ECO-ECO-SYSTEM DYNAMICS

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ABSTRACT

The United Nation's promotion of Sustainable Development Goals (SDGs) requires researchers and practitioners involved in planning and policy making to take fuller account of dynamic interactions. Rio '92 and the Millennium Declaration supported "integrated assessment models" for long-term policies. Most work still relies on conventional economic relations (e.g. Stern Report)[2] that monetize some environmental and social variables, but are unclear about the dynamics of natural resources essential for economies and societies. The global economic ecosystem's complexity requires an integrated, multidisciplinary, systemic approach to make sustainability policies. System Dynamics provides an ideal basis for such models by incorporating real world causal relations, cross-sector effects, change in resource stocks, and long-term effects of continuing business as usual compared to the effects of assumptions about environmental shifts and new policies More extensive use of it is needed to give politicians an integrated long-term outlook by incorporating the interactions between the economy, society, and ecosystem so they can generate sustainable policies. System dynamic modeling must address these relations more completely; convince more people to use these models; and convey the results to politicians. The Millennium Institute's Threshold21 model includes analysis of SDGs and sustainable development strategies -- a major step towards eco-eco system dynamics.

INTRODUCTION:

The United Nations called on member states in Rio +20 to reach an agreement on a new set of Sustainable Development Goals (SDGs). This sends a strong message to the development planning community -- researchers, modelers, and decision makers -- to build models that take much better account of the full range of factors on which sustainable development is based in order to provide better analysis for more sustainable policy making. Following the UN Conference on Environment and Development in Rio in 1992, the Millennium Declaration for the Millennium Development Goals (MDGs), and subsequent programs to address sustainability, there has been discussion about the development of the so-called "integrated assessment models" for long-term evaluation of policy options. In practice however, the major modeling work on this (e.g. the Stern Report)[2] still rely fundamentally on a largely economic framework and approach to modeling. Beyond the normal economic relations, they include some variables outside the economy, but they are based on conventional monetary valuation. They show that the economic costs of not doing things like mitigating Green House Gas (GHG) emissions can be high over time, and the benefits of shifting to things like renewable energy will

[1] Valuable assistance was provided by Matteo Pedercini and Ade Onasanya of the Millennium Institute

[2] Stern, Sir Nicolas. 2006. Executive Summary, Stern Review on the Economics of Climate Change, New

[2] Stern, Sir Nicolas. 2006. Executive Summary, Stern Review on the Economics of Climate Change, New Economics Foundation

pay off over time compared to business as usual at a reasonable discount rate. However, such monetization does not address many critical, ethical, and broader eco-system sustainability issues, and it only takes account of direct effects, not indirect ones. It thereby tends to obscure the actual dynamics of how the ecosystem and natural resources are related to our economy and society and how they constitute the foundation of our development. Taking account of these relations has become more critical for maintaining the capacity of the ecosystem to support the increasing burden our expanding global economy and population will place on these resources over the next decades and beyond. The UN group working on the SDGs have stressed the necessity of taking account of the relations among the economy, society, and environment, and need more tools to do so.

Environmental models have been developed in parallel with the economic ones. Many are used to support the IFCC studies, which highlight the challenges faced in relation to environmental issues such as climate change and resource depletion. They make projections based on continued business as usual (BAU) economic activity and then indicate the changes needed in certain economic outputs, like reduced GHG emissions, to increase the chances of sustainability. This leads to recommendations to shift policies to achieve some of their goals, like increasing renewable energy use or accepting crop shifts due to climate change. But it does not take account of further relations and feedbacks with more economic and social factors.

While both of these modeling approaches address many of the same sustainability issues, like causes and changes needed to avoid serious problems such as excessive climate change, they focus primarily on direct effects within their own economic or environmental relations. One example was the early promotion of corn based ethanol as a beneficial way of replacing fossil fuel use with renewables to reduce emissions. The initial economic models considered only the cost of growing corn and extracting the ethanol. They did not take full account of the emissions of all the related farm activity, production of fertilizer, etc. When the full life cycle results of corn ethanol production and the lower miles per gallon of ethanol compared to gasoline were included, the more complete analysis showed that the overall effect would be a net increase in CO_2 emissions per mile driven. The environmental models took account of the full production elements related to corn based ethanol, but they did not consider the longer term effects of the increased use of corn for ethanol would have on food availability, which would be reduced and lead to higher food prices as more corn was shifted to ethanol production. Fortunately, both of these issues were raised by people who had a more integrated view, and this has reduced, but not totally eliminated, the production of corn-based ethanol.[3] While some models do take account of first step direct effects beyond their own sectors, it has become increasingly clear that a truly integrated, multidisciplinary approach is needed to represent the actual nature and dynamics of how our eco-systems, economies, and societies interact over time, to provide a more coherent and consistent understanding of challenges that need to be addressed, and to help policy makers cooperate to reach agreement on more sustainable policies.

[3] Political interest groups supported by those who make money from the corn based ethanol also have worked to maintain its use.

System Dynamics is a highly innovative approach to modeling that offers an ideal platform for the development of integrated and multidisciplinary models. It offers a solid basis for the analysis of factors that underlie the proposed SDGs, for analyzing the full cross sector effects of policies to achieve the SDGs, and for monitoring and evaluating progress being made by the sustainable development strategies. It has been developed over the past 50 years and has been used in a number of interesting areas. A broadly promulgated example of applying system dynamics to address such sustainability issues in an integrated manner is the Millennium Institute's Threshold-21 (T21) model, which has been implemented in more than 35 countries to help them create and implement strategies to achieve the Millennium Development Goals (MDG), adapt to climate change, and improve welfare in a sustainable manner. Several examples of its use are described in Boxes below. The model has also been adapted globally in UNEP's Green Economy Report to show how shifts to 'greener' investment can improve economic results over time. This Green Economy approach is now being applied nationally in developing countries.

It is clear that System Dynamics has highly advanced features that will make a major contribution to the extension of integrated modeling to help define and achieve the SDGs and help countries create sustainable policies. The application of its real world causal relation process contributes a lot to learning about how factors interact, directly and indirectly, and highlights these factors to policy makers. It takes account of more cross-sector relations and facilitates the incorporation of detailed sector studies and views of participating sector experts, which contributes to building more cooperation. It can also provide a longer term view than most other models. This contributes a great deal to understanding the real world relations being modeled and illustrating where there are positive and negative effects several steps through the causal process and into other sectors. This goes beyond most orthodox economic modeling, which tries to adapt the model to the theoretical views of the economic relationships being modeled and takes little account of results that go through non-economic areas. Despite its use in a number of areas and some useful application of system dynamics in policy making system, dynamic modeling has not yet reached a level of use where it has a consistent impact on public policy makers or their economic and other advisors. In view of the critical impact economic development has had and will continue to have on the environment, it is increasingly important to be able to take account of the interaction between the economy and the ecosystem. System dynamics can increase people's capacity to do this. More effort is needed to do eco-eco-system dynamic modeling and to expand its use in both academia and the political world. ISDC and other system dynamic groups can help achieve this.

WHY SYSTEM DYNAMICS IS VITAL:

This modeling approach moves well beyond conventional models in a number of ways. This paper will focus primarily on comparisons with socio-economic modeling, and to some extent with environmental modeling. Much progress has been made in most modeling techniques over the past decades, and vast advances in computer technology have permitted much more complex models to be created and run quickly. However, many shortfalls remain.

Briefly, established economic models are based on translating economic theory into a quantitative framework. Simple ones tend to be linear (or exponentially linear) to show the effects of different growth rates of the main variables on the major economic balances, but they include little, if anything, about the interactions among the economic sectors. These include the IMF and World Bank accounting and RMSM.. models. They generate little useful information beyond the short term, and that is even more illustrative of the effects of different assumed growth rates than descriptive of the real causal relations in the economy. They take account of only a limited number of economic relations focused on budget, investment, and trade balances, and they do not include social or environmental factors in generating their projections. They are based to some extent on econometric determined correlations.[4]

More advanced models, such as computable general equilibrium (CGE) models, take much more account of the economic relations among the economic sectors included. Extending the early Input-Output models, CGEs include exchanges among a number of economic sectors, investment, consumption, the government, and trade, which cover a large number of markets. This involves creating a large matrix showing the flows from all the producers, consumers, etc. to and from each other. The flow in each cell in the matrix is then converted into an equation that in the context of a simultaneous solution to the whole model will determine the supply by the provider, the demand by the user, and the price of the exchange that will balance the supply and demand in that market. Their overall solutions generate balanced market equilibria in all cells of the matrix where exchanges occur and are based on achieving an optimum equilibrium for the overall economy. The optimum is typically defined as maximizing GDP, and may be subject to constraints about minimum or maximum acceptable values of some variables. Typically, the CGE model is solved to compare the optimum results of different policies or other assumptions with the base case set of policies. This is a comparative static result that provides useful information about how optimum GDP and all the other variables that will shift as a result of the policy changes tested. However, the process does not show the path of the changes that occurs for any variable, just the comparison of "instantaneously calculated" equilibrium values between the two solution of the model. It also does not show how long the transition will take, since it assumes that all markets will reach the new equilibrium instantly.

Progress has been made to further reflect reality in CGE models, partly to better address MDG goals. These CGEs are referred to as MAMS.[5] They are designed to include a number of the MDG targets from the social sector and generate scenarios over time, using one year intervals, They assume that markets don't reach equilibrium instantly, but

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[4] I helped develop the RMSM model of the World Bank many years ago and have analyzed many applications. I also reviewed many of the IMF models in countries I was working on.

[5] For example, Aid, Service Delivery, and the Millennium Development Goals in an Economy-wide Framework, by François Bourguignon, Carolina Diaz-Bonilla and Hans Lofgren of the World Bank, July, 2008

provide an exogenous assumption about how close the market will move toward equilibrium in each sector in each period. They also provide 'rules' about what changes will occur in the base input set of variables in each period going forward. These would include exogenous assumptions about such things as the population growth, and endogenous changes resulting from the value of some variables in a period, such as net saving, which is carried forward as new investment into the next period, thereby increasing the capital stock and output capacity. These models also include factors like education, health, access to water in what are called MDG production functions that can be incorporated into the economic base of the MAMS model. These versions of the CGE models produce better results and show year by year shifts in all variables as they approach optimization, but still are quite limited in the links between the social and environmental factors that affect and are affected by economic development.[6] They also are based on the assumptions that economies will always tend toward a stable equilibrium, have unlimited access to necessary resources (unless limits are specified in the model) or generate substitutes efficiently, and can dispose of any waste. They also typically ignore what economists call externalities, which are side effects that are not included in the normal market actions. For example, a new chemical plant will generate positive GDP effects which are taken into account, but if it produces pollution in nearby streams, the negative effects of that pollution downstream on farmland, health, etc. are not taken into account because they are not part of the economic market. As economic activity becomes more pervasive and global, there are more externalities that need to be taken into account. These models take a huge amount of time and effort to construct and run, and only highly skilled modelers can really understand their relations, how they generate scenarios, and properly interpret the results.

However, these economic models remain mostly within their own narrow boxes and take little account of the relations of the economic activity with the rest of society and the world, nor of the sustainability of the development beyond certain MDGs. Conventional economic models that focus entirely on the standard economic relations underlie most analyses of proposed economic policies. In fact, many politicians and their analysts are using even more constrained models that only represent their 'partisan' views of what is the right economic policy, despite considerable lack of supporting evidence to justify the results. In addition, they typically ignore the social and environmental issues.[7]

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[6] Some models do try to include economic-type equations of social factors like education and effects of health expenditures, but these are often outside the simultaneous solution indicating change over time. One approach to create an endogenous demand for education included relations based on the assumption that consumers of education were able to estimate the discounted present value of the benefits of education (even before they had been educated) in order to determine the amount of education that is worth having compared to the value of working on the family farm.

[7] Economic models based on the assumptions of pure free markets, supply side stimulus, etc. produce policy recommendations that do not take account of the lack of validity in the real world of many of the assumptions on which such models and their results are based. In addition, they tend to ignoring social and environmental factors. So they are not justifiable to support sound policies, but are often used to support political positions of special interest groups.

Various environmental models used by IFCC and others do address many of the critical environmental changes occurring, which are often the result of economic activity, such as climate change. They estimate how things like warming are likely to affect agricultural production, drought and flooding, and other factors. But they do not take account of the feedback and interactions between the environment and the economic and social activities. They do provide valuable input that can be used in system dynamic models to further expand the eco-eco-dynamics that need to be addressed.

The rapid growth of the world's population and extensive globalization of the world's economic activity mean that a much broader set of relations needs to be taken into account. With the increased complexity and density of economic and social activity, the multitude of critical direct and indirect interrelations among economy, society, and environment factors have much more significant effects than was the case a century ago when the population was one third its current level and economic activity much smaller. It is increasingly clear than simply basing policies on the modeling of a sector or other limited area will miss critical cross sector relations and thereby will not produce the best results and may well cause serious problems for sustainability. This is why it is very important to apply system dynamics more broadly for public policy making and get the message out to the decision makers to clearly demonstrate more realistic and broader effects of different policies and the kinds of dangers that will arise in the future.

STRENGTHS OF SYSTEM DYNAMICS:

System dynamics is a much more appropriate modeling system to address these issues of achieving sustainable development of our society and economy, which depend on the limited and variable foundation of the eco-system. There are several very important aspects of system dynamics that make it appropriate for these applications. It has no inherent limitations on the variables, sectors, or time frame to be considered. This enables the modeler to adapted the structure to the key aspects of the situation being addressed. The results can be readily and clearly demonstrated to policy makers, as can the relations that lead to the results. Valid relations that the policy maker wants to consider can also be added, which can improve the model and build the confidence of the policy maker. This process is very important in that it contributes to learning more about what needs to the done to design development policies that will help better achieve more sustainable development over the long term in a highly populated world, demonstrate how achieving SDGs will positively affect overall well being while protecting the foundations in the ecosystems, and convince policy makers and the public that these policies are necessary to assure more sustainable development, so as to gain their support. The main strengths of System Dynamics are summarized below.

System dynamic models are based on real world causal relations. This information can be derived from many sources, but needs to be validated as actual causal relations, not just correlations. While these relations need to be quantitative, they do not need to be expressed in economic value terms, which allows a much more extensive and comprehensive model base. Causal loop diagrams also help understand the complexity of many of these relations much more easily than normal economic model equations, and they demonstrate both positive and negative feedback loops. Doing this causal analysis in cooperation with experts in various related areas also helps learn more about the relations that need to be taken into account and the critical steps that occur in the causal relations. See Box 1.

System dynamic models readily take account of externalities beyond the economic markets. They can include pollution and the effects it has on other factors downstream, which may not be monetarily valued. For example, the effects of the pollution on reduced soil fertility, higher illness rates, and lower worker productivity and/or higher mortality rates are likely to affect the economy over the longer term through such factors as a reduced work force and higher medical expenses. These need to be taken into account in making decisions, representing non-market based values of improving human welfare, and attaining more sustainable development.

Box 1: Mozambique

In 2004, MI applied its T21 model in Mozambique with the support of the Carter Center to help develop their Agenda 2025 Development Strategy. One of the main policies considered was constructing roads in rural subsistence agricultural areas to give farmers more access to markets for inputs and to sell their crops. Incorporating detailed information from the Agricultural and Transportation Ministries, the model showed how over time, incomes would increase in the areas with access to the newly build roads – reducing poverty. It also showed improvements in urban incomes and agricultural exports due to the increased production and commercial activity. However, when this was discussed with a broad based group of policy makers, the Health Ministry pointed out that increasing the roads and commerce on them would be an increase in HIV/AIDs infections. Based on their studies, these factors were included in the model, which then showed the negative social side-effects of the roads, as well as the positive economic results, which were now lower due to the labor force reductions and increased mortality in affected areas. As a result, policy makers got together to incorporate HIV preventative measures and treatment capacity into the road building program, protecting the benefits and mitigating the negative side effects.

System dynamics readily takes a long term-view in its scenarios. While it cannot make prefect predictions, it does illustrate likely longer term paths of all the variables, which may shift from continuous trends typical of most economic models to tipping points and major shifts. This is very important in dealing with sustainability and environmental issues, since they are associated with long term effects by human standards, but which are quite short term in environmental periods. It is also important to be able to take account of structural changes that will occur over time and not just assume that current stable structures will continue. There are many inherent structural changes that occur – shifts in the structure of the population will affect the economy; depletion of resources (water, fertile land, etc.) will affect the bases for production; climate change will affect many things. The normal time lags for many of these results is much longer than what most humans or models are used to dealing with, but the long-term effects certainly need to be addressed if humanity is to survive as long in the future as it has in the past. It is important to take account of structural changes due to both endogenous factors in the model and exogenous ones that are likely to occur. See Box 2. And different rates of exogenous change can be run to see how sensitive the rest of the model is to the rate of change.[8]

Box 2: USA Fuel Efficiency

In 2007, MI developed a T21 model to address energy issues in the USA. It was used by several policy makers to demonstrate that increasing the CAFÉ standard of fuel efficiency would actually help the economy over time. Applying the proposed increase in the CAFÉ standard slowly increased average car fuel efficiency over about 30 years, which was how long it took for the more fuel efficient cars to constitute all of the fleet. GDP grew more compared to continuing the base level of fuel efficiency due to several factors, primarily less need to import oil and lower expenditures on auto fuel that led to more expenditures on other consumer items based on local production. This helped create more jobs and demand, which raised production. And CO2 emissions declined compared to the base case. These gains more than offset minor losses in the automobile and gasoline industries. This convinced more policy makers to support the higher CAFÉ standard, and it was passed. However, looking further into the future, CO2 emissions started going up again. The model showed that the increased domestic production that resulted from the reduction in gasoline consumption led to more use of energy by local industries, which was provided by coal produced electricity at the margin. This highlighted the need for further CO2 reduction policies and demonstrated the value of long term integrated scenarios.

These strengths illustrate the importance of using system dynamics to get beyond the economic factors and produce a more complete view of the relations among economic, social, and environmental factors. It gets out of the conventional boxes and takes account of the cross sector relations that are, in fact, how the world really functions. This approach promotes more thinking outside the box and encourages those working with the model to take account of more cross sector relations and learn from specialists in the sectors about the relations that are involved in their sectors and with other sectors. This broader spectrum of modeling is very important.

Other important key factors include how system dynamic models can be readily updated to add additional sectors and more information about existing sectors. These models produce graphic scenarios to demonstrate and compare the results of different policies and assumptions, as well as tables. This makes the results much more comprehensible to non-modelers, which includes most policy makers and the public. Such comparisons of different policies and assumptions with system dynamic models demonstrate the results of policies across many variables. This, combined with the causal link charts, helps convey the critical relations and their results to non-modelers, which can lead them to have more comprehensive discussions and generate more integrated policies. This transparency enables groups of policy makers to get together and discuss policy options and combinations of policies across different sectors beyond their normal relatoins,

[8] As the system dynamic model becomes more extensive and complex, more of these exogenous factors can be made endogenous, for example the rate of temperature increase due to GHG emissions.

sharing the ‘common policy language’ of the system dynamics model. It makes it easier to reach compromises when the overall results and benefits to the whole constituency are demonstrated. See Box 3. These factors help explain why system dynamics modeling which integrates economic, social, and environmental factors needs to be more broadly applied and promoted.

Box 3: Getting Policy Makers Together: Namibia and Bhutan

In 2011-2, MI, supported by the Japanese CCA program administered by UNDP, worked with Namibia to develop better Climate Change Adaptation policies. A meeting of major ministries and other key stakeholders was held to elicit their main concerns about CCA and possible impacts on other sectors. In discussing resources, the Mining Ministry pointed out that they would expand production of uranium mining and provide necessary foreign exchange resources. When asked what they needed to do so, they replied that they only needed more water and energy, which they did not see as a problem. The ministries dealing with water and power immediately pointed out that those were two of the most scarce resources available in Namibia and most threatened by climate change. Based on this revelation, those involved in mining, energy, and water agreed to meet and work our a mutually agreeable plan to manage water and energy for mining while not aggravating other sectors covered in their CCA program.

Earlier, MI had worked with the government of Bhutan to help them meet their objectives of improving Gross National Happiness (GNH). The government was committed to these goals more than economic growth and felt it had adequate income supported by its exports of hydropower to India. Having been involved in the development of the model to improve the government’s policies to increase GNH with much more spending on social benefits – health, education, water access, nutrition, etc. primarily in urban areas, the Strategy Directors of the major ministries met to discuss the results. One thing the model demonstrated was that since 70% of the population lived in rural areas and depended on agriculture, which would only grow at 1% pa under the proposed policies, there would be massive migration into urban areas. It was determined that this was not feasible, so the social ministries decided to shift some of their investment resources to improve the rural economy incomes in order to reduce immigration. This was done and proved successful in improving overall welfare.

MUCH DONE, MUCH MORE TO DO:

The most comprehensive indicator of the serious sustainability challenges we face is the estimate of the current level of the global foot print. This represents the amount of biologically productive land and sea area necessary to supply the resources a human population consumes and to assimilate associated waste, all in a sustainable manner consistent with the earth’s capacity to renew these resources. The current level of this footprint at 1.5 earths means that the use of global resources by our economies and societies amounts to one and a half times the sustainable amount available on the earth. We are exhausting necessary resources – effectively draining the illustrative water stock tank of system dynamic courses. But the large amounts of most of these natural resource stocks keeps most users from understanding their depletion, since they seem to be fully available in the short term.[9] However, many parts of the world already face serious problems of water availability and are encountering more soil depletion which will reduce agricultural production and weaken their food security. So some areas are beginning to understand the risks of the expanding footprint.

Probably the best known risk factor of the current economy's impact on the environment is climate change, due to emissions of GHG. This includes many indirect cycles beyond fossil fuel emissions of CO_2. As warming occurs, more methane is emitted from melting arctic tundra. And as the amount of ice is reduced in the arctic, the exposed Arctic Ocean absorbs more solar heat, which also leads to more warming and shifts in the Jet Streams that affect weather volatility in the lower latitudes. Warming also affects water availability in the rest of the world, agricultural productivity, and habitability of much land. Some areas benefit, but most don't.

Expansions of societies and increased use of agricultural land, various chemical pollutants emitted, and other behavior factors of the modern economy are threatening the habitats of many species, which increases their chances of their extinction. While not all species can or need to be protected from extinction, as a number have become extinct through natural processes over paleontological time, it is vitally important to assure many do survive because they are vital to the survival of our productive and social processes. For example, loss of bees would greatly hurt agriculture because they are vital for pollination of many crops.

The structure of the environment and mix of species will continue to change over time, but it is very important to prevent or mitigate changes in the environment and species populations that will be detrimental to continued human development and welfare. Given these increasingly vital interconnections between the economy, social expansion, and the environmental foundation, it is very important to take them into account in designing policies and in making the necessary changes in behavior patterns that will assure the sustainability of the foundations of our human systems for our children and grandchildren, not just increasing next year's income as much as possible.

The SDGs need to be designed to provide important information about changes in critical sustainability variables and to keep the public and policy makers informed about how policies and activities are affecting sustainability. The specifics of the SDGs are still being discussed. It is important for those working on them to include the key factors that affect sustainable development and preserving the environmental foundation of economic and social progress. Doing so will require taking fuller account of the relations among these three dimensions of our global structure and to take a long term view, since many factors that affect sustainability only appear after a long term in human terms, but it is essential that appropriate actions be early enough to avoid and tipping point to assure that we do not run into a sustainability abyss. There are critical tipping points that if passed will mean that certain goals cannot be achieved. Defining SDGs, developing the policies to achieve them, and monitoring how well progress is being made will require much

[9] See Global Footprint Network at http://www.footprintnetwork.org for more information about this.

more comprehensive, real world based, and long term tools than have been typically used in the past. Fortunately such tools exist in system dynamics.

System dynamic models have been used to address many of these important issues. Limits to Growth[10] raised a number of questions about the effects of continued traditional development on the ecosystem. Other models have addressed sustainability issues, including ones done by John Sterman and others at the Sloan School.[11] The University of Bergen and others teach courses on system dynamics in economics. The Millennium Institute developed its system dynamic model, Threshold 21, when its founder, Dr. Jerry Barney, learned in writing the USA study, Global 2000[12] in 1980 that different US government departments used different models with different basic assumptions about the same exogenous variables. He recognized the need for a more consistent integrated model and searched for one. After much effort, he discovered system dynamics at MIT, met with Jay Forrester and others, and was able to use system dynamics to develop the Threshold 21 model for the Millennium Institute, with much assistance from experts at MIT. Since its creation in the 1990's, T21 models have been used in a number of countries to support more coherent strategic planning, as has been discussed in the Boxes. The T21 process has also been used by UNEP in its Green Economy Report to demonstrate how shifting to green investment will improve both sustainability and human welfare.[13] But unfortunately, all of this work has only had limited effects on moving decision makers toward more sustainable policies.

This is why it is very important to become more active in promoting the systemic approach for critical decision making. Action is required at several levels. First, more basic modeling needs to be done that relates the economy to the ecosystem in adequate detail. It needs to analyze how major economic activities are likely to develop over time, how they will effect the ecosystem, and what feedbacks there will be from the ecosystem that will affect the economy and social wellbeing. These relations will be both positive and negative, and it is critical to understand which will be most important. Such modeling is not just extending existing relations; it involves studying the important cross sector causal effects that would become more clear from integrating the economic and ecosystem relations so that the modelers would learn more about the depth and direction of such relations. This improved understanding of real world relations would provide the basis for developing policies to improve the positive benefits and mitigate the negative ones over the longer term. The relations that are analyzed and indicators developed need to extend well beyond normal economic indicators of GDP and profits of special interest groups. They need to take account of expanding global sustainability indicators, including SDGs, preservation of essential environmental resources, and assuring human

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[10] Donella H. Meadows, Gary. Meadows, Jorgen Randers, and William W. Behrens III. (1972). The Limits to Growth, New York: Universe Books

[11] MIT Economics doesn't seem to have any interest, unfortunately.

[12] The Global 2000 Report to the President: Entering the 21st Century. 1980. A report by the Council on Environmental Quality and the Department of State. By Gerald O. Barney, Study Director

[13] UNEP, 2011, Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication, www.unep.org/greeneconomy

welfare. This does not mean trying to protect and preserve the environment and society as it existed in the past, but assuring that the inevitable changes in both the economy and ecosystem going forward avoid major cliffs and other factors that would undermine the sustainability of the ecosystem foundation that supports our economies and societies.

Second, it is very important to <u>get the message out</u> that more comprehensive methodologies need to be used at design and implement policies that will assure the sustainability of the ecosystem that supports our economies and societies. Too many people suppose that these problems are overstated, based on their hopes and beliefs that major changes are not necessary and on the publicity supported by special interest groups who want to protect their short term profits from continuing BAU. Decision makers and the public need to understand the broader and longer term risks posed by continuing business as usual, which many partisan groups support. While the scientific analysis of the threats to the ecosystem and climate change are well established, if not precise, the potential impacts on the economy and society over time have not been publicized clearly enough.

System dynamic models designed to address these issues can more realistically and convincingly demonstrate to decision makers and the public what is going to happen as a result of continuing business as usual in terms of more comprehensive and meaningful indicators and factors. The models produce easily understood graphic outputs that compare results of different scenarios over time and demonstrate the causal relations that lead to the results shown. They can reveal to non-modeler audiences what is likely to happen, and they can be very effective in changing people's minds -- especially where the results of past decisions on the current problems being faced can be clearly demonstrated. The boxes above give good examples of this. Based in the eco-eco-system dynamic modeling that is available and can be strengthened, it would be possible to get out the message explaining how to attain sustainable development by numerous means, including by hard copy articles beyond academic journals, by website information, and by widely circulated blogs.

Third, it is important to <u>convince decision makers and their advisors to use this systemic approach</u> in their analysis and development of viable policies. Too many of even the highly competent economic advisors still rely on conventional economic models and theory to develop policies. They rarely look out of their sector boxes to see the broader issues that need to be addressed and the impacts of the sector policies that they propose on other sectors related to the environment and social welfare. It is important that they learn to take a broader view of the effects of policies across sectors, which can be achieved if they understand how to take a more integrated view of the issues being addressed. Significant progress can be achieves by spreading the use of the systemic approach more widely in academia and managing more sharing of information and cooperation among the departmental silos that have grown up. While this greater concentration on individual sectors is partly due to the increased amount of information and details that must be mastered in each department, it needs to be recognized that this increased knowledge also means that we have the basis to understand better the relations among the sectors, which is essential for understanding how the world really functions since all sectors interact in reality. This more integrated approach is increasingly important due to the extent that global activities involving the economy, society, and environment have become more complex and interactive in today's world – and will become much more so in tomorrow's.

Reaching decision-makers can be difficult, but there have been cases where some success has been achieved, such as the Montreal Protocol and the use of Threshold 21 to convince a number of Congressmen to pass the CAFÉ increase in 2007. (Box 2) More effort is needed to inform decision-makers and their advisors about the need for more coherent develop policies, to demonstrate what policies will work best overall, and to identify the negative side effects that need to be mitigated. This will require more publicity and more means of making direct contacts with these policy making individuals to better inform them about the systemic challenges being faced by means of non-partisan models. This will help convince them of the real relations and impacts of strategies so they can build their policies on a more integrated basis, which will certainly benefit their legacy as well as the sustainability of the country.

Given the global nature of the ecosystem and the globalization of the economy, more international consensus and cooperation will need to promoted. The recent work by UNEP with the Green Economy Report is a first step in this direction. It uses a system dynamic model[14] to demonstrate how shifting 2% of global investment to green activities that reduce GHG emissions and help protect the environment will lead to an economic structure that is more sustainable in 2050 than what will happen by continuing business as usual. This model demonstrates that while there will be some slower growth in the early years of the shift to greener investments, well before 2050, GDP and job growth will pass BAU and more sustainability will be assured. The model demonstrates that there will be more poverty reduction and that in key areas like agriculture, food security, and water availability, the green investment program will assure sustainability, in contrast to the business as usual path, which will cease being sustainable soon after 2050, leading to serious problems. This is the kind of information that can be used to convince policy makers to make better policies.

Fourth, continued support for this work is vital to its success. The development of the world's economies, societies, and their relations to the ecosystem are ongoing processes that continually change. There will be no stable equilibrium or standard environmental situation. The changes are due both to human based transformations and nature based shifts in the ecosystem. It is important be able to incorporate these changes in the past into the models being used and to take account, to the extent possible, how they will continue to shift in the future. A significant part of this future change can be included in sophisticated eco-eco-system dynamic models, and they can be regularly updated as new data and causal relations become available. They can also include shifts in political and social priorities, which also change over time.

These models should remain works in progress. This will require continued support and development in academic institutions, further education of students in a broad range of

[14] The global model used is based on Millennium Institute's Threshold 21 and was developed by MI. UNEP is now promoting the use of the model in many countries to help achieve green local policies.

areas about the systemic approach, and continued presentations and dialogues with the policy makers and their advisors. This relationship needs to be institutionalized over time. One important element is to assure and emphasize that the eco-eco-system dynamic models are based on the best possible representation of reality. They need to be assuredly non-partisan, and should involve all major political interests to assure that the dynamic Eco-Eco-System approach is broadly understood, accepted, and used. The more that different groups become familiar with the models and are able to propose realistic relations that can be incorporated, the more likely they will be to accept the results of the models and reach agreements on the better policies, unless they are totally ideologically driven. See Box 4. It is important to build and continue the support base for the eco-eco-system dynamic models, incorporate a broad set of SDGs, and assure their continued expansion and improvement. And this information needs to be continually disseminated as broadly as possible.

Box 4: Bringing Together the Opposition; Jamaica

MI had worked with the Planning Institute of Jamaica (PIOJ) for several years in the early 2000's to train their staff and adapt the T21 model to their issues. They used it to develop their strategy to become a high income country. However, with an upcoming election, the Director of the PIOJ was worried that the opposition party would win, and was likely to throw out the tools used by its predecessor, including the T21 that PIOJ depended upon. So he decided to try to convince them to keep the model. He arranged a meeting with the leaders of the opposition, MI, and PIOJ to discuss the model. T21 was presented in some detail to the leaders of the opposition, and their first response was that it was just another instrument that the governing party used to prove its own points, so they had no reason to keep it. The director of PIOJ then asked them to describe what were the key policies they wanted to implement. They described five, and it was possible to run three of them in the model as it was structured. They were quite interested in the results. MI also explained how the additional policies they were interested in could easily be incorporated into the model to demonstrate the results broadly. The opposition then expressed further interest in the model and asked more questions about how they could use it. They decided it was non-partisan and agreed to continue its use in PIOJ after they were elected. And they kept the Director in place. So T21 can form a viable and enduring long term policy tool.

CONCLUSIONS:

Based on the above discussion, it is quite clear that we face serious challenges in order to achieve sustainable development and protect the earth from a major ecosystem shift that will seriously threaten the survival of our societies and economies. Current policies are not addressing most of the major challenges to achieve sustainability, and the basic modeling tools used for policy making tend to ignore most of the important non-economic issues and cross sector causal effects. So policy makers and the public are not well informed and not yet willing to make the necessary broad based changes in policies and related behavior patterns. We have seen that to the extent the public has become better informed about some specific issues and understands the risks and need for change, more people have been willing to make changes. This highlights both that more understanding of the cross sector sustainability issues and the effects of policies over time is needed and that this information needs to be much more broadly disseminated in a non-partisan manner. This fully supports the proposal to work harder to get the message out systemically, along with the need to design stronger models and build support for better policies to achieve more sustainability.

The System Dynamic approach has been demonstrated to be the most effective tool for taking account of the interactions among the society, economy, and ecosystem; for generating scenarios to illustrate what is likely to happen if no policies are changed, particularly the negative effects on the supporting environment and society that need to be addressed; and to demonstrate how more appropriate policies will assure more sustainability and protect human welfare. It is quite effective in generating useful indicators of progress toward sustainability (including SDGs), demonstrating how cooperation across sectors can address the important challenges, and indicating how to reduce or prevent the negative effects while promoting the positive ones. These results can be transparently and convincingly presented to non-modelers and non-technicians, which will help build support among the public and decision-makers, as has been demonstrated in a number of cases described in the Boxes. Thus it is very important to expand system dynamic modeling to take account of more sustainability issues; to get more academics, students, and political advisors involved in the application of these models; to get the message out to the public; and to actively promote more sustainable policies. We need to strongly encourage more development and use of Eco-Eco-System Dynamics.

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