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ANALYZING THE ROLE OF INTEGRATED, DYNAMIC, NATIONAL DEVELOPMENT PLANNING MODELS TO SUPPORT POLICY FORMULATION AND EVALUATION

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1. Abstract

With poverty, hunger and climate change issues arising over the last few years, policy makers are urged to find ways to solve critical interconnected issues. In this context, the role of data is crucial to provide all the relevant information to policy makers to allow them to act timely and find longer-term solutions.

The main motivation for the Millennium Institute's work stems from the acknowledgement that these critical issues are cross sectoral and there is a need for integrated tools to close the gap between the current linear and the required dynamic and holistic thinking. System dynamics based modeling tools are especially needed when facing issues such the climate change, poverty and hunger nexus, where the available conventional sector-detailed modeling tools are inadequate (e.g. optimization and econometric models).

These models, on the other hand, require data inputs that can be used to both parametrize and calibrate them. Parametrization helps to initialize the model correctly, and calibration allows for the refining of future scenarios. Consistent data series are therefore crucial to properly advise policy makers, as well as integrated models are essential to bring coherence to future cross sectoral scenarios.

In addition, the Millennium Institute (MI) aims at evaluating whether policy-relevant issues should be contextualized to effectively support formulation and evaluation of actions. This implies (1) the analysis of the context in which issues arise, whether they are global, regional and national, and (2) the study of various policy options that are being considered for solving social, economic and environmental issues. While the analyses carried out with conventional linear programming and optimization models are limited

by narrow boundaries and lack of feedbacks, computer simulation models based on System Dynamics can effectively support the analysis of both context and policies.

The present research work proposes the utilization of integrated models based on Millennium Institute's Threshold 21 (T21). MI's T21 models are as closely replicating reality as possible and are very powerful tools to inform policies based on "*what if*" scenarios. Being systemic and dynamic, they use statistics to highlight feedbacks and also unintended consequences, while also supporting evaluation of progress and measuring impacts.

MI's research work argues that explicitly representing the context in which issues arise, and where policies are formulated and implemented, within an integrated framework, enriches the analysis of proposed policies and provides coherence and useful insights to policy makers. Results of the analysis carried out on several case studies over the last 15 years clearly indicate the relevance of consistent statistical information to identify, among others, the likely emergence of various unexpected side effects and elements of policy resistance arising over the medium and longer term due to the interrelations existing between society, economy and environment. Furthermore, side effects or unintended consequences may arise both within one sector and in the other areas; nevertheless, these behavioral changes influence all society, economy and environment spheres.

2. Methodologies Review

Every methodology, as well as its applications, has strengths and weaknesses. These depend on the specific characteristics of the methodology (its foundations) and on the issues being analyzed (its application). For instance, when projecting longer-term energy scenarios, using exogenous assumptions on population and economic development may lead to an inaccurate analysis (Stern, 2007), especially in rapidly evolving contexts. Optimization, econometrics and simulation are here presented.

Optimization models, which generate "a *statement of the best way to accomplish some goal*" (Sterman, 1988), are normative, or prescriptive, models. In fact, these models provide information on what to do to make the best of a given situation (the actual one) and do not generate insights on what might happen in such situation or what the impact of actions may be. In order to optimize a given situation, these models use three main inputs: (1) the goals to be met (i.e. objective function), (2) the areas of interventions and (3) the constraints to be satisfied (Sterman, 1988). Therefore, the output of an optimization model identifies the best interventions that would allow reaching the goals (or to get as close as possible to it), while satisfying the constraints of the system (IIASA, 2001 and 2002).

Econometrics measures economic relations, running statistical analysis of economic data and finding correlation between specific selected variables (Sterman, 1988). The structure of the system is specified by a set of equations, describing both physical relations and behavior, and their strength is defined by estimating the correlation among variables using historical data. Econometrics uses economic theory to define the structure of the model. The quality and validity of projections is therefore highly connected to the soundness of the theory used to define the structure of the model.

While optimization models are prescriptive and econometric models are heavily relying on the history of the system analyzed, simulation models are descriptive and focus on the identification of causal relations influencing the creation and evolution of the issues being investigated. Simulation models are in fact "what if" tools that provide information on what would happen in case a policy is implemented at a specific point in time and within a specific context.

Simulation models aim at understanding what the main drivers for the behavior of the system are. In the case of System Dynamics, this implies identifying properties of real systems, such as feedback loops, nonlinearity and delays, via the selection and representation of causal relations existing within the system analyzed. The results of the simulation would then show the existence of correlations in a dynamic manner, which are the outputs of an econometric analysis. On the other hand, the main assumptions of simulation models are those causal relations forming the structure of the model: instead of using economic theories, simulation models represent theories of how the system actually works. In other words, instead of fitting existing theories to the issues being analyzed, simulation models proposed a theory of their own, highly customized and tailored around the issues to be analyzed and the peculiarities of the system.

3. Approach

The approach proposed by the Millennium Institute uses System Dynamics as its foundation, but it incorporates various methodologies, including optimization (e.g. to regulate the use of power generation plants), econometrics and economic theory (e.g. for the calculation of GDP, through a Cobb-Douglas function). As a matter of fact, a variety of factors have to be investigated when analyzing policy options for a specific geographical context, most of which are unique of the environment analyzed. Including feedback loops, non-linearity and delays in the framework of analysis requires a profound customization of the model, going beyond a new parameterization. This implies the investigation and eventually understanding of the processes that generated past changes in the behavior of the system as well as the implications of future policy implementation. The identification of such processes includes the analysis of hard and soft information, and is not as straightforward as in the case of detailed complexity analysis; nevertheless the customization aimed at representing dynamic complexity adds to the accuracy in which key indicators can be forecasted. Furthermore, the inclusion of cross-sectoral relations -social, economic and environmental- allows for a wider analysis of the implication of policies by identifying potential side effect or longer-term bottlenecks for development.

Three levels of analysis have to be considered when building the integrated simulation models presented here, aimed at supporting policy formulation and evaluation. These include: the structure of the system analyzed (integrated, through causal relations and feedbacks), possible scenarios (e.g. technological development, natural disasters), and policies (e.g. subsidies, incentives and/or mandates). How these three levels are supported with solid and coherent information, and interact with each other, will greatly determine the success of any national development plan over the medium to longer term.

Firstly, in order to design and evaluate national development policies the structure of the system analyzed (e.g. social, economic and environmental) should be properly analyzed and understood. Using the example of energy, this includes the investigation of the main drivers of demand, and how supply can respond to its needs; in the case of poverty reduction, this implies understanding what are the key factors influencing poverty and what are the main drivers for their behavior. This is a broad investigation heavily relying on soft and hard data analysis, as we are in rapidly changing times and various cross-sectoral interdependencies are emerging.

Secondly, economic volatility, as well as natural disasters and other unexpected events, can have a considerable impact on the effectiveness of energy and environmental policies over time. For these reasons scenarios have to be defined, to reduce the uncertainty coupled with the analysis carried out. Policies would then be evaluated based on the structure of the system analyzed as well on a variety of possible scenarios.

Thirdly, the implementation of policies for longer-term national development should be tested. In order to do so effectively -and evaluate whether they create synergies, bottlenecks or side effects across sectors-, their impacts have to be evaluated for a variety of social, economic and environmental indicators. Policies are “shocks” to the system, which in turn responds to these changes. For this reason, the system itself should be analyzed focusing on feedbacks and causal relations, with a specific interest on medium to longer-term impacts (which go beyond the implementation delays of policies -i.e. inertia of the system-).

To conclude, the understanding of the functioning mechanism of the system allows for the identification of medium to longer-term sectoral and cross-sectoral implications of policy implementation. These impacts have to be analyzed with the understanding that different sectors are influenced by different key causes defining the success (or failure) of policies. In other words, a policy can have very positive impacts for certain sectors and create issues for others. Furthermore, successful policies in the longer term may have negative short-term impact, for which mitigating actions may be designed and implemented.

3.1 Threshold 21 (T21)

Threshold 21 (T21) is structured to analyze medium-long term development issues at the regional and national level. This model integrates the economic, social, and environmental aspects of development planning in a single framework. T21 is created to complement budgetary models and short-medium term planning tools by providing a comprehensive and long-term perspective on development (Millennium Institute, 2005).

T21 supports policy planning in various ways, both by highlighting key development issues in the baseline scenario, and by projecting different policy choices and scenarios in alternative simulations. These results provide a good basis for the creation of dialogue and for further defining chosen policy actions, as well as for monitoring and evaluation of their performance.

The main characteristics of T21 include (Millennium Institute, 2005):

a) Integration of economic, social, and environmental factors;

b) Representation of important elements of complexity – feedback relationships, non-linearity and time delays;

c) Transparency in the structure, assumptions, equations, and data requirement;

d) Flexibility in creating customized versions of countries based on country-specific conditions;

e) Simulation of the short- and long-term consequences of alternative policies; and

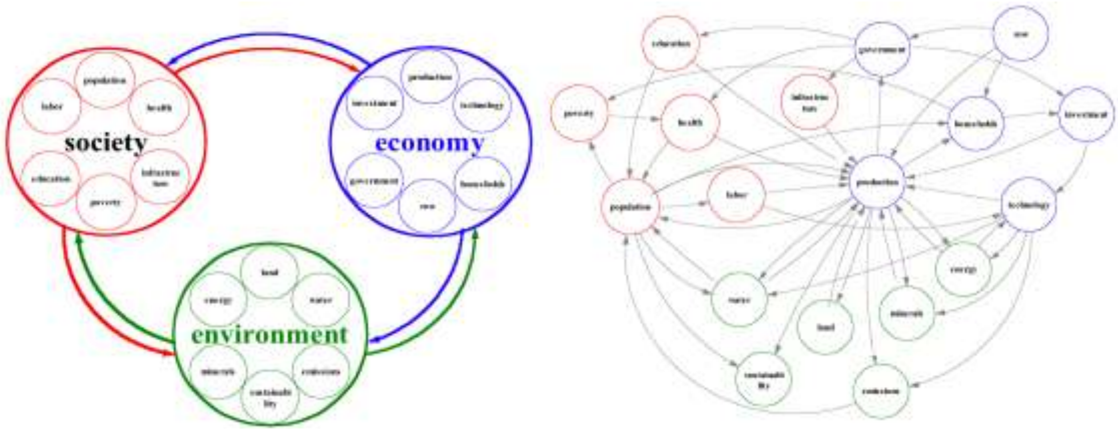
f) Provision of comparison to reference scenarios and supports advanced analytical methods, such as sensitivity analysis and optimization.

T21 provides policymakers and other users with an estimation of the impacts of the implementation of different policy choices on a variety of sectors, both social, economic and environmental. In addition, T21 allows for the simulation of scenarios based on assumptions proposed by different agencies and organizations. In other words, this model -and its various customizations- represent the common basis on which divergent ideas and assumptions can be simulated to create a dialogue among parties. This is done through the explicit representation of feedbacks among economy, society, which are important components to identify paths for sustainable development.

T21 is built around a core structure that broadly reflects the structure and relations of the social, economic and environmental sector, which are called spheres in the model. These models are highly flexible and are customized to a specific set of issues for a given geographical area. Within each major sphere are the sectors, modules, and structural relations that interact with each other and with factors in the other spheres.

The figure below represents a conceptual overview of T21, with the linkages among the economic, social, and environmental spheres.

Figure 1: Conceptual overview of T21



The Social sphere of T21 contains detailed population dynamics organized by sex and age cohort, health (identified by the proxy "life expectancy"), education and other sectors (see table 1).

The Economy sphere of the model contains disaggregated major production sectors (agriculture, industry and services). The calculation of production is characterized by Cobb-Douglas production functions with inputs of resources, labor, capital, and technology. A Social Accounting Matrix (SAM) (Drud et al., 1986) and a System of National Accounts (SNA) (IMF, 2008) are used to elaborate the economic flows and balance supply and demand in each of the sectors. Standard IMF budget categories are employed, and key macro balances are incorporated into the models (IMF, 2001).

The Environment sphere tracks land allocation (i.e. urban, agricultural, fallow, forest, and desert), water and energy demand. T21 accounts also for energy supply and fossil fuel production, air emissions (CO_2, CH_4, N_2O, SO_X and greenhouse gas) and the calculation of the ecological footprint.

Table 1: Modules, Sectors and Spheres of T21-Starting Framework.

SOCIETY	ECONOMY	ENVIRONMENT
Population Sector:	**Production Sector:**	**Land Sector:**
1. Population	14. Production and Income	30. Land
2. Fertility	15. Primary Agriculture	**Water Sector:**
3. Mortality	16. Agriculture	31. Water demand
Education Sector:	17. Industry	32. Water supply
4. Primary Education	18. Services	**Energy Sector:**
5. Secondary Education	**Technology Sector:**	33. Energy demand
Health Sector:	19. Technology	34. Energy supply
6. Access to basic health care	**Households Sector:**	**Minerals Sector:**
7. HIV/AIDS	20. Households accounts	35. Fossil Fuel production
8. HIV children and orphans	**Government Sector:**	**Emissions Sector:**
9. Nutrition	21. Government revenue	36. GHG, CH_4, N_2O, SO_X

Infrastructure Sector:	22. Government expenditure	**Sustainability Sector:**
10. Infrastructure	23. Public investment	37. Footprint, MDG, HDI
Labor Sector:	24. Gov. balance and financing	
11. Employment	25. Government debt	
12. Labor	**ROW Sector:**	
Poverty Sector:	26. International trade	
13. Income distribution	27. Balance of payments	
	Investment Sector:	
	28. Relative prices	
	29. Investment	

The major feedback loops underlying society, economy, environment, and energy include population and income (involving economic and social spheres); labor availability (involving economic and social spheres); public and private economy (involving the economic, environmental, and energy spheres); resources and environment (involving social, economic, environmental, and energy spheres).

The major feedback loops underlying society, economy, environment, and energy follow:

- Public economy (involving the economic sphere);
- Private economy (involving the economic sphere);
- Resources and environment (involving economic and environmental spheres);
- Labor availability (involving economic and social spheres);
- Population and income (involving economic and social spheres).

4. Country case studies

Two recent case studies exemplify how T21 can be customized and utilized to support policy formulation and evaluation: Mauritius and Jamaica.

Under the leadership of the Ministry of Renewable Energy and Public Utilities of the Republic of Mauritius and with support from UNDP, the Millennium Institute (MI) has carried out a recent assignment on *the System Modelling of Long Term Energy Policy*. The goal of the project was to empower the Ministry of Renewable Energy and Public Utilities, and the Government of Mauritius, with a flexible, integrated, dynamic and user-friendly simulation model that allows for the evaluation of energy policy proposals to make informed decisions on longer term policy planning. This model was jointly developed and uniquely customized to Mauritius with a team of local experts from Ministries, governmental agencies and academia and used data collected with support of the Central Statistics Office (CSO). Thanks to its flexibility and ease of use, on top of its integrated and dynamic nature, the Mauritius Model allows for a cross sectoral analysis of the impacts of about 20 energy policy provisions, as highlighted in the Long Term Energy Strategy document, with simulations running from 1990 to 2025 able to dynamically capture both historical and future changes in the system analyzed. These policy provisions range across energy efficiency (e.g. sectoral efficiency improvement), renewable energy (e.g. construction of wind farms, and definition of feed-in tariffs), transport (e.g. vehicle age, public transport subsidy and congestion charge); power sector (e.g. cost-reflective electricity prices), and fossil fuels (e.g. expansion of HFO plants and installation of a coal-fired power plant). A variety of key assumptions are made available to the users for the testing and simulation of alternative scenarios; the user interface is equipped with more than 40 parameters/assumptions that range across society, economy and the environment, directly allowing for the incorporation of findings from other -upcoming- studies.

Our previous experience suggests that when a government has embraced the use of MI's national planning models investing in capacity building, such as Jamaica, has had many benefits. In the specific case of Jamaica, the national planning institute (Planning Institute of Jamaica, PIOJ) has taken the lead in the development of the model -with the support of the Millennium Institute- and has trained a team of four staff to acquire the needed skills to actively support and eventually independently perform model building. Jamaican experts from PIOJ attended a full time 6 weeks training course in System Dynamics and National Development Planning offered by the Millennium Institute and the University of Bergen (UiB), in Bergen, Norway. After this initial training, during the development of the model -that lasted for about 1 year- data collection and the creation of the model followed. Shorter training sessions were performed in Jamaica, to perform analysis of data, their consistency across sectors and their use in formulating the structure of the model. After the model was built, PIOJ has independently improved and expanded the model, with a good understanding of its structure and confidence in the data used.

4.1 Validation: 25 years of work in national development strategies

Over the last 25 years MI has worked with over 40 countries to support longer term development planning. This section provides an overview of the performance of selected T21 models created by the Millennium Institute over the last 10 year, excluding recent ones (for which the validation of medium term forward looking projections would be premature). This analysis serves to provide an indication of the reliability and validity of projections simulated with T21, using causal relations, feedback, nonlinearity and delays, as the main pillars of the model.

4.1.1 T21-Malawi, 1997

In 1997, MI developed a T21 model for Malawi to help its government translate the Vision 2020 goals into measurable objectives through national stakeholder consultations and analysis of scenarios. The outcome was a new national development strategy, *Reaching the Vision*, that sets out the path to attaining the national vision.

Past projections (comparing simulations against history at the time when the model was built): the model performs well for total population with an average deviation smaller than 5% from UNPOP and WDI values. For real GDP, yearly dips in 1992 and 1994 -caused by severe droughts that occurred in Malawi- were not captured, due to the longer-term analysis carried out.

Future projections (comparing simulations against additional historical data now available): for 1998-2006, the total population still stays within 5%, and for GDP the model is able to reproduce its medium to longer term quite well, but underestimates growth after 2001.

4.1.2 T21-Italy, 1998

In 1998, under a contract with ANPA, Italy's National Agency for the Protection of the Environment, and with collaboration from ENEA, the Italian Department for New Technology, Energy, and the Environment, MI customized the T21 template model to Italy and began an exploration of how best Italy could achieve its various international environmental commitments.

Past projections: the Italy model performs very well against actual data. Total population has an average deviation of 2% and Real GDP is about exactly the same as WDI.

Future projections: for 1999-2006, total population remains within 2% until 2003 and after that is still within 4-5% historical data. The Real GDP remains about 4% throughout, getting closer to historical data toward 2005 and 2006.

4.1.3 T21-Thailand, 2002

In 2002, MI created the T21-Thailand model to look at population, reproductive health, and HIV/AIDS.

In terms of past and future projection, total population has an average deviation of only about 2%. The simulation of the HIV Adult Prevalence Rate has a difference of only about 0.2% both past and future, and captures the longer-term trend pretty well, despite inconsistencies between UNDP and UNAIDS data (the sources used for the comparison).

4.1.4 T21-Papua, 2002

In 2002, Conservation International and MI collaborated on pursuing a more cooperative approach to address the concerns of various interest groups represented in Papua’s environmental and economic resources to create T21-Papua: A new approach to integrating development planning with biodiversity conservation.

Past projections: both population and Real GDP fall within 5% of actual data.

Future projections: population remains within 5% and Real GDP deviates from data after 2004.

As for total forest land, the model performs very well both past and future, in spite of a change in classification methods at FAO. As a consequence, the simulation is consistently about 5% lower than

Total Forest and Wooded land, but 5% higher than Total Forest Land, perfectly matching the long term trend.

4.1.5 T21-Bhutan, 2002/2004

In 2002, MI and the Government of Bhutan (GoB) collaborated to create a T21 model. In 2004, as part of the Netherlands Climate Change Studies Assistance Program, the GoB decided to use T21 to investigate impacts of climate change on Bhutan.

For past projection, the model accurately simulates the trend of total population and GDP falls within 5%. For future projections, total population continues to match the trend in WDI and UNPOP data, and projected GDP underestimates the actual growth after 2006, due to the completion of a major hydroelectric plant that was not included in the baseline scenario.

4.1.6 T21-Cape Verde, 2003

In 2003, Senior Cape Verdean government officials identified T21 as an excellent tool to assist in undertaking integrated strategic planning, involving diverse stakeholders in the planning process, and monitoring performance against agreed goals. MI developed T21 Cape Verde specifically to support the Poverty Reduction Strategy Paper (PRSP) process.

Past projections: for total population there is an average deviation of 3% with UNPOP data, and for Real GDP it is also within 3% from IMF and WDI data.

Future projections: the total population is now within 5% of actual data and Real GDP remains within 3% of WDI data.

4.1.7 T21-Ghana, 2003

In 2003, MI created T21-Ghana (*Assessing best options for meeting the Millennium Development Goals in Ghana*) in order to assess the impact of MDG-related interventions on the national economic and social development, and the synergies (or lack thereof) among them.

Past projections: for total population there is an average deviation of only 2% from UNPOP and WDI data, and for Real GDP the projection falls to within 3%.

Future projections: population is within a maximum of 3% and GDP is in the range of 4%.

4.1.8 T21-Mozambique, 2003

In 2003, MI worked with Mozambique's government ministries and civil society groups to build their capacity to use T21, and use it as a framework for broad dialogue on policy issues, thus increasing broad participation in national planning.

Past projections: the total population falls within 4% of UNPOP and WDI data, and the Real GDP varies over time and is mostly within 4% of actual data.

Future projections: population has a deviation of between 4-5% and GDP falls consistently within 2-3% of actual data.

4.1.9 T21-Mali, 2003

In 2003, under The Carter Center's Development and Cooperation Initiative (DACI) with the Government of Mali, MI used T21 to support the preparation of Mali's poverty reduction strategy paper for the World Bank (PRSP).

Past projections: for population there is an average deviation within 3% of both WDI and UN data, and for Real GDP there is variation within 5% of WDI data.

Future projections: population has 4% average deviation, while GDP is within 3% of actual data.

4.1.10 T21-USA, 2004

The second version of the model for the United States, which focused on the economic sector and was created and featured on C-SPAN, overall performs very well on the major indicators.

Past projections: the total population falls to within 3% of UNPOP and WDI, total real trust funds have an average deviation of about 4%, and Real GDP has an average deviation of just 3%.

Future projections: population remains within 3%, total real trust funds grows to around 5%, and Real GDP growth was slightly underestimated between 2004 and 2007.

5. Conclusions

Despite the fact that models are not, and will never be, perfect representations of reality, this research work argues that explicitly representing the context in which policy issues arise –social, economic and environmental-, and where policies are formulated and implemented, enriches their analysis and provides useful insights to policy makers.

The present study proposes the utilization of an integrated cross-sectoral medium to longer-term research approach, complementary with other tools and methodologies, in which integrated models are used to minimize exogenous assumptions by endogenizing key variables to increase coherence of scenarios and improve the understanding of the system. Feedback loops, nonlinearity and delays are explicitly represented when linking society, economy and environment to each other. This representation of the context, coupled with the understanding of the political dimensions during the modeling process, allows a better understanding of the functioning mechanisms driving the behavior of the systems analyzed, making possible the identification of structural changes (i.e. loop dominance) responsible for behavioral changes. This approach includes also an active involvement of policy makers and stakeholders aimed at creating a relationship of mutual trust to maximize the effectiveness and validity of the models used by correctly understanding and incorporating the political context. By doing so, the context, built into an integrated model, becomes a fundamental driver in the modeling process and complements the analysis of energy policy formulation and evaluation.

MI's T21 is a quantitative tool for integrated and comprehensive development strategy analysis and policy formulation. Its purpose is to inform the larger process of strategic planning by facilitating information collection, deepening understanding of the key structural relations, and enhancing the analysis of development strategies. T21 provides insight into the potential impact of development policies across a wide range of sectors and shows how different strategic alternative policy choices lead to, and achieve, the desired development goals and set targets.

The strengths of T21 build on the dynamic and cross-sectoral integration features that inform the strategic planning process. These features, together with T21 flexibility for customization, improved transparency and participation, support of development strategy analysis and planning, and informed analysis for policy documents make T21 a unique tool in the planner's tool box.

Filling a major gap in modeling tools, T21 is among the first models that support integrated planning aimed at analyzing policy issues in a comprehensive way, while simultaneously considering society, economy, and environment. The model represents a large number of issues and integrates work from previous T21 models with a new set of sectors customized to the context analyzed. The flexibility of the methodology used and the comprehensiveness of the structure make T21 a good tool for understanding and analyzing the validity, effectiveness, and outcomes of complex policies. In spite of its underlying dynamic complexity, T21 is a tool that bridges science and policy making through the integration of cross sectoral data and knowledge, so that anyone can use it to test alternatives.

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