SANDIA REPORT
SAND2010-0555
Unlimited Release
January 2010

Anticipating the Unintended Consequences of Security Dynamics

George Backus, James Overfelt , Len Malczynski, David Saltiel, Paul Moulton Simon

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Approved for public release; further dissemination unlimited.

Sandia National Laboratories

NNSA National Nuclear Security Administration

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

NOTICE: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government, nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represent that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, any agency thereof, or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof, or any of their contractors.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865) 576-8401
Facsimile: (865) 576-5728
E-Mail: reports@adonis.osti.gov
Online ordering: http://www.osti.gov/bridge

Available to the public from
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Rd.
Springfield, VA 22161

Telephone: (800) 553-6847
Facsimile: (703) 605-6900
E-Mail: orders@ntis.fedworld.gov
Online order: http://www.ntis.gov/help/ordermethods.asp?loc=7-4-0#online

SAND 2010-7001
Unlimited Release
Printed January 2010

Anticipating the Unintended Consequences of Security Dynamics LDRD Project: 117807

George Backus (Org. 1433), James Overfelt (Org. 1433), Len Malczynski (Org. 6721), David Saltiel (Formerly Org. 6721; now Office of the Chief Financial Officer, U.S. Department of Energy), Paul Moulton Simon (Formerly Org. 5925; Deceased)

Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-MS0370

Abstract

In a globalized world, dramatic changes within any one nation causes ripple or even tsunamic effects within neighbor nations and nations geographically far removed. Multi-national interventions to prevent or mitigate detrimental changes can easily cause secondary unintended consequences more detrimental and enduring than the feared change instigating the intervention. This LDRD research developed the foundations for a flexible geopolitical and socioeconomic simulation capability that focuses on the dynamic national security implications of natural and man-made trauma for a nation-state and the states linked to it through trade or treaty. The model developed contains a database for simulating all 229 recognized nation-states and sovereignties with the detail of 30 economic sectors including consumers and natural resources. The model explicitly simulates the interactions among the countries and their governments. Decisions among governments and populations is based on expectation formation. In the simulation model, failed expectations are used as a key metric for tension across states, among ethnic groups, and between population factions. This document provides the foundational documentation for the model.

Acknowledgements

The late Paul Moulton Simon provided great insights on how nations, governments and people worked – together and in opposition to one another. He brought a biting sense of humor that made points and generated understandings inaccessible through any other methods. His unique vantage point for perceiving the process of political evolution and human nature will be truly missed.

We gratefully acknowledge the support of the Sandia LDRD office in funding this effort.

Table of Contents

Overview 7
Project Background 7
Project Characterization 9
Model Conceptualization And Design 11
Model Basis 11
Model Structure 14
Comparison to Other Research 17
The E3MG Model: 17
The REMI Model 18
The IFs Model 21
General Equilibrium Models 22
System Dynamics Models 23
Data Sources 25
Conflict Metrics 27
Summary 29
References 31

Appendix A: GTAP Data Specificity 35
Appendix B: World Bank Data Specificity 37

Overview

Project Background

The global connectivity of the modern world has brought many opposing forces into enduring conflict. Inevitable economic disruptions, resource shortages, and nature disasters lead to fragile societal conditions that are ever more sensitive and whose failure now quickly cascades across many borders. For example, pandemics and the destabilizing governmental power-voids they produce could be facts within a few years. Soon, national and international security organizations will require tools to anticipate, assess, analyze, and mitigate extreme-event conditions. Military interventions and advanced technology utilization need to incorporate societal dynamics to ensure desired outcomes. The return to stability and the avoidance of unintended consequences depends on understanding and managing the intertwined economic, societal, cultural, and political dynamics within a region. The US defense and intelligence community needs the capability to anticipate and plan for remote, destabilizing events that threaten US and global security. These same communities depend on SNL for support in making the right decisions. SNL has an urgent need to develop the basic capabilities to evaluate socio-economic dynamics and behavioral responses prior to intervention. While macroeconomic models of essentially all countries in the world exist, they are universally devoid of security considerations and conflict dynamics. Past attempts at assessing conflict initiation and evolution have depended on quantifying static conditions, such as poverty or ethnic majorities -- with minimal success. New methods described in this report address the behavioral dynamics and expectation formation that appear to show much promise. Enhancing macroeconomic models to include endogenous security metrics and adding behavioral dynamics should produce a reliable tool set that SNL and the nation can use to address emerging and evolving threats. Such an approach could simulate the impending dynamics, delineate the complex social-behavioral phenomena, and determine intrinsically secure engagements that alleviate the cascading, unintended consequences that cause enduring global destabilization.

A large body of empirical evidence shows that humans, even a group of experts, have a minimal ability to mentally unravel the feedback dynamics in real systems. These limitations cause incomplete decisions process whose consequence is avoidable blind-siding. Simulation models formalize, document, and benchmark the best knowledge available. They can elucidate the dynamics and support reliable decision-making. Further, they allow the comparison of model results to reality and promote continued improvement. Through such models, SNL can apply engineering methods to add the behavioral element to the "engineering of national security."

Complex, social-behavioral interactions, for which no nation yet has adequate proficiency, will dominate future security activities. If SNL is "the primary national security laboratory that federal agencies call on to help solve the nation's most difficult problems," it must ensure it can address the approaching threats. Any misunderstanding of international societal dynamics hampers the ability to mitigate WMD-proliferation

conditions. Further, SNL is routinely asked by the defense and intelligence community whether it can provide support for influence and info-ops, and societal assessment of both terrorist activities and the consequences of allied intervention strategies (including attempts at nation building). The purpose of this effort is to develop intrinsic security processes within the region and the ability to evaluate tradeoffs of solution cost and graded risk.

There are no existing macroeconomic or societal models that address security dynamics or coordinated kinetic and non-kinetic intervention. The reason for this lack is may be due to academics being adverse to such models (they violate some basic tenets of orthodox "equilibrium" economics) and the current short-term prioritizations driving the war on terror. Nonetheless, defense and intelligence planners are recently able to step back and see the larger unfolding picture. There are many types of macroeconomics models, but only a few even have the foundation to serve the needed function. The methods developed at REMI (www.remi.com) and Cambridge Econometrics, Ltd. (www.camecon.com) provide the computational machinery to produce a self-consistent model and to work effectively with limited data. The authors worked on the development of both models (Backus 1994, Nabors et. al. 2002) and we apply the relevant components of that work to this work. Methods developed by Backus and Glass (2006) combined with new V&V approaches under development at SNL (McNamara et. all 2008) can provide robust behavioral-response simulations (Backus et. al. 2010). The foundation of these behavioral methods comes from Nobel Prize winning work by Daniel McFadden on Qualitative Choice Theory that accurately portrays human decision making (McFadden 1986,1982,1974) and by Clive Granger on Cointegration that determines those variables which affect decisions with enduring or transient significance(Granger 1981, Engle and Granger 1987,1991). These techniques can integrate disparate perspectives and information, qualitative as well as quantitative, into analysis and decision support systems. The methods are compatible with orthodox macroeconomic assumptions and used for all matter of choices (including those associated with security), but no one has attempted to integrate (security related) behavioral response mechanics within a macroeconomic framework. Other than for accommodating data limitations and more complex statistical methods (to ensure consistency and model stability) we do not expect, nor have so far experienced, any compatibility hurdles.

We have developed a complete database (other than verification) for the entire globe and the model can automatically configure itself to any inter-regional analyses among 224 nation-states. The current configuration we are using for testing is a 6 region-configuration composed of China, Russia, U.S., European Union, Middle East, and Rest-of-World.

Partially related to this work, project staff provided input to the National Intelligence Estimate for the NIC/Whitehouse on the climate change and conflict. We took advantage of additional work by European Union countries on climate change and cascading failures [for example, as based on historical dynamics, e.g., Stewart, & Fitzgerald (2000)] to enhance the dynamics our modeling effort includes on conflict evolution and cross-nation spillover.

The macroeconomic model includes employment and wages by employer (i.e., industrial sectors – including agriculture), investments, consumption, government, prices, technology, and trade. The model is designed to include labor classes with an association to education and ethnic backgrounds. The model logic to explicitly captures the migration of business and people across nations. Nonetheless, thorough testing and validation assessment, not completed before the end of this project, is required before the model results can be used with confidence.

Project Characterization

This modeling project focuses on the economic activity of businesses, government institutions, and the population within and among nation states from the time period of 1960 to 2060. The historical period is used to give context to future conditions.

The model simulates the interactions among and within the nations over time, capturing delayed feedback response that can produce unintended consequences. The model has capability to consider 250 nations and currently includes the completed data sets for simulating any and all existing 224 nations and their associated (self-governing) territories. The model design focuses on comprehensive integrated assessment. All simulation represent the entire global socioeconomic system and the constraints such self-consistency imposes.

For transparency, when the user selects key nations of interest, the model automatically configures itself for those selected nations, key neighbor/partner nations and with an aggregate (residual) rest-of World (ROW). This process balances overall complexity (understandability) with the detail for the primary concerns of interest.

The model simulates international trade for over 30 commodities (including labor) and the geopolitical tensions associated with changes in economic conditions -- and the population's perception of those changes. The behaviors of governments and population are based on changing expectations and thus capture what was previously considered the paradoxical frequency of violence among relatively better-off populations.

Natural resource endowments and constraints are explicitly simulated in the model, but energy is not given any special status or presented in a differently level of detail than, for instance, land or metal ores. Technological advances are endogenous to the model as a function of innovative capability and the need to innovate. This approach overcomes the paradox of large high-tech investments struggling countries and strategic initiatives with "advanced-nations" often having a poor correlation with future national conditions.

The model simulates the changing stocks of resources, productive capacity, and financial assets to ensure that the user understands the impacts of the various socioeconomic and geopolitical the time-constants relative to the time constants of any policy interventions.

The model explicitly include inventory dynamics to capture prices transients (including those in financial markets).

The remainder of this report explores the foundations of the model development. The ultimate purpose of the model developed in this effort sis to address the unintended consequence of political, economic, and military interventions in response to changes in the socioeconomic or geopolitical status of a foreign country.

Model Conceptualization And Design

Conventional macroeconomic models, as will be discussed more in the next section, assume optimal equilibrium conditions. This work uses system dynamics to simulate the disequilibrium conditions that are generally experienced during disruptive (national security) events.

Model Basis

The basis for the model is the GTAP (Global Trade Analysis Project) database developed at Purdue University (Hertel 1993, https://www.gtap.agecon.purdue.edu/default.asp). This database contains trade data from 1960 and recognizes 87 commodities across 115 nations/regions. Using World Bank data and other sources (discussed in a later section) we produce a self-consistent data set for 224 nations and 30 commodities. Many of the GTAP commodities focus on detailed agricultural products. We aggregate these into three categories (Agriculture, fish, forest) to maintain a focus on overall socioeconomic and geopolitical dynamics. The GTAP model includes investments which we separate out and use to estimate capital stocks and production-to-capacity relationships.

The model structure can distinguish rural versus urban conditions, but we have not yet mapped the data sets with this information into the model parameters. We keep track of inter-nation flows by an accounting approach that explicitly keeps track of the origination and receiving regions for all commodities (goods and services). The model does recognized skilled versus unskilled labor but we have not implemented the algorithms to cause laborers (population segments) to change their status between these two categories. The model allows 4 arbitrarily defined ethnic groups within any region and the migration of those populations to other regions. We have not yet exercised this capability. The model structure does consider greenhouse and "other" pollution because they may become source of international tensions, should global treaties dictate compliance requirements. The model currently updates with 3 month time-increments and therefore does not include any implicit to explicit time-constant below 6 months. To prevent generating any misperceptions on model resolution, the aging of capital and human stock is divided into three categories (young, middle, and old), rather than by individual year vintages.

The model is conceptualized to allow the separation of industries into a distribution of firms (agent based modeling). Some economists note that the classical use of representative firms or aggregate categories produce both static and dynamics inconsistencies (Keen 2001). Our experiments using McFadden's qualitative choice theory (QCT) indicates that QCT results are not overly sensitive to these inconsistencies. Therefore, for testing we only have one representative firm per commodity per nation. Because the destabilization of large forms within a nation can destabilize a nation's economy, the model structure does maintain the capability to include agent-based macroeconomic (Testfatsion 2006, http://www.econ.iastate.edu/tesfatsi/amulmark.htm#Basic)

dynamics. Further, a distribution of firms more correctly captures innovation dynamics that affect the ability for nations to accommodate change. Conventional macroeconomic models consider technology as an exogenous conditions. Studies relating economic dynamics to biological evolution indicate the dynamic outcome may be significantly different when multiple-path (many firms) versus single path (aggregate industry) are assumed (Raup 1991, Vermeij 2004).

Despite having a complete data set for all 224 nations-states, the model itself can only simulate 6 nation/aggregates at a time. The model automatically configures itself to self-consistently capture the dynamics among the particular nation(s) of interest, the salient neighbors/partners, and a residual (aggregate) Rest-of-World. Having more than 6 interacting regions produces a level of dynamic complexity that masks (or causes distractions to) the dynamics most critical to intervention assessment. For relevancy, the initial testing of the model is configured to represent China, Russia, the Middle East, the United States, Europe, and the ROW.

The tables below show the specificity within the Unintended Consequence (UC) model structure.

Table 1: UC Model Resources

Skilled labor	Unskilled labor
Water	Wind
Solar	Minerals
Forest	Land
Ocean	Fish

Table 2: UC Model Pollution

Greenhouse Gases	Other Pollutants

Table 3: UC Model Labor Levels

Skilled	Unskilled

Table 4: UC Model Age Vintages

Youth	Middle	Mature

Table 5: UC Model Ethnic Groups

Ethnic1	Ethnic2
Ethnic3	Ethnic4

Table 6: UC Model Intra-Regions

Urban	Rural

Table 7: Countries Available for Simulation

Arubae	Afghanistan	Angola	Anguilla
Antarctica	Albania	Andorra	Netherlands Antilles
United Arab Emirates	Argentina	Armenia	American Samoa
Antigua And Barbuda	Australia	Austria	Azerbaijan
Burundi	Belgium	Benin	Burkina Faso
Bangladesh	Bulgaria	Bahrain	Bahamas
Bosnia And Herzegowina	Belarus	Belize	Bermuda
Bolivia	Brazil	Barbados	Brunei Darussalam
Bhutan	Botswana	Central African Republic	Canada
Switzerland	Chile	China	Cote D Ivoire
Cameroon	Drc Congo	Congo	Cook Islands
Colombia	Comoros	Cape Verde	Costa Rica
Cuba	Cayman Islands	Cyprus	Czech Republic
Germany	Djibouti	Dominica	Denmark
Dominican Republic	Algeria	Ecuador	Egypt
Eritrea	Spain	Estonia	Ethiopia
Finland	Fiji	Falkland Islands (Malvinas)	France
Faroe Islands	Micronesia	Gabon	United Kingdom
Georgia	Ghana	Gibraltar	Guinea
Guadeloupe	Gambia	Guinea-Bissau	Equatorial Guinea
Greece	Grenada	Greenland	Guatemala
French Guiana	Guam	Guyana	Hong Kong
Honduras	Croatia	Haiti	Hungary
Indonesia	India	Ireland	Iran
Iraq	Iceland	Israel	Italy
Jamaica	Jordan	Japan	Kazakhstan
Kenya	Kyrgyzstan	Cambodia	Kiribati
Saint Kitts And Nevis	S Korea	Kuwait	Laos
Lebanon	Liberia	Libyan Arab Jamahiriya	Saint Lucia
Liechtenstein	Sri Lanka	Lesotho	Lithuania
Luxembourg	Latvia	Macau	Morocco
Monaco	Moldova	Madagascar	Maldives
Mexico	Marshall Islands	Macedonia	Mali
Malta	Myanmar (Burma)	Montenegro	Mongolia
Northern Mariana Islands	Mozambique	Mauritania	Montserrat
Martinique	Mauritius	Malawi	Malaysia
Mayotte	Namibia	New Caledonia	Niger
Norfolk Island	Nigeria	Nicaragua	Niue
Netherlands	Norway	Nepal	Nauru
New Zealand	Oman	Pakistan	Panama
Peru	Philippines	Palau	Papua New Guinea
Poland	Puerto Rico	N Korea	Portugal
Paraguay	French Polynesia	Qatar	Reunion
Romania	Russian Federation	Rwanda	Saudi Arabia
Sudan	Senegal	Singapore	St Helena
Svalbard & Jan Mayen Islands	Solomon Islands	Sierra Leone	El Salvador
San Marino	Somalia	St Pierre And Miquelon	Serbia
Sao Tome And Principe	Suriname	Slovakia	Slovenia
Sweden	Swaziland	Seychelles	Syrian Arab Republic
Turks And Caicos Islands	Chad	Togo	Thailand
Tajikistan	Tokelau	Turkmenistan	East Timor
Tonga	Trinidad And Tobago	Tunisia	Turkey
Tuvalu	Taiwan	Tanzania	Uganda
Ukraine	Uruguay	United States	Uzbekistan
Saint Vincent & Grenadines	Venezuela	Virgin Islands Uk	Virgin Islands Us
Viet Nam	Vanuatu	West Bank & Gaza	Wallis And Futuna Islands
Samoa	Yemen	South Africa	Zambia
Zimbabwe			

Note that per the tables below model can include opposition (rebel) government activities within a nation and its interaction across nations.

UC Model Commodities

Agriculture	Forest
Fish	Coal
Primary Oil&Gas	Mining
Textiles	Paper
Refining	Chemical
Metal	Non-Metal
Machines	Other Manufacturing
Electricity	Gas Distribution
Water Utilities	Construction
Trade	Transportation
Communications	Finance, insurance, real estate
Govt Services	Govt Consumption
Govt Opposition	Unskilled Labor
Skilled Labor	GHG
Other Pollution	Other/Misc.

Model Structure

As will be noted in the next section, conventional models have components which typically represent households, firms and governments, or represent savings, consumption, and intermediate goods. In our model, we consider governmental institutions and households to be economic actors in the identical vein as industry. Thus, our model only contains the components of an economic actor and its regulator (which may be a government but may also be a separate body, such as an external entity). The components of the model are: Accounting, Assets, Capacity, Delivery, Finance, Markets, Monetary, Planning, Pollution, Price, Production, Regulatory, Resources, and Technology. Figure 1 shows the connection of these components to one another.
A post-processor can transform model results into the composites often recognized and used for analyses.

In the model, the Regulatory functions determine laws, tariffs and taxes and how they apply to the other commodity sectors. Laws are exogenous, but revenue producing activities are an endogenous function of governmental needs.

The planning component determines the future need for productive capacity, inventory adjustments, and future demand based on the trends of historical conditions. Studies indicate this is much more realistic and accurate than approaches using optimization or modeled clairvoyance. (Sterman 2000)

The production component must serve expected demand and maintain inventory. Production comes from productive capacity. The capacity capability may be limited because of a shortages of production factors, such as materials or labor, or by reductions in resource quality such oil, fishing, or water. Production has fixed operating costs, such maintenance, and variable costs, such as the cost of consumable production factors. It

has a stock of production factors and inventory that it must maintain to allow production for serving demand. It also produces its own inventory to ensure it can meet immediate demand, and it determines its future demand for production factors from other sectors.

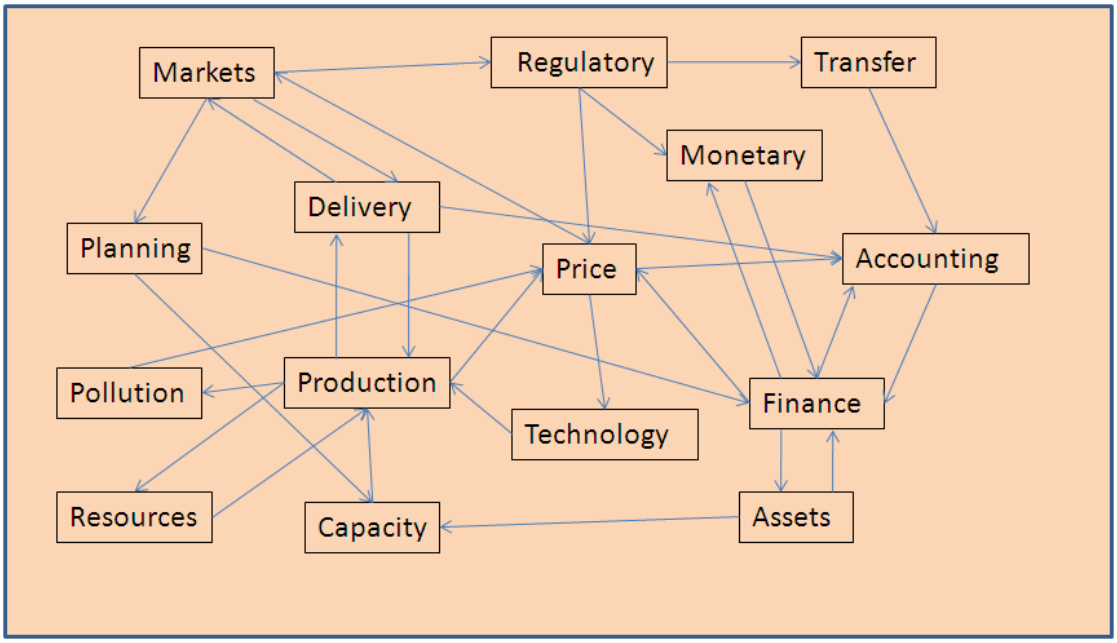

Figure 1: UC model Component Connectivity

The monetary sector represents the regulatory function of the central (or international) bank. It sets interest rates and adjust exchange rates to maintain employment or to control inflation.

Price is a composite of fixed and variable costs and profits. Price is determined as a function of supply/ demand conditions and costs. Fixed costs include interest payments and depreciation. Variable costs include the consumable factors of production used to make a product. Transportation costs, taxes, and tariffs increase the delivered cost experienced by the consumer.

The market component determines the demand of each commodity from each nation based on market prices, consumer preferences, and government regulation (e.g. quotas). The demand allocations are based on QCT.

The transfer component can generate transfer payments, such as subsidies and welfare payments across sectors. These may the endogenous consequence of government financial needs or are set exogenously. Income and royalty taxes are also specified in this component. The sector also includes the transfer of dividends across sectors and the payments from foreign national laborers to families abroad.

The Delivery sector allocates the production to the demand specified in the market sectors. It also does the inventory accounting.

The resource sector determines the availability of resources in terms of the effort to extract or obtain them. Land, minerals, commons-goods (fish, air, sun, biomass, water) and labor are all considered resources that may be depletably finite or renewable.

The technology component determines changes in technology and thereby economic productivity,. The primary relationship improves technology based on need (Backus 1996), but technology can also be exogenously specified. Endogenous technology dynamics can use both evolutionary (Nelson and Winter 1985) and induced-change (Ruttan 2000) algorithms. The model keeps track of marginal productivity (investments) and average productivity (embedded in capital stocks).

The capacity component accounts for the delays in investments becoming productive capital, the costs of construction, and capacity retirements.

The asset component keeps track of debt and equity plus gross, tax and net assets. It also does the accounting for retirements and depreciation.

The accounting sector determines profits, income taxes, interest payments other income, total costs, funds for operations, returns on investment, dividends, current assets and current liabilities.

The Finance sector determines debt repayments, fund required, debt limits, equity limits, new debt, new equity, short term investments, redemptions, government loans/repayment, nationalization, financial stocks, and retained earnings.

Lastly, the pollution component simply performs the accounting of greenhouse gas and other (gaseous, liquid and solid) pollution from economic activities.

Comparison to Other Research

Although there are many models that simulate international economics, other than the UC model described herein, only the International Futures model from the University of Denver attempts to also include geopolitical conditions.

Most international macroeconomic models assume general equilibrium conditions inappropriate to the purpose of national security assessment. Two models, E3MG: An Energy-Environment-Economy (E3) Model at the Global Level, from Cambridge Econometrics Ltd (UK) and the REMI model (from Regional Economic Models, Inc.) use combined statistical and structural approaches to capture macroeconomic transients. The summary of these three modeld below relies heavily on the published content of their websites. We do utilize structure form the E3MG (http://www.camecon.com/suite_economic_models/e3mg.htm) and REMI (www.remi.com) models, but only use data and concepts form the International Futures model (http://www.ifs.du.edu/).

The E3MG Model:

E3MG is a sectoral econometric model for the world that has been developed with the explicit intention of analyzing long-term energy and environment interactions within the global economy and assessing short and long-term impacts of climate change policy.

E3MG produces comprehensive annual forecasts to the year 2020, and long-term forecasts to the year 2100 and includes a set of fully endogenous technical progress indicators. The E3MG model provides a single-model framework in which detailed industry analysis is consistent with macro analysis; the key indicators, including world trade and technical progress, are modeled separately for each sector and region, and are aggregated to determine global impacts. (Barker, et. al. 2009, 2006, 2005, Kohler et. al. 2006)

E3MG provides a highly disaggregated breakdown of economic activity (and energy use, based around the following model classifications:

- 20 World regions, including explicit treatment of the US, Japan, India, China, Mexico, Brazil and the four largest EU economies
- 42 Industrial sectors based on the NACE classification, including 16 service sectors and disaggregation of the energy sectors
- 28 Consumer spending categories
- 12 different fuel types, and 19 separate fuel user groups
- 14 atmospheric emissions

E3MG has been built by teams at Cambridge Econometrics and the University of Cambridge as a contribution to the work of the UK Tyndall Centre for Climate Change Research. E3MG is a component of the Tyndall Centre's Community Integrated Assessment System (CIAS) being developed as an intermediate scale coupled climate-ocean system in the Cambridge Centre for Climate Change Mitigation Research, Department of Land Economy, University of Cambridge. The E3MG model was used to assess the impacts of binding global climate agreements at the Copenhagen United Nations Climate Change Conference in November 2009.

Model details and documentation are available at: http://www.camecon.com/.

The REMI Model

The REMI model is a dynamic forecasting and policy analysis tool that can be variously referred to as an econometric model, an input-output model, or even a computable general equilibrium model (Treyz 1993). In fact, REMI integrates several modeling approaches, incorporating the strengths of each methodology while overcoming its limitations.

REMI model contains detailed industries. At its core, the REMI model incorporates the complete inter-industry relationships found in input-output models. REMI model captures economic changes over time, allowing firms and individuals to change their behavior in response to changing economic conditions. These responses are based in part on general equilibrium economic theory. REMI model is sometimes referred to as an "econometric model," due to the underlying equations and response estimations using advanced statistical techniques.

The spatial dimension of the economy is represented by the underlying "New Economic Geography" structure of the REMI model. This incorporates the productivity and competitiveness benefits due to the concentration, or agglomeration, of economic activity in cities and metropolitan areas, and to the clustering of industries.

The REMI model incorporates aspects of four major modeling approaches: Input-Output, General Equilibrium, Econometric, and Economic Geography. Each of these methodologies has distinct advantages as well as limitations when used alone. The REMI integrated modeling approach builds on the strengths of each of these approaches.

Figures 2 and 3 show the REMI model structure.[1] Model details and documentation are available at: http://www.remi.com/.

[1] Figures used with permission.

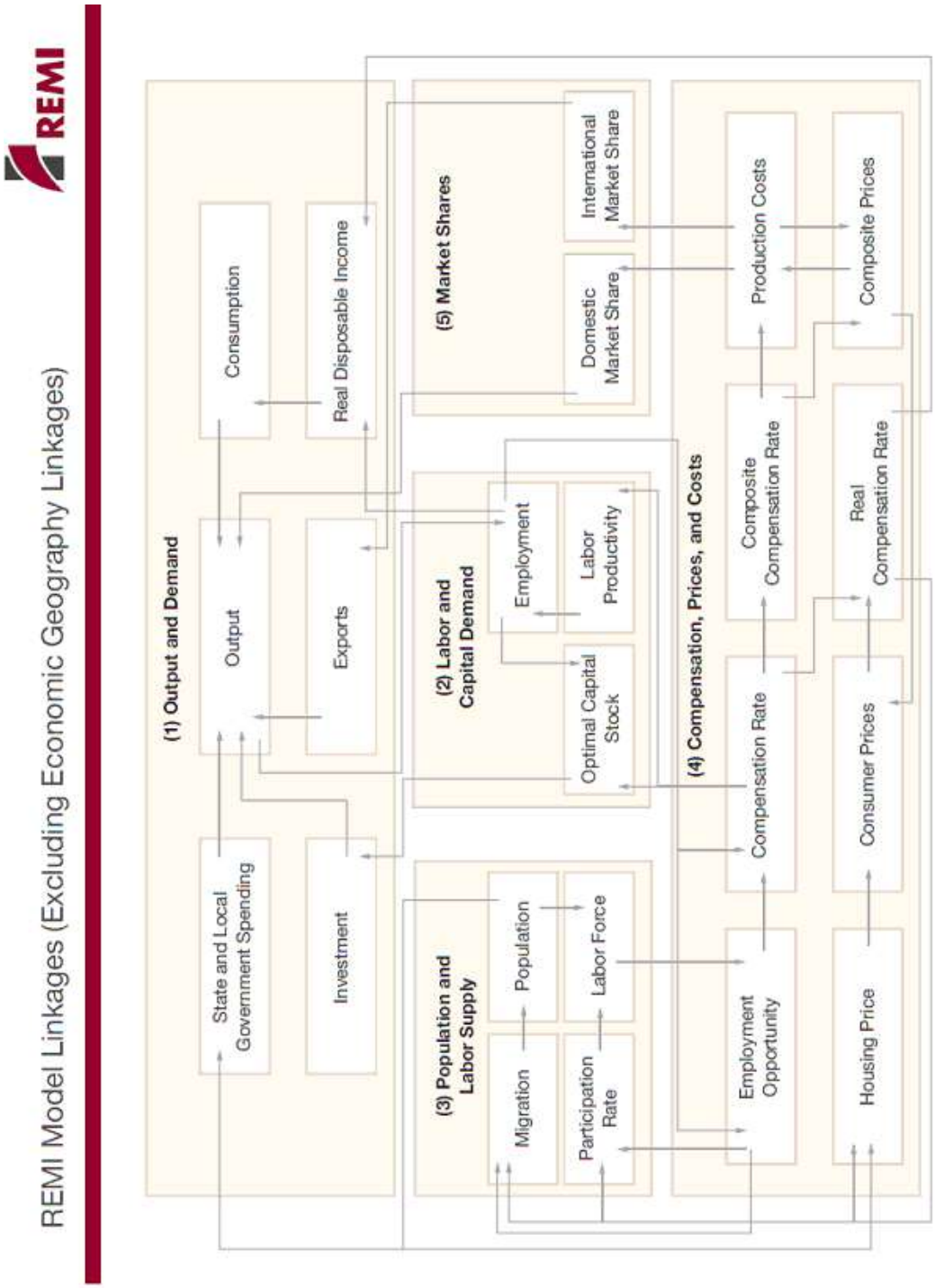

Figure 2: REMI Model Components and Linkages.

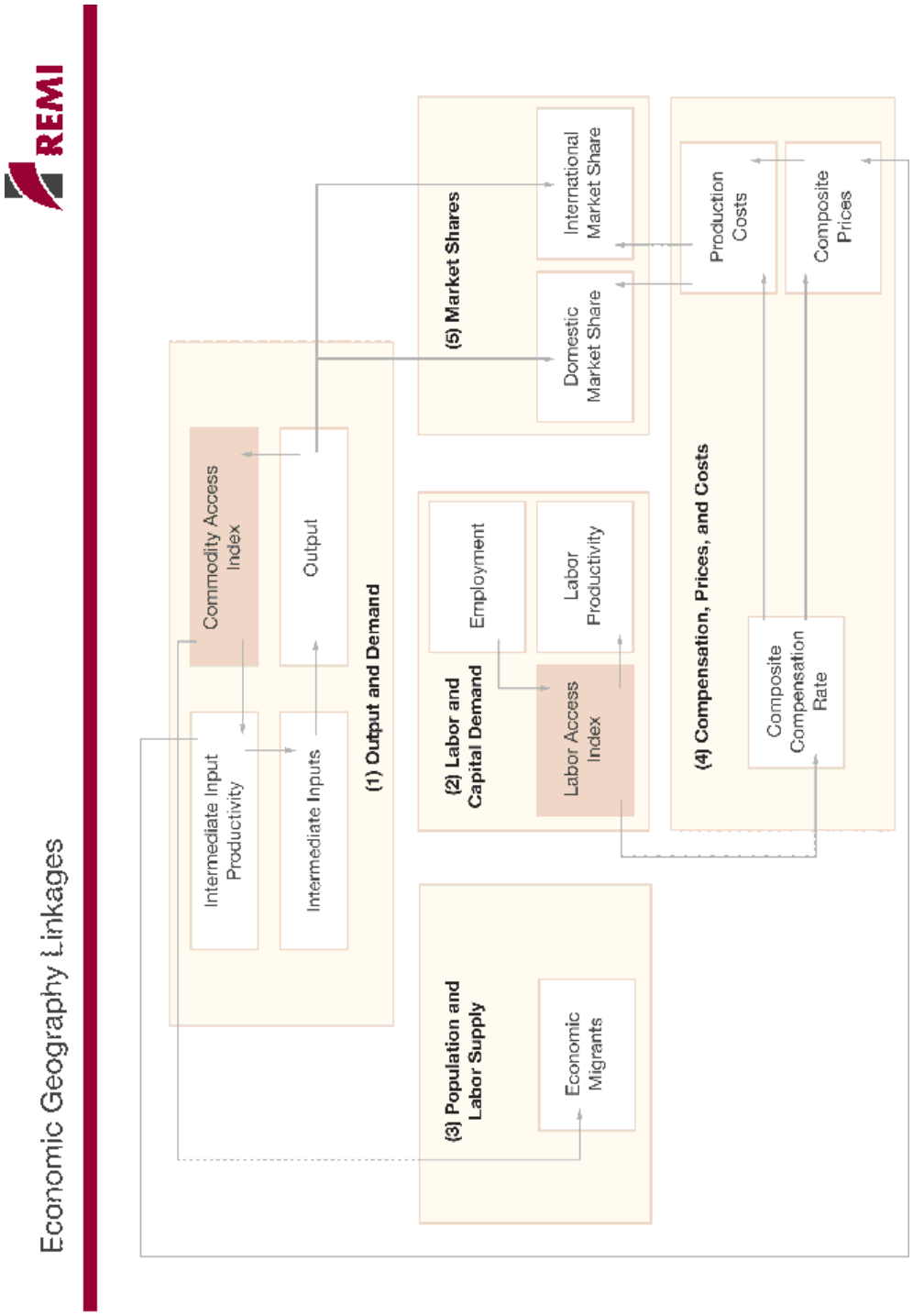

Figure 3: REMI Model Detail on Intermediate Demand and Factor Access

The IFs Model

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 183 countries interacting in the global system Hughes, B. (2001, 2006). 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. Figure 4 shows the structure of the model.

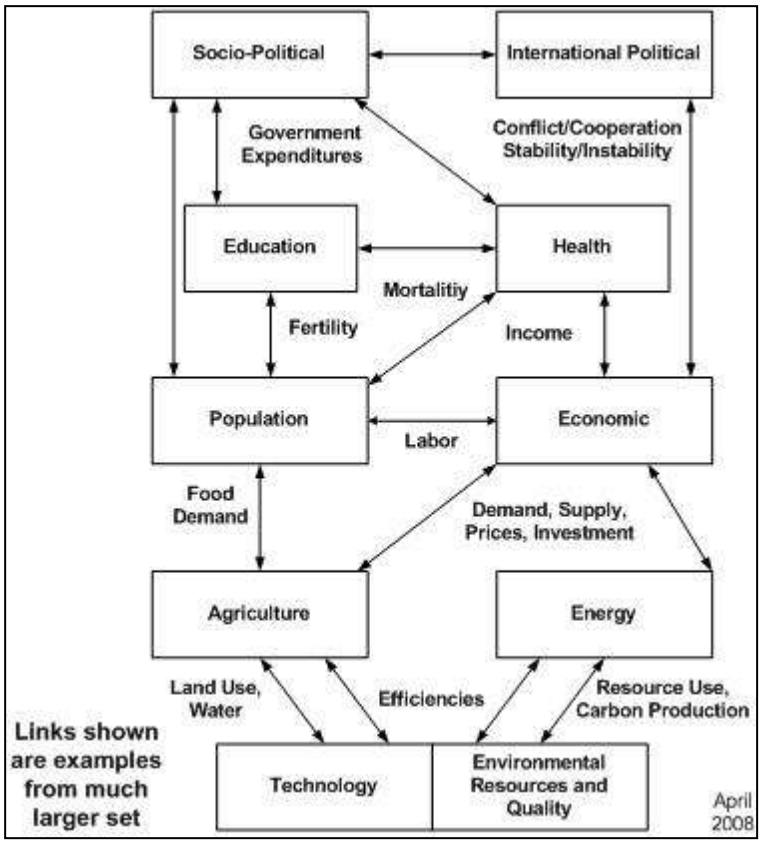

Figure 4: IFs Model Structure.

IFs was a core component of a project exploring the New Economy sponsored by the European Commission. Forecasts from IFs supported Project 2020 of the National Intelligence Council as well as the NIC's Global Trends 2025 for the Obama administration in early 2009. IFs was used to provide driver forecasts for the fourth Global Environment Outlook of the United Nations Environment Program. IFs is also a key piece of the research project supported by DG INFSO of the European Commission to forecast ICT trends.

The model was developed over several generations, principally by Dr. Barry B. Hughes of the University of Denver and the Josef Korbel School of International Studies. IFs is continually being revised and updated, most importantly through the institutional support and structure of the Pardee Center. The model's website explains more about the history and philosophy of the model. Model details and documentation are available at: http://www.ifs.du.edu/ Through its web site, IFs is freely available to users both on-line and in downloadable form.

General Equilibrium Models

Several institutions produce general equilibrium global macroeconomic models. The UC model work uses no structures from such models, but they are noted here for completeness.

The Global Trade Analysis Project (GTAP) model from Purdue University is a static model from which this work obtains its primary data. (https://www.gtap.agecon.purdue.edu/)

Harvard has the widely used Intertemporal General Equilibrium Model (Goettle 2007, http://www.hks.harvard.edu/m-rcbg/ptep/IGEM.htm)

The International Monetary Fund (IMF) has the New International Macroeconomic Model (Bayoumi 2004), http://www.imf.org/external/np/res/gem/2004/eng/)

The World Bank models are called INKAGE (van der Mensbrugghe 2005) and MAMS (Lofgren and Diaz-Bonilla 2008), http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTDECPROSPECTS/0,,contentMDK:20279477~menuPK:538204~pagePK:64165401~piPK:64165026~theSitePK:476883,00.html

IHS Global Insight provides a proprietary commercial service based on macroeconomic simulation models (http://www.ihsglobalinsight.com/ProductsServices/ProductDetail1097.htm) The Department of Energy's National Energy Modeling System's macroeconomic module is based on the Global Insight model and is primarily and Input-Output model in structure. http://www.eia.doe.gov/oiaf/aeo/overview/macroeconomic.html.

System Dynamics Models

The Millennium Institute provides a global model based on an extension of the WORLD3 model developed at MIT (Meadows 1974) called Threshold21 (http://www.millenniuminstitute.net/integrated_planning/tools/T21/) We do not use any part of that work but do utilize the theory of stocks an flows that it highlights. Other MIT researchers (Jay Forrester, John Sterman, Michael J. Radzicki, Thomas Fiddaman) have also developed macroeconomic models which do contain many of the theoretical underpinnings of the UC model.

Data Sources

To obtain the required coverage, we use data from multiple sources. We use the GTAP data as the referent because it has the most thorough per review process. We scale or normalize all other data to it. All data is further aggregated or scaled to conform to the UC model specificity noted earlier.

The Global Trade Analysis Project (GTAP), is coordinated by the Center for Global Trade Analysis, which is housed in the Department of Agricultural Economics at Purdue University. https://www.gtap.agecon.purdue.edu/ Appendix A provides the specifications for GTAP data.

The World Bank data is the secondary source for most data beyond basic economic conditions. We currently use the 2009 version of World Development Indicators. http://go.worldbank.org/U0FSM7AQ40 Appendix B provides the scope of the World Bank data.

The International Futures model contains a large collection of assimilated and normalized data sets. We do not use the data directly but review the data to cross check our use and combining of multiple data sets. http://www.ifs.du.edu/

The International Monetary Fund produces global nation-state data sets: International Monetary Fund World Economic Outlook http://www.imf.org/external/data.htm

The UN has many region-specific data sets:

United Nations Statistical Division http://unstats.un.org/unsd/default.htm

United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) http://www.unescap.org/stat/data/

UN Economic Commission for Africa http://www.uneca.org/statistics/

Asian data are also available from the Asian Development Bank http://www.adb.org/Economics/

The US AID program additional maintains a data set: Latin America and the Caribbean: Selected Economic and Social Data, http://lac.eads.usaidallnet.gov/

Stanford University maintains a African data set:
http://library.stanford.edu/depts/ssrg/africa/statistics.html
http://www.economicswebinstitute.org/ecdata.htm

The European Union and OECD both produce well known and respected data sets.

Eurostat is the Statistical Office of the European Communities:
http://www.esds.ac.uk/international/support/user_guides/eurostat/cronos.asp

Organization for Economic Co-operation and Development has its data at:
http://www.oecd.org/statsportal/0,3352,en_2825_293564_1_1_1_1_1,00.html

Conflict Metrics

Conventional efforts to determine the potential for conflict from the historical frequency of conflict within a country or the static conditions of military presence, ethnic dominance, and/or poverty (Bearce and Fisher 2002, Hirshleifer,200, Cashman 2000, Stewart, & Fitzgerald 2000, O'Brien 2002). The International Futures model uses the status of democracy, mortality rates, and GDP per capital. We use the dissonance between expectations and perceived current conditions (Backus et al. 2010)

Many individuals are well known for their research on the causes of conflict: Christopher Cramer at the University of London, Peter Brecke int Sam Nunn School of International Affairs at Georgia Institute of Technology, Nicholas Sambanis at Yale University, Sean O'Brien at DARPA, Stephen M. Shellman at Florida State University, and Paul Collier at the World Bank.

Several data sets are available on conflict as noted below:

Correlates of War Inter-State War data set
http://www.correlatesofwar.org/cow2%20data/WarData/InterState/Inter-State%20War%20Format%20(V%203-0).htm

Data on Armed Conflict CSCW and Uppsala Conflict Data Program (UCDP) at the Department of Peace and Conflict Research, Uppsala University,
http://www.prio.no/CSCW/Datasets/Armed-Conflict/

Conflict Vulnerability database
http://payson.tulane.edu/conflict/datasets/data_sets.htm

Human Security gateway
http://www.humansecuritygateway.com/showRecord.php?RecordId=22064

University of Texas (Paul Hensel) International Conflict and Cooperation Data Page
http://www.paulhensel.org/dataconf.html

World Bank Economics of Conflict
http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/EXTPROGRAMS/EXTCONFLICT/0,,menuPK:477971~pagePK:64168176~piPK:64168140~theSitePK:477960,00.html

KOSIMO: University of Heidelberg Databank on Political Conflict
http://www.hiik.de/en/kosimo/index.html

Summary

In this work we have developed a foundation for socioeconomic and geopolitical simulation suitable to analyze potential unintended consequences from national security interventions. The consideration of the integrated global socioeconomic system through realistic feedback and delays is one composite aspect of the modeling system that allows the capability. Another unique aspect of the simulation framework is the use of expectation formation to determine the dissonance between expected and perceived existing conditions. A final aspect is the ability to automatically configure the model to the problem.

The Unintended Consequence model can simulate any configuration for 229 nation states at a resolution of 30 economic sectors. It captures the interacting dynamics among the stares as issues unfold over time. Qualitative choice methods ensure explicit consideration of the stochastic (uncertain) characteristics of international events.

Via new funding, we are working to bring this work to maturity and make it directly useable and beneficial to the concerns of the intelligence and defense communities.

References

Backus G. and T. Barker (1994), "Macroeconomic Linkages and Impacts: Technical and Fiscal Options in National Green-House Gas Abatement," *Proceedings of the International Conference on National Action to Mitigate Global Climate Change*, UNEP Collaborating Centre on Energy and Environment, Copenhagen, Denmark, June 7-9 1994.

Backus, G. (1996), Preliminary Simulation of National Research Council of Canada Case Studies, Policy Assessment Corporation, Denver, Colorado.

Backus, G. and R. Glass, 2006, *An Agent-Based Model Component to a Framework for the Analysis of Terrorist-Group Dynamics.* SAND2006-0860. Sandia National Laboratories, Albuquerque, NM. https://cfwebprod.sandia.gov/cfdocs/CCIM/docs/06_0860P_ConceptualModel1.pdf

Backus, G. Explorations in Combining Cognitive Models of Individuals and Systems Dynamics Models of Groups, (2008) SAND2008-4717, September 2008

Backus, G., M Bernard, A. Bier, M. Glickman and S. Verzi (2010), Development of a Generalized Psychological Simulation Model, Sand Report XXXX, Sandia National Laboratories, Albuquerque, NM

Barker T., A. Dagoumas and J, Rubin (2009), The macroeconomic rebound effect and the world economy, Energy Efficiency, Springer Netherlands, Issue Volume 2, Number 4 / November, 2009, Pages 411-427

Barker, T., Pan, H., Köhler, J., Warren, R. and Winne, S. (2005) 'Avoiding dangerous climate change by inducing technological progress: scenarios using a large-scale econometric model', chapter 38 in Schellnhuber, H. J., Cramer, W., Nakicenovic, N., Wigley, T. and Yohe, G. (Eds.) *Avoiding Dangerous Climate Change*, Cambridge University Press, 2005.

Barker, T., Pan, H., Köhler, J., Warren, R. and Winne, S. (2006) 'Decarbonizing the Global Economy with Induced Technological Change: Scenarios to 2100 using E3MG'. In Edenhofer, O., Lessmann, K., Kemfert, K., Grubb, M. and Köhler, J. (eds) *Induced Technological Change: Exploring its Implications for the Economics of Atmospheric Stabilization, Energy Journal Special Issue* on the International Model Comparison Project.

Bearce, D.H. and E. Fisher (2002) Economic geography, trade and war, Journal of Conflict Resolution 46, 365-393.

Bayoumi, T. (2004) GEM,a New International Macroeconomic Model: Occasional Paper 239, International Monetary Fund, Washington, DC

Cashman, G. (2000) What Causes War?. Lexington Books. Boston, MA.

Engle, R.F., and C.W.J. Granger (1987) Co-integration and error correction representation, estimation, and testing, Econometric, Vol. 55, pp 251-276.

Engle, R.F., and C.W.J. Granger. (1991). Long-Run Economic Relationships: Readings in Cointegration, Oxford University Press, Oxford, UK.

Goettle R., M Ho, D. Jorgensen, D Slesnick and P Wilcoxen (2007) , IGEM, an Inter-temporal General Equilibrium Model of the U.S. Economy with Emphasis on Growth, Energy and the Environment., U.S. Environmental Protection Agency (EPA) Office of Atmospheric Programs Climate Change Division, EPA Contract EP-W-05-035

Granger, CWJ (1981) , "Some properties of time series data and their use in econometric model specification," Journal of Econometrics, Vol. 16, pp. 121-130

Hertel, T. (1997) Global Trade Analysis: Modeling and Applications, Cambridge University Press.

Hirshleifer, Jack, 2001. The Dark Side of the Force: Economic Foundations of Conflict Theory. Cambridge University Press, Cambridge, UK.

Hughes, B. B. and Hillebrand, E. E. (2006) Exploring and Shaping International Futures. Paradigm Publishing, Inc.

Hughes B., Choices in the face of uncertainty: the international futures (IFs) model (2001), Futures, Volume 33, Issue 1, February 2001, Pages 55-62.

Keen, S. 2001. Debunking Economics: The Naked Emperor of the Social Sciences. New York City: St. Martin s Press.

Kohler J. & Terry Barker & Dennis Anderson & Haoran Pan, 2006. "Combining Energy Technology Dynamics and Macroeconometrics: The E3MG Model," The Energy Journal, International Association for Energy Economics, vol. 0(Special I), pages 113-134.

Lofgren H., C Diaz-Bonilla (2008), MAMS: An Economy-wide Model for Development Strategy Analysis, Development Prospects Group, World Bank, Washington, DC

McFadden, D., (1986), "Econometric Model of Probabilistic Choice," in Structural Analysis of Discrete data with Econometric Applications, ed. C.F. Manski and D. McFadden, Cambridge, MA, MIT Press.

McFadden, D. (1982), "Qualitative Response Models," in Advances in Econometrics, Ed. Werner Hildenbrand, Cambridge University Press, New York.

McFadden, D. (1974), "Conditional Logit Analysis of Qualitative Choice Behavior," in Frontiers in Econometrics, Ed. P. Zarembka, New York, Academic Press.

McNamara, L., G. Backus, T. Trucano, S. Mitchell, and A. Slepoy (2008) , R&D for computational cognitive and social models : foundations for model evaluation through verification and validation . SAND2008-6453, Sandia National Laboratories, Albuquerque, NM.

Meadows, D. L., Behrens, W. W., III, Meadows, D. H., Naill, R. F., Randers, J., & Zahn, E.K.O. (1974). Dynamics of growth in a finite world. Waltham, MA: Pegasus Communications.

Nabors, O., G. Backus and J. Amlin (2002), "Simulating the Effects of Business Decisions on a Regional Economy: Experience during the California Energy Crisis," *Journal of Industry, Competition and Trade: From Theory to Policy*, Issue 3
Raup, D. M. (1991), Extinction: Bad Genes or Bad Luck?, W. W. Norton, New York

Nelson, R. and S. Winter, (1985) An Evolutionary Theory of Economic Change, Harvard University Press

O'Brien, S (2002). Anticipating the Good, the Bad, and the Ugly: An Early Warning Approach to Conflict and Instability Analysis, Journal of Conflict Resolution Issue 46: pp. 791-811

Ruttan, V. (2000), Technology, Growth, and Development: An Induced Innovation Perspective, Oxford University Press

Sterman, John (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World, McGraw-Hill/Irwin, Boston

Stewart, F., & Fitzgerald, V. (2000). War and underdevelopment. Volume 1. The economic and social consequences of conflict. Oxford: Oxford University Press.

Tesfatsion L. and K. Judd (eds), Handbook of Computational Economics, Volume 2: Agent-Based Computational Economics, Handbooks in Economics Series, North-Holland/Elsevier, the Netherlands, Spring 2006.

Treyz, G. (1993) Regional economic modeling: a systematic approach to economic forecasting and policy analysis, Kluwer Academic Publishers, Boston

van der Mensbrugghe, D. (2005), LINKAGE Technical Reference Document: Version 6.0", World Bank, Washington DC, January 2005.

Vermeij, G., (2004), Nature: An Economic History, Princeton University Press

Appendix A: GTAP Data Specificity

GTAP data include all trade volumes and prices between areas (nations) by commodity. It includes economic activity (demand and supply) by commodity volume and value with all taxes and transportation costs. Investment volumes are subsumed in the data but readily separated out.

GTAP Endowments (Stocks)

Land	Capital
Unskilled Labor	Natural Resources
Skilled Labor	

GTAP Transportation Types

Land	Water	Air

GTAP Commodities (57)

Paddyrice	Woodproducts
Wheat	Paperproducts,publishing
Cerealgrainsnec	Petroleum,coalproducts
Vegetables,fruit,nuts	Chemical,rubber,plasticprods
Oilseeds	Mineralproductsnec
Sugarcane,sugarbeet	Ferrousmetals
Plant-basedfibers	Metalsnec
Cropsnec	Metalproducts
Cattle,sheep,goats,horses	Motorvehiclesandparts
Animalproductsnec	Transportequipmentnec
Rawmilk	Electronicequipment
Wool,silk-wormcocoons	Machineryandequipmentnec
Forestry	Manufacturesnec
Fishing	Electricity
Coal	Gasmanufacture,distribution
Oil	Water
Gas	Construction
Mineralsnec	Trade
Meat:cattle,sheep,goats,horse	Transportnec
Meatproductsnec	Seatransport
Vegetableoilsandfats	Airtransport
Dairyproducts	Communication
Processedrice	Financialservicesnec
Sugar	Insurance
Foodproductsnec	Businessservicesnec
Beveragesandtobaccoproducts	Recreationandotherservices
Textiles	PubAdmin/Defence/Health/Educ
Wearingapparel	Dwellings
Leatherproducts	Investment

GTAP Countries (87)

Australia
NewZealand
RestofOceania
China
HongKong
Japan
Korea
Taiwan
RestofEastAsia
Indonesia
Malaysia
Philippines
Singapore
Thailand
Vietnam
RestofSoutheastAsia
Bangladesh
India
SriLanka
RestofSouthAsia
Canada
UnitedStates
Mexico
RestofNorthAmerica
Colombia
Peru
Venezuela
RestofAndeanPact
Argentina
Brazil
Chile
Uruguay
RestofSouthAmerica
CentralAmerica
RestofFTAA
RestoftheCaribbean
Austria
Belgium
Denmark
Finland
France
Germany
UnitedKingdom
Greece
Ireland
Italy
Luxembourg
Netherlands
Portugal
Spain
Sweden
Switzerland
RestofEFTA
RestofEurope
Albania
Bulgaria
Croatia
Cyprus
CzechRepublic
Hungary
Malta
Poland
Romania
Slovakia
Slovenia
Estonia
Latvia
Lithuania
RussianFederation
RestofFormerSovietUnion
Turkey
RestofMiddleEast
Morocco
Tunisia
RestofNorthAfrica
Botswana
SouthAfrica
RestofSouthAfricanCU
Malawi
Mozambique
Tanzania
Zambia
Zimbabwe
RestofSADC
Madagascar
Uganda
RestofSub-SaharanAfrica

Appendix B: World Bank Data Specificity

World Bank World Development Indicators contain time series for over 200 countries and can go back as far as 1960. http://go.worldbank.org/U0FSM7AQ40

1. WORLD VIEW
1.1 Size of the economy
1.2 Millennium Development Goals: eradicating poverty and saving lives
1.3 Millennium Development Goals: protecting our common environment
1.4 Millennium Development Goals: overcoming obstacles
1.5 Women in development
1.6 Key indicators for other economies

2. POPULATION
2.1 Population dynamics
2.2 Labor force structure
2.3 Employment by economic activity
2.4 Decent work and productive employment
2.5 Unemployment
2.6 Children at work
2.7 Poverty rates at national poverty lines
2.8 Poverty rates at international poverty lines
2.9 Distribution of income or consumption
2.10 Assessing vulnerability and security
2.11 Education inputs
2.12 Participation in education
2.13 Education efficiency
2.14 Education completion and outcomes
2.15 Education gaps by income and gender
2.16 Health systems
2.17 Disease prevention coverage and quality
2.18 Reproductive health
2.19 Nutrition
2.20 Health risk factors and future challenges
2.21 Health gaps by income and gender
2.22 Mortality

3. ENVIRONMENT
3.1 Rural population and land use
3.2 Agricultural inputs
3.3 Agricultural output and productivity
3.4 Deforestation and biodiversity
3.5 Freshwater
3.6 Water pollution
3.7 Energy production and use
3.8 Energy dependency and efficiency and carbon dioxide emissions
3.9 Trends in greenhouse gas emissions
3.10 Sources of electricity
3.11 Urbanization
3.12 Urban housing conditions
3.13 Traffic and congestion
3.14 Air pollution
3.15 Government commitment
3.16 Toward a broader measure of savings

4. ECONOMY
4.1 Growth of output
4.2 Structure of output
4.3 Structure of manufacturing
4.4 Structure of merchandise exports
4.5 Structure of merchandise imports
4.6 Structure of service exports
4.7 Structure of service imports
4.8 Structure of demand
4.9 Growth of consumption and investment
4.10 Central government finances
4.11 Central government expenses
4.12 Central government revenues
4.13 Monetary indicators
4.14 Exchange rates and prices
4.15 Balance of payments current account

5. STATES AND MARKETS
5.1 Private sector in the economy
5.2 Business environment: enterprise surveys
5.3 Business environment: Doing Business indicators
5.4 Stock markets
5.5 Financial access, stability, and efficiency
5.6 Tax policies
5.7 Military expenditures and arms transfers
5.8 Public policies and institutions
5.9 Transport services
5.10 Power and communications
5.11 The information age
5.12 Science and technology

6. GLOBAL LINKS
6.1 Integration with the global economy
6.2 Growth of merchandise trade
6.3 Direction and growth of merchandise trade

6.4 High-income economy trade with low- and middle-income economies
6.5 Direction of trade of developing economies
6.6 Primary commodity prices 345
6.7 Regional trade blocs
6.8 Tariff barriers
6.9 External debt
6.10 Ratios for external debt
6.11 Global private financial flows
6.12 Net official financial flows
6.13 Financial flows from Development Assistance Committee members
6.14 Allocation of bilateral aid from Development Assistance Committee members
6.15 Aid dependency
6.16 Distribution of net aid by Development Assistance Committee members
6.17 Movement of people
6.18 Characteristics of immigrants in selected OECD countries
6.19 Travel and tourism

Distribution

1	MS0899	Technical Library	9536 (electronic copy)
1	MS0123	D. Chavez, LDRD Office	1011

Sandia National Laboratories