AN ARTIFICIAL INTELLIGENCE APPROACH TO SOCIO-ECONOMIC SIMULATION: APPLICATION TO THE ECONOMIC INTEGRATION OF EUROPE

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ABSTRACT

It is often difficult to accommodate judgmental information together with quantitative data in an economic model. One approach is to embed human decision-makers as role players within a simulation exercise. Their behavior is recorded by the computer system, becoming a part of the modeling process. We consider some of the human interface requirements to accomplish this integration, a methodology using supervised linkage of spreadsheet with DYNAMO models, and an example of its application toward modeling the 1992 economic unification of Europe.

REQUIREMENTS OF SOCIO-ECONOMIC SIMULATION

Socioeconomic models are likely to be characterized by rapid change and great complexity. Conversational inquiry and update capabilities are necessary for anybody to be able to know what's in the model and make changes as required.

The possibility for group participation is intrinsic to the simulation defined here. Thus access by multiple decision-makers is a requirement.

Governance should be formalized to provide a mechanism for control of competitive behavior among decision-makers. When decision-makers become preoccupied with the short-term antagonisms of their conflict, their policies can deadlock. In principle it may be possible to support a simulation exercise with an anarchistic approach. With one or more coordinators to direct factions of participants, individuals may strive for their particular goals while not interfering with the simulation process as a whole.

There is a need for a common mode of expression. Simulation participants need to spend a maximum amount of time communicating with each other and the computer, and a minimum amount of time in learning new computer technology and software details. This suggests using a well known spreadsheet program as a kind of universal language that most practioners have already learned.

Competition or cooperation is an option to be selected with each exercise. Participants must have a way to control release of the information essential to their individual operations, such that information is shared with collaborators, but restricted from competitors.

There is a need for data privacy. A competitive posture on the part of one or more simulation participants requires the system to respect the privacy of the competitors' strategic information. The need for cooperation among participants imposes a requirement that the system facilitate the sharing of information. Secrecy of information must also be preserved so that regulating authorities' strategies may remain unknown to those being regulated, and that information internal to law enforcement agencies in general not be released to the public.

Modern electronic spreadsheet programs have the capability to accommodate these requirements. In this present study, Lotus 123 and Supercalc5 have been used almost interchangeably.

A SIMULATION INVOLVING TWO COUNTRIES

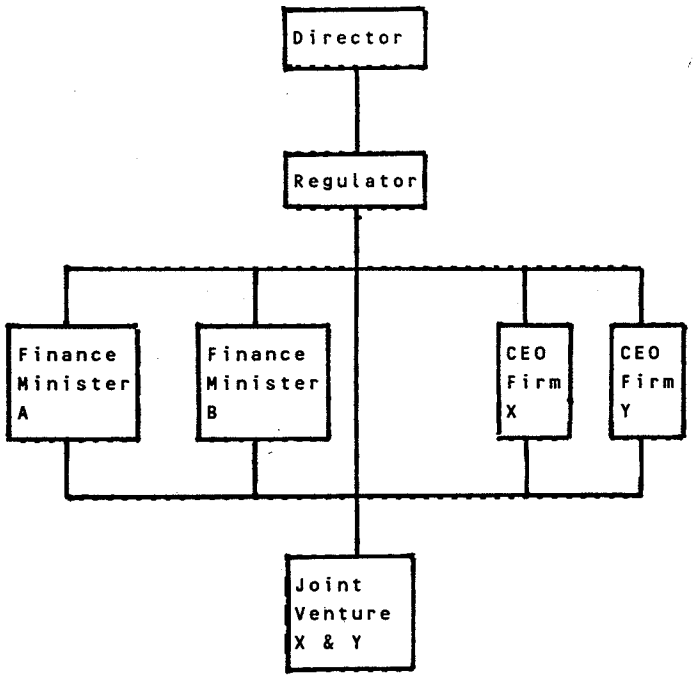

Figure 1 - Organization Diagram of Participants

Figure 1 is an organization chart for a simulation involving two firms in two countries. Complexity can grow rapidly. The Energy Sector might permit representation from the oil, coal, nuclear, power utilities and transportation industries. The Conservation and Environment people can include regional organizations such as the California Air Resources Board, national organizations exemplified by the U.S. Environmental Protection Agency and international organizations such as the International Maritime Organization, World Health Organization and World Meteorological Organization. Other participants might include households and banks.

The model is organized accordingly. Each simulation participant has a reserved private model for which only he and the director may read cell contents. This private area may be a region reserved in the main model, or a special model which is a spreadsheet that can be linked to the main model. For all storage other than this private area, the participant can only read numeric results, and not actual cell contents [formulas, etc.].

Here some variables from the two-country model, displaying internal conditions of country A, together with its trade relationship to country B. Cooperation between EC countries is essential toward making EC 92 work. If one country stimulates its income through expansionary fiscal or monetary policy, imports will rise. Consequently, the exports of its trading partners will rise concomitantly. Table 1 shows dependent variables whose numeric values [only] are available to all participants:

Y	national income
Y(d)	disposable income
C	consumption
r	the rate of interest
X-M	trade surplus (deficit)
S	private savings
S-I	savings surplus (deficit)
T	net tax revenues
G-T	budget surplus (deficit)
X	exports
M	imports
I-I(0)	induced investment

Table 1 - Dependent Variables

Table 2 shows independent variables. Their values are also available to all participants:

c	marginal efficiency of capital
l	liquidity preference
s(d)	sensitivity of the demand for money to changes in the rate of interest
s(s)	sensitivity of the demand for loanable funds to changes in the discount rate
e	exchange rate b/a
C(0)	autonomous consumption
I(0)	autonomous investment
G	government spending
Y(B)	B's national income
t	marginal income tax rate
mpc	marginal propensity to consume
T(0)	autonomous tax revenues
TP(0)	autonomous transfer payments
p	relationship between transfer payments and income

Table 2 - Independent Variables

Strategies and Policies of Participants

The following are independent variables whose cell contents may be read and written by their proper owners. For all other participants only numeric values may be read.

m(A)	A's marginal propensity to import
m(B)	B's marginal propensity to import

Because country B's income is a function of its exports (A's imports) and A's imports are a function of A's marginal propensity to import, changing m(A) will change B's exports and, consequently, its income.

Figure 2 is a sample display screen from the spreadsheet model, showing numeric values only.

	DEPENDENT VARIABLES	
Y	equilibrium national income in country A	2989
Y(d)	disposable income	2194
r	interest rate	10.0738951
C	consumption	1955
I	investment	899
X=M(B)	exports	204
M=X(B)	imports	1569
X-M	trade surplus (deficit)	-1365
S	savings	239
S-I	savings surplus (deficit)	-660
T	net tax revenues	795
G-T	budget surplus (deficit)	-705
	INDEPENDENT VARIABLES	
Ms	money supply	1293
P	price level	1
I(0)	autonomous investment	1000
c	marginal efficiency of capital	10
T(0)	autonomous tax revenues	300
t	marginal tax rate	.4
TP(0)	autonomous transfer payments	850
p	relationship between transfer payments and income	.05
G	government spending	1500
e	exchange rate	5
C(0)	autonomous consumption	200
S(0)	autonomous savings	-200
mpc	marginal propensity to consume	.8
mps	marginal propensity to save	.2
Y(B)	B's national income	10724
Ms	money supply	1293
P	price level	1
l	liquidity preference	.5
s(d)	sensitivity of d for money to the rate of interest	20
	COUNTRY A'S POLICIES	
	Country A Trade Index	105
m(A)	A's marginal propensity to import	.105
	COUNTRY B'S POLICIES	
	Country B Trade Index	95
m(B)	B's marginal propensity to import	.095

Figure 2 - A Sample Screen for the 1992 Example

Table 3 contains statistics that have proven useful for this series of simulation exercises. Unless otherwise stated, statistics given here are taken from the Los Angeles Times. Values of those variables whose names are followed by numbers in parentheses are from the Statistical Abstract of the United States, 1991 edition; the parenthesized numbers refer to the table number.

Variable	Value	Unit
Air Pollution [361]	4.26	$ * 10^9
Air Transport [410]	41.7	$ * 10^9
Auto Sales	8.4	10^6
Budget Surplus [Deficit] [489]	-162	$ * 10^9
Consumer Price Index	135	
Consumption [690]	3235	$ * 10^9
Domestic Crude Oil Production	7.5	bbls * 10^6
Dow-Jones Industrial Average	2912	
Electric Power Production	51.1	mw(e) * 10^9
Investment [690]	716	$ * 10^9
Money Supply Growth [M1]	.072	
National Income [690]	4881	$ * 10^9
Oil Imports	6.84	bbls * 10^6
Prime Rate	.09	
Retail Sales	150	$ * 10^6
Savings [701]	642	$ * 10^9
Tax Revenues [455]	945	$ * 10^9
Water Pollution [361]	4.82	$ * 10^9

Table 3 - Statistics of the Economic Environment

Figure 3 below is a DYNAMO model enumerating a spectrum of industrial and public works projects, ranging from 1 to 20 years in duration.

```
*       CAPITAL IMPROVEMENT PROJECTS
FOR     AGE=1,5/AGE2=2,5
A   TTPOP.K=SUMV(POP.K,1,5)   TOTAL PROJECTS
L   POP.K(1)=POP.J(1)+DT*(STRT.JK-AGOUT.JK(1)-TERM.JK(1))
                              PROJECTS
L       POP.K(AGE2)=POP.JK(AGE2)+DT*(AGOUT.JK(AGE2-1)-AGOUT.JK(AGE2)-
X        TERM.JK(AGE2))
N       POP(AGE)=IPOP(AGE)
T       IPOP=10E3/5E3/1E3/.75E3/.5E3    PROJECTS
                              INITIAL
R   STRT.KL=SCLPRD(STRTRT,1,4,POP.K,2)
                              STARTS (PROJ/YR)
T       STRTRT=100E2/50E2/10E2/1E2/50E-2    PROJ/YR/PROJ
                              START RATE
R   AGOUT.KL(AGE)=POP.K(AGE)/PRD(AGE)
                              PROJ MATURING (PROJ/YR)
T       PRD=1/2/5/10/20 YR    PERIOD SPENT IN A CLASS
R   TERM.KL(AGE)=TERMRT(AGE)*POP.K(AGE)
                              TERMINATIONS (PROJ/YR)
T       TERMRT=95E-2/75E-2/50E-2/75E-2/95E-2 PROJ/YR/PROJ
                              TERMINATION RATE
PRINT TTPOP,POP
PLOT  POP(AGE),TTPOP=T
SPEC  DT=.05/LENGTH=10/PLTPER=1,PRTPER=1
RUN   BASIC
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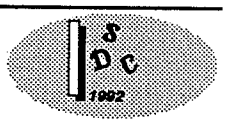
Figure 3 - DYNAMO Model of Capital Improvement Projects



The simulation director is sole custodian of the DYNAMO model and maintains the master spreadsheet. Figure 4 below corresponds to the decomposition diagram of Figure 1. It shows how the participants' spreadsheets are linked to the master spreadsheet through the hidden block.

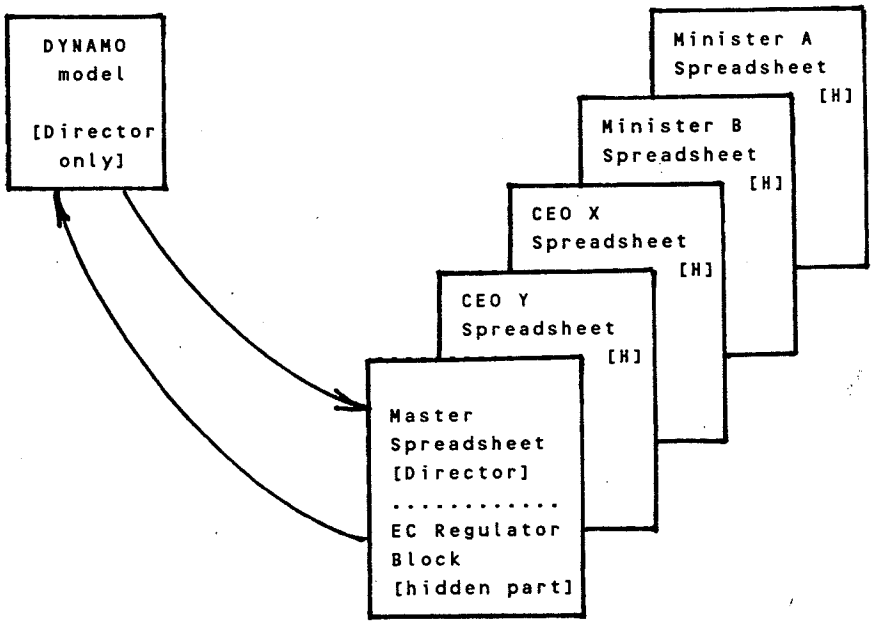


Figure 4 - DYNAMO Model Linked with 4 Hidden Spreadsheets and Hidden Block of Master Spreadsheet

FURTHER PERTURBATIONS OF THE PRESENT EXAMPLE

Within the model presented above, we vary three parameters here. Countries A and B are provided with opportunities to cooperate while improving their respective situations.

Increasing the Value-Added Tax [VAT]. The VAT might be perceived as part of the overall marginal tax rate, cited in Table 2.

Realignment of High Tech or Weapons Trade. Switching sources of weapons products or from weapons to infrastructure might be interpreted as an increase in induced investment.

Realignment of Agricultural Exports. Investment impact here must be viewed as relatively small. The nature of the product is that it is eventually eliminated. Impact on national income cound be positive or negative.

CONTINGENCIES FOR FURTHER STUDY

The following contingencies are of a highly speculative nature, so they are merely suggested for the reader's contemplation while the underlying economic model undergoes further development.

Another Energy Crunch. Loss of income for the economy as a whole, in addition to substantial increase of costs in certain particular sectors, characterize this possibility.

Global Warming. National and international authorities, in conjunction with industry representatives, can experiment with taxes, consumption and costs of correction.

Mobile Desalinization. Under the aegis of a multinational organization, implementation costs of desalinization equipment could be spread over a larger user base, providing greater access to a larger number of people.

A Public Health Crisis. Loss of income in most sectors of the economy, an addition to a substantial increase of household sector costs, characterize this contingency.

RESULTS

This simulation game offers a technique for rapidly presenting participants with challenges to which they must respond, either for survival or for enhancement of quality of life. By offering participants both flexibility and privacy, the game permits cooperative behaviors as well as competition.

Just as citizens' voting behavior would tend to modify the future political environment and military commanders' weapons trade-offs affect all future battle plans, the state of the simulated economy evolves while the system "learns" the behaviors of the participants. Significance of the system's adaptation increases where market effects, substitution of resources, or negotiating and bargaining behaviors are involved.

As the participants and the algorithms gain experience, the system's adaptation to decision-makers' behavioral patterns is incorporated within the simulated economic environment. The result is a truly interactive process, as the model's properties continue to influence participants' behavior and this behavior, in turn, causes changes in the policies and procedures comprising the model.

It has provided a major contribution to our teaching and research activities.

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BIOGRAPHICAL SKETCHES

John Walter's main teaching and writing areas are systems analysis and design. Most of his consulting is in software quality, systems development, data communications, statistics and simulation. John was a co-founder of a multinational computer service firm based in Europe. John holds a DSc in Applied Computer Science from the University of Paris Faculty of Sciences, an MS in Systems Engineering from West Coast University, and a BA in math. He holds the CISA, CDP, and CSP certifications, is a registered professional engineer, and has been elected a Fellow of the Institute for the Advancement of Engineering. He has served as an officer, organizer, and speaker for ACM, DPMA and IEEE, as well as a guest speaker for ASM, the EDP Auditors Association and the Structured Techniques Association. For further information about this present paper, John may be reached at [213] 516-3348 or WALTER@DHVX20.CSUDH.EDU

Carol Lopilato is Professor of Finance and International Business at California State University, Dominguez Hills. She received a PhD in International Finance and Managerial Economics from the University of Southern California in 1980. Her doctoral thesis was a study of exchange rate policy within a monetarist framework in Chile. Dr. Lopilato is writing a workbook which incorporates Lotus 1-2-3 applications in managerial economic decision making. She has served as Associate Dean of the School of Management and was awarded a Fulbright to Ireland during the 1989-90 academic year to study the effects of "Europe 1992."