Possible Futures for Bangladesh, Tunisia, and the United States: Technical Report

The Millennium Institute's Contribution to the First Model Comparison by the UN's Global Modeler's Forum

by
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Acknowledgments and Caveats

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The models, analyses, assumptions, conclusions, and recommendations presented in this paper are those of the authors and do not necessarily reflect the thinking of the UNCSD or of the governments, or clients in the respective countries addressed.

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Executive Summary

THRESHOLD 21, a national integrated assessment model, is applied to a "developing" country (Bangladesh), a "transitioning" country (Tunisia), and a "developed" country (the United States). The 50-year scenarios explored are the Conventional Development, Optimism / Hope, and the Pessimism / Fear scenarios from the UN Commission on Sustainable Development (UNCSD) and a Toward Sustainability scenario from the Millennium Institute.

The scenarios for Bangladesh suggest that slow, steady progress toward poverty alleviation and environmental restoration is possible through significantly increased investment in social services (education, family planning, health, and nutrition), moderately increased investment in goods production, and modest increases in agricultural production. While Bangladesh has made progress in slowing its population growth, there is no room for complacency here because in several scenarios population growth overwhelms the benefits of increased goods and agricultural production. Preventing girls from having an education slows GNP growth and, after a lag, reduces life expectancy for men and women.

The scenarios for Tunisia suggest the progress achieved over the past decades can be maintained and increased if thoughtful responses are made now to the limits of water and oil resources that will be encountered. Modest investments in agriculture (especially for increases in irrigation efficiency) are needed to maintain food production as water supplies decline. Investments in increasing water supplies have reached the point of diminishing returns and need to be shifted to increased efficiency. Investments in alternative energy and energy efficiency technologies are needed to reduce future dependence on oil imports.

The scenarios for the United States suggest that its use of its own and the world's energy resources and the world's disposal space for carbon dioxide are currently unsustainable. A massive shift to the use of U.S. coal resources or even a continuation of the current rate of use (until depletion) of world oil resources implies large emissions of carbon dioxide, climate change, and sea level increases that are unsustainable for island countries and lowland countries like Bangladesh. The most effective scenarios for change call for large investments in renewable energy sources and energy efficient technologies and reductions in investments in goods production capital. The scenarios

suggest that a sustainable economy for the United States can be achieved without reducing quality of life as measured by the UN Human Development Index.

Overall, the analyses illustrate many commonalities in the sustainability challenges faced by the poorest developing countries and the richest developed countries. The analyses also illustrate how a national integrated assessment model like THRESHOLD 21 can bring priorities for sustainable development into sharp and understandable focus for every country. Such models can also improve understanding and cooperation among countries on issues that can be resolved only with understanding and cooperation.

Introduction

This paper has been prepared for the first Global Modelers Forum (GMF) comparison, which was organized by the UN Commission on Sustainable Development (UNCSD). The paper provides perspectives on the challenges of sustainable development confronting three types of countries: a "developing" country (Bangladesh); a "transitioning" country (Tunisia); and a "developed" country (the United States).[1] The perspectives are developed using the Millennium Institute's THRESHOLD 21 national sustainable development model. The scenarios emerged from discussions with UNCSD staff.

The Model: THRESHOLD 21

The THRESHOLD 21 model is an *integrated assessment tool* for application to any country at any stage of development. (See Appendix B for a more complete description). THRESHOLD 21 (a) integrates many sectoral models in a transparent fashion, (b) simulates the short- and long-term consequences of alternative policies, and (c) permits easy analysis of a wide range of scenarios by tracing causes of change and making comparisons to reference scenarios. The model provides policymakers and other users with a general sense of the consequences to be expected from alternative policy choices, not precise predictions.

THRESHOLD 21 has several unique features which make it an exceptionally powerful and user-friendly tool for policy exploration:

- THRESHOLD 21 has been constructed with Vensim®, a 4th-generation systems dynamics modeling language. Vensim's diagrammatic programming interface allows for rapid and clear sectoral model development and subsequent ease of explanation. Vensim's "Causal Tracing™" feature enables a user to trace easily the behavioral determinants of any variable or indicator.[2] For example, if agricultural productivity falls, Causal Tracing can be used to understand, in seconds, the reasons for the change.
- Many of the indicators used or proposed by UN agencies and other bodies, such as the UN Commission on Sustainable Development (UNCSD), UN Environmental Program (UNEP), UNICEF, UN Fund for Population Activities (UNFPA), and the World Bank, have been implemented in THRESHOLD 21. Coupling these indicators with a model capable of making projections allows policymakers to see the impact of policy choices on indicators of interest.

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[1] Throughout this paper we use the adjectives, "developing," "transitioning," and "developed," as suggested by the UNCSD. However, we have reservations about these terms and the paradigm they imply. Appendix A explains our reservations and our position on sustainable development, indicators, and models.

[2] Vensim® and Causal Tracing™ are trademarks of Ventana Systems, Inc.

- At the core of THRESHOLD 21 is a simplified version of the World Bank's Revised Minimum Standard Model - Extended (RMSM-X), which is the "national flight simulator" used by the Bank in formulating Country Assistance Strategies and assessing possible loans.

THRESHOLD 21 includes *linkages and feedbacks* among the economic, social, resource and environmental sectors. These intersectoral connections are critical to guiding a country towards a sustainable future. For instance, water limitations may affect the production of food, which in turn will affect the health of workers and the productivity of the economy. With THRESHOLD 21, policymakers can observe the whole picture of how a decision in one sector will affect other sectors.

THRESHOLD 21 is a work in progress. We are committed to many further years of work refining and extending the model. Please bring to our attention suggestions for improving the model that you may have.

The national versions of the model are in different stages of development: Bangladesh (version 0.4), Tunisia (version 0.4), and the United States (version 0.1). Consequently, the analyses described below cannot cover exactly the same range of possibilities for each country.

The Scenarios

The scenarios used with the THRESHOLD 21 model are based on ones suggested by UNCSD staff for the first Global Modelers Forum (GMF) comparison. They are global scenarios in the sense that they describe possible futures for the entire planet.

The THRESHOLD 21 models are "global" in the sense that they address most of the issues of concern to a country, but they are "national" in a geographic sense. Consequently, it was necessary to adapt the geographically global scenarios provided by the UNCSD for use with the national THRESHOLD 21 model.

The UNCSD provided three scenarios: a "Conventional Development Scenario," a "Optimism / Hope Scenario", and a "Pessimism / Fear Scenario".

1. The UNCSD "Conventional Development Scenario" describes a general continuation of the kind of development that has characterized the past several decades. The UNCSD staff provided a detailed numeric global description for this scenario.

2. The UNCSD "Optimism / Hope Scenario" describes a situation in which there are no environmental or resource constraints to growth that cannot be overcome by market-driven substitution and technological advance and in which poverty alleviation for any size of population is attempted through

economic growth alone. In this scenario, population is allowed to increase, pollution is not seen as detrimental, and resources, including energy, are not limited.

3. The UNCSD “Pessimism / Fear Scenario” describes a situation in which there are environmental and resource constraints that *cannot* be overcome by market-driven substitution and technological advance and in which poverty alleviation is attempted not by economic growth alone, but by efficiency of resource use and reduction of waste everywhere, and by efforts to improve health and education, and slow population growth in the most populous countries. Oil and other resources are considered to be finite, and it is assumed that population growth rates need to be limited and that pollution has deleterious effects for human health and for the productivity of agriculture and ecosystems.

The following paragraphs describe our national-scale adaptations of the UNCSD scenarios.

1. Our Base Case scenario for each country is, principally, a continuation of the policies that enabled the THRESHOLD 21 model to reproduce the recent historical data for that particular country. To the extent that each country is following a “conventional” development path, the Base Case is the equivalent to the UNCSD Conventional Development Scenario.

2. In our equivalent of the UNCSD “Optimism / Hope” scenario we make no effort to slow population growth, or abate pollution, and assume there are few, if any, limits on energy and other resources. We introduce no limits on energy resources, ignore or minimize the affect of pollution, and do not invest in programs to reduce population growth.

3. In our equivalent of the UNCSD “Pessimism / Fear” scenario we attempt to reduce the consumption of energy, invest in social services (including education for girls and family planning), and increase some of the assumed deleterious impacts of pollution.

The strategy used to explore scenarios for each country begins with the Base Case scenario—our equivalent of the UNCSD Conventional Development Scenario. Next, other scenarios, including our equivalents of the UNCSD “Optimism / Hope” and “Pessimism / Fear” scenarios, are explored and compared with the Base Case.

In addition to these three scenarios suggested by the UNCSD, we explore a scenario of our own design called “Toward Sustainability.” The objective of this scenario is long-term sustainability. The scenario is not defined in advance but rather through dozens of experiments with the THRESHOLD 21 model to find the mix of investment incentives and other strategies that most successfully moves the individual country toward a sustainable future.

There are, of course, different indicators of sustainability. The World Bank's "Total Capital" and "Genuine Savings" indicators are broad, helpful indicators which we used, but they are not sufficient because they sometimes fail to signal adequately some urgent, severe difficulties. We examined many indicators in assessing sustainability, and the indicators we emphasized varied by country and sector.

In addition to the UNCSD scenarios and our Toward Sustainability scenarios, we have included a few more scenarios for each country which explore an issues of special concern for that country.

Because THRESHOLD 21 is a market-oriented model, policy choices are expressed primarily in terms of policy actions that alter or shift the attractiveness of investment in the different sectors of the economy, something we term "Investment Biases." These are, in effect, relative prices or the balance between taxes and subsidies for specific sectors. The user of THRESHOLD 21 "steers" by shifting the investment biases to encourage investments in one sector or another. Then, after a response delay, the market moves new investment to the favored sector(s) and away from others.

The investment biases are shifted using slide-bar variables on the Policy Selection Screen. For the Base Case all investment biases are set to "1," which is the set of policies that allowed the model to reproduce the history of the country. A detailed technical explanation of the function of the investment bias variables is provided in Appendix B.

The Analyses

This section presents the analyses for the developing country, the country in transition, and the developed country. The analysis for each country is presented in four parts: (1) the country and client, (2) the country-specific version of the THRESHOLD 21 model, (3) the scenarios and the analyses, and (4) the recommendations.

For each country, a similar set of scenarios are run and compared. The comparisons are all in reference to each country's Base Case scenario, which assumes a continuation of policies for the past decade or so.

The THRESHOLD 21 model includes more than 1,000 variables and permits the development of quite detailed and rich scenarios. The short analyses presented here focus on only a dozen or so key variables.

Scenario analysis with THRESHOLD 21 is best done "live" with a computer rather than with black-and-white text and graphs. With the computer, the different variables are shown in colors, and the causes of unexpected developments can be tracked down in seconds with Vensim's Causal Tracing. Additional scenarios can also be run in seconds. This text report will, nonetheless, provide an interesting introduction to the capabilities of THRESHOLD 21.

The Developing Country: Bangladesh

The country and client

The People's Republic of Bangladesh has approximately 107 million inhabitants in an area of 144 thousand square kilometers. Its per capital GNP in 1990 was $210; eradicating poverty remains one of the primary goals of public policy. Bangladesh's economy is heavily dependent on foreign aid. Its fertile land and natural gas deposits are its only natural resources; utilizing these is a challenge due to the many natural disasters which afflict the region. A combination of weak public and financial institutions has also hampered efforts to move the country's development efforts forward. Although literacy, health and nutrition standards are extremely low, significant progress has been made over the last decade. Adult literacy is roughly 29 percent, and school enrollment is substantially lower than that in many comparable countries. Bangladesh's medium- and long-term external debt was projected to reach roughly half of GDP by 1994, at $13.4 billion. (World Bank, 1992).

The Millennium Institute has been working with the UNICEF office in Dhaka to prepare the Bangladesh version of THRESHOLD 21. UNICEF leadership in Dhaka feels strongly that the needs of their clients—the children of Bangladesh—cannot be met in the 21st Century without a more integrated and systemic approach to development there. For this reason, UNICEF commissioned the THRESHOLD 21 model for Bangladesh in the hope that the model can provide a vehicle for dialogue and understanding among government, business, media, and the donor community.

THRESHOLD 21 for Bangladesh

Work on the first version of THRESHOLD 21 for Bangladesh began in Spring of 1994 and was completed in the Spring of 1995. Work on the Bangladesh version was suspended from Summer 1995 to Summer 1996 due to the political transition in Bangladesh. However, during this time the generic version of THRESHOLD 21 was improved with additional sectors (energy, water, forestry, land, technology, and greenhouse gas emissions), other sectors were improved, and indicators added. Bangladesh-specific work resumed in September of 1996.

An updated version of the THRESHOLD 21 model for Bangladesh was delivered to UNICEF-Bangladesh in November 1996. It includes all of the updates to the generic version of THRESHOLD 21 and is the most advanced country-specific version available at this writing.

The following sectors are included in the Bangladesh THRESHOLD 21 model: agriculture, demographics / conceptions, economy (including production, consumption, import, export, and a supply and demand model), education, energy, environment (pollution), forestry, goods (industrial production, including an investment allocation model), greenhouse gas emissions, health, land, military, nutrition, social services, services, technology, trade, water, and RMSM's national flow of funds. In addition, the model includes development indicators such as UNDP's Human Development Index (HDI) and Gender-related Development Index (GDI), the World Bank's MEP (Monitoring Environmental Progress) indicators, selected indicators from UNICEF, UNCSD and UNFPA, and unemployment. The Environment sector tracks NO_x, SO_x, CH_4, and CO_2 emissions.

The Bangladesh Centre for Advanced Studies is using this version of THRESHOLD 21 for a long-term study sponsored by the World Bank. The Bangladesh Institute of Development Studies is seeking to use THRESHOLD 21 in ongoing collaborative research. A users group has formed in Dhaka.

Analysis of Scenarios for Bangladesh

When using the THRESHOLD 21 model, policy inputs for scenarios are made using the Policy Selection Screen. The Policy Selection Screen for THRESHOLD 21-Bangladesh is shown in Figure 1.

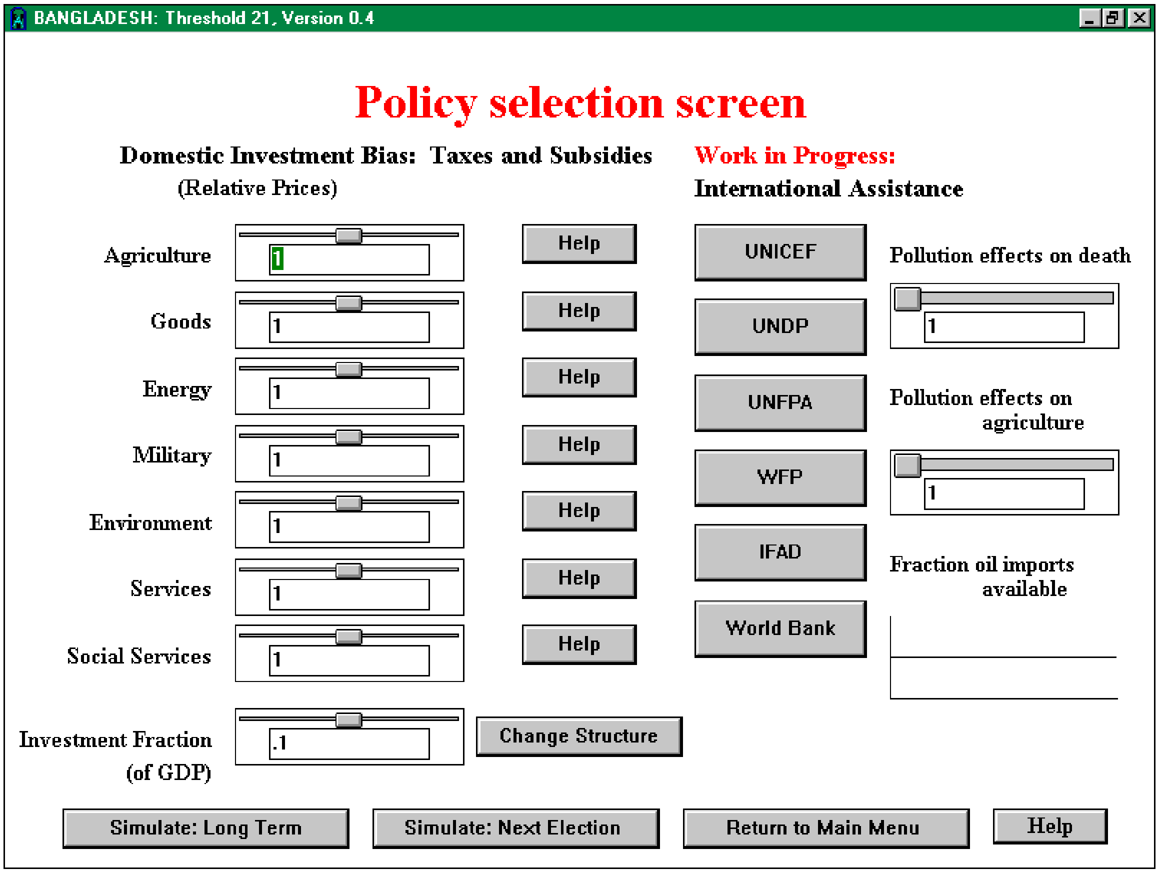

Figure 1. Policy Selection Screen for the Bangladesh version of THRESHOLD 21

As shown in Figure 1, the Policy Selection Screen for THRESHOLD 21-Bangladesh has domestic investment bias slide-bars for six sectors: Agriculture, Goods Production, Energy, the Military, the Environment, Social Services, and Services. Exogenous inputs for Threshold 21-Bangladesh include Investment Fraction of GNP, Pollution effects on death, Pollution effects on Agriculture, and Fraction of oil imports available. The International Assistance buttons (UNICEF, etc.) are "work in progress" and not yet fully connected. Details on the functions and effects of the policy input variables are provided in Appendix B.

To begin the application of THRESHOLD 21-Bangladesh, the model is used to simulate the historic period 1965-1995 with the investment slide-bars all set at 1. The results (shown in part in Appendix B) are compared with the actual data for the period, and adjustments are made as needed to achieve a satisfactory fit.

Once the model is satisfactorily calibrated, the Base Case scenario is run. The Base Case is a continuation of historic policies, which means a simulation of the 1995-2050 period with the investment biases all set at 1. Other specific inputs for the Base Case are presented in Appendix B, as are the general assumptions for Threshold 21 and the specific assumptions of the Bangladesh version. The Base Case provides the reference scenario against which the other scenarios are compared.

Figure 2 shows the overview screen for the Base Case scenario in which six variables (population, agricultural production, goods produced, forest land, pollution intensity, and human development index) out of a thousand or so variables in the model are displayed for the period 1996 to 2050. The simulation runs in approximately 20 seconds on a 66 MHz 486 and about 10 seconds on a 100 MHz Pentium. These results are not simple projections but rather the consequences of the dynamic interactions among all of the sectors of the model. Investment decisions, adjusted production levels, and much more are guided by the simulated market in a THRESHOLD 21 based on the unfolding developments in the scenario. Below the graph, the variables are identified and their units specified. ("Dmnl" stands for dimensionless.) The scales for the various curves on the graph are provided at the left of the graph in the same order as the variables are listed below the graph. The upper group of numbers and units refers to the top of the graph; the lower group refers to the bottom of the graph. Labels have been applied to the curves for identification on the black-and-white graph. On the computer screen, each curve is a different color.

Graphs of about 100 more variables and indicators can be reviewed on the computer by clicking on the "view sectors" button or on the "view indicators" button. Using the "do analysis" button, all 1000+ variables can be graphed and scenarios compared within seconds. Some screens automatically compare scenarios (e.g., see Figure 3).

Much can be learned from the overview screen. Population peaks in about 2042 at 190 million persons, then starts to decline. Agricultural production increases, but only at about the same pace as population, so per capita calorie intake does not increase dramatically. Industry grows at a slower pace than agriculture. Pollution worsens substantially. The Human Development Index (HDI), which is a composite of literacy, life expectancy and education, goes up steadily due to improvements in education and life expectancy. Forest land continues to shrink as it is converted to agricultural use.

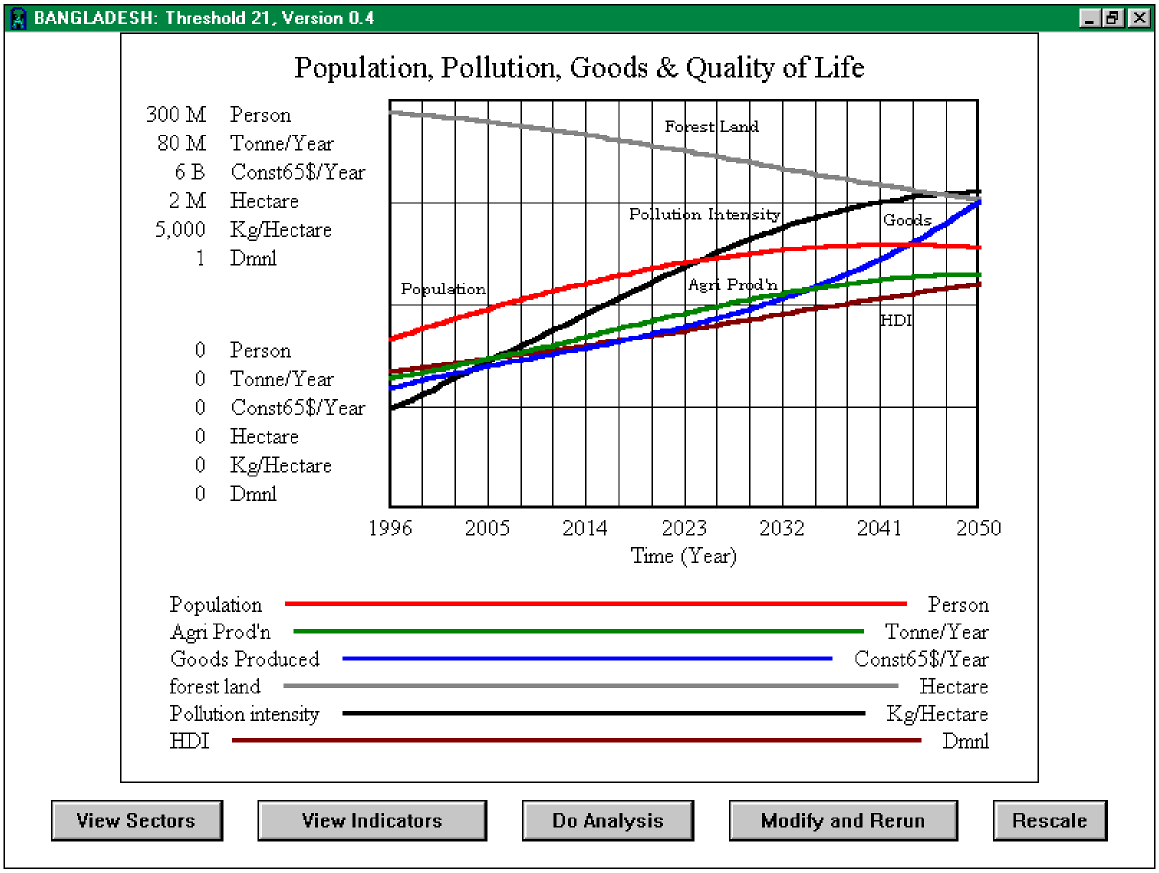

Figure 2 Overview Screen from THRESHOLD 21: Bangladesh model, Base Case Scenario

Initial Experiments with Changes from Base Case

In our initial experiments with changes from the Base Case, we made a general survey of the consequences of increased investment in each of the seven sectors. To do this, we changed the Investment slide-bars from 1 to 1.2 for each of the seven sectors. For example, Figure 3 shows the results of increasing the investment in the Agriculture sector from 1 to 1.2.

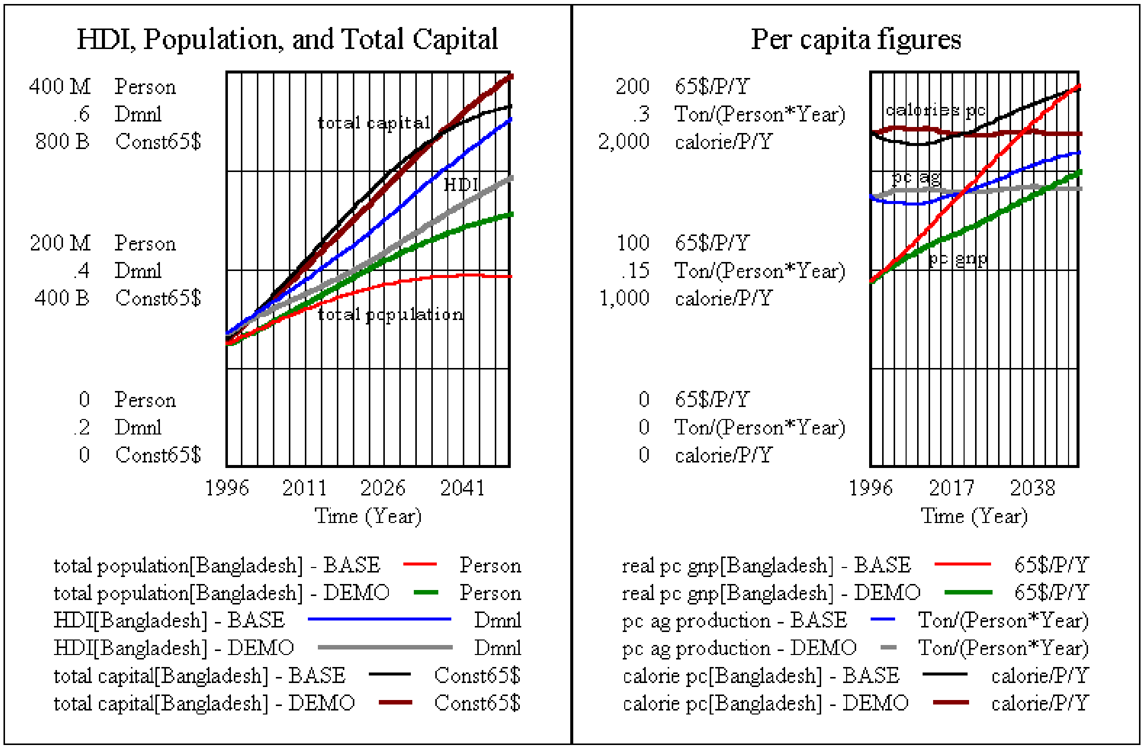

Figure 3. Effect of Increasing Agriculture Investment Bias to 1.2

The results of these experiments are summarized in Table 1, which provides an overview of how increased investment in different sectors will influence development trends in Bangladesh over the next 50 years.

Sector	Investment	Total Population	Human Dev't Index	Total Capital	GNP per capita	Ag Prod'n per capita	Calories per capita
Agriculture	1.0 → 1.2	↑↑↑	↓↓	↓ then↑	↓↓↓	↑then↓↓	↑then↓↓
Goods	1.0 → 1.2	↓↓	--	↑	↑	↓	↓
Energy	1.0 → 1.2	↑↑	↓	--	↓	↓	↓
Military	1.0 → 1.2	↑	↓	--	↓	↓	↓
Environment	1.0 → 1.2	↑	↓	--	↓	↓	↓
Services	1.0 → 1.2	↓	↓	↓	↓	↓	↓
Social Services	1.0 → 1.2	↓↓↓	↑	↓	↑	↑	↑
Investment %	0.10 →0.15	↓↓↓	↑↑	↑↑	↑↑↑	↑↑	↑↑

Table 1: Summary of the effects of changes in the investments biases in single sectors relative to the Bangladesh Base Case. Note: Three arrows indicates a marked change relative to the Base Case; two arrows indicates a significant change; a single arrow indicates a slight change.

Solely increasing the investment in the agriculture sector causes the total agricultural production to increase markedly relative to the Base Case. Per capita agricultural production and per capita calories initially increase; yet the total population increases significantly and ultimately overwhelms these modest improvements. GNP per capita declines; total capital initially declines but ultimately recovers as the population grows. HDI decreases due to reductions in life span and income caused by the other factors.

Solely increasing investment in the Goods sector (industrial production) has the beneficial effect of increasing industrial production, slightly increasing total capital, moderately decreasing the total population and slightly increasing GNP per capita. Agricultural production per capita and calories per capita decline slightly. HDI remains relatively unchanged.

Solely increasing investment in the Energy sector seems to be somewhat counterproductive: total population goes up, HDI and agricultural production and calories per capita decline slightly, and GNP drops. Total capital is unchanged.

Solely increasing investment in the Military sector, as well as solely in the Environment sector, produces no significant change in the Table 1 indicators over the Base Case. Investment in the Environment sector does diminish pollution intensity over time, however.

Solely increasing investment in Services (communications, transportation, etc.) seems to be wholly counterproductive, although not terribly so.

Solely increasing investment in Social Services (education, health care, "family planning") produces significant changes in all the indicators, nearly all in the "right" direction. Total population declines quite significantly due to investment in family planning and education. HDI is up, and GNP per capita, agricultural production, and especially calories per capita are up. Total capital is down somewhat over the Base Case, probably due to the reduced population.

Finally, we begin to look at rates of investment and the propensity to save. As can be seen in the last line of the table, increasing the percent of the GDP which is used for investment has the greatest beneficial impact on Bangladesh. If Bangladesh could increase its national domestic investment, in the long run it would benefit the country by generating a smaller population and increased wealth per capita. However, this slide-bar is a new addition to the THRESHOLD 21 model and we are still experimenting with it. Initial analysis suggests it is highly beneficial. While it is easy to change a variable and increase investment in the model, it is far from clear what policies and circumstances a government could change to cause such increases in investment and savings. Such policies and measures would probably involve psychological and confidence factors that are currently not well understood. But the impact of increased investment is obviously important and we will continue to develop this aspect of the model.

Optimism/Hope Scenario

See the Introduction for a description of the UNCSD Optimism / Hope scenario and our adaptation of the scenario.

For Bangladesh, we test our equivalent of the UNCSD Optimism / Hope scenario by not limiting energy imports, not worrying about pollution, not trying to control population growth, and maximizing goods production. Specifically, we moved the Goods slide-bar to 1.3. Figure 4 provides an overview of the results.

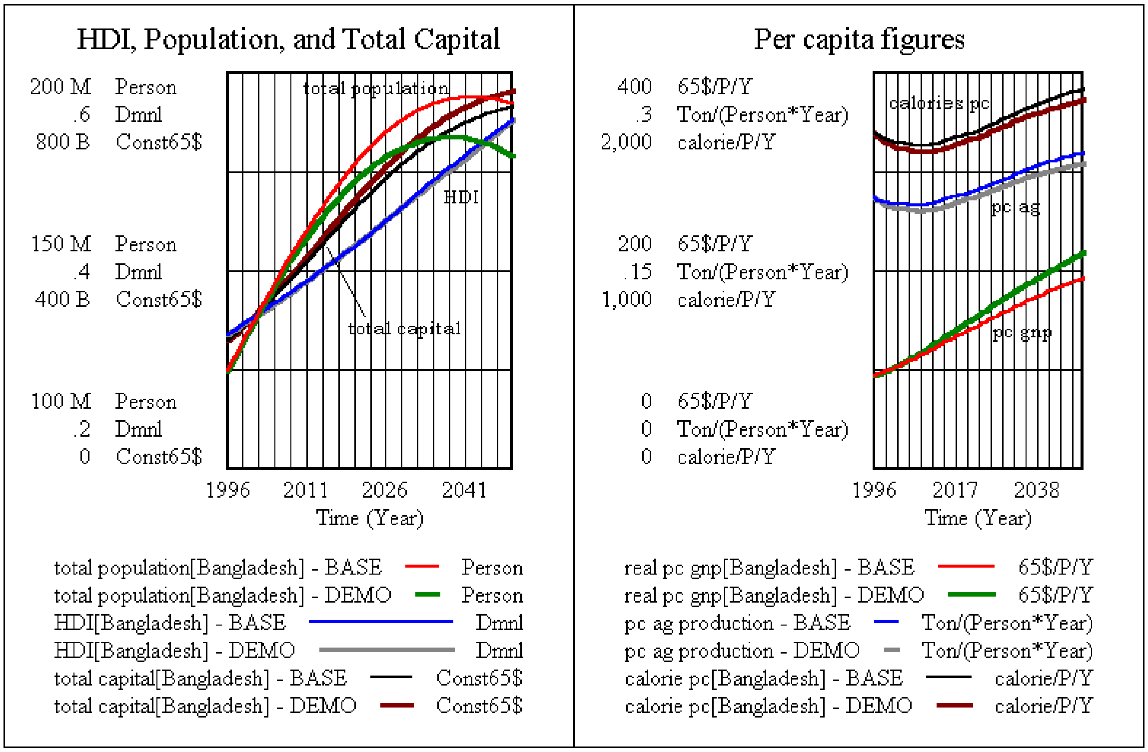

Figure 4. The UNCSD Optimism / Hope Scenario (Demo) compared with the Base Case Scenario, Bangladesh

In our equivalent of the UNCSD Optimism / Hope scenario, relative to the Base Case:

- population decreases
- calories per capita decrease slightly (this indicator was already so low as to be nearly life threatening)
- industrial output increases greatly
- pollution intensity increases somewhat more rapidly
- the rate of deforestation is less
- total capital is increased moderately in the long run
- the HDI trend is relatively unchanged
- the energy imports required increase moderately.

The model assumes Bangladesh can import any amount of energy needed. One possible "What if" to explore in the future is "What happens to the Optimism / Hope scenario if energy imports are constrained?"

Pessimism/Fear Scenario

See the Introduction for a description of the UNCSD Pessimism / Fear scenario and our adaptation of the scenario.

For Bangladesh, we test our equivalent of the UNCSD Pessimism / Fear scenario by attempting to reduce (or at lease stabilize) population, and we assume that pollution has deleterious effects. To do this, we constrain energy imports, invest in social services, and magnify the impact of pollution. Specifically, we move the Social Service slide-bar to 1.3, we constrain oil import availability from 100% in 1996 to 50% in 2045, and we increase the effects of pollution by a factor of 2. Figure 5 shows what happens.

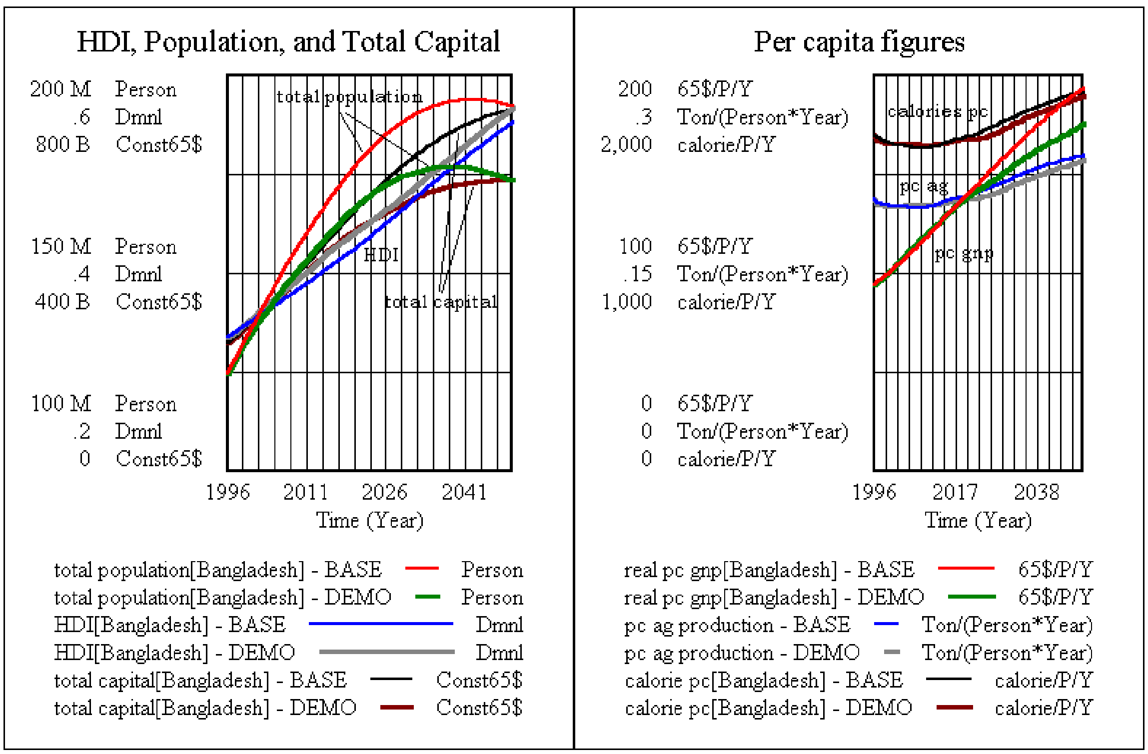

Figure 5. The UNCSD Pessimism / Fear Scenario (Demo) compared with the Base Case for Bangladesh

In our equivalent of the UNCSD Pessimism / Fear scenario, relative to the Base Case:

- the rate of increase of industrial output is less
- population peaks significantly lower (20-25 M less)
- total capital is down significantly
- HDI is modestly increased
- per capita GNP is down

- calories per capita and per capita agricultural production are down only slightly
- energy imports needed are reduced very significantly
- the rate of deforestation is less
- pollution intensity levels off and starts to decline

A Run Exploring the Effects Assuming that Pollution has Stronger Detrimental Effects

In the next scenario, we explore the impact of the possibility that the assumed detrimental effects of pollution on deaths and agriculture are too low. We test this possibility by increasing the detrimental effects of pollution by a factor of 10 over the Base Case.

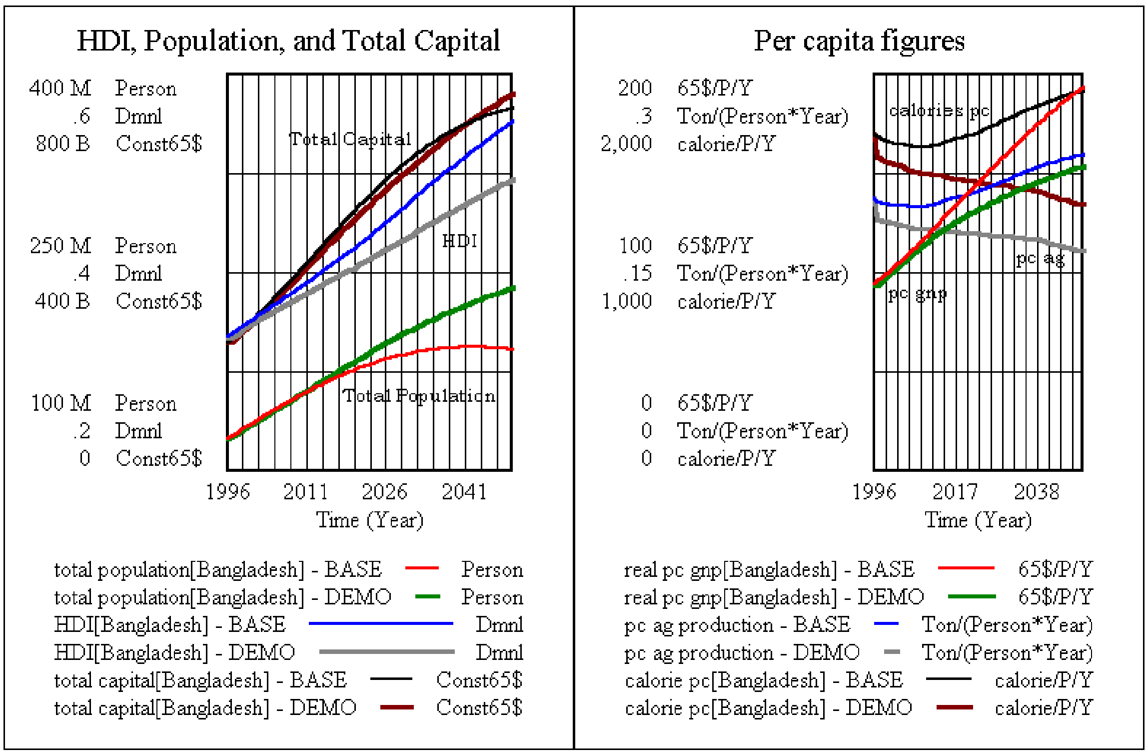

Figure 6. Effect of a 10-fold Increase in the Effects of Pollution

Figure 6 shows that if the detrimental effects of pollution are 10 times worse than assumed in the Base Case, many more people will die of pollution-related illnesses, per capita agricultural production and per capita calories will decrease due to pollution's effects, and the overall HDI will be much lower, all relative to the Base Case.

A Run Exploring the Effects of Limiting Oil Imports

As noted above, THRESHOLD 21 is an open economy model, meaning that the "rest of the world" is able and willing to provide as many imports and to absorb as many exports as the country may wish. Specifically, this is true of energy imports, which in the case of Bangladesh, become large.

This scenario investigates the consequences of assuming that the fraction of the energy Bangladesh would like to import and is actually available on the international market at prices Bangladesh can afford falls from 100% to nearly zero over the next 50 years. This is accomplished using a "lookup" function.

Figure 7 shows the Vensim interface to a "lookup" function. This particular lookup function, the "fraction oil imports available" function, controls how much of unmet domestic demand for energy oil will be satisfied internationally. A policymaker can enter the function's X and Y values in the table on the left, or they can use their mouse to enter and move points on the graph.

In order to simulate the effects of limited availability of energy on the Bangladesh economy, some assumptions were made about how the productive sectors of the economy -- agriculture, goods production, and services -- would behave in the absence of any oil. Specifically, we assume that without oil Bangladesh can still function, but with significant losses of production. Specifically, we assumed that without energy,

- 30% of agricultural production would be lost
- 50% of goods production would be lost, and
- 30% of the output of the service sector would be lost

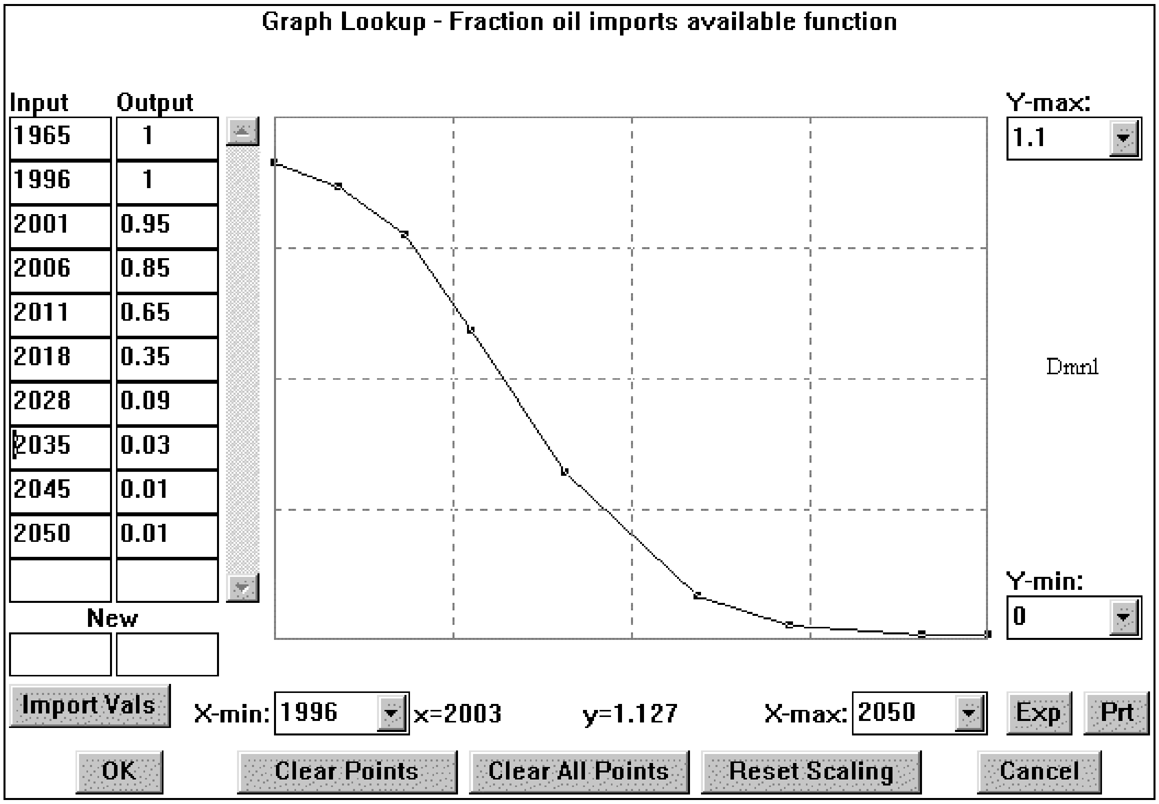

Figure 7. Fraction of Oil Imports Available Function showing the fraction of oil imports available falling from 100% in 1996 to near zero in 2050.

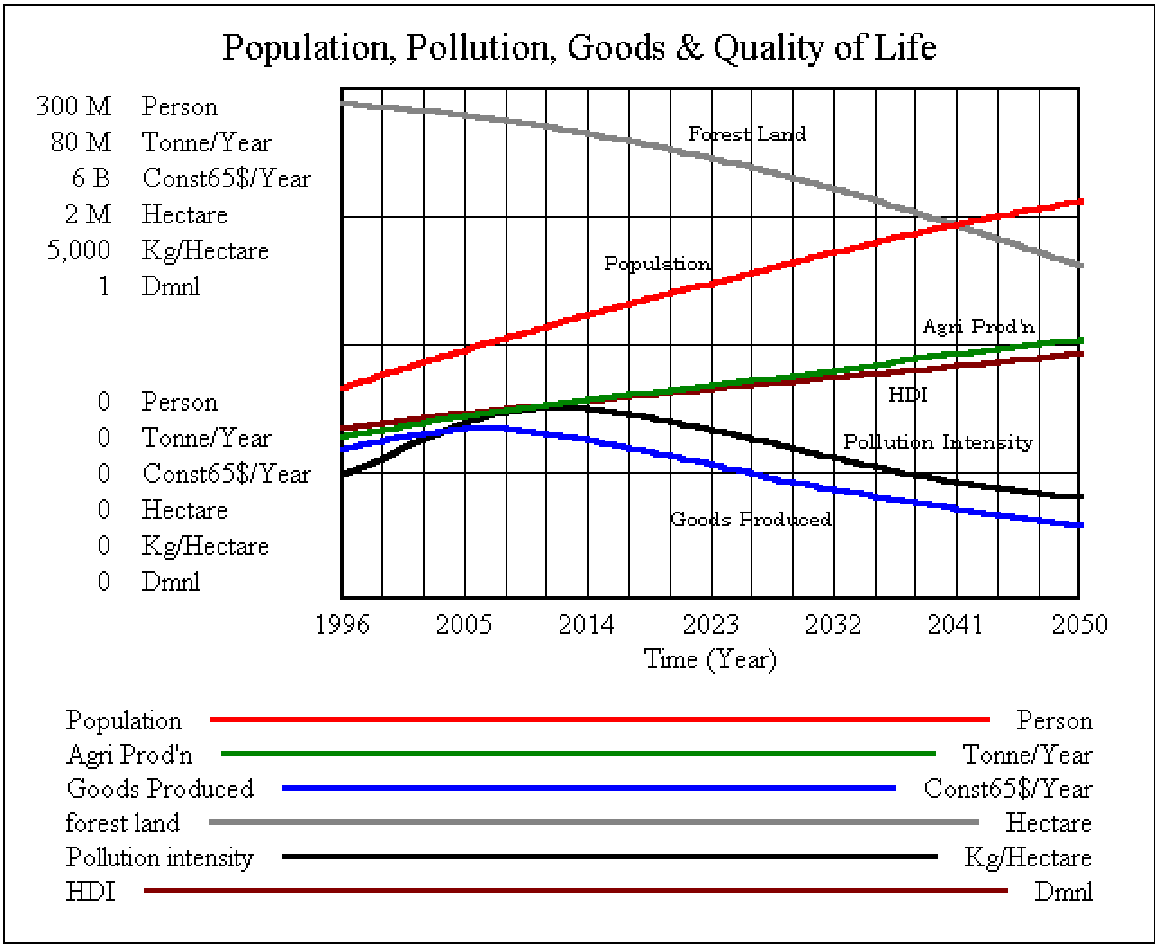

Figure 8. A Run Assuming Limitations on Effects of Limiting Oil Imports, as shown in Figure 7 (first of two graphs)

To understand the effects of limiting oil imports to Bangladesh over the next 50 years, compare Figure 8 with the Base Case in Figure 2. Population increases from the Base Case peak of 190 million in 2042 to 225 million (and still growing) in 2050; agricultural production diminishes from approximately 50 M tonnes / year to 40 M; goods produced drops from 4.6 B to about 1 B; and the Human Development Index declines from 0.55 to 0.49. Furthermore industrial and agricultural production will be affected negatively in a very significant way (compare Figure 9 with Figure 4). Real GNP will grow only very slowly.

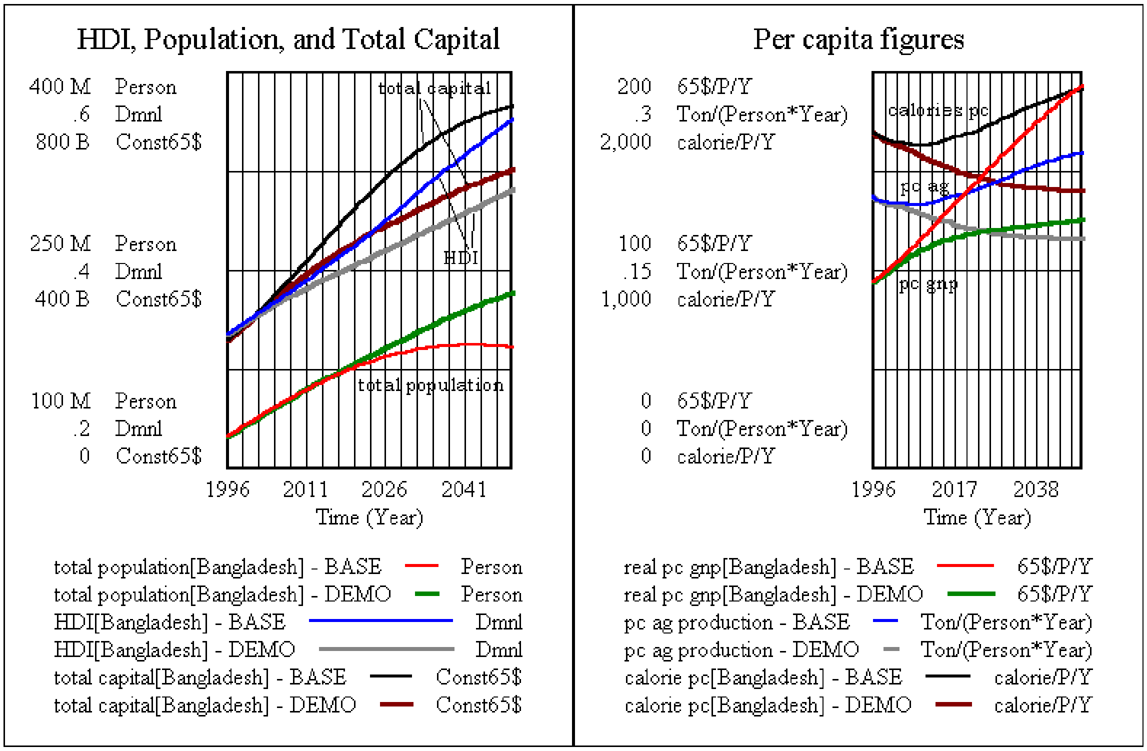

Figure 9. A Run Assuming Limitations on Oil Imports as Shown in Figure 7 (second of two graphs)

Towards Sustainability Scenario

The approach we have taken to begin formulating a sustainable strategy for Bangladesh is to begin with the real conditions which now exist: a) a large proportion of the people, especially children, are undernourished; b) per capita GNP is very low, and c) a population growth rate which, if not reduced, will outpace economic advances and accelerate the destruction of the environment. To counter these trends, we selected 1.1 for the investment bias in Agriculture, 1.2 in Goods, and 1.3 in Social Services. We also set the oil import availability to decline from 100% to 50% over the next 50 years. The results are shown in the figures below.

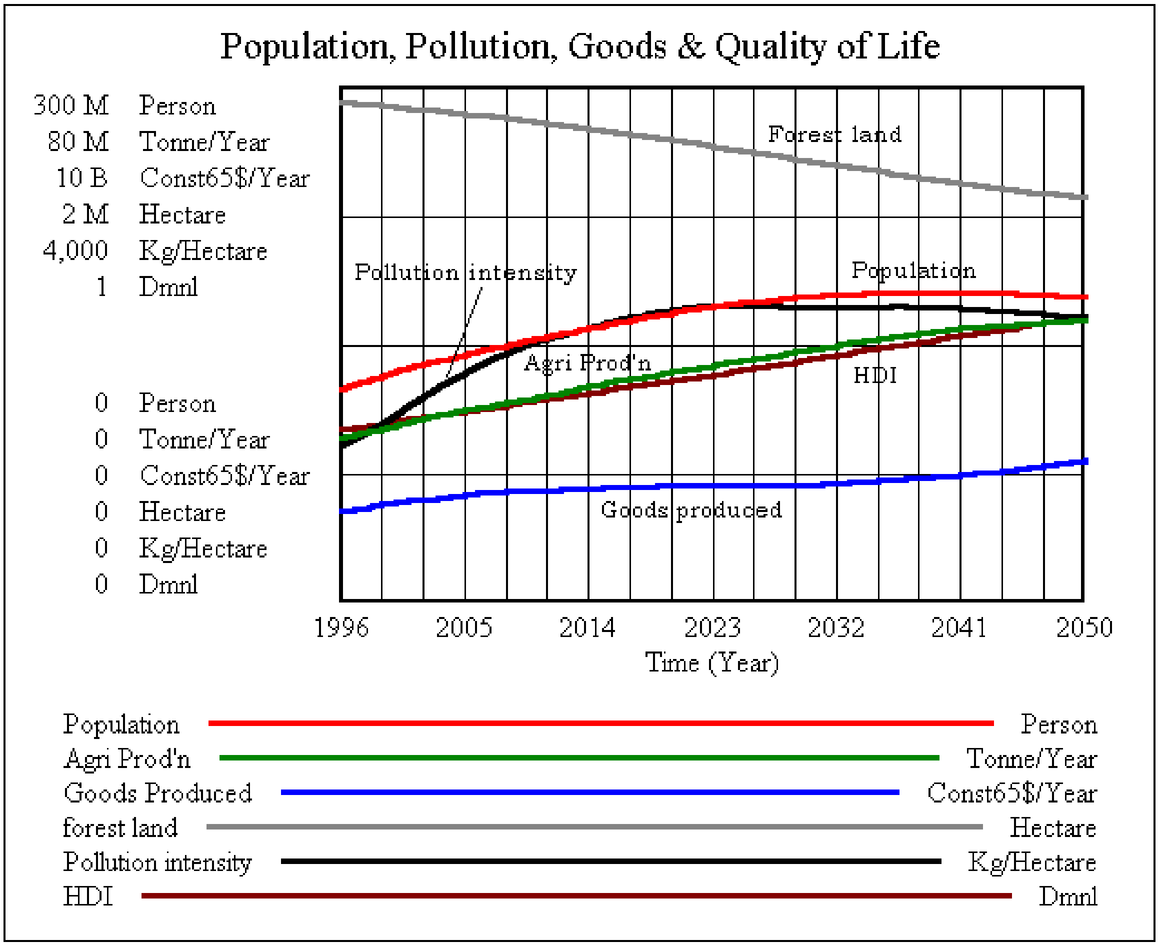

Figure 10. A Towards Sustainability Scenario for Bangladesh (first of two graphs)

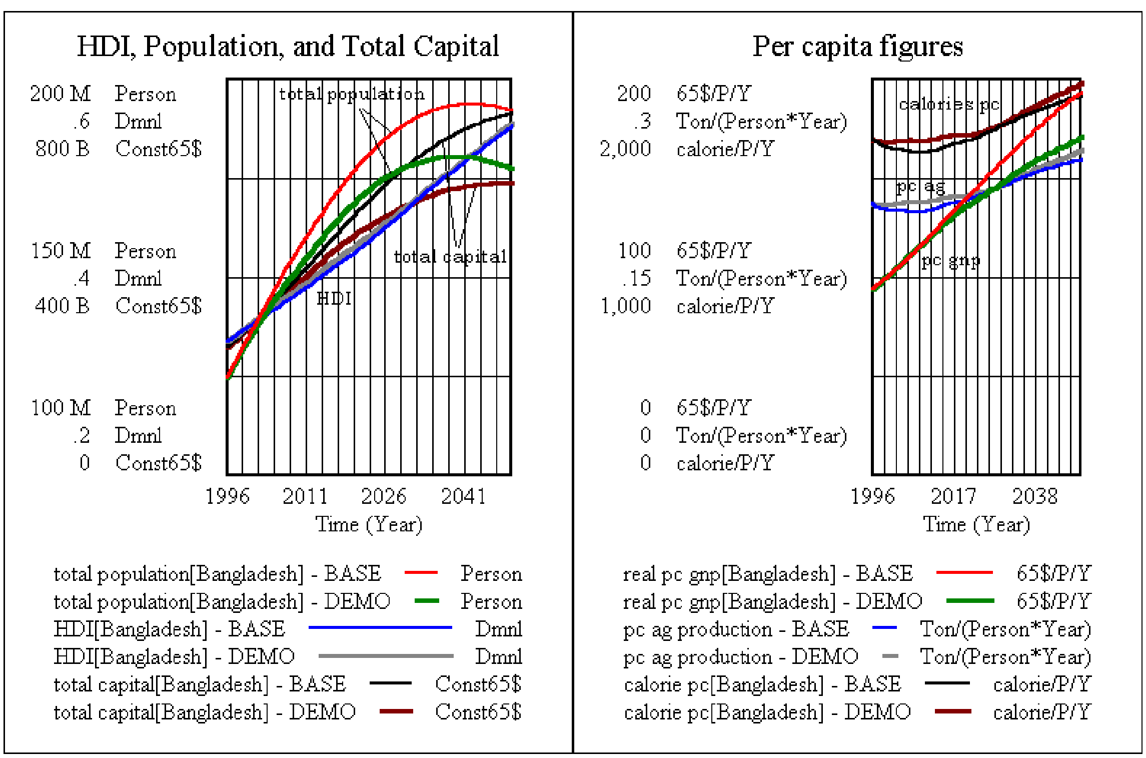

Figure 11. A Towards Sustainability Scenario for Bangladesh (second of two graphs)

In this Towards Sustainability scenario, population growth slows down and reaches a peak of 178 million persons in 2038. Per capita food and per capita GNP are both improved, and the HDI indicator shows a positive change. With the economic and living conditions improved, the government and people in Bangladesh have more opportunity for social and environmental improvements.

A Run with a Structural Change

THRESHOLD 21 has the ability to examine structural changes in a society or economy.[3] A number of structural changes have been proposed such as to examine the impact of changing tax policies, say from taxing income to taxing resource use and pollution, or to examine the effect of educating or not educating girls.

In the Bangladesh model, we explored the effect of a structural change by inserting a binary switch around the part of the model which simulates the education of girls. The switch controls whether or not girls are allowed to enter school at the time they would normally enter school.

Below Figures 12, 13, and 14 show the effect of preventing girls from entering school for a 10 year period starting in 2000. The most immediately apparent effect is upon goods production. This is because the quality of a person's education affects their capacity as a worker. If the female half of the workforce in a nation is denied an education, the resulting decline in labor productivity will quickly and adversely affect the output of the economy and the nation's productivity, especially if much of the output is labor intensive.

[3] Structural changes can be implemented with binary switches. The new structure must first be programmed into THRESHOLD 21 by putting in the relationships between the new structure and the existing model. The new structure can then be activated (or the existing structure de-activated) during a run of the model using a binary time series. When the value of the time series is zero, the structure will be dormant or "off." When the value of the time series is one, the structure is turned "on", i.e., included in the operation of the model.

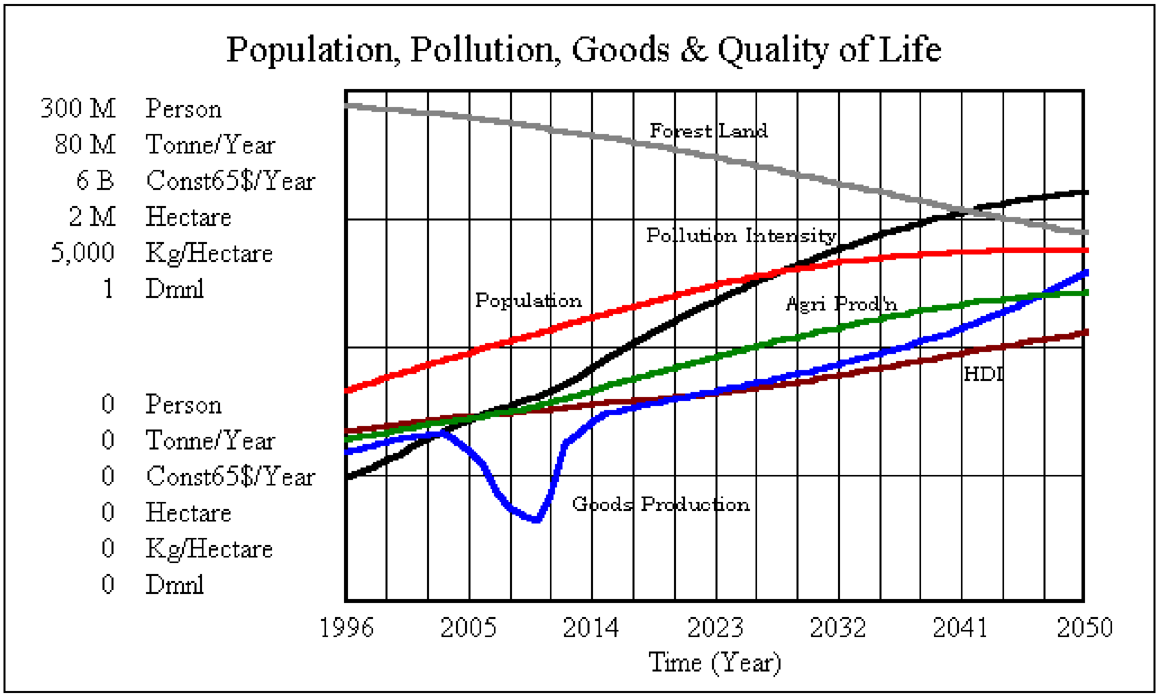

Figure 12. Effects of Preventing Girls from Entering School from 2000 to 2010 (first of three graphs)

As seen in Figure 13, not only does goods production fall, but also per capita agricultural production and per capita GNP. On the other hand, population increases because in the model the success of the family planning program is linked to the education level of girls.

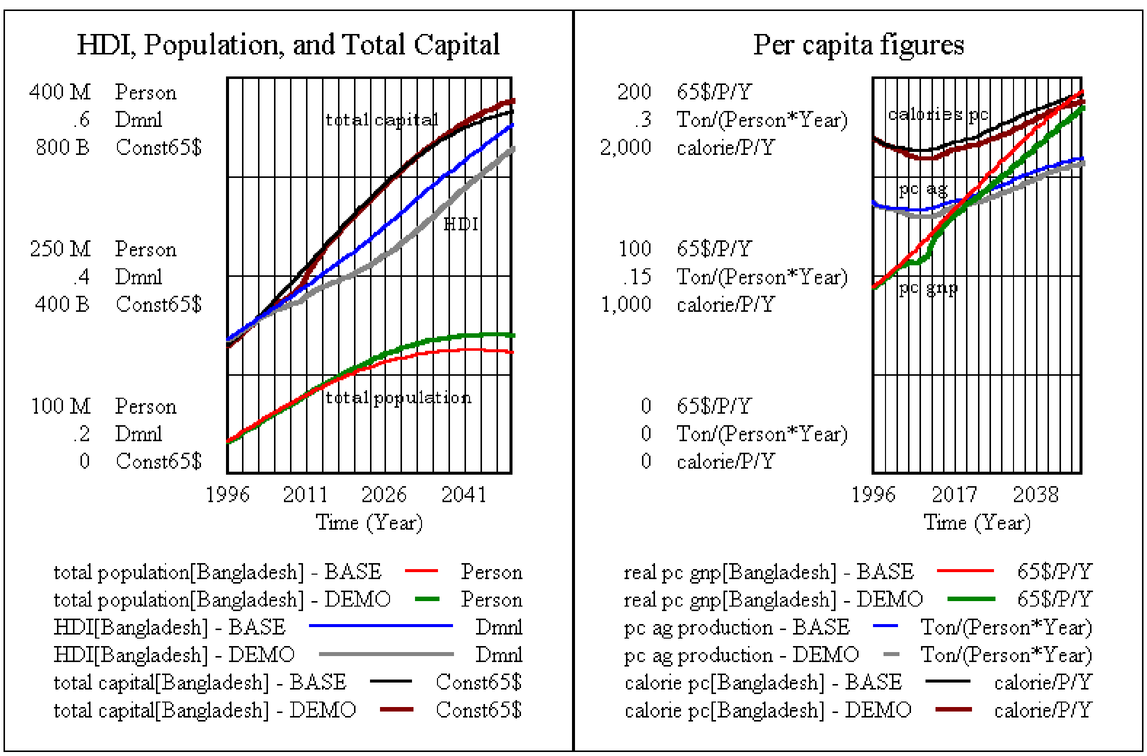

Figure 13. Effects of Preventing Girls from Entering School from 2000 to 2010 (second of three graphs)

The next figure (14) shows that preventing girls from entering school for 10 years has a long-term impact on the overall life expectancy of males! After a delay of nearly 20 years, the reduction of male life expectancy is significant.

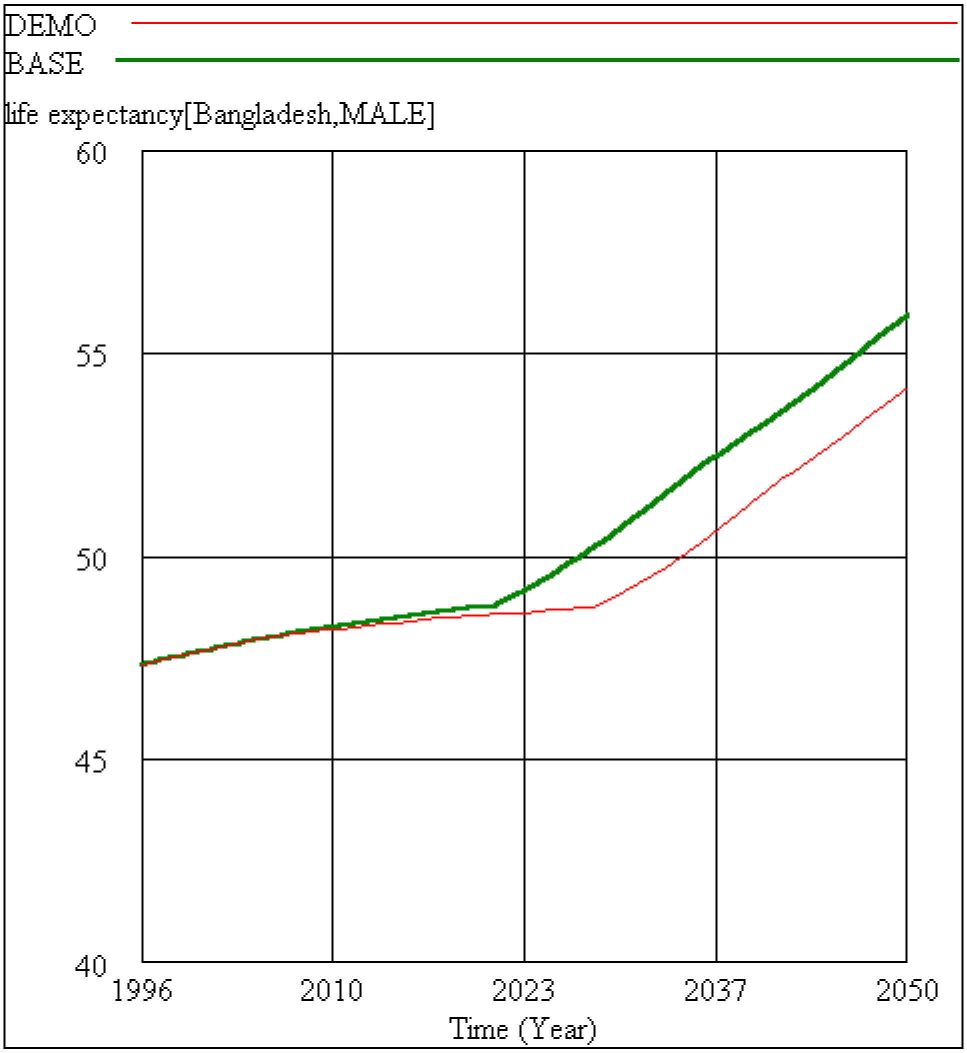

Figure 14. Effects of Preventing Girls from Entering School from 2000 to 2010 on Male Life Expectancy (third of three graphs)

Our current model assumes that industrial productivity is related to quality of education so when girls are not allowed to enter school, the quality of education goes down immediately. A more realistic approach is to base productivity on adult literacy (which will be implemented in the next version of the model) and hence, the effects of varying year-to-year levels of education will be delayed and smoothed over time.

A Possible "Best" Scenario

There may be other scenarios -- as yet undiscovered -- which can demonstrate still more improved outcomes for Bangladesh, but the "best" scenario so far discovered is shown in Figure 15. In this scenario the investment bias for the Agriculture sector is set to 1.1, Goods to 1.2, and Social Services to 1.3.

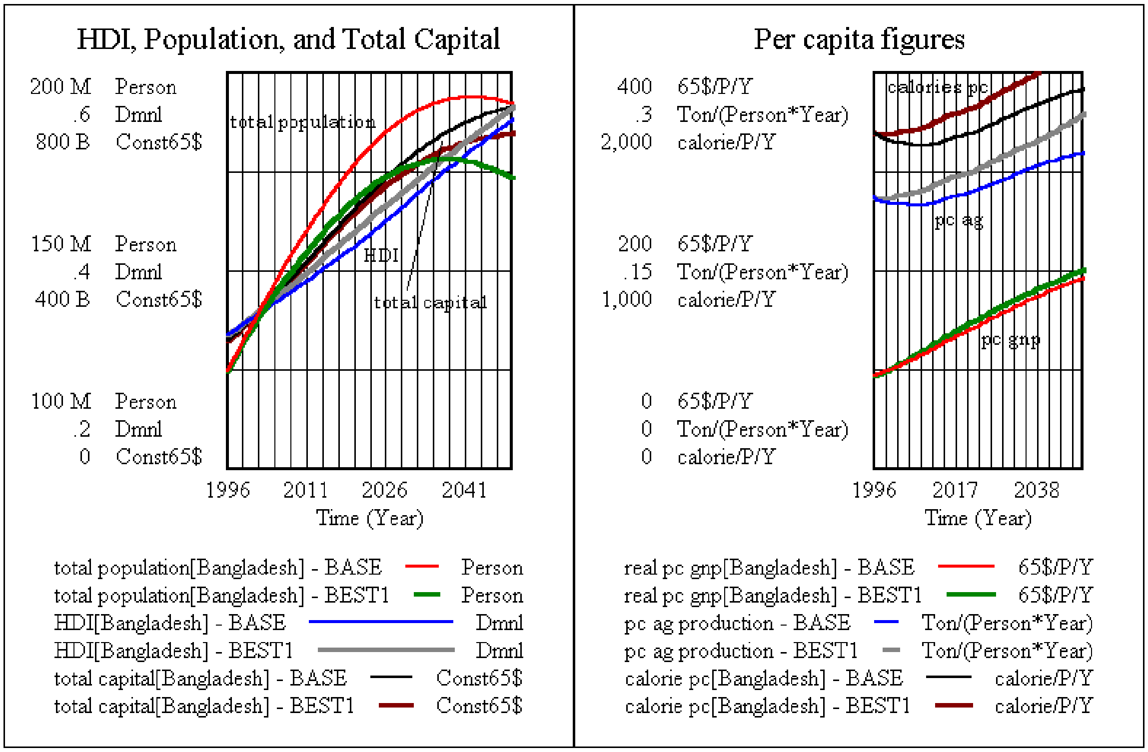

Figure 15. A Possible "Best" Scenario for Bangladesh

Recommendations for Bangladesh

Based on exploration of a variety of investment scenarios, our best recommendations, at this time, for Bangladeshi policymakers are the following:

- Increase the investment in Social Services very significantly in order to reduce population growth. There is no room for complacency on population. Significant improvements in essentially all per capita indicators are difficult to achieve and sustain until population growth stops. Furthermore, complacency on population can lead to growth that overwhelms any material advances.
- Increase investment in the production of goods so as to improve the material quality of life of Bangladeshis. This will contribute to improved labor productivity and also to reducing incentives for large families.
- Increase investment in the agriculture sector modestly in order to assure adequate foodstuffs. Bangladesh cannot afford social disorder, and history includes many examples of countries having social unrest when food prices increase.

These recommendations assume that oil imports will continue without constraint and at current prices, including those which constrain import or export ability, especially for oil.

It is recommended that Bangladeshis explore for themselves and with the donor community a wide range of scenarios. Initial policy explorations indicate that if energy demand cannot be met, it will have a severe impact on the quality of life in Bangladesh.

It is also recommended that the Bangladesh THRESHOLD 21 model be compared with alternative models and all sectoral models be examined by experts, especially those familiar with Bangladesh.

Bangladeshi policymakers face difficult choices and deserve the support and understanding of everyone. Population levels can be reduced and the quality of life improved most easily by investing in the goods production sector. Yet, the likelihood of constrained oil imports looms. The THRESHOLD 21 model shows that it may be possible to design a "towards sustainability" policy that improves, or at least maintains, the quality of life, while reducing dependence on imported oil. Obviously there are many other issues to be considered so it is important that Bangladeshi planners, policymakers, business leaders, NGOs, and the donor community adopt and extend the work the Millennium Institute has begun with the Bangladesh THRESHOLD 21 model.

The Country in Transition: Tunisia

The country and client

The Republic of Tunisia, a medium-sized country of roughly 8 million people, has successfully promoted economic and social progress while effectively managing its limited natural resources. An oil boom from the mid-'70s through the mid-'80s brought in substantial revenues in addition to those produced by commodities and phosphate mining. Petroleum resources are nearing depletion, however, which will leave Tunisia a net oil importer. GNP per capita in 1990 was $1,440, exceeded on the African continent only by the OPEC economies and South Africa. Population growth in Tunisia has declined continuously while life expectancy has risen and infant mortality has fallen. Long-term emphasis on developing human resources and maintaining economic stability have been priorities for the Tunisian government. Women and young people have made great strides in education and entering the workforce; unemployment, however, has gradually increased to approximately 15 percent. A balance of payments crisis in the mid-'90s was averted by strong intervention, and the country's debts in the early '90s have remained approximately 4 percent of GNP. (World Bank, 1992)

The Millennium Institute has been working with the Tunisian Institute for Strategic Studies (ITIS) to develop the Tunisian version of THRESHOLD 21. ITIS, which reports to the office of the President, is a relatively new part of the government and is charged with developing an integrated perspective on the long-term future of Tunisia.

THRESHOLD 21 for Tunisia

The Tunisian version of THRESHOLD 21 was developed from an early version of the Bangladesh model. THRESHOLD 21 was adapted to the Tunisian context by the Millennium Institute working in conjunction with the Tunisian modeling team at ITIS. Additional submodels were designed and implemented in cooperation with the Ministry of Water to extend and improve the water sector of the model.

The following sectors are included in the Tunisia THRESHOLD 21 model: agriculture, demographics / conceptions, economy (including production, consumption, import, export, and a supply and demand model), education, energy (fossil fuel, electric, and renewable), environment (pollution and environmental control), forestry, goods (industrial production, including investment allocation), greenhouse gas emission, health care, land, military, nutrition, social services, technology, trade, water, and flows of funds. In addition, the Tunisia THRESHOLD 21 model includes a wide range of indicators such as UNDP's Human Development Index, the World Bank's MEP Indicators, and selected indicators from UNICEF.

The additional sectors added to the Tunisia model include submodels for reservoir water supply, reservoir capacity, phreatic water supply, aquifer water supply, pumping capacity, and water demand. Average annual water inflow and reforestation rates can be set from the Policy Selection Screen in the Tunisia model, as assumptions regarding these factors are important in policy discussions in Tunisia.

Several sectors of THRESHOLD 21 need additional refinement before they fully reflect the Tunisian situation. The Tunisian team is especially interested in refinements to capital flows (the Tunisian RMSM), education, and health.

The President has asked ITIS for a report and a conference on the future of Tunisia, with special attention to demography, water, and energy. ITIS plans to use the THRESHOLD 21 for this report and hopes to interest many ministries in parts of the THRESHOLD 21 model. The sectoral models (agriculture, population, education, energy, goods, health care, and nutrition) have been separated out to operate independently and shared with the relevant ministries. Critiques and improvements are invited. In addition, a more detailed water model has been developed in cooperation with the Ministry of Water.

ITIS, in cooperation with the Millennium Institute, has begun developing a training center to train other groups from other countries in the use of THRESHOLD 21. The first group trained was the group in Malawi preparing the National Long-Term Perspective Study for Malawi.

Analysis of Scenarios for Tunisia

When using the THRESHOLD 21 model, policy inputs for scenarios are made using the Policy Selection Screen. The Policy Selection Screen for THRESHOLD 21-Tunisia is shown in Figure 16.

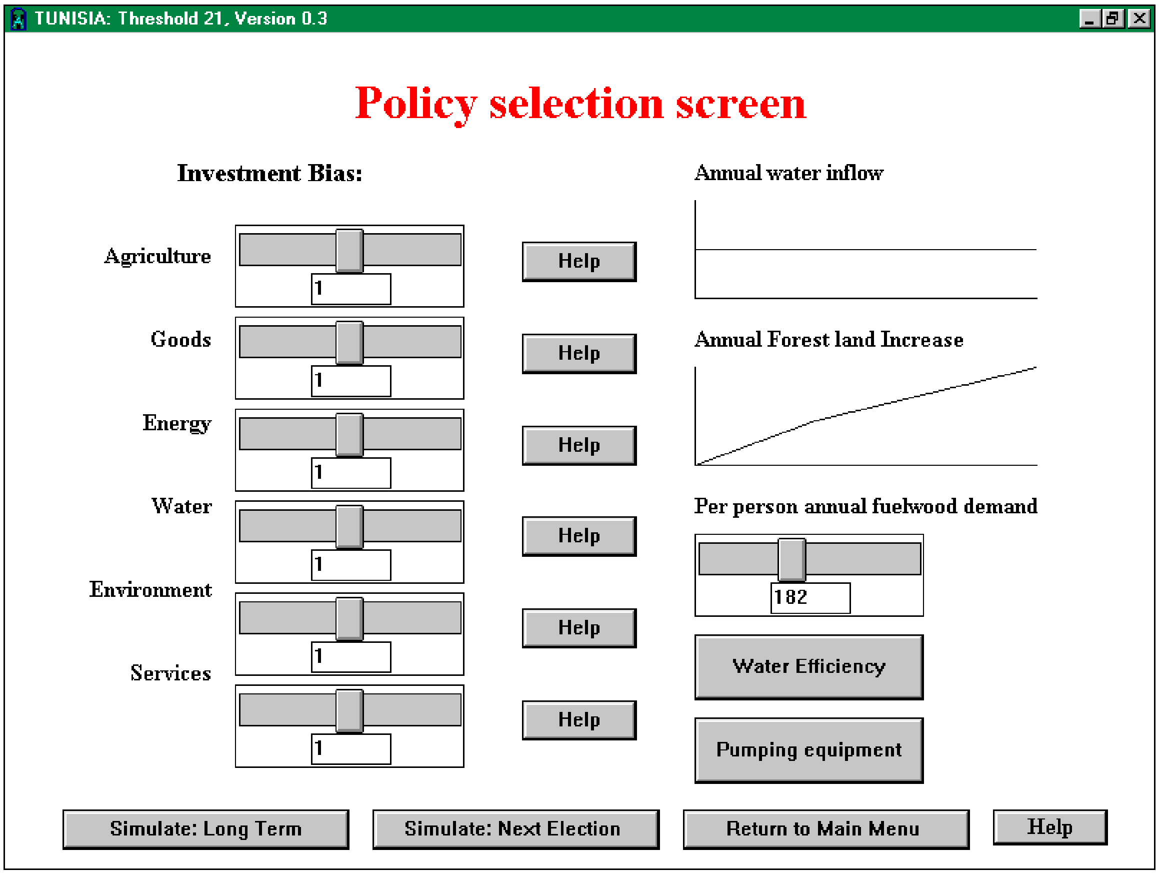

Figure 15. Policy Selection Screen for Tunisia THRESHOLD 21 Model

As shown in Figure 16, the Policy Selection Screen for THRESHOLD 21-Tunisia has investment bias slide-bars for six sectors: Agriculture, Goods, Energy, Water, Environment, and Services. (The Services sector includes education, family planning, etc.) Exogenous inputs for the THRESHOLD 21-Tunisia model include *Annual water inflow* and *Per person annual fuelwood demand*. These assumptions are quite important and are placed here to keep them clear in the user's mind. Two additional buttons, *Water Efficiency* and *Pumping equipment*, allow a user to simulate the result of investing in water use efficiency, rather than in water pumping capacity. Details on the functions and effects of the policy input variables are provided in Appendix B.

To begin the application of THRESHOLD 21-Tunisia, the model is used to simulate the historic period 1965-1995 with the investment slide-bars all set at 1. The results (shown in part in Appendix B) are compared with the actual data for the period, and adjustments are made as needed to achieve a satisfactory fit.

Once the model is satisfactorily calibrated, the Base Case scenario is run. The Base Case is a continuation of historic policies, which means a simulation of the 1995-2050 period with the investment biases all set at 1. Other specific inputs for the Base Case are presented in Appendix B, as are the general assumptions for Threshold 21 and the specific assumptions of the Tunisian version. The Base Case provides the reference scenario against which the other scenarios are compared.

Figure 17 shows the overview screen output from the Base Case scenario for the period 1995 to 2050. Population grows from approximately 9.5 million to 15.5 million. Goods production increases strongly and then peaks circa 2035; pollution peaks roughly 5 years later. The Human Development Index (HDI) improves slightly, peaks slowly around 2020, and then begins to decline around 2034. Oil and gas reserves peak at $2x10^{15}$ BTUs circa 2007 and decline strongly afterwards.

The agricultural production curve is perhaps the most interesting. Agricultural production first increases, enters a minor slump in 2005, increases again, then suffers a significant decline in 2015, recovers modestly for a couple of decades, and then begins to decline again around 2040. Analysis using Causal Tracing™ reveals that the cause of the slump is exhaustion of aquifer water in 2005, and the cause of the next decline is depletion of phreatic water (to annual replenishment levels) in 2015. The declines in agricultural production are directly related to the declines in the availability of water. The gradual decline in HDI is a result of the decline in GNP, in turn due to a decline in energy production -- primarily oil and gas. The decline in goods production is due to declining labor productivity, also due to the declining availability of energy. The long-term decline in agricultural production is also due to the declining availability of energy.

Annual water demand exceeds annual supply circa 2045 (see Figure 18); however, seasonal shortages probably occur much earlier. Calories per capita decline, but precise values are not available because the agricultural sector of the model has not yet been fitted to the widely fluctuating Tunisian data, and agricultural trade is not fully operational in the Tunisian version of THRESHOLD 21.

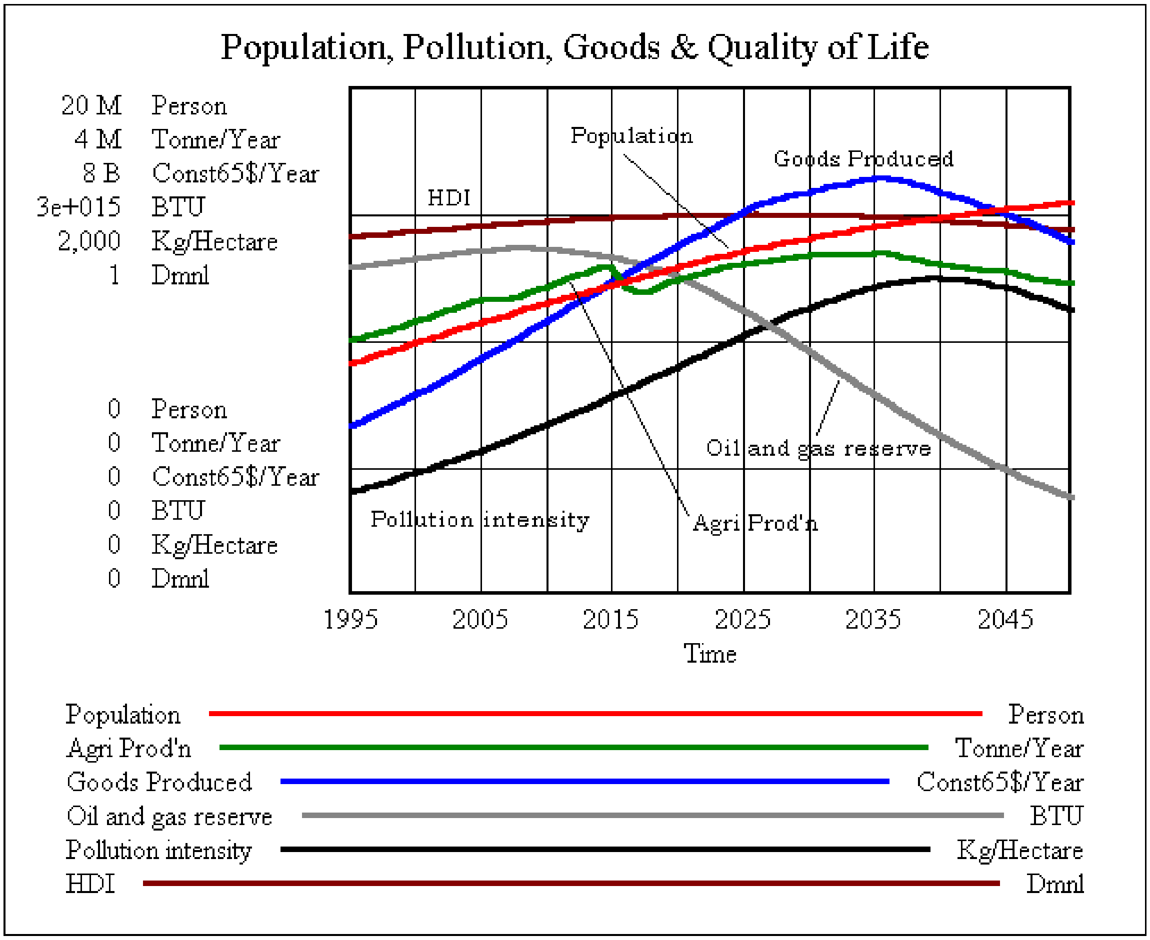

Figure 17. Overview Screen from the THRESHOLD 21 Tunisia Model, Base Case Scenario

Water is a limiting resource in Tunisia. If current policies remain in effect, Figure 18 shows what may happen to Tunisia's ground and reservoir water over the next 50 years.

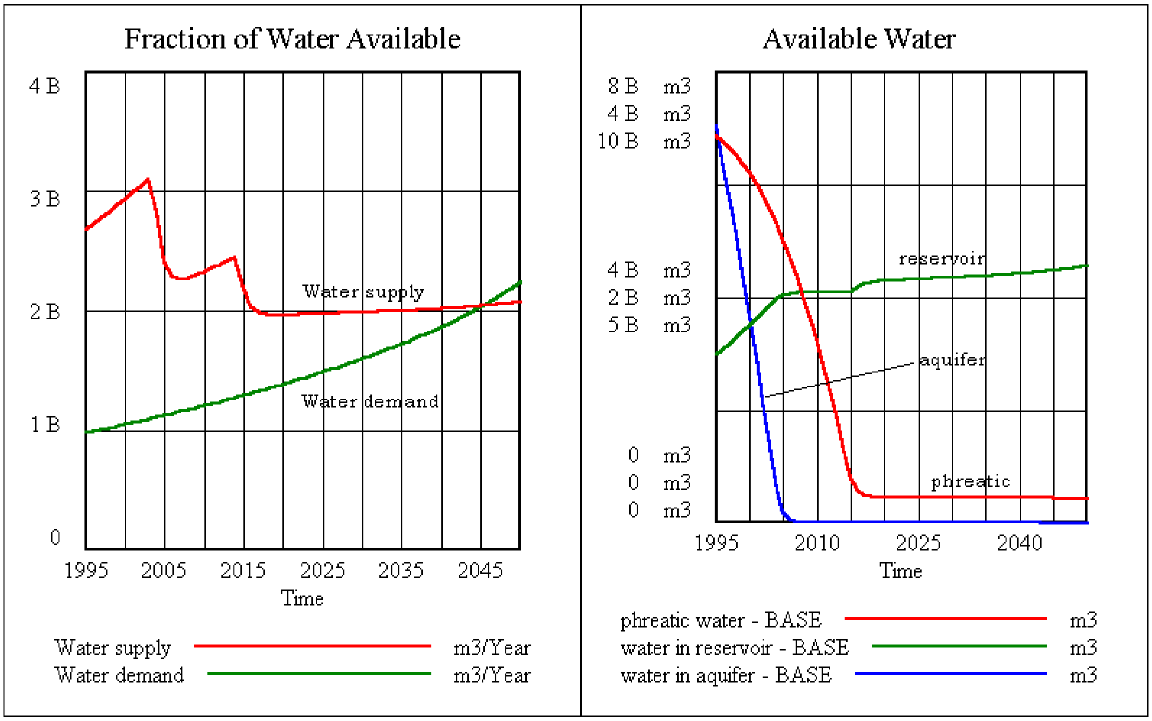

Figure 18. Water Variables, THRESHOLD 21-Tunisia, Base Case Scenario

Initial Experiments with Changes from the Base Case

In our initial experiments with changes from the Base Case, the investment bias slide-bars of the Tunisian model were moved from 1 to 1.2 for each of the six sectors. Table 2 summarizes the effects.

Sector	Investment	Total Population	Human Dev't Index	Total Capital	GNP per capita	Ag Prod'n[4]	Calories per capita
Agriculture	1.0 → 1.2	--	--	--	--	↑↑↑	↑↑
Goods	1.0 → 1.2	↓↓	↑↑	↑↑↑	↑↑↑	↓↓	↓↓
Energy	1.0 → 1.2	--	--	--	--	--	↑ & ↓
Water	1.0 → 1.2	↑	--	↓	↓	↓↑	↓↑↓↑
Environment	1.0 → 1.2	--	--	--	--	--	--
Services	1.0 → 1.2	↓	↑ then --	↑ then↓	↑ then --	↓	↓

Table 2. Summary of effects of changes of investment biases in single sectors relative to the Tunisia Base Case Scenario. Note: three arrows indicates a marked change relative to the Base Case; two arrows indicates a significant change; a single arrow indicates a slight change.

Solely increasing investment in the agriculture sector causes the total agricultural production to increase markedly. However, the impact of exhausting the aquifer and the phreatic water is still felt severely. Agricultural production is increased sufficiently, however, that production levels in 2015 -- at the bottom of the trough -- are 10-15%

[4]Agri Prod'n” is taken from the variable “pc crop food consumption,” which in the Tunisian model is identical to the usual THRESHOLD 21 variable “Agricultural Prod'n per capita.

above the highest production levels of the Base Case. Per capita agricultural production and per capita calories also increase markedly. Total population, HDI, total capital, and GNP per capita are not different from the Base Case. Annual water demand exceeds water supply circa 2045 (with seasonal shortages sooner). Calories per capita start at 1,700 in 1995, climb to 2,050 during the period 2000 to 2020, and then slowly decline to about 1,600 in 2050; these figures would be higher if agricultural trade were operational in the Tunisian version of the model.

Solely increasing investment in the Goods sector (industrial production) significantly increases the production of goods, greatly increases total capital, and significantly decreases the total population, and consequently greatly increases the GNP per capita over the Base Case. HDI is improved significantly (approx. 10%). Agricultural production declines, slowly at first, and then significantly over the long-term. Annual water demand exceeds annual water supply a bit sooner, circa 2043 (with seasonal shortages even sooner). Calories per capita, which start at 1,700 in 1995 and in the Base Case steadily declined to 1,250 in 2050, now declined even more severely to about 1,100 in 2050. However, agricultural trade is not operational in the Tunisian version of THRESHOLD 21.

Solely increasing investment in the Energy sector does not appear to have much effect: total population, HDI, total capital, GNP per capital and agricultural production are virtually unchanged compared to the Base Case; calories per capita experiences some minor short-term differences but is basically also unchanged, ending at 1,250 in 2050. Water still runs out 2045.

Solely increasing investment in the Water sector minimizes the effect of aquifer exhaustion on agricultural production -- the investment means more phreatic water can be pumped -- however this accelerates the exhaustion of the phreatic water and causes the decline in agricultural production which occurred in 2015 in the Base Case to occur a few years earlier. Over the long-term, agricultural production is up slightly. Water runs out slightly later, in 2046 (with seasonal shortages sooner).

Solely increasing investment in the Environment sector does not cause any change in total population, HDI, total capital, GNP per capita, agricultural production, and calories per capita. Pollution intensity does decline slightly. Water runs out in 2045 (with seasonal shortages sooner).

Solely increasing investment in the Services sector (education, health care, “family planning”, etc.) causes total population to decline somewhat, initially improves HDI slightly (but produces no change from the Base Case over the long run), and diminishes total capital slightly over the long run. Agricultural production is slightly lower (because investment in Services has shifted some investment away from Agriculture), as is calories per capita (because agricultural production declined more rapidly than did population).

Optimism/Hope Scenario

See the Introduction for a description of the UNCSD Optimism / Hope scenario and our adaptation of the scenario.

For Tunisia, we test our equivalent of the UNCSD Optimism / Hope Scenario with two scenarios. In the first, we encourage increased investment in the industrial sector (Goods). Figure 19 gives a snapshot of the effect of moving the Goods slide-bar to 1.2.

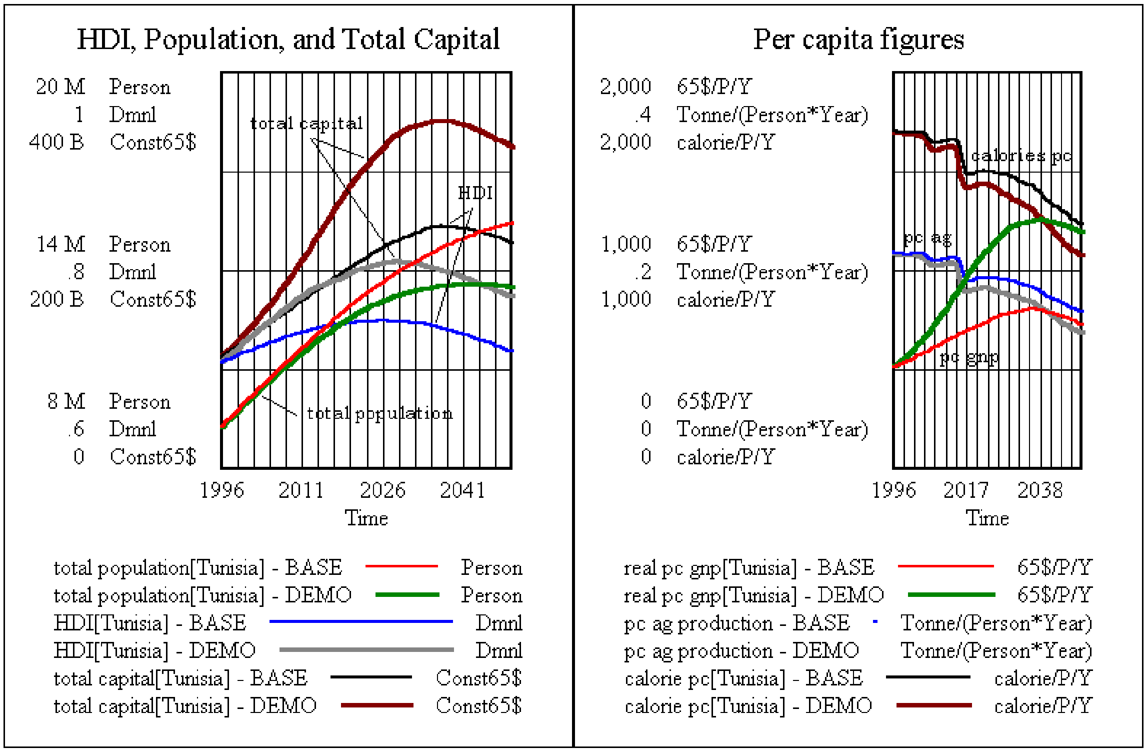

Figure 19. A First UNCSD Optimism / Hope Scenario (Demo) compared with the Base Case Scenario, Tunisia

In this version of the "Optimism / Hope" scenario

- industrial output is greatly increased
- HDI is significantly increased
- calories per capita is much lower (but agricultural imports are not included)
- annual water demand exceeds annual supply circa 2043; however, seasonal shortages probably occur much earlier
- required energy imports increase by half

In the second equivalent of the UNCSD Optimism / Hope scenario, we encourage investment in both the industrial sector (Goods), and in the agriculture sector (Agriculture). Specifically, we try to improve calories per capita by moving the Agriculture slide-bar to 1.2 and the Goods slide-bar to 1.2. Figure VII-3b provides an overview of the results.

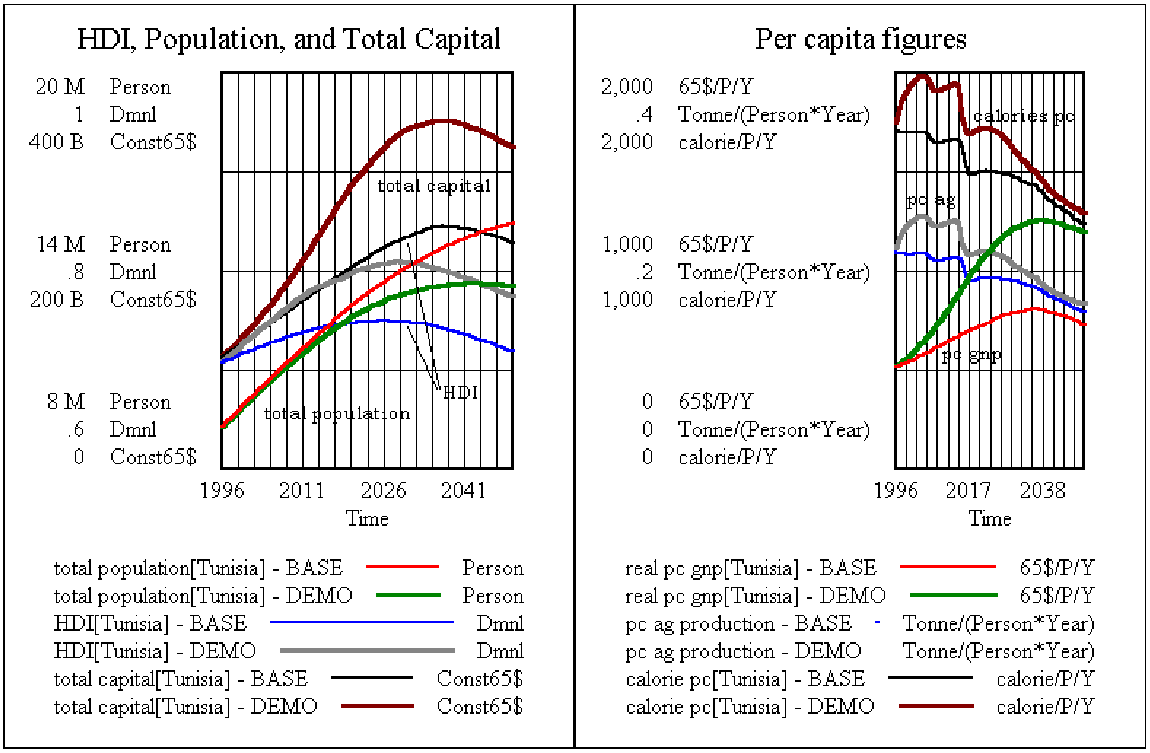

Figure 20. A Second UNCSD Optimism / Hope Scenario (Demo) compared with the Base Case Scenario, Tunisia

In this version of the "Optimism / Hope" scenario

- industrial output is greatly increased
- HDI is greatly increased
- the calories per capita indicator is much higher (but agricultural trade is not included)
- pollution intensity increases by half
- annual water demand exceeds annual supply circa 2043; however, seasonal shortages probably occur much earlier
- required energy imports increase by half

As with the Bangladesh case, one "What if" to explore is "What happens to either of these scenarios if energy imports are constrained?" This will be one focus of future versions of the model.

Pessimism/Fear Scenario

See the Introduction for a description of the UNCSD Pessimism / Fear scenario and our adaptation of the scenario.

For Tunisia, we test our equivalent of the UNCSD Pessimism / Fear Scenario by attempting to reduce population growth by moving the Services slide-bar to 1.2 (thereby increasing investment in education and family planning) and by moving the

Goods slide-bar to 0.8 (decreasing investment in industrial activity). The results are shown in Figure 21.

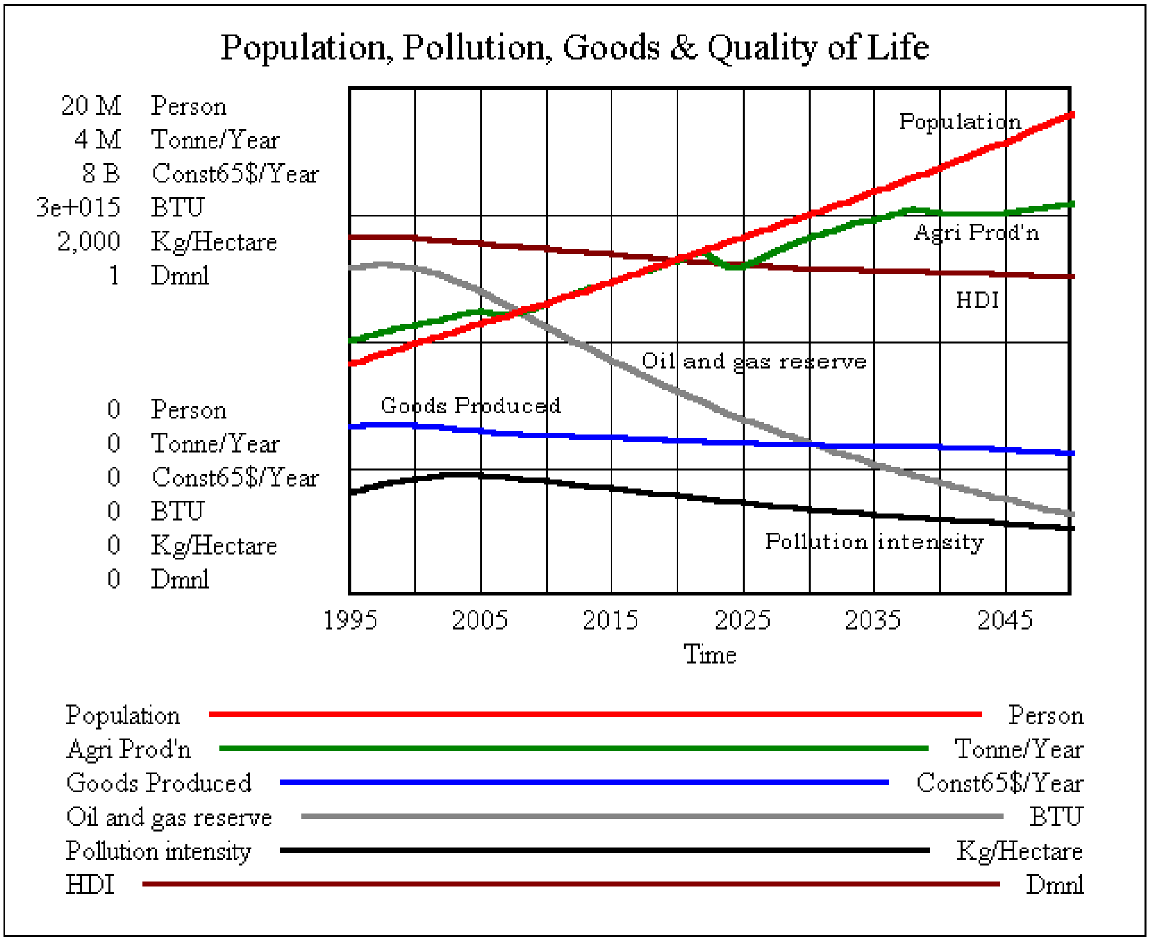

Figure 21. A Pessimism / Fear Scenario

In our equivalent of the UNCSD Pessimism / Fear scenario, relative to the Base Case:

- Population goes up. This somewhat surprising result occurs because when Goods investment is significantly reduced, GNP is much smaller, and there is less income to invest, including in social services. So while the percentage allocated to Services (including family planning) is bigger, the actual dollar amount is smaller, and family planning receives fewer resources
- calories per capita declines approximately as in the Base Case
- industrial output declines slightly
- pollution intensity also declines slightly
- HDI declines significantly (down 10%)
- water demand does not exceed supply until 2050; however, seasonal shortages probably occur much earlier
- Tunisia is able to export energy until 2014 or so; and the oil imports required overall are much less than in the Base Case

The above scenario reveals that at least the current level of investment (or greater) in the industrial sector (Goods) is required in order to slow population growth and at the same time to maintain a reasonable quality of life.

Another Pessimism / Fear scenario: In a second equivalent of the UNCSD Pessimism / Fear scenario, an alternative strategy is explored to address the need to maintain a reasonable quality of life. In this scenario, Investment in Goods is increased slightly over the Base Case to 1.1 while investment in Services is kept at 1.2. The results are shown in Figure 22.

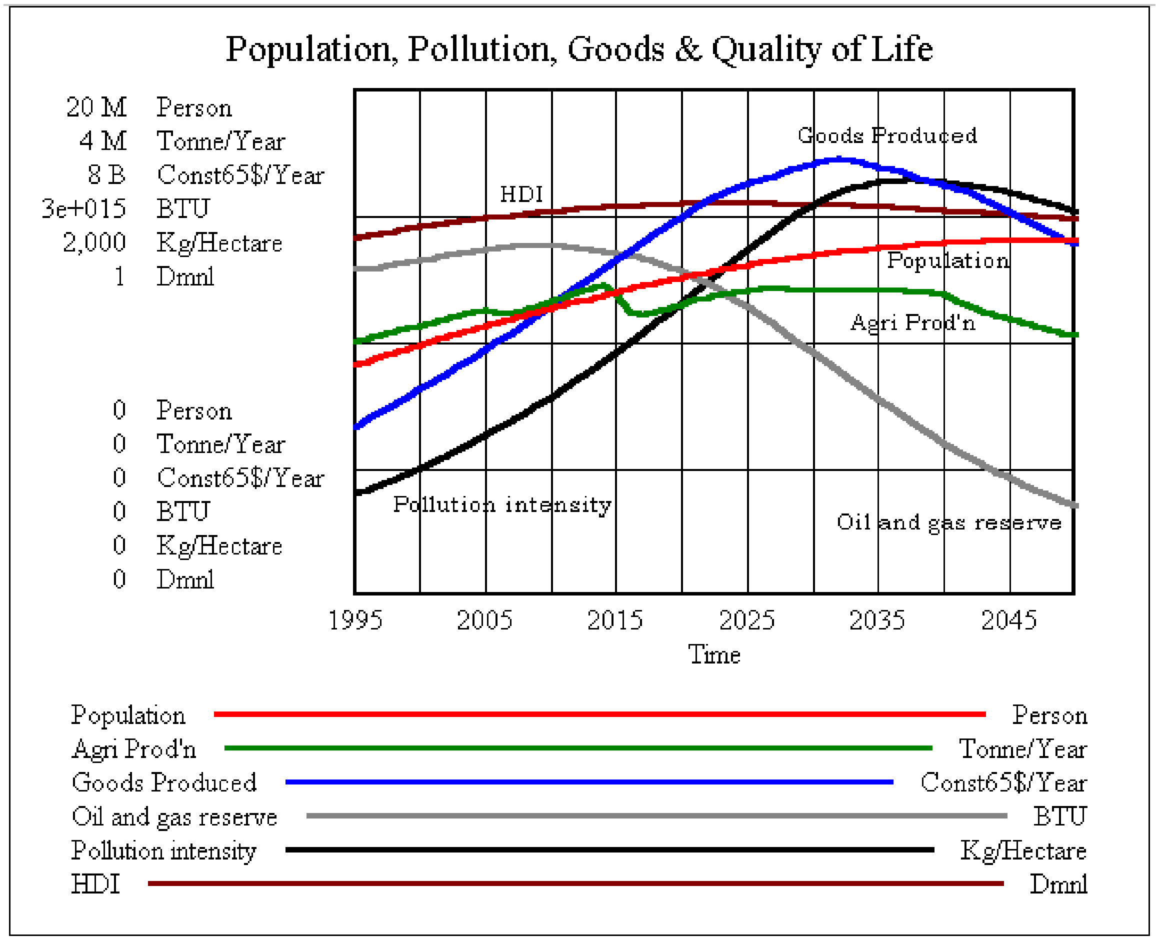

Figure 22. A Second Pessimism / Fear Scenario

In this alternate Pessimism / Fear scenario, relative to the Base Case:

- population levels off
- agricultural production and calories per capita are down
- industrial output , per capita GNP, and total capital are all greatly improved
- pollution intensity increases very significantly (about 20-30%)
- HDI is improved (up 5-10%)
- water demand does not exceed supply until 2044; however, seasonal shortages probably occur much earlier

- Tunisia is only able to export energy until 2000; and then required oil imports are more than in the Base Case

Towards Sustainability Scenario

To begin formulating a sustainable strategy for Tunisia, we begin with the conditions which now exist: a) the population is only barely emerging above poverty -- if goods production is not maintained, population growth rates will increase; b) aquifer and phreatic water are being used at rates much beyond replenishment rates; and c) the country will soon be heavily dependent on imported energy. As an approximation of a Towards Sustainability scenario, we selected 1.1 for the investment bias in Agriculture, left Goods at 1 and Services at 1. The results are shown in Figure 23 below.

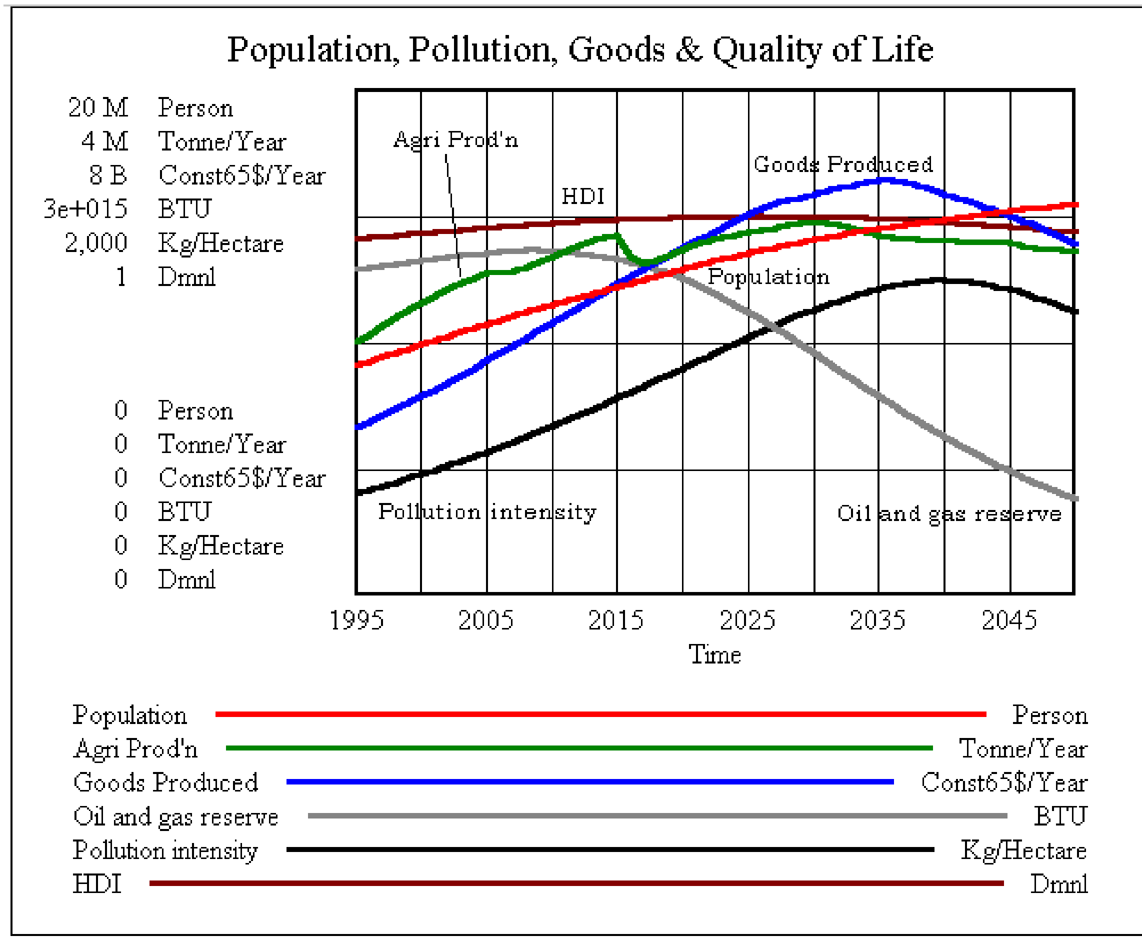

Figure 23. A Towards Sustainability Scenario for Tunisia

The next figure (24) shows the changes over the Base Case -- mainly in agricultural production and calories per capita.

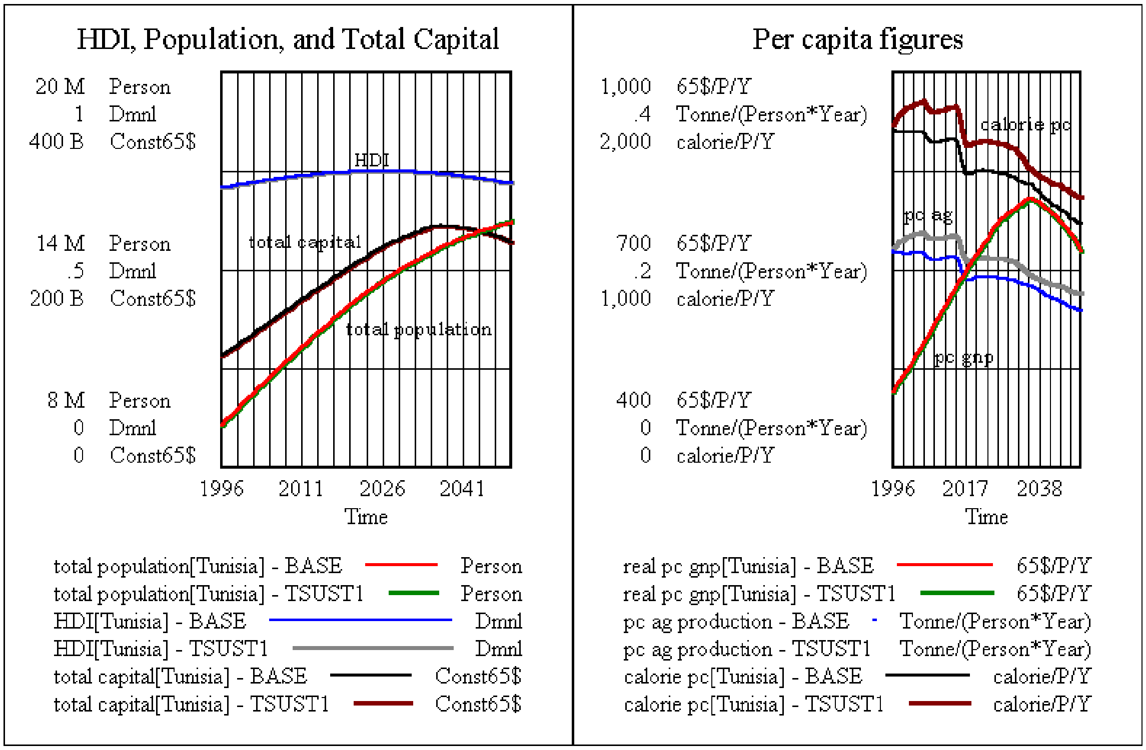

Figure 24. A Towards Sustainability Scenario for Tunisia (2)

This scenario is only slightly changed from the Base Case. The increased investment in the Agriculture sector does not get around the impact of the aquifer's exhaustion or the depletion of phreatic water, but it is the best strategy for increasing agricultural production in the face of those shortages (see Figure 25 below). Investment in the Water sector, at least in the default configuration of the model, merely accelerates the rate at which the aquifer and phreatic water is pumped from the ground. We address this in the next section.

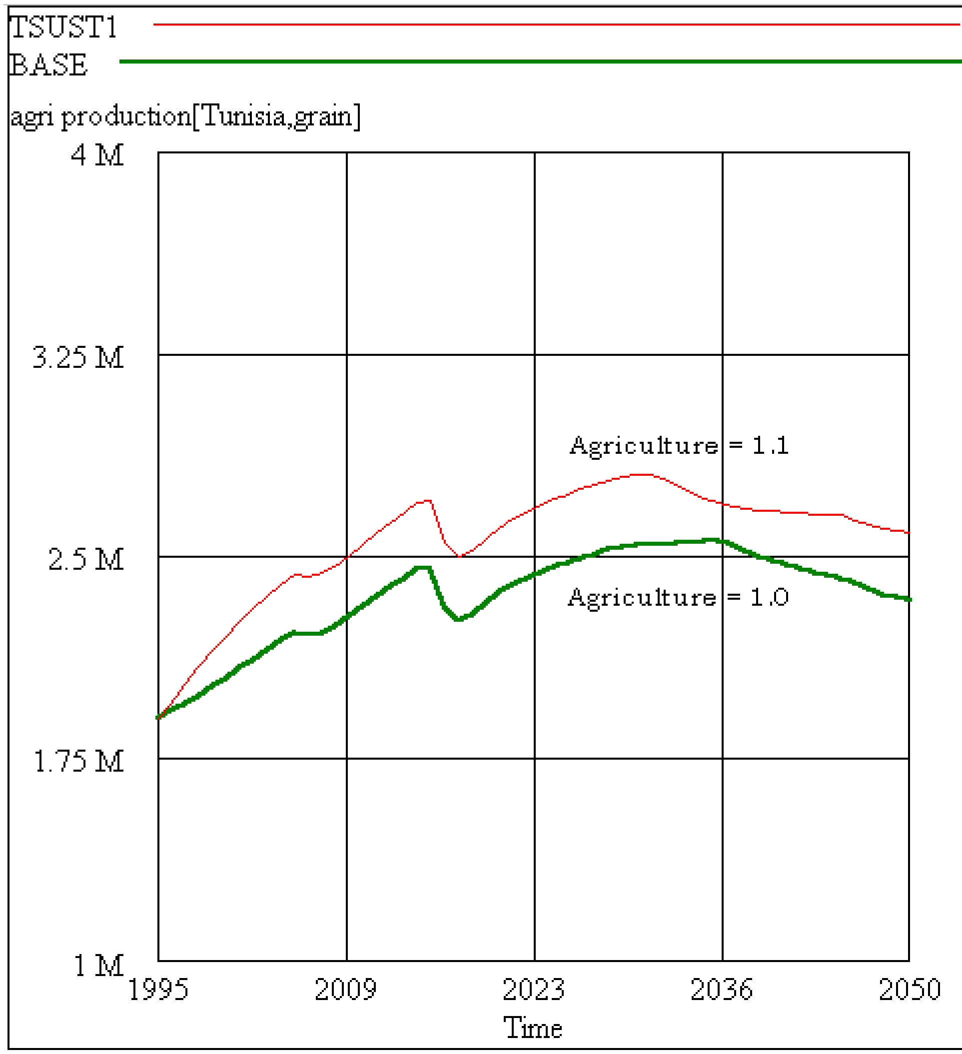

Figure 25. Effect of Agricultural Investment

There are other scenarios which will increase the Total Capital, per capita GNP, etc. and improve the quality of life over the Base Case, but they do so at the cost of increasing the amount of oil imports required.

When the ability to restrict the availability of oil imports has been added to a future version of the Tunisia THRESHOLD 21 model, we will explore scenarios where the oil import availability is set to decline from 100% to 50% over the next 25-50 years.

A Possible "Best" Scenario

As revealed by the previous cases, the main obstacles to achieving a sustainable future for Tunisia are in the areas of water and energy. As mentioned above, two buttons have been added to the Policy Selection Screen in the Tunisia THRESHOLD 21 model to enable policymakers to simulate the effects of investing in water use efficiency rather than in water pumping capacity. Prior to adding these buttons, investment in the Water sector was used in three ways: 30% of the investment went to pumping capacity, 60% went to building the capacity of the water systems (reservoirs, etc.), and 10% went to "other" investment in the water sector. Now, if the *Water efficiency* button is selected, the investment in pumping capacity instead will be used to improve water use efficiency. As a result, pumping capacity will not be expanded, and will actually decrease with depreciation of equipment. In addition, the model also doubles the technology advance parameter for water.

We explored several scenarios in which we attempt to improve the quality of life over the Base Case by increasing investment in Agriculture to increase calories per capita, increasing investment in Goods to improve material well-being, and increasing investment in Services to try to slow the rate of population growth. We explored these scenarios both with investment shifted to improve water use efficiency and without. At the same time we attempted to minimize the need to import oil. Specifically, we set the investment bias for the Agriculture sector to 1.1, Goods to 1, and Services to 1, and *Water efficiency* was turned on.

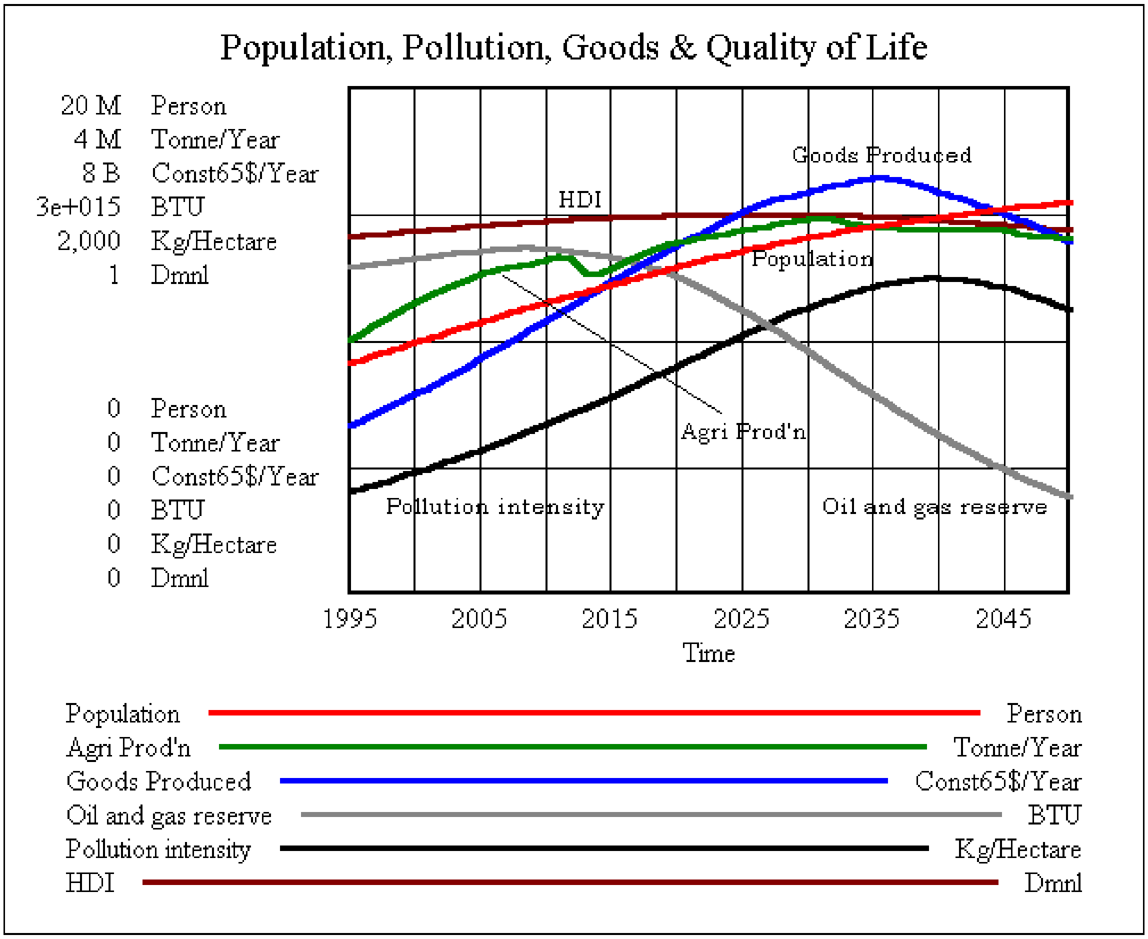

Figure 26. A Possible Best Case Scenario for Tunisia

With investment in the water sector skewed toward "water efficiency" (and away from "pumping capacity"), total water demand is less and supply is able to meet demand to 2050 and beyond. (In the current version of the model the *Water efficiency* button causes investment in pumping capacity to be turned off completely, so as the pumping infrastructure depreciates, Tunisia is increasingly unable to extract phreatic water. Analysis shows, however, that increased water efficiency should enable Tunisia to satisfy water demand well beyond 2050 (see Figure 27; compare with Figure 18). The next version of the model should have an improved water use efficiency submodel.)

There may be other scenarios -- as yet undiscovered -- which can demonstrate still more improved outcomes, but the scenario shown in Figure 26, is the best we have found to date.

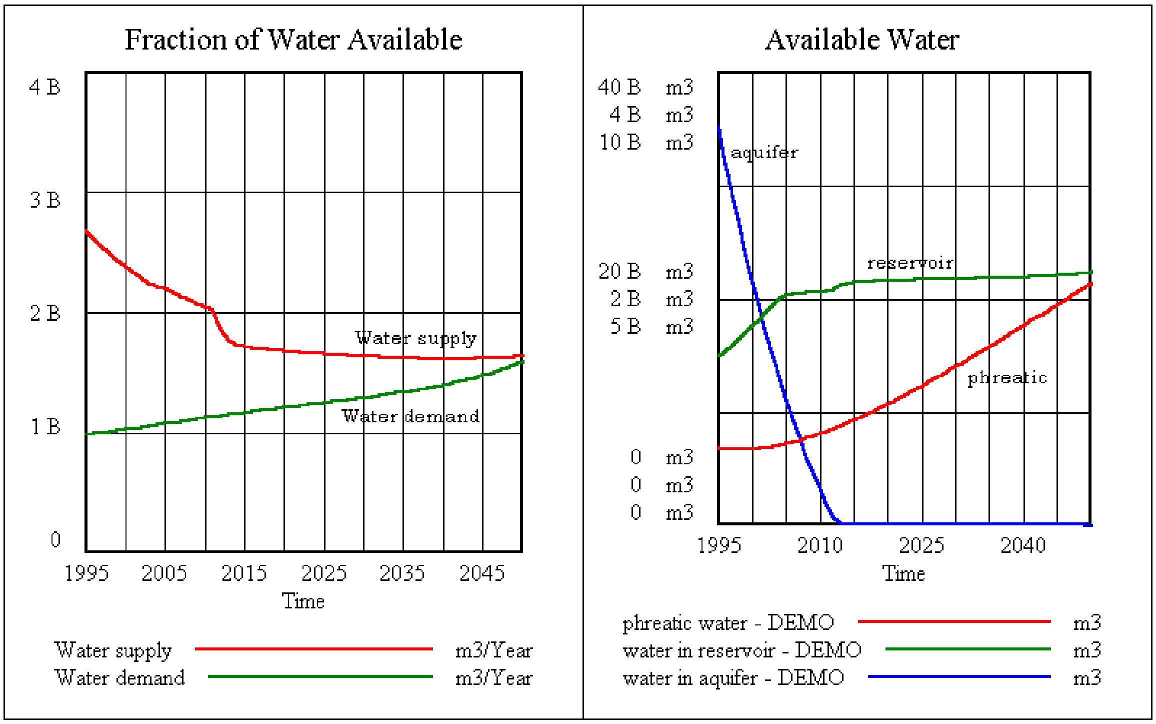

Figure 27. A Possible Best Case Scenario for Tunisia -- Water

Recommendations for Tunisia

Exploration of a variety of investment scenarios, some of which have been highlighted above, for addressing some of Tunisia's most pressing development issues -- water and energy shortages, and the need to continue to improve the material quality of life -- leads us to make the following tentative recommendations to Tunisian policymakers:

- Invest modestly more in agriculture. This is the most cost effective means of overcoming the projected drops in agricultural production due to water shortfalls.
- Invest in improved water use efficiency as a way to overcome projected inability of water supply to meet water demand. Increased water use efficiency will also increase any existing water supply safety margin, which will help buffer against climatic variations in natural water inflows.
- Invest in alternative energy technologies in order to reduce dependence on oil imports (which are projected to be needed within the next 15 years).

Current policies in effect in Tunisia seem to assume that oil imports will be available when needed without constraint and at current prices. In future a version of the model which is capable of constraining oil imports, a wide range of policy assumptions should be explored, including those which constrain overall import or export ability, especially for oil. It is clear from experience with the Bangladesh model, that if energy demand cannot be met, it will have a severe impact on the quality of life in Tunisia.

The Tunisia THRESHOLD 21 model should be compared with alternative models and all sectoral models should be examined by experts, especially those familiar with Tunisia. The recommendations made in Appendix C for overall improvements to THRESHOLD 21 also should be followed for the Tunisian version.

Tunisian policymakers also face difficult choices. Infrastructure, technology, and efficiency measures to address limited water resources must continue to be a priority, as well as the projection that Tunisia will soon need to import increasing amounts of oil unless alternative sources of energy are developed. Further development of the Tunisia THRESHOLD 21 to enable exploration of investment strategies to address these issues is key.

The Developed Country: The United States

The country and client

The United States of America, a developed country, is bounded by Canada on the north, by Mexico on the south, the Atlantic Ocean on the east, and the Pacific Ocean on the west. Its land area is 9,166,600 sq. km. The climate of the U.S. is mostly temperate, with some semiarid, tropical, and arctic climates. The U.S. population of 263.8 million is growing at 1.02% (1995) Male life expectancy is 72.8 years; female life expectancy is 79.7 years. As of 1979, 97% of those over 15 can read and write. It has highly diversified and technologically advanced industries. The national product per capita was $25,950 in 1994. GDP growth was 4.1% in 1994. Exports in 1994 came to $513 billion and imports to $664 billion. The U.S. is the world’s second largest producer and number one exporter of grain. Agriculture accounts for 2% of GDP and 2.9% of the labor force. The U.S. is a donor country. It provided economic aid of $115.7 billion from FY1980-89 (CIA, 1995).

The Changing Horizons Fund and the Los Trigos Fund have supported the Millennium Institute’s work to develop the United States version of THRESHOLD 21. The United States is a powerful symbol and example of “development,” and the funders hope that the U.S. THRESHOLD 21 model can help create an example of a sustainable economy, population, and lifestyle in the United States that will be an example to other countries.

THRESHOLD 21 for the United States.

The U.S. version of THRESHOLD 21 was developed from an early version of the Bangladesh model and adapted to model the United States by the Millennium Institute.

The U.S. version of THRESHOLD 21 is currently the least advanced version of THRESHOLD 21. It contains the following sectors: agriculture, demographics / conceptions, economy (including production, consumption, imports, exports, and a supply and demand model), education, energy (fossil fuel production, and demand & production, nuclear, renewable), environment (pollution and environmental control), goods (industrial production, including an investment allocation model), health care, military, nutrition, services, technology, trade, and RMSM's National Flow of Funds. The U.S. model includes selected indicators such as UNICEF's World Summit for Children goals and the UNDP's Human Development Index (HDI).

Immigration rates can be set from the Policy Selection Screen in the U.S. model as this is an important policy issue for some Americans.

The U.S. version has no forestry sector and only rudimentary tracking of greenhouse gases. The energy sector provides only limited possibility for substituting coal for oil in the form of synfuels. This is a significant limitation because, one way or another, the U.S. economy will depend on oil, even after its domestic oil supplies have run out and even if domestic coal production is increasing.

The Institute has placed the U.S. version on its World Wide Web site and is actively seeking collaborative arrangements with other groups interested in applying the model. Several are particularly interested in using the model to study how the United States would change if it implemented the "tax shift" idea of eliminating corporate income tax and instituting a tax of equal magnitude on resources used (throughput) and waste / pollution generation.

Analysis of Scenarios for the United States

When using the THRESHOLD 21 model, policy inputs for scenarios are made using the Policy Selection Screen. The Policy Selection Screen for THRESHOLD 21-United States is shown in Figure 28.

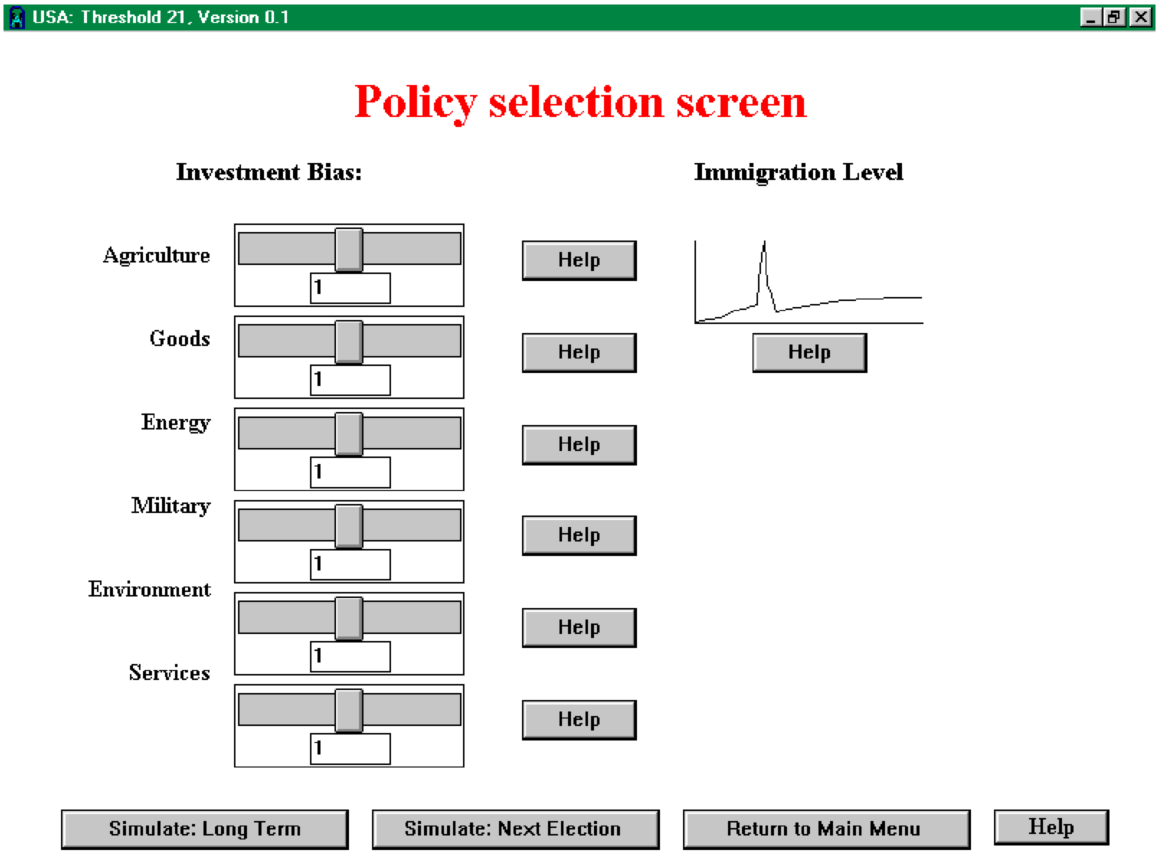

Figure 28. Policy Selection Screen for U.S. Threshold 21 Model

As shown in Figure 28, the Policy Selection Screen for THRESHOLD 21-USA has investment bias slide-bars for six sectors: Agriculture, Goods, Energy, Military, Environment, and Services. (Investment in [Social] Services affects quality of education, quality of health care, and both family planning effectiveness and desired family size, which in turn affect the fertility rate). From this screen users can also set U.S. immigration levels for the period 1995-2050. Details on the functions and effects of the policy input variables are provided in Appendix B.

To begin the application of THRESHOLD 21-U.S.A., the model is used to simulate the historic period 1965-1995 with the investment slide-bars all set at 1. The results (shown in part in Appendix B) are compared with the actual data for the period, and adjustments are made as needed to achieve a satisfactory fit.

Once the model is satisfactorily calibrated, the Base Case scenario is run. The Base Case is a continuation of historic policies, which means a simulation of the 1995-2050 period with the investment biases all set at 1. Other specific inputs for the Base Case are presented in Appendix B, as are the general assumptions for THRESHOLD 21 and the specific assumptions of the U.S. version. The Base Case provides the reference scenario against which the other scenarios are compared.

Figure 29 shows the overview screen for the U.S. Base Case scenario for the period 1995 to 2050. The most striking feature of the overview screen is the decline in oil and gas reserves. Equally striking is the fact that, in spite of the declining oil and gas reserves, the U.S. economy continues to grow. The reason is the substitution of coal for oil. The model projects that by the year 2010, the majority of U.S. domestic energy demand will be met by coal production (see Figure 30). Whether or not this comes to pass will depend on the technologies the U.S. chooses to use to meet (or reduce) its energy demand.

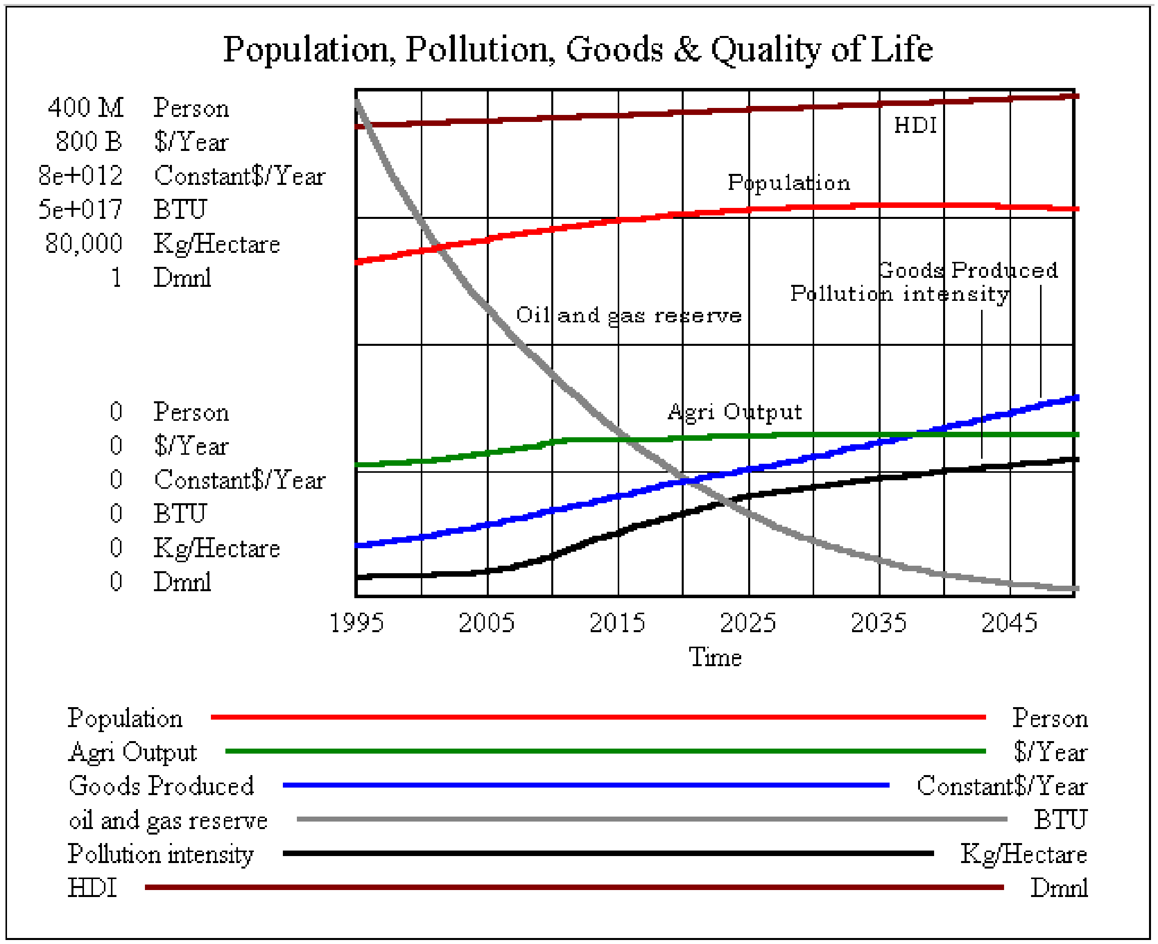

Figure 29. Overview Screen from the THRESHOLD 21-USA Model, Base Case Scenario

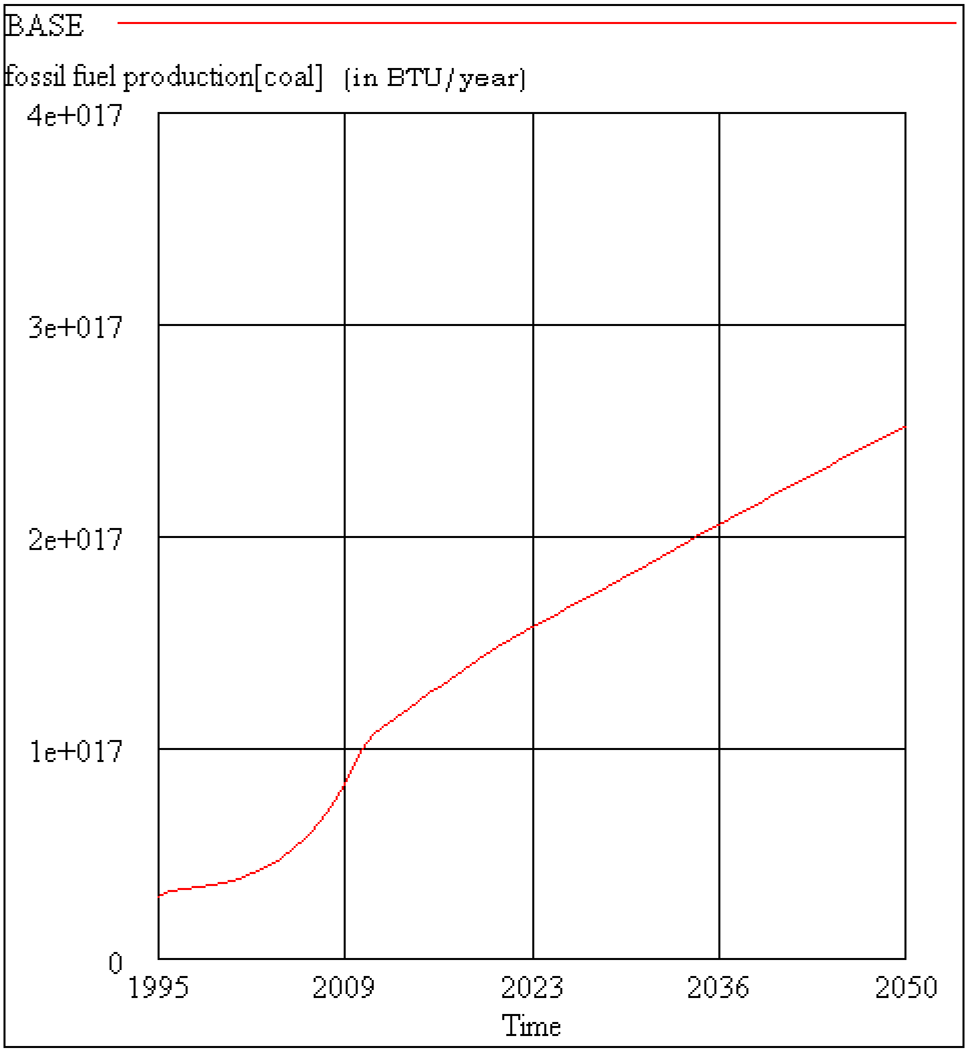

Figure 30. Projected U.S. Coal Production, the THRESHOLD 21-USA Model, Base Case Scenario

Initial Experiments with Changes from the Base Case

In initial experiments with changes from the Base Case, the investment slide-bars of the U.S. model were moved from 1 to 1.2 for each of the sectors. A summary of the effects is given in Table 3.

Sector	Investment	Total Population	Human Dev't Index	Capital Total[5]	GNP per capita	Agri Prod'n[6]	Calories per capita
Agriculture	1.0 → 1.2	--	--	--	--	↑↑↑	↑↑↑
Goods	1.0 → 1.2	↓↓	--	↑↑↑	↑↑↑	↓ -- ↓↓	↓ -- ↓↓
Energy	1.0 → 1.2	--	--	--	--	-- ↓ --	-- ↓ --
Military	1.0 → 1.2	--	--	--	--	--	--
Environment	1.0 → 1.2	--	--	--	--	--	--
Services	1.0 → 1.2	↓	↑↓	↓	↑	↓	↓↓

Table 3. Summary of effects of changes of investment biases in single sectors relative to the USA Base Case Scenario. Note: three arrows indicates a marked change relative to the Base Case; two arrows indicates a significant change; a single arrow indicates a slight change.

Solely increasing investment in the Agriculture sector causes total agricultural production as well as calories per capita to increase very markedly. Total population, HDI, total capital, and GNP per capita are unchanged from the Base Case.

Solely increasing investment in the Goods sector (industrial production) greatly increases the production of goods, greatly increases capital total and GNP per capita (see Figure 31). Because the investment in Goods diverts some investment away from the Agriculture sector, agricultural productivity and calories per capita decline somewhat overall. Population falls modestly due to increased material wealth, education, and effectiveness of family planning.

Solely increasing investment in the Energy sector has little overall effect. Total population and HDI are unchanged over the Base Case. Agricultural production and calories per capita follow virtually the same pattern as the Base Case.

Solely increasing investment in the Military sector has very little effect on the key indicators other than to reduce the overall fraction of goods available. (As the model is currently designed, investment in the Military sector takes investment away equally from every other sector.)

Solely increasing investment in the Environment sector has little effect on the overall behavior of the model. The main effect is to improve environmental technology which in turn lowers the generation of air pollutants other than CO_2.

Solely increasing investment in the Services sector (education, health care, family planning, etc.) causes total population levels to decline modestly and increases per

[5] "Capital Total", the sum of the capital invested in all the sectors, is being used here as a proxy for "Total Capital", which also includes Natural and Human Capital. Natural and Human Capital are not yet calculated in the U.S. model.

[6] "Agri Prod'n" is being used as a proxy for "Agricultural Prod'n per capita", as that is not yet calculated in the U.S. model.

capita GNP somewhat. Agricultural production is slightly lower and calories per capita are slightly lower. The Human Development Index is unchanged.

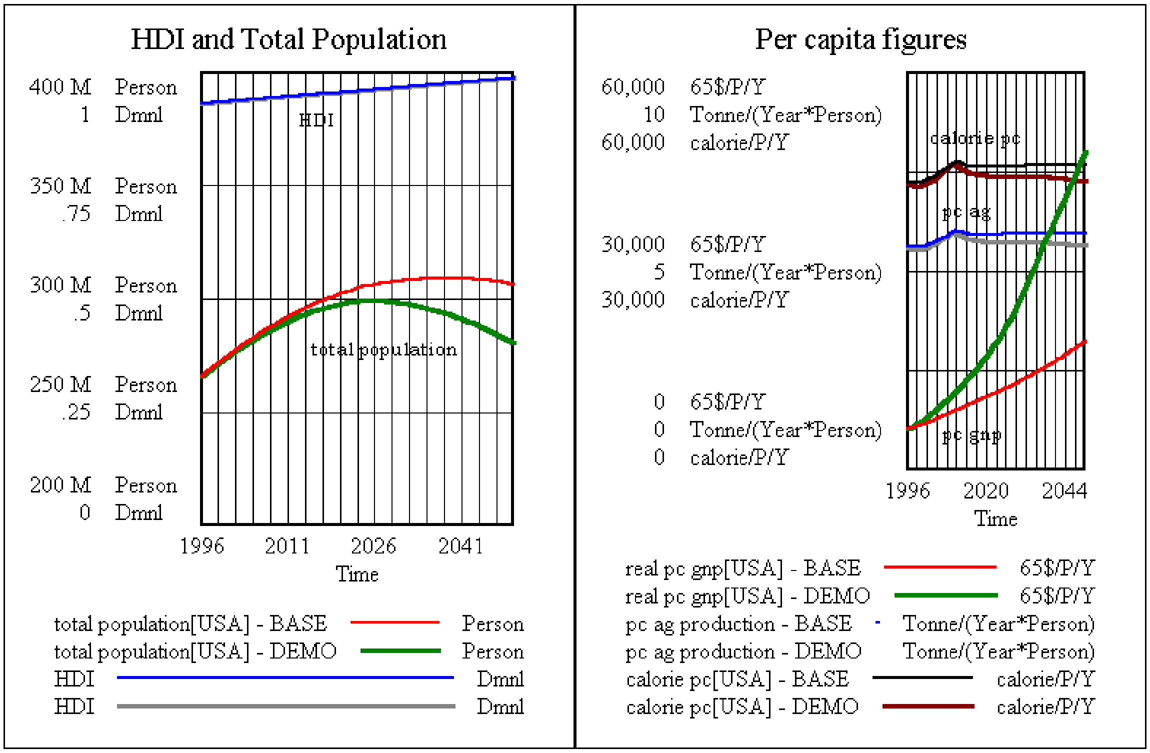

Figure 31. Effect of Increasing Goods Investment Bias to 1.2

Optimism/Hope Scenario

See the Introduction for a description of the UNCSD Optimism / Hope scenario and our adaptation of the scenario.

For the United States, we test our equivalent of the UNCSD Optimism / Hope scenario by shifting significant investment into the Goods sector (set to 1.2), by investing a bit more in Agriculture (set to 1.1 to compensate the fact that shifting more investment into Goods would take some away from Agriculture), by not trying to slow population growth, and by not limiting energy resources. Figure 32 shows what happens.

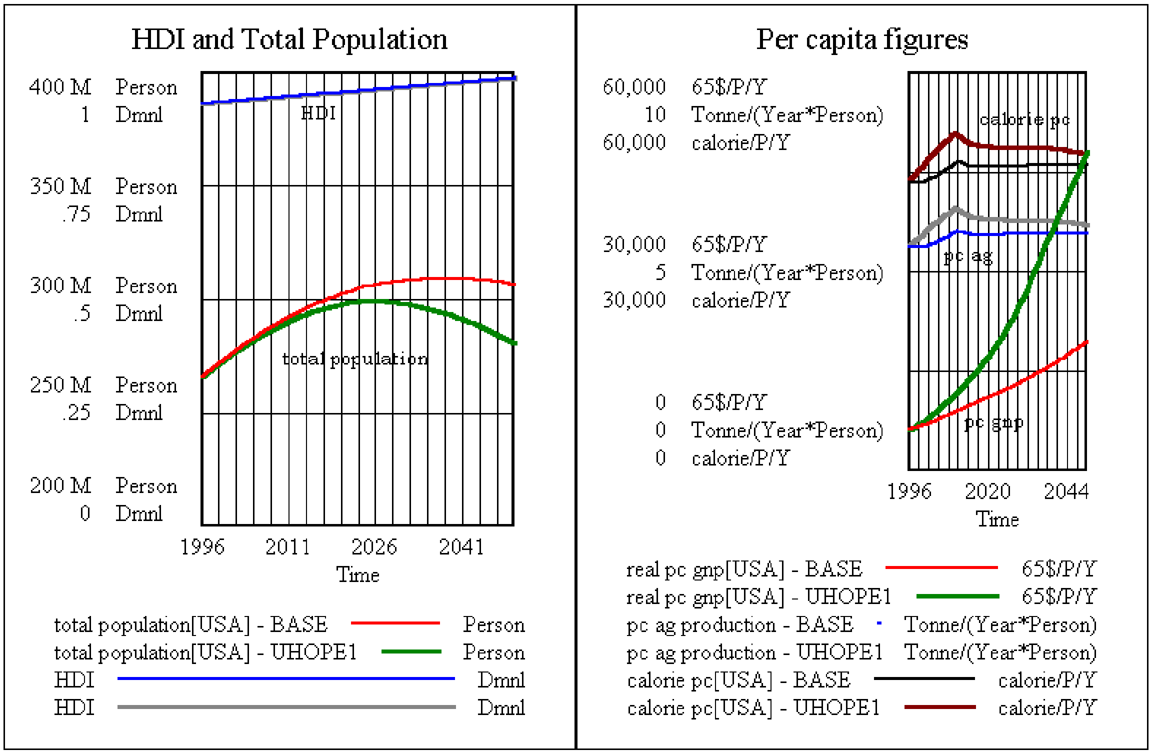

Figure 32. The UNCSD Optimism / Hope Scenario (Demo) compared with the Base Case Scenario, USA.

In this Optimism / Hope scenario,

- total population decreases
- the Human Development Index is unchanged
- agricultural production increases significantly
- goods production doubles
- pollution intensity more than doubles
- per capita GNP increases greatly
- capital total nearly triples
- energy production doubles, as does the consumption of coal
- oil imports level off at 3x1016 BTU / year around 2008 after domestic coal production reaches a level to satisfy energy demand
- the generation of CO_2 from fossil fuels nearly triples (from 6.5×10^{12} kg / year in the Base Case to 1.4×10^{13} kg / year)

One major “What if” in response to this scenario is “What if fossil fuel consumption must be constrained to meet treaty requirements for CO_2 emissions?”

Pessimism/Fear Scenario

See the Introduction for a description of the UNCSD Pessimism / Fear scenario and our adaptation of the scenario.

For the United States, we test our equivalent of the UNCSD Pessimism / Fear scenario by trying to a) limit the amount of fossil fuels consumed by reducing Goods production, b) reduce pollution by investing in the Environment, and c) reduce population by investing in social services (although in the U.S. model social services are not yet disaggregated, and the population is already beginning to level off). Specifically, we set Goods =0.9, Environment =1.2, and services =1.3. Figure 33 provides an overview of the results.

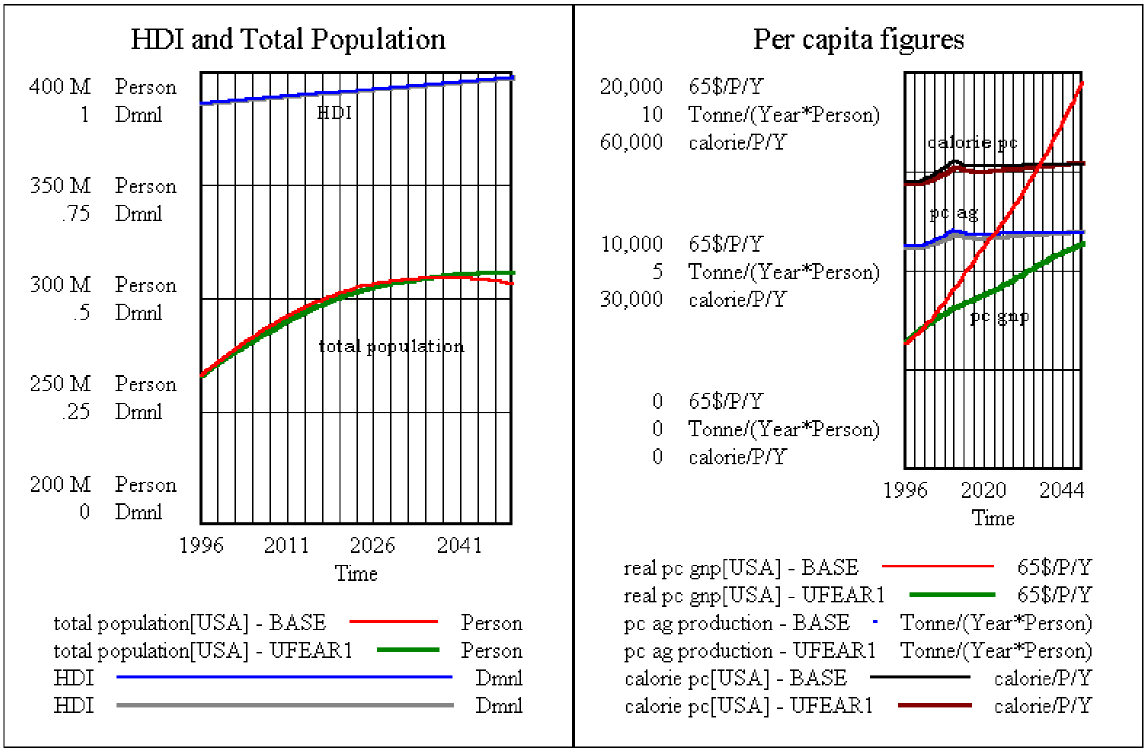

Figure 33. The UNCSD Pessimism / Fear Scenario (Demo) compared with the Base Case Scenario, USA

In this Pessimism / Fear scenario, relative to the Base Case:

- population at first declines slightly but then begins to increase
- HDI is unchanged
- agricultural production is down slightly
- energy production is down by more than one third
- CO_2 generation has dropped by about one third
- per capita GNP has dropped by nearly a factor of two

As with Tunisia, it may be desirable to maintain (or even increase) the current rate of investment in the Goods sector and to use other means to reduce the use of energy, at least fossil fuels. To test this possibility, we ran a second Pessimism / Fear scenario, in which we reset Goods to 1 and increased investment in the Energy sector to 1.5. Figure 34 presents an overview of the results.

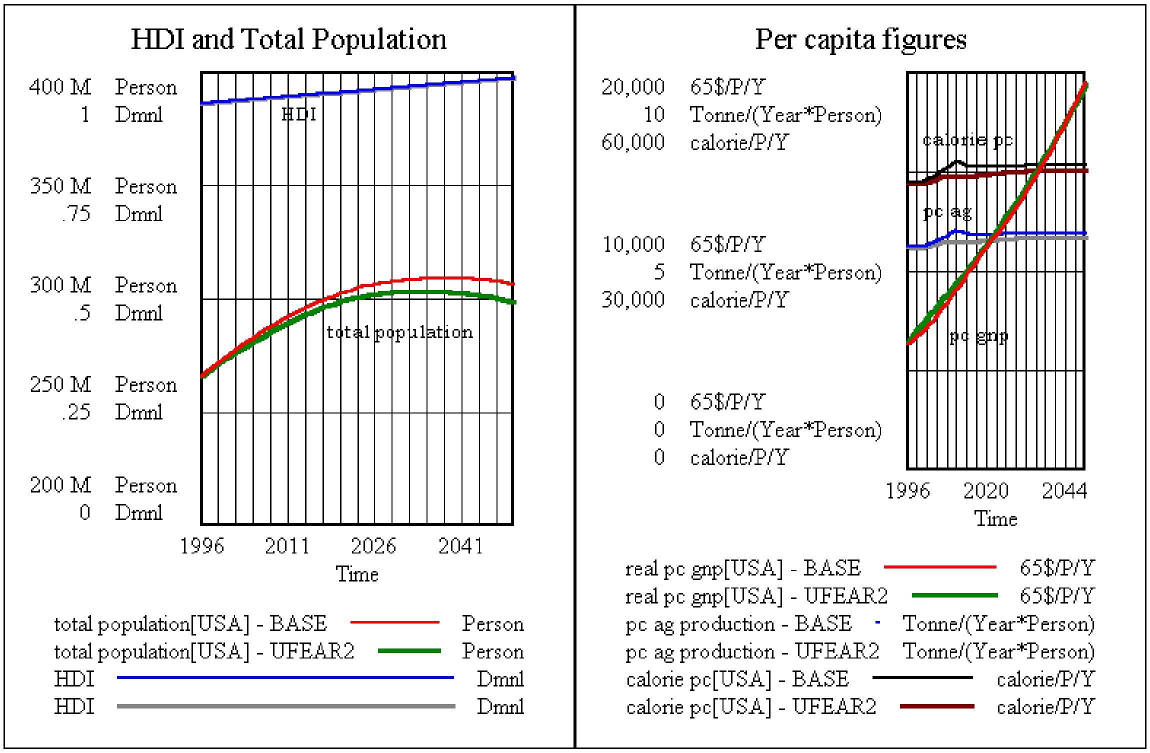

Figure 34. A Second UNCSD Pessimism / Fear Scenario (Demo) compared with the Base Case Scenario, USA

In this second Pessimism / Fear scenario, relative to the Base Case:

- population declines over time
- HDI appears to be unchanged
- agricultural production is slightly down
- energy production only down very slightly, however nuclear and renewable energy production has begun to grow
- CO_2 generation is down by only about 10%
- per capita GNP is relatively unchanged

In future versions of the U.S. THRESHOLD 21 model we will also explore the effects of constraining energy imports and magnifying the impact of pollution and also targeting Energy sector investment dollars to particular technologies.

Towards Sustainability Scenario

In the Towards Sustainability scenario we try to find a pathway which will help achieve long-term sustainability. This is not an easy task to do for the United States.

We begin with existing conditions for the United States: a) population growth is nearly at replacement levels in the U.S. (while it would be desirable to achieve a stable population, population growth is not the most serious problem in the U.S.); b) the quality of life (as measured by the HDI, or GNP per capita) for most people in the U.S. is far above the world's average; and c) resource consumption, especially fossil fuels and CO_2 emissions are unsustainably high. Massive U.S. coal consumption is, in principle, sustainable from the huge U.S. coal resources, but the associated huge emissions of CO_2 are not sustainable in terms of the consequences for others: climate change and sea level rise potentially flooding completely many Island States and much of low-lying countries like Bangladesh.

After many experiments, we found one set of investment biases that approximates a Towards Sustainability scenario for the United States. In this case we reduced Goods production severely to 0.8, increased investment in Energy to 1.4, and attempted to compensate for the tendency of the population to grow again by increasing investment in Services to 1.4.

The results are shown in Figure 35 below. The HDI is unchanged. Population is about 7% higher in 2050. Food per capital is essentially unchanged. GNP per capita, however, falls from nearly $20,000 per year to about $6,000 per capita.

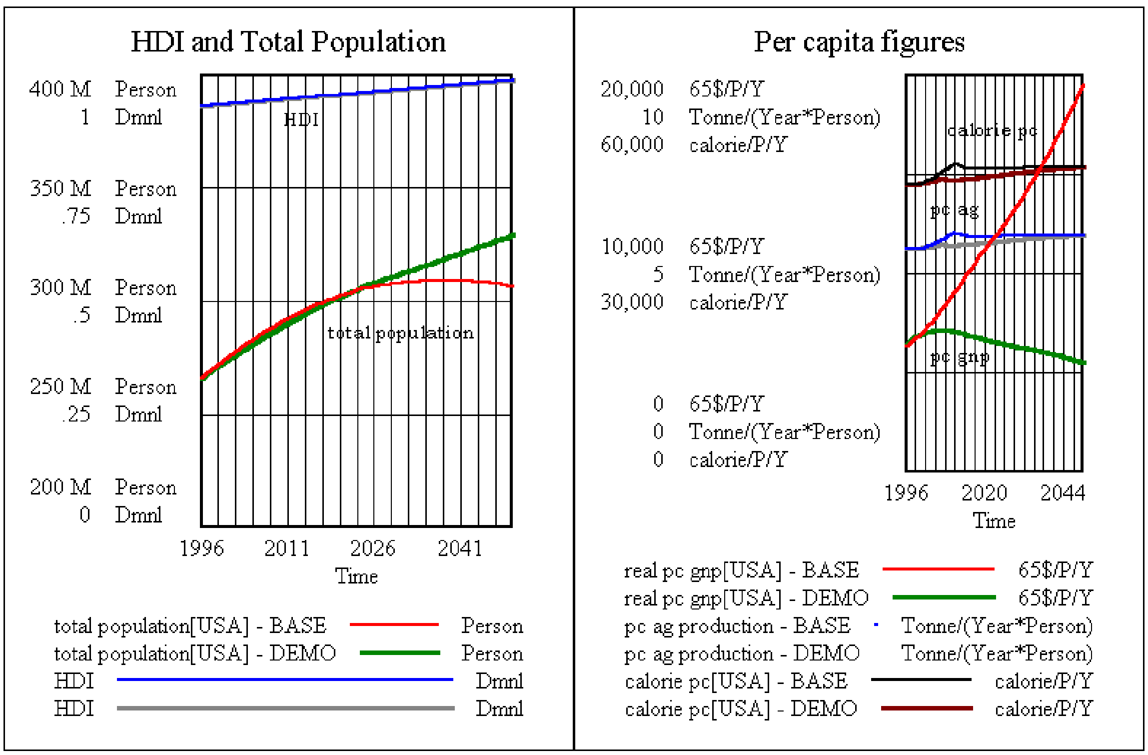

Figure 35. A Towards Sustainability Scenario for the USA

Figure 36 shows the components of energy production for this Toward Sustainability scenario. Coal production remains near its current rate, a drop of nearly two-thirds (relative to the Base Case) by 2050. Increasing the investment in Energy helps to increase the rate at which both nuclear and renewable sources of energy come on line. Only by reducing Goods investment to 0.8 or lower, was it possible to reduce coal production from its current rate.

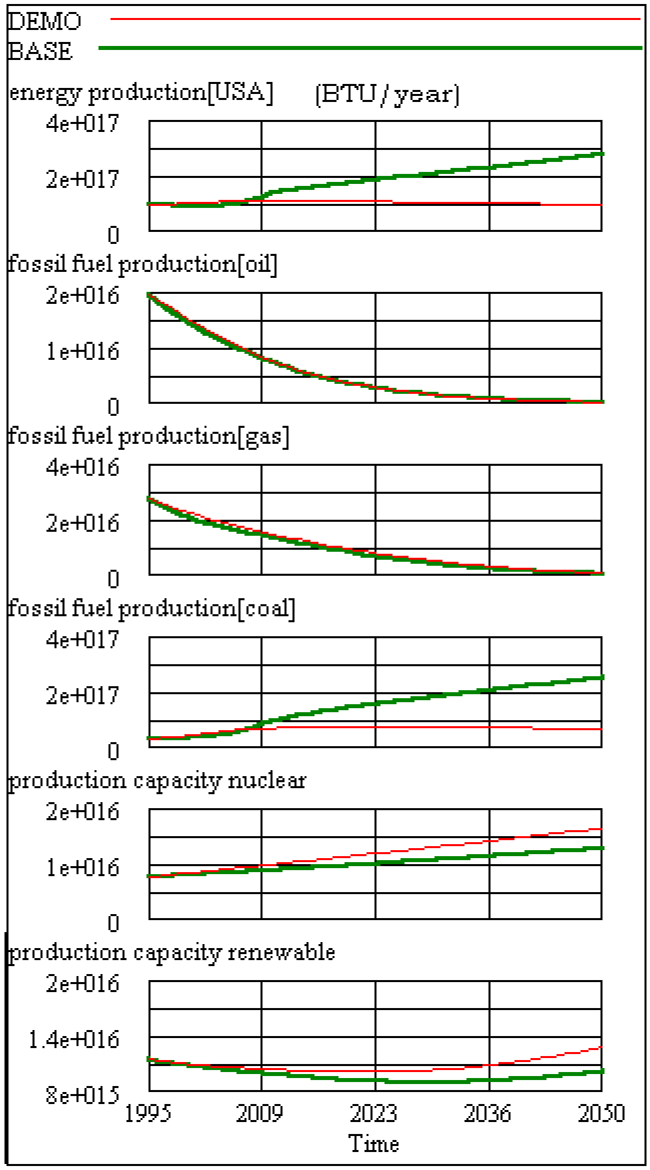

Figure 36. Components of Energy Production

A Second Toward Sustainability Scenario

In this second scenario, we ask, "How quickly might it be possible for the United States to reduce it's dependence on fossil fuels and make the transition to alternative sources of energy? And what effect might this have on the other indicators of progress?" We test this scenario with a large increase in investment in the energy sector, a shift of the investment bias for energy from 1 to 10.[7]

[7] Such large shifts in investment biases have not been thoroughly tested in THRESHOLD 21. A quick review of the model's behavior, however, shows nothing obviously in error. The changes that occur are large, but understandable. Also, such a large shift in investment priorities raises questions of political dynamics not addressed by the model.

Figures 37 and 38 present the key results of this scenario. It appears that through very heavy investment in the Energy sector, the United States could limit the exploitation of oil and coal while increasing the production of energy from sources (nuclear and renewable) which do not increase the amount of CO_2 released to the atmosphere. Both of these alternative sources, especially nuclear, have long-term environmental and security implications. In this scenario, the U.S. could maintain and even increase goods and agricultural production.

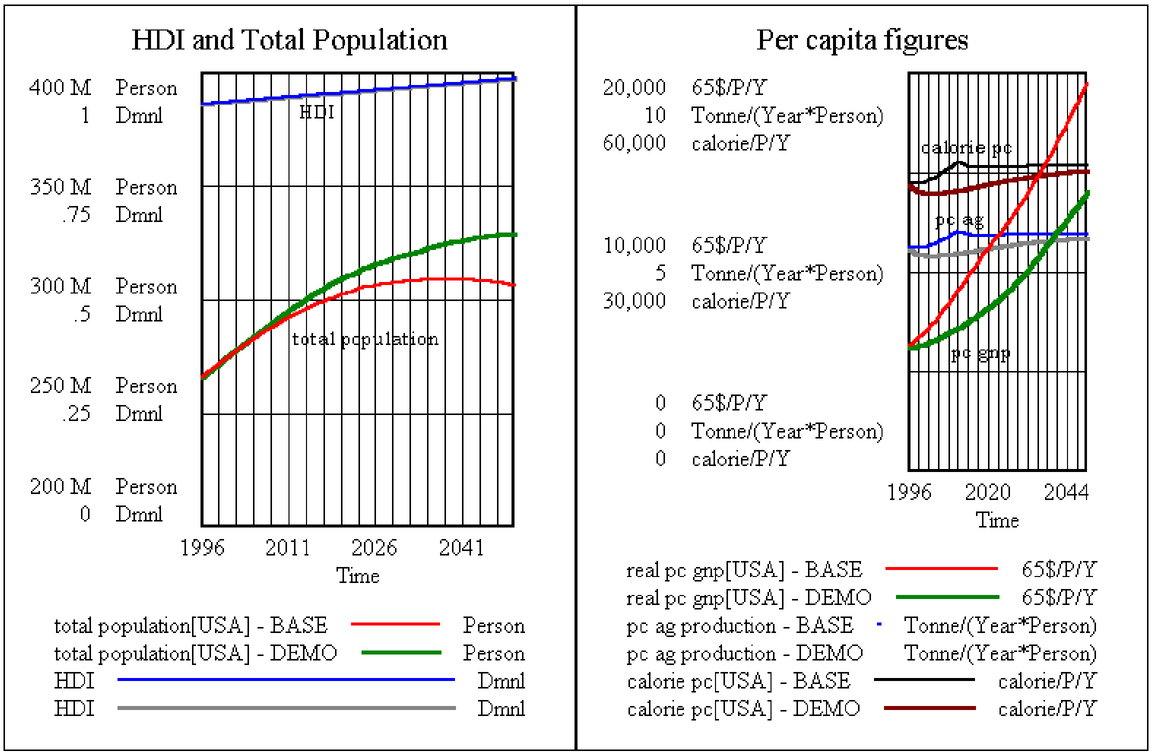

Figure 37. An Energy Transition for the USA

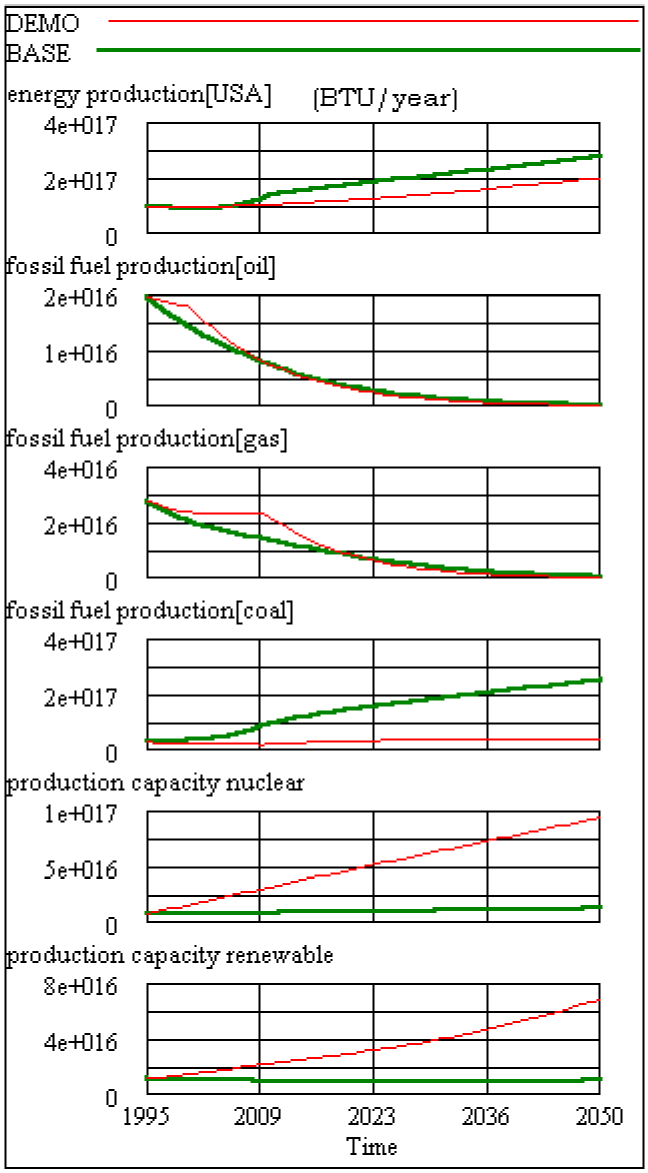

Figure 38. An Energy Transition (2)

Recommendations for USA

The current and projected emissions of CO_2 by the U.S. have unsustainable global consequences. If the U.S. is to reduce the CO_2 emissions, it must reduce the consumption of fossil fuels.

After exploration of a wide variety of investment scenarios, we find only one way for the U.S. to decrease significantly its resource consumption, especially of fossil fuels, namely to reduce economic activity by reducing investment in the Goods sector. Such a reduction can be accomplished without seriously reducing measures of quality of life such as the HDI.

It may be extremely difficult to reduce the consumption of fossil fuels and emissions of CO_2 in the U.S. without also reducing the production of material goods. In the two Pessimism / Fear scenarios, the CO_2 reductions achieved were only 10% in one case and a third in another.

We recommend, therefore, that the robustness of these conclusions be explored. If they are supported and evidence of the seriousness of the global accumulation of atmospheric pollutants continues to accumulate, the United States should:

- Reduce the attractiveness of investment in the Goods sector.
- Increase investment in the Energy sector to accelerate the development of alternative, non-fossil fuel energy sources.
- Increase the attractiveness of investment in Social Services to restrain population growth stimulated by reductions in economic output.
- Continue to restrict immigration in order to limit population growth.

While such measures may constrict economic activity and reduce traditional measures of progress (such as GNP), other measures of progress, such as HDI, continue to improve in the scenarios we explored.

The analysis reported above assumes that oil imports will continue without constraint and at current prices. From a variety of other analyses, we know this assumption is not likely to be true, and our preliminary explorations indicate that if U.S. energy demand cannot be met, the U.S. economy will be altered significantly.

The THRESHOLD 21-USA model should also be compared with alternative models, and all sectoral models examined by experts familiar with the U.S.

The United States is in the enviable position of having one of the highest levels of development -- capitalization, education, resources, etc. -- which affords it the ability to explore a wide range of policy options before the country experiences the same level of stress as more imminently faces Bangladesh or Tunisia. Yet the United States is also one of the most heavily dependent upon fossil fuels. It will continue to be one of the main contributors to increasing atmospheric CO_2 unless it makes some major changes in its consumption patterns. Preliminary analysis with the THRESHOLD 21-USA model hints, however, that it may be possible to find an investment strategy that would help the U.S. move away from dependence on fossil fuels and still maintain or improve the quality of life.

Appendices

Appendix A: Reflections on Sustainable Development, Models, and Indicators

This paper begins with a sentence that uses the adjectives “developing”, “transitioning”, and “developed” to describe groups of countries. These terms were suggested by CSD staff and are used widely in international development work. However, implicit in these terms is a paradigm of an inevitable, permanent progression of countries from being “developing” to being “transitioning” to being “developed”, and it is a false paradigm.

There is nothing inevitable about such a “transition” from “developing” to “developed.” In fact, it seems very doubtful that the resource and environmental constraints of the planet could sustain the entire population of Earth living as wastefully and destructively as people do in “developed” countries (e.g., the United States, Japan, and Germany).

Also, there is nothing permanent about the conditions in “developed” countries. The “developed” countries are wasting their resources, polluting their environments, and increasing their populations in ways that are not sustainable. The so called “developed” countries are also “developing” in the sense that they are changing.

Alternative adjectives are sometimes used. The World Bank, for example, refers to groups of countries by income levels, e.g., high income countries, etc. Others refer to industrialized countries, etc. While they are more descriptive and less paradigmatic, they leave unanswered the question of where is “development” going?

Since about 1970 the term “sustainable” has begun to be applied to “development.” The concept was defined first by the Brundtland Commission: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. (Brundtland, 1987). While this definition makes a good starting point, it has been criticized because it is too vague to measure.

Further refinement was given in the *Agenda 21* report from the Earth Summit in Rio (UN, 1994). Even *Agenda 21*, however, is being seen increasingly as inadequate. *The Children’s Edition Agenda 21* (Peace Child International, 1994), for example, identifies 11 major deficiencies in *Agenda 21*.

The issue of sustainability is complex, and the Canadian Government has made a major contribution by establishing the International Institute for Sustainable Development. This organization collects and documents efforts to define Sustainable Development (International Institute for Sustainable Development, 1992).

A brief, insightful discussion of current thought on "sustainable development" also is presented in the introduction to Herman Daly's *Beyond Growth*. As Daly explains, at the root of the problem of sustainable development is the fact that the economy is a subsystem of the ecosystem and we must find a way to recognize this fact. He identifies three alternative strategies for dealing with this conceptual problem. The first is to expand the economic subsystem until everything is included in the economic system -- i.e., until everything has a price. The second approach is to go in the other direction: shrink the economy until everything is ecosystem. This is possible, Daly argues, because "Relative values correspond to embodied energy content, and economies, like ecosystems, are governed by the dictates of survival." The third strategy is to see the "economy as subsystem of the ecosystem and to recognize that while it is not exempt from natural laws, neither is it fully reducible to explanation by them." (Daly, 1996)

Our approach is most closely linked to Daly's third alternative. In THRESHOLD 21 we begin with the World Bank's RMSM (Revised Minimum Standard Model) capital flows model, along with an economic sector including demand and production functions, and a trade sector. This model treats the economic subsystem as if it is entirely separate from the ecosystem. Then we have added additional models to cover the environmental and social components of a nation. The linkages between the former and the latter are not yet as strong as we would like, and this is the focus of our current refinement of THRESHOLD 21.

The issues related to sustainable development are many, complex, and interrelated. There is no alternative but to use models to address them. The only issue is which model to use.

Most development decisions are made on the basis of "mental models" in someone's mind. These mental models may be excellent in some respects, but they have limitations: they continue to shift and change and cannot be examined and shared effectively with others.

Computer models are a way of stating mental models precisely so that they become open to inspection and refinement by others. Some computer models are difficult to inspect, but advances in hardware and software technology of the past few decades make it possible to develop understandable computer models. We are trying to make THRESHOLD 21 easy to understand and inspect.

It is also essential that models and indicators be used together. When indicators are applied to historical statistics (i.e., to past behavior) they provide new perspective on the past, but they cannot tell us about what we most need to know: the future consequences of current policy decisions. To understand the future consequences of policy interventions, indicators must be coupled to a model. The model provides the input needed to calculate the future value of an indicator. Together, the model and the indicators tell us the future impact of current choices and actions.

Much work and discussion is underway (at the World Bank, the UN, and in non-governmental organizations) to develop measures and indicators of sustainability. Most such approaches for assessing long-term sustainability look beyond the classical economic measures (such as GNP) to formulate composite or complementary measures that take into account the health and wealth of the non-economic sectors. Two such measures are Total Capital and its derivative, Genuine Saving, as proposed by the World Bank's *Monitoring Environmental Progress* (World Bank, 1995) and *Sustainability and the Wealth of Nations* (Serageldin, 1996) (See Figure 39.).

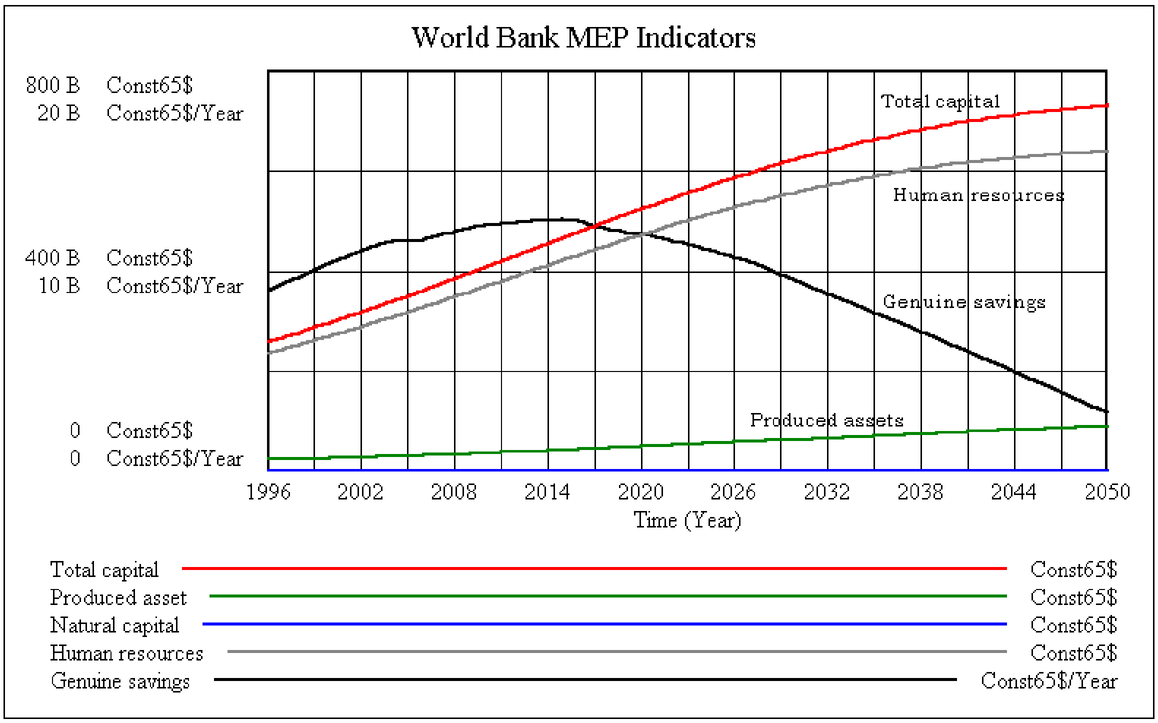

Figure 39. World Bank MEP Indicators for Bangladesh Base Case

There are many perspectives from which to look at the health of a country, and a monetary or even numerical value cannot be placed on everything. Any assessment of the long-term viability of a nation's long-term agenda must look at a broad range of indicators. We have included in the more recent versions of THRESHOLD 21 (for Tunisia and Bangladesh) a wide range of the indicators used frequently today, including those developed by The World Bank and some of those developed by the UNCSD (see Figure 40) and by UNICEF. So, using THRESHOLD 21, one can evaluate both the usefulness of a particular set of indicators as well as how different policy choices affect indicators.

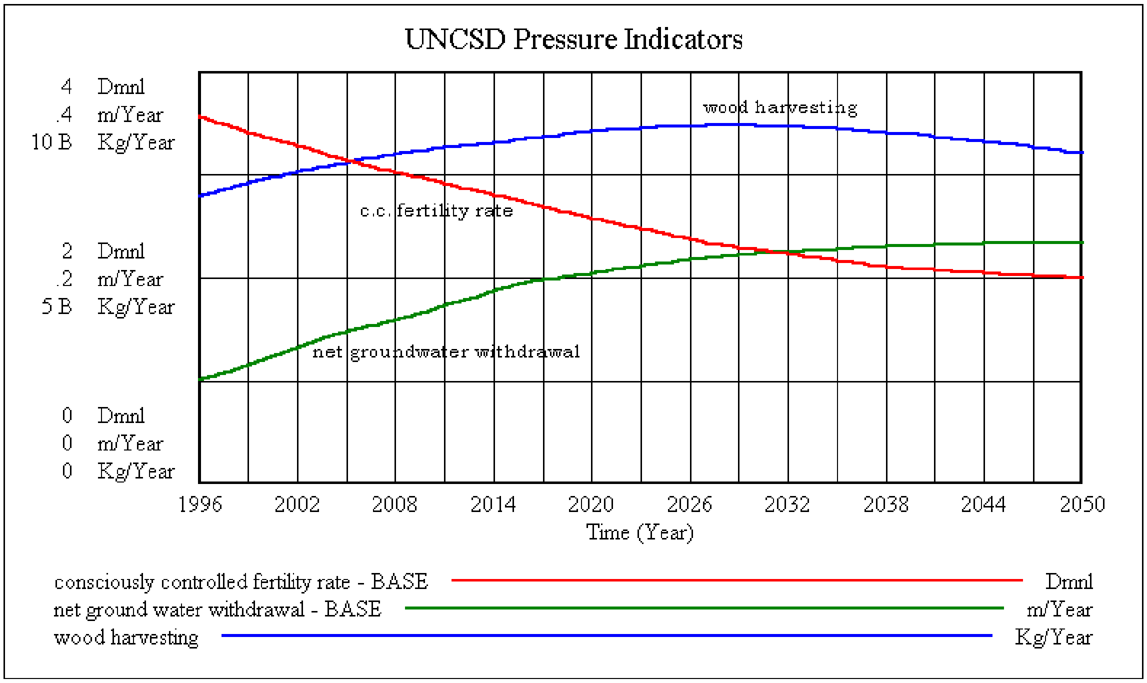

Figure 40. UNCSD Pressure Indicators for Bangladesh Base Case

Appendix B: The THRESHOLD 21 Model

Introduction

This appendix provides a brief overview of THRESHOLD 21, its major assumptions, and a description of how the model is used. Further information is available in the THRESHOLD 21 documentation (Millennium Institute, 1996) and in the help screens of the model itself.

The Model: An Overview

THRESHOLD 21 is a continuous time model based on the stock-and-flow methodology used in economic, demographic, resource, environment, and social science models. Demographic, resource, environment, and social models are relatively easy to express as stock-and-flow models; traditional economic models are more difficult. The linkage of the economic sector to other sectors is most difficult.

Our goal for THRESHOLD 21 is to produce a model that can be calibrated quickly from electronic data sources. The model is to address the full range of issues inherent in policy decisions for sustainable development. The model must be "transparent" so that it is easily understood and can be helpful in increasing understanding, communication, and cooperation. As Rolf Carriere, UNICEF Representative to Bangladesh, has said, "THRESHOLD 21 creates a 'forum' in which policymakers think and speak with each other in a common language, where their 'mental models' are graphically displayed and available for discussion, improvement, and cooperation." (Carriere, 1995.)

The Millennium Institute's long-term goal is to have a version of THRESHOLD 21 in use in every country of the world and to link the country-specific versions together in a Global THRESHOLD 21. The global version would balance the imports and exports of one country with the exports and imports of every other country, and from there explore scenarios for the whole planet moving towards sustainability.

To interest groups in every country in using THRESHOLD 21, we chose to build the model around the World Bank's Revised Minimum Standard Model (RMSM), one of the most influential models in the world. The Bank's RMSM is required for the preparation of the Bank's Country Assistance Strategy (the "CAS"), the document which sets the investment strategy for each country with which the Bank works. The CAS guides not only the World Bank, but often influences many of the other multi-lateral development banks, parts of the UN, and many private banks.

In building THRESHOLD 21, we started with a simplified version of RMSM then added other sectors not in the Bank's model: demography, education, environment, agriculture, water, forestry, land, nutrition, health care, energy, goods, economy, trade, service, and sometimes military.

The resulting THRESHOLD 21 is a powerful simulation model that enables long-term integrated analysis of the economic, social, and environmental health of a nation. It is based on more than twenty years' experience with hundreds of national and sectoral models.

THRESHOLD 21 is available for application in any country. To convert the generic version to an application for a particular country requires 2-3 capable people working 3-4 months. Policy results can be obtained in 6-9 months. A serious planning model may require a team of 6-8 working over 2 years. Costs range from US$50,000 to US$200,000, including the model license.

The system requirements are modest. A THRESHOLD 21 model can be developed and run on any IBM compatible PC with a 486 or later CPU, and 8 MB RAM with MS Windows 3.1 or later. Run-only versions require approximately 6 MB of hard disk space. The "research version" is used for developing new country models and requires 50 MB of hard disk space, which includes space for the installation of the Vensim® software from Ventana Systems, Inc.

There are currently four national versions of the THRESHOLD 21 model -- for Bangladesh, China, Tunisia, and the USA -- and a new modeling team is beginning in Malawi with the assistance of the Tunisian team.

The first version of THRESHOLD 21 was for Bangladesh. It was developed with funding from UNICEF-Dhaka and cooperation from the Bangladesh government (specifically the Planning Commission, the Bangladesh Bureau of Statistics, and the Ministry of Finance), and several non-governmental organizations including the Bangladesh Institute of Development Studies. A first version of the THRESHOLD 21 model for Bangladesh was completed in the Spring of 1995; the most recent refinements were completed in November 1996.

A first version of a THRESHOLD 21 model for Tunisia was completed in the Spring of 1996, and additional extensions to this model currently are being developed by the Tunisians.

The version for the United States is still under development.

None of the national models is "finished" As the individual national models are refined and extended, the improvements are shared with the other research teams and incorporated into the other versions. See Appendix C for plans and ideas for improving THRESHOLD 21.

Major Assumptions

The following material describes a list of major assumptions in the THRESHOLD 21 model generally. Following these general assumptions are assumptions for each country-specific version of THRESHOLD 21.

1. The major driving force of the model is positive feedback. There are two major positive feedback loops: (a) production, income, investment, and increased production, and (b) population, births, and more population.

2. A wide variety of negative feedback loops related to policy, markets, resources, and environment regulate and limit growth from the positive feedback loops.

3. Population change is related to births and deaths. Births are determined by conceptions. Deaths for each male and female age cohort are based on life table data plus other influences: nutrition, pollution intensity, sanitation, population density, and health care.

4. Conceptions are directly influenced by two variables: the size of the sexually active female cohorts, and their conception rates. Conception rates are influenced by many variables, including capital in social services, per capita GNP, and family planning effectiveness.

5. Market and policy decisions combine to shift investments among the six sectors: agriculture, goods (industry), energy, environment, social services, and military.

6. Capital in each sector increase with investments and decrease with depreciation.

7. Agricultural productivity is the product of agriculture land and land productivity.

8. Agricultural land increases with deforestation, and decreases due to land degradation and urban expansion (population increase).

9. Land productivity is related to: water availability, energy availability, quality of education, seed availability, labor availability, capital in agriculture, agricultural technology, and pollution intensity.

10. Goods (industrial) production is the product of labor in goods and employee productivity.

11. Per capita productivity of labor in goods is influenced by: capital in goods, energy availability, quality of education, and industrial technology.

12. Energy is classified into three categories: fossil fuel, nuclear, and renewable. Fossil fuel is further classified into oil, gas, and coal.

13. Investment in energy is allocated to fossil fuel, nuclear, and renewable. Production of nuclear energy and renewable energy are related to capital in these two energy sub-sectors. Production of fossil fuel energy depends on both capital and proven reserves. Oil, gas, and coal are modeled individually with interactions.

14. Commercial energy demand depends on real GNP and energy technology. The difference between energy demand and energy production is energy exports or imports. The model assumes that all needed imports of energy are met from the rest of the world.

15. The environment (pollution) sector simulates the generation of air pollution of CO_2, CH_4, NO_x, and SO_x from energy consumption, and non-energy industrial and agricultural activities. With an increase in environmental capital, environmental technology develops, which in time will reduce emissions of CH_4, NO_x, and SO_x, but not of CO_2. Pollution dissipation is a function of pollution intensity: the stronger the pollution intensity, the longer it takes to dissipate.

16. The social service sector has its own capital and investment rate. Capital in Social Services influences education, health care, and family planning.

17. The education sector simulates the primary school system, including students, teachers, and classrooms. Quality of education depends on: dropout rate, student-teacher ratio, student-classroom ratio, and female enrollment ratio.

18. The health care sector simulates the numbers of doctors, nurses, and hospital beds, and from them the quality of health care indicator is derived.

19. The food and nutrition sector computes the per capita intake of calories and protein. It computes the quality of nutrition against international standards. This sector includes separately both crop food and animal food. Human food includes beef, mutton, pork, poultry, eggs, milk, and fish.

20. The technology sector simulates the technological advances in agriculture, goods, services, energy, and environment. The rate of technological advance is related to the characteristics of the sector and the investment rate for the sector.

21. The UN Human Development Index (HDI) indicator is computed based on UNDP's Human Development Report.

22. The elementary trade sector simulates the imports and exports of goods and food.

23. The flow of funds (national accounts) sector is based on a simplified version of the World Bank's Revised Minimum Standard Model (RMSM).

The country-specific assumptions are described in the following sections.

Bangladesh

1. All needed imports are met, unless the variable "fraction oil imports available" is changed (by the model user) from 1 to less than 1 for some years.

2. A "social disturbance" indicator has been added.

3. Service production is the product of labor in service and service labor productivity. In the case of Bangladesh, service labor comes largely from excess labor in agriculture. Service labor productivity is related to capital in service, service technology, and quality of education.

4. The military sector consumes a portion of GNP.

5. The water sector simulates the lowest ground water table for the dry season and projects the number of various types of pumps that will be needed in the future to meet water needs.

6. The forest sector simulates the rate of deforestation due to fuelwood demand, commercial non-fuel demand, and forest land conversion to agricultural land.

7. The land sector simulates the change of agricultural land due to forest land conversion, land degradation, and land lost to urbanization (population increase).

8. The technology sector simulates the technological advances in agriculture, goods, services, energy, and environment. The advance is related to the characteristics of the sector and the amount of investment in the sector.

9. The MEP indicators are computed based on the World Bank's Monitoring Environmental Progress report.

10. The number of employees in capital-intensive industrial enterprises has been added.

11. Unemployment indicators are computed based on an algorithm developed at the Millennium Institute.

12. The greenhouse gas emission indicators are based on documentation and standards published by the Intergovernmental Panel on Climate Change.

The numeric inputs for the Base Case scenario for Bangladesh are as follows:

- propensity to save, savings rate = 0.08
- fraction goods imported = 0.3
- target food exports = 0
- fraction agricultural production exported = 0
- animal product import and export = 0
- fishery is an exogenous variable = 1 Million Ton / year
- reference per capita food consumption = 0.25 Ton / person / year
- agricultural labor is assumed to be fully available
- renewable energy only includes hydropower
- energy demand will always be met, by importing, if domestic shortage exists
- technology advance parameter[service] = 0.06
- technology advance parameter[energy] = 0.08
- technology advance parameter[goods] = 0.01
- technology advance parameter[agriculture] = 0.01
- technology advance parameter[environment] = 0.08 *Note: The technology advance parameter is a multiplier, based on historical trends for each sector, which represents the improvement in efficiency based on investment over total capital (relative investment). In other words, if, in the energy sector, investment this year is 10 and total capital is 100, there will be a technology advance causing an increase in efficiency in the energy sector of 0.08 * 10/100. This is a mechanism for calculating how investment in a particular sector will improve the technological efficiency of that sector.*
- primary education only, ages 6 - 10
- reference pollution intensity = 1500 kg / ha -- (all pollutants are aggregated)
- reference agriculture pollution ratio =0.28kg / tonne-- this ratio converts agricultural production into pollution (which is currently only NH_4 from cattle).

Tunisia

1. The water sector simulate the water demand and supply from surface (reservoir) and ground (phreatic and aquifer) sources.

2. The greenhouse gas emission indicators are based on documentation and standards published by the Intergovernmental Panel on Climate Change (IPCC).

The numeric inputs for the Base Case for Tunisia are as follows:

- propensity to save, savings rate = 0.15
- fraction goods imported = 0.3
- fraction agricultural production exported = 0
- animal product export = 0 tonne / year
- animal product import = 0 tonne / year

- fishery = 20000 tonne / year
- reference per capita food consumption = 0.2 Ton / year / person
- effect labor availability agricultural productivity = 1. This means that agricultural labor is assumed to be fully available.
- renewable energy only includes hydropower
- energy demand will always be met, by importing, if a domestic shortage
- technology advance parameter[energy] = 0.08
- technology advance parameter[goods] = 0.015
- technology advance parameter[agriculture] = 0.01
- technology advance parameter[environment] = 0.08 *Note: The technology advance parameter is a multiplier, based on historical trends for each sector, which represents the improvement in efficiency based on investment over total capital (relative investment). In other words, if, in the energy sector, investment this year is 10 and total capital is 100, there will be a technology advance causing an increase in efficiency in the energy sector of 0.08 * 10/100. This is a mechanism for calculating how investment in a particular sector will improve the technological efficiency of that sector.*
- primary education only, ages 6 - 10
- reference pollution intensity = 150 kg / ha -- (all pollutants are aggregated)
- reference agricultural pollution ration = 0.28 kg / tonne -- this ratio converts agricultural production into pollution (which is currently only NH_4 from cattle).

United States

1. An immigration and emigration component has been added to the demographics sector.

2. An energy sector based on the Fossil2 (IDEALS) model of U.S. Department of Energy has been added.

The numeric inputs for the Base Case scenario for the United States are as follows:

- propensity to save, savings rate = 0.15
- fraction goods imported = 0.3
- target food exports = 0
- fraction agricultural production exported = 0
- animal product export = 0
- animal product import = 0
- fishery is an exogenous variable = 1 M tonne / year
- reference per capita food consumption = 0.2 tonne / year / person
- agricultural labor is assumed to be fully available
- renewable energy only includes hydropower
- energy demand will always be met, by importing, if domestic shortage exists

- technology advance parameter[energy] = 0.08
- technology advance parameter[goods] = 0.50
- technology advance parameter[agriculture] = 0.01
- technology advance parameter[environment] = 0.08 *Note: The technology advance parameter is a multiplier, based on historical trends for each sector, which represents the improvement in efficiency based on investment over total capital (relative investment). In other words, if, in the energy sector, investment this year is 10 and total capital is 100, there will be a technology advance causing an increase in efficiency in the energy sector of 0.08 * 10/100. This is a mechanism for calculating how investment in a particular sector will improve the technological efficiency of that sector.*
- primary education only, ages 6 - 10
- reference pollution intensity = 1500 kg / ha -- (all pollutants are aggregated)
- reference agriculture pollution ratio = 0.28 kg / tonne -- this ratio converts agricultural production into pollution (which is currently only NH_4 from cattle)

Using THRESHOLD 21

Simulating the Past Before Simulating the Future

A two-step process is used in applying THRESHOLD 21. First, the model is used to simulate the past, typically from 1965 to 1996. Second, when the past has been satisfactorily simulated, projections are made to 2050 based on input from the Policy Selection Screen of the model.

For the first time period of the application, results are compared with historic data from various sources, such as the World Bank's World Data 1995 and the UN's population database. From this comparison users gain confidence in the model's accuracy.

Figures 41, 42, and 43 show comparisons between the historical data and the simulation for Bangladesh, Tunisia, and the United States, respectively.

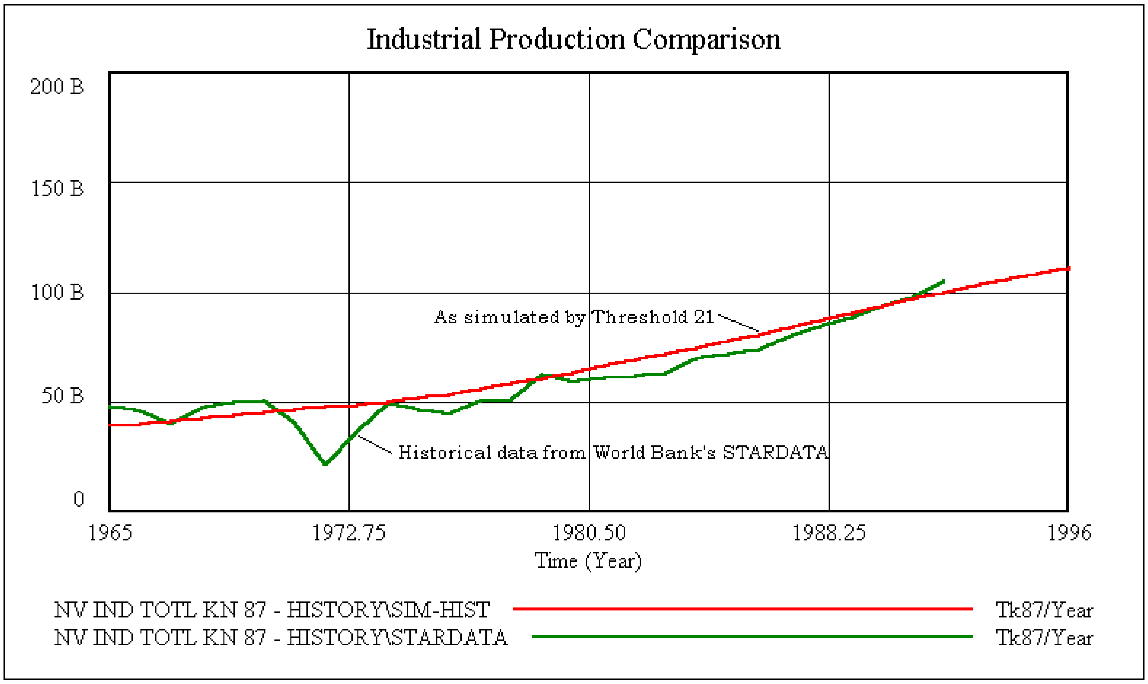

Figure 41 Bangladesh Comparison of Historical vs. Simulated Industrial Production. Note: When the model for Bangladesh was developed in 1993, historical data were available only through 1992.

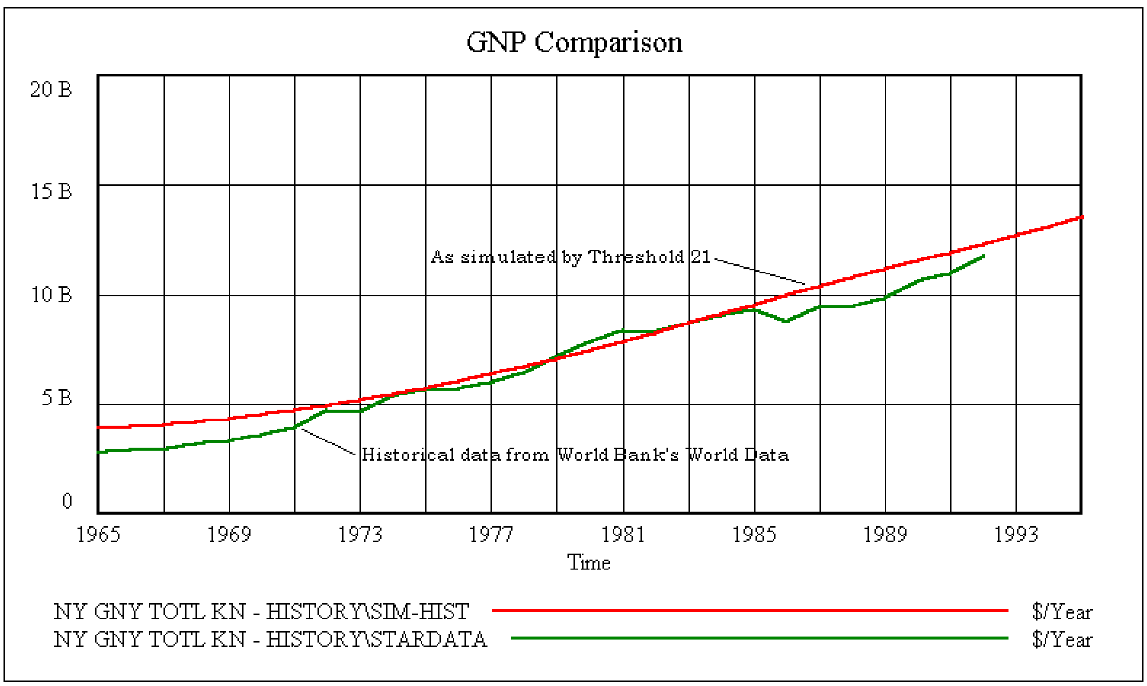

Figure 42. Tunisia Comparison of Historical vs. Simulated GNP

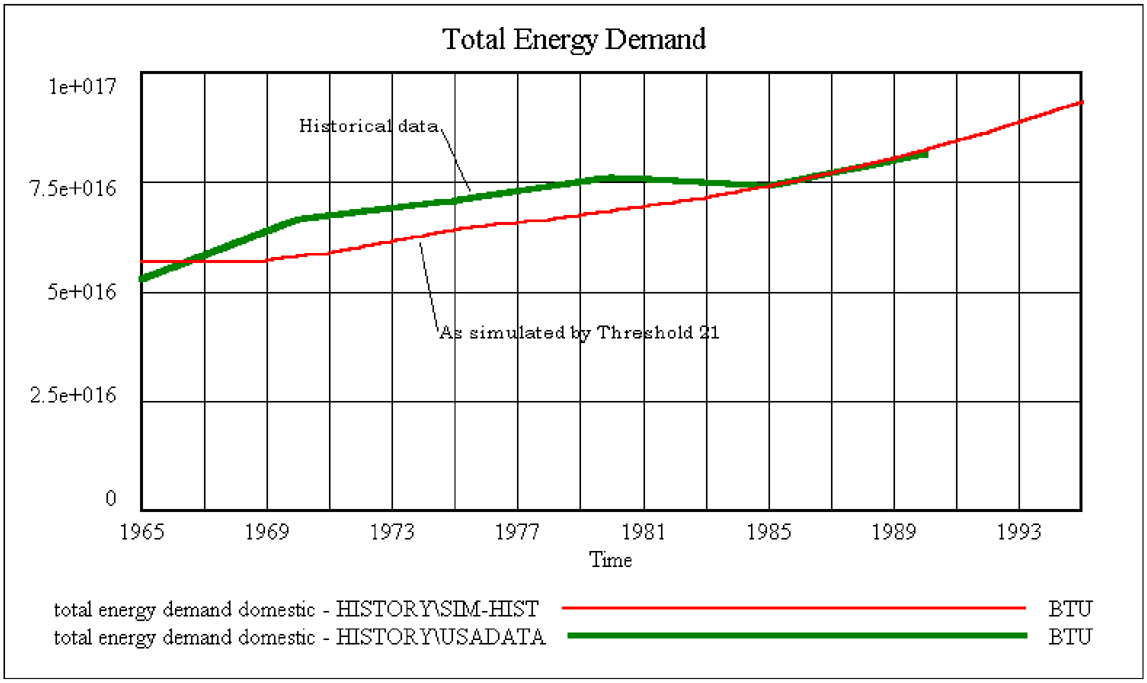

Figure 43. U.S. Comparison of Historical vs. Simulated Total Energy Demand

Policy Input

The main "control panel" for the THRESHOLD 21 model is the "Policy Selection Screen" (see Figure 1). From the Policy Selection Screen users can set a number of parameters which affect the course of a simulation. Most of the parameters affect the levels of investment, either redirecting investment within the country, or setting levels of international assistance.

The following sections provide an overview of the Domestic Investment Biases, the Investment Fraction, international assistance, and other means to enter policy decisions into THRESHOLD 21 Then follows a more detailed description of the operation of the Domestic Investment Biases.

Overview of the Domestic Investment Biases

When all of the Domestic Investment Biases are set to 1, the policies that allowed the model to reproduce the recent history of the country are continued into the future. Increasing the bias for a particular sector represents a change of tax and subsidy policies that result in making investments in that sector more attractive than under current policies. Decreasing the bias has the opposite result.

The specific effects of the Domestic Investment Bias for each sector are as follows. In all cases, the effects are phased in over a five-year implementation period.

- Increasing the Agricultural Investment Bias increases the market attractiveness of investment in agricultural capital, agricultural technology, and irrigation.

- Increasing the Goods Investment Bias increases the market attractiveness of investment in goods manufacturing capital and industrial technology.

- Increasing the Energy Investment Bias increases the market attractiveness of investment in energy production capital (in fossil fuel, nuclear, and renewable) and energy production technology.

- Increasing the Military Investment Bias increases the flow of funds through government consumption into military capital.

- Increasing the Environment Investment Bias increases the market attractiveness of investment in environmental protection capital and into environmental technology.

- Increasing the Social Services Investment Bias increases the market attractiveness of investment in education (classrooms and teachers), health care (doctors, hospitals, nurses), and family planning programs.

- Increasing the Services Investment Bias increases the market attractiveness of investment in service capital and service technology; as a result, the quantity and quality of transportation, communication, banking, and other services (excluding education, health care, and family planning) increase over a 5-year implementation period.

Internal to the model, there is a fixed total to invest at any time. The investment biases simply shift the attractiveness of investment from one sector to another. A technical explanation of the effects of moving the slide-bars is provided in the section below, "Detailed Explanation of Domestic Investment Bias Variables".

Investment Fraction

At the bottom of the Policy Selection Screen is a slide-bar for the "Investment Fraction (of GDP)". Investment fraction is not yet modeled endogenously because we have not yet found a good theory of the determinants of propensity to save and invest; these determinants are to some degree psychological and cultural in origin. Instead, the slide-bar sets exogenously the portion of the country's GDP that will be invested. For some countries, this factor is extremely important.

Some data (from the World Bank's *World Data* 1995) help set a context for consideration of investment. Bangladesh historically invested from 5 to 16% of its GDP during the period from 1960 to 1994, the average being about 11%.

The Investment Fraction parameter is not yet implemented in the Tunisia or U.S. models, but for comparison:

- Tunisia invested from 17 to 32% of its GDP from 1960 to 1994, averaging about 26%.
- The United States invested from 16 to 22% of its GDP during 1960 to 1993, averaging about 19%.

Country-Specific Custom Features

The THRESHOLD 21 policy selection screen can be customized to the needs of modelers or policy analysts, and the country-specific versions of THRESHOLD 21 have various custom policy inputs.

*Pollution Effects (Bangladesh only).*There is still uncertainty as to the magnitude of adverse impact of air pollution on human health and agricultural productivity. In the Bangladesh model, two slide-bars allow policymakers to explore the effects of pollution on the human death rate and on agricultural productivity. Coefficients have been set within the demographic and agricultural sectors to represent best estimates of how pollution affects these sectors. The slide-bars enable users to ask question such as "What if the effect of pollution is actually ten times greater than scientists currently think?" by changing a multiplier. The multiplier value is used only for the duration of one simulation.

Availability of Oil Imports (Bangladesh only): THRESHOLD 21 is an "open economy" model. This means that the "rest of the world" is always ready, willing, and able to provide any needed imports and to purchase any potential exports. In the Bangladesh model, a time-dependent coefficient, "fraction oil imports available", can be set by users to explore alternatives to the assumption that any amount of energy is always available to import.

Change Model Structure (Bangladesh only): In the Bangladesh model, a button on the Policy Selection Screen, "Change Structure", opens a second screen which provides a means for turning on or off different parts of the model. For the moment, a "Girl Entrance Yes / No Parameter" controls whether or not girls will be allowed to enter school.

Water Inflow (Tunisia only): In the Tunisia model, a time-dependent exogenous, "annual inflow", allows policymakers to experiment with the effect of different assumptions about the amount of annual water inflow to Tunisia. For Tunisia, a water constrained country, this assumption is extremely important, and occasionally different policymakers are unconsciously making different assumptions about this variable. Dialog and consensus are improved by placing this assumption in a conspicuous place on the Policy Selection Screen when everyone can be aware of what is being assumed.

Reforestation (Tunisia only): In the Tunisia model, a time-dependent exogenous, "total conversion to forest land", allows policymakers to experiment with the effect of different reforestation policies.

Water Capacity vs. Efficiency (Tunisia only): In the Tunisia model, two buttons have been added to the Policy Selection Screen: "Water Efficiency" and "Pumping equipment". The purpose of the modification is to simulate the effects of investing in water use efficiency, rather than in water pumping capacity.

Immigration (USA only): In the U.S. model, a time-dependent exogenous, "immigration constant," enables policymakers to assess the impact of different immigration quotas.

International Assistance: Work in Progress

The THRESHOLD 21 policy selection screen contains six buttons ("UNICEF", "UNDP", "UNFPA", "WFP", "IFAD", and "World Bank") labeled "Work in Progress: International Assistance." These buttons indicate a future direction for the development of THRESHOLD 21, but are not yet fully operational.

Ultimately, through the International Assistance buttons, it will be possible to specify the amount and type of assistance from international organizations (UNICEF, etc.). When these specific forms of assistance and their expected consequences are linked to the model, it will be possible to explore alternative scenarios and coordinate the assistance strategies of the United Nations agencies, for example.

Detailed Explanation of the Domestic Investment Bias Variables

In order to explain the affect of the Domestic Investment Bias variables on the operation of the model, we first need to explain how the model simulates economic activity and automatically allocates investment, and then we will explain how a user may influence this process via the Domestic Investment Bias slide-bars. The Domestic Investment Bias inputs are key parts of THRESHOLD 21. They represent the influence of tax and subsidy policies on market decisions and the flow of investments to the different sectors of the economy.

How the Model Allocates Investment

The investment model in THRESHOLD 21 does a number of things: It represents the action of the market in shifting investment among different sectors to meet expected demand; it limits increases in capital to what the economy can provide; it causes the changes in capital to take place over a period of time to allow ordering, production, and delivery of capital; and it takes account of depreciation.

The "target goods demanded" variable

The model represents the operation of the market by attempting to have production meet a target amount of goods demanded. This "target goods demanded" is the sum of the targets for goods consumption, goods export, and investments by sector.

The key equation is:

target goods demanded =
target goods consumption +
target goods exports +
sum of target investments by sector

"Target goods consumption" is calculated by the model based on such variables as disposable income, the price of food, the price of goods, the propensity to save, and the target food consumption. "Target goods exports" is calculated by the model based on the level of goods produced and a target fraction for export.

The "target investment" for each sector is calculated based on the production needed to bring supply and demand into balance over time. The key equation is:

target investment [sector] =
depreciation [sector] +
(target capital [sector] - capital [sector]) / time adjust [sector]

In words, this equation is saying the target investment consists of two terms. The first term, "depreciation", ensures the target investment covers what is being lost to depreciation. The second term makes a step toward the target capital. The step is the target capital minus the capital that is already there divided by the time required to order, produce, and deliver the capital. The "target capital" is calculated in each sector and is the amount of capital required to meet expected demand in the sector. It is based on such variables as current capital, current production, and expected growth in demand. The calculation is unique to each sector.

The allocation of actual goods supply

However, the target level of goods demanded may not be satisfied. Demand will be constrained by the goods supply, i.e., by what can actually be produced by the economy (goods production) and actually be imported (goods imported).

The key equation is:

goods supply =
goods production + goods imported

Hence, the fraction of goods available (the ratio of the goods supply to the target goods demanded) at any specific time determines what proportion of the "target goods demanded" can be satisfied. The key equation is:

fraction goods available =
goods supply / target goods demanded

Therefore the actual amounts of goods available for consumption, for export, and for investment in each sector are:

goods consumption =
target goods consumption * fraction goods available

goods exports =
target goods exports * fraction goods available

investments by sector =
target investment by sector * fraction goods available

An example illustrates how the model allocates the actual production to consumption, exports, and investment. If the target for "goods consumption" is 100 and for "goods export" is 30, and each of the six sector target investments is 10 (agriculture, goods, energy, water, environment, services), then the total target goods demanded is:

target goods demanded =100 + 30 + 6 * 10 = 190

On the production (supply) side, assume GDP plus imports equals 120; then the "fraction of goods available" is 120 / 190. This value of "fraction of goods available" is used to compute the actual distribution of available goods to consumption, exports, and investments:

goods for consumption = 100 * (120 / 190) = 63.2
goods for export = 30 * (120 / 190) =18.9

and, for example, investment in the agriculture sector,

investment in agriculture = 10 * (120 / 190) = 6.3

The targets and actual values for this example are as follows:

Variable	Target	Actual
Goods for Consumption	100	63.2
Goods for Export	30	18.9
Investment in Agriculture	10	6.3

In summary, in each cycle of a simulation, the THRESHOLD 21 model will automatically set target capital levels in each sector, derive the requisite target levels of investment, and then apportion the actual production of the economy in an to attempt to meet the targets.

Adding "policy bias" variables

Now we may explain how to influence the investment process by biasing the target capital in one or more sectors.

There is a separate slide-bar variable for each of the six (seven in the Bangladesh model) sectors of the THRESHOLD 21 model. The variables controlled by the slide bars are called "policy bias target capital [sector]" -- the policy bias to be applied to the target capital variable for a particular sector. They are multipliers that typically range in value from 0.5 to 1.5 (i.e., 50% to 150%).

The policy bias variables represent the combined effects of taxes, subsidies, and other policies that together determine the relative attractiveness in the market of investing in the various sectors. Policy bias variables are used to compute the new target investment levels at the beginning of each calculation interval by biasing the target capital in each sector.

The policy biases are inserted in the equations for target investment. The general form of the equation becomes:

target investment [sector] =
depreciation [sector] +
(target capital [sector] * policy bias target capital [sector] - capital [sector])
/ time adjust [sector]

The Effects of Moving the Investment Bias Slide-Bars

Consider the agriculture sector as an example. The target investment in agriculture is computed as:

target investment agriculture =
depreciation agriculture + (target capital agriculture *
policy bias target capital agriculture - capital agriculture) / time adjust
capital agriculture

If capital in agriculture already is 60, and the model is already trying to increase this level to 80 (target capital agriculture) over a 5 year period (the time required to adjust capital in agriculture) in the face of depreciation in agriculture of 6 (10% per year), then with the policy bias set at 1 (continuation of historic policies), the target investment in agriculture is:

target investment agriculture =
6 + (80 * 1- 60) / 5 =
6 +20/5 = 10

Now, if we, as the policymaker, increase the policy bias to 1.2 by moving the slide-bar, we get:

target investment agriculture =
6 + (80 * 1.2 - 60) / 5 =
6 +36/5 = 13.2

This is the target investment, not the actual investment. To calculate the actual investment, we need to recalculate the target goods demanded and the fraction of goods available.

The target goods demanded is the sum of consumption, exports, and investments. So, if target investments increase, the target goods demanded must increase too.

Using the number calculated above for target investment in agriculture in the equation for target goods demanded gives:

target goods demanded =
target goods consumption +target goods exports +
target investments by sector =
100 + 30 + 5*10 + 13.2 = 193.2

Before increasing the bias, the target goods demanded was 190.

If goods supply (goods produced plus goods imported) remains unchanged at 120, the fraction of goods available becomes 120/193.2.

Now we can compute again the actual investment in Agriculture and see the final direct effect of moving the Agriculture Investment Bias slide-bar from 1 to 1.2:

investment in agriculture =
target investment agriculture * fraction goods available =
13.2 * 120/193.2 = 8.2 (vs. 6.3 before)

Note that while actual investment in agriculture has gone up, goods consumption and exports have fallen to:

goods consumption =
target goods consumption * fraction goods available =
100 * 120 / 193.2 = 62.1 (vs. 63.2)

goods exports =
target goods export * fraction goods available =
30 * 120 / 193.2 = 18.6 (vs. 18.9)

The investment levels of all of the other sectors also have fallen. For example:

investment in energy =
target investment energy * fraction good available =
10 * 120 / 193.2 = 6.2 (vs. 6.3)

These reductions are as they should be because there is only a fixed amount to consume, export, and invest. The policy bias influences the relative attractiveness of the investment in various sectors, but the total available remains fixed. In this sense, the policy biases have a "zero sum" result.

Thus the interaction of the target demand and the slide-bars' influencing of investment allocations provide a convenient way to represent the combined effects of key policy levers such as taxation and subsidy as they alter the relative attractiveness in the marketplace of investment in the different sectors.

Appendix C: Plans and Ideas for Improving the THRESHOLD 21 Model

The Millennium Institute is committed to making the THRESHOLD 21 model a full-functioned, user-friendly integrated assessment tool for country-level analysis. The following paragraphs identify some of our priority plans for further work on the model and other ideas suggested by the analysis performed for this paper.

Priority Plans

The current THRESHOLD 21 national models operate in an almost totally "open economy" mode, save for constraints recognized and self-imposed by users. By this we mean that THRESHOLD 21 assumes the existence of a rest-of-the-world from which anything can be imported or exported indefinitely into the future at current prices. In order to provide a more realistic policymaking environment, the national versions of THRESHOLD 21 need improved linkage of their exogenous variables to a global context. Ideally, this global context would be dynamic, and it is a goal of the Millennium Institute to create a sufficient number of national models which could then be linked together into a world model, to provide such a dynamic "rest of world" context for each national model. In the interim, improved methods for monitoring and perhaps constraining the exogenous variables need to be added to the national versions. As a first step in this direction, we are planning to add a simple "Rest of World" sector to place more realistic constraints on imports and exports.

Technology change is represented in a rather generic fashion, yet technology change often has profound impacts on how a society or economy is organized and on the productivity of a nation. The potential affects of technology change need to be better understood, and mechanisms for simulating the possible affects need to be included in THRESHOLD 21.

Multi-lateral investment cannot yet be simulated and tracked. Currently, all investment, whether it be from the UN, one of the banks of the World Bank Group, from, commercial banks, or from corporate investment, must be lumped together. The Millennium Institute's goal is to be able to specify the level and kind of investment made by any one of the aforementioned agencies. We feel this is key to facilitate policy coordination amongst the various agencies.

Economists have requested a means of being assessed of consistency among national accounts variables. To meet this need, a Social Accounting Matrix (SAM) is being added to make economic consistency apparent.

The system of connections between the monitory flows in the RMSM model and the physical world of people, resources, and environment are a priority for strengthening.

Further Ideas

In the course of conducting the analyses for this paper, Mr. Bogdonoff developed a number of ideas and suggestions for improvements to THRESHOLD 21. His suggestions are as follows:

Overall suggestions

Add "reality" checks and "conservation of" checks.

Two kinds of checks could be added to the THRESHOLD 21 models. The first are run-time checks designed to let policymakers know whether a scenario they have just run is realistic or not. For example, a simple warning or graph could let model users know that per capita calories had fallen below starvation levels.

The second kind are checks to ensure that as improvements or modifications are made to the model, that they have not inadvertently introduced errors or inconsistencies. Some simple error checking code could be added to the model to increase confidence in its output. A kind of "double-entry accounting" could be used to guarantee the "conservation of energy", the "conservation of dollars", and the "conservation of people", for example. The sum of the employed and unemployed should equal total population, for example. The sum of energy generated and imported should equal sum of energy consumed and exported.

Where possible, add double-entry accounting for: population; land; energy; greenhouse gases; water; currency; and other stock variables to ensure that calculations are performed correctly ("what goes in, must come out"). For example, when forest land is converted to agriculture and pasture land , the amount of forest land decreases, yet the agriculture and pasture land does not increase. (This is so in the Tunisia version of the model, and perhaps in others, too.)

Expand investment options.

For example, in the Tunisia model, instead of just one slide-bar for increasing investment in the Water sector, there could be an additional button which would take you to a panel where you could allocate the investment in the Water sector proportionally between "capacity" (to allocate investment capital in expansion of pumping capacity) or to "efficiency" (to invest in increased irrigation efficiency or water conservation measures). We have implemented a simple version of this in the Tunisia model with the Pumping capacity and Water efficiency buttons. However, a mechanism that allowed for more precise allocation is desirable. In the Energy sector, it would be desirable to be able to allocate investment in that sector among fossil fuel burning technologies and renewable technologies.

Increase connections to RMSM.

Current inputs to RMSM are: agricultural production, energy production, food exports, fraction goods available, goods exports, goods produced, index price food, index price goods, index price of energy, price deflator, price of energy, price of food, price of goods, propensity to save, target investment total, total population, value social service activity. Current outputs from RMSM are: foreign reserve, and disposable income. These connections need to be strengthened in the context of an overall economic model that links, through price, the monetary representation of RMSM to the physical aspects of the other sectors.

Link the savings rate to the investment rate.

Domestic savings rate and foreign savings need to be linked to investment rate. Now they are only linked to consumption.

Improve the ability to specify the source and target of foreign investments.

Foreign investment needs to be represented in a way that allows one to observe the relative and combined consequences of contributions of the various donor and investor programs.

Add a "social satisfaction" indicator and/or a Political sector.

In one of the scenarios we ran, all of the main environmental and social indicators improved significantly, except for the per capita agricultural production and calories per capita. Calories per capita dropped from 1700 to below 1500. Obviously, improving the other sectors at the expense of agricultural productivity and individual quality of life is not realistic, and in the real world the public would find ways of making its dissatisfaction known. In the current version of the model, there are no "social satisfaction" or "political unrest" indicators to warn a policymaker away from such a scenario. Future versions would benefit from the addition of such indicators. A social satisfaction indicator might be built on such things as calories per capita, pollution intensity, unemployment, water per capita, and other relevant indicators. A political sector could also be added. GLOBUS is one model with a political sector which might provide a template for THRESHOLD 21. (Bremer, 1987)

Add the means to analyze current NGO development agendas and strategies.

For the U.S. and other national models, include mechanisms in the model to allow policymakers to compare and evaluate the alternative development strategies that NGOs and others are promoting. Are these strategies relevant? Important? Effective? What is their impact over the long run? Will they become irrelevant in the face of larger trends?

Add a visual indicator of the relative investment levels.

The Investment Bias slide-bars are a good tool for shifting the allocation of investments among the various sectors. However, they do not give a sense of the relative investment levels among the sectors. (For example, when the policy selection investment biases are set to "1", what is the relative distribution of investment? Is the Military sector currently allocated 5% of the investment resources in a country, or 50%?) One suggestion is to add a visual indicator to the policy selection screen -- perhaps a bar chart -- or to add a button which then displays a table or a pie chart -- to show the relative investment allocation.

Enhance the linkages between the Energy and the Agriculture, Goods, and Services sectors

In the face of finite and diminishing fossil fuel resources and / or the possible need to reduce CO_2 emissions, policymakers will need to explore scenarios in which fossil fuels and CO_2 absorption capacity are limited. The current THRESHOLD 21 models make some simple assumptions about the energy requirements of the productive sectors of the economy -- agriculture, goods, and services. We do not know very well how these sectors would behave in the absence of oil, for example. Future versions of the model might incorporate country-specific factors for how each sector would respond to energy shortages, and the extent to which non-fossil fuel energy sources could be substituted. Such detail might increase understanding of the relative importance of investment in alternative technologies.

Enhance the Health sector to include the modelling of diseases, e.g., AIDS

Epidemics like AIDS are having a major impact in some developing countries, often affecting the most productive age groups of the population. Other diseases such as schistosomiasis, malaria, and malnutrition also could be modeled.

Complete the glossary of terms and rename some variables.

With the current version of the documentation, it is difficult to know when you have the right variable when you select a variable for analysis. A complete glossary would help users.

Add additional footnotes to documentation.

Continue to increase the references and footnotes in the documentation identifying the literature from which the sectors and equations derive. Eventually add such references into the equation window in THRESHOLD 21.

Suggested Improvements for Country-specific versions

The following material provides suggestions on the Bangladesh, Tunisia, and United States versions.

Bangladesh version

Some suggestions for specific improvement to the Bangladesh THRESHOLD 21 model include:

- Improve the import and export models, especially for energy, to enable users to constrain imports and exports (limits, tariffs, etc.).
- Improve monitoring of pollutants -- add more pollutants; disaggregate by urban and rural.

- Add the ability to model rural to urban migration and its effects.
- Improve the employment model, including the ability to disaggregate by urban and rural, and perhaps by income group.

Tunisia version

Some suggestions for specific improvement to the Tunisia version include:

- Improve the import and export models, especially for energy, to enable policymakers to constrain imports and exports (limits, tariffs, etc.).
- Improve the water use efficiency submodel.
- Add ability to invest in renewable energy (technology).
- Connect the “Water Efficiency” button to the “transfer loss” variable.
- Review the connections between the forest land sector and the rest of the model.
- Add the ability to return to the main display panel of a work-in-progress (Back to WIP).
- Add the option to show the data behind the curves (View Table button).

U.S. version

Some suggestions for specific improvement to the U.S. version include:

- Add a forestry sector, and a greenhouse gas “sector.”
- Add a more realistic industrial energy sector.
- Improve the display of only the oil and gas reserves (on the six-curve summary display) to convey more adequately the status of overall energy use in the U.S. model by including the sum of total energy consumption (sum of oil, gas, coal, nuclear, renewable) on this summary display and by showing all imports and exports of energy along with reserves on the graphs for the energy sector.
- Add the ability to turn off nuclear investment and ability to invest preferentially in renewable sources of energy.
- Add ability to reduce domestic energy demand or improve energy use efficiency, and perhaps also the ability to increase use efficiency by a user-specified factor.
- Add the full suite of indicators that are already calculated in the other versions of the model; especially calculate Natural, Human, and Total Capital.
- Allow for investment in the Military sector to reduce investment available in other sectors differentially (e.g., to be able to say Military investment makes resources disproportionately unavailable to the social services or the goods sector). Perhaps each sector should have its own set of rates at which it taxes the other sectors in order to obtain its target level investment. Or perhaps each sector should have an “elasticity of taxation” which determines how easy it is to take money away from that sector.
- Add the ability to return to the main display panel of a work-in-progress (Back to WIP).

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