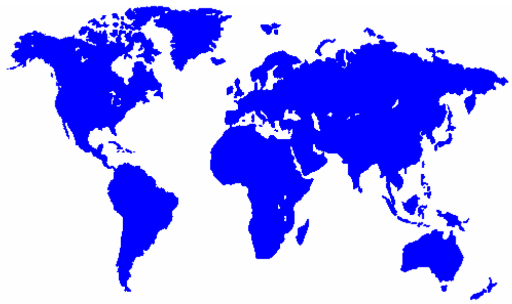

Forecasting Long-Term Global Change: Introduction to International Futures (IFs)

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Barry B. Hughes
Frederick S. Pardee Center for International Futures
Graduate School of International Studies
University of Denver
www.ifs.du.edu

International Futures:
Exploring Alternative
Global Possibilities

IFs

Introduction to International Futures (IFs)

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Abstract

International Futures (IFs) is a large-scale, long-term, integrated global modeling system. It represents demographic, economic, energy, agricultural, socio-political, and environmental subsystems for 182 countries interacting in the global system. The central purpose of IFs is to facilitate exploration of global futures through alternative scenarios. The model is integrated with a large database containing values for its many foundational data series since 1960. IFs is available to users both on-line (www.ifs.du.edu) and in downloadable form.

IFs is a structure-based, agent-class driven, dynamic modeling system. The demographic module uses a standard cohort-component representation. The 6-sector economic module structure is general equilibrium. The socio-political module represents life conditions, traces basic value/cultural information, and portrays various elements of formal and informal socio-political structures and processes.

IFs is used increasingly widely. It was a core component of a project exploring the New Economy sponsored by the European Commission. Forecasts from IFs supported Project 2020 (*Mapping the Global Future*) of the National Intelligence Council and will also support the NIC's Project 2025 for the US administration taking office in 2009. IFs provided driver forecasts for the fourth Global Environment Outlook of the United Nations Environment Program.

A generous gift in 2007 established the Frederick S. Pardee Center for International Futures at the University of Denver. The Center's core project in coming years will be a series of volumes called Patterns of Potential Human Progress. The first volume, *Reducing Global Poverty*, will appear in late 2008. Volumes on global education and health will follow it.

1. What is International Futures (IFs)?

International Futures (IFs) is a large-scale integrated global modeling system. The broad purpose of the International Futures (IFs) modeling system is to serve as a thinking tool for the analysis of near through long-term country-specific, regional, and global futures across multiple, interacting issue areas. The IFs project is based at the Frederick S. Pardee Center for International Futures. [1]

IFs is heavily data-based and also deeply rooted in theory. It represents major agent-classes (households, governments, firms) interacting in a variety of global structures (demographic, economic, social, and environmental). The system draws upon standard approaches to modeling specific issue areas whenever possible, extending those as necessary and integrating them across issue areas. The menu-drive interface of the International Futures software system allows display of results from the base case and from alternative scenarios over time horizons from 2000 up to 2100. It provides tables, standard graphical formats, and a basic Geographic Information System (GIS) or mapping capability. It also provides specialized display formats, such as age-cohort demographic structures and social accounting matrices.

The system facilitates scenario development and policy analysis via a scenario-tree that simplifies changes in framing assumptions and agent-class interventions. Scenarios can be saved for development and refinement over time. Standard framing scenarios, such as those from the National Intelligence Council's Project 2020 and the United Nations Environmental Programme's *Global Environmental Outlook-4*, are available.

The remainder of this document provides additional information on the modeling system. By far the most extensive documentation is, however, available in the Help system of IFs itself. That includes full documentation through causal diagrams, equations, and computer code. See www.ifs.du.edu for Help system and documentation and to access both web-based and downloadable versions of the model (full, not partial versions).

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[1] The Frederick S. Pardee Center for International Futures provides the foundational funding of the IFs project. The Center's flagship project is a series of volumes on *Patterns of Potential Human Progress*. Important support also comes from the U.S. National Intelligence Council, earlier for assistance with its *Project 2020: Mapping the Global Future* and now with its Project 2025. In addition the United Nations Environment Programme supported IFs for contributions to its *Global Environment Outlook 4*. And the Commission of the European Union provided funding for its TERRA project. None of these institutions bears any responsibility for the analysis presented here. For earlier funding thanks also to the European Union Center at the University of Michigan, the CIA's Strategic Assessment Group, the National Science Foundation, the Cleveland Foundation, the Exxon Education Foundation, the Kettering Family Foundation, the Pacific Cultural Foundation, the United States Institute of Peace, General Motors and the RAND Pardee Center for funding that contributed to earlier generations of IFs. Also of great importance, IFs owes much to the large number of students, instructors, and analysts who have used the system over many years and provided much appreciated advice for enhancement. Thanks also to earlier team members (some of whom the Help system identifies). Members of the current IFs team include Kazi Imran Ahmed, Jonathan Chesebro, Janet Dickson, Bethany Fisher, Sheila Flynn, Julius Gatune, Kia Tamaki Harrold, George Horton, Anwar Hossain, Mohammod Irfan, Jaime Melendez, Jonathan Moyer, Edison Oquendo, Cecilia Peterson, José Solórzano, and Marc Sydnor.

2. Purposes of International Futures (IFs)

International Futures (IFs) is a tool for thinking about near through long-term country-specific, regional and global futures. Although it is increasingly used in policy analysis, it began as an educational tool. Even in analysis applications the primary strengths of the system are in framing investigation and analysis. Users of computer simulations should always treat the forecasts as highly contingent scenarios, not as predictions.

More specifically, IFs is a thinking tool, allowing variable time horizons up to 100 years, for exploring human leverage with respect to pursuit of key goals in the face of great uncertainty. The goals that motivated the design of IFs fall generally into three categories: human development, social fairness and security, and environmental sustainability.

Humans as Individuals	Personal Development/Freedom
Humans with Each Other	Peace and Security/Social Fairness
Humans with the Environment	Sustainable Material Well-Being

Figure 1 The human systems and issues of interest to the IFs project

Across these levels, the project especially identifies Sen (1999), Rawls (1971), and Brundtland (UN 1987) for their seminal contributions.

IFs assists with:

- Understanding the state of the world and the future we may see
  - Identifying tensions and inconsistencies that suggest political risk or economic risk in the near and middle term (a “watch list” functionality)
  - Exploring longer-term trends and considering where they might be taking us
  - Learning about the dynamics of global systems
- Thinking about the future we want to see
  - Clarifying goals/priorities
  - Developing alternative scenarios (if-then statements) about the future
  - Investigating the leverage that humans may have in shaping the future

3. Elements of the Model

For introduction to the character and use of the current model see Hughes and Hillebrand (2006). Full documentation of the International Futures (IFs) modeling system, except for the most recent model developments, exists in the on-line help system of the system itself. Only very basic summary information on the structure of the system and on its capabilities for support of analysis is provided here.

The extensive data base underlying IFs includes data for 182 countries over as much of the period since 1960 as possible. Insofar as possible, data represent 182 countries since 1960. In addition to providing a basis for developing formulations within the model, the database facilitates comparison of data with “historic forecasts” over the 1960-2000 period. The model itself is a recursive system that can run without intervention from its initial year (currently 2000), while the model interface facilitates interventions flexibly across time, issue, and geography.

Figure 2 shows the major conceptual blocks of the International Futures system. The elements of the technology block are, in fact, scattered throughout the model. The named linkages between blocks and the linkages themselves are illustrative, not exhaustive.

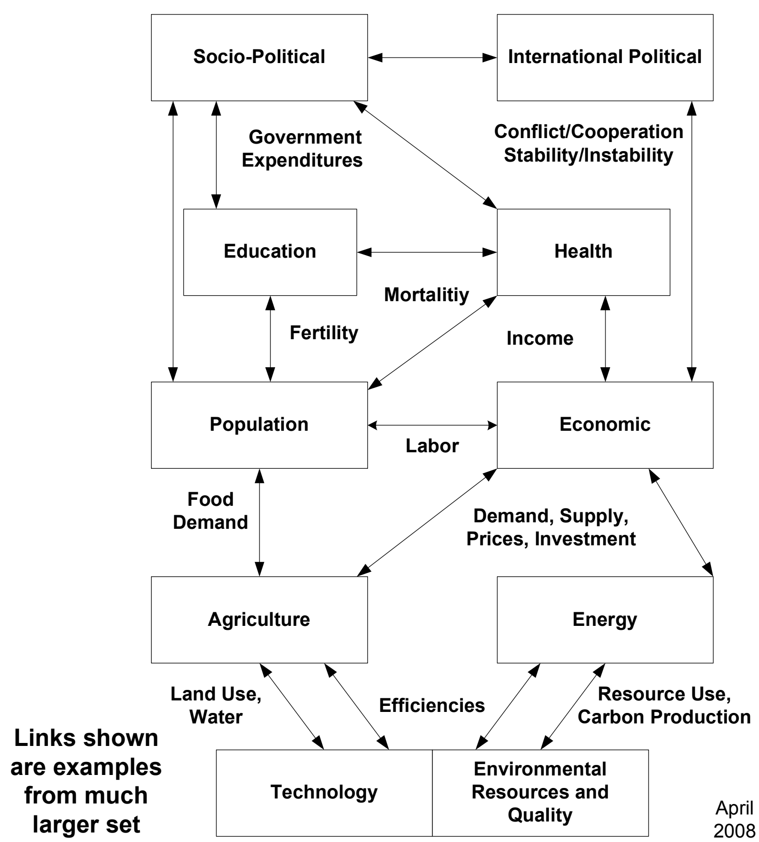


Figure 2 The modules of International Futures (IFs)

The population module:

- represents 22 age-sex cohorts to age 100+ in a standard cohort-component structure
- calculates change in cohort-specific fertility of households in response to income, income distribution, education levels, and contraception use
- calculates change in mortality rates in response to income, income distribution, and assumptions about technological change affecting mortality
- separately represents the evolution of HIV infection rates and deaths from AIDS
- computes average life expectancy at birth, literacy rate, and overall measures of human development (HDI)
- represents migration, which ties to flows of remittances

The economic module:

- represents the economy in six sectors: agriculture, materials, energy, industry, services, and information/communications technology or ICT (other sectors could be configured because the system uses raw data from the Global Trade and Analysis (GTAP) project with 57 sectors in Release 6)
- computes and uses input-output matrices that change dynamically with development level
- is a general equilibrium-seeking model that does not assume exact equilibrium will exist in any given year; rather it uses inventories as buffer stocks and to provide price signals so that the model chases equilibrium over time
- contains a Cobb-Douglas production function that (following insights of Solow and Romer) endogenously represents contributions to growth in multifactor productivity from human capital (education and health), social capital and governance, physical and natural capital (infrastructure and energy prices), and knowledge development and diffusion (R&D and economic integration with the outside world)
- uses a Linear Expenditure System to represent changing consumption patterns
- utilizes a "pooled" rather than bilateral trade approach for international trade
- has been imbedded in a social accounting matrix (SAM) envelope that ties economic production and consumption to a very simple representation of intra-actor financial flows (it represents only the skilled and unskilled households of the GTAP project)

The education module:

- represents formal education across primary, secondary (lower and upper separately), and tertiary levels
- forecasts intake or transition from lower levels, rates of survival and/or completion, as well as net and/or gross enrollment
- differentiates males and females
- is fully linked to population
- computes education or human capital stocks by adult age cohort

The health module (early in development):

- differentiates mortality causes by communicable disease, non-communicable disease, and injuries with multiple subcategories
- uses WHO Global Burden of Disease distal driver formulations and introduces assorted proximate drivers for policy intervention

The socio-political module:

- represents fiscal policy through taxing and spending decisions
- shows six categories of government spending: military, health, education, R&D, foreign aid, and a residual category
- represents changes in social conditions of individuals (like fertility rates, literacy levels or poverty), attitudes of individuals (such as the level of materialism/postmaterialism of a society from the World Values Survey), and the social organization of people (such as the status of women)
- represents the evolution of democracy
- represents the prospects for state instability or failure

The international political module:

- traces changes in power balances across states and regions
- allows exploration of changes in the level of interstate threat

The agricultural module:

- represents production, consumption and trade of crops and meat; it also carries ocean fish catch and aquaculture in less detail
- maintains land use in crop, grazing, forest, urban, and "other" categories
- represents demand for food, for livestock feed, and for industrial use of agricultural products
- is a partial equilibrium model in which food stocks buffer imbalances between production and consumption and determine price changes
- overrides the agricultural sector in the economic module unless the user chooses otherwise

The energy module:

- portrays production of six energy types: oil, gas, coal, nuclear, hydroelectric, and other renewable energy forms
- represents consumption and trade of energy in the aggregate
- represents known reserves and ultimate resources of fossil fuels
- portrays changing capital costs of each energy type with technological change as well as with draw-downs of resources
- is a partial equilibrium model in which energy stocks buffer imbalances between production and consumption and determine price changes
- overrides the energy sector in the economic module unless the user chooses otherwise

The environmental module:

- allows tracking of remaining resources of fossil fuels, of the area of forested land, of water usage, and of atmospheric carbon dioxide emissions

The implicit technology module:

- is distributed throughout the overall model
- allows changes in assumptions about rates of technological advance in agriculture, energy, and the broader economy
- explicitly represents the extent of electronic networking of individuals in societies
- is tied to the governmental spending model with respect to R&D spending

There are large numbers of intervention points for the user across all of these modules. A later section outlines intervention and scenario development.

4. The Philosophic Approach to Modeling

A number of assumptions underlie the development of IFs. First, issues touching human development systems are growing in scope and scale as human interaction and human impact on the broader environment grow. This does not mean the issues are necessarily becoming more threatening or fundamentally insurmountable than in past eras, but attention to the issues must have a global perspective, as well as local and regional ones.

Second, goals and priorities for human systems are becoming clearer and are more frequently and consistently enunciated. The UN Millennium Summit and the 2002 conference in Johannesburg (UNDP 2003: 1-59) set specific Millennium Development Goals (MDGs) for 2015 that include many focusing on the human condition. Such goals increasingly guide a sense of collective human opportunity and responsibility. Also, our ability to measure the human condition relative to these and other goals has improved enormously in recent years with advances in data and measurement.

Third, understanding of the dynamics of human systems is growing rapidly. Understandings of the systems included in the IFs model are remarkably more sophisticated now than they were then.

Fourth, and derivatively, the domain of human choice and action is broadening. The reason for the creation of IFs is to help in thinking about such intervention and its consequences.

Given the goals of understanding human development systems and investigating the potential for human choice within them, how do we represent such systems in a formal, computer-based model such as IFs? Human systems consist of classes of agents and larger structures within which those agents interact. The structures normally account for a variety of stocks (people, capital, natural resources, knowledge, culture, etc.) and the flows that change those stocks. Agents act on many of the flows, some of which are especially important in changing stock levels (like births, economic production, or technological innovation). Over time agents and the larger structures evolve in processes of mutual influence and determination.

For instance, humans as individuals within households interact in larger demographic systems or structures. In the computer model we want to represent the behavior of households, such as decisions to have children or to emigrate. And we want to represent the larger demographic structures that incorporate the decisions of millions of such households. The typical approach to representing the stocks of such demographic structures is with age-sex cohort distributions, altering those stocks via the flows of births, deaths, and migration. IFs adopts that approach.

Similarly, households, firms, and the government interact in larger economic and socio-economic systems or structures. The model can represent the behavior of households with respect to use of time for employment and leisure, the use of income for consumption and savings, and the specifics of consumption decisions across possible goods and services. It should represent the decisions of firms with respect to reinvestment or distribution of earnings. Markets are key structures that integrate such activities, and IFs represents the equilibrating mechanisms of markets in goods and services. Again there are key stocks in the form of capital, labor pools, and accumulated technological capability.

In addition, however, there are many non-market socio-economic interactions. IFs increasingly represents the behavior of governments with respect to search for income and targeting of transfers and expenditures, domestically and across country borders, in interaction with other agents including households, firms, and international financial institutions (IFIs). Social Accounting Matrices (SAMs) are structural forms that integrate representation of non-market based financial transfers among such agents with exchanges in a market system. IFs uses a SAM structure to account for inter-agent flows generally. Financial asset and debt stocks, and not just flows, are also important to maintain as part of this structural system, because they both make possible and motivate behavior of agent-classes.

Further, governments interact with each other in larger inter-state systems that frame the pursuit of security and cooperative interaction. Potential behavioral elements include spending on the military, joining of alliances, or even the development of new institutions. One typical approach to representing such structures is via action-reaction dynamics that are sensitive to power relationships across the actors within them. IFs represents changing power structures, domestic democracy level, and interstate threat.

Still further, human actor classes interact with each other and the broader environment. In so doing, important behavior includes technological innovation and use, as well as resource extraction and emissions release. The structures of IFs within which all of these occur include a mixture of fixed constraints (for instance, stocks of non-renewable resources), uncertain opportunities for technological change in economic processes, and systems of material flows.

In summary, International Futures (IFs) has foundations that rest in (1) classes of agents and their behavior and (2) the structures or systems through which those classes of agents interact. IFs is not agent-based in the sense of models that represent individual micro-agents following rules and generating structures through their behavior. Instead, as indicated, IFs represents both existing macro-agent classes and existing structures (with complex historic path dependencies), attempting to represent some elements of how behavior of those agents can change and how the structures can evolve.[2]

In representing the behavior of agent classes and the structures of systems, IFs draws upon large bodies of insight in many theoretical and modeling literatures. While IFs frequently breaks new ground with respect to specific sub-systems, its strengths lie substantially in the integration and synthesis of bodies of earlier work.

[2] Philosophically, this approach rejects the premise that all model structures must be built up from micro-agent interaction. Although micro-agent modeling is laudable in more narrowly-focused models, global systems and structures are far too numerous and well-developed for such efforts to succeed across the breadth of concerns in IFs (see again Figure 1).

5. History and Future of the IFs Project

International Futures (IFs) has evolved since 1980 through four “generations,” with a fifth generation of development now underway.

The first generation had deep roots in the world models of the 1970s, including those of the Club of Rome. In particular, IFs drew on the Mesarovic-Pestel or World Integrated Model (Mesarovic and Pestel 1974). The developer of IFs had contributed to that project, including the construction of the energy submodel. IFs consciously also drew on the Leontief World Model (Leontief et al. 1977), the Bariloche Foundation’s world model (Herrera et al. 1976), and Systems Analysis Research Unit Model (SARU 1977), following comparative analysis of those models by Hughes (1980). That generation was written in FORTRAN and available for use on main-frame computers through CONDUIT, an educational software distribution center at the University of Iowa. Although the primary use of that and subsequent generations was by students, IFs has always had some policy analysis capability that has appealed to specialists. For example, the U.S. Foreign Service Institute used the first generation of IFs in a mid-career training program.

The second generation of International Futures moved to early microcomputers in 1985, using the DOS platform. It was a very simplified version of the original IFs without regional or country differentiation.

The third generation, first available in 1993 and completed in 1999, became a full-scale microcomputer model. The third generation improved earlier representations of demographic, energy, and food systems, and added new environmental and socio-political content. It built upon the collaboration of the author with the GLOBUS project and adopted that project’s economic submodel (developed by the author). GLOBUS had been created with the inspiration of Karl Deutsch and the leadership of Stuart Bremer (1987) at the Wissenschaftszentrum in Berlin.

The third generation produced three editions or major releases of IFs, each accompanied by a book also called *International Futures* (Hughes 1993, 1996, 1999). The second edition moved to a Visual Basic platform that allowed a much improved menu-driven interface, running under Windows. The third edition incorporated an early global mapping capability and an initial ability to do cross-sectional and longitudinal data analysis.

The fourth generation took shape beginning in early 2000. Increasing interest in the model as a policy analysis tool by several important organizations heavily influenced new directions. First, General Motors commissioned a specialized version of IFs named CoVaTrA (Consumer Values Trends Analysis) with updated and extended demographic modeling and representation of value change. An alliance was established with the World Values Survey, directed by Ronald Inglehart (Inglehart and Welzel 2005), to create that version. Second, the Strategic Assessments Group (SAG) of the Central Intelligence Agency supported a specialized version named IFs for SAG. The work involved in preparing IFs for SAG greatly extended and enhanced the socio-political representations of the model, both domestic and international. Third, the European Commission sponsored a project named TERRA which led to a specialized version named IFs for TERRA. Also the RAND Pardee Center sponsored some work in a project to explore the potential for substantially reducing global poverty and developing a global social safety net. Work on IFs for TERRA led to enhancements across the model, including improved representation of economic sectors, updated IO matrices and a Social Accounting Matrix (Duchin 1998), GINI and Lorenz curves, and formulations for extended environmental impact representation that draw upon the Advanced Sustainability Analysis framework of the Finland Futures Research Center (Kaivo-oja, Luukhanen, and Malaska 2002).

Throughout the emergence of the fourth generation of IFs (incorporating all of the above elements) there was also a heavy emphasis on enhanced usability. Ideas from Robert Pestel in the TERRA project led to the creation of a new tree-structure for scenario creation and management.

The fifth generation of work on the system is now underway and has three major thrusts. The first is continued enhancement of the model itself, including the clearer and more extensive representation of the agent classes and their points of leverage. The desire to make the model a more valuable scenario-testing and policy-analysis tool guides that development. For instance, the further elaboration of the social accounting matrix structure, the development of education and health sub-models, and the substantial redesign of an economic production function with endogenous multifactor productivity are among several development directions.

Second, the project continues to make model interface and usability enhancements. These include a number of specialized displays, such as those to see the social accounting matrices, to display progress towards Millennium Development Goals, to explore poverty at different income levels, and to represent the educational attainment of population cohorts. Mapping and data analysis tools are being strengthened. The ability to drill into selected countries and to explore futures at the state or province level has been added.

The third thrust is institutionalization of the IFs system via (a) increased accessibility, transparency and openness and (b) broader and deeper connections with other modelers and model users. Large-scale models are often difficult to access, much less to understand and use with confidence. The first step in greatly increasing accessibility to IFs was the sponsorship of the web-based version of the model by the National Intelligence Council in its Project 2020 (NIC 2004). Among the methods that have been developed to make IFs more transparent are creating the ability to access flow charts, equations, and even computer code on demand for a user interested in particular variables/sub-areas of the model. One method the project has explored to make the model more open is the ability to add Vensim (system dynamics) modules and Excel modules to the model. Ultimately, making large-scale models into living tools will require providing general structures into which sophisticated users can insert new components in modular form. Like earlier generations, the fifth generation is likely to take several years to unfold.

6. The Use of IFs

One central goal of the IFs project is that the model be easy to use. The size and scope of the model complicate accomplishing this goal. Nonetheless, basic use of the model has three simple functionalities. The first is display of results, because most users begin with considerable exploration of the model's base case before turning to scenarios. The second is scenario analysis (or policy analysis more generally), normally involving simple interventions at first, and then more extensive ones. The third functionality is more detailed investigation of the model itself, with an eye perhaps to changes or extensions. Such investigation often builds on data analysis. This section comments in turn on display, scenario analysis, and data analysis.

6.1 Display

The display capabilities of the IFs platform contain most standard formats such as tables, line graphs, bar charts, and pie diagrams. IFs also contains a Geographic Information System (GIS) capability that allows mapping of all variables from the base case or other scenarios. The IFs system offers the user the ability to choose any variables or parameters in the model and to display those over time in any combination and with any output format. In addition, computational capabilities exist to combine and/or transform existing variables into ones newly defined by the user.

The wealth of variables and parameters in the model make it difficult, however, for beginning users to identify important focal points. Therefore the fourth and fifth generations have added several additional display capabilities. These include Flexible Packaged Displays for easy access to model forecast results. Others are Country Profile and Basic Report capabilities, which show the user a basic sub-set of variables for any country or region in the model (or grouping of countries/regions) in any forecast year. A simple double-click on a cell brings up a table of the selected variable over time and across scenarios. The user can customize the sub-set of variables displayed in the report. The Basic Report can also be tailored for use as a watch list around variables suggesting political risk or economic risk.

In addition, the fourth generation began the building of specialized display capabilities. One specialized display shows population variables using the typical age-sex format (see Figure 3). Similar displays show education by level across age and sex cohorts or cohort-based variables from the World Values Survey. Still another shows a social accounting matrix (see Figure 4) with collapsed categories that can be expanded across sub-categories or over time by double-clicking on cells. Another shows historic progress towards the Millennium Development Goals (MDGs) along with the goal line to 2015 and the model forecast. Another allows display of Lorenz curves and calculation of Gini indices for any variable in the model. In essence, such specialized displays help organize images of and learning about the structural systems discussed earlier.

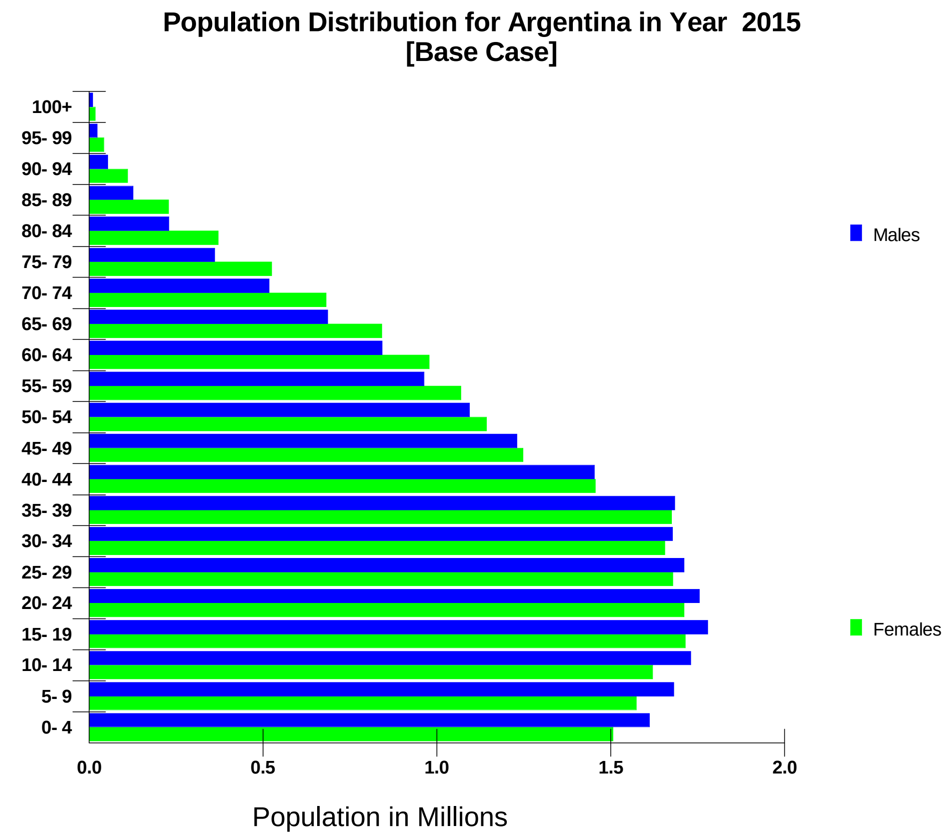
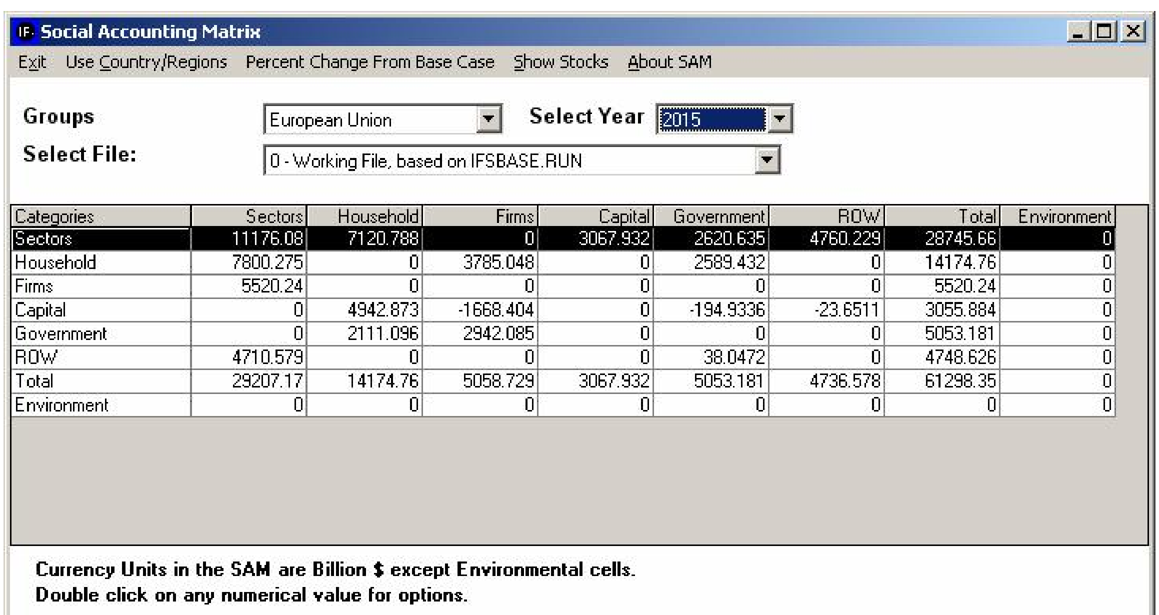


Figure 3 Age-sex cohort distribution for Argentina in 2015 (Base Case)



Social Accounting Matrix

Exit Use Country/Regions Percent Change From Base Case Show Stocks About SAM

Groups: European Union Select Year: 2015

Select File: 0 - Working File, based on IFSBASE.RUN

Categories	Sectors	Household	Firms	Capital	Government	ROW	Total	Environment
Sectors	11176.08	7120.788	0	3067.932	2620.635	4760.229	28745.66	0
Household	7800.275	0	3785.048	0	2589.432	0	14174.76	0
Firms	5520.24	0	0	0	0	0	5520.24	0
Capital	0	4942.873	-1668.404	0	-194.9336	-23.6511	3055.884	0
Government	0	2111.096	2942.085	0	0	0	5053.181	0
ROW	4710.579	0	0	0	38.0472	0	4748.626	0
Total	29207.17	14174.76	5058.729	3067.932	5053.181	4736.578	61298.35	0
Environment	0	0	0	0	0	0	0	0

Currency Units in the SAM are Billion $ except Environmental cells.
Double click on any numerical value for options.

Figure 4 Collapsed social accounting matrix (SAM) from IFs

6.2 Scenario Analysis

International Futures (IFs) supports investigation into integrated global demographic, economic, social, and environmental transitions. Integrated modeling offers a number of advantages that supplement individual issue analyses:

1. The ability to compare the impact that alternative policy levers produce relative to a range of goals within a consistent framework. No modeling system will ever provide a comprehensive representation of all complex underlying systems, but over time such an integrated system can evolve to capture what analysts identify as the dominant relationships and the dominant dynamics within them. Both relationships and dynamics are essential.

2. The potential to explore secondary and tertiary impacts of policy interventions or of attaining policy targets. For instance, we know that rebound effects are persistent in many systems that have a general equilibrating character; without the representation of such equilibration, such rebound effects are difficult, if not impossible, to analyze.

3. The option of exploring interaction effects among the policy interventions themselves. While we want to consider interventions individually, in order to isolate the leverage they provide us, we also need to investigate them in combinations that might, on one hand, represent politically feasible policy packages or, on the other hand, maximize our ability to reach goals.

To take advantage of this analysis potential, it must be relatively easy to build and refine a scenario. Tied closely to the model structure, the IFs interface facilitates the iterative development of scenarios through use of a scenario tree structure as shown in Figure 5.[3] That tree structure distinguishes among key framing assumptions, policy interventions, and relationship parameters. The modeling system carries standard framing scenarios such as the four major scenario families of the Intergovernmental Panel on Climate Change (IPCC), the four scenarios of the National Intelligence Council's Project 2020, and the four scenarios of the United Nations Environmental Programme's Global Environmental Outlook.[4] This system has been used, for example, in development of a global sustainability scenario (see the next section of the paper). The three component parts of the total sustainability scenario (policy levers around human capital,

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[3] Robert Pestel identified the need for a "policy cockpit" to facilitate interaction with IFs. The scenario-tree interface is a significant step towards creating such a cockpit. Ronald Inglehart also urged the development of a more game-like interface for the IFs system. For many years, one of the most active users of IFs in the classroom has been Richard Chadwick at the University of Hawaii. He has imbedded use of the model in Thomas Saaty's (1996) framework of hierarchical decision-making, and he advocated the more conscious inclusion of such an approach in the model's interface. The Guided Use scenario interface is a step in that direction.

[4] See also work of the Global Scenario Group (Kemp-Benedict, Heaps, and Raskin: 2002; Hammond 1998), which influenced the UNEP GEO scenarios.

growth/equity and environmental quality, respectively) are saved in scenario input files that can be retrieved into the tree structure of Figure 5 for examination and alteration.

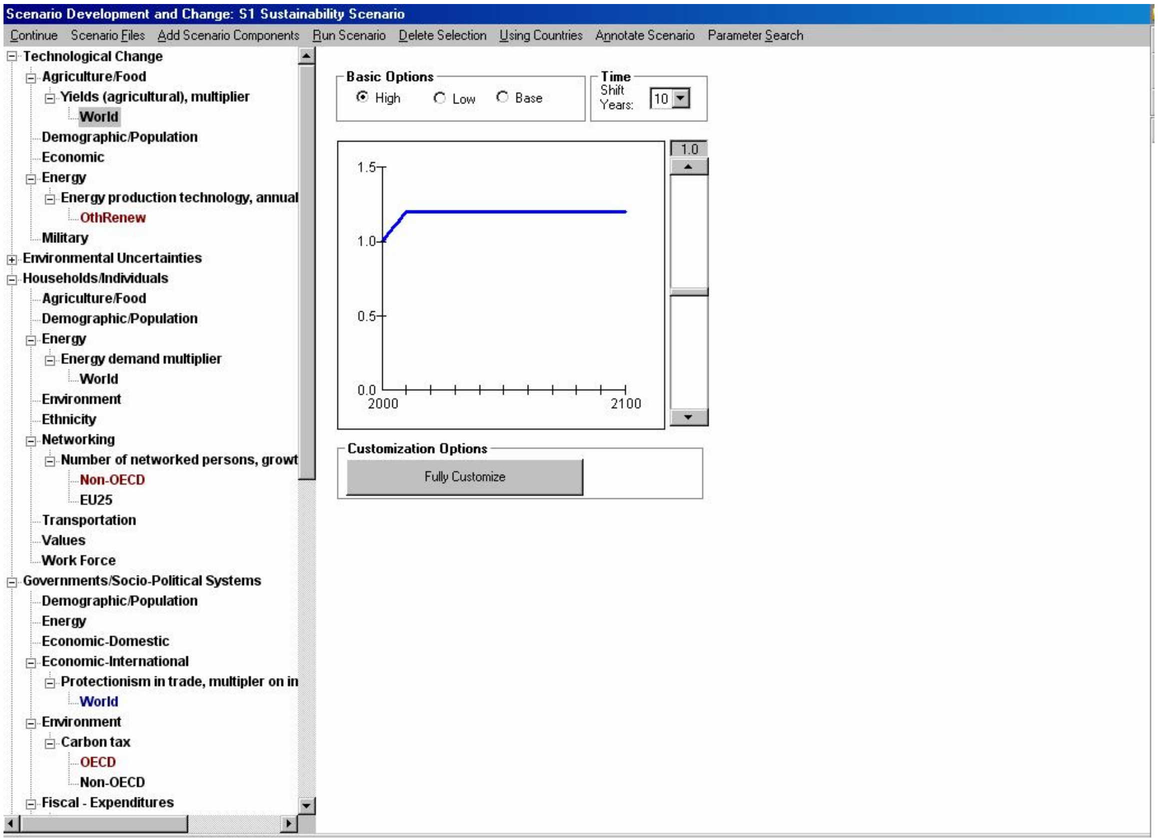

Figure 5 Policy cockpit/scenario management system

The IFs project has also worked with analysts at the RAND Frederick S. Pardee Center for Longer Range Global Policy and the Future Human Condition. The intention, so far not fully successful, has been to link IFs with the Computer-Assisted Reasoning System (CARS) of the Pardee Center so as to explore the effects of a wide range of social options over a selection of global scenarios (Lempert, Popper, and Bankes. 2003).

6.3 Data Analysis

In addition to display and scenario capabilities, the graphical user interface or GUI of IFs is the port of entry into data analysis capabilities. The database of IFs draws widely from standard sources, including the United Nations (basic population data, as well as data on migration and HIV/AIDS), the World Bank (considerable economic and social data), the IMF (international financial data), the Organization for Economic Cooperation and Development (social expenditures), the Global Trade and Analysis Project (input-output matrices and income returns to skilled and unskilled households). In addition, a large number of specialized sources were used in preparation of the database and are credited in the data dictionary (see also Hossain with Hughes 2004).

IFs includes a variety of tools for analyzing these extensive data, all of which share a constant format within IFs. These include again a GIS mapping capability for simple uni-variate display. The tools include cross-sectional (bi-variate and multi-variate) and longitudinal statistical analysis, with graphical display as well as statistics computation. The tool kit also includes the ability to produce historic validation runs of the model over the 1960-2000 period with the capability of comparing model results with empirical series from the data base.

A key problem in all large-scale global modeling is initialization of variables and parameters. Updating the base year of large-scale models often involves several person-years of effort. Basic problems include missing data, incompatible data from different data sources, and simple unit conversion. To simplify initialization and to allow flexible re-regionalization of the model, IFs has relied for some time on a pre-processor that uses a staged sequence of data processing steps to create a new initialization through data consistency checking and hole filling. The pre-processor, in turn, draws upon the modeling platform's statistical analysis capability for estimating missing values.

6.4 Extended Capabilities

A number of other capabilities exist via the graphical user interface (GUI). These include the ability to change the regionalization of IFs. In recent years, however, IFs has moved away from Student or Professional editions with limited geographic representation (e.g. 14 or 60 world regions) and makes the full 182-country version available to all users. Aggregation to groupings of countries for output and analysis is flexible in the system. Extended capabilities also allow the addition of new countries to the database (most recently Eritrea and Palestine). A recent extension allows the division of countries into states or provinces and the exploration of both data and forecasts for those selected countries.

7. Analysis with IFs

The IFs project is producing a growing number of studies and publications. Some of these document the model itself and its use. Others treat substantive issues, generally falling into the three categories that Figure 1 identified. Because of the volume of writing, this section will not discuss specific forecasting results, but rather provide pointers to categories of work that may be of interest. Please visit the IFs website for many of the papers referenced here.

With respect to the model itself, assistance with analysis within and across issue areas is available in Hughes and Hillebrand (2006). For publications concerning the model and its development over time see Hughes (1999, 2001) and UNESCO (2002). There are also a substantial number of working papers of the project on various topics, many of which will emerge as published scientific documentation over time. These treat topics such as the basic structure of IFs (Hughes, Hossain, and Irfan 2004), the incorporation into IFs and use of social accounting matrices (Hughes and Hossain 2003), the treatment of productivity and growth in IFs (Hughes 2005 and 2007), a set of indices within the model (Hughes 2005c), and the IFs database (Hossain and Hughes 2004). See also discussion of the comparison of IFs results with those of other forecasts and of more general validation efforts (Hughes 2004b and 2006).

With respect to humans as individuals and issues of human development, writing and publication in this area of the project has built a body of work over time. See Hughes (2001) on the "Global Social Transformation" and a working paper on forecasting the Human Development Index (Hughes 2004c). See also the power point presentation by Revi (2007) on global and Indian population and education forecasting.

The project's volume series on Patterns of Potential Human Progress is, of course, central to work in this area. Papers presented on education (Dickson, Irfan, and Hughes 2007) and health (Peterson, Solórzano, and Hughes 2007) are foundational to forthcoming volumes. So is the article on poverty by Hughes and Irfan (2007). The volume by Hughes, Irfan, Khan, Rothman, and Solórzano(2008) kicks off the series.

With respect to humans in interaction and issues of peace/security and fairness/justice, the project again has built a foundation. For publications, see Hughes (2004) on "Regimes and Social Transformations" and Hughes (2007) on "Forecasting Globalization." Most significantly, see the US National Intelligence Council's (2004) study on *Mapping Global Futures*, which used IFs in support of its scenario analysis.

See also the working paper by Chadwick (2006) on Korean security futures. Among project working papers Hughes (2002b) discussed both model structures and analysis in areas including democratization, state failure, and international political interactions. In this same general issue area, but as a bridge to the next is the paper on future oil prices and geopolitics by Hillebrand (2008).

With respect to humans and their environment and issues of environmental sustainability, the project has produced a number of studies. For publications see Hughes and Johnston

(2005) on sustainable futures, with special attention to European Union policy initiatives and options, and UNEP's (2008) *Global Environmental Outlook-4* for which IFs provided demographic and economic drivers as well as significant social forecasting. The working paper supporting the UNEP work was Hughes (2005b).

There is also IFs project-based work that clearly cuts across two or more of the issue areas of the project. Some of that tends to have a geographically-specific focus. For instance, see Gatune's (2008) emerging volume on the *Future of Africa* and Revi's (2007b) Powerpoint presentation on the futures of India and China.

No one is more familiar with the weaknesses of any model than its developers. IFs has many, many remaining weaknesses. It is important to return in conclusion to the statement of purpose for the project. International Futures (IFs) is a tool for thinking about long-term global futures. The results of models should never be considered "predictions" and accepted uncritically. A model can, however, be a wonderful instrument for exploration of possible futures and for organizing thoughtful investigation of human leverage with respect to them. This is what IFs seeks to be.

Bibliography

Bremer, Stuart A., ed. 1987. The GLOBUS Model: Computer Simulation of World-wide Political and Economic Developments. Boulder, CO: Westview Press.

Chadwick, Richard W. "Korea 2020: National Security Futures, Democracy, and Choices: Building a Korea Peace Structure," paper using IFs and available on the IFs web site.

Dickson, Janet R., Mohammod T. Irfan, and Barry B. Hughes. 2007. "Education and Human Development," paper presented at the Annual Conference of the Human Development and Capability Association, New York, New York. September 18-20, 2007.

Duchin, Faye. 1998. *Structural Economics: Measuring Change in Technology, Lifestyles, and the Environment*. Washington, D.C.: Island Press.

Gatune, Julius. 2008. *The Future of Africa.* Book manuscript in near final form (using IFs).

Hammond, Allen. 1998. *Which World? Scenarios for the 21st Century*. Washington, D.C.: Island Press.

Herrera, Amilcar O., et al. 1976. *Catastrophe or New Society? A Latin American World Model.* Ottawa: International Development Research Centre.

Hillebrand, Evan. 2008. "How Will Future Oil Prices Affect Geopolitics?" paper prepared for the annual meeting of the International Studies Association, San Francisco, March 2008.

Hossain, Anwar, with Barry B. Hughes. 2004 (July). "The IFs Database," prepared for the National Intelligence Council. Unpublished working paper available on the IFs website.

Hughes, Barry B. 1980. *World Modeling*. Lexington, Mass: Lexington Books.

Hughes, Barry B. 1987. "Domestic Economic Processes," in Stuart A. Bremer, ed., *The Globus Model: Computer Simulation of Worldwide Political Economic Development* (Frankfurt and Boulder: Campus and Westview), pp. 39-158.

Hughes, Barry B. 1997. "Rough Road Ahead: Global Transformations in the 21st Century," *Futures Research Quarterly* 13, No. 2 (Summer): 83-107.

Hughes, Barry B. 1999. *International Futures: Choices in the Face of Uncertainty,* 3rd ed. Boulder, Co: Westview Press.

Hughes, Barry B. 1999b. "The International Futures (IFs) Modeling Project," *Simulation and Gaming* 30, No. 3 (September, 1999): 304-326.

Hughes, Barry B. 2001. “Global Social Transformation: The Sweet Spot, the Steady Slog, and the Systemic Shift,” *Economic Development and Cultural Change* 49, No. 2 (January): 423-458.

Hughes, Barry B. 2001b. “Choices in the Face of Uncertainty: The International Futures (IFs) Model, *Futures* 33 (2001): 55-62.

Hughes, Barry B. 2002. “Sustainability Analysis Using the International Futures (IFs) Modeling System,” prepared for a “conversation on sustainability…” sponsored by the Initiative for Science and Technology for Sustainability, the Global Scenario Group of the Stockholm Environmental Institute, and the project on Systems of Integrated Research, Assessment, and Decision Support for Global Environmental Change (SIRAD) at Harvard University. Boston, July 11-13.

Hughes, Barry B. 2002b. “Threats and Opportunities: International Futures for the Strategic Assessments Group” Unpublished IFs working paper.

Hughes, Barry B. and Anwar Hossain. 2003 (September). “Long-Term Socio-Economic Modeling: With Universal, Globally-Integrated Social Accounting Matrices in a General Equilibrium Model Structure.” Unpublished working paper of the IFs Project.

Hughes, Barry B. 2004. “Regimes and Social Transformation,” in Arild Underdal and Oran Young, eds., *Regime Consequences: Methodological Challenges and Research Strategies*. Kluwer Academic Publishers, pp. 335-358.

Hughes, Barry B. 2004b (March). “The International Futures Base Case: Comparison with Other Forecasts,” prepared for the National Intelligence Council’s Project 2020 and IFs project use. Unpublished working paper on the IFs web site.

Hughes, Barry B. 2004c (February). “Forecasting the Human Development Index” Unpublished IFs working paper on the IFs website.

Hughes, Barry B. 2005c (May). “Indices in IFs” Unpublished IFs working paper on the IFs website.

Hughes, Barry B. 2005a (May). “Forecasting Productivity and Growth with International Futures (IFs)” Unpublished IFs working paper on the IFs website.

Hughes, Barry B. 2005b (November). “UNEP GEO-4 Driver Scenarios (Fifth Draft): Using IFs with Pardee” Unpublished IFs working paper on the IFs website.

Hughes, Barry B. 2005c (May). “Indices in IFs” Unpublished IFs working paper on the IFs website.

Hughes, Barry B. 2006 (June). “Assessing the Credibility of Forecasts Using International Futures (IFs): Verification and Validation. Unpublished IFs working paper on the IFs website.

Hughes, Barry B. 2007. "Forecasting Globalization: The Use of International Futures (IFs)," in George Modelski, Tessaleno Devezas, and William R. Thompson, eds., *Globalization as Evolutionary Process: Modeling, Simulating, and Forecasting Global Change*. London and New York: Routledge (Taylor and Francis).

Hughes, Barry B. 2007b (December). "Forecasting Global Economic Growth with Endogenous Multifactor Productivity: The International Futures (IFs) Approach" Unpublished IFs working paper on the IFs website.

Hughes, Barry B. with Anwar Hossain and Mohammod T. Irfan. 2004. "The Structure of IFs," Unpublished IFs working paper on the IFs web site.

Hughes Barry B. and Mohammod T. Irfan. 2007. "Assessing Strategies for Reducing Poverty," *International Studies Review* 9, no. 4 (Winter 2007): 690-710.

Hughes, Barry B., Mohammod T. Irfan, Haider Khan, Krishna B. Kumar, Dale S. Rothman, and José Roberto Solórzano. 2008. *Reducing Global Poverty.* Boulder: Paradigm Publishers, forthcoming.

Hughes, Barry B. and Peter D. Johnston. 2005. "Sustainable Futures: Building Policy Options into a Scenario for Development in a Global Knowledge Society," *Futures* 37: 813-831.

Hughes, Barry B. and Evan E. Hillebrand. 2006. *Exploring and Shaping International Futures*. Boulder, CO: Paradigm Publishers.

Inglehart Ronald and Christian Welzel. 2005. *Modernization, Cultural Change, and Democracy: The Human Development Sequence.* Cambridge: Cambridge University Press.

Kaivo-oja, Jari, Jyrki Luukhanen, and Pentti Malaska (2002). "Methodology for the Analysis of Critical Industrial Ecology Trends: an Advanced Sustainability Analysis of the Finnish Economy." Turku, Finland: Finland Futures Research Centre, unpublished manuscript.

Kemp-Benedict, Eric, Charles Heaps, Paul Raskin. 2002 (March). Global Scenario Group Futures: Technical Notes. Boston: Stockholm Environmental Institute, Tellus Institute. PoleStar Series Report no. 9.

Leontief, Wassily, Anne Carter and Peter Petri. 1977. *The Future of the World Economy*. New York: Oxford University Press.

Lempert, Robert J., Steven W. Popper, and Steven C. Bankes. 2003. *Shaping the Next One Hundred Years: New Methods for Quantitative Long-Term Policy Analysis*. Santa Monica: The RAND Pardee Center.

Mesarovic, Mihajlo D. and Eduard Pestel. 1974. *Mankind at the Turning Point*. New York: E.P. Dutton & Co.

Peterson, Cecila Mosca, José Roberto Solórzano, and Barry B. Hughes. 2007. "Enhancing Global Health," paper presented at the Annual Conference of the Human Development and Capability Association, New York, New York. September 18-20, 2007.

Revi, Aromar. 2007 (March). "World and National Population and Education: IFs 5.34 Global and National Population-Education Trend Benchmarking" Powerpoint presentation.

Revi, Aromar. 2007 (May). "Future Histories: Exploring Pathways for India and China in the 21st Century" Powerpoint presentation given at the India China Institute of The New School, April 30, 2007.

Rawls, John. 1971. *A theory of justice.* Cambridge, Mass.,: Belknap Press of Harvard University Press.

Saaty, Thomas L. 1996. The Analytic Network Process: Decision Making with Dependence and Feedback. Pittsburgh: RWS Publications.

Sen, Amartya Kumar. 1999. *Development as freedom.* 1st. ed. New York: Knopf.

Systems Analysis Research Unit (SARU). 1977. *SARUM 76 Global Modeling Project*. Departments of the Environment and Transport, 2 Marsham Street, London, 3WIP 3EB.

United Nations. 1987. *The World Commission on Environment and Development.* Oxford: Oxford University Press.

United Nations Development Programme (UNDP). 2003. *Human Development Report 2003: Millennium Development Goals*. New York: Oxford University Press.

United Nations Environment Programme (UNEP). 2008. Global Environment Outlook-4. (See especially Chapter 9, "The Future Today," to which IFs contributed.) Nairobi, Kenya: United Nations Environment Programme.

UNESCO. 2002. "International Futures (IFs) Model," *UNESCO Encyclopaedia of Life Support Systems (EOLSS)*. Oxford: Eolss Publishers.

United States National Intelligence Council (NIC). 2004 (December). Mapping the Global Future: Report of the National Intelligence Council's 2020 Project Based on Consultations with Nongovernmental Experts Around the World. Washington, D.C.: USGPO.