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jorgen.randers@bi.no

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DYNAMIC MACROECONOMICS FOR A FINITE PLANET
A new paradigm for macroeconomic policy analysis illustrated by the Earth4All system dynamics model.

Jorgen Randers
Professor emeritus
Climate strategy
Department of Law and Governance
BI Norwegian Business School
Oslo, Norway

THE NEED TO DETHRONE NEOCLASSICAL THINKING

I give this presentation for one reason only: I wish to help dethrone neoclassical theory (NCT) as the dominant paradigm for macroeconomic policy analysis. And to replace neoclassical thinking with a new paradigm – system dynamics (SD) - which is better suited to achieve what I see as the ultimate goal: namely high wellbeing for the global majority on a thriving planet.

Neoclassical theory (NCT) promotes the idea that human wellbeing is best served by maximizing the growth in GDP and distribute the goods and services afterwards. NCT further recommends measuring GDP in a way that overrepresents the interests of the rich and underrepresents the value of public goods, that largely benefit the poor.[1]

Finally, NCT wants us to discount future costs and benefits at high (observed market) rates. All of this makes NCT unsuited to increase the wellbeing of the global majority in an increasingly crowded world. In spite of this, neoclassical theory has grown to dominate economic thinking during the last seventy years.

[1] GDP measures the sum of the value of the output from the private sector and the public sector. The private sector GDP is measured as the output of the private sector, multiplied with the price that 'people with money' are prepared to pay (the 'market price' – which does not tell that many producers get big producer surpluses and that many "have-nots" cannot afford to buy). The public sector GDP is measured as the output from the public sector valued at cost (which is largely the wage cost of public employees).

NCT was a good idea when we were poor and lived in a relatively empty world. It is suicidal in the current world, where every move seems to have an impact on everything else, and where the human footprint is already huge relative to planetary boundaries.
NCT does not give useful guidance on what to do when the negative side effects of growth – more environmental damage, more inequality and more social tension – starts overwhelming the benefits from further growth. NCT simply reiterates the dogma of maximum growth in GDP – which obviously cannot be the right policy advice when we know that more output leads to more environmental damage, more inequality, and more social tension. We need better guidance on how to navigate the troubled and rapidly changing waters ahead.

NCT cannot give such guidance. NCT gives advice about what should be done to increase the growth rate in GDP – in a stylized economy near equilibrium. NCT was useful when we were poor and lived in an empty world. At that time a bigger pie could make everyone better off – if properly distributed. No longer so. Today, in our much fuller world, a bigger pie may cause more intangible disadvantage than tangible benefits.

This paradigm shift – the shift from NCT to a new perspective on global development – is urgent. People already feel the negative side effects of current growth and look for solutions – not more of the same, but a credible alternative.

We need a new theory, a new paradigm, that does not only handle output growth, but also handles inequality, environmental damage, and social tension as integral elements of the theory. A theory that does not optimize a simplistic linear approximation to the real world but simulates the effect over time (the dynamics) of policy proposals – in a realistic non-linear representation of the real world, far from equilibrium. In short, we need a tool to that is capable of forecasting the future consequences of (contemplated) policy change in a rapidly evolving world.

Luckily such a theory/perspective already exists. The simulation-based system dynamics paradigm has matured during the last fifty years. But it has always been, and still is, fiercely opposed by the many who believes in NCT. Which is natural: Neoclassical thinkers do not want to lose their position as the chief suppliers of wisdom. And certainly not to a competing paradigm that does not respect/support the pet dogma of maximum GDP growth, free trade, low taxes, and a small state.

We know from history that paradigm shifts take a lot of time – generations. But once the shift starts, it normally happens fast. Furthermore, we know that the shift typically starts when the old paradigm is no longer able to deliver what it promised – in our case when NCT is no longer is able to deliver higher incomes for everyone, without bothersome externalities.

The current waves of extreme weather, social tension, political stalemate and national breakdown may be the force that finally brings down NCT. And help introduce an alternative guide to global policy making – what I like to call “dynamic macroeconomics for a finite planet”. This alternative is a simulation paradigm, tracking developments over time in response to policy shifts, instead of finding the theoretical equilibrium with the highest GDP.

In the following I present the basis for my view in more detail. I use a mild tone – in spite of the urgency – in the hope of communicating across the abyss to the NCT majority. I don’t want to speak only to the converted – the rising minority of heterodox economists. My goal is to accelerate the shift from neoclassical thinking to system dynamics thinking.

THE THREAT OF DECLINE IN HUMAN WELLBEING

1. Looking fifty years ahead, I see accelerating change and rising frictions – between man and nature, among nations, and within nations – in a world that is getting ever fuller.

Figure 1 Change and frictions in an ever fuller world
(Source: owen.gaffney@nobelprize.org)

Unless there is truly extraordinary action. I believe human wellbeing will decline– because of rising environmental damage, rising inequality, and rising social tensions. The main reason is that the human footprint has become very big relative to the carrying capacity of planet Earth.

The growth in the human footprint is a result of successful pursuit of growth in output (and GDP) – which served us well while we were poor, and the world was relatively empty – say until 1970. Since then, world has gotten ever fuller. Today the world is so crowded that most policy action has unintended side effects – both in the short term and especially in the long run.

2. Recently my colleagues and I wrote the *Earth for All* book[2]. The book describes what will happen over the next fifty years if we continue conventional decision-making practices – including the continued focus on growth in GDP.

High lights from the NEA scenario (see Figure 2), which assumes there is "no truly extraordinary action"

- Pop peak around 2050
- GDP growth, but at slower rates
- Rising inequality
- Continued warming and biodiversity loss
- Rising social tensions
- Declining wellbeing – because of the negative side effects of growth
- Huge regional variation

[2] For much more information see www.earth4all.life/the-science

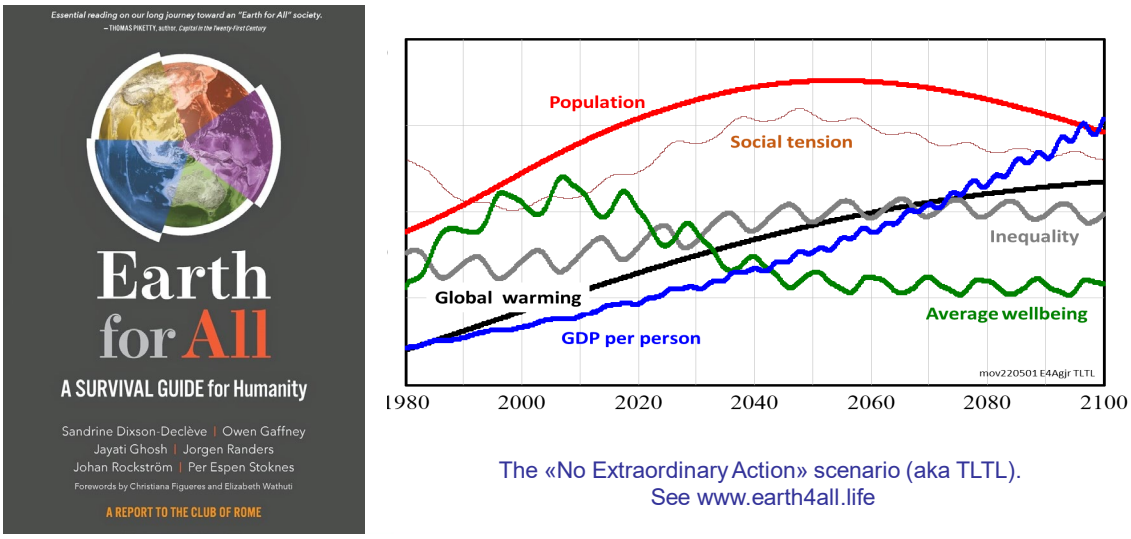

Figure 2 Main trends in global development in the "No Extraordinary Action" scenario of the Earth4All global model. (NEA aka TLTL)
Source: www.earth4all.life/the-science

It is not obvious what should be done to improve the future outlook. But it is clear that it will not suffice to maximize growth in GDP. Something else must be done if we are to reach the goal of increased wellbeing for the global majority.

3. The main conclusion from *Earth for All* is that pursuit of conventional policy will lead to higher GDP, but lower wellbeing for the majority. This decline – if allowed to continue for decades – may trigger local social collapse.

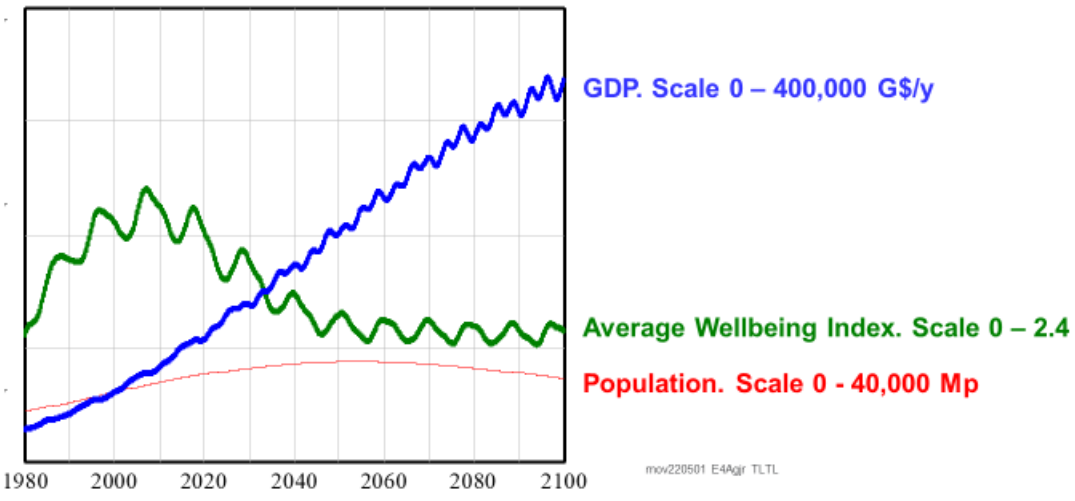

Figure 3 GDP growth leads to wellbeing decline - World 2020-60
(Source: mov220501 E4Agjr)

The reason is obvious, the negative externalities of continued growth become so strong that they overwhelm the benefit from increased consumption.
Social collapse – national breakdown – may occur if the decline in wellbeing is allowed to continue so long that it erodes public trust in the government's ability to solve problems.

It is not straight forward to tell what could be done, beyond the simple advice that one much avoid the decline in wellbeing.

REQUIREMENTS FOR A NEW PARADIGM

4. In an increasingly crowded and turbulent, where everything affects everything else, one needs a new way to explore the consequences of policy action.

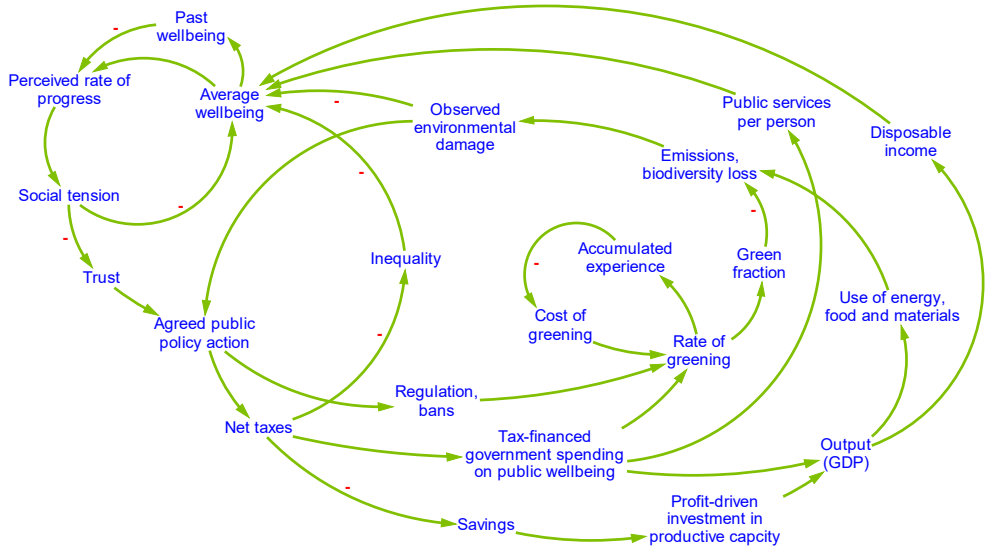

Figure 4 1causal loops in Earth4All model

The policy challenge is accentuated by the fact that everything depends on everything else. We need a tool to help decide whether proposed policy action will indeed lead to rising wellbeing for the majority. And a tool that help demonstrate that continued maximum growth in GDP according to the recommendations of neoclassical theory does not lead to increased wellbeing.

5. It is no longer enough to study the effect of proposed policy on GDP. One must study the effect on all variables that influence human wellbeing in a major way.

1. Worker disposable income per person – after tax and transfers
(in 2017 PPP $ per person per year)

2. Public spending per person
(in 2017 PPP $ per person per year)

3. Inequality
(Owner disposable income divided by worker disposable income)

4. Environmental damage
(Global warming in degrees Centigrade since 1850)

5. Social tension
(The rate of decline in wellbeing during last 5 years)

Figure 5 The 5 components of the Earth4All *Average Wellbeing Index*.)

In the past focus on GDP was a practical guide to increased wellbeing. It is till useful in large parts of the world. But once a nation is moderately affluent, other aspects of wellbeing become more important: Inequality, social security, participation, environmental quality, the feeling of progress. See Figure 5.
The negative externalities of single-minded pursuit of higher GDP are so strong that they must be made an endogenous part of the analysis of optimal policy.

6. It is no longer enough to use linear thinking and estimate the effect on a final equilibrium. One must accept the reality of circular causality and the need for new mathematics (differential equations instead of linear algebra).

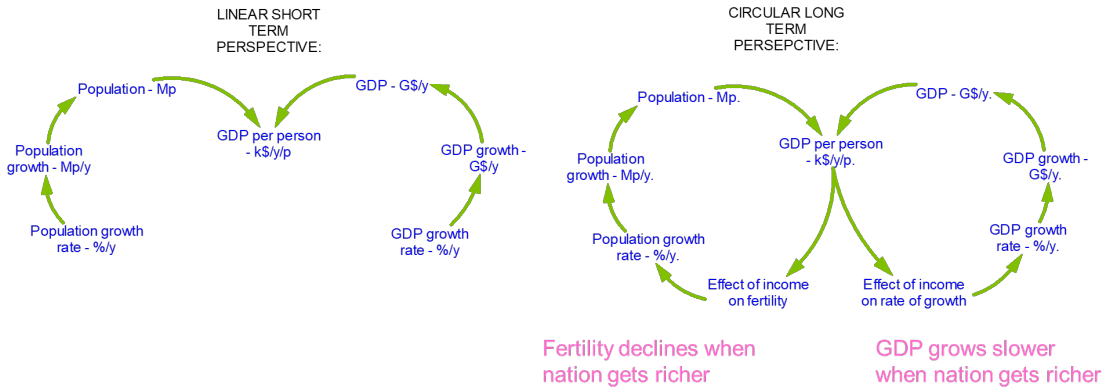

Figure 6 GDP per person is determined by two feedback loops

An example (see Figure 6): In order to forecast the future path of GDP per person, one way is to forecast GDP and then Population size, and then divide the two. This is the conventional linear short-term approach. But this approach disregards the fact that the growth rate in population and the growth rate in GDP are both influenced by GDP per person. To obtain a better model of the real world, it is necessary to close the loops in the figure.

To unravel what this model says about the future, one must make the (more complicated) calculation of what will happen when the growth rates of the two loops depend on GDP per person. This is hard to do by hand, but easily done using computer simulation. It requires differential equations, which are normally not solvable in closed form.

7. It is no longer enough to study the effects of policy change in the short term (<2 years). One must lengthen the time horizon to cover the feedback effects triggered by the first move.

Normally a social system generates feedback effects in response to the initial trigger/the initial policy shift. This feedback response often softens the initial reaction but may even reverse the direction of its impact. Analyses must go far enough in time to clarify the long-term feedback effects.

An example (see Figure 8): What happens if you increase the savings rate? In conventional linear analysis, the shock moves along the following chain of events: savings rate->savings->investment. But in the fuller long term perspective the shock continues via investment->capacity addition ->capacity->output->GDP->income which in turn closes the loop through demand->savings.

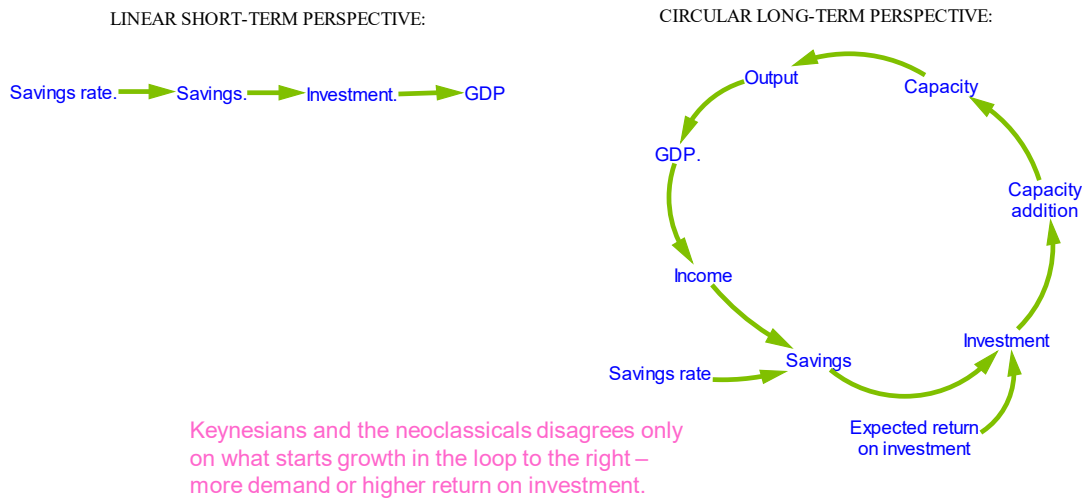

Figure 7 16 Linear versus circular causality
(Source: cld230925 Population structure)

Thus, the linear conventional view is part of a causal loop – a circular causality. This loop generates growth or decline when disturbed by an external shock, depending on the gain in the loop. In a smooth or oscillatory manner, depending on the delays in the loop.

8. It is no longer enough to study (economic) flows. One must track the changes in the relevant stocks, since normally it is the accumulated stocks that determines what happens next, not the current flows.

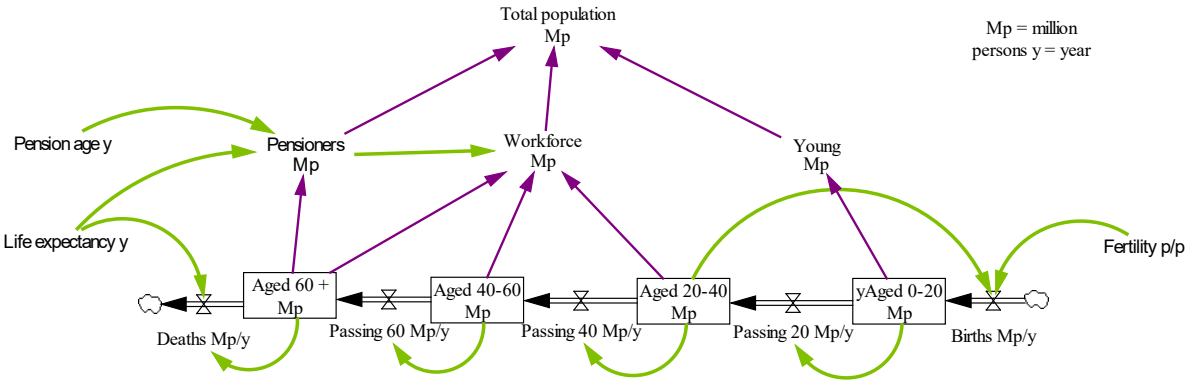

Figure 8 Stocks and flows in population growth.

An example (see Figure 9): Births accumulate increase the number of young, who age via the working age categories, into the number of old – which is reduced over time by deaths. If the birth rate declines and life expectancy increases – as they do now – the effect on the working age population is complex. The dependency ratio (= number of young plus the number of old divided by the number of in working age) rises but much more slowly than the number of old divided by the number in working age. The latter is easily reduced by a higher pension age.

The number of births per year is mainly determined by the number of women in the 20-40 age group. It is stock (state)-determined, not rate determined, like most social systems.

9. It is no longer enough to rely on economic data (time series in dollar terms). It is always helpful – and sometimes necessary – to supplement with non-economic data (physical flows), and even very-hard-to-quantify (soft science) data.

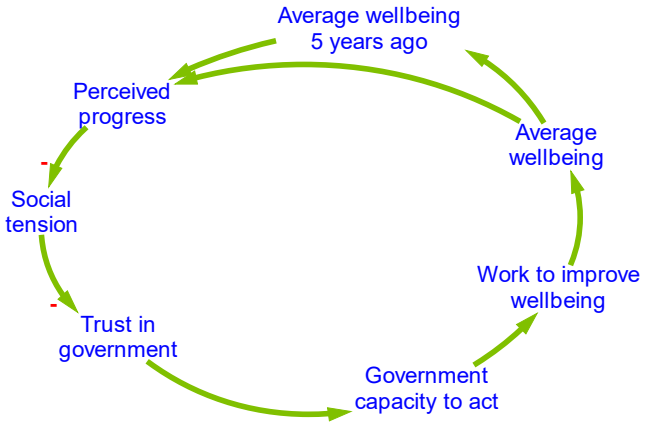

Figure 9 The vicious cycle of rising tension (causing social collapse).

An example (see Figure 10): I believe the risk of societal collapse is influenced by causal loop in the figure. Social collapse – national breakdown, insufficient public support for government action – may occur if wellbeing declines for so long that the public tires and loses trust in the government's ability to solve the problem. This further weakens the ability of the government to act, worsening the crisis, lowering wellbeing, increasing social tension, lowering trust, and further reducing the ability of the government to act.

10. It is no longer enough to study/build theory on historical correlation. The focus must be on the underlying causality – cause and effect relationships.

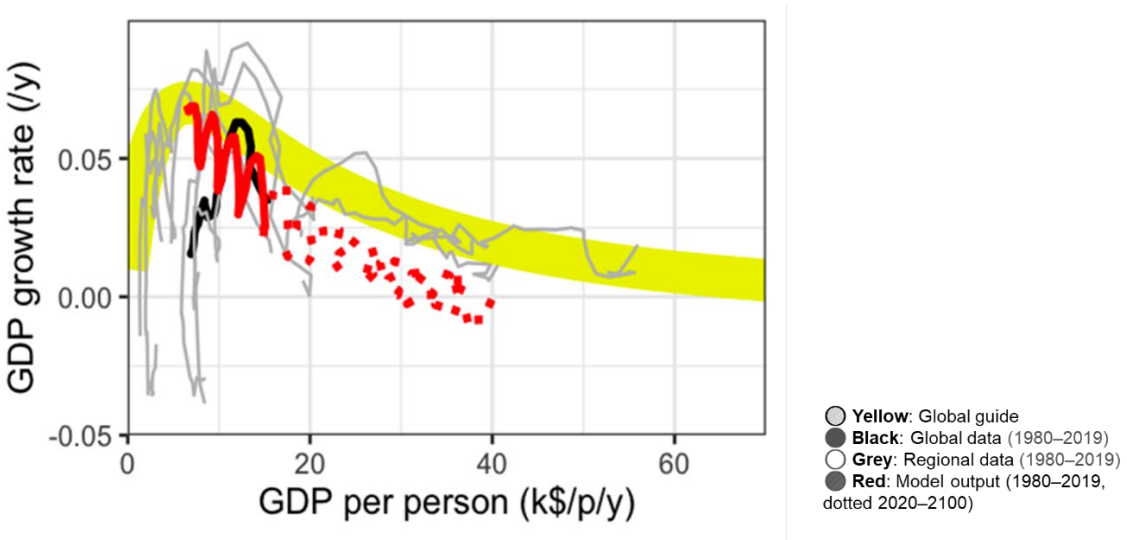

Figure 10 GDP growth slows when a country gets richer – regional data. (Source: www.earth4all.life plus private communication Felix Barbour and David Collste, 2023

An example (see Figure 12): Many believe that the growth rate in the economy is determined by exogenous technological advance – say 1 %/y. Closer scrutiny shows that the growth rate in GDP per person declines as nations get richer. This is not only a correlation, but a causal relation caused by slower growth in labour productivity when rich nations expand the fraction of their economies in services and care.

11. It is no longer sufficient to assume a linear response to an input. The real world includes non-linearities – which tend to dominate system behavior when the system is pushed against limits.

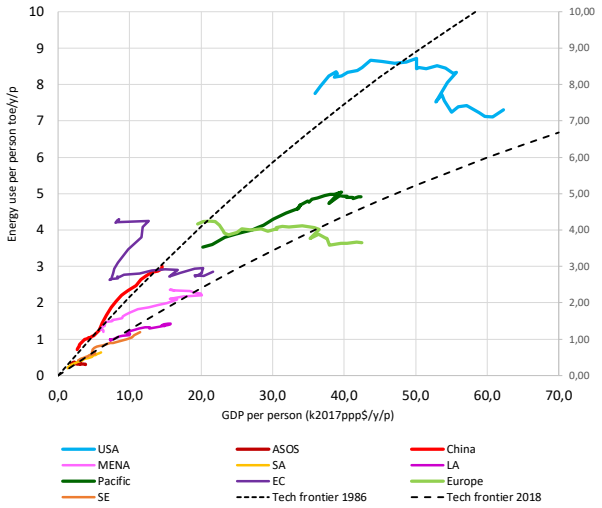

Figure 11 Total energy use per person (in tons of oil equivalents per year per person) rises with income, but stagnates and even declines at very high incomes. Data for 10 regions from 1986 to 2018.

An example (see Figure 11): Most analysts believe that energy use increases with income and GDP per person. But in fact the relationship levels off at higher values of GDP per person, and this has enormous influence on rational forecasts of future energy use. In fact, the energy use per person in the US has declined since 2005, in spite of rising incomes.
Non-linearities become important when the system is strongly forced (for example by physical limits) and often shape the extreme behavior modes of the system.

SYSTEM DYNAMICS AS A NEW PARADIGM

12. There already exists a practical and mature method for the study of complex systems – system dynamics. SD could become the mainstream guide to better policy, but is fiercely resisted by NCT.
System dynamics is fully capable of handling the requirements to the new paradigm listed above.
System dynamics has existed since 1980 as user-friendly software running big models on small PCs in seconds. But the system dynamics perspective/paradigm meets significant resistance because it violates central dogma in neo classical theory (the equilibrium perspective) and method (linear optimization based on observed correlations in numerical data)

13. The strength of system dynamics paradigm is illustrated by the Earth for All model of human wellbeing on a finite planet towards 2100. The model helps clarify the consequences of radical policy to stop the decline in human wellbeing.

Figure 11 24 Total energy use per person (in tons of oil equivalents per year per
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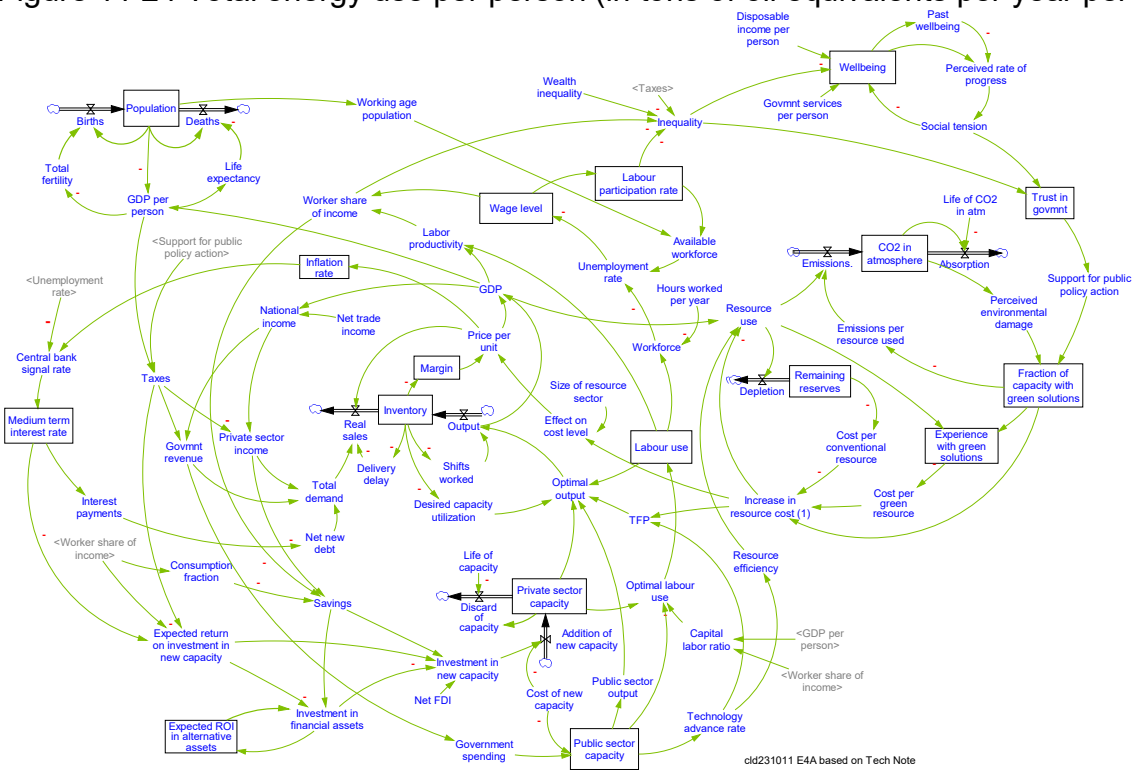

Figure 12 Aggregate causal loop diagram for the Earth4 All global model (Source: cld 231011 E4A based on Tech note)

Earth4All is an integrated global assessment model, built top-down and including both a representation of the Human world and of the Natural world. Expressed partly in physical units and partly in economic units. Fully capable of testing the effect of conventional macroeconomic policy changes. Not only on GDP, but on future size of the workforce, debt levels, environmental damage, inequality, social tension and so on.

1. Eliminate global poverty
Use new growth models: more plan less market

2. Reduce inequality
Tax the rich to pay for higher wellbeing for the working majority

3. Empower women
Free education, health, contraception and opportunity to all

4. Halt biodiversity decline
Shift to carbon-positive agriculture to protect remaining forests

5. Stop climate change
Replace fossil energy with sun, wind, efficiency, and CCS

Figure 13 Five turnarounds to increase the well-being of the global majority.

In the *Earth for All* project we wanted to find ways to halt the decline in human wellbeing, which is what we expect unless there is truly extraordinary action. We ended with five policy proposals – 5 transformative actions – shown in Figure 13. They are well known and not very surprising. They are Eliminate global poverty, Reduce inequality, Empower women, Halt biodiversity decline, and Stop climate change. All by 2050.

But the 5 transformative actions have never been implemented, and we wanted to know more about the consequences of doing so. Therefore, we implemented the 5 actions in the Earth4All model – as parameter changes reflecting the necessary policy change. For example, reducing climate gas emission through more renewable energy, reducing inequality through transfers from rich to poor, reducing poverty through increased use of industrial policy in non-industrialized countries, and so on.

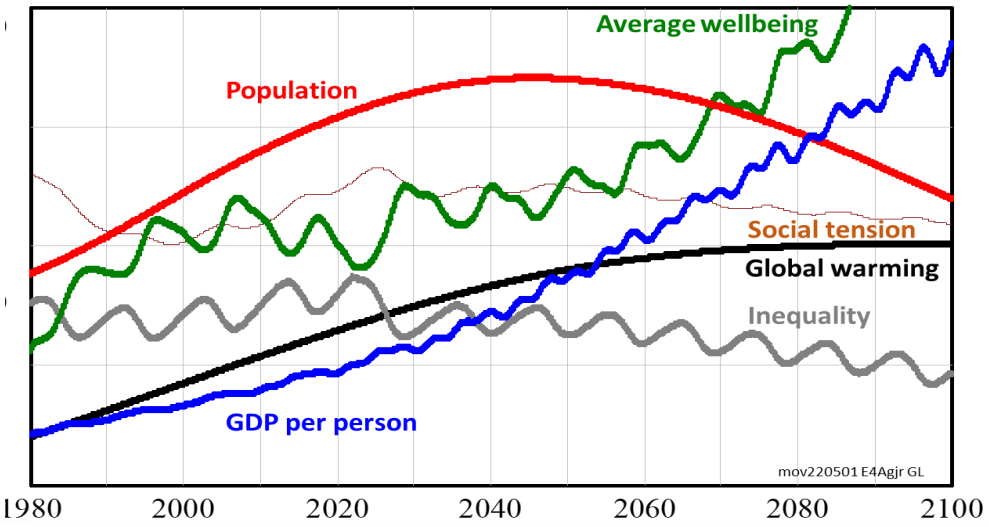

Figure 14 Main trends in global development in the “Giant Leap” scenario - Earth4All model (Source: www.earth4all.life/the-science)

The model keeps track of the numerous effects of such policies and shows that they do indeed lead to increasing wellbeing in the model system. It is important to stress that the uncertainty is huge – only the major shifts in trends are reliable. And ought to be explained in words.

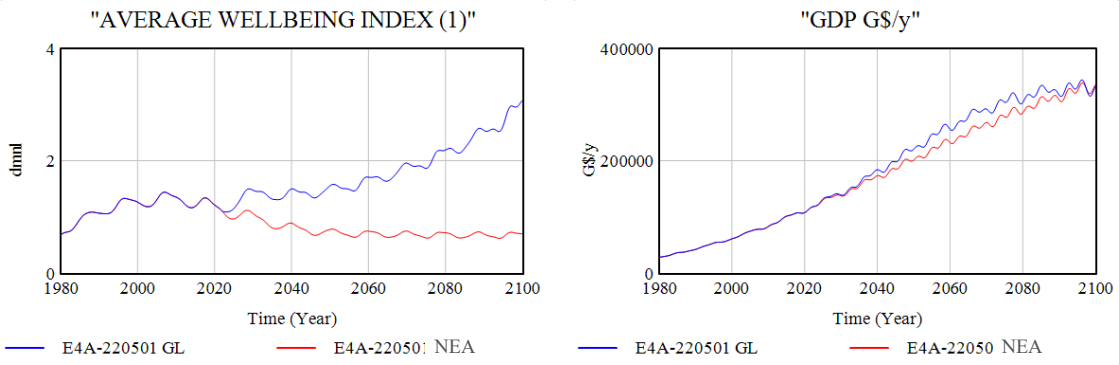

Figure 15 Comparing two scenarios: “Giant Leap” (GL) and “No Extraordinary Action” (NEA) (Source: www.earth4all.life)

The model is useful because it enables one to compare how all the variables in the two scenarios.

14. Neoclassical theory is not suited to describe the real world in a manner which is useful for long-term policy making. System dynamics simulation can help.

The world system is not unidirectional system where A causes B causes C causes growth in GDP. The world system is a dynamic system full of feedback and circular causality. And hence cannot be well described as a set of linear equations with a computable equilibrium. The world system is much better described as a set of differential equations, which can only be solved through computer simulation.

Policy makers need more than a recipe from NCT about how to maximize GDP growth in a future equilibrium (which normally will have shifted before we arrive there). Policy makers need a tool that is able to track the development over time of important system variables - as the system moves evolves into the future. System dynamics is one such tool.

THE FUTURE OF THE NEW SYSTEM DYNAMICS PARADIGM

15. The best way forwards is peaceful coexistence between SD and NCT

I do not believe that the small minority of heterodox economists will win an early victory over the well-established neoclassical macro paradigm (NCT). Therefore, I suggest that system dynamics should be introduced as a supplement to NCT. The two can beneficially be used in parallel, as tools in global and macroeconomic policy making.

In practice this would mean to allow young system dynamics professionals into the teaching of macroeconomics. But this may be too hard for the newcomers, and thus the building of parallel academic structures may be the only way ahead. This is expensive and will take a lot of time.

16. Promising sign 1: Increased willingness to deviate from NCT dogma

Since 2000 we have seen political will to deviate from NCT dogma (= no subsidies, small state, lower taxes):

German subsidies to renewable energy
Norway subsidies to electric cars
UK subsidies to offshore wind
US support to *domestic* renewable capacity
EU protection of *domestic* industry by a Border cost adjustment on carbon intensive imports.

Subsidies are paid for in different ways – borrowing, taxes, printing money, typically shifting the burden to future generations. But this is necessary in order to make them politically acceptable today.

17. Promising sign 2: Theoretical innovation led by practical policy making.

Political practice may lead to theoretical developments (like experimental results in physics forced a revision of Newtonian mechanics).

For example: Modern monetary theory was placed center stage by the UK Central Bank Carney a decade ago.

Some nations (WeGo, WeAll) are exploring alternatives to maximum GDP growth. Other nations are putting in place deliberately inefficient policies (industrial policy, trade limitations) in order to improve wellbeing, even when it reduces GDP growth.

18. We may live to see the introduction of system dynamics as a competing paradigm for global policy making.
Perhaps under the label "Dynamic Macroeconomics for a Finite Planet" to highlight its focus on dynamics, its broader scope, and its macroeconomic roots.

We need a good tool for reliable policy analysis