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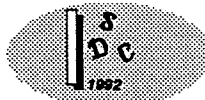
Competition or cooperation is an option to be selected with each
exercise. Participants must have a way to control release of the
information essential to their individual operations, such that
information is shared with collaborators, but restricted from
competitors.

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.
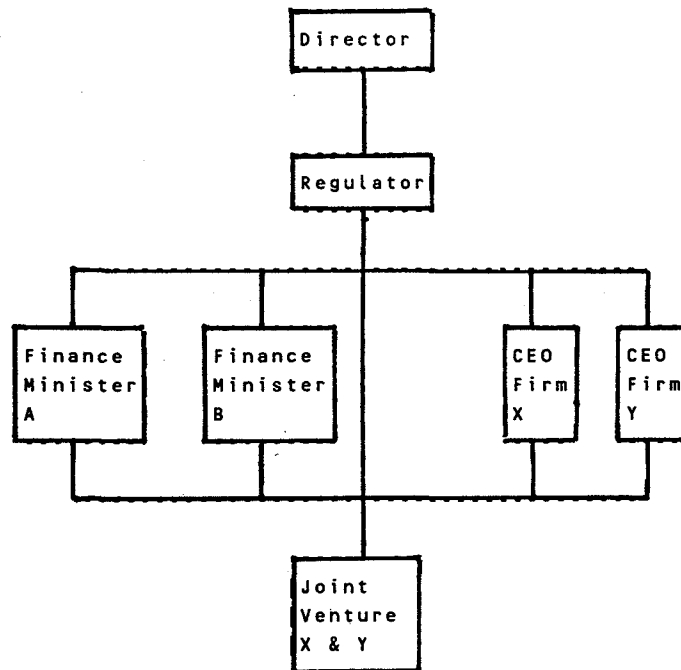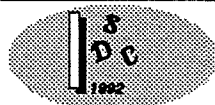

A SIMULATION INVOLVING TWO COUNTRIES

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 <u>dependent</u> <u>variables</u> 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
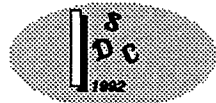

Table 2   -   Independent Variables

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

LINKING SPREADSHEETS WITH DYNAMO

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
```

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.
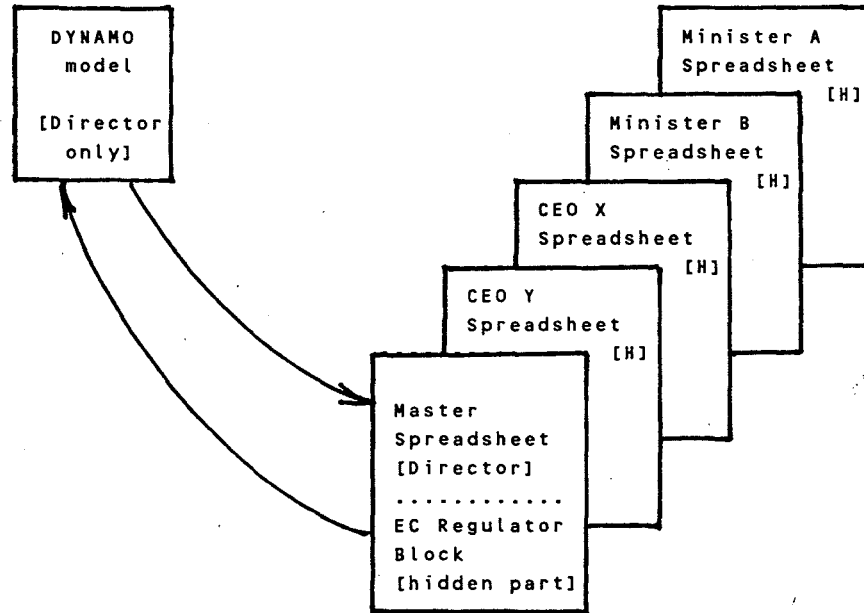

Figure 4 - DYNAMO Model Linked with 4 Hidden Spreadsheets and Hidden Block of Master Spreadsheet

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.
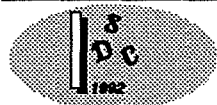
CONTINGENCIES FOR FURTHER STUDY

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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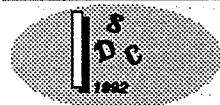
BIOGRAPHICAL SKETCHES

John Walter's main teaching and writing areas are systems analysis
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