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Introduction

In this very tentative paper we address the relationship between economic growth and sustainable development from a specific perspective. We give full attention to the potential of a strategy that mobilizes knowledge, learning and innovation to approach 'sustainable development'. In recent contributions it has been pointed out that these same factors have been at the origin of the current unsustainability itself (Sanders 2012, p.6). Inventions and innovations making possible more intensive and extensive use of both renewable and non-renewable natural resources have been prerequisites for population growth and for making the world economy as non-sustainable as it has become.

But in spite of this observation, which we do accept, it is difficult to envisage any successful strategy for environmental survival that does not make full use of knowledge and innovation. We will not argue that a more knowledge-based and innovation-driven development, by itself, will take us in the right direction. But we will argue that with a directed effort toward resource economy the mobilization of knowledge and innovation is a prerequisite for success. Therefore the struggle is not for or against advancing knowledge and stimulating innovation but rather a struggle about giving new directions for innovation and learning.

A second major point is that 'institutions matter'. We cannot envisage any change in the direction of sustainability without 'radical institutional change'. We will discuss a series of minor reforms and policy changes including 'nudging'. But we recognize that the required changes may need to go as far as challenging the current version of capitalism as well as the predominant governance system. The current system of global governance where nation states focus their policy efforts upon national growth and upon safeguarding the international competitiveness of domestic firms is not compatible with moving in the new directions. Neither is the current dominant status of a profit driven and privately controlled financial sector organized at the national

level but operating globally. In the new governance mode market mechanisms and competition must be used to reduce the need for detailed planning and regulation. But their functioning will need to become much more restricted by regulations. And increasingly such regulation must become agreed upon at the global level.

Defining the problem

When discussing whether long term economic growth should be restricted, or even stopped, because of its negative environmental impacts it is necessary to define what economic growth is. There is no single correct way either to define or to measure economic growth. There are certain conventions that have been agreed upon through the UN system and those conventions are not always sensible and meaningful, especially not if one wants a close correlation between economic growth and growth in welfare, well-being and living standards. But they are generally used and without accepting some set of conventions we can't even state the problem. So in what follows we will use a definition and assume a measurement method that corresponds to the conventions and measurement practices used at national statistical offices. We assume that total real production Y is measured as GNP in constant prices. So the question that we will ask is if it is possible to maintain a growth in GDP compatible with long term environmental sustainability.

When we ask the question if long run growth in GDP is compatible with environmental sustainability it is of course necessary to have a reasonably clear conceptualization of what we mean by sustainability. Environmental sustainability is a multidimensional concept. It includes at least the following aspects:

Pollution of water and air

Resource exhaustion

Global warming

Loss of "carrying capacity" and "resilience" of ecosystems

Loss of recreational and esthetical values connected to natural and cultural landscapes (amenities)[1]

What is a tolerable development in these dimensions is not easy to define. It is a relative concept that is elastic and continuously changing over time.[2] It also depends on our knowledge about how the environment reacts on different impacts from economic activities. One might consider to set the level on the basis of what our own generation of decision makers define as 'tolerable' – this corresponds to how Myrdal defines dominating values ("the modernization ideals") in the 'Asian Drama'. Alternatively it might be set by assemblies of 'enlightened' citizens who have got access to a reasonable amount of knowledge about risks and opportunities.

We need to specify the time span of the analysis. Taking the very long view it may be argued that the laws of thermodynamics will bring the human existence on the planet to an end at some point whatever we do. This is not very helpful. We should, however, think at least a couple of generations ahead. Global warming is an example where radical action now is a prerequisite for avoiding sufferings already for the next couple of generations. How much weight we give to the interests of future generations will be reflected in the discount rates we use when discussing green investments.

We also need to specify the unit of analysis in geographical space. Some of the sustainability issues such as desertification and deforestation will require local action. Cities are important units of analysis and potential collective actors. The strongest set of policy instruments and foras for debate are at the national level instruments and national action, including the readiness to give up national sovereignty, will in the short to medium term be decisive for developing new green strategies. But enhancing national performance may not lead to acceptable global outcomes. One country may reduce its footprints dramatically by getting rid of certain polluting activities in such a

[1] The problem lies not only in these dimensions in their own respect. It becomes complicated by the interrelations between them. There are also discontinuities and irreversible changes in the set of future options. Examples are soil erosion, desertification, loss of groundwater reservoirs, and loss of biodiversity.

[2] There may be important differences across cultures that make global agreements on what is acceptable degrees of sustainability difficult to reach. In some cultures the original nature may be seen as something that should be protected. In other cultures the nature refined by man may be seen as more valuable and in yet others the technological control of nature is seen as natural.

way that they are just moved to another part of the world where the negative global impact becomes worse. The most obvious case is of course global warming.

In what follows we focus upon growth and sustainability at the world scale but we see it as reflecting different national patterns of development. As we shall see the predominance of national governance and the competition among nation states is one of the most serious hindrances for making growth less unsustainable and for slowing down global warming

On the complexity of growth

It is important to take some of the basic characteristics of economic growth on board from the beginning. The following five more or less interrelated "stylized facts" are useful to keep the complex nature of the notion of economic growth in mind and avoid simplified views and conclusions.

First, economic growth is a synthetic and aggregated measure of very different economic activities. Furthermore, the growth rate depends on a number of accounting conventions about what to include and exclude. For example, measures only include activities in the formal sector, which means that comparisons between countries at different levels of income are difficult and that the measures change with changes in the demarcation line between the formal and informal sector.

Second, economic growth is always connected to structural change. The empirical record is clear on this point. In economic growth the economy always expands in some sectors while other sectors stagnate (Kuznets 1971). Outside growth models there is no such thing as balanced growth where everything grows with the same rate. In the long run economic growth is always a process of technological, organizational and institutional transformation and, hence, of structural change.

Third, economic growth is not a normal or natural condition. This is the classical economists' view: increase is natural and will occur wherever opportunity and scarcity exists. Remove the obstacle and growth will take care of itself. As observed by Landes (1998): "Growth and development call for enterprise and enterprise is not to be taken for granted." Similarly, discussing the dynamics of cities Peter Hall (1998) observes that innovative bursts of growth are rare phenomena: "What makes a particular city, at a particular time, suddenly become immensely creative,

exceptionally innovative? Why should this spirit flower for a few years, generally a decade or two at the most, and then disappear as suddenly as it came?" In short: growth is not a basic, default state of the economy. It has to be understood and dealt with in its unique, specific, historic and context dependent forms.

Fourth, economic growth is connected to institutions and institutional change. It has never been controversial to state that economic growth depends on technological change. It has been less obvious that institutions play an equally basic role in economic growth as technologies do. Classical economists (especially Karl Marx) realized this. Institutional economists like Veblen, Commons, Myrdal, Polanyi, etc. regarded it as decisive and, lately, institutions have again been elevated to a crucially important role. Such ideas about the supremacy of institutions may be too vague to be really useful but if we focus on the institutions that form the learning capabilities of individuals and organizations it is clear that a connection between institutions on one hand and growth and development on the other hand may be regarded as a "stylized fact". Building institutions that promote 'green learning' is therefore a major challenge.

Fifth, economic growth is difficult, maybe impossible, to plan or control in a capitalist economy. The key instrument of competition in the capitalist economic process is new knowledge. As a consequence the economic process becomes a learning process - experimental, searching and groping. Such processes may be triggered by and given direction by political decisions but outcomes can't be known and planned in advance. This is true also for political attempts to move the economy toward sustainability. The centrally planned economy may have a greater capacity to steer the direction of change but historical examples illustrate that it might be at the cost of learning and innovation. And so far their capacity to move growth toward sustainable trajectories have been all but impressive.

What does it mean to slow down growth?

It follows from the stylized facts above that there is no automatic causality from growth to the sustainability of the world. Seen from a purely technical perspective one can construct scenarios where technical and structural change take forms that reduce the ecological footprint over time while the economy keeps growing. To illustrate this point we will start by stating the problem in very simple terms.

Total production will reflect number of working hours and production per hour (Q). Number of working hours will reflect number of employed (L) and average number of working hours per employed (T).

$$Y=L \times T \times Q \qquad (1)$$

Aggregate economic growth measured as percentage per annum (y) can thus (as approximation) be broken down in annual percentage growth in numbers of employed (l), growth in working hours per employed (t) and growth in output per working hour (q).

$$y=l+t+q \qquad (2)$$

This disaggregation of aggregate growth is useful when it comes to the discussion of what it implies for respectively employment and working hours to reduce or nullify the rate of economic growth. It is useful also because it may help to capture very different types of changes adding to aggregate economic growth at the world level. While mature economies in the OECD area will be characterized by moderate trend change in the total labor force operating in the formal sector this may not be the case countries in Africa and in India where more than half the population are active in the unmeasured informal sector and where the proportion has been growing.

Breaking down L, Y and Q in respectively formal and informal part may be necessary to capture the character of global growth and its impact upon sustainability. The mechanisms linking growth to environmental sustainability may be very different if we focus upon growth reflecting increases in labor productivity in a mature economy or if we focus upon the activities of informal sector workers or upon their integration into the formal sector.

Reducing working hours (T) and reducing the supply of labor (N) by for instance being more generous to old people, to parents with small children and to handicapped

would reduce growth in the rich countries and it may be argued that it would be affordable for the population in these countries. But currently the opposite strategy is on the political agenda. The current emphasis on increasing the supply of labor in the North of Europe is motivated by the competitiveness of the national economy a problematic perspective that we shall come back to later.[3]

A less attractive method to slow down growth would be to leave people who want to work, including the young generation, jobless. The fear of this kind of involuntary 'ecological unemployment' is sometimes exploited by sectoral capitalist organizations to organize opposition against taxes on specific polluting industries and sometimes with support from trade unions. In such situations it is important to point out that unemployed could be absorbed in green jobs, for instance by offering jobs in the recycling sectors.

In the less developed countries a transfer of workers from the informal to the formal sector may be seen as prerequisite for long term social sustainability. Understanding how this kind of transfer can take place without worsening the ecological foot-print is a major challenge for research and for policy makers. It is important to note that informal sector activities may have significant negative impact upon the environment (deforestation and desertification). In such cases the impact of the transfer may go in different more or less green directions.

Environmental impact.

What is the induced impact on environment of economic growth? To make it simple we and for illustrative purposes we will focus upon one environmental dimension at the time – it could be the use of one specific non-renewable scarce resource or the emission CO2.[4] For a given volume of production (Y) we assume a quantity of this resource (R) to be used. We can then define resource productivity as:

$$Y/R=A \qquad (3)$$

[3] One of the most obvious paradoxes and failures of the European project that reflects the strength of the national perspective on public policy is that the focus of national economic policy in the North of Europe is now strongly on increasing the supply of domestic labor while the unemployment in the South of Europe has reached record levels.

[4] See footnote 1 for caveats.

We define the growth in R as r, the growth in Y as y and the growth in resource productivity as a. The difference between the rate of growth in production and the growth of resource use is crucial. We can identify three alternative environmental paths:

$a>0$

$a=0$

$a<0$

One obvious objective for a green strategy is to increase resource productivity ($a>0$). The more ambitious strategy would be to actually reduce resource use per period of time in absolute terms over time ($r<0$).[5]

$$r=y-a \qquad (4)$$

may be rewritten as

$$r=n+t+q-a \qquad (5)$$

$r<0$ implies that

$$n+t+q<a \qquad (6)$$

Let us first assume that we refer to a mature economy where resource use per capita is very big. In such an economy the employment volume and the normal working hours per employee may be assumed to remain constant. In this case it is a requirement for a gradual reduction of resource use per time period that resource productivity grows at a higher rate than labor productivity.

$$a>q \qquad (7)$$

Since 2000 labour productivity has been stagnating in many of the mature economies – q has been growing with less than 1-3% per annum. Is it possible to reach a growth

[5] In some cases the requirement is to reduce the use of a specific resource (carbon) with high rates in order to avoid ecological crisis (global warming).

in resource productivity that is higher than 3% per annum? The answer is of course different for different resources.

One reason for optimism could be that for historical reasons the dominating technical trajectory has been to develop systems that increase labor productivity while much less attention has been given to the increase resource productivity. But to change the attention will require strong and clear incentives in terms of taxes, rationing and sanctions of resource abuse. A successful strategy would result in new patterns of investments that are resource saving rather than labor saving.

Ecological economists such as Sanders (2012) are skeptical to this kind of reasoning and he rightly points to the fact that increasing resource productivity will lower the price and this might through substitution and income effects actually increase the use of the resource so that we end up with a situation where:

$$a<q \qquad (8)$$

This implies that incentives need to be continuously adapted and be made stronger over time to counter such effects. Sanders adds the argument that it will be increasingly difficult to attain high rates of growth in resource productivity because of diminishing returns. This might be the case for some resources although the opposite may also be the case. Moving toward more sustainable solutions may involve virtuous circles. It took quite a while before the historical secular growth in labor productivity ran into diminishing returns.

But of course there are limits for how far problems can be solved by increasing resource productivity. It is obvious that in the very long run any non-renewable resource will be used up if the R is not brought down to zero. The time frame of the analysis is obviously important. This has been a problematic issue to handle in the limits to growth discussions we will show in the next section.

The IPAT formulation.

Another way to formulate the trade off between growth and development takes departure from the well-known “Ehrlich equation”. This equation comes in several versions and has influenced much of the growth-environment debate. The most common formulation is simply called “the IPAT equation”:

I=PAT (9)

I=Environmental impact;

P=Population;

A= Affluence;

T=Technology;

The environmental impact of human activities (i.e. human production and consumption in broad sense including formal as well as informal sectors) is the product of the size of the population, its prosperity (which corresponds to aggregate income per capita in the section above) and the technology used.

There has been much discussion about which of the three factors (P, A and T) that matters most. Ehrlich and Holdren (1972) have underlined population growth as the basic and most serious problem, while Commoner (1972) has put the blame almost exclusively on the specific kinds of technological development that has accompanied economic growth, especially after World War II, affecting ecosystem structure and functioning. Examples are detergent phosphate, fertilizer nitrogen, synthetic pesticides and tetraethyl lead. Already in the 1970s there was a fierce discussion between Ehrlich and Holdren on the one side and Commoner on the other. The discussion revealed, amongst other things, both the importance of avoiding ambiguity in the definitions of the variables and the necessity to take interactions between them on board. *Furthermore, it became clear that if technical change has the power to increase negative environmental impacts it also has the power to do the opposite*.

It is mainly biologists and ecologists that use the IPAT equation. But since the root of the problems is not nature but human behavior in natural and social settings several reformulations of the "master equation in industrial ecology", as it is sometimes called, have been proposed. This may be done in many ways of course, some more helpful than others. [6]

[6] $I=aP^bA^cT^de$; (e is an error term) which has been suggested by Deitz and Rosa (1994, 97, 98) may ring some bells for economists but doesn't really increase our understanding.

IPAT and its reformulations have functioned as catalysts for much of the literature and debate on environmental/ecological problems. In all their simplicity they put the limitation of our choices into focus. Furthermore, since the possibilities to control and significantly limit both the population growth and the seemingly permanent quest for increasing production and consumption are seriously circumscribed the only remotely possible way to address the environmental problems seems to lie in new technology. However, such "technological" solutions require *major changes* in the character and direction of technical change. The question if such radical changes are realistic, if at all possible, has also become a recurring theme in the debate as reflected in the notion of "Factor X": "How many times is it possible for the amount of wealth extracted from one unit of natural resources (the resource productivity) to increase within a certain time span as a result of technological improvements and is this sufficient for sustainable development?" Or what is the realistic sustained rate of growth of resource productivity growth (=a).

Ecological economics approaches to limits to growth.

The IPAT formulation of environmental/ecological restrictions on economic process has a Malthusian ring. Some things (population and affluence) have an inherent tendency to expand beyond quite inelastic limits (i.e. there are limits to how much "impact" the environment can absorb and this spells catastrophe, sooner or later). Constraints on economic activity set by Nature have been a recurring topic from the birth of political economy as a scientific discipline. The Physiocrats regarded the productive power of land as the source of all economic value. Ricardo referred to the "original and indestructible powers of the soil" and the uneven quality of land as a productive factor was the basis for his theory of income distribution. More recently *Biophysical limits to growth* have been much discussed within the new discipline of "ecological economics".

Kenneth Boulding and Nicholas Georgescu-Roegen inspired much of this debate. Boulding's article "The Economics of the Coming Spaceship Earth" (1966) first put the question on the agenda and his reformulation of the process of production as an evolutionary interaction between energy, materials and knowledge (Boulding 1978, 1981) was seminal for the whole approach. For the discussion of the distribution of income and wealth in the short and medium term it may be adequate to regard

production as resulting from combinations of labor and capital, he argued. In order to understand societies long run opportunities, however, the focus must be on energy, materials and knowledge. The crucial factor is the evolution of knowledge. But production of goods or services can never be totally decoupled from energy and materials and how we handle the inescapable dependence of production on energy and materials determines our future.

Box: Energy, materials and knowledge and three kinds of scarcity

At the very core of economic theory we find the issue of more or less efficient allocation of *scarce* resources. Sanders (2012) argues that one reason why economics and economists cannot deal with sustainability is that the kind of scarcity that they operate with is relative rather than absolute. Markets cannot allocate non renewable resources. In our own work we have argued that standard economics has a problem with dealing with knowledge since knowledge is a resource that is enhanced by use. When people use their skills these skills are further developed.

At a general level this opens up for the possibility that human learning can be mobilized to overcome the absolute scarcity of non-renewable resources. But it would require a society and institutional set up where learning is both intensified and given a clear direction. We do not see the current version of capitalism as offering such a set-up.

Boulding emphasized that human behavior is embedded in a larger interconnected system. To understand the consequences of our behavior, economic or otherwise, we must first develop a scientific understanding of the "ecodynamics" of the general system, the global society in which we live, in its material as well as non-material dimensions. For all practical purposes the Earth is a closed ecological system and our future depends on if we can develop an economic and social system with a "throughput" of matter and energy that respects the ecological limits. With a slight reformulation of Boulding we can say that this is the ultimate challenge for the learning economy.

Boulding didn't believe that "exponential growth in a limited world " is possible, but

he was not very clear about how and when the limits would materialize. Georgescu-Roegen (1971) was more outspokenly pessimistic. He discussed the constraints to the economic process from a thermodynamic perspective: "The entropic nature of the economic process". Georgescu-Roegen argued that the economic process inevitably transforms valuable natural resources (low entropy) into waste (high entropy). The universe is moving irreversibly from relatively ordered states to the chaotic outcome of maximum disorder or entropy. Low entropy is scarce, energy is a limiting factor to the economic process and society is anchored to a material base with distinct constraints and it evolves in a unidirectional irreversible way. The natural constraints on the economic process can't forever be solved by technological means. The laws of thermodynamics imply limits to the substitution of physical capital for natural capital. In the long run they are complements because physical capital requires materials and energy for its production and maintenance.

In continuance of the discussion of biophysical limits to growth the question of the uncertainty about the environmental effects of economic activity has been raised (Constanza et al. 1997). These uncertainties are increasing for example in the wake of climate change, which also leads to additional irreversible damages to ecosystems. Climate change was not yet on the agenda when Boulding and Georgescu-Roegen formulated their warnings, but it seems clear that this development only makes the questions they raised more pertinent.

Limits to limiting growth.

From a pragmatic point of view it is clear that even if the limits imposed by the entropy law only will severely restrict the economic process in the very long run there are good reasons to act already now since the signals sent by global warming, climate change, ongoing resource depletion, damaged ecosystems, desertification, smog in high-growth regions, etc. already are serious enough. There are good reasons to put environmentally motivated restrictions on the economic process, some of which will limit economic growth as it is conceptualized and measured today.

This will not come by itself and it will not be straight forward. As Georgescu-Roegen (1975) puts it: "But anyone who believes that he can draw a blueprint for the ecological salvation of the human species does not understand the nature of evolution, or even of history -- which is that of permanent struggle in continuously novel forms,

not that of a predictable, controllable physico-chemical process, such as boiling an egg or launching a rocket to the moon."

Unwanted and unplanned reductions of economic growth don't effectively solve environmental problems, which otherwise could serve as a comfort in the current troubled times. It does not remove or reverse environmental damages already done, and it doesn't necessarily prevent current rates of environmental destruction from continuing more or less unabated (see box below). Moreover, decision-makers often react to reduced economic growth in ways, which hurt the environment rather than help it. Investments in cleaner technologies are postponed, cheaper and more polluting fuels are substituted for cleaner more expensive ones, etc.

Box: The crisis has not helped reducing CO2 emissions and global warming

In the annual environmental performance report it is demonstrated that the carbon This year's Climate Change Performance Index (CCPI) shows some interesting and worrying results:

■ In 2010, the most recent data period for this year's CCPI, the world saw another record breaking increase in global CO2 emissions. Not only have global emissions risen to another all time high, but this increase has also been the steepest emissions surge in history.

■ Not only are emissions rising at the global level. As well at the national level is little good news to tell. Not one of the examined countries has managed to change to a development path that is compatible with limiting global warming substantially below 2 °C. No country's effort is deemed sufficient to prevent dangerous climate change. Therefore, as in the years before, we still cannot award any country with 1st, 2nd or 3rd place.

Another problem is that economic welfare theory has supported a kind of market-ideology based resistance to all serious environmental policy measures except the ones within the 'market failure' approach. Many people oppose or give low priority to the radical measures that are needed to deal with climate change. Hence such measures are Pareto suboptimal. If the measures are so radical that it is unlikely that

we can compensate the losers according to Kaldor –Hicks principles than we should abstain from action. Welfare theory actually forbids us to counteract serious ecological threats. Hence, to be successful, any government committed to the protection of the natural environment must campaign on the basis of moral imperatives and not rely on self-interest and calculus of pecuniary costs and benefits (Hodgson 2012).

But governments themselves are too much focused upon the short term. This is illustrated by the high discount rates used when assessing the usefulness of public investments. In many countries governments operate with discount rates are set at 5-6% and that result in neglect of the long terms needs for sustainability. In an economic situation with big reserves of unemployed labour a lower discount rate would be a way to create green jobs both in the short and the long run.

As Scitovsky (1980) has pointed out, capitalism works best when it is flexible. Its capacity to generate technical and organizational change has been its main advantage, politically as well as economically. It has scored much worse on matters of equity. The experimental character of capitalism connected to its incentive structure and decentralized decision structure has allowed it to expand into new directions when stagnating in the former growth areas. The most important strength of capitalism is, thus, connected to economic growth.

This rather positive assessment of what capitalism has been able to attain needs to be confronted with the more recent experience of the financial crisis and its aftermaths. The extreme growth in the financial sector brought the mature economies into a process of 'negative growth' and neither production nor consumption have reached again the pre-crisis level. One paradox is that the outcome is a situation where the financial sector has strengthened its dominant position not only in the economy but also in relation to politics. Rather than reining in the financial institutions governments try to adjust their behavior to what they expect financial markets to accept. Hereby they can obtain low interest rates and attract capital.

One consequence of this accumulation mode dominated by financial capital is that income inequality has increased and that governments are afraid to attack the causes of growing inequality. The decoupling of finance from production has consequences for the sustainability of capitalist growth. While 'production focused' capitalism has

driven our economies toward unsustainable growth 'financial dominated' capitalism is even further away from the reality of natural resource. Here nature appears as figures on boards for commodity trade.

How important is growth?

One basic cause of growth lies in people's ability and willingness to engage in consumer learning. Even when basic needs for "comfort" become saturated consumers go on establishing new consumer wants. This is of course strongly stimulated by both direct and indirect sales efforts exposing consumers to what should be seen as model life styles. Consumers form new wants and habits when innovation activities of firms make it possible and it certainly makes policies for reduced growth difficult.

Economically as well as politically it is difficult to decouple the economy from growth. How important, then, is economic growth for our possibilities to live the lives we have reason to value? It is well known that economic growth is not the same as economic development and that there are many reasons why economic growth may not deliver the expected increases in human wellbeing. The "freedoms" discussed by Sen (1999), which deeply affect human well-being, i.e. political freedoms, economic facilities, social opportunities, transparency guarantees and protective security, do not automatically improve as a result of economic growth. Furthermore, the distribution of income, wealth and power doesn't seem to be positively affected by economic growth.

Empirical research shows that to a large extent people give higher priority to other values than the ones most clearly delivered by economic growth. In his book "Happiness" Layard sums a large amount of empirical research up in the following way: "So what really does affect us? Seven factors stand out: our family relationships, our financial situation, our work, our community and friends, our health, our personal freedom and our personal values. Except for health and income, they are all concerned with the quality of our relationships" (Layard 2005).

One of the researchers Layard refers to is Easterlin (1998). Commenting on the many new good and services that has been developed during the last two centuries Easterlin

asks if there is reason to think that some sort of saturation or culmination will occur: "The answer suggested by the evidence considered here is that economic growth does not raise a society to some ultimate state of plenty. Rather, the growth process itself engenders ever growing "needs" that lead it ever onward." (Easterlin 1998).

Another limitation of the ability of economic growth to deliver increasing well-being is put forward by Fred Hirsh (1976). According to him economic growth results in increasing positional competition both in areas where scarcity is social and material. A typical example of the first type is the competition for jobs in leading positions. People use more and more functionally unnecessary education to compete for a strictly limited number of jobs. Competition for a physically limited number of good spots to build recreational houses, driving prices higher and higher, is an example of the second type. Both cases are close to zero-sum situations. To the extent that economic growth is driven by positional competition the positive welfare effects will be very limited.

There are, thus, a number of good reasons to be skeptical about the alleged ability of economic growth to produce human well-being. However, as long as there on balance is a positive effect, however small, of growth on well-being, which seems to be the position taken by most economists, economic growth may be defended as a policy goal.

Especially in low-income countries it is, for obvious reasons, difficult to build a broadly convincing case against growth in spite of its often clear negative environmental effects. Even within Amartya Sen's definition of well-being as anchored in rights and freedoms the need for food and shelter and also for access to education and learning cannot be realized with the current distribution of resources and it will require economic growth in specific regions to give such rights and freedoms.

Can growth become sustainable under current capitalism?

One can discuss pro et contra for economic growth as a policy goal in many ways. One can build strong arguments for restricting it for environmental reasons. One difficulty with envisaging sustainable growth is that growth is strongly connected both to the modern nation state and to the prevailing economic system. Capitalism

works best when it is flexible and expanding. Long term controlled zero growth (or even low growth) under capitalism requires a political regulation system with a strength and sophistication we haven't yet seen. Without such a regulation system it would not in a long-term, low-growth scenario, be possible to avoid increasing regional and sector specific unemployment and a host of problems related to the distribution of income, wealth and power.

It is impossible to say anything with certainty about the possibility to implement the technical and institutional changes that would make economic growth compatible with reasonable definitions of environmental sustainability. Nevertheless, optimism about this topic seems to have been increasing lately and even if it is not clear what this change in outlook rests upon we now turn to a discussion what can be done to make growth more environmentally sustainable. We would point to a change in governance that would move us toward 'democratic and participatory engineering and management of growth'.

In order to reduce the environmental impact in terms of natural resources, low entropy energy and ecosystems resilience the focus evidently has to be on the creation and utilization of knowledge. This is in accordance with the approach of ecological economics discussed above. Quite generally, final demand should be, increasingly, composed of good and services with low environmental impact and technological and organizational knowledge should systematically be developed towards the same goal. Progress in any of the following dimensions would move us in the right direction:

a) New processes (production, transport and logistics) requiring less resource input per unit of production
b) Substituting non-renewable with renewable resources
c) New products which are more long lasting and more recyclable
d) A change in the sectoral composition of the economy toward less resource intensive production activities
e) A change in the location of economic activities that reduce resource use for transport
f) New forms of agglomerations and new principles for housing that reduce resource use

The question is how such developments can be supported. We will discuss some main channels for this. The speed and character of the environmental destruction connected to the economic process will be profoundly affected by what happens to *values*, *institutions, and policies*. A specific but very important issue is the geographical distribution of the economic process. In that context the environmental effects of

urbanization, especially *city growth*, will also be discussed. Finally we will take into consideration some aspects of the *consumption structure*, which, as argued above, is of key importance.

Values.

If people feel strongly about the environment and rank environmental values high this will make implementation of environmental protection policies more likely and it will support institutional change in this direction. It will also make it easier to shape more environment friendly consumer habits. The good thing is that values and expectations about the future are malleable. The values connected to expected future increases in material living standards my, for example, change in a more modest direction.

But where will such values come from? Values are shaped in complex process over time and there are no guarantees that new "good values" will automatically emerge to protect the social fabric when needed. Environmental destruction will not necessarily produce new values to protect the environment once people realize that there is a serious threat. It is true that the increasing focus on the environment in the public debate and the increasing scientific knowledge about the character of the threats have resulted in a broadening environmental awareness. In for example the Euro Barometer questionnaires people tend to place environment problems as one of the most important questions for the future. Lately, however, the environment problem in the broad sense including climate change has lost some of its urgency in people's minds. The international crisis seems to retard the development of stronger environmental values. Also the widespread and increasing individualism of our times in the Western cultures holds such values back. Concern for the environment is a collective concern, i.e. a concern for something that is common for many people, in fact for the whole mankind. This doesn't fit very well with the surging individualism.

The unequal distribution of income between countries is connected to powerful demonstration effects. Consumption patterns in high-income countries are sought copied in low-income countries. Relentless consumerism building on fast consumer learning spreads over the globe. This means that values that induce more environmental friendly consumption patterns have to be developed first in the rich countries. An increasing attention among both producers and consumers to economizing with environmental resources has to be built through a combination of

regulations and incentives. The US and Europe has to lead the development of environmental values. Urging the fast growing emerging economies to take their "fair" share of the responsibility for the global environment (as seems to be the present stand of most high income countries) will not sound convincing to these countries and will not make consumer values more sustainable.

Another strategic player in the global game is of course China. China has set a world records both in rates in economic growth and in terms of local pollution. But the political leaders have recognized the problem and have taken initiatives that may make a difference in the long run. The explosive growth in some green industries like Solar and Wind energy has been nurtured by public policy. Recently China has decided to introduce a carbon tax. On the other hand the rate of installment of 'clean production' and renewable energy sources has been less impressive. Also in China local interests and pressure groups will slow down the movement toward a green technological trajectory. Another crucial issue is if China will be willing to join global agreements that restrain their capacity to pursue national self-interest. The growth trajectory as well as the general political strategy has been based upon offering citizens access to material progress and to change the value sets of Chinese consumers might be at least as difficult as changing them in the US and Europe.

We do not expect major impact from isolated moral campaigns in favor of good green behavior on the behavior consumers, workers, farmers, managers and capitalists. A problem with the global ecological crisis is that the individual actor tends to see his/her share of responsibility for the environment as so marginal that even those who accept that the problem is important will be reluctant to change behavior. But we do expect that there can be quite substantial changes in what are the most widely accepted norms. But such changes will be based more upon new institutional frameworks and regulations than upon moral preaching.

Institutions and policies.

Deep changes in economic behavior (i.e. changes in the ways research organizations prioritize between different tracks to pursue, changes in the ways firms develop and chose product- and process technologies, changes in how consumers distribute their purchases and changes in how politicians strive for and reach power) imply deep changes in the institutional framework. Less and less doubt remains about the

necessity of drastic changes in economic behavior if something remotely similar to environmentally sustainable development is to be achieved. Hence a broad range of deep institutional reforms must be put on the agenda.

In this context *the institutions of the learning society* are the central ones. Three types of changes have to be supported: Energy efficiency has to be increased, low carbon technologies have to be worked out, environment friendly goods and services have to be developed and, of course, consumers have to prefer and buy them. The often-underlined necessity to halt deforestation (Nicolas Stern 2009) may here be thought of as included in development of low carbon technologies. This means that institutional learning and policy learning on broad fronts are necessary. Taxes, carbon trading, regulation, technology support, and measures that halt deforestation may be mentioned. New instruments and new ways of using them have to be built up in these areas. Deeper environmental awareness and new visions about the relations between environment and society, foresight, data collection, theory development, new environmental bureaucracies, new forms of cooperation between the research system and the political system, new legal and regulatory frameworks have to be developed.

It is difficult or impossible to describe in detail the depth and breadth of the necessary changes. Development of institutions and policies has to support each other partly by design and partly by evolution. Because of the immense magnitude of the environmental challenge *inclusive* political and economic institutions are called for (Acemoglu and Robinson 2012). Inclusive institutions distribute power and economic influence widely, establish legally binding restraints on the people in power ("the rule of law"), secure property rights and create incentives for large parts of the population to invest in learning and participate not only in production but also in its management. If institutions are not inclusive enough the creative destruction of vested interests, which so often block necessary new policies, will be obstructed. The structural change, which is needed in sustainable growth and development, will be too slow. To draw the development and implementation of technologies in directions that can significantly retard the present accumulation of environmental problems may very well require development not only of a wide range of new institutions but also of institutions that include broad majorities of the population into political and economic decision-making. This may adequately be called deep institutional change.

The fact that the Nordic countries with their small size, high taxes, strong trade unions and generous unemployment support have become among the most successful economies worldwide both in quantitative (GNP) and qualitative (well-being and happiness indexes) terms is a paradox seen in the light of neo-liberal dogma. Danish experts doing research on the labor market and the welfare state have referred to this in terms of 'bumble-bee'-economies. The parallel is underestimating the paradox since the Nordic countries have been more successful in terms of 'flying' than the other species among national economies.

Social inclusion is an important aspect of this. On the basis of our own research we would explain much of the success by 'social capital' and refer to the capacity of citizens to enter into collaboration with others that do not belong to their primary group. This is reflected in high levels of trust making business transactions as well interactive learning across organizational borders more effective than in other national contexts. Historically at the level of the national political systems 'class co-operation' has been fundamental when responding to deep crisis. Finally, it is reflected in wider active participation in processes of organizational change and organizational learning at the level of the workplace.

With reference to these characteristics we have argued that the Nordic countries have a competitive advantage in 'the learning economy'. We believe that the same characteristics, if taken properly into account, could be used to give the Nordic countries a lead position in relation to the shaping of a new Green Innovation Trajectory. The kind of deep transformation in consumption and production pattern that is necessary can only take place with some degree of broad participation. Egalitarian societies may be more ready to go green than societies with high degrees of inequality.[7]

A critically important issue is how the many necessary institutional changes are connected to the process of globalization and to the regulation power of nation-states. In a situation where nation states compete politically and economically with each other they are not ready to go alone with policies and institutional changes that risk affecting competitiveness negatively. If international cooperation and regulation can't

[7] It is interesting to note that Denmark and Sweden take the fourth and fifth position in the national ranking published by The Climate Change Performance Index 2013. Position 1-3 are left empty since they require a diminished foot-print and no country succeeded to attain that.

be established environmental destruction may continue in spite of a political will for increased environmental protection.

Historically nation states in Europe and elsewhere have served as frameworks for uniquely high rates economic growth. High rates of growth have made it possible to establish a welfare state and helped to create class compromise. The current global governance system is strongly rooted in this history and new emerging economies such as China and India also use national political institutions to foster rapid economic growth. There is a strong connection between the nation state as institution and current economic growth trajectories.

In modern terminology this becomes especially clear when governments focus upon increasing international competitiveness. The idea is that welfare, employment and growth requires that domestic firms and experts have conditions that are at least as attractive as those found in other countries. In its most crude form competitiveness is reduced to the level of wages or wage costs per unit of production. Business lobbyists are especially active when it comes to use the competitiveness argument to promote self-interest. They use it to call both for lower wages and for lower taxes.

Increasingly the efforts of governments to respond to the ecological challenge by taxes on pollution and resource use has become attacked at the national level because they undermine the competitiveness of domestic firms or make it less attractive for foreign firms to invest in the country. This tendency has actually been reinforced in connection with the financial crisis. In Europe the strategy to cope with the euro crisis has been launched as a 'competitiveness pact'. This focus upon national competitiveness may have contradictory impact upon the use of resources. On the one hand it reduces the rate of growth in production but on the other hand it slows down the increase in resource productivity. Industries that pollute and operate resource intensive activities are sheltered in order to avoid more job loss.

One way to overcome the competitiveness trap is of course to make global or at least international agreements on environmental regulation. The capacity to engage in such transnational agreements will be of decisive importance for the possibility to move toward sustainable development. This requires a major change in perspective. As it stands today the nation state remains a 'natural' arena for discourse and action. Even

in critical contributions to social science 'methodological nationalism' tends to prevail.

Structural change.

To ease and induce restructuring of production and consumption is an integrated part of making economic growth more sustainable. To increase energy efficiency in production will change the structure of production broadly speaking. Choice and development of materials, methods of production, and machinery by firms will be affected at all stages of production. As mentioned above several policy instruments are available to affect these choices. Knowledge about how different structures of production and different production methods affect the environment may thus be utilized in policy making.

Looked upon in this way the structure of production is an induced, indirect reflection of choices made by firms in their ongoing pursuit of profits and capital accumulation. But the specialization pattern of the economy can also be thought of as a policy instrument in a more direct way. Environmental policies may aim at drawing final consumer demand in more sustainable directions. Also here there are, of course, several policy instruments, most of them affect consumer choice through changed price relations while others use more direct regulation.

Of course, many improvements, for example in energy-efficiency, are not achievements of policy-making but rather results from long term trends in structural change, such as the shift from industrial society to a service-based economy. Even the successful case of California, which has held per-capita energy use roughly constant for the last 40 years whereas it has risen by about 40 percent in the rest of the U.S., only about one quarter of the improvements, can be explained by policy-making efforts to increase efficiency.

An indirect, small-step policy instrument, which may complement the traditional ones is "nudging". It has recently been suggested that in many cases decision-making can be "nudged" into a certain directions without altering the available choices much. "A nudge can be anything that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives. To count as a nudge, the intervention must be easy and cheap to avoid". (Thaler and Sunstein

2008). This approach is sometimes called “libertarian paternalism”.

But the nudge idea may be pushed a bit further by not only taking into account what would be best for the individual, but by also going for generally acknowledged political goals like environmental protection. It matches the usual nudging criteria if there is scientific evidence that action is needed and there is wide political consensus. Nudging could, thus, be applied also to technology choice. A board of experts from various scientific disciplines could be appointed to compose a catalog of criteria that a technology for environmental reasons has to meet[8]. If a technology scores high, because it induces very low energy-consumption for example, it could qualify to governmental funding or promotion. The technological nudges resulting from such a process could be supported by, for instance, making them the default choice in publically funded institutes like schools and hospitals.

Some progress has already been made along these mostly indirect and incremental lines to change consumption patterns. It is more questionable if significant reductions in consumers’ strong “addiction to exosomatic comfort” are possible.

To follow the progress in structural change toward sustainability it would be useful to give much more attention to and to refine Input-Output analysis so that both knowledge and natural resources are given a more significant position as inputs and outputs. Input-output analysis can give as full a picture of the overall economy as general equilibrium but it is free from the ideological assumptions that markets are the best tools to allocate resources.

Environment and the city.

Economic growth is inextricably linked to urbanization and city growth. Those regions and countries that experience economic growth also tend to urbanize quickly and those urbanizing faster typically experience higher rate of economic growth. No country has ever achieved sustained economic growth without urbanizing and countries with the highest per capita income tend to be more urbanized (UN-HABITAT 2010).

[8] This could be combined with the engagement of ordinary citizens through tools such as consensus conferences where citizens make choices together on the basis of the expert knowledge that they are offered at the conference.

Cities have always been locations for the main producers of new knowledge and vehicles for economic growth. This is because density, diversity and interaction feed innovation and since the extent to which economic growth can be decoupled from environmental destruction hinges on learning and innovation the way cities develop may very well be crucial in this respect. There are several ways in which cities may help economic growth to become cleaner. Large groups of people living and working in close proximity put strains on natural resources and energy and create different kinds of pollution. But in creative periods and environments city development has also been characterized by astute recognition of such problems and mobilization of efforts to solve them. Cities contribute to a more sustainable development by on the one hand clearly demonstrating problems that need to be solved and on the other hand by providing creative environments for the solution of these problems.

In addition to this dense populations use far less energy and materials per capita on living, heating, and transport than more dispersed populations. Increased and improved public transport has, especially in cities, great potential to reduce carbon emission. Furthermore, waste management and waste treatment are much more efficient in cities than in less urbanized areas. In fact in the last decades many cities have gone from net emission to net reduction of greenhouse gases in waste management mainly as result of enhanced energy- and material recovery. Waste prevention systems may add to the benefits already achieved (Johnson et al. 2011).

The next decades China, India and other big, fast-growing countries will continue to urbanize rapidly. The ways their cities will develop will have a huge impact on energy consumption and carbon emission. Urbanization and city growth are main factors affecting the natural environment of the future world (Glaeser 2011).

Are there alternative to the current version of capitalism that could cope with the sustainability problem?

So far capitalism has proved to be quite resilient when confronted with crises that could threaten its survival. The big wars and the crisis in the 1930s transformed capitalism into different varieties that could combine the interest of those at the top with the majority of the electorate and in the West the political groups that challenge the system are only marginal and they only show up spontaneously in the form of anti-global and anti-Wall Street.

Therefore it may appear far-fetched just to think about alternatives to capitalism and what we can imagine is probably a new variety than a completely different system. One way to specify what is wrong with current capitalism is to specify four differents forms of capital that shape growth.

Diagram 1: Resources fundamental for economic growth – combining the tangible and reproducible dimensions

	Easily reproducible resources	Less reproducible resources
Tangible resources	1. Production capital	2. Natural capital
Intangible resources	3. Intellectual capital	4. Social capital

The diagram illustrates that economic growth is faced with a double challenge in terms of sustainability and that there is an immanent risk of undermining not only the material basis of material production (Segura-Bonilla 1999), but also the knowledge base. The creation of tangible capital may be threatened by a neglect of environmental sustainability. We will argue that the production and efficient use of intellectual capital is fundamentally depending upon social capital (Woolcock 1998). A development strategy that focuses only on production capital and intellectual capital is not sustainable.

But the diagram is incomplete – we might say that it is like playing Hamlet without the Prince of Denmark. Over the last decade it has become increasingly clear that financial capital has become less connected to the other forms of capital and at the same time the form of capital that dominates capitalist dynamics. Financial capital attracts the best brains and it increasingly set the limits for what kind of public policies that can be implemented. It is difficult to see how there could be a change in the accumulation pattern without reducing the power of financial capital.

It is not easy to formulate a way out of this. Socialist planned economies have not, as was hoped by many people, been able to show another way. The problems with technical change, flexibility and democracy were not effectively tackled in the Soviet

Union or the other counties within the same paradigm of socialist economy and few people would pick The Peoples Republic of China, Vietnam or Cuba as role models in this context. We can't rule out, of course, that another type of socialist economy, dynamic, democratic and with effective environmental regulation, can be established, but visions about how this may be done are at the moment in very short supply.

There is a need for a pragmatic engineering perspective rather than a dogmatic marketeer perspective. The actual degree of scarcity must become the starting point for developing strategies where markets and planning instruments are used in a management fashion with broad participation of citizens. To organize such a form of governance at the national level is a tremendous task. It is of course even more so at the transnational level. Europe and its institutions will soon be tested in these respect. Europe could become a model but it would require forms of leadership that so far have been out of sight.

Innovation and sustainability

In this section we present some ideas on how innovation may contribute to a more sustainable path of development. We will refer to the kinds of changes that we listed above as different kinds of changes that move us toward sustainability:

a) New processes (production, transport and logistics) requiring less resource input per unit of production
b) Substituting non-renewable with renewable resources
c) New consumer products which are more long lasting and more recyclable
d) A change in the sectoral composition of the economy toward less resource intensive production activities
e) A change in the location of economic activities that reduce resource use for transport
f) New forms of agglomerations and new principles for housing that reduce resource use

Before addressing each of these we will come with general reflections on an innovation oriented approach to sustainability.

General reflections on innovation and sustainability

A significant amount of current innovation efforts undermine sustainability. One example is product innovations for consumers that are designated and designed exclusively to stimulate consumers' appetite for new models. Another example is

process innovations that lead to more use of resource per unit of value produced. In a market economy process innovations that make resource intensive products less expensive will move the production structure in the wrong direction. Therefore it is necessary to redefine innovation policy from 'general innovation support' toward 'directed innovation support'. While it is impossible to steer learning and innovation processes in detail history gives many examples of how they might be 'guided' by governments and actually end up with economies following a new technological trajectory.

If scientists are correct in their conclusions that there is urgency to cope with global warming it is obvious that market forces cannot solve the problem without guidance or the state taking on the role of Entrepreneur. The 'effective demand' of future generations is zero. Therefore there is a need for forces outside the marketplace to intervene in a very strong way. It does not exclude the use of market mechanisms and it does not imply central planning and total loss of autonomy for agents in the private sector. The need for creativity and entrepreneurship with both individuals and organizations 'thinking out of the box' may actually be bigger than ever.

Guidance may take the form of a combination of taxes, subsidies, public production, public procurement, standard settings and prohibitions. One important criterion for selecting and designing policy tools must be how they affect innovation and learning. There is for instance a scholarly literature on how the design of standards may respectively promote or slow down innovations. Measures should be designed not so that they freeze procedures. They should give freedom in choice of method as long as the outcome is that specific green objectives are reached.

One of the arguments against such guidance is that the measures taken are costly and that given the uncertainty regarding the future we should postpone the introduction of such measures, while we in the meantime create more knowledge through R&D efforts. By pursuing R&D we can when the time comes introduce much more effective and much less costly solutions. This argument has been the second position taken by Bjørn Lomborg – the skeptical environmentalist.[9] It reveals a lack of

[9] For a long period he was in denial when it comes to global warming. At some point when this position was not possible to defend he turned to the new position that research is what should be done now.

understanding of the innovation process assuming it to be linear rather than interactive. One of the clearest conclusions from innovation research is that effective new solutions can only be developed in a process where research efforts are applied and where there is feedback from users to producers of new solutions.

We have referred to the very fundamental institutional problem that nation states dominate political governance. They have the most powerful tools when it comes to intervene while some of the most important environmental problems are transnational and global. There are two types of responses to this problem. One is to point to a green competitiveness strategy and the other is to point to the need for international or even global agreements.

If it was possible to convince governments in charge of economic policy and national industrial interests that taking the lead in moving on to a green technology would actually give an advantage in international competition we might expect governments to introduce green policies in order to enter a process of 'green competition'. This has taken place at a modest scale when it comes to windmills in Denmark, electrical cars in California and wind and solar power in China. There is certainly truth in this argument but it meets with resistance for different reasons.

One reason is that a coherent green strategy will disfavor industries with a long historical legacy and with strong political power. Organizations that represent the enterprise sector as well as the financial industrial complex will tend to oppose government intervention if some of those they represent get worse off. Therefore it becomes important for government to establish alliances with those parts of the enterprise sector that do have an interest in a green innovation strategy.

Another factor reducing national efforts in the West is that there is general resistance among the establishment, often fed by mainstream macro economists, to selective policy giving the state a steering role. The assumption that 'the market' can and should do the job of allocating resources and that governments should only be involved when there are obvious cases of market failure is widely spread. This market dogmatism in the West may be contrasted to the extreme degree of pragmatism that characterizes the Chinese leaders who have no problems with using any kind of mix of market, management and planning as long as it works. One of the interesting results from innovation research is that 'pure markets' are quite ineffective when it

comes to promote innovation and that markets where innovations are frequent are organized around an interaction between producers and users. A change toward a green innovation strategy will require a battle with this kind of market dogmatism.

But of course there are initiatives that need to be taken that can be difficult to implement at the national level without international co-ordination. If industries are footloose specific new green burdens may result in outsourcing to other countries and in extreme cases the outsourcing may result in a net negative global impact upon the environment. This might be the case if activities are moved to a country without any green ambitions. So in parallel with national efforts there is a need to design global co-operation.

So far much of the attention in connection with global co-operation has been on reaching agreements on targets for reduction of the amount of CO2 produced. We think that changing the perspective somewhat and giving more attention to how to promote innovation in green technologies might help getting out of the current stalemates. The establishment of problem based 'mega-science' and mega-technology projects where national scholars and enterprises collaborate and share knowledge relevant for solving ecological problems (water, desertification, renewable technologies) might be one way to make national agreements in this area more realistic. Global engineering universities with a strong profile in terms of sustainability technologies could be another type of new institutions that could move things in the right direction.

<u>New Processes (production, transport and logistics) requiring less resource input per unit of production.</u>

One of the reasons why labor productivity has been growing for centuries is that labor constantly has become more and more costly. We would argue that a similar effect on resource productivity may come from an ongoing increase in green taxes. While a steep increase in a tax might have the strongest immediate impact on behavior it will need to be combined with a long term incremental increase over time in order to shape a new trajectory where the focus and the attention is moved from labor to resource productivity.

To develop new capital goods for production purposes that are less intensive in the use of resources will require a combination of different kinds of innovation efforts. Research, development and design efforts among producers of capital equipment need to be combined with close interaction with the user industries or with the public sector as user. Especially when moving on to a new trajectory the close interaction between producers and users will be of crucial importance. To locate and to give special attention and support to lead users will be an important part of the strategy. Learning to produce and learning to use the new equipment will require major efforts. Existing business and work organization principles will need to be assessed and developed to support the new technologies.

Substituting non-renewable with renewable resources.

This refers both to energy production, the distribution of energy and the use of energy. While there has been major technical progress in the production of renewable energy some of the most important bottle necks have to do with storage and with linking production to the distribution nets. When it comes to use in for instance electrical vehicles the bottle-neck is a combination of battery technology and the absence of infrastructure.

Without going into detail there seems to be a rather clear agenda for research, development and experimentation. What is needed is a mobilization of resources to attack and solve the problems. Again major problem based collaborative projects, both national and transnational need to be established in order to open up bottlenecks. A specific task for intelligent innovation strategy is to locate strategic missing links. There are many cases where there is a great potential in linking knowledge fields to each other but where there is no spontaneous mechanism that couples the fields. One example could be to link new insights from biotechnology and nanotechnology to the research on different forms of renewable energy.

New consumer products which are more long lasting and more recyclable.

It is a difficult challenge for public policy to intervene in order to realize this objective. Superficial forms of intervention could take aim at the sales efforts that stimulate consumers to ask for more and more recent models. Alternative would be to establish a collaboration between enterprise sector and regulatory authorities where

the producer could become recognized as a green standard producer. For instance a green car producer may have to offer both a car that is environmentally friendly, recyclable and a 20 year guarantee to the buyer.

The third possible action would involve consumers in the process. Consumer organizations may be given a clearer mandate to rank products according to their environmental impact and government may set a threshold for what are acceptable minimum standards and actually exclude the non-acceptable ones from the national markets.

Again the innovation process will require both research and development and the interaction with users. In some fields users may actually be engaged in the innovation process either as user panels or as members of consumer organisations. Upgrading the skills and insights of consumers through training and information campaigns when it comes to recycling and durability may go hand in hand with negotiations with a d certification of producers.

A change in the sectoral composition of the economy towards less resource intensive production activities.

An interesting question is if a green innovation strategy would slow down change including structural change. The answer will be that some forms of innovations need to be slowed down – innovations that exploit consumers urge for newness in material goods and innovations that lead to growth in resource-intensive production. But at the same time there will be a need to speed up innovation and actually we would expect the restructuring of the over all economy to be accelerated in the move toward green production.

This has implications for finance of innovation and investment. To channel finance into new green industries there will be a need to establish 'green development banks' where government play an important role as determining the direction of investment. Not when it comes to pick specific projects but when it comes to promote specific new industries that need to be promoted in order to build a green production and innovation system. So the most fundamental mechanism behind economic growth – structural change – will be strengthened rather than weakened.

This restructuring will of course be reflected in shifts in the demand for labor. There will be sectors where specific jobs disappear while new jobs in other sectors are created and many existing jobs will require new skill and new perspectives on how to do things. Very ambitious combinations of education, life-long learning and labor market policies will be required in order to transform green innovations into wide production and use. Not least will there be a need for new kinds of education and for retraining of engineers, designers, skilled workers and managers.

A change in the location of economic activities that reduces resource use for transport

To transport resources from one part of the world to another requires major resources and among ecological movements there have been proposals aiming at co-localisation of production and consumption. On the other hand the conventional economic wisdom is that any trade that actually takes place is 'rational' in the sense that the specialization that it reflects contributes to a more efficient allocation than what there would be without trade.

The actual efficiency of the current pattern of global trade and of the volume of transport of people and goods that it results in is difficult to judge because a substantial part of the trade is 'managed' and takes place within transnational corporations. Taxes on international transport and international trade that correspond to the impact upon the environment – so that the activities would reflect the costs might be useful to scale down some forms of trade of marginal usefulness.

There is an ongoing innovation process aiming at more efficient methods of transport and again it is an area where a combination of national and global problem based projects could result in major breakthroughs. The high degree of concentration in the sector might require that third parties – for instance at the UN-level - help the major business groups join forces in order to develop more sustainable modes of transport.

New forms of agglomerations and new principles for housing that reduce resource use.

The construction sector is for different reasons among the most conservative in terms of innovation and organizational change. To some degree this reflects a special kind of division of labor where those who design projects are separated from those who implement them. A specific factor is that architects in charge of the design operate in

separation from the engineers that transform the design into practical solutions. Another factor that slows down innovation is that the themes that work to construct a new building are put together ad hoc so that the cumulative learning is limited from one project to the next.

When it comes to build green buildings some of these weaknesses of the innovation process may need to be overcome. Also new combinations of technologies and disciplines may help develop new forms of housing that are both comfortable esthetic and sustainable. This is an area where government already set standards and developing new standards that are more ambitious in collaboration with experts and citizens is a natural step. Again the standards should be goal oriented rather than very specific prescriptions so that room is left for creativity.

Towards a greening innovation system.

In the last sections we discussed how innovation could contribute to a more sustainable path of development. If these different initiatives where taken we believe that we might end up with a new kind of innovation system. It would be system where the different components converged toward new objectives and gradually accepted new norms for what is acceptable in term of environmental conditions. The attention would be much more turned to how innovations impact the environment. The performance indicators used to measure progress would be different and consumers would have found new ways to satisfy their need for stimulation and newness.

We see no *technical* barriers for moving the innovation system in this direction. However, as pointed out already in the introduction the political and institutional barriers are huge. Vested interests, nationalism, finance capital, economic marketer dogma and political short termism constitute huge barriers for the change that is needed. We can only hope that a new way of tackling the ecological crisis will develop as problems become more serious. This new perspective must combine participation and democratic procedures with a long term engineering view where problems are recognized as they are and where all kinds of solutions are considered without ideological prejudice.

Conclusions

It is an open question if the capitalist process of production and accumulation can become environmentally sustainable. It is of course important not to "confuse the limits of one particular development paradigm, with the limits to growth of the system in general" (Freeman 1992). It is clear, however, that the scale of the problem requires *radical* changes not only in *technologies* but also in *values*, *institutions*, *policies* and *consumption patterns* to develop what Christopher Freeman (1992) two decades ago termed a "green techno-economic paradigm".

On the background of the discussion above we can reformulate the 'factor X' question: "How many times is it possible for the amount of wealth extracted from one unit of natural resources to increase within a certain time span as a result of technological improvement in combination with changes of values, institutions, policies, and patterns of consumption and is this sufficient to decouple economic growth from destruction of our common environment?"

If we restrict the analysis to a situation where the current architecture of capitalism is left unchanged there is little ground for optimism. It is difficult to see how necessary changes can be installed under current governance where financial capital rules real, intellectual and natural capital. And envisaging the alternatives to the current system is not an easy task. So our optimism is very relative and conditional indeed. But the alternative, to accept that we have to look ahead without hope, is worse.

Inspired by the suggestive title of Christopher Freeman's book (1992) "The Economics of Hope", we take a conditionally optimistic stance to the question.

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