insufficiently sensitive to detail, while in most instances they are dynamic equilibrium models unsuited to deal with the complexity of the dynamics underlying behavior (Beckert, 2016).

2.4.1 FINANCE

In recent years a very important, and growing, proportion of total financial capital is no longer engaged in the production of goods or services, but entirely devoted to speculation. Figure 2.4 and Figure 2.5 show how the leverage of the proportion of available capital in the US that is not invested in productive capacity has in recent some years constituted close to 40% of total financial capital.

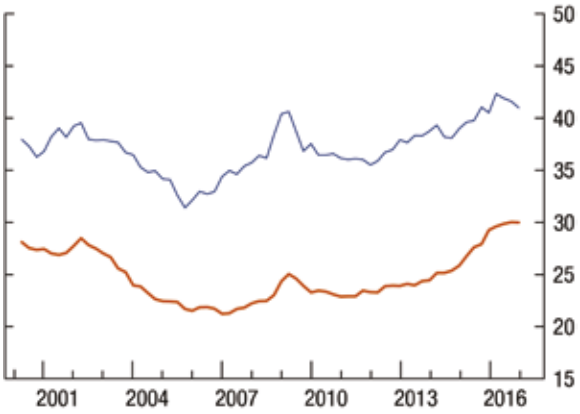

Figure 2.4. Gross leverage for speculative-grade and investment-grade firms, 2000-2016. Gross leverage is the ratio of the book value of total debt to the book value of total assets. Source: US Federal Reserve (2016).

Figure 2.5. Fraction of total income (in the USA) invested in production (without capital gains tax) and speculation (with capital gains tax). The global recession of 2008 has depressed both figures, but the relationship is still the same. After: Washington Center for Equitable Growth (2018).

The mobility of such speculative capital, and the fact that these huge financial means are controlled by fewer and fewer people and institutions, has had the destabilizing effect of contributing to a rapid succession of financial crises that we have seen in the last sixty years (Economist, 2014). Several aspects of this trend are so dangerous that we need to include them in our thinking about the future.

2.4.2 TRADE, PROTECTIONISM AND INVESTMENT FLOWS

Several developed economies have exhibited a trend towards protectionism. While protectionist policies are often implemented under the pretext of protecting jobs or correcting bilateral trade imbalances, they ultimately restrict economic growth in the long run, since it inhibits trade in intermediate goods and the creation of value chain niches. The uncertainty produced by the threat of protectionism also hampers flows of investment in global capital markets, as it generates uncertainty regarding future economic growth (Erokhin, 2017). This is aggravated by trends in international aid, migration, climate change and geopolitics. Protectionism also threatens food sustainability by drastically shifting value chains and forcing replacement of staples and other foods with less sustainable varieties. Trade has a major role in stabilizing food prices, as well as shifting production from areas of high environmental risk to less risky areas (IFPRI, 2018).

The effects of protectionism in developed countries will be felt most acutely in the least developed countries (LDCs) (UNDESA et al., 2018). Many LDCs are dependent on external demand for commodity exports, as well as foreign aid for budget support (Timmer et al., 2011). In a closed world economy, many LDCs will continue to lag behind more developed economies, and this will have important ramifications in other sectors. LDCs will not achieve the economic growth required for sustainable development without a significant increase in investment. However, many of these countries are unable to attract the levels of investment they require due to institutional deficiencies, an over-dependence on commodities subject to fluctuation in prices, and a dearth of basic infrastructure to support fledgling industries.

2.4.3 DEBT

The rapid increase in global indebtedness (Figure 2.6) is directly linked to overall financial and economic stability. As long as the world - and most countries - are on a growth trajectory this is not necessarily a problem as people have enough confidence that this debt will be reimbursed, and because inflation reduces the debt load.

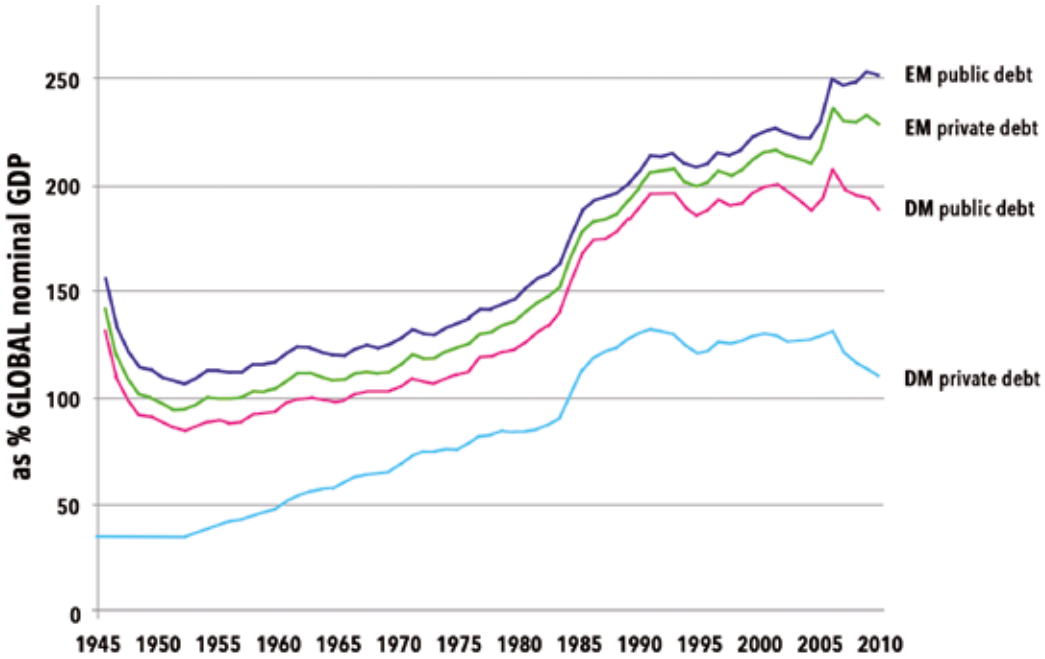

Figure 2.6. Private debt in developed and developing countries exceeds public debt. After: Hugman and Magnus (2015).

We have to remember, though, that this whole system is *fiduciary*, and that if trust in it is for some reason or other undermined, it could collapse very easily, leading to major social unrest. There are many hair triggers that may cause such a collapse. We have seen how individual nations have seen trust in their financial systems collapse due to mismanagement or actual cheating (Argentina, Greece or Ireland are more recent examples). That is not affecting world financial stability as long as there are other economies that can serve as 'lenders of last resort' because they are bigger and in better shape. However, with the overall increase in debt level among both large and small countries this mechanism may itself be under threat. And because each crisis is countered by central banks with an increase in their debt levels, the underlying instability increases with each such event (Figure 2.7). Moreover, as an ever-larger percentage of gross domestic product (GDP) is devoted to interest payments, the proportion of GDP that is available for spending is reduced. Ultimately, this may limit the potential for further investment in infrastructure or towards the expansion of productive capacity

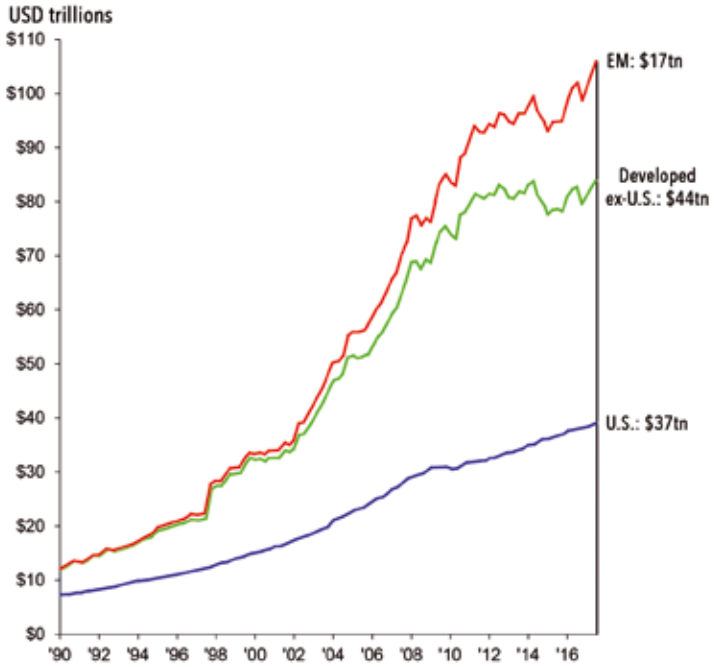

Figure 2.7. Public debt in the US, other developed countries, and emerging markets. After the 2007 debt crisis, public debt has increased rapidly, to level off (except in the US) after 2010. After: Durden (2017).

2.4.4 AGING POPULATION EFFECT ON SAVINGS, DEBT AND PENSION SYSTEMS

A major demographic trend with tremendous economic implications that represent a challenge for sustainability is population aging and its consequences on welfare systems in developed and developing economies. This includes pension and healthcare systems, in addition to a possible decrease in savings and investments (Bosworth et al., 2004).

The irreversible trend of an aging world population has profound implications on the sustainability of social welfare systems. In developed countries, an increased burden will be placed on public transfer systems, due to concurrent trends of a growing proportion of pensioners and a diminished tax base. However, the majority of the increase in the population above the age of 60 will occur in the Global South (UNDESA, 2017), where the elderly are less likely to have retirement savings plans or to be supported by public welfare systems, and instead depend on assets and labor income.

Without the means to support themselves in retirement, many of these people are susceptible to poverty. An aging world population also means that the share of non-communicable diseases in the global disease burden will grow, increasing pressure on countries' health expenditure, adding to the fiscal burden of government budgets.

Low productivity growth in developed economies in recent years has been explained by aging workforces, a slowdown in total factor productivity in the ICT sector, declining contributions of trade to economic growth, and stagnation in levels of educational attainment (Adler et al., 2017).

Between countries, global inequality has decreased globally in the last decade thanks to the contribution of China and India in their economic development process. As these and other emerging markets continue to grow, the economic hegemony of the United States and its Western allies will be gradually replaced by a multipolar world economy, in which India, China, Indonesia and Brazil become increasingly important economic hubs for financial services, manufacturing and innovation (Timmer et al., 2011).

However, this trend does not mean that economic growth will be evenly distributed. Many LDCs are at risk of continued vulnerability to economic shocks for reasons mentioned above. Their economic vulnerability is compounded by the fact that many of the LDCs are facing disproportionately high threats from climate change, have rapidly-growing populations, and also have weak governments and vulnerable security situations. These trends are inhibiting the ability of LDCs to bridge the gap between themselves and the emerging and developed economies. Without appropriate economic growth and investment, their populations may continue to grow at unsustainable rates, they will not be able to provide adequate education to their youth, and the coverage of health services will remain incomplete and fail to tackle preventable causes of morbidity and mortality (UNDESA et al., 2018).

2.4.5 WEALTH DIFFERENTIALS

The global economy has created excessive material wealth differentials between individuals by concentrating material wealth in a relatively small, if growing, proportion of the world's population (Figure 2.8). This has caused a steepening of the wealth disparities within and between countries in another very long-term 'deep' trend (Scheidel, 2017).

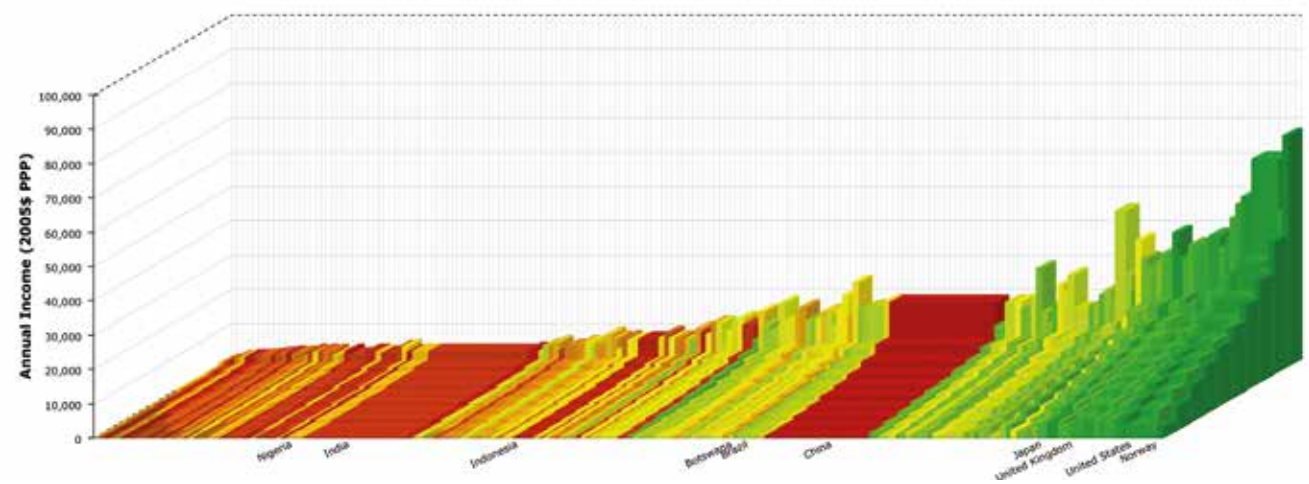

Figure 2.8. Worldwide difference in wealth distribution. Source: Blundell (2018) based on Sutcliffe (2004).

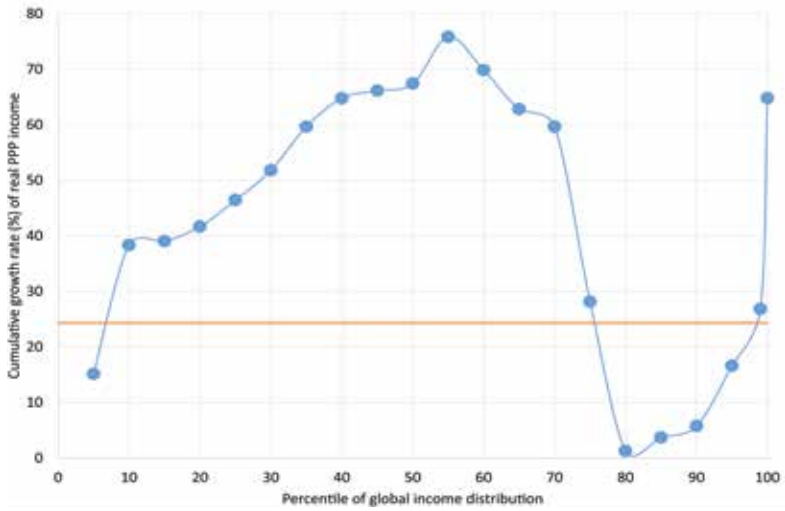

Figure 2.9. Global growth incidence curve, 1988-2008. One sees that below the 10th percentile incomes have grown very strongly, while incomes between the between the 10th and the 50th percentile incomes have grown substantially, whereas from the 50th percentile to the 80th, incomes have substantially declined. From the 80th to the 95th, they have grown some, and beyond the 95th, they have grown exponentially. Source: Licensed under CC BY 3.0 IGO by Lakner and Milanovic (2016).

If we look at the evolution of wealth globally, (Figure 2.9), the so-called "elephant curve" (Lakner and Milanovic, 2016), representing the growth in average household income of each percentile group worldwide between 1988 and 2008, we see the combined effect of three trends: 1) rapid and substantive income growth for the poorest part of the world population, especially in developing countries, but starting from a very low base, 2) absence of, or low, income growth for the middle classes in the developed countries, and 3) rapid growth for the richest people in the developed and some developing countries (notably China).

Corlett (2003) shows that differences between countries' population growth rates and the selection of countries included in the statistics (notably Russia, Japan and China) accentuates some of the contrasts, but this does not fundamentally change the picture that the middle classes in developed countries have not seen any increase in real income in this period.

Figure 2.10 shows the evolution of the wealth gap over the last century (1900-2010). In particular, it illustrates how the 'big bang' of the 1980s, engineered by Reagan and Thatcher, has hugely increased the wealth gap in the English-speaking world, but much less so in continental Europe. The important lesson is the fact that, indeed, governments do shape markets, and would be wise to regulate them if they want to preserve social peace!

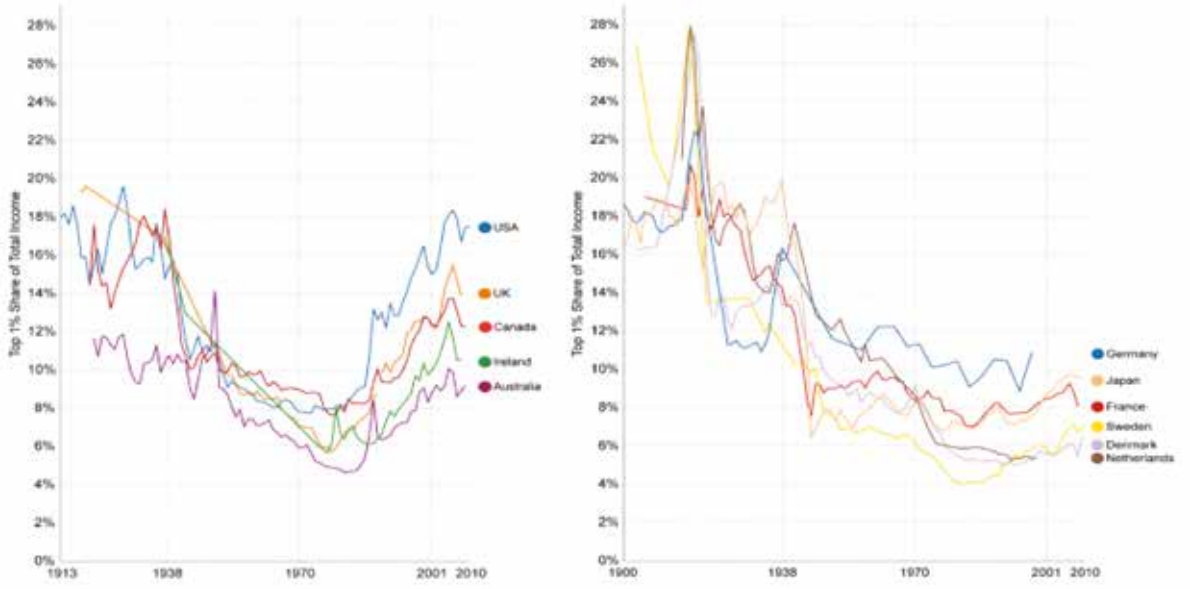

Figure 2.10. The evolution of inequality. The 1980s 'big boom' in the financial regulation has inverted the reduction of inequality in the anglo-speaking world, but at least until 2010 not in other parts of Europe. Source: Licensed under CC-BY-SA by Roser (2018).

Education is one of the major differentiating factors in lifelong earnings capacity. The increased reliance of industry and services on ICT requires higher levels of education to deal with more and more complex tasks. Currently, this is one of the major barriers to optimize use of modern technologies.

Turning now to some of the consequences of the wealth gap, Figure 2.11 presents the relationship between income inequality and societal challenges in a number of countries worldwide, by projecting energy use (here taken as a proxy for wealth) against social progress.

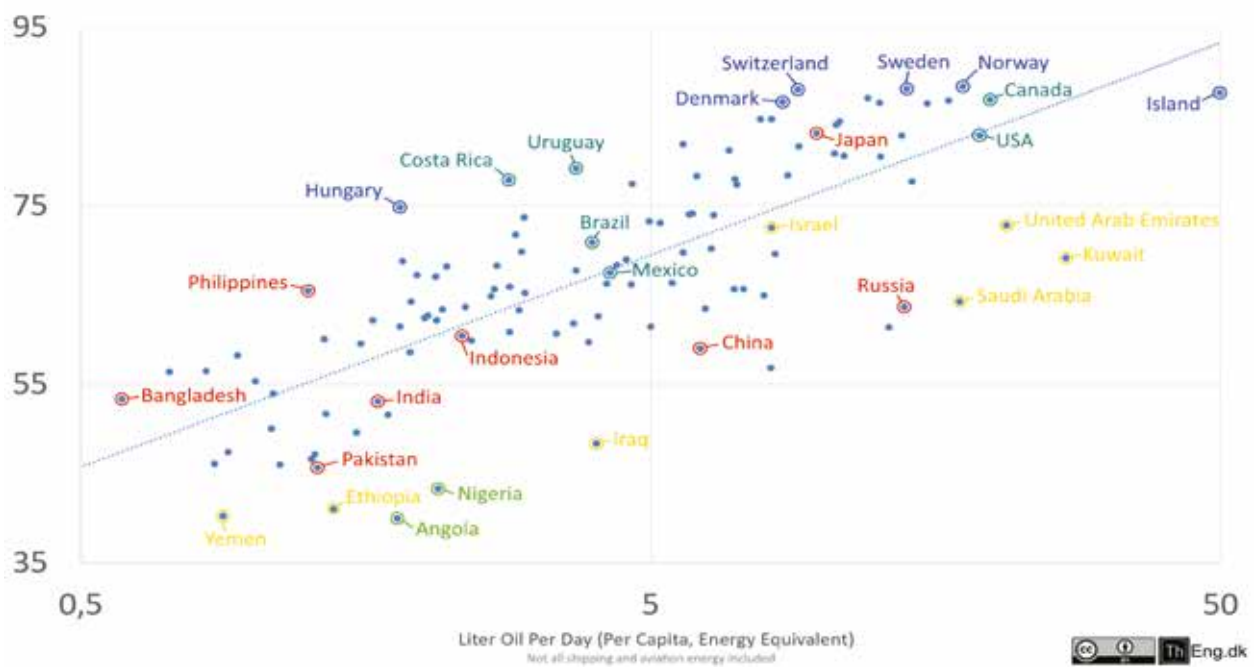

Figure 2.11. Social Progress Index vs Energy per country. The relationship between per capita energy use (here taken as a proxy for wealth) and social progress (an indicator combining life expectancy, math and literacy, infant mortality, homicides, imprisonment, teenage births, trust, obesity, mental illness, including drug and alcohol addiction, social mobility). Source: Wikipedia (2018), licensed under CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/legalcode).

The growing wealth discrepancy seems a manifest case of a societal planetary boundary that we are approaching or have already crossed. Some see it as an early warning sign of major social adjustments - in the developed nations as a protest against the squeeze of the middle classes, and in developing nations as a 'revolution of rising expectations' triggered by the fact that a small proportion of the population is getting (very) rich.

2.4.6 INNOVATION

When politicians and other people, talk about "innovating our way out of the sustainability conundrum", we would respond that the last two-and-a-half centuries of accelerating, undirected innovation in every domain of human life have actually caused our present sustainability predicament!

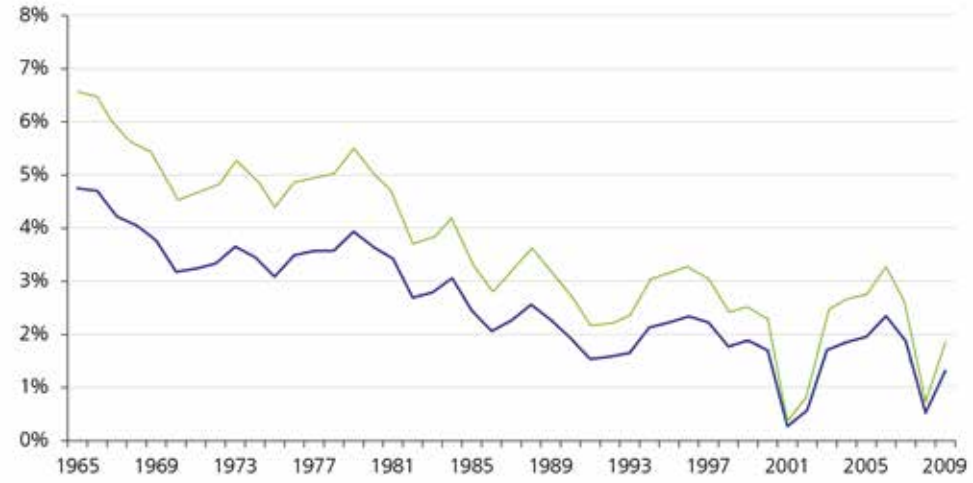

Figure 2.12. Evolution in return on invested capital in the US 1965-2011. The blue line represents the evolution of Return on Assets; the green line that of Return on Investment. After: Hagel et al. (2010).

In accordance with their values, our Western societies will strive to maintain a degree of innovation. But their current "(technological) progress"-related orientation and its values should not blind us to the fact that for many populations, this may not be such a fundamental value.

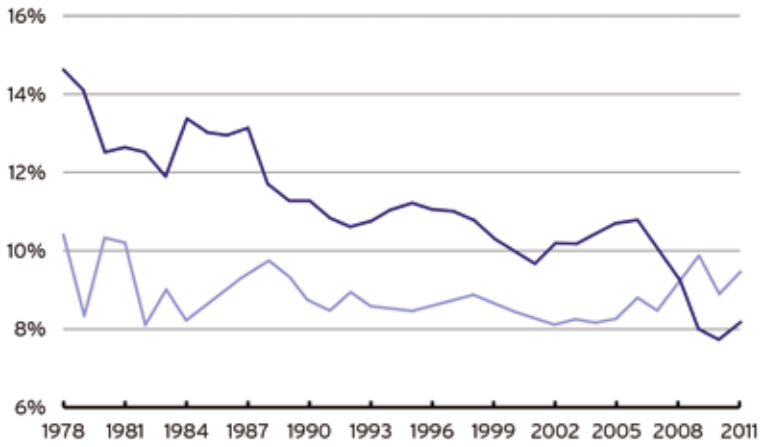

Figure 2.13. Annual new firm creations (dark blue line) and existing firm deaths (light blue line). After: Hathaway and Litan (2014).

Moreover, there are dynamics within our industrialized societies that could undermine our innovativeness. Summers (2016) argued that we may be reaching a plateau in the expansion of our global economies. Whereas his argument is purely couched in terms of economics and finance, it raises a more fundamental question: "Is it becoming more and more difficult to 'invent' novelty that has a major impact on value creation?"

One observes in the USA an overall decrease in return on invested capital (Figure 2.12) as well as a decline of entrepreneurship (Figure 2.13) that might be linked to an overall decline in the frequency of major innovations. Strumsky et al. (2010) show that between 1947 and 2006 the average number of patents per inventor has gone down from 2.4 to 1.7, while the number of people involved in a patent has gone up from about 0.6 to 2.5. If this trend continues, it will affect the growth potential of the economy.

2.4.7 FROM PRODUCTION TO DISTRIBUTION

In the current system, our production economy derives its profitability from the gap between cost of production and perceived value of the product in the eyes of the consumer. That has driven the search for ever cheaper production methods worldwide, ever more efficiency in all aspects of production: human, financial, logistical, and technological. But worldwide limits to cheap labor, enabling large-scale industrial production, are looming. Although there remain pockets of relatively low labor cost, the profitability and existence of the traditional market-based production economy may come under stress.

Automation will no doubt mitigate this as robotics and AI replace human activities. Computers can increasingly associate diverse information into patterns, enabling them to respond appropriately to changing circumstances. For one, how *to use information can now be determined by computers*, enabling many more economic and other activities to be managed by them.

Economist and technologist Brian Arthur (2017) argues that this will bring us to a point where it is possible to produce enough goods and services for everyone through automation [if we can find ways to do so in environmentally sustainable ways]. This will trigger a major shift from an economy in which production of goods is the driver to one in which *ensuring general access to what can be produced* is the challenge. Arthur argues that this will bring about the following major changes:

- *The criteria for developing and assessing policies will change*. GDP and productivity are relatively good measures of the physical economy, but are much less effective in measuring the virtual economy.
- *The free-market philosophy will be less suitable* to the new situation because the focus shifts to more or less equitable distribution of value, away from the idea that the more is produced, the better it is.
- *The new era will not be an economic, but a political one*. The paradigm of the society at the service of the economy will have to be inverted to place the economy at the service of the society.

The transition is likely to cause a period of major upheaval, in which a number of social questions need to be answered: "How will we find meaning in a society where jobs no longer provide it?", "how will we deal with privacy in a society where every bit of information about everyone is concentrated in databases?", and "will we abdicate individual learning in favor of computer data and algorithms?" The changes and the upheaval will be as important as those that accompanied the Industrial Revolution, and may well take as long. Who knows?

2.5 PEOPLE'S EXPERIENCES AND IDEAS

In this domain, we want to draw attention to two of the many potential changes that are currently observable, but which are only indirectly related.

2.5.1 THE SPECTACULARIZATION OF EXPERIENCE

Radio and television are among the earlier precursors of the full information technology. People did not have to be literate to peruse them, and their visual nature greatly enhanced their impact. Together, they hugely enhanced people's capacity to escape from everyday existence and live, albeit for a short moment, in a fantasy world. Guy Debord (1994) pointed to the fact that these media promoted the confounding of sincerity with authenticity and of emotion with emotional images.

As the tele-amusement industry developed, it habituated more and more people to live, at least in part, in a fantasy world. Over the past half century or so, this led to a fuzzing of the boundaries between fantasy and reality. In the 24 hour news cycle, this is achieved by presenting news in a simplified 'bite-size' form. Most websites follow the same pattern, leaving it up to the user to digest the full message or only a highly simplified version, leaving much to the viewer's fantasy.

The computer games industry is a direct continuation of this trend, but here the opportunity to escape into a fantasy world is no longer centrally controlled. In the process, *many dimensions of reality have been removed*. That has created a field of tension between people's experience and the real world, which in our opinion is, and will continue to be, of great impact on people's ideas and decisions.

2.5.2 CHANGES IN SOCIETY'S 'VALUE SPACE'

In the relationship between observations, information and knowledge/understanding, values play an essential role. They distinguish between signal and noise, and align a society's members around certain information and resource flows, enabling them to communicate, collaborate and differ of opinion within a set of – often implicit – values. We call the society's 'value space' the total set of dimensions according to which a society attributes value to ideas, actions, institutions, material goods, etc.

Individual value differences are the result of the fact that people acquire their individual cognitive system ('world view') in different socio-environmental networks. Sharing a value space means that people's conceptions are sufficiently close to facilitate frequent constructive interaction. Within it, value differences allow individuals to create an identity and drive the information exchanges that are responsible for societal (and socio-environmental) change. Partaking in these information exchanges requires knowledge of the society's 'tools for thought and action' (language, customs, institutions and belief systems).

When a society is growing, it includes more and more people, knowledge and resources. That involves the construction of a set of utility functions, which initially will be relatively adaptable, but over time experience and complexity will expand and harden. A few terms come to dominate, leading to simplification and loss of dimensionality. Eventually the functions become brittle and can no longer adequately deal with change. The limits of the value space are reached. That generally results in an important increase in unintended consequences of actions, and in a reduction of the society's ability to implement new inventions. Is our current society at that point?

2.6 NATURAL RESOURCES

Due to the way in which the research into sustainability-related issues has developed, investigating natural resources and their relationship with society from the outside inward (for instance, having climate change, deforestation or carbon emissions as the starting point), the domains that fall under this heading have been extensively explored. As this section specifically aims to develop an inside-out perspective that puts the societal dynamics at the core and sees their impact on the environment as secondary, we will not contribute much to these domains, but only briefly ('pro forma') point to some of them. We use the energy and food sectors as examples.

2.6.1 ENERGY

Clearly, this topic has been looked at from all angles and disciplines, and there is very little to be added. Basically, the societal dynamics that are driving our societies have increased energy consumption from approximately 20 gigajoules (GJ) per capita per year at the beginning of the Industrial Revolution to approximately 80 GJ per capita per year now (Figure 2.14). Clearly this is very unevenly divided between the developed and the developing world. In the US, in 2013, average per capita consumption was in the order of 290 GJ equivalent per year, while in India it was only about 25 GJ. Most of that serves in building, maintaining and running our material and institutional infrastructure. A growing need for energy is fundamental to the way in which the world is currently moving, and energy consumption, for political and economic as well as societal reasons, is not likely to decrease in the foreseeable future. Reduction of its climate impact is therefore essential.

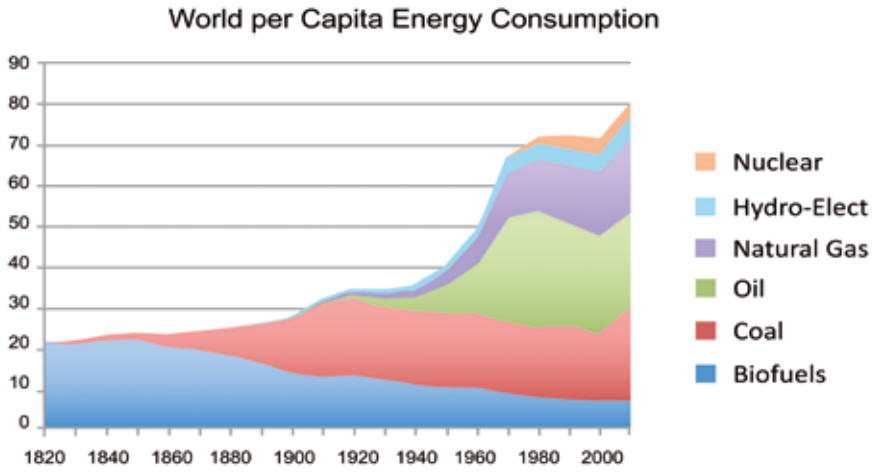

Figure 2.14. Evolution of per capita energy consumption since the Industrial Revolution. Source: Tverberg, Our finite World, licensed under CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/legalcode).

As the sustainability conundrum has not been tackled at its societal root but mostly from the environmental perspective, core societal and social dynamics affecting the role of energy indirectly in the sustainability transition have thus far suffered from a lack of investment and attention.

Without tackling the societal causes of that development, we will not attain a sustainable development for human societies on this planet!

2.6.2 FOOD (IN-) SECURITY

We are facing a potential crisis in the provision of water and food for the world population that could very easily trigger major conflicts as a result of climate change, for example in Africa where the major powers are currently buying up land suitable for cultivation. Recent increases in food prices due to speculation are early warning signs that food security is becoming a worldwide concern. Figure 2.15 shows how, worldwide, food prices came under pressure because of one political act (stimulus of vegetal ethanol production) in one of the countries that exports a very large quantity of food (the US). It immediately led to food riots in Mexico! That tension is likely to grow further with the increase in global population and the demand of more and more non-vegetal foods. Currently we see that traditionally food exporting countries are beginning to import substantive quantities of food. The topic is of major concern, both scientifically and politically.

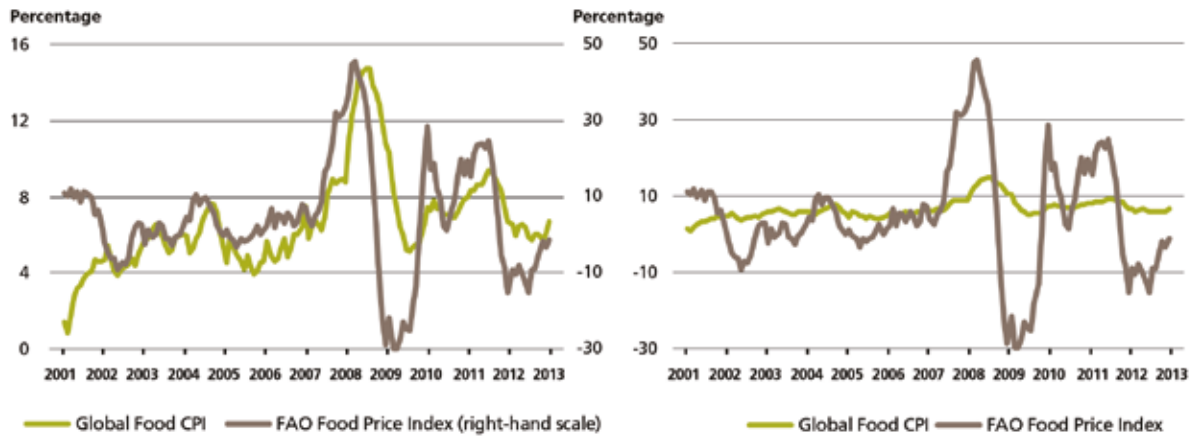

Figure 2.15. Food prices have recently spiked as a result of speculation and ethanol production to partly replace fossil fuel. Source: FAO (2017).

2.7 CONCLUSION: NON-LINEAR INTERACTIONS

We have highlighted a selection of domains in societal dynamics where there are substantive chances for quantum non-linear change. The selection is of course arbitrary. We could have taken different themes and looked at them from different perspectives. They all concern the current or near-future state of long-term trends that are the cumulative result of earlier events and processes. But underlying, long-term path-dependent second-order dynamics are the drivers behind the trends involved.

These are very deeply embedded in our societal structures, have many feedback and anticipation loops among themselves and will prove extremely difficult to change. Almost all of them individually have potential "tipping points" in their trajectories – non-linear change points that are due to the unanticipated consequences of earlier dynamics.

But that is not all. As mentioned at the beginning of this chapter, *the real danger for our societies is that a collision between several such non-linear tipping points will generate colossal disruptions, leading to a period of global chaos in all areas of human activity. Accelerated by rapid technological change, such as the ICT revolution, this may well occur on much shorter timescales than the occurrence of eventual natural (climate-related) tipping points [...].*

This requires us to fundamentally change our perspective in order to understand and deal with the societal and socio-environmental dynamics involved. *We need to view them in their full complexity.* Our introduction of a long-term perspective shows that history matters – and that it is shaped by human decisions and events. At any time in the past (and the present), there were options among the directions that system dynamics could take. Some of these were adopted, others were not. Which trajectories were instantiated depended on a highly complex, multidimensional set of interactions between both societal and natural dynamics operating at different spatial and temporal scales (from the millennial to the instantaneous). Such interactions created, for different domains and different societies, path-dependent evolutions, in which the options the system adopted at any point co-determined later outcomes. The present-day manifestations of these path-dependent evolutions are the different cultures, technologies, institutions and values that we observe on the planet. One conclusion of this section is therefore that there are no 'planetary' solutions to the current sustainability conundrum – different societies will have to develop different ways forward. *There is no universal 2030 or 2050 tool box that fits all!*

The different dynamics involved can for long periods remain unobserved, then suddenly lead to unanticipated interactions among each other that rapidly change the structure of a system ('tipping points'). It seems to us that we are currently in an epoch where this is happening at a global scale, so that we are faced with a situation in which approaches that seemed thus far to enable us to understand and manage the various regional and local systems are no longer able to do so. We can no longer manage dynamics that, using our traditional perspective, are unmanageable. We can no longer hope to steer everything. Unanticipated consequences of earlier systemic actions are creating entirely novel, uncontrollable syndromes. In the face of these, the best we can do is to identify guardrails and to try and leverage dynamics so that they stay within bounds compatible with them. *We have to move from designing for control of system dynamics to designing for change in these dynamics!*

To do so, we have to open up our complete sets of societal norms, practices and values, all levels of our societal institutions, to fundamental change. *It is not only a question of our systems of societal and social-environmental governance, but also of our collective and individual 'truths', the nature of our social interactions, and (in short) everything we hold dear about our current way of life.* Many, if not all, among us will in one way or another resist that, and it will therefore be difficult to consciously achieve at a societal scale. But as we can observe already in many instances in the last decade or so, the emerging changes wrought by the information revolution will, willy-nilly, force us to adopt novel values, norms and behaviors. That process is driven bottom-up, as people adapt to the new technologies involved. It cannot be driven towards a particular set of goals or values. *Rather than attempt to do that, we will (have to) adapt our values and goals to the uncontrolled and uncontrollable dynamics involved!* Although that may seem very challenging, our long-term perspective points to the fact that humans have done exactly that under a range of different circumstances in the past. It is one of the characteristics of human beings that has enabled them to become the dominant species on Earth. But generally, they have not really done so until they were in a '*force majeure*' situation.

TURNING THE TIDE

Above we have introduced a number of long-term trends in current global societal dynamics, and how they might be impacted and accelerated by the current ICT revolution. We have concluded that the real danger is in the non-linear interactions between a number of these dynamics. We have then reasoned that any attempts to deal with these different dynamics individually will be insufficient in view of the intimate embeddedness of the various dynamics that are acting upon our societies and their environments. Instead, *we argue for a holistic approach to the sustainability conundrum and to the SDGs that emphasizes the many different dynamic relationships between dynamics that are usually considered singly or in pairs.* Now we need to turn our attention to what can, and should, be done to inflect current trends.

The challenges that we have presented so far prompt choices from among the following:

1) Trying to stop the current trends by attacking the roots of much Western "progress-related" thinking and the market-based system that it has generated, including the idea that technology will continue to progress in the direction it has taken in information technology, genetics and related fields.

2) Admitting that a de-growth scenario is at least for the moment impossible, and instead trying to mitigate the consequences or our current dynamics. That is what the carbon dioxide (CO_2) mitigation efforts are all about, and raises the question whether we could extend the same approach to other domains and what that would take, scientifically, politically and economically?

3) Try and reduce the vulnerability of different subsets of the overall societal dynamics by taking structural measures that constrain their envisioned negative consequences. One could describe that as placing guardrails along the trajectories of these dynamics, while searching for pathways to reach the SDGs (combining forward-looking and backcasting).

4) Move towards one or more scenarios that are rooted in an alternative, more stable and more sustainable vision of the future by trying to fundamentally change the mindsets that drive the current dynamic, and re-build our global societal systems based on such novel mindsets, values, goals and institutions.

Option 1) is difficult to achieve in view of the trends we have already set in motion. We are currently seeing, globally, in the Earth system community a distinct move towards option 2), supporting political efforts such as the protection of the oceans and the arctic, as well as civic initiatives such as that of the Transition Towns movement. That effort should evidently be continued, but it seems to be insufficient *from the perspective of the societal dynamics that are driving us currently.* The TWI2050 initiative is committed to achieving option 4) by back-casting from the TWI2050 normative goal rooted in the aspirations of the SDGs. The approaches to deliver option 4) are however still being developed and that is why we think for the time being investing simultaneously in options 3) and 4) is the most suitable way forward.

[...]

CONCLUSION: DESIGNING FOR CHANGE

The main conclusions to be drawn from this chapter can be summarized as follows:

- Our current global society has come close to a tipping point in its long-term evolution. Patterns that have been established many years - in some cases centuries - ago have almost imperceptibly led to a conundrum that has our current societies in its grip. The degradation of the natural environment is but one aspect of this, albeit a very perceptible one. Other dimensions of this evolution, here called 'mega-trends', touch on our international diplomatic order, our democratic form of government, the societal and economic health of our communities, our values, etc.
- These mega-trends are currently accelerating very rapidly as a consequence of the ICT revolution, which is likely to change many aspects of our relationships with space and time, our experience of the natural and societal realms in which we function as human beings, our social organization, etc. Because we are only at the beginning of this development, it is difficult to get a sense of where how this development will play out, but an important period of relative chaos is certain.
- Our reductionist, fragmented approach to science is partly responsible for the fact that many relationships between these trends have not been observed. In particular, we need to develop a better integrated perspective on the world around us, which strives to be holistic, bridging the many gaps between current disciplines and sectors, including the SDGs. That perspective should focus on *learning from the past, about the present, and for the future!*

The particular societal dynamic in which we have been involved, globally, over the last few centuries has, in its extreme form, led to the production-to-waste dynamic that governs many present-day societies. Without tackling the core of that dynamic, sustainability cannot be achieved. Technological or other solutions to specific challenges in particular domains will not suffice. That core is the societal dynamic that drives human interactions with the environment. After all, humans define what they consider their environments by selecting aspects of that environment that they become conscious of, and many others which they ignore. On that basis, they define the environmental challenges they perceive, and the "solutions" that they conceive to deal with them. Thus, all issues concerning the environment are dealt with within society itself. There is no direct communication with the environment, only (self-referential) communication *within* society *about* the environment (Luhmann, 1989).

Hence, the dominant approach to socio-environmental matters, for historical reasons, has focused on their societal dimensions *from the outside* – from the perspective of the environment. It has thus focused predominantly on the symptoms of the current conundrum, rather than its causes, on the relationships humans have had with their environment, rather than on the drivers that have pushed societies into the current particular forms of production-to-waste relationships with the Earth system.

Another core lesson from this chapter is that rather than change course when circumstances (whether social or environmental) force us to do so, we have to anticipate the need for change in all we design or decide. Hence the title of this conclusion: designing for change. The developments that our societies have set in motion with the Industrial Revolution have so accelerated change that we can no longer be content to be re-active to what is going on around us in the global socio-environmental Earth system. Instead, we have to anticipate and be continuously interactive with all other elements of the system we are a part of.

Thus far, we have as human societies mainly related to linear projections from the past and present into the future. This is no longer sufficient: the global system we are part of is fundamentally a complex system with many different nonlinearities which, over time, create tipping points and unanticipated consequences of human decisions and actions. Its complexity exceeds our capacities to understand or deal with it. But we can (and must) do better than we have up to now.

Part of achieving that is developing a high-dimensional holistic perspective that stretches our minds across the interactions that are likely to occur between phenomena and dynamics in specific domains. That perspective should replace society at the core of its concerns, rather than the economy. It also requires much more frequent and in-depth reflexivity on all processes in society, so that course corrections can be implemented. Third, it implies the development of our capacity to understand our relationship with the future, to accept the need for anticipation and long-term planning, and the need for a priori evaluation of potential unintended consequences of our decisions and actions.

To achieve these goals, it seems imperative that we adopt a complex adaptive systems approach to sustainability issues. Looking at societal processes bottom-up, identifying the behavior of individuals and all the different groups and networks that constitute societies will give us a very different perspective on the dynamics driving us in an unsustainable direction, and will thus facilitate designing different trajectories to achieve our goals. The ICT revolution is on the brink of enabling us to so, as the combination of 'Big Data', High-Performance Computing, the Cloud and ML together enable us to move away from the traditional social science approach based on polls

of a very limited number of people (a few 1000's or 10,000's out of populations of millions or more) followed by generalizing extrapolation onto whole populations. We will be able to analyze the attitudes and dynamics of each of the individuals in populations of millions directly, as is already to some extent done for major elections on the basis of the thousands of data-points about every individual that have been collected by certain companies. That in turn, using network analytics will enable us to trace the emergence of new ideas, attitudes and interaction networks between very large numbers of individuals.

But we are currently not there yet. Let us see what can be done with the tools that we currently have at our disposal!

1. SUSTAINABILITY IS A SOCIETAL ISSUE

For many years sustainability issues were principally the domain of the natural and life sciences. Now they are studied as socio-environmental system dynamics in order to mitigate the consequences of human behavior, rather than studying how to change that behavior itself. We must finally acknowledge that *the real sustainability challenge is societal, not environmental.*

Societies define and shape what they consider their environments, what they see as the main challenges in those environments, and what kind of solutions they can try and offer. Hence, *placing society at the center of the sustainability debate* is the next quantum jump to develop in our thinking.

Over long-term time, the many human societies on Earth have developed different ways to interact with their environments, through a co-evolution between perceptions, ideas, values, institutions and ways. We must investigate these at the global level as well as at that of the cultures involved.

2. THE IMPORTANCE OF THE LONG TERM

Most current sustainability research is confined to the study of the last couple of centuries. This is insufficient because in doing so we cannot understand three different aspects of the complex processes involved:

- The slow, millennial, societal and natural dynamics against which the faster, shorter-term dynamics play out – tectonics and deep cultural evolutions for example. These are not easily noticeable at shorter timescales, but can play important roles;
- The full range of system states that socio-environmental dynamics can assume – there may have been such states in the past that could be useful to understand in the present. Biological agriculture, for example, harks back to farming before the invention of chemical fertilizers and pesticides;
- Second order changes (changes in the way change proceeds) that reveal important dynamics that often play out very slowly, at deep levels, and change the dynamics driving shorter-term processes.

Moreover, such a short-term approach looks at the current, highly disturbed state of the socio-environmental system without understanding other, less disturbed ones. It is as if one would be trying to heal a very ill patient without knowing what a healthy person looked like.

3. THE SECTORIAL APPROACH IS NOT GETTING US ANY FURTHER.

By studying the dynamics of individual sectors of our terrestrial life-support systems (water, biodiversity, food security, climate, energy etc.) we cannot take the many connections between these subsystems (and others) fully into account, thus missing crucial interactions. Well-nigh thirty years of research have enabled us to know the sectorial dynamics of such domains rather well, but have not brought us much closer to understanding the ways in which they are connected. *We need to adopt a holistic approach to reach the next level of understanding of the very complex socio-environmental dynamics that have driven us into the current sustainability conundrum.* This goes against a long-standing tradition of western thinking that isolates parts of a whole, studies them in detail and then assumes that by bringing them together we gain a perspective on that whole. Thus we distinguish between nature and society, as well between scholarly disciplines. Those distinctions shape many of our practical decisions about the environment, as well as our research.

In practice, however, the whole is more than the sum of its parts. T*o truly understand the dynamics involved holistically, we must achieve intellectual fusion between disciplinary ways of thinking*, and that is hampered by our education as well as our career- and science funding structures.

4. TO THINK ABOUT OUR FUTURE, WE NEED TO USE A COMPLEX ADAPTIVE SYSTEMS APPROACH

Rather than be reactive to the dynamics driving us towards unsustainability, we have to become pro-active and begin to design for change. That implies learning from the past about the present (as we currently do) ***for the future*** (which we don't usually do). Our western science originally developed to explain the present by systematically proving its theories and ideas, which one cannot do for the future. Thinking about the future was therefore not conducive to one's scientific career.

The Complex Adaptive Systems approach responds to this need in that it assumes that all systems are complex, that "Occam's razor" (always opting for the simplest theory) is not helpful, and that instead of focusing (ex post) on the origins of dynamics, we must *(ex ante) study the emergence of novelty, acknowledging the fact that multiple futures can emerge at any point in a system's trajectory.*

5. THE ICT REVOLUTION IS ACCELERATING MANY ONGOING TRENDS

Currenty, the acceleration of the Information and Communication Technologies (ICT) is rapidly accelerating a number of societal trends that have begun long before this latest technological revolution. Among these are:

- The desintegration of the rules that govern the interaction between (nation-) states;
- The underming of the structure of our representative democracatic systems;
- The destruction of communities based on solidarity, particularly in urban contexts;
- The loss of control over information processing that led to a relative convergence of societies around basic norms and values;
- The reduction of the dimensionality of our experience through television, film and computer gaming.

Together, these trends are affecting the very basis of our current social structures and insitutions. They will produce major societal tipping points once they start interacting more closely, and this might very probably happen before 2030 or 2050, thus putting in jeopardy our chances of achieving the SDGs.

6. EXCEEDING PLANETARY BOUNDARIES IS DESTABILIZING OUR ENVIRONMENT

All this must be seen in light of the environmental tipping points that will result from current developments in climate, biodiversity, pollution of land and sea, saturation of the environment by certain chamicals, etc. The interaction between these ongoing natural processes may well cause major environmental tipping points alongside the societal ones mentioned under point 5, either before or after 2050. Such a conjunction of societal and environmental tipping points on a global scale is unheard of in human history, and may well lead to a period of chaotic system behavior, in which the current symbiosis between humans and their natural environments is profoundly distorted, societies will lose their current structure and people will be at a loss on how to proceed. The threat of societal instability makes the search for staying within environmental boundaries only more urgent and important.

7. FROM HERE TO THE FUTURE AND BACK, OR THE INVERSE?

To project into the future is, of course, fraught with difficulties. It can be done in two ways. Either one extrapolates from the present to the future, or one determines what kind of future is plausible and desirable and then constructs a roadmap from the present to the desired future. In the former case, the resultant futures are constrained by present-day thinking and existing trends, while the second approach does enable us to conceive "out-of-the-box" futures, but it is more difficult to see how these could be realized.

We must link these two ways of conceiving our future. On the one hand, we should project a fundamentally different (sustainable) future, to be implemented differentially across countries, while on the other we must assume some form of "progress" from the present to that future or futures. This dilemma requires that one 'sails between Scylla and Charybdis', following a very narrow set of paths. The methodology for such a way forward is in many ways still to be developed, so that we can take the possibility of fundamental changes in our socio-economic and environmental conditions into account. Our models are an attempt at moving forward in that domain.

8. WE NEED TO KNOW MUCH MORE ABOUT HUMAN PERCEPTION, COGNITION AND DECISION-MAKING

These topics have thus far remained outside the core of the sustainability sciences, yet they are essential in understanding and where possible predicting how the system (or parts of it) might behave. There are a number of major potential choices coming up if we are to attain a sustainable environment, such as "What role to accord to future technologies?", "How to improve the global governance system to avoid major tipping points?", etc. But there are also, in daily life, myriad decsions that cumulatively impact on the overall trajectory of our Earth system. So in both (and other) instances it is of great importance to understand biological or societal dynamics that might impact on decisions taken.

Any and all of these decision also have unintended consequences, and improving our capacity to look for these and evaluate decisions against the options that we open at the time but were not chosen, is another domain that, if better understood, could contribute to improving our chances for a sustainable long-term socio-environmental system.

Many of our societies are now at a tipping point where they can step up the pace of transition towards implementing the 2030 Agenda and the Paris Agreement. This tipping point situation is characterized by three major bifurcations: The transformation towards sustainability, nationalist counter-transformations and the far-reaching dynamics of the digital transformation.

References

For references please refer to TWI 2050 publication: "Transformations to Achieve the Sustainable Development Goals". The above text is an excerpt from this publication.

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