Sustainability in a Bipolar Global System: A Global Modeling Study with North-South Differentiation

Gönenç Yücel
Boğaziçi University
Bebek Yolu Sok. Ozkan Polat Ap. No:21/5 Etiler, Istanbul, Turkey
Tel: +90-212-3581914 Fax:+90-212-2651800
gonenc.yucel@boun.edu.tr

Abstract

Traditional global models address important global problems using highly aggregated measures, but it may be argued that the world is strongly non-homogeneous at least at some fundamental level: developing (South) nations and developed (North) nations may have very different, asymmetric problems, goals and structures. This study aims to investigate these two distinct groups of economies in a context of global sustainability. We identified population, economic growth, welfare gap, energy supply and pollution as key issues and analyzed them in a systems perspective. A dynamic feedback model, which discriminates these two groups of nations, is constructed based on WORLD-3 model in order to study the dynamics of key parameters related to these issues for the period 1975-2050. Simulation experiments reveal that population characteristics of South and current mode of economic activity, which is extensively dependent on non-renewable energy resources constitute serious obstacles for the sustainability of the system. Hence, stabilizing the population growth in South, transition to alternative energy resources and investment support to South for this transition are vital for closing the welfare gap between blocks and sustaining the global system.

1. Introduction

Sustainability of the current pace and mode of global development became a hot issue in the last quarter of the 20th century (Barney, 1980; Barney *et al.*, 1991; Brundtland, 1987; Goldsmith et al., 1972; GSI, 2001; IISD, 2002; Meadows et al., 1972; Meadows et al., 1992; Ward and Dubos, 1972) and since then it is subject to numerous academic, governmental and public discussions. Most probably, the single common conclusion regarding the issue is the multi-disciplinary nature of the problem. Hence, the problem of sustainability of human activity on earth requires studying the world as a system composed of economic, environmental, social, and even political sub-systems at a global scale. This characteristic of the problem induced several well-known global modeling studies, which had differing scopes, perspectives, disciplines, and methodologies (Fey and Lam, 2000; Forrester, 1971; Herrera, 1976; Hughes, 1999; Meadows *et al.*, 1974; Mesarovic and Pestel, 1974; Onishi, 2002).

This study is also similar to those conducted before in that it approaches the problem of global sustainability with a holistic perspective. The issue that stands at the core of this study is the characteristic heterogeneity among nations and its importance regarding global sustainability studies. When the economic welfare indicators are studied, a significant clustering among nations is observed (Brandt, 1980; World Bank 2002; World Bank, 2003). The top and bottom clusters in the welfare spectrum are commonly referred as North and South, respectively. The most striking fact about this structure is the continuously widening gap between North and South blocks, and differing demographic and economic characteristics of these two blocks induced by that welfare gap. As a result of this difference, the dominant dynamics in their economic, social and environmental processes are expected to be different; hence the obstacles they will encounter regarding sustainability will also differ in type, magnitude and timing. For example, global industrial and agricultural output should be doubled within this century in order to keep welfare approximately at the current level due to population growth. Although a doubling of the global output is a probable scenario, most of this increase is not expected to be in the South, where demanding population will be born. Hence, the problem is no longer the possibility of needed increase in output, but the global distribution of that increase. Hence, it is of great importance to identify the mentioned heterogeneity while studying policies regarding global sustainability.

We identified population, economic growth, welfare gap, resource supply and related pollution as the key issues. Considering the large scale and dynamic feedback nature of the problem, system dynamics methodology is employed and a simulation model that covers the mentioned issues in varying detail levels is constructed in order to provide an experimental simulation platform for the analysis of these problems in their interconnected context. It is important to note that WORLD-3 model developed by Meadows *et al.*(1974), provided a valuable basis for conceptualizing and constructing the model to be discussed in the following sections.

In this article we aim to present the model and summarize the observed outcomes under several scenarios and policy options in relation to issues covered.

2. Model Description

As mentioned before, the model aims to cover interrelations between economic, demographic and environmental systems, in the context of North-South differentiation. In this manner, model contains two interacting and almost identical structures that differentiate mostly at initial parameter values. Although the focus is on these two blocks, significance of the aggregated contribution of economies that are excluded from both North and South blocks in certain global issues like pollution and resource consumption make it inevitable to represent them in the model (*for a detailed discussion on the classification of economies see Yücel, 2004*). This third block is named as Rest-of-the-World (RoW) block, and some simplified structures to generate responses of RoW block are also included in the model.

Before discussing the simulation results, a brief introduction to the model structure is provided in the following section. A detailed discussion of the model structure is given in Yücel (2004). Additionally, it is important to note that some structures of the model, especially the ones related to population, are very similar to the ones in WORLD-3 model (Meadows *et al.*, 1974). Those structures will be indicated and additional information regarding those may be found in Meadows *et al*, 1974.

Overview of the Model

The model is composed of nine sectors grouped under four sector groups; economic activity, population, resource usage and pollution sector groups. Each sector group contains at least two sectors, one for the North and one for the South block. Pollution sector is the only exception as it is a single sector. Additional structures to represent the

Rest-of-the-World (RoW) block are introduced to some of these groups. A high-level representation of these sectors and their major interactions are given in Figure 1.

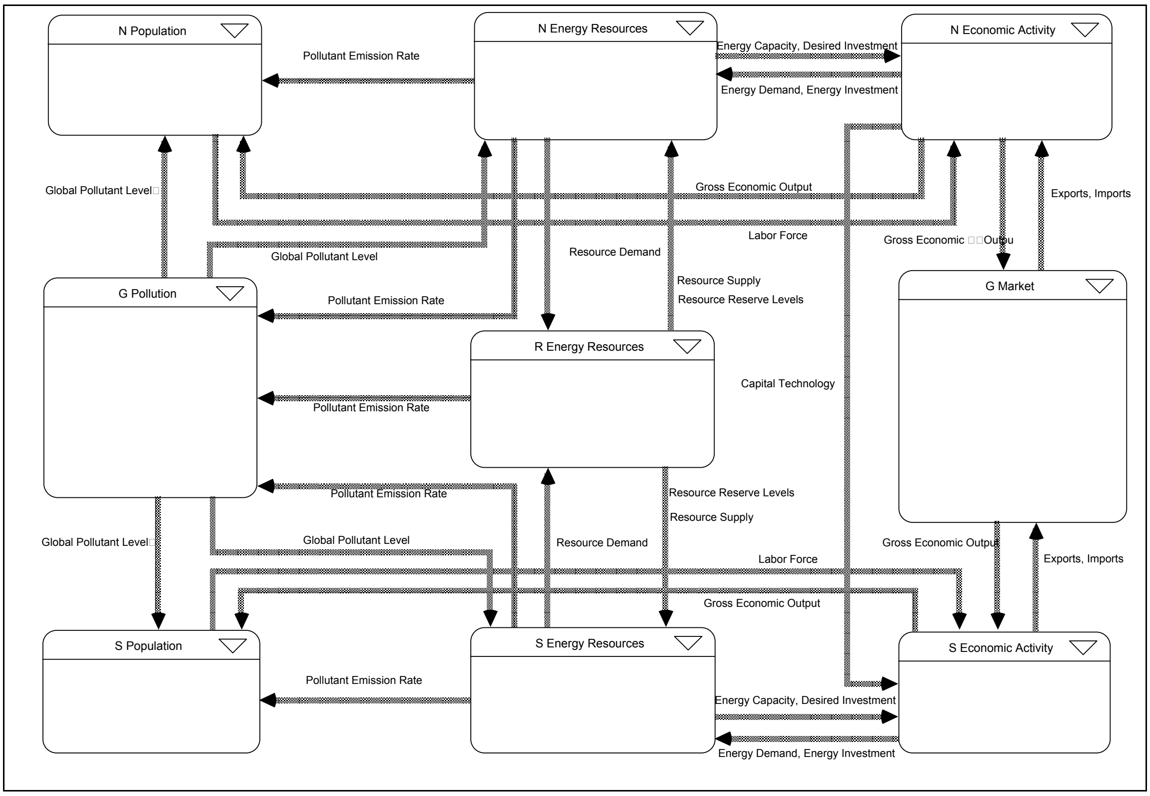

Figure 1: High-level representation of the sectors and major input-output relations

<u>Population Sector Group:</u>

This group is composed of population sectors of North and South. We aim to explain existing and probable future differences in the population dynamics of these two blocks, and we identified fertility level, life expectancy, population base and the age distribution in the population as key aspects to focus on (UNPD, 2003; Cohen, 1995; Barney, 1991). Population structure used in WORLD-3 provided a perfect basis covering all these aspects, so a slightly modified version of this structure is used.

Major feedback relations related to the population dynamics are summarized in Figure 2. Output per capita from economic system determine the health expenditures and affect the life expectancy. Other factors that affect the life expectancy are global pollution level and local pollution emissions. On the other hand, as a wealth indicator output per capita is assumed to affect the number of children desired per woman, which is also affected by perceived infant mortality level. In order to acquire reliable dynamics, an aging-chain structure with three sub-population groups is used to generate overall population level. This level provides an important feedback to the economic system as it determines the labor force, which affects capital-output ratio.

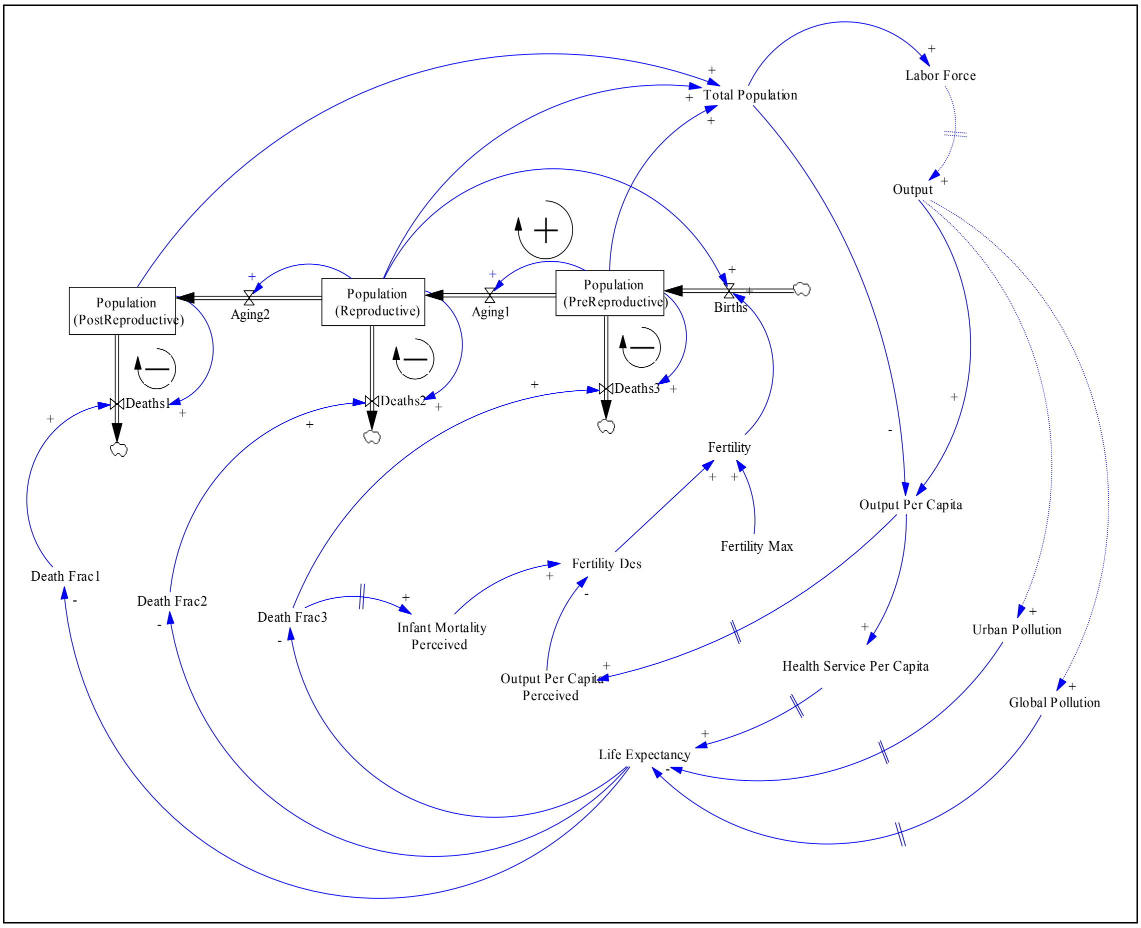

Figure 2. Major causal relationships for the population sector

Economic Activity Sector Group:

This group is composed of four sectors, which are mainly responsible for simulating the intensity of economic activity and explaining the effects of this activity on environmental and social systems. Briefly, the economic output generated in these sectors determines the welfare level, which is represented by output per capita. This level provides feedback to both life expectancy via improved health services and to population growth via decreasing desired number of children. In turn population growth affects economic system via size of the labor force. On the other hand, output generated in this sector is mainly responsible for the environmental stress of man on environment. This stress is in the form of resource usage to support economic activity, and emissions of the economic activity byproducts, or pollutants, to the environment.

Formulating the relation between economic and environmental systems was a complicated task due to variety of resources and pollutants flowing between them, and also due to the aggregation level used in the model. Instead of aggregating a number of resources to a single flow, only the flows regarding key resources are modeled. As suggested by Muilerman and Blonk (2001), these resources are identified as the ones that are ultimately essential for the functioning of the economic system, and that have the potential of acting as a bottleneck. Supplying nearly 90 per cent of global commercial energy demand in year 2001 (World Bank, 2003b), fossil fuels were clearly the best fit for such a classification. Apart from their usage intensity, installed energy infrastructures totally dependent on fossil fuels make it hard to switch to an alternate energy source. We also employed a similar approach for the pollution flow, and greenhouse gases are identified to be the key pollutant damped to environmental system, as they are a common by-product of a great variety of economic activities and are directly related to fossil fuels usage.

Economic systems of North and South are assumed to be supply-driven systems with two types of homogenous goods. Gross domestic product, free of exchange rate and price differences, is used as the indicator of economic output. Considering the 75-year horizon of the study, short-term market adjustment mechanisms as price, wage, interest or exchange rate are not modeled explicitly. It is assumed that global demand and supply are in equilibrium in the long-run, which is also supported by Saeed (1994). Three production factors are identified in the model; capital, labor and resources. Existing capital and labor determines the output capacity of the economic system. However, resource availability determines the capacity utilization and in fact the final output.

Economic systems of North and South differentiate mainly based on four aspects regarding capital and labor. These aspects are production specialization, labor skill development, capital technology development, and capital-output ratio.

Considering that the factor that differentiates output generated by North from South is mainly the technology content of the output, economic output is classified as high technology goods and low technology goods (Chichilnisky and Cole, 1979; Chichilnisky *et al.*, 1979). Country blocks have dynamic capital-output ratios in these two output segments, and model is designed to provide blocks the flexibility of shifting production capacity between these two, thus allowing production specialization. Decisions regarding the allocation of production capital are mainly affected by the marginal gains of the blocks in shifting a unit capital between these two goods. Figure 3 summarize the main interactions regarding capital shifting mechanism in the model.

We assume that labor skill in any of the output segments improve according to "learning-by-doing" principle. Through a delayed effect, improved labor skills result in decreased capital-output ratio in that output segment. We hypothesize that this mechanism is one of the factors that induce output specialization between blocks. As well as labor skill, it is evident that technology embedded in capital also decreases the capital-output ratio. In order to capture a probable diversification between blocks regarding this ratio, dynamics of development in capital technology is included in the model. Differing from the most other sections of the model, differing structures are constructed for North and South. North is identified as the "technology developer" and South as "technology adopter". To be more specific, it is assumed that South has no capability of innovating new technology and it adopts new technologies from North after a certain delay following the appearance of the technology (Figure 4).

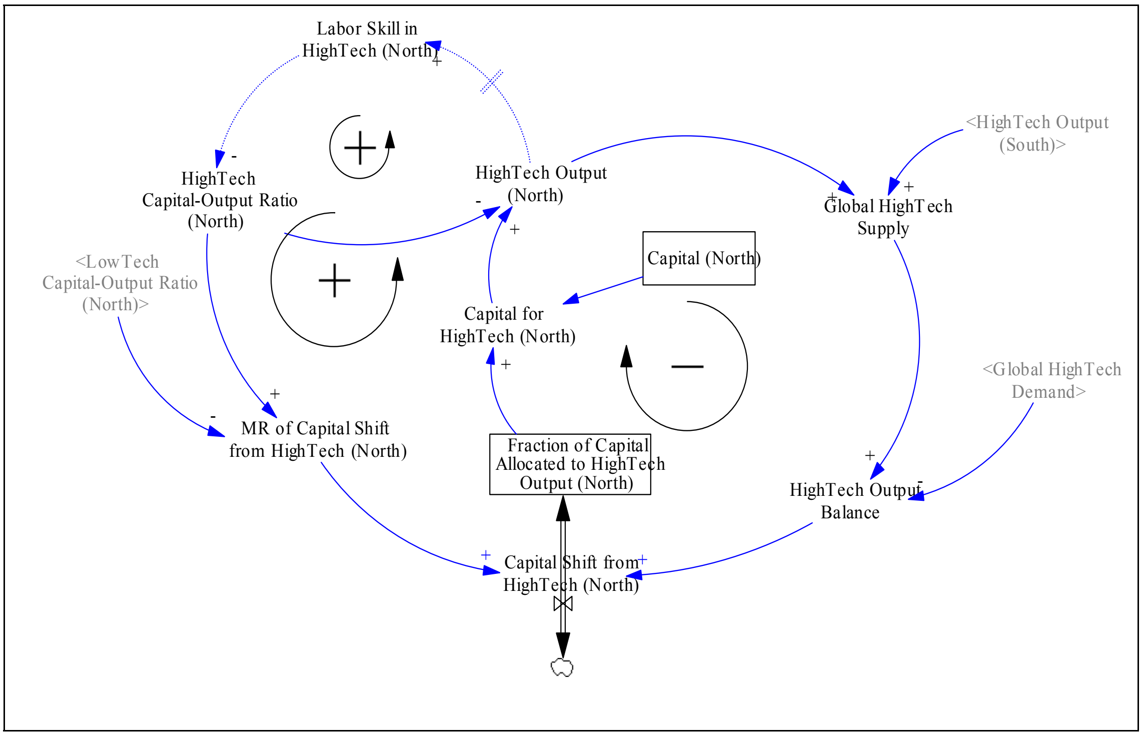

Figure 3. Main causal interactions regarding capital shifting mechanism

One of the most striking distinctions between North and South is related to their labor forces. South stands as labor abundant with its limited capital accumulation and crowded population. However, North stands as an economic system in which labor force is close to stagnation and growth in capital surpasses the growth in labor. Hence, it is clearly evident that capital deepening effect may have an important influence on the probable differences in the economic growth experienced in North and South. Capital-output ratio is formulated such that it is affected by labor-capital ratio, as well as labor skill and capital technology.

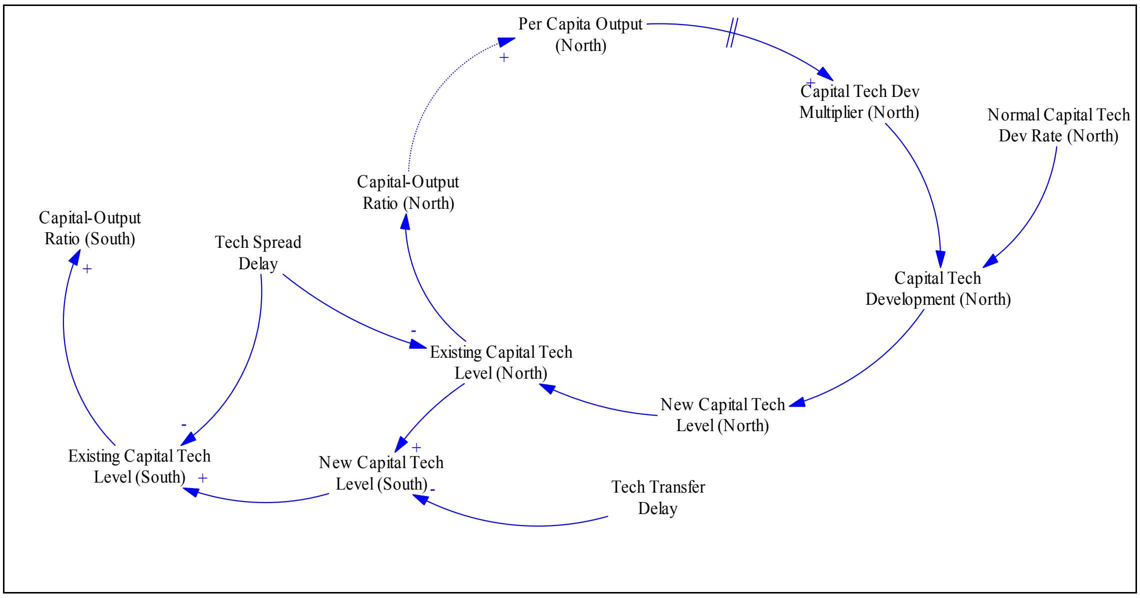

Figure 4. Main causal interactions regarding technology adoption

Third sector of the group is a global market sector, in which all output exchanges between blocks take place. According to the fully integrated global economy assumption, no preference between suppliers and consumers are set in the market. Every consumer is equally likely to get goods from each supplier, and every supplier is equally likely to send goods to each consumer. Based on these assumptions, the amount of goods shipped from a block to another is determined using the weight of the consumer in global market. This weight is calculated as the share of a block's demand for a specific good in global demand for that good.

Last sector in this group is a calculation sector that is constructed to generate rough estimates for RoW block's economic activity level and resource demand.

Energy Resources Sector Group

Two of the sectors in the group belong to North and South, and they include structures related to allocation of energy demand among renewable and non-renewable resources, maintaining the non-renewable resource stocks, capacity adjustment for renewable energy generation and technological improvement in renewable energy productivity.

The fraction of energy demand directed to renewable alternatives is considered to be dependent on decreasing non-renewable resources availability, increasing pollution accumulation, and competitiveness of alternative resources against non-renewables. (Figure 5).

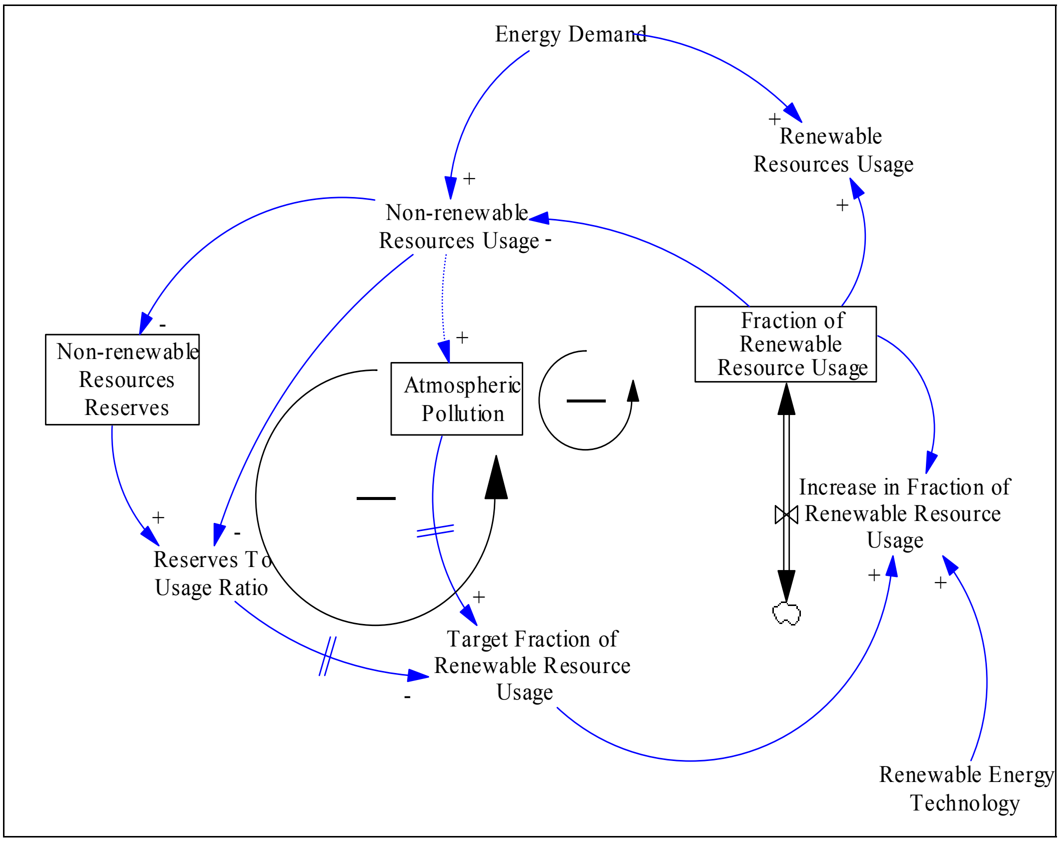

Figure 5. Basic causal relationships in the allocation of energy demand

Energy capacity of a block is equal to the sum of energy that can be generated by the means of renewable and non-renewable resources. Energy from non-renewable resources is assumed to be constrained by the stock of resources available. This stock is managed as in the case of a simple inventory problem; orders for non-renewable resources are calculated based on the current inventory and desired stock levels, which are determined based on forecasted energy demand. On the other hand, local capacity of renewable energy resources is assumed to be determined by the capacity of the installed infrastructure, as we assume that estimated potential of renewable energy resources are far above the amounts that can be demanded by economic activity in the following five decades (UNDP *et al.*, 2000). Investment decisions for renewable energy capacity are given by considering the current level of capacity, the desired level of capacity and the capacity ordered but not installed.

As it can be noticed, no resource extraction structure is included in these two sectors. According to the WEC statement, 80 per cent of world oil and natural gas liquids (NGL) production come from 20 countries (WEC, 2001), and none of them is from South block and only two of them are from North. Furthermore, domestic demands of these two North producers are above their yearly production, so they are also net importers. Based on these facts, this study identifies both North and South blocks as net importers of non-renewable resources, and global reserves of non-renewable energy resources are assumed to be totally located in the RoW block. This sector covers dynamics of new reserve discoveries and resource extraction/production from the discovered reserves. The sector directly interacts with the other energy sectors by receiving demand from them for non-renewable resources and supplying to meet these demands.

Pollution Sector

This single sector represents the dynamics of pollution generation as a consequence of economic activity, and global diffusion of this pollution. As explained above, we selected greenhouse gases (GHG) as the pilot pollutants. Sector mainly interacts with energy sectors in determination of the GHG emissions. On the other hand, global pollution level both affects the life expectancy in population sectors, and provides feedback to the energy sector related to allocation of energy demand among non-renewable and renewable resources.

The level of pollutant in the atmosphere and its level in the global sinks are separated. The atmospheric level increases by emissions due to non-renewable resource usage to support economic activity. On the other hand, an outflow from atmospheric pollutant stock to global pollutant sinks, which represents the concentration driven diffusion is defined.

We assumed that non-anthropogenic pollutant fluxes from land-to-atmosphere and fluxes from atmosphere to land are in balance and their contribution to the long-term atmospheric levels is insignificant. So this sector mainly focuses on the GHG flows due to economic activity and GHG uptake by oceans.

In order to summarize the interactions among systems covered in the model, major feedback mechanisms between the systems are presented in Figure 6.

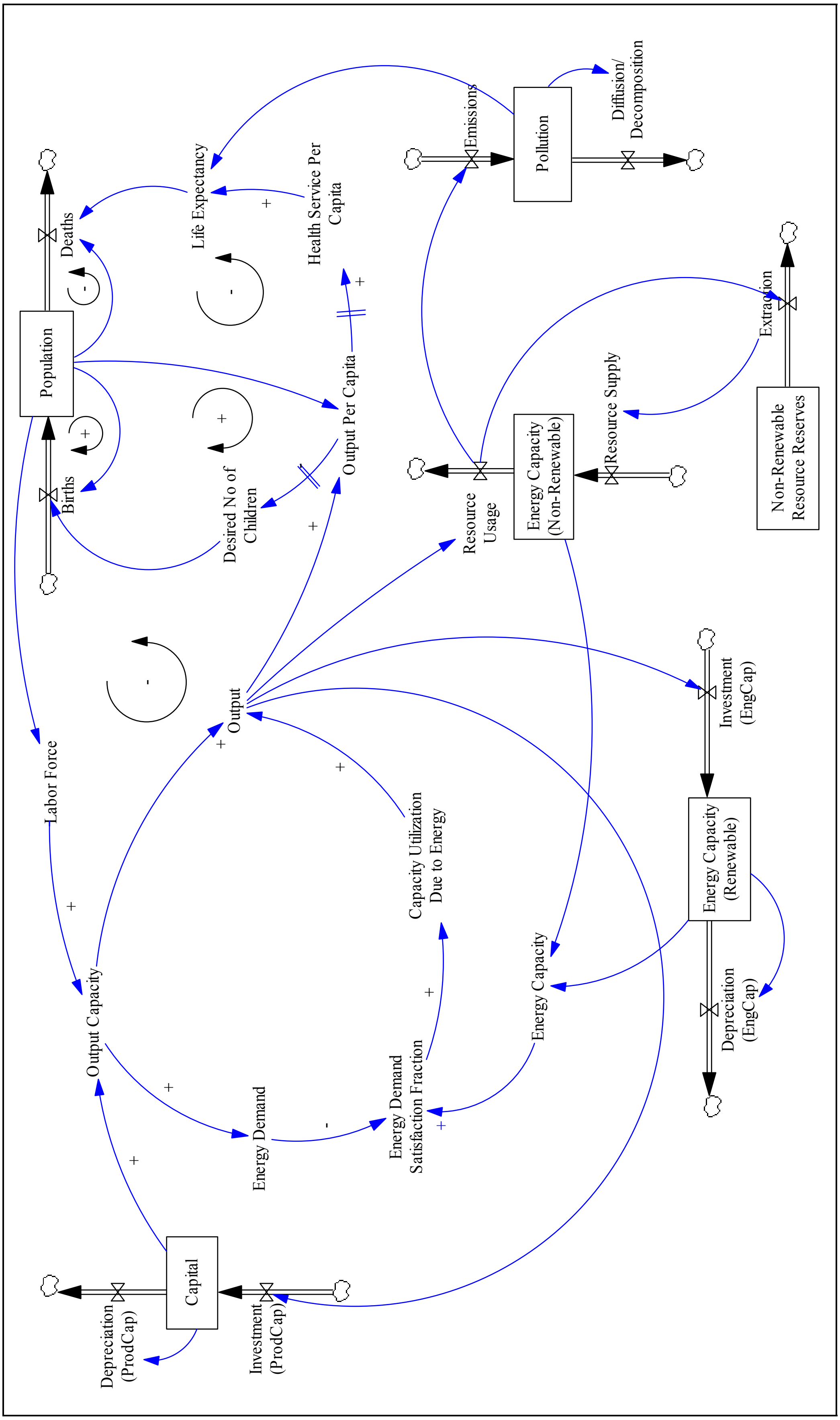

Figure 6. A summary of feedback relations in the model

3. Model Validation

A formal validation procedure, which includes *extreme value*, *behavior sensitivity* and *phase relationship* tests, is followed in order to detect "structural flaws" of the model (Barlas, 1996; Forrester and Senge, 1980). Necessary structure modifications are made in the process. We skip the results of these tests due to lack of space. (See Yucel 2004). After these tests, behavioral validity of the model is tested with the emphasis on the pattern prediction rather than point prediction. The model behavior for the period 1975-2000 is compared with real data, as long as reliable data are available. Most important comparative graphs are provided in Figure 7 through Figure 16. The model is concluded to be a valid representative of the real system in terms of both structure and behavior, with respect to the purpose of this study.

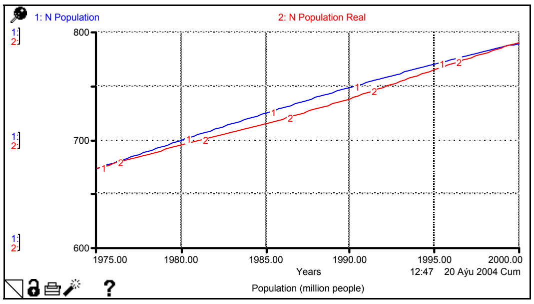

Figure 7. Real data vs. model generated population for North

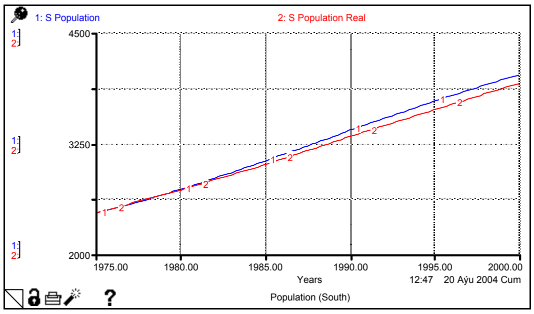

Figure 8. Real data vs. model generated population for South

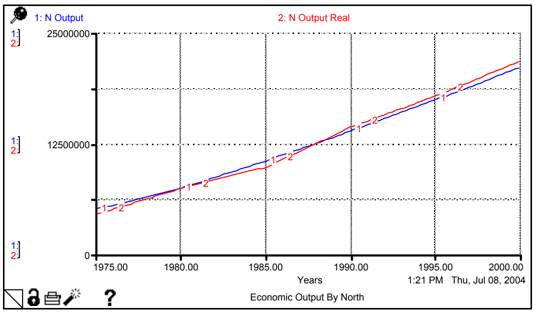

Figure 9. Real vs. model generated economic output for North

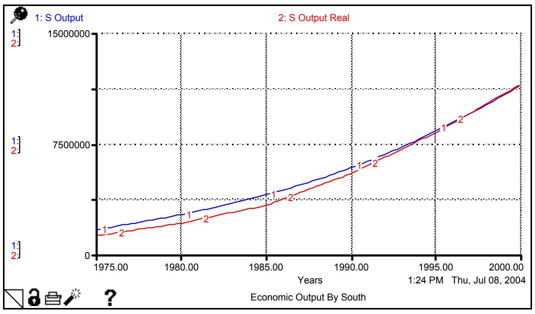

Figure 10. Real vs. model generated economic output for South

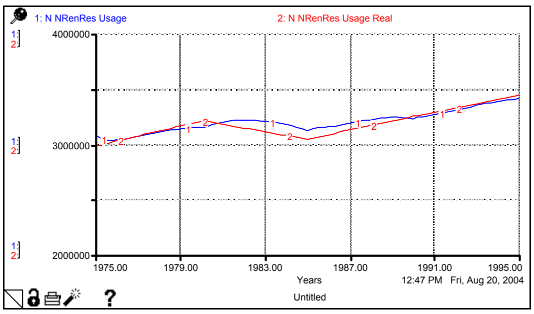

Figure 11. Real vs. model generated non-renewable resource usage by North

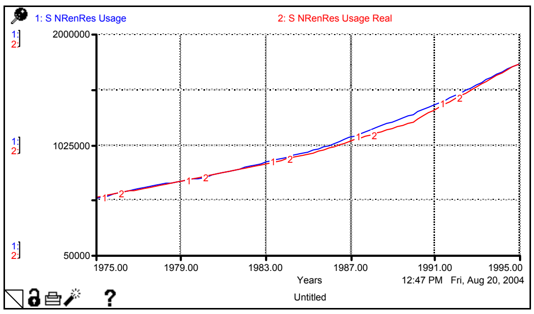

Figure 12. Real vs. model generated non-renewable resource usage by South

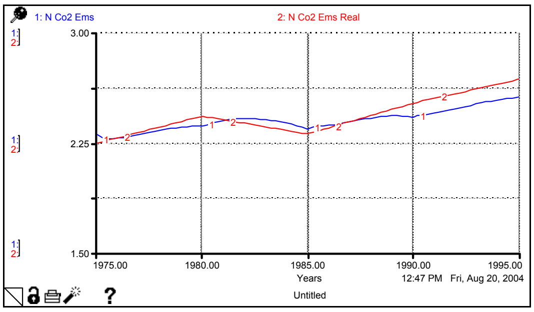

Figure 13. Real vs. model generated CO_2 emissions from North

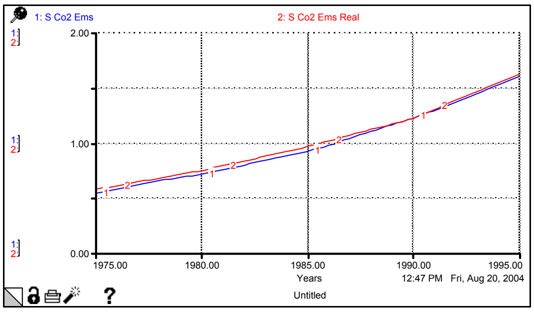

Figure 14. Real vs. model generated CO_2 emissions from South

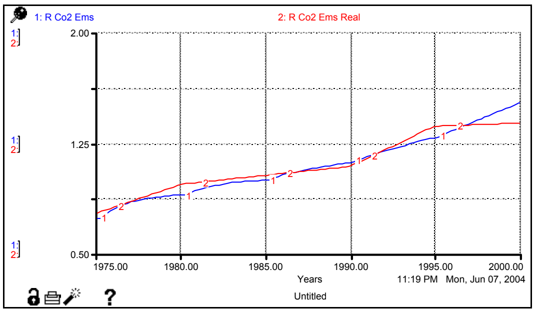

Figure 15. Real vs. model generated CO_2 emissions from RoW

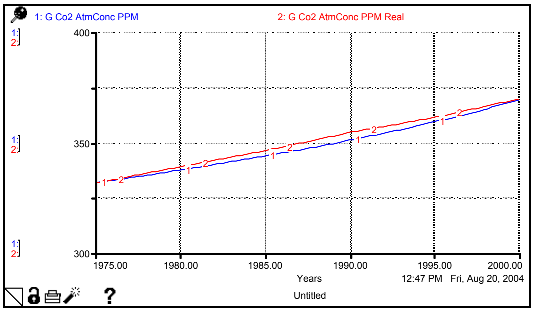

Figure 16. Real vs. model generated atmospheric CO_2 concentrations (ppm)

4. Reference Behavior Of The Model

Population:

As expected, global population that is dominated by the growth in South reaches a level of eight billion by 2050 (Figure 17, line 1). Population growth in South seems to stabilize by the end of the run, and this mainly due to the decreasing fertility, which dominates the growth effect of increasing life expectancy (Figure 17, line 2). On the other hand, decreasing fertility rate coupled with the high mean age of North results in a declining population after the first quarter of the century (Figure 18, line 1). Outcomes support projections in *World Population Prospects* (UNPD, 2003).

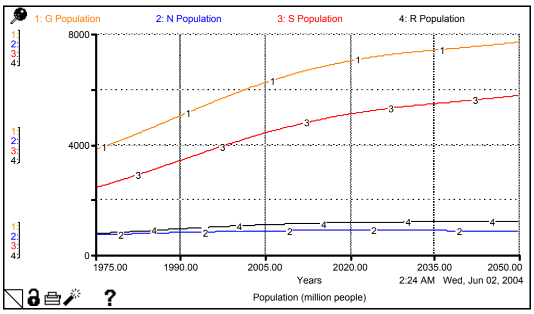

Figure 17. Population dynamics in the base run (Global and for all three blocks)

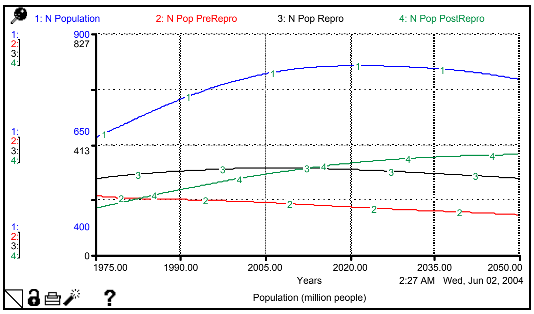

Figure 18. Dynamics of total population and age groups for North

Economic Output:

Gross output levels of blocks are observed to be as in Figure 19. Currently experienced growth patterns are disturbed in both blocks prior to 2030, when a recession due to energy shortage appears.

North seems to recover in about 10 years and recaptures economic growth, which is even faster than the growth experienced before. In Figure 20, it is evident that energy capacity (line 2) is the factor that constrains the economic output. However, the output capacity of the existing production factors (line 1) is considerably higher and continues to increase even during the recession period. So, the recession period can be described as a period of underutilization of the existing output capacity due to energy scarcity. The steep increase in the North's output after 2030 is mainly caused by increased utilization of preexisting production factors, which is attained as new alternative energy capacity is installed.

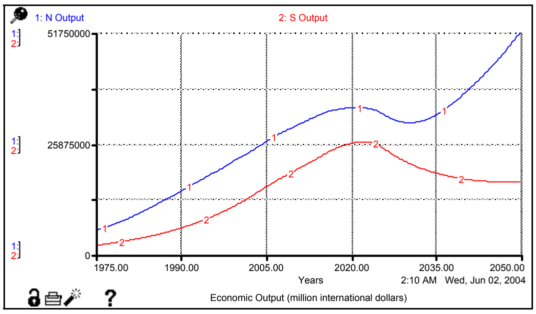

Figure 19. Gross output levels of North (line 1) and South (line 2)

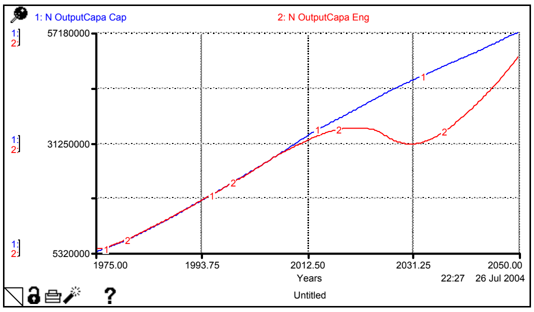

Figure 20. Output capacity of North with available production factors (line 1) and energy capacity with available resources (line 2)

Although overall pattern is similar for South, impact of the recession is a bit harder. There is no decrease observed in the output capacity of production factors (*S_OutputCapa_Cap*), but rate of change of this variable stagnates (marked with an eclipse on Figure 21) for South, which is not the case for North. On the other hand, South does not experience a fast recovery, because of slower alternative energy capacity installation due to late response and limited investment power. Additionally, investment required for alternative energy capacity constitutes a remarkable portion of total investment capacity of South, which indicates less investment for production capital.

As seen in Figure 22, a continuously widening welfare gap is observed. Although South demonstrates a faster growth in gross output, population dynamics of this block prevents it from closing the gap in terms of output per capita even in the pre-recession period. Situation after 2030 is even worse that the starting point of the run.

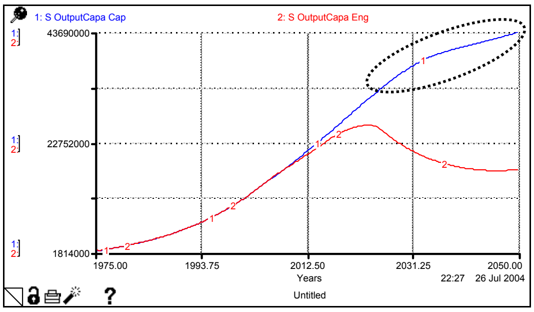

Figure 21. Output capacity of South with available production factors (Line 1) and energy resources (Line 2)

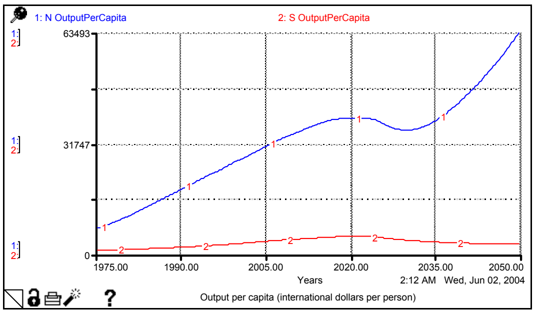

Figure 22. Behavior of output per capita in North and South

Energy Resources Consumption:

In Figure 23, the status of the non-renewable energy resource reserves (line 2) are presented as well as the global extraction rate (line 3). Discovered reserves increase until the year 2005 as a result of discoveries offsetting and even exceeding the extraction rate. On the other hand, the extraction rate reaches its peak point around 2025 and starts to decline as a response to decreasing reserve availability.

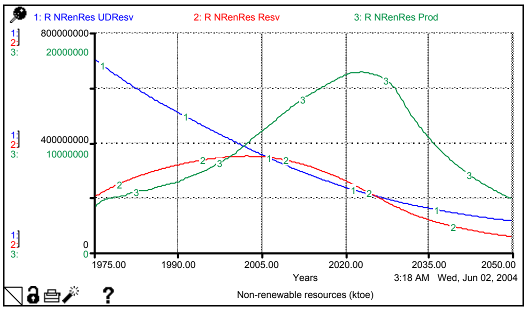

Figure 23. Non-renewable energy resources reserve levels and production rate

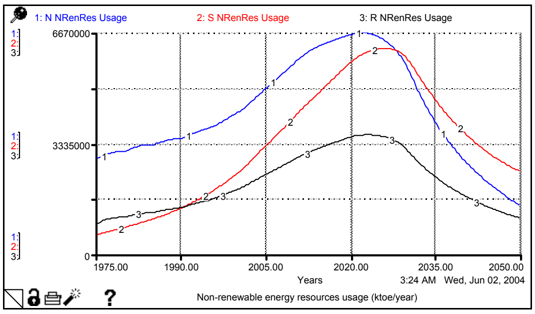

Figure 24. Non-renewable energy resources usage rate in all three blocks

Observed non-renewable resource usage patterns for all three blocks are almost identical (Figure 24). However, causes of the decline vary between North and South. Decline in North is mainly due to decreased demand for these resources as a consequence of shifting to renewables. However, decline in South's usage is mainly due to decreased non-renewable resources supply from RoW. Besides, South emerges as the fastest growing non-renewable resource user and its share in global usage catches up the level of North in the second quarter of the century.

Global Pollution:

As GHG are directly related to non-renewable resource usage, patterns observed in emissions are very similar to the ones observed for non-renewable resource usage (see Figure 24 and Figure 25). It is observed that atmospheric concentration of CO_2, which is the dominant member of GHG family, almost stabilizes around 530 ppm by volume by 2050.

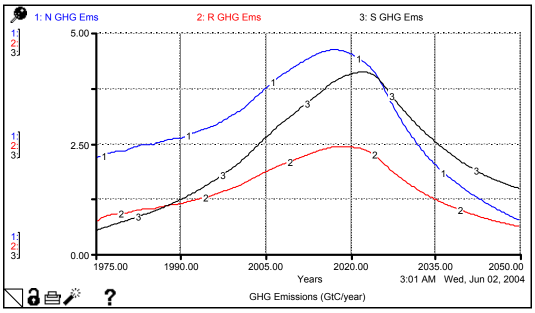

Figure 25. CO_2 emission rates for all three blocks

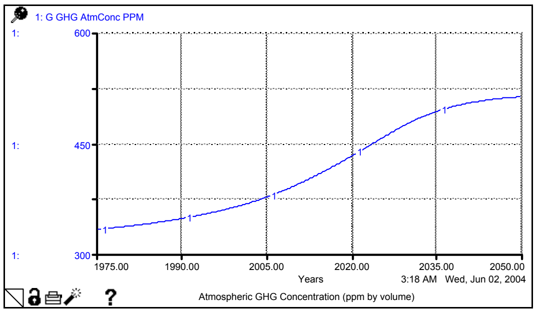

Figure 26. Atmospheric CO_2 concentration

Following the base run, model is used as a test bed for several scenarios and policies. Outcomes from a selection of these scenarios and policies are summarized in the following section.

5. Scenario And Policy Analysis

In the reference behavior, non-renewable resources are identified as the major bottleneck regarding economic sustainability. Hence, a set of alternative scenarios regarding reserve levels and energy intensity of economic activity are generated and tested. Even in the most optimistic ones (e.g. doubled reserve levels, and steeply decreasing energy intensity) overall behavior regarding resource usage does not change and resource based recession is not altered, but just delayed. Common observation from these scenarios is increased global pollution due to delayed transition to alternate resources, which in fact causes a decrease in life expectancies in both blocks. Following figures present the observed dynamics related to resource reserves from two of these scenarios.

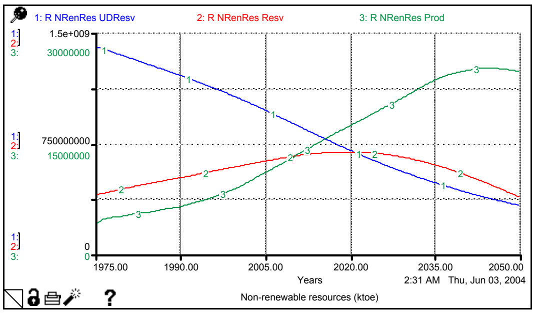

Figure 27. Global non-renewable resource production (line 3) and reserve levels (line 2) in "optimistic non-renewable energy reserves" scenario

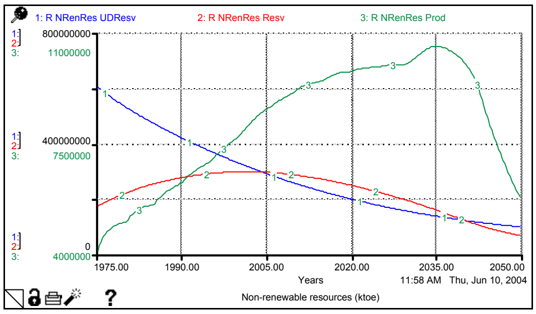

Figure 28. Global non-renewable resource production (line 3) and reserve levels (line 2) in "decreasing energy intensities after year 2000" scenario

One of the distinctive scenarios is related to balance of goods exchanged between blocks. Although financial institutions are excluded, a simplified scenario pretending that the balance of goods exchanged changes in favor of North. In fact factors determining the terms of trade vary, but international debt is assumed to be responsible for such a distortion, which is likely to occur in the following decades. It is assumed that due to increasing foreign currency deficit, goods received from North are decreased (representing the import reduction) by 20 per cent in year 2000 and balance is restored in 10 years. As South specializes in low technology goods, exploiting its abundant labor force, it becomes very much dependent on high technology goods from North for capital investment. Hence, investment pattern of South is significantly interrupted (Figure 29, line 1) as a consequence of reduced high technology goods shipment. As seen, capital stock stabilizes for South (Figure 29, line 2), which implies the output pattern seen in Figure 30 (line 2).

Based on the known causal interactions and dynamics observed in the previous runs, stabilizing the population, speeding up the transition to renewable resources and providing external support for constructing alternative energy systems for South are identified as the goals to be reached in sake of global sustainability.

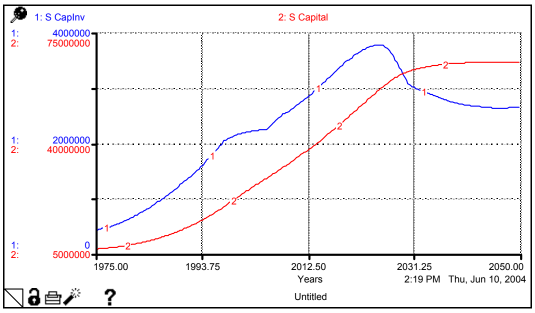

Figure 29. Capital stock and capital investment for South in “distortion in the balance of goods” scenario

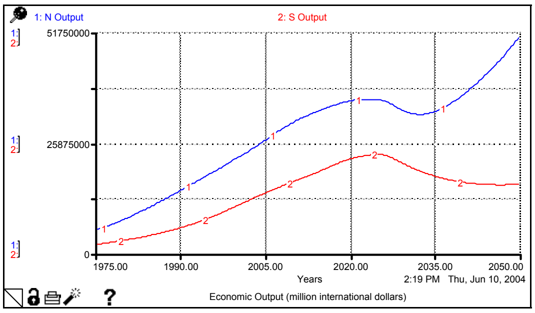

Figure 30. Gross economic output in “distortion in the balance of goods” scenario

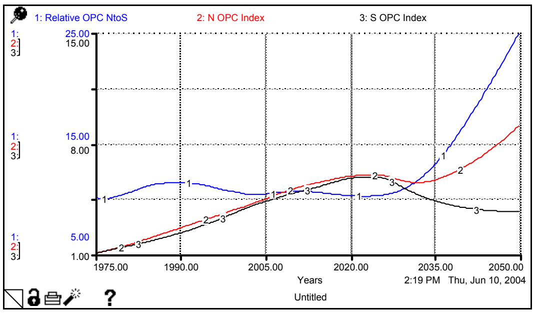

Figure 31. Indexed economic output per capita in “distortion in the balance of goods” scenario

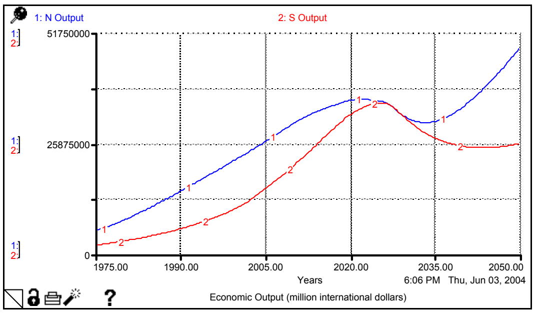

Figure 32. Gross economic output in “increased technology transfer after year 2000” policy

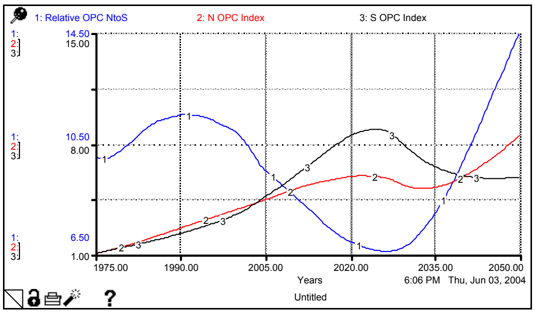

Figure 33. Output per capita levels in “increased technology transfer after year 2000” policy

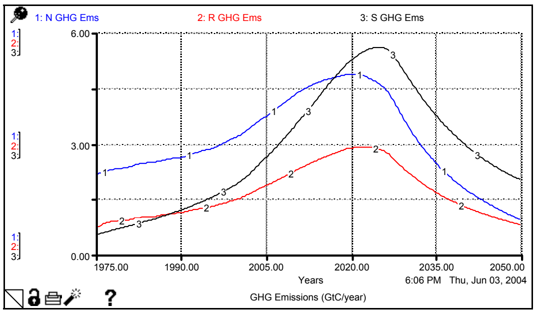

Figure 34. CO_2 emissions in “increased technology transfer after year 2000” policy

One of the tested policies aimed to speed up the economic growth in South via increasing the technology transfer from North. Growth is expected to decrease the fertility rate and also provide investment power for transition required in energy supply. Hypothetically such a policy may be conceptualized as free transfer of knowledge. A significant increase in gross and per capita output is observed for the South block in the period prior to energy shortage (Figure 32, line 2; Figure 33, line 3), such that North-South output per capita ratio almost halves in this period (Figure 33, line 1). This change is due to decreased capital-output ratio as a consequence of increased technology level for South. However, general behavior in the energy shortage era is almost the same; a significant per capita output decrease and a widening welfare gap between blocks. Additionally, as South experiences a faster growth and its energy demand grows faster, energy shortage is observed earlier than the reference case.

Decision mechanism regarding transition to alternative resources, which uses the dynamic reserves-to-demand ratio as an indicator, is seen to be insufficient and too slow to initiate a timely transition. In this policy run, blocks are forced to start and progress in the transition prior to the perception of scarcity signals by introducing exogenous targets. Utilizing its vast investment capacity, North successfully completes the transition by 2050. Despite this achievement, primarily due to reduced investment capacity, behavior of economic output switches to linear growth from the formerly observed exponential one. On the other hand, economic growth of South is seriously disrupted due to allocation of limited investment capacity to construction of alternative energy infrastructure (Figure 35).

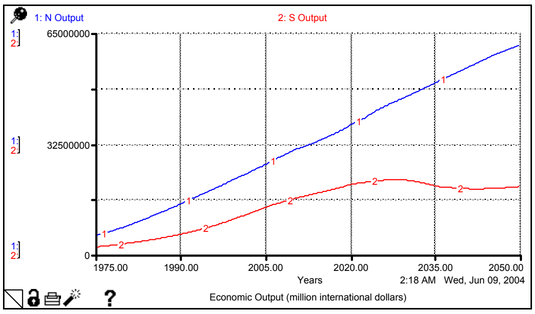

Figure 35. Economic output with "increasing targets for renewable energy-1" policy

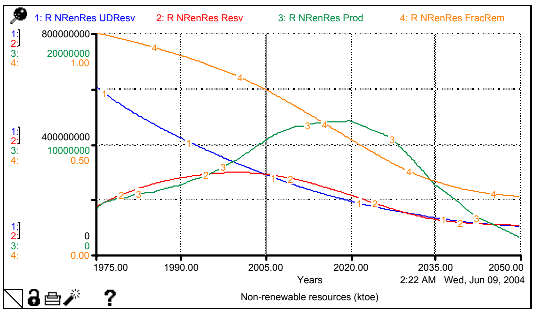

Figure 36. Resource reserves with "increasing targets for renewable energy -1" policy

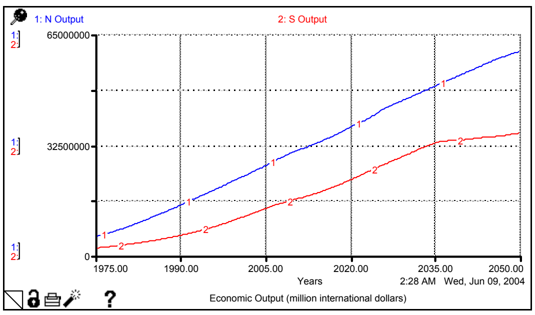

Figure 37. Economic output with "increasing targets for renewable energy-2" policy

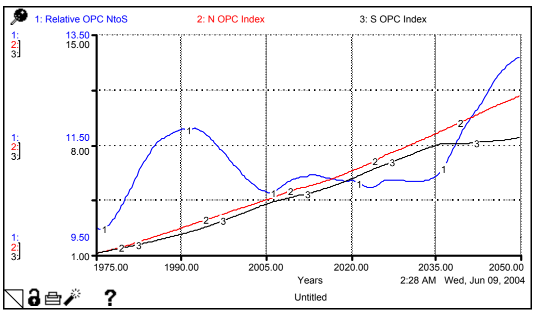

Figure 38. Indexed per capita output with "increasing targets for renewable energy-2" policy

A modified version of this policy (*increasing targets for renewable energy-2*), in which target level for renewable resource usage is relaxed for South is also tested. This can be evaluated as an allowance for South in non-renewable energy resources usage. Significant improvement is attained for South, an almost undisrupted economic growth, which reaches the highest level of all runs in this study (Figure 37). Although economic indicators observed with this policy are better than the former case, environmental indicators are a bit poorer.

In the final policy to be mentioned in this paper, energy transition in South is supported by the investment capital from North. According to this policy North provides South capital to be invested in renewable energy sector, as long as non-renewable resource usage prevails in North. The amount of the support is directly proportional to the amount of resources consumed by North. The setting of this policy provides striking results. First of all, North originated support provides an important relief, and South manages to complete a significant portion of energy transition, which is almost 70 per cent, by year 2050. This transition prevents the significant growth in non-renewable resources demand of South, and global resource consumption is dominated only by North. As a consequence of decreased global resource demand, North experiences a slower transition to renewables. Apart from economic indicators, increased level of per capita output levels results in increased life expectancy levels at South. This increase results in a slowdown in the death rate, and the stabilization level of the global population is increased a bit above 8 billion people. No significant change is observed in CO_2 levels, as North compensates for the decreased non-renewable resource usage by South.

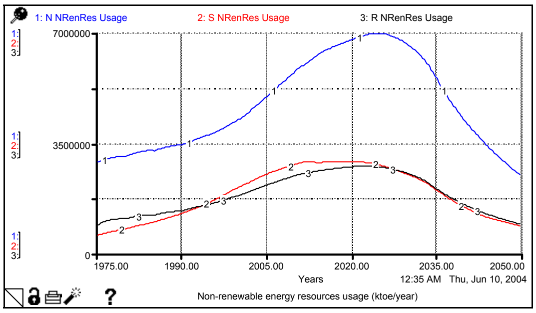

Figure 39. Non-renewable resource usage with “North supported energy transition in South” policy

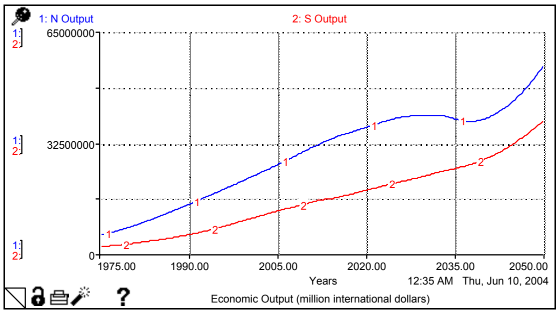

Figure 40. Economic output by North and South with “North supported energy transition in South” policy

6. Conclusions

This study aims to study long-term sustainability of the economic, environmental and social systems at a global level with North-South distinction. In the context defined, the model covers population, economic activity, energy supply, and pollution issues for two separate country blocks; developed (North) and developing (South) countries.

According to the reference behavior of the model, it does not seem viable to close the welfare gap between North and South, given the current prevailing non-renewable-resource-based growth system. An economic output level that provides the living conditions of North to crowded South population is observed to be far away from feasibility with the currently known environmental capacity in supplying key inputs and absorbing key pollutants. Hence, a non-renewable-resource-based system adapted by the growing South population will take the global system even closer to its limits.

Throughout the scenario analysis stage, population dynamics of South is identified as the major problem for South's well-being. Apart from that, it is observed that energy resource usage patterns are insensitive to the initial reserve levels. Unless currently known preferences and valuations in non-renewable energy resource usage are altered, delays embedded in the perception and reaction processes related to energy transition makes an energy crisis inevitable.

In the policy analysis stage it is concluded that for the cases in which both economies stay dependent on non-renewable resources, North benefits from policies that prevent South's economic growth, as growth of South indicates faster resource depletion. A common conclusion from all policies tested is that the usage of finite non-renewable resources should be altered as soon as possible. It is evident that cumulative load of growing South and North is too much for the finite capacity of the earth. It is also observed that an energy scarcity due to depletion of non-renewable resources results in an economic recession that has more serious impacts on South, compared to North. Recovery of South from such a crisis in a reasonable time frame seems plausible only with the investment support of North needed for building alternative, renewable energy capacity. This support may be in the form of technology transfer, investment or aid. However, the nature of this support and its potential debt accumulating consequences, not modeled in this study, must be carefully managed.

The model constructed for this study provides a platform to study the interactions of the North and South blocks in a closed system. In the context defined, only one main economic input (energy) and one representative pollutant (greenhouse gases) are modeled. It would be beneficial to increase the number of main inputs and pollutants that may affect economic performance and especially health in future research. In another direction, more explicit formulations of the market mechanism and financial flows accompanying physical goods can also provide new important results regarding the connection between the economic systems of both blocks. Finally, covering the food supply as another limit to growth, and defining its relations with pollution and population dynamics may be beneficial.

References

- Barlas, Y., 1996, "Formal Aspects of Model Validity and Validation in System Dynamics", *System Dynamics Review*, Vol.12, No.3, pp. 183-210.
- Barney, G.O., 1980, *The Global 2000 Report to the President of the U.S.*, Pergamon Press, New York.
- Barney, G.O., K. Barney and J. Blewett, 1991, *Global 2000 Revisited: What Shall We Do?,* http://www.millenniuminstitute.net/publications/G2R.pdf
- Bremer, A.S. (ed.), 1987, *The GLOBUS Model: A Computer Simulation of Worldwide Political and Economic Development*, Westview Press, Colorado.
- Bruntland, G. (ed.), 1987, *Our common future: The World Commission on Environment and Development*, Oxford University Press, Oxford.

- Chichilnisky, G., S. Cole and J. Clark, 1979, "A Model of the Relation between Technology and North-South Income Distribution", in *Models, Planning and Basic Needs*, S. Cole and H. Clark (ed.s), Pergamon Press, Oxford.
- Chichilnisky, G. and S. Cole, 1979, "A Model of Technology, Domestic Distribution, and North-South Relations", *Technological Forecasting and Social Change*, 13, pp. 297-320.
- Cohen, J.E., 1995, *How Many People Can the Earth Support?,* W. W. Norton & Company, New York.
- EIA (Energy Information Administration), 2001, *U.S. Anthropogenic Greenhouse Gas Emissions by Gas*, http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html
- Fey, W.R., and A. C. W. Lam, 2000, "The Bridge to Humanity's Future", The Proceedings of the ISSS 2000 International Society for the Systems Sciences 44th Annual Meeting.
- Forrester, J.W., 1971, *World Dynamics*, Wright-Allen Press, Cambridge.

Forrester, J.W., P.M. Senge, 1980, "Tests for Building Confidence in System Dynamics Models" in *System Dynamics*, A.A. Legasto, J.W. Forrester and J.M. Lyneis (ed.s), North-Holland, Amsterdam.

- Goldsmith, E, R. Allen, M. Allaby, J. Davoll and S. Lawrence (ed.s), 1972, *Blueprint for Survival: by the Editors of The Ecologist*, Houghton Mifflin Company, Boston.
- GSI (Global Sustainability Institute), 2001, *Global Sustainability: the History / Time Line of an Idea*, http://www.global.rmit.edu.au/resources/historyofanidea_25.07.01.pdf
- Herrera, A.O., 1976, *Catastrophe or New Society: A Latin American World Model,* International Development Research Center.
- Hughes, B.B., 1999, *International Futures: Choices in the Face of Uncertainity,* Westview Press, Colorado.
- IISD (International Institute for Sustainable Development), 2002, *The Sustainable Development Timeline*, http://www.iisd.org/pdf/2002/sd_timeline2002.pdf
- Meadows, D.H.., D.L. Meadows, J. Randers and W.W. Behrens, 1972, *The Limits to Growth*, Potomac Associates, New York.
- Meadows, D.L, W.W. Behrens, D.H. Meadows, R.F. Naill, J. Randers and E.K.O. Zahn, 1974, *Dynamics of Growth in a Finite World*, Wright-Allen Press, Massachusetts.
- Meadows, D.H., J. Richardson and G. Bruckmann, 1981, *Groping in the Dark: The First Decade of Global Modeling*, John Wiley &.Sons, New York.
- Meadows, D.H., D.L. Meadows and J. Randers, 1992, *Beyond The Limits*, Chelsea Green Publishing, Vermont.
- Mesarovic, M. and E. Pestel, 1974, *Mankind at the Turning Point*, E.P. Dutton & Co., New York.
- Muilerman, H. and H. Blonk, 2001, "Towards a Sustainable Use of Natural Resources", *Stichting Natuur en Milieu*, http://www.snm.nl/org/index.php
- Mukherjee, J., 1996, *Environment and Development: A Study of North-South Conflict*, Ph.D. Thesis, University of Illinois at Urbana-Campaign.
- Onishi, A., 2002, "FUGI Global Modeling System: Integrated Global Model for Sustainable Development", *Journal of Policy Modeling*, no.24, pp. 561-590.
- Saeed, K., *Development Planning and Policy Design: A System Dynamics Approach*, Avebury, Hants, 1994.

- UNDP (United Nations Development Programme), United Nations Department of Economic and Social Affairs, World Energy Council, 2000, *World Energy Assessment: Energy and the Challenge of Sustainability*, UNDP, New York
- UNDP (United Nations Development Programme), 2002, *Energy for Sustainable Development: A Policy Agenda*, New York
- UNPD (United Nations Population Division), 2003, *World Population Prospects: The 2002 Revision Highlights*, New York.
- Ward, B. and R. Dubos, 1972, *Only One Earth: The Care and Maintenance of a Small Planet*, Penguin Books, Suffolk.
- WEC (World Energy Council), 1998, *Survey of Energy Resources*, 18th ed., World Energy Council, London.
- WEC (World Energy Council), 2001, *Living in one World*, http://www.worldenergy.org/wec-geis/publications/reports/liow/foreword/foreword.asp
- WEC (World Energy Council), 2003, *WEC Statement 2003: Renewable Energy Targets*, London.
- World Bank, 2002, *Globalization, Growth and Poverty: Building an Inclusive World Economy*, Oxford University Press, New York.
- World Bank, 2003, *World Development Report 2003*, World Bank, Washington, D.C.
- World Bank, 2003a, *World Development Indicators 2003*, World Bank, Washington, D.C.
- Yücel, G., 2004, *Modeling the Dynamics of Global Sustainability, Based on Developed-Developing Nations Distinction*, M.Sc. Thesis, Boğaziçi University.