THE FUTURES OF GLOBAL INTERDEPENDENCE (FUGI) MODEL

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Contents

Summary

The new frontiers of science and technology in the twenty-first century will appear in the fields of information technology, space, environment, biotechnology, new energy, and new materials. They will have tremendous impact on development of the world economy and on the global environment. The FUGI global model has been developed as a medium to provide global information to human society and to find possibilities for policy coordination among countries to achieve sustainable development of the world economy under the constraints of the changing global environment. The FUGI model has been used by UN organizations for the purpose of long-term projections of the

world economy and policy simulations since 1981. The FUGI models 9.0 M200 and M80 classify the world, respectively, into 200 countries and 80 countries and regional groupings where each national/regional model is globally interdependent through international trade, financial flows, and information flows. The UNCTAD (United Nations Conference on Trade and Development) Secretariat made use of the model for policy simulations of the Asian Financial Crises in 1998. In 2000, the UNCTAD Secretariat officially adopted the FUGI model for projections of the world economy and alternative policy scenario simulations.

2. Purposes, Structure, and Function of the FUGI Global Model 9.0 M200 / 80

2.1. Purpose

In the twenty-first century it is expected that integrated progress of technology, culture, and economic development will be seen in the global human society which is a dynamic organic system, made up of constituent parts or members that are globally interdependent. The new information technology innovation will have tremendous impact on human life, culture, and economic development. Historically speaking, human behaviors under the global cultural changes imposed by the increasingly interdependent global human society are rather new experiences and challenges for the human society.

Under these circumstances, the **FUGI** (*Futures of Global Interdependence)* global model seems likely to play a significant role in efforts to envisage the future of global interdependence and to provide global information on the economic development and environmental changes under alternative policy scenarios for sustainable development.

Project FUGI was started in 1976 with the cooperation of three Japanese institutions, namely, the University of Tokyo, Osaka University, and Soka University, under the sponsorship of the National Institute for Research Advancement in Tokyo. The original FUGI model consisted of three parts: a Global Input-Output Model (GIOM), a Global Resources Model (GRM), and a Global Economic Model (GEM), Types I, M15. Yoichi Kaya, Faculty of Engineering, the University of Tokyo, Yutaka Suzuki, Faculty of Engineering, Osaka University, and the author coordinated the development of these models. Work in progress was reported at the IIASA global modeling symposiums in 1977 and the years following. The first-generation FUGI global economic model (Type I, M15), designed by the author in 1965, was the development of the Multi-Nation Economic Model which applied the 15 countries in Asia for the purpose of projections of the Asian economy.

Drawing on experiences with global modeling in the 1970s, the author developed a fourth-generation FUGI global economic model (Type IV, M62) that divided the world into 62 countries/regions and consisted of approximately 30 000 equations. It was first made public at a seminar on comparative simulations of global economic models held at Stanford University, June 25–26, 1981, and hosted by Bert Hickman. The UN Secretariat, Department of International Economic and Social Affairs, Projections and Perspective Studies Branch, soon afterward adopted this model for the purpose of long-term projections and policy simulations of the world economy. It was used from 1981 to

1991, when it was replaced by the new generation FUGI global model 7.0 (Type VII). For the period 1985–1986, a new generation of the FUGI global model was designed as an *early warning system for displaced persons*. During the period 1990–1995, the FUGI model 7.0 M80 was designed as integrated global model. The FUGI model 9.0 M200 / 80 as a successor has been designed for the period 1997–1999.

Information on the FUGI global model 9.0 M200 PC (Windows 2000 or Windows 98) and its software (FUGIDB and FGMS200) designed in 2000 is also available.

2.2.Model Structure and Function

FUGI global model 9.0 M200 / 80 consists of nine integrated major subsystems: (I) Population, (II) Foods, (III) Energy, (IV) Environment, (V) Economic Development, (VI) Peace and Security, (VII) Human Rights, (VIII) Health Care, and (IX) Digital Divide (Information technology). The FUGI Global Model 9.0 M200 / 80, for example, classifies the world into 200 / 80 countries and regional groupings. Each country or regional group model is globally interdependent through direct linkages of the world trade matrices, export / import prices, primary commodities prices, foreign exchange rates, official development assistance, private foreign direct investment, external debt, LIBOR, EURO dollar interest rate, and so on. It is also globally interdependent through indirect linkages of population changes, economic development policies, energy policies, environmental police, and so on (see Chart 1: Outline of the FUGI Global Model 9.0 M80).

Developed Market Economics		**Developing Economics**
Asia-Pacific		**Asia-Pacific**
1 Japan		23 China, Mainland
2 Australia		24 China, Hong Kong and Macao
3 New Zealand	WORLD TRADE	25 Taiwan, Province of China
	MATRIX 80×80	26 Korea, Republic of
		27 North Korea
		28 Indonesia
		29 Malaysia
		30 Philippines
North America	EXPORT	31 Singapore
4 Canada	IMPORT	32 Thailand
5 United States	PRICES	33 Myanmar
		34 SEAO
		35 Bangladesh
		36 India
Western Europe	OIL &	37 Pakistan
6 Belgium-Luxembourg	COMMODITIES	38 Sri Lanka
7 Denmark	PRICES	39 SWAO
8 France		40 Pacific Islands
9 Germany, Federal Republic of		
10 Greece		**Middle East**
11 Ireland	FOREIGN	41 Iran
12 Italy	EXCHANGE	42 Iraq
13 The Netherlands	RATE	43 Israel
14 United Kingdom		44 Kuwait
15 Portugal	ODA	45 Saudi Arabia

16 Spain		46 MIDO
17 Austria		
18 Finland		**Africa**
19 Iceland	EXTERNAL	47 Algeria
20 Norway	DEBT	48 Egypt
21 Sweden		49 Libya
22 Switzerland		50 Morocco
		51 Tunisia
	LIBOR &	52 Ethiopia
	EURO	53 Gabon
Economies in Transition	RATE	54 Ghana
75 Bulgaria		55 Kenya
76 Czech-Slovakia		56 Liberia
77 Hungary		57 Nigeria
78 Poland	PRIVATE	58 Sudan
79 Romania	FOREIGN	59 South Africa
80 CIS (Former USSR)	DIRECT	60 SOSO
	INVESTMENT	
		Latin America
		61 Argentina
		62 Bolivia
	FISCAL	63 Brazil
	MONETARY	64 Chile
	POLICIES	65 Colombia
		66 Mexico
	ENERGY	67 Ecuador
To be continued from 72	POLICIES	68 Paraguay
		69 Peru
Mediterranean	ENVIRONMENT	70 Uruguay
73 Turkey	POLICIES	71 Venezuela
74 MEURO		72 LACO

Chart 1. Outline of the Fugi Global Model 9.0 M80.

The Economic Development system as a major core of the model has eleven economic sub-blocs such as (1) labor and production at constant prices, (2) expenditure on GDP at constant prices, (3) income distribution: profit-wage, (4) prices, (5) expenditure on GDP at current prices, (6) money, interest rate, and financial assets, (7) government finance, (8) international balance of payments, (9) international finance, (10) foreign exchange rate, and (11) development indicators. For further detailed explanation of the Economic Development system (see *Appendix 1: The FUGI Global Model 9.0 M 200 / 80: Theoretical Model*).

2. Data-Supporting Expert System and Model Management in Hardware and Software

During the period 1990–1999, with the cooperation of system engineers, the author designed a significant new software system for global modeling. This expert software system, named **FGMS** (acronym for FUGI Global Modeling System) together with **FUGIDB** (FUGI model database) was researched and developed as a package for specific use in making computations for the FUGI global model 9.0 (Type IX) M 200 /

80. The **FGMS** software system consists of (1) **CONTROL**, data file control systems for listing, loading, printing, and updating country (**CNT**), region (**RGN**), and variable (**VAR**) data files, (2) **DSERVE**, supplementary data servicing programs for updating and storing **RGN.DAT** files, and so on, (3) **ESTIMATE**, estimating parameters of the model, (4) **SIMULATE**, making simulations using the FUGI global model, (5) **OUTGT**, printing out simulation results in forms of 170 World Tables, and (6) **UTILITY**, receiving data from **FUGIDB** to initialize and overwrite the time-series data, **RGN.DAT,** and to create variable data files,**VAR.DAT**. It can carry out automatic estimation of a given set of structural parameters of the FUGI model, using OLS and MLBM and forecast simulations efficiently, using an automatic error correction system. This expert system has already passed through the experimental stage and entered the stage of practical application. It is hoped that the FUGI global model and its software, **FGMS**, can contribute to progress in integrated global modeling.

The latest FUGI global model 9.0 (Type IX) M200 / 80 classifies the world into 200 and/or 80 countries and regional groupings (see *Appendix 2: Regional Classifications of FUGI Global Model 9.0 M200 / 80*). Both models M200 and M80 can be run on IBM RS/6000 or Windows PC systems using FGMS. The internationally compatible country data file (**CNT**) and regional data files (**RGN**) for M200/80 are produced from the original database (**FUGIDB**). To carry out computer simulations efficiently, the FUGI model 9.0 M80 reclassifies the world into 80 countries/regions so that the model can produce long-term forecast simulations of sustainable global development with constraints of global environment changes. As a result, the M200 model plays the role of a large spaceship using the RS/6000 AIX workstation and the M80 model plays a small scout ship, for global modeling research using a personal computer (running Windows 2000 or Windows 98). The M200 model also can be run using a powerful personal computer (with Windows 2000 or Windows 98) that installs **FGMS 200** software.

The global model simulation exercises using M200 / 80 cover the baseline projection of the global economy for 1991–2033. The model can provide information not only on global economic development but also on environmental changes in the space age. Information on the FUGI model is available on the Internet home page <http://fugimodel.t.soka.ac.jp>.

3. The Human Intelligence System of Estimating Structural Parameters of the Model

Then we estimate the FUGI global model’s structural parameters. Because the economic development system is basically designed as an econometric model, for each structural equation it is necessary to estimate parameters using time-series and cross-country data. We decided, for the sake of convenience, to employ the least squares method (OLS) and Most Likelihood Method by Beach-MacKinnon (MLBM) in case of certain degrees of serial corrections in a given structural equation. As a result, we found that the model might adequately estimate parameters under certain degrees of coefficients of determinants. Given these methodological constraints, we have made our choices of the optimum combinations of variables according to the following criteria:

Idealized structural equations for the model as a theoretical concept (for instance FUGI-MODEL M200 or M80 DATA) are first set forth, and only afterward are parameters estimated by OLS, in accordance with time-series data for the countries in question, making use of all the major explanatory variables. As a result, in cases where an explanatory variable's statistical "*t*" value is very low (less than 0.7) and no great degree of precision in the setting of parameters is to be expected, that explanatory variable will be automatically eliminated, if there is no N (neglect t value) constraint. Explanatory variables with sign constraints will be similarly eliminated in cases where they do not conform to the inevitable limiting sign conditions (+ or −) originally conceived by the theoretical model.

The process of estimation is repeated for the remaining variables, and the most theoretically desirable combination of explanatory variables is automatically selected through statistically determined values and judgments based on expert knowledge. In case of certain degrees of serial corrections in OLS estimation (for instance the DW ratio is beyond a given criteria, 2.0 +/− 0.7), the MLBM estimation method is automatically adopted in place of OLS estimation. Because of the very large number of structural equations and parameters, which the FUGI global model 9.0 develops in this way, it is nearly impossible for each parameter to be carefully checked by the researcher. Rather, for this large-scale model, the structural equations in each country are checked according to an expert system whereby a set of estimated parameters is intelligently installed into the model. Furthermore, the time span for estimating parameters of each structural equation is selected to get the most theoretically appropriate combination of the explanatory variables within the above constraints taking into account the latest information and data.

An example of an automatic estimate reached through the ultimate decision of the computer is the following:

< Exports from Japan to USA >

E142 LOG (E#MAT<JPN, USA>) = −4.6082 + 0.6624* LOG (GDP#<USA>),
(1.04)
−1.6411* LOG (PES<JPN>. 1 *FERSI<USA>. 1 / CP I<USA>. 1),
(−5.97)
+0.4377*LOG (SUMT4 (RD#<JPN>. 1)
(1.30)
R*R = 0.9834 DW = 0.5182
SE = 0.161 1976–1999 (MLBM)

< Exports from USA to Japan >

E143 LOG (E#MAT<USA, JPN>)= −7.3445 + 1.2079*LOG (GDP#<JPN>),
(9.31)
−0.3851* LOG (PES< USA>. 1 / PESAME.1),
(−2.08)
−0.3008*LOG (PES<USA>. 1 * FERSI<JPN>. 1 * (1 + CTR@<JPN>. 1 + NTB@<JPN>. 1) / CPI<JPN>. 1))
(−3.08)
R*R = 0.9924 DW = 1.91
SE = 0.050 1976–1999 (OLS)

In the above, which is an example of the method of estimating export functions for developed market economies, the designation E#MAT<AME, AME> indicates a trade matrix; the first AME indicates that the exporting countries are developed market economies, while the second AME indicates that the importing countries are also developed market economies.

The designation <JPN, USA> is an example of estimating Japan's export functions with regard to exports from Japan to the United States. In accordance with time-series data, the dependent variable E#MAT<JPN, USA> is indicated, while explanatory variables correspond to the theoretical model given in Appendix 1 (see *Appendix 1: The FUGI Global Model 9.0 M 200 / 80: Theoretical Model*). Here we have made estimates using time-series data for the years 1976 through 1999. Of course, depending on the countries involved, some of the explanatory variables may be eliminated while others are used, but in the case of Japan's exports to the US, the theoretically optimum combination is the case in which all the variables are employed. It so happens that in the case of the US exports to Japan, all the explanatory variables given in the theoretical model are not always employed. This software system, at the same time that it deals with estimates, checks the appropriateness of the equations so that test results are intelligently revealed. In cases where the estimation results are inferior to expectation, it is usually possible, by such operations as altering estimation time spans or adding new explanatory variables based on newly acquired data, to get parameters that have a better descriptive capability and that give greater precision in forecasting.

Because the structural equations used in the FUGI global model 9.0 M200 / 80 number more than 150 000 / 40 000, it would necessarily be difficult for any individual to make judgments, by mere observation, about such a great number of structural equations. It was for this reason that we developed an intelligent system for carrying out such operations by computer judgment based on expert knowledge.

In such computations it is possible that estimated results may be unsatisfactory from the point of view of both statistics and economic theory, and cannot in unaltered form be satisfactorily disposed of by computer. In such cases, by activating an option program, the computer can find an appropriate means for handling the case in question, sometimes through such operations as taking the "number one explanatory variable" (i.e. the one considered to be the most significant) and comparing it with other variables over the whole span of time for which data are available, or by giving instructions to the effect that other various types of limitations on the process of selection be set in advance.

4. Dynamic Simulation Testing for Verification, Validation, and Accreditation of the Model

4.1. Dynamic Simulation Testing

The structural parameters estimated by the **ESTIMATE** program are automatically filed into the **MDL.DATA** file (simulation model file), together with the relevant equations in the **EQF.DATA** file (model equations file), and the **SLAIMUTE** program may be used for dynamic simulation testing of the model.

Dynamic simulation testing comprises first of all a test to see whether or not the model's system is functioning properly over time. In other words, it is a test of the “fitness” of the data already on file (**RGN**), and (**CRS**). **RGN** denotes the time-series data file for estimating the parameters of the model and **CRS** means the cross-section data file for the simulation purpose.

The dynamic simulation test, for instance, “final test,” would not involve making sequential calculations by taking as initial values the actual values for each year over the period of years in question. But it would use actual values only for the starting year of 1980, after which computations would be carried out sequentially, assigning to each year initial values which are the estimated, not the actually observed, values for that year, based on the computed values for the previous year. By this procedure, a test is made of the degree to which the model’s computed values for the last year in question differs from the actual values for that year. At the same time a test is made of whether or not the model has accurately taken account of the ups and downs in the actual values of such variables as GDP# and fixed investment resulting from changes in economic conditions during the period of years in question. In this way, the degree to which the model can accurately reflect changes in economic variables as indicated by statistical data for past years can to a certain extent be tested by the variables of deviations, for instance, GDP#D (= Actual GDP# figures−Estimated GDP# figures). Every variable of the FUGI global model has a deviation variable with suffix **D** so that the **Automatic Error Correction System (AECS)** might work properly. Therefore, it is reasonably expected that the FUGI global model could behave as if forecasted errors would be nil in the dynamic simulation testing. As a matter of fact, we can identify the confidence level of the model by the degrees of deviation variables.

However, it does not necessarily follow that just because the model may have accurately fit the statistical data of past years it will have the capability to make accurate forecast simulations for the future. With regard to this point, it will be necessary to evaluate the reliability of the model’s dynamic system structure. By repeating alternative baseline simulation tests, or sensitivity tests, they can show whether the model’s forecasts tend to diverge from or converge toward intelligent estimates of future conditions made by experts with the benefit of specialized knowledge. It is possible that such dynamic simulation tests over future years might also reveal unforeseen deficiencies in the model.

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Biographical Sketch

Akira Onishi is Vice President of Soka University, and an economics and global modeling educator. His academic background is in both economics and systems engineering. He received his Ph.D. in Economics from Keio University and his Ph.D. in Systems Engineering from Tokyo Institute of Technology. He had an opportunity to work at the United Nations ESCAP and the ILO, 1966–1970. At Soka University, Tokyo, he has served as Dean, Department of Economics, 1976–1991, Dean, Graduate School of Economics, 1976–1991, Director, Soka University Institute for Systems Science (SUISS), 1990–present, Dean, Faculty of Engineering, 1991–1995, Dean, Graduate School of Engineering, 1995–1999, Vice President, 1989–present. He served as President of the Japan Association of Simulation and Gaming, 1993–1997. He has received many academic awards: International Biographical Roll of Honor to the Global Modeling Profession from the American Biographical Institute, US, 1989, the first Supreme Article Award from the Japanese Association of Administration and Planning, 1991, 20th Century Award for Achievement from the International Bibliographic Centre, Cambridge, England, for Global Modeling, 1993, Excellent Article Award from ECAAR, 1997, Japan Association Simulation and Gaming Award, 1998, and 2000 Outstanding Intellectuals of the 20th Grand from the IBC, 1999. He was selected as one of the First Five Hundred in 2000 for service to Economic Sciences by the IBC. He is well-known as an original designer of the **FUGI** *(Futures of Global Interdependence)* model. The United Nations Secretariat, Department of International Economic and Social Affairs, adopted this model for long-term projections and policy simulations of the world economy from 1981 to 1991. During the period 1985–1986, he designed the Global Early Warning Systems for Displaced Persons (GEWS) under the auspices of the United Nations Independent Committee of Human Rights. The UNCTAD Secretariat has officially adopted the FUGI model for projections of the world economy and policy scenario simulations since 2000. The latest FUGI model as an integrated global model not only provides global information on sustainable development but also on displaced persons or refugees who might become seen as a serious global issue in the twenty-first century.