LIVING WITHIN THE PLANETARY CAPACITY: A DYNAMIC FEEDBACK APPROACH

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ABSTRACT

This article explores the root causes of *throughput* growth in market economies addressed in the literature in classical economic thinking, growth theory, ecological economics and system-dynamics. Today, with the intertwined influence of persisting low GDP growth and high unemployment rates, increasing commodity prices, widening income gaps, lasting severe social conflicts and ecosystems destruction, the *growth paradigm* is under strong scrutiny. In this research, we explore and create various feedback hypotheses, first to see whether there is a growth imperative in modern market economies. Then, the feedback models are used to assess potential counterintuitive responses to environmentally motivated strategies, to identify leverage points for a transformation towards a sustainable society and to guide future computer modeling activity that will help testing and development of high leverage policies. The analyses focus on the quest for an economy operating within the biophysical boundaries of natural environments, hence rather than GDP and alike monetary measures of economic growth, the scale of *throughput*, the food of human social metabolism is emphasized. Throughput is factored into *per capita throughput* multiplied with *population*, and the concern here is the drivers of growth in per capita throughput, not the human population.

Keywords: throughput, limits thinking, growth paradigm, growth dilemma, biophysical limits, feedback thinking, dynamic modeling

Glossary of terms:

Throughput: The flow of natural resources from the environment, through the economy, and back to the environment as waste.

Social metabolism: The manner in which human societies organize their growing exchanges of energy and materials with the environment.

Growth paradigm: The proposition that economic growth is good, imperative, essentially limitless, and is the principle remedy for a litany of social problems.

Limits to growth: The proposition that growth of throughput is limited by the nature's biophysical capacity, and growth in human wellbeing stagnates with continuing economic growth.

Decoupling (eco-economic): The ability of an economy to grow in monetarily measured (non-physical terms), without corresponding growth in social metabolism and its throughput (in physical terms).

Growth dilemma: The dilemma of reconciling our aspirations for the good life with the constraints of a finite planet.

Uneconomic growth: Growth of an economy beyond a scale, where further growth can cost to the society more than it is worth.

Feedback hypotheses: A working theory about the structural root causes of a complex, dynamic problem.

I. INTRODUCTION

Biophysical Limits and the Evidence for Overshoot

In global scale, there is mounting evidence indicating that human impact on the planet's biophysical systems is destabilizing the crucial ecosystem processes and depleting resources, which support human life on earth. According to the ecological footprint sustainability accounting framework, humanity's resource demand has overpassed the planetary carrying capacity by mid 1970s and since then has reached to one and a half planets (WWF 2014), indicating that the current resource extraction and pollution loading at global scale is more than one and a half of what the earth's productive ecosystems can accommodate. More recently, earth system scientists have identified nine planetary boundaries which define a "safe operating space" for the humanity and they argue that the three of them, climate change, rate of biodiversity loss and the interference with the nitrogen cycle has already been crossed by human activity, creating unacceptable risks of abrupt environmental change from local to global scales (Rockström and Steffen, et al. 2009). Among multiple planetary boundaries, the atmospheric capacity to absorb greenhouse gases inducing anthropogenic climate change is acting as the most pressing constraint with its truly global impact on human societies and diverse ecosystem functions and with its close relevance to the crucial choices of our times essentially in energy use, technology development and socio-economic adaptation. IPCC (2014) warns that human impact on the climate system is clear, many changes observed since 1950 are unprecedented over decades to millennia, and climate change will amplify the existing risks and create new risks for human and natural systems.

Beyond the environmental risks created through destabilizing of ecosystems, there are multiple biophysical resource limits urging for fundamental change in the ways knowledge is produced, technology is developed and wealth is delivered to ever growing human populations. Today, there are 7.3 billion people inhabiting the planet earth, and according to UN (2012) medium fertility scenario, global human population is expected reach at 9.6 billion in 2015 and at 10.9 billion in 2100. World's arable lands are largely degraded due to intensive fertilizer use and erosion and arable land allocation for agricultural production is reaching its limits (UNEP 2007). Most of the world's fisheries are overexploited and wild catches are decreasing (FAO 2014). The growing gap between oil production and discoveries indicates that production is heading towards peak (Ayres 2014, p. 69) and the share of unconventional fuel, namely shale gas, bitumen and tar in global fuel supply is increasing. It is expected that resource constraints, at best, will increase energy and commodity prices in the 21st century and at worse, create an unstable economy (Jones et al. 2013). There is emerging research indicating towards possible links between social unrest, regional wars and impact of climate change on water and agricultural production (see for example Gleick 2014; Kelley et al. 2015).

Ecosystems destabilization, crossing of planetary boundaries, climate change, fisheries collapse, oil peak and problems alike are caused by growing human social metabolism and by the lack of sufficient alternatives to change the dominant course of socioeconomic development. Observed from a local perspective, global risks may appear distant in time as well as in space, therefore can be perceived less persuasive as a threat to survival by ordinary citizens. The lack of appropriate institutions consistent with the geographical and temporal scale of global problems can discourage positive action for social transformation. However, problems caused by the systematic growth in consumption particularly at the developed world, and the corresponding growth for demand of natural resources at the underdeveloped world create impact at local levels, building new socio-ecological pressures in new *commodity frontiers* (Moore 2000). As the resource limited world is plundered with growth, the frontiers of resource extraction and waste disposal are reaching at the farthest corners and is being resisted by counter-movements of citizens and indigenous groups (Martinez-Alier et al. 2010). Global Atlas of Environmental Justice (EJAtlas, 2015) reports almost 1400 cases of environmental conflicts in seven continents rising mostly around extractive industries and nuclear plant construction, waste and water management, infrastructure development, biodiversity conservation and other industrial plant projects.

Social Limits to Growth, Instability, Inequality and Happiness

UN (2012)'s stagnant global population projection for the end of the twenty-first century is shared in the global forecast by Randers (2013) and in the baseline scenario by Piketty (2014). On the other hand, the same forecasts and baseline scenarios assume that, particularly in the mature economies, growth in per capita economic output will decline but in overall, is going to stay at positive values, indicating that the long term growth in economic output is not expected to die out in the foreseeable future (Piketty 2014, p. 100; Randers 2013, p. 68). The decoupling of energy and material use from economic output in GDP terms is relative and weak, and absolute decoupling is a myth, even for the OECD countries (Jackson 2011, p. 70-72). In sum, human social metabolism and throughput seems destined to grow.

Research in human wellbeing and happiness shows that, beyond biophysical limits to growth in physical (real-real economic) terms, there are social limits to growth in non-physical (economic) terms. Firstly –above certain income levels, which satisfy basic material needs and conditions for flourishing as an individual and a community– additional income goes to *positional* or *status goods* that are important in establishing social standing. Hence, conspicuous consumption, a rat race for catching up with the others becomes a socioeconomic driving force. Meanwhile, variables indicating genuine human progress, such as life expectancy, infant mortality, participation in education and alike stagnate with increasing income levels (see Jackson 2011, p. 56-58).

Although there are reasons to believe that growth can be an instrument for equalization (see for example Piketty (2014, p. 83)) inequality has increased over the last 20 years even within advanced economies (Jackson 2011, p. 5), during an era when the per capita GDP growth rate was around 1.5 percent (implying a doubling time of about 45 years). Research shows, people above basic income levels value stability and equality more than absolute income as a source of happiness (Nguyen, Fleming, and Su 2015) and therefore growth in itself is not justified as a goal for socio-economic progress. The growth imperative in per capita output for a stable, secure economy is paradoxical.

Intellectual Response to Limits

So far, for almost a century, the response towards problems of resource scarcity and pollution has been to invest in “eco-efficiency”, the technology multiplier T in I=PAT, i.e. impact is factored into population, affluence and technology multipliers (Ehrlich and Holdren 1971), by advancing process and product design, and improving recycling and sanitation. While innovation came with substantial benefits to social and environmental wellbeing, it also created significant costs. Forrester (1971) and Meadows and Meadows et al. (1972) first showed that in a growth driven world, so called “obvious responses” of techno-efficiency improvements would not solve the problem of involuntary, undesired limits to growth in the long term. They argued that, as long as the population and consumption growth continues in a limited world, techno-efficiency is going to temporarily alleviate the scarcity problems, however fire back in the long term with more severe collapse patterns. Ecological economists have long been concerned about the "rebound effects" (Madlener and Alcott 2009) motivated by the Jevons paradox known by the 19th century British economist's name, who observed that improvements in coal use efficiency had further increased its consumption in various industries (Alcott 2005). Sterman (2012) provides several examples of well-intentioned innovation with so-called side effects, or "policy resistance" where attempts for alleviating resource scarcity or contamination, or efforts for resource conservation led further deterioration of the problems that they intended to solve. Based on past data on resource use and economic growth (in GDP terms) Jackson (2011, Chapter 5) discusses in length, why the industrial ecologist's "decoupling" agenda is a pie in the sky or rather unsustainable in the longer term.

Particularly after the economic crisis in 2008, which started with the financial meltdown in US housing markets, a general consensus has emerged that the world is not facing a financial crisis but a multitude of interconnected environmental, economic and social crises (Urhammer and Röpke 2013). Arguably, once neglected "limits thinking" is now becoming mainstream in sustainability discourse. Urhammer and Röpke (2013) review the proposals for Green Growth (of OECD), Green Economy (UNEP), Green New Deal (UNEP and New Economics Foundation-NEF), Great Transition (NEF), Prosperity Without Growth (Sustainable Development Commission-SDC), Steady State Economy (Center for the Advancement of Steady State Economy-CASSE) and Degrowth (by Research & Degrowth) and they argue that at their common core, these proposals have a shared interest in taking positions towards the problem of growth. Among these, Urhammer and Röpke (2013) identify Great Transition, Steady State Economy, Prosperity Without Growth and Degrowth as no-growth economic narratives. The "growth paradigm" and the "growth imperative" is depicted as the root cause of the current multi-facet crises (for example in Jackson 2011; Kallis, Kerschner, and Martinez-Alier 2012; and Czech and Daly 2013) however the interconnectedness of the economic, financial, resource and security issues operating underneath needs through delineation.

Research Purpose

The purpose is to develop a holistic understanding of the drivers of growth in throughput of modern market societies. For this purpose, benefiting form the literature in classical economic thinking, growth theory, ecological economics and system dynamics, we create causal loop diagrams that represent the interconnectedness of resource, economical, financial and security issues that can build up a growth imperative structurally embedded in modern socioeconomic systems. Literature in dynamic complexity emphasizes the counterintuitive behavior of social systems (system's resistance against well-intentioned policies) caused by the feedbacks, delays and nonlinearities in their system's structures (Forrester 1968; Sterman 2000). With regard to policies motivated towards environmental protection, there are legitimate concerns on the links between sustainability as an inter-generational equity problem, and economic equality and distribution as an intra-generational equity problem (Hahnel 2011). While sustainability strategies failing to address the short-term distributional issues are doomed to fail because of lack of popular support (because short-term dominates over the longer term), growth oriented policies motivated to alleviate short term distributional problems and therefore able to draw popular support are doomed to fail because of resource depletion and security issues (as the long term eventually dominates).

Beyond lack of political acceptance due to short-termism of the society as a whole, well-motivated environmental policies can create various rebounds (see for example, van den Bergh (2011)) counteracting the efficiency gains achieved by technological progress and regulation. Feedback rich problem conceptualization and a gradually developing holistic approach is expected to improve our understanding of the trade-offs between the short-term and long-term goals of environmental strategies and the rebounds in resource consumption.

Moreover, this exercise is expected to identify the links between possible intervention points for various sustainability actors, such as the movements for ecosystem conservation (either fighting against development projects for pristine ecosystems conservation or for protection of livelihoods), environmental justice movements (fighting against environmental discrimination and unequal distribution of environmental bad), social justice movements (fighting for just income, healthcare, education and community development) and various eco-efficiency specialists (people on the ground developing convivial tools for resource protection and those working in high-tech research and development). Lastly, holistic feedback approach is expected to create a blueprint for high leverage modeling and analysis that can guide efforts for a transformational change towards a sustainable society.

Next section is a literature review on ecological macroeconomics and system dynamics. After that, we look into several indicators of compounding growth in throughput of human social metabolism focusing on the last and next fifty years of affairs with data presented on time graphs, and suggest a starting hypothesis to begin the investigation. In the following section, we develop two seemingly separate feedback hypotheses on the drivers of growth in throughput, one from the consumption and the other from the production perspectives. The last section discusses future activity that will help further pursue this research agenda.

II. LITERATURE REVIEW

The Call for an Ecological macroeconomics

The research agenda labeled as ecological macroeconomics and eco-Keynesian extension to the conventional framework fundamentally focuses on the tradeoffs in allocation of the economic output to consumption and investment, the composition of consumption, investment and government spending among different uses, possible links between the production function and the resources and fiscal and monetary policies that drives consumption and investment decisions. Yet, the long-term consequences of current policies as well as possible rebound effects are not explored because of the lack of a feedback rich, holistic problem and model conceptualization.

System Dynamics

There are few studies in system dynamics explicitly addressing the growth and limits problem and pointing towards the potential conflict between intra- and inter-generation equity, or other possible sources of worse-before-better outcomes of sustainability policies. World Dynamics (Forrester 1971) is the first study that illustrates the non-linear interaction of biophysical world and human enterprises in a finite world and the simulated overshoot and collapse patterns created by multiple limits and delays in their perceptions. It is the first study, which demonstrates that the "obvious" response to holding on to eco-efficiency will not work. Limits to Growth (Meadows and Meadows, at al. 1972) is arguably the most well known study in system dynamics and together with its recent updates, is still widely cited in the literature addressing the problem of biophysical limits to growth. The fundamental message of Limits to Growth (LTG) is often expressed around the three fundamental conditions of overshoot and collapse, namely growth (of population and per capita consumption of material goods), limits (of the biophysical world) and delays (in perception, decision and action) which are certainly still relevant for the global socio-economic system. LTG and its updates are not designed to investigate the root causes of throughput growth, neither for policy design nor for strategic analysis of a transition from an economy with an apparent growth imperative towards an economy that can manage without throughput growth. On the other hand, useful insights created by the authors of LTG inspiring a second generation of research on limits are utilized in this paper.

The "ecocosm paradox", a dynamic hypotheses on the peculiar interactions of the biophysical world with human enterprises, by Fey and Lam (2001) resonates with the more recent sustainability literature. For example, the exponential and hyper exponential growth patterns in world per capita GDP and per capita consumption presented in Fey and Lam (2001) is now addressed as "great acceleration" (Steffen et al. 2015). The "sufficiency criterion", addressing the adequacy of remaining stocks of resources and infrastructure to support future human life implies the thresholds, tipping points and the resilience concept (Rockström and Steffen, et al. 2009) which calls for the precautionary principle. Finally, beyond stabilization, the agenda for reduction of consumption to a "level that can be sustained forever from the resources and infrastructure available" implies de-growth, understood as equitable downscaling of society's throughput (Schneider, Kallis, and Martinez-Alier 2010).

On the part of ecological macroeconomics, there is a developing conceptual framework concerned with the material scale of the economy. It is acknowledged that, this framework lacks novel analysis tools and a dynamic feedback approach that can look for the longer term and the counterintuitive consequences of today's decisions. On the part of system dynamics, the generations of limits to growth models address the interdependencies between resource, human population and capital structures of the global economy, depicts the limits of business as usual eco-efficiency motivated sustainability strategies, however do not provide instruments for a strategic analysis of options for an economy within a desired material scale.

III. PROBLEM DEVELOPMENT OVER TIME

From dynamic systems perspective, it is useful to unravel the development patterns of variables over time characterizing the growth of human enterprises. Rather than going into analytical specifics, here we present in Figure 1 the compounding growth patterns in selected global socio-economic and earth system variables presented by (Steffen et al. 2015) under the term "great acceleration". Great acceleration terms the unprecedented systematic take off and sharp acceleration in human consumption by the mid-twentieth century, which corresponds to a leap in growth of the world's per capita output particularly in Europe and in growth in population particularly in non-European world (see the data in Piketty 2014, p. 80 and p. 94). In Figure 1, the selected variables of real GDP, primary energy use, fertilizer and water consumption (upper row) are flow variables, representing perturbation of earth system states by the human socio-economic system. The selected variables of carbon dioxide, ocean acidification and terrestrial biosphere degradation that represent the state of the earth system are stocks, as well as population (lower row).

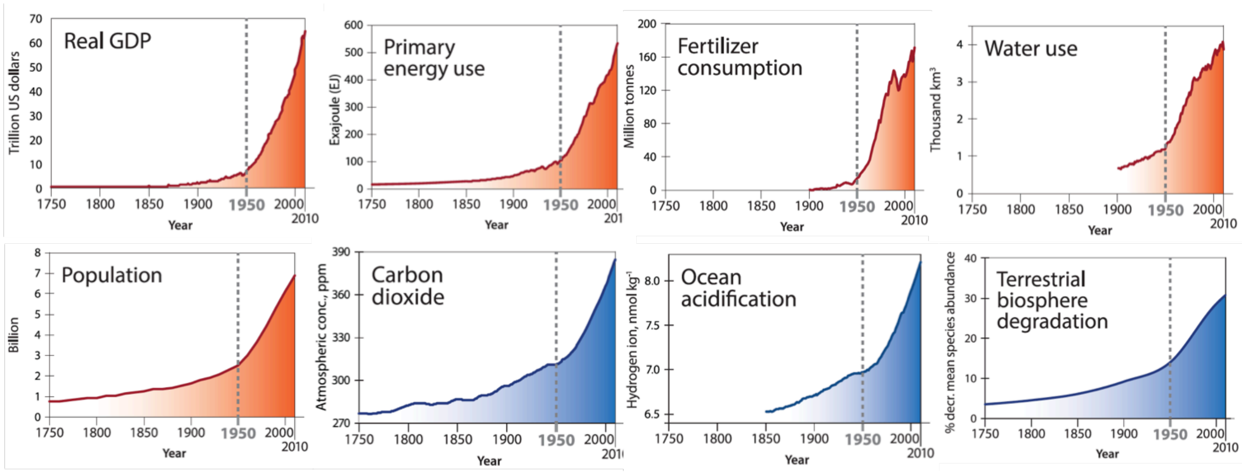

Figure 1. Great acceleration, adopted from Steffen et al. (2015)

Compounding growth is produced by dominant reinforcing (positive) feedback loops in system structures. A starting hypothesis, that explain the great acceleration is depicted in Figure 2. Economic output causes depletion and degradation of the earth's biophysical capacity (which actually is the throughput created under specific technology and management). Degradation depletes from the biophysical capacity to create a balancing loop (B1). Biophysical capacity, if conceptualized as a renewable resource (such as forests or fisheries), grows by regeneration (R1), but regeneration rate is reduced as the biophysical capacity grows to its ultimate limits (B2). On the other hand, if biophysical capacity is conceptualized as a renewable sink (such as atmospheric carbon reservoir), then alternatively, regeneration would create a balancing loop (B2 rather than R1) and the biophysical limits will constitute a positive feedback loop (R1 rather then B2). In both cases, the biophysical limits loop induces a nonlinearity yielding environmental tipping points with uncertain thresholds, and when these tipping points are overpassed, degradation of the biophysical capacity accelerates.

Increased economic output and material welfare create the conditions for accommodating more population, and further increases the output (R2). Similarly, increased output creates the conditions for higher productive capital and per capita output, further increasing the total output (R3). As the biophysical capacity is depleted by the output, reduced resource base interferes investments and hampers further growth in per capita output (B3) –yet a latent influence (an involuntary limits to growth) that has not yet been substantially observed (Steffen et al. 2015).

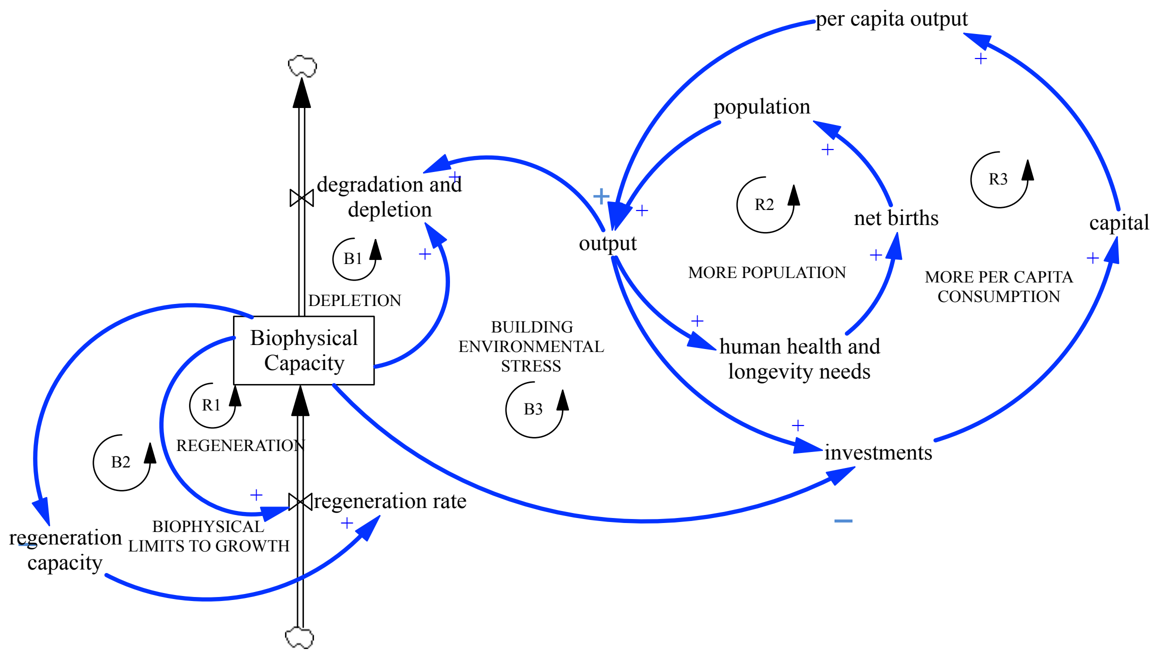

Figure 2. The ecocosm paradox, modified from Fey and Lam (2001)

IV. DEVELOPING FEEDBACK HYPOTHESES

In macroeconomic theory, output represents the nominal or real value of aggregate consumption (in monetary terms), which is postulated as equal to aggregate production. The *throughput*, the real-real (material) component of the *output* is a physical quantity, which is hard to measure in aggregate terms at macro scale. Its scale depends on aggregate output, its composition into different economic sectors, and the dominant technology embodied in the activities at each economic sector. Therefore, *output* drives the change in throughput and environmental impact at a macro scale.

Drivers of per capita output growth can best be analyzed from two separate angles: The consumption and the production. Although the assumption in macroeconomic theory, of aggregate consumption equals aggregate production is misleading and dynamically confusing (because inventories accumulate their differences), in long-term perspective as adopted in this work, it is reasonable to assume inventories being stable, and the consumption and production flows being equal. However, no matter this assumption is reasonable, separate analysis of the drivers of consumption and production create richer and more useful insights on the causes of growth in output, and therefore in throughput.

Drivers of Consumption

Consumption depends on *income* and income depends on economically productive *work* and *rent*. Hence, how much and how an economy makes people work, earn and consume explains the environmental impact (Figure 3). Environmental impact is illustrated with Herman Daly rules: Sustainability is achieved when renewable sinks are renewed at a rate equal to waste discharge, renewable resources are renewed at a rate equal to their depletion and non-renewables are depleted at a rate equal to creating renewable substitutes (see Dietz, O'Neill, and Daly 2013, p. 63). Figure 3 aggregates the first and the second conditions and dismisses the third condition for visual clarity. Degradation and depletion of biophysical capacity can also be interpreted as the *throughput* caused by consumption.

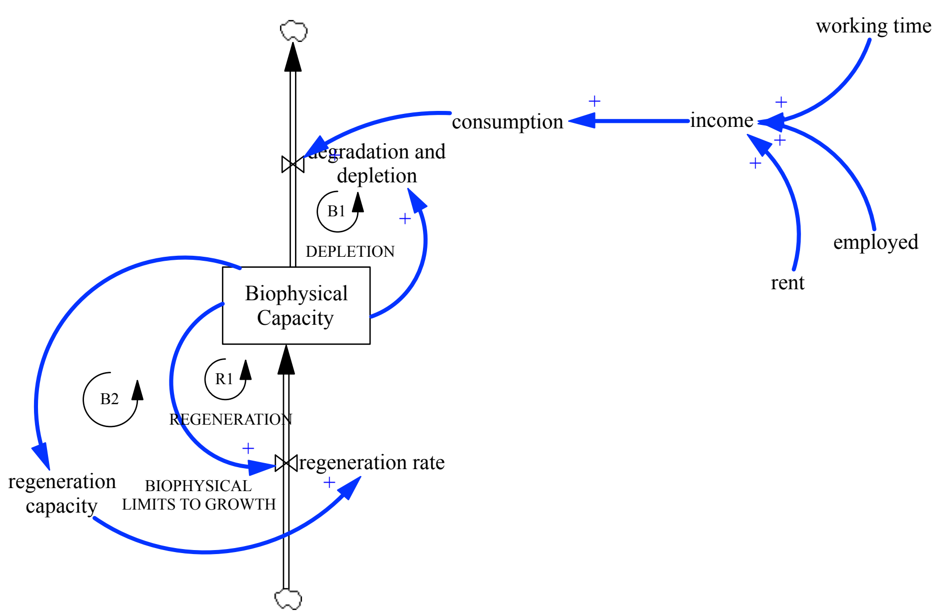

Figure 3. Consumption as the cause of ecosystems depletion with "Herman Daly rules"

If the ultimate goal of an economy were to help people improve their subjective well being (happiness), and if consumption of fundamental goods and services (food, shelter, education, sanitation and healthcare) –prosperity in Jackson (2011)'s terms is an indispensable means for its acquisition, consumption could reasonably be expected to satiate as it reaches at desired (normative) levels (Figure 4, the balancing loop, B4). Consumption is also the source of profits, saved and invested by firms to grow their capital structures, employ more people, and generate more income, therefore more consumption. Also, depending on the ownership structures, more capital creates higher rents and more income, and further boosts consumption (R2 and R3 loops in Figure 4). Under the conditions of stable population, i.e. with a limited number of employed, the growth in capital by consumption multipliers would not last long. The environmental stress (B3) would impose a third limiting factor on growth on consumption and the over-depletion of the biophysical capacity should be avoided.

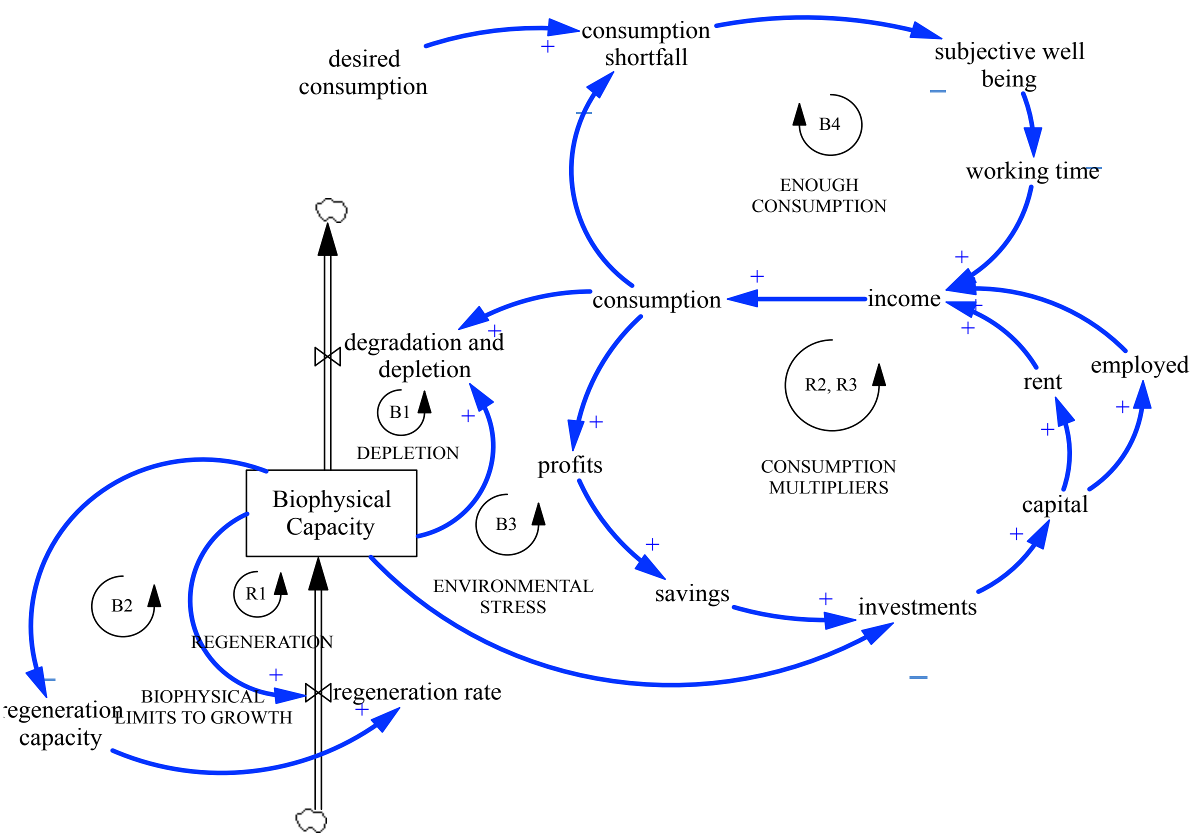

Figure 4. Loops avoiding consumption over-consuming of the biophysical capacity

The dynamic story of the structure in Figure 4 takes us to a stationary consumption and is contrary to the humanities experience at least the last two hundred years. What has been wrong so that the per capita output has systematically increased after the industrial revolution? Figure 5 enriches our view from the consumption side by incorporating two more positive feedback loops, simplified and modified from (Sterman Forthcoming). Competitive consumption (competition for positional goods that symbolize social status, such as larger houses, exotic diet, a college degree, distant summer vacations, discretionary flights etc.) drives desired consumption upwards, reduces subjective wellbeing and boosts working times (R4). With increasing working times, time allocated for economically non-productive, but socially responsible work (efforts for social change, community service etc.) decreases, people's leisure time erodes and reduces subjective wellbeing (R5). Paradoxically, the loss of wellbeing is compensated with more work, more income and more consumption, which can further fuel the consumption multipliers by generating profits to be invested by the firms.

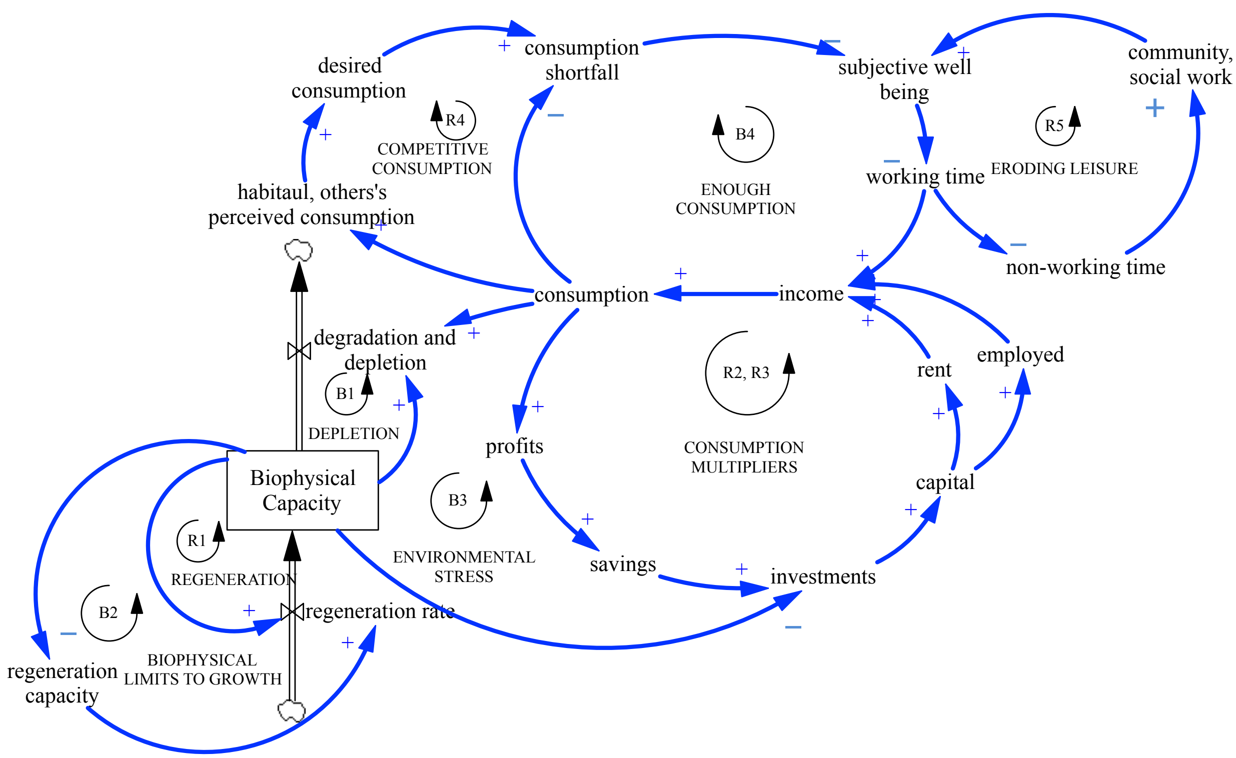

Figure 5. Increasing competitive consumption and declining leisure

So far, together with the consumption multipliers (R2, R3), the competitive consumption (R4) and eroding leisure (R5) loops explain the growth imperative in the socioeconomic system. If carefully investigated, the cause-effect relationships building these feedback loops reveal insights on how the growth imperative can be alleviated. As for the consumption multipliers (a) the condition of capital, i.e. business ownership structures influence the amount of rent income in the system and can act as the driver of growth. For the competitive consumption, (b) the link between work and remuneration and income distribution (c) consumerism as a cultural and ethical phenomena influence the loop strength. For eroding leisure, (d) time allocation between economically productive (market) activities and non-market work; the channels available in the society to create socially responsible activity which does not profit the markets and (e) the making of the social well being, the way it is influenced by consumption and by helping ourselves and others through community work are the determinants of loop power.

Various components of modern sustainability movement work for the concerns listed above to create an economy with an alleviated growth imperative, yet with the capacity to deliver wellbeing to the populations. People are engaging in activities to develop alternative business structures that do not prioritize corporate profits, struggling for economic equity in the workplace, working against consumerism, advocating work sharing instead of long working days, promoting convivial forms of production and as an alternative to corporate division of labor and trying to deliver more of their well being from non-market socially motivated work rather than individual consumption. Schor (2010) discusses alternative uses of time wealth of human beings and provide a rich account of movements and individuals working to deliver their well being from lesser market work and more community activity. Some of the concerned sketched out around the loops in Figure 5 are covered by Dietz, O'Neill, and Daly (2013) as well.

Back to the feedback complexity in Figure 5, given that the population growth is ruled out, therefore the number of employed has limits, and the total time endowments of the individuals are limited, one may expect to arrive at steady consumption rates, which would avoid systematic increase in bio-capacity depletion. Because this is contrary to past experience and expectations under business as usual, working on the drivers of growth in production can yield further insights consistent with our starting hypotheses.

Drivers of production

Production depends on economically productive *work*, the number of *employed*, *technology* and the *capital*. Production creates throughput and depletes and degrades world's biophysical capacity. This impact is depicted in Figure 6.

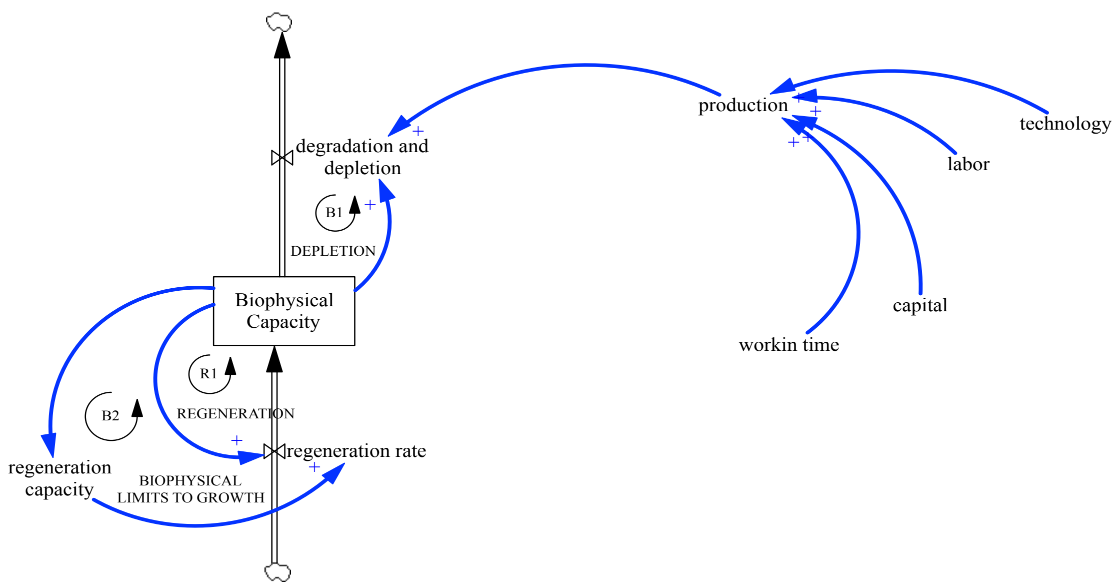

Figure 6. Production as the cause of ecosystems depletion with "Herman Daly rules"

If the ultimate goal of the economy were to satisfy the needs of the population, as the production reaches at desired levels that is necessary to deliver prosperity, working time, investments and productivity increase would be reduced to yield stationary production levels (Figure 7, B4, B5 and B6 loops). Profits generated from production should continue to be invested for new capital formation and technologies and would continue to create new employments. Under the condition of a non-growing population, the production multipliers (R2, R3 and R4) would not be effective for long and would be further controlled by the balancing loops of "enough", as well as by the developing environmental stress (B3).

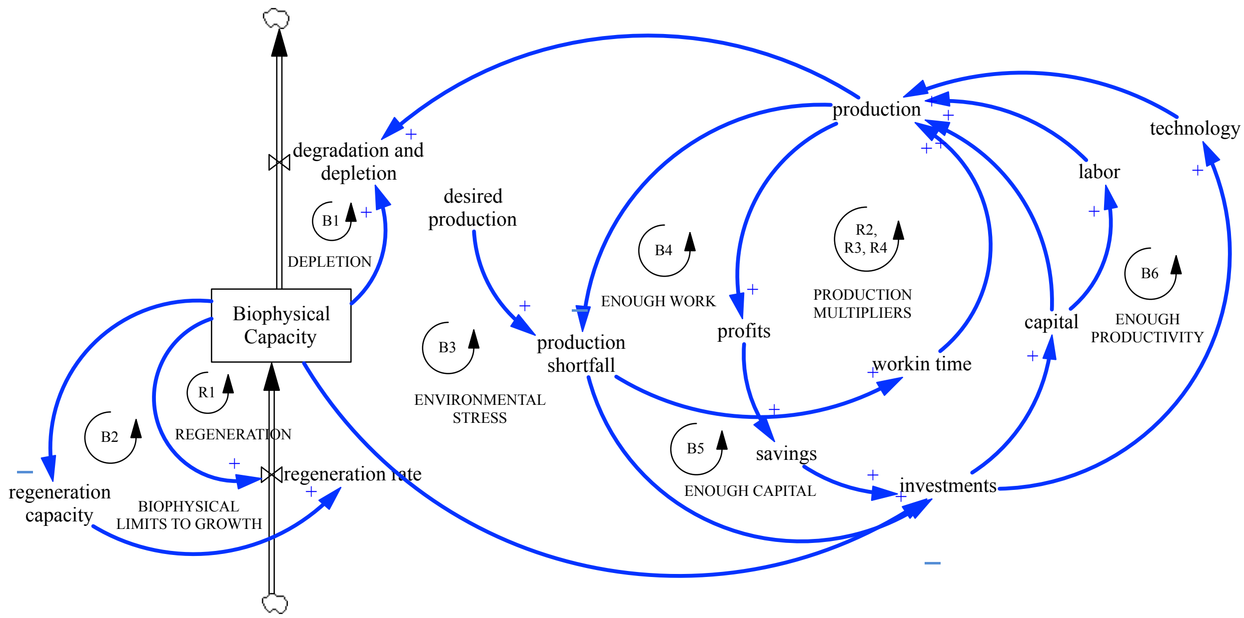

Figure 7. Loops avoiding production over-depleting the biophysical capacity

Yet, steady production contradicts our experience and future expectations on per capita growth. Capitalist markets force businesses to increase their production for the sake of securing their market shares and profits. Desire for higher production creates multiple reinforcing loops in the system to work and invest more and to seek for productivity increases through technological progress (R5, R6, R7 loops). More work, capital and productivity boosts production, businesses set higher output and profit targets to survive the market pressures, and engage in promotion and advertising activities to get demand (desired consumption) at compatible levels with their production targets (desired production). Enhanced technology helps productivity increases as well as eco-efficiency, which help alleviating the environmental stress. Indeed, this creates a reinforcing loop (R8) and various rebound effects, by reducing resource prices, encouraging investments and production, as well as creating further technological progress and eco-efficiency improvements.

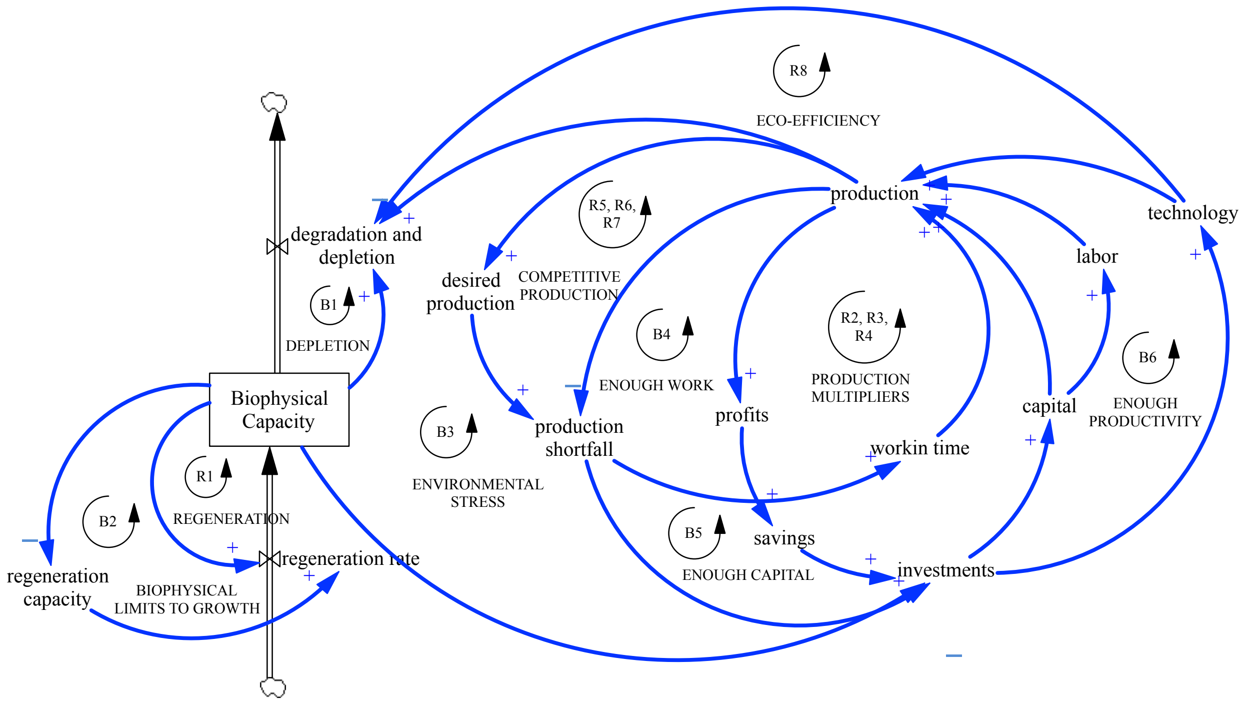

Figure 8. Competitive production and eco-efficiency as the drivers of growth

Together with the production multipliers (R2, R3 and R4), the competitive production loops (R5, R6 and R7) and the eco-efficiency loop (R7) create the conditions for growth in production. The cause-effect relationships building up these loops yield insights on the factors that would help reduce the power of these loops. For the production multipliers, (a) the composition of investment, the ways the savings are invested and (b) the technology policy, the contributions of technological progress to productivity versus eco-efficiency are the fundamental concerns. For competitive production, (c) alternatives to markets and profit seeking business enterprises are critical in alleviating the growth imperative.

These dynamic insights are in line with the demands of the sustainability and justice movements. Worldwide, environmentally concerned and motivated people are demanding governmental incentives for a shift in the composition of capital investments from fossil fuel to renewable based alternatives, research enterprises are working on eco-efficiency improvements in resource use and waste deposition, environmental management activities are working for better monitoring, assessing and regulating the pollutants, and environmental and social justice movements are demanding alternatives to markets and profit seeking corporations.

V. FUTURE WORK

The interplay between desired consumption and production can further be analyzed to integrate the two models and yield further insights on the growth imperative. What determines the desired consumption, together with the factors cited above, is the innovation, product development and marketing of the businesses driven by the quest for securing or increasing their shares in a market, where all others compete for the scarce costumer base. Therefore, desired consumption is driven by desired production of the businesses. Similarly, what influences desired production, together with the factors cited above, is the vulnerability and responsiveness of the consumer citizens to innovation, new products and newer life styles. Arguably, desired production is driven by the desired consumption, although apparently the influence from production to consumption is more relevant.

The big picture provided in this analysis can be enriched by working on other big pictures aiming to delineate the factors of finance, state, and security: Finance, by regulating the savings, creating opportunities for deficit investments and consumption and by detaching the claim on wealth (money) with the actual wealth (the material environment and the skills) can influence the course of growth in economic output. Different finance models prioritize different investment categories and shape the resulting environmental impact created by production and consumption. Given the current metrics of national progress, such as the gross national product (GDP), state is identified as the sole actor with an explicit desire for growth in GDP terms, so as to secure employment and provide income for the impoverished, without disrupting the established political and economic power in the system. Moreover, the state is part of a bigger game, namely the interstate system where all other states fight for power and supremacy generally acquired by higher outputs in GDP terms, tax revenues, bigger populations and military spending, and facilitated by trans-boundary regional and global conflicts. Lastly, social conflicts arising from intra-generational equity problems drain economic, intellectual and community resources otherwise can be utilized to fight against long-term sustainability problems threatening the survival of humanity on earth.

Beyond this big-picture approach, system thinkers and analysts, economists, social philosophers, educational experts and scientists, intellectuals with varying expertise and social movements should focus on the singular concerns raised by the feedback loop analyses and shared by the widespread modern sustainability literature. Particularly for system thinkers and analysts, a challenging task is to deal with those problems through simulation modeling and analysis and to generate novel instruments for teaching and education in systems and sustainability.

NOTE: Complete version of this paper is available from the author.

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