TOWARD A REPLICATIVE MODEL OF SOCIO-ECONOMIC SYSTEMS

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> "If an engineer were given the job of predicting how a complicated electrical network would respond as numerous inputs were varied, he would want to know the components contained in the system, the way in which they are interconnected, and the operating characteristics of the individual components. If he were denied this information and given only very aggregative data about how total electric consumption, total power produced, and average voltage in the system varied over time, he might not regard the problem as completely insoluble, but he would certainly feel as though he were working blindfolded with both hands tied behind his back."
>
> G. H. Orcutt et al.

1. AGGREGATION VS. REPLICATION

Today, the situation of economists is very similar to the one of an engineer which is described in the above passage. Because, he is only given the information about certain types of economic aggregates, such as national income, total consumption expenditures and private domestic investment. He will not be given what he really needs for his job ; that is, the data about the operating characteristics of the very components of our system. So, we might say, that he is the economist who is ordered to grasp, while blindfolded, the behavior of our economic system.

Thus far, economic predictions have been based on highly aggregative time series. The essence of predictions of such type is as follows. Instead of taking such basic components of our system as households, we take a theoretical large unit called the household sector. Then we try to establish a formula which expresses how this large unit behaves. That is, we list outputs and inputs. The outputs, for example, are expenditures on durable goods, investments in financial assets, etc. The inputs are what the behavior of the unit responds to ; for example, income, tax payments, financial assets holdings, etc. Finally, we specify operational characteristics which represent the manner in which inputs are converted into outputs.

However, in the actual world, the decision making units are not the household sector but an individual household, and not the firm sector but an individual firm itself. Therefore, it is desirable to build up a model which consists of the conponents of firm and household, and to make predictions based on the assumed actions of and interactions among the

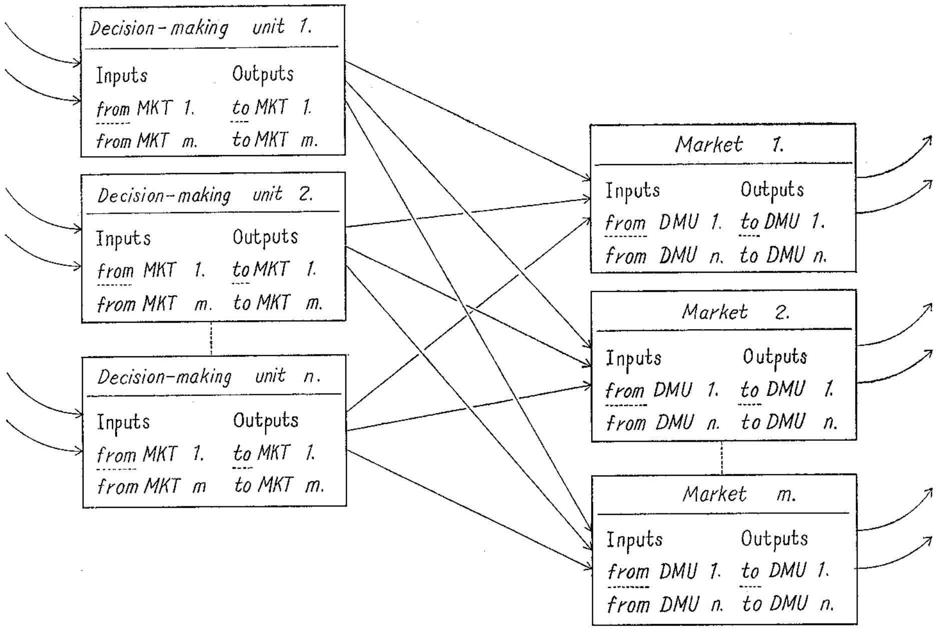

Exhibit 1. A Simplified Network Representation of an Economic System (adapted from G. H. Orcutt et al.)

decision making units rather than those based on the assumption of the aggregate behavioral relationships of the firm sector and the household sector. We propose a replicative method as one manner to construct a model which is composed of the true decision making units, instead of the traditional macro-economic model which is composed of economic sectors. The amount of computation which is necessary to operate this type of model is much larger than in the case of a macro-economic model. Furthermore, an "interaction" type of replicative model—shown in Exhibit 2–a—needs thou-

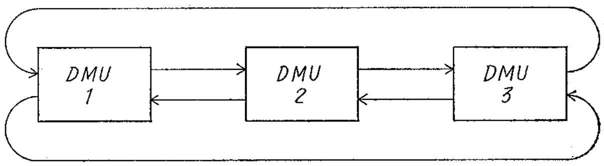

Exhibit 2–a. Incomplete Arrow Diagram for Information Flows in an Interaction Model

Exhibit 2–b. Incomplete Arrow Diagram for Information Flows in a Recursive Model

sands of times more computation than a "recursive" type model—shown in Exhibit 2–b—which considers only one direction of action. For that reason, we must proceed gradually and take several steps before we attempt a design for a complete interaction type model. So we get as the first step the building of a type of "recursive" model—Demographic Simulator.

There is a study by the team of G. H. Orcutt, M. Greenberger, J. Korbel, and A. M. Riblin as a pioneer work. The author's model was created as the follower to this study. In section 2 the author sketches the outline of his model, and in section 3 he introduces some of the results of experiments with the model.

2. Demographic Simulator

Our simulator NTU–III was made to be one of the building blocks for a bigger replicative model. The model of demographic process is indispensable as one of the major parts for a model of socioeconomic system. (see Exhibit 3). The change of size and composition of the population is expressed by what mathematicians call a Markovian process. In the case of a detailed population model like ours, the Markovian matrix—transition matrix—is very large.

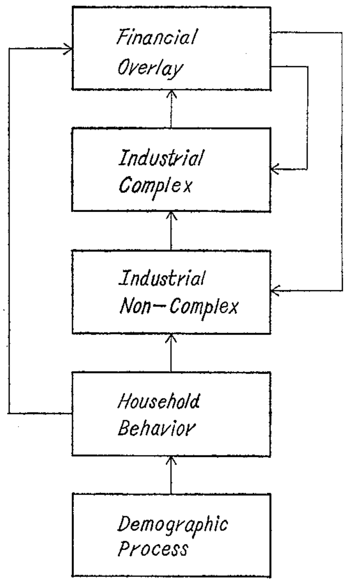

Exhibit 3. Building Blocks of a Suggested Comprehensive Model of Replicative Type

In the case of NTU–III, one word in a file stores data concerning an individual who is described by one of 8 status variables A, B, ···H, in Exhibit 4. The number of crossclassification cells is equal to the number or behaviors which an individual has. That is product of the number of values which each variable would take, and is about 10^{10}. NTU–III is built to process a population the size of which is approximately two hundred thousand to five hundred thousand. The hundred million Japanese population is reduced to one five-hundredth, that is the sample of two hundred thousand size, which is called initial population. Starting from it, the computer produces the yearly change of population and finds the annual total of labor supply. Therefore, the number of states which the entire population would have is the number of ways to distribute the entire population into each cell; that is $\sum_{N=20\times 105}^{50\times 105} N\times 10^{10} > 10^{17}$. Although it includes states which could not possibly happen in

<table>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td></tr>
<tr><td colspan="6"></td><td colspan="6">A</td><td>B</td><td colspan="2">C</td><td colspan="4">D</td><td colspan="3">E</td><td colspan="2">F</td></tr>
</table>

A: age: 0～56
B: sex; 0 (male), 1 (female)
C: school and occupation;
 0 (graduated middle school)
 1 (high school)
 2 (completed higher education)
 3 (agricultural engagement)
D: location of employment; 0～15
E: location of birth; 0～15
F: marital status; 0 (unmarried), 1 (married)

Loc. No. 0	Hokkaido	Loc. No. 8	North Kinki
Loc. No. 1	North Tōhoku	Loc. No. 9	Hanshin
Loc. No. 2	South Tōhoku	Loc. No. 10	Kii
Loc. No. 3	North Kantō	Loc. No. 11	San-in
Loc. No. 4	South Kantō	Loc. No. 12	San-yo
Loc. No. 5	Hokuriku	Loc. No. 13	Shikoku
Loc. No. 6	Chūbu	Loc. No. 14	North Kyūsyū
Loc. No. 7	Tōkai	Loc. No. 15	South Kyūsyū

Exhibit 4-a.

PARA (A); Age-specific mortality rates table.
PARB (BA); Age-specific birth rates table for male and female child.
PARC (CBHE); Career parameters, (0B 0E); for entrance into high school, (0B 1E); for engagement into agriculture after middle school graduation, (1B 0E); for entrance into higher-education, (1B 1E); for engagement into agriculture after high school graduation, (30E); for departure from agriculture, (41E); for re-entrance of married woman.
PARD (BA); Age-specific marriage rates table.
PARM (CBED); Migration parameters, (0BED); after middle school graduation, (1BED); after high shcool graduation, (2BE); after higher education, (30E); after departure from agriculture.

Exhibit 4-b.

reality, it is nevertheless impossible to store an astronomical size transition matrix like this.

After all, it is practical to store 10^5 individual records rather than 10^{17} behavior probabilities. That is the reason for us to prefer replicative simulation of the "Monte-Carlo" type to the usual analytic method. Exhibit 5a and 5b show the block chart of NTU–III. The records of an individual are taken in turn out of the file by a program named PROCESS and is scrutinized by a DEMOGRAPHIC routine or an ENTRANCE routine. In any given case, these subroutines make a "decision" with help of the RANDom routine and the Table Look up routine. In the concrete, DeMiSE

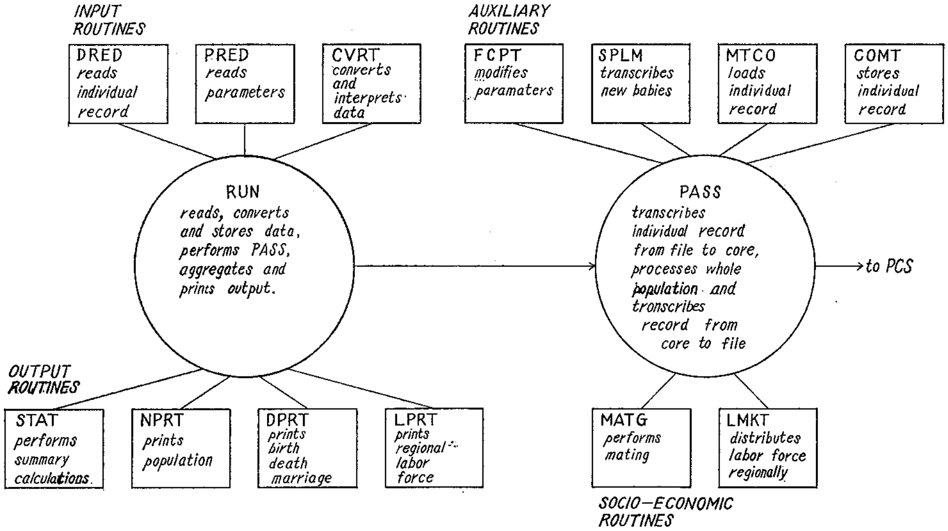

Exhibit 5-a. Block Chart I-Model NTU-III

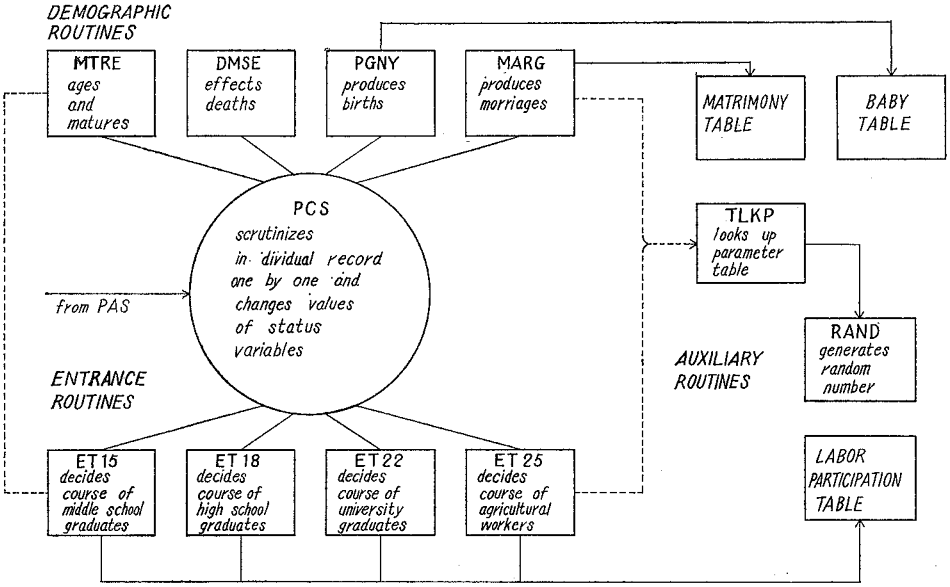

Exhibit 5-b. Block Chart II-Model NTU-III

routine decides whether an individual dies or not in a given period. ProGeNY routine decides whether a woman gives birth to a boy or to a girl. MARriaGe routine decides whether marriageable men and women are included to the group of prospective brides and grooms or not.

As far as thinking of population and labor supply, there is no input except a parameter which is the index of trend change. In short, there is

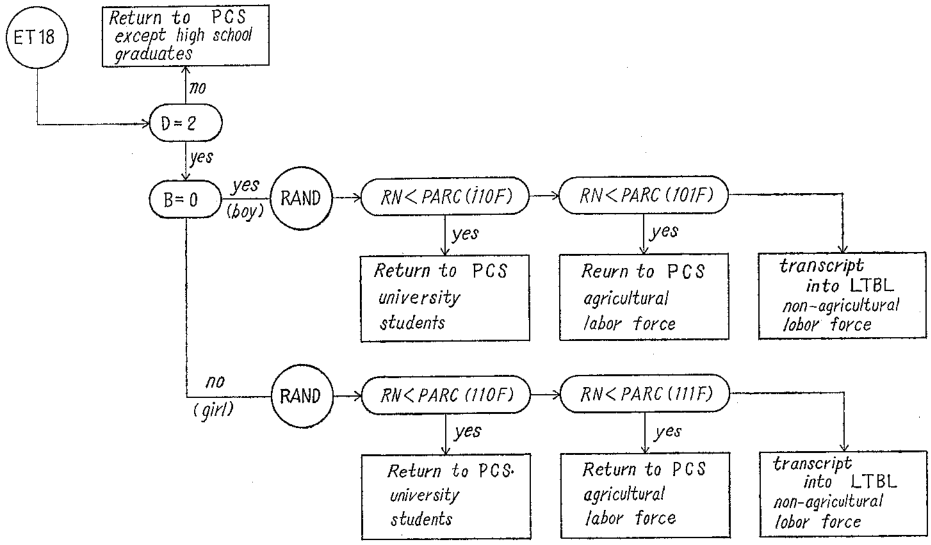

Exhibit 6. Flowchart of Subroutine "ET 18"

no possibility for output of one unit to come in as input of another unit, so that there is no need to think of interaction except in the case of coupling in a table of prospective brides and grooms. Therefore, we only need to think of a relation between status variables and of a relation between status variables and output variables. Exhibit 6, which shows subroutine ET–18, one of the ENTRANCE routines, has the function of deciding high school graduates' ways-whether they are going to colleges or universities or to find jobs. It is the substance of one period of operation to take an individual record out of a file, to process it in regard to the entire population, and to return it to the file. This is called a "PASS". It is the substance of an experiment to do the PASS for prescribed number of periods, called the pass count, and to compile and print the results. This is called a "RUN".

WHAT OUR EXPERIMENTS SHOW

One of our simulation tests shows a curve which predicts Japanese population over some two hunred years. In the beginning, it rises for a while, but later it descends in a gradual slope, and at the end the curve is becoming flat.

Shown in Exhibit 7–a and 7–b is a special solution of a system in the case of a certain specific combination of initial conditions and parameter values. According to it, about one hundred million, or the present population, will continue for approximately a hundred years. Then, it will decrease suddenly. For the next 150 years, it falls to the level of 90 million. After

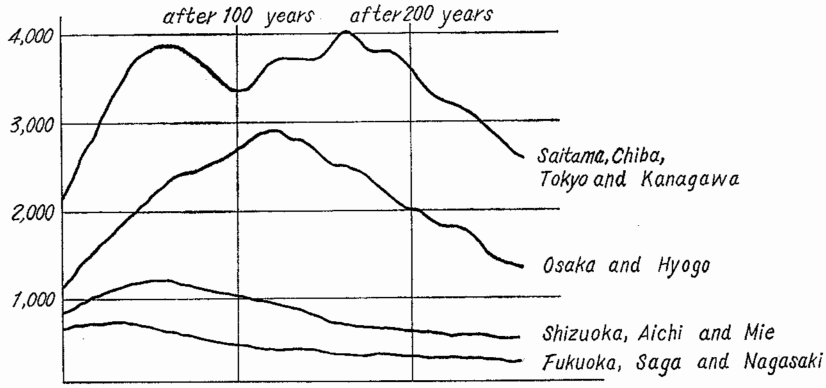

Exhibit 7-a. Population by Region: Simulation Test by Parameter Set 301-2 (fixed)

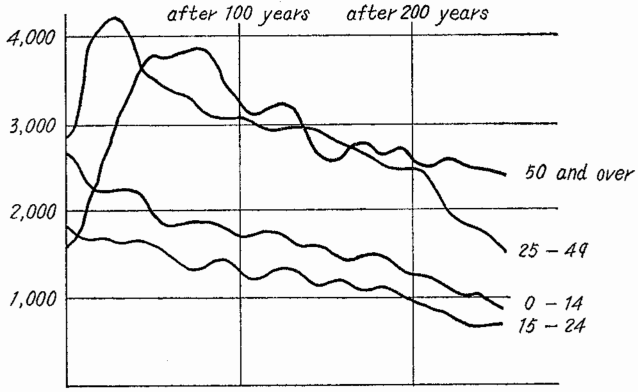

Exhibit 7-b. Population by Age Group: Simulation Test by Parameter Set 301-2 (fixed)

200 years, it drops down to the level of 70 million and, 300 years later, it reaches 45 million which is less than half of the present population.

For example, the population in Tokyo and its outskirts swells rapidly and 50 years later it nears to the level of 39 million, which is close to twice the present population. After this, it will once descend. 160 to 170 years later, the population reaches a peak above 40 million. Thereafter, it decreases along with the diminution of the total population of Japan; 300 years later, it settles down to the level of 23 million.

Many demographers have already noted the coming drastic change of age composition of the population in Japan. Our simulation tests also gave extremely different curves according to age group. As shown in Exhibit 7-b, the group of people under 14 years old shows a very sharp downward curve, and the group of 15 to 24 shows a descendent curve next to the first group. Also the group of 25 to 49 turns to a downward curve even though it shows an upward trend for about 30 years. Finally, the group above 50 years old shows a steady rising curve. It comes near the level of 40 million and holds this condition for a while, but 30 years later, as the total population begins to decrease, it turns out to show a gradual descendent curve. Also the rate of entering to high schools, colleges and universities, is increasing steadily. Thus, we are led to the conclusion that a shortage of labor supply of young people will be keenly felt.

Of course, we should not consider that simulation result to be anything other than the possible outcome which would occur under the assumption that the conditions were kept as they are now. Of course, the computer can only process given propositions analytically. The above mentioned result explicates the conclusions which are developed by the three conditions that the rate of birth is small, that the rate of entering higher schools is high, and that the rate of migration among regions is large. It is not that we believe that, in reality, these conditions will be kept as they are now. They, of course, will change themselves. Therefore, we forecast not their changes themselves but the result which the changes would bring.

Computer simulation opens vast possibilities for various interesting experiments about how diverse combinations of the parameter change affect future population. For example, computer simulation estimates how the compositions of populations change in the future as the average age of marriage decreases a little, or how labor power supply is changed in the future as the rate of entering schools increases.

It is possible to have sensitivity tests by performing series of experiments systematically. Among the parameters, some give comparatively large influence to the result. It is also possible to find out which parameters should be under detailed, big-budget investigation and which parameters need not be. Good estimates of parameters and sufficient data about their time-change characteristics are needed for a good simulation to be made. In the present situation, available statistical sources are very few and limited. It is necessary to develop greater data support for our type of models. In the next part, I will explain what actually should be organized for the data support.

Finally, let me conclude this part by adding a few words about policy-experimentation. A parameter such as the rate of birth is ordained by not only the income level but also the mode of living or the cultural characteristics in a certain society. It is still unknown to what extent a parameter like this is controllable by means of policy. On the other hand, a parameter such as the rate of interregional movement has a comparatively large ability to be controlled by policy. On the assumption that the rate of migration among regions is possibly changed by policy instruments, it is very important to confirm by experiments how the population by age group or the labor power by age group are affected by changing the rate of moving among regions.

Actually, the current chief topic is what to do to the regions where population effluence is extreme. In our experiments, the low birth rate and the tendency of finding employment outside of the native regions have an implication that the populations of the Tohoku, San-in and similar districts would become close to zero. It is a major problem in the future how the nation would use its land as a whole. I do not believe it is right to think that the future development pattern in Tohoku or San-in districts is already set by what is called locational advantages. Computer simulation should be used to release us from the fatalism that the course of future events has already been arranged.

Need for Unified Information Systems

E. Hearle and R. Mason give some useful ideas about what should be the information system in the '70s for many local government bodies in the U.S.A. As is well known, the local government offices in the U.S.A. as well as in Japan have various kinds of data files. But considerable parts of them overlap between branches. Most of the data is concerned with the people and the material resources in regional circumstances. They are common to all organizations of the same region. Hearle and Mason suggest setting up unified data handling centers, at least one in each State, in order to standardize the data and to keep it in concentrated custody and to entrust all kinds of data processing to large scale EDP.

It should be noted that the words Unified Information System limit the purpose of this system. It is possible as a principle to unify the data processing without changing present institutional situations of self-governing organizations or administrative institutions. And it is desirable that this center does not give influence the political or administrative position of the organizations. Each self-governing organization can have its own political vision, and can make its own independent decision. In other words, each organization gives concrete form to its predictive activity and the information system receives from it the prescriptions and performs the data processing, programming and computation for it. In short, the system offers three services. The first one is to store the data, the second is to process various kinds of data in accordance with the instructions of the participant organizations, and the third is to provide the processed information.

In order to extend the scope of activities of the system in the future, it is desirable to gather more data than that which is stored at sresent by each participant organization. But there remains a problem and it will be important. It is necessary to lay down legislative rules which are considered with great care about confidentiality. Many ways to keep the files confiden tial have been designed. One of them is for a competent supervisor to hold the keys to the terminal station. Another one is to request a special code for the message which is sent to the center from each station for a job utilizing individual records in the file.

Anyway, it is certain that machines follow rules better than human beings do. Another merit of the system is that it is considered easier to control gathered than scattered information. Today we do not believe in wire tapping and we feel easy after sealing envelopes. We have no worry about personal secrets in medical doctor's files or about the fairness of the courts of justice. In accordance with these, it is not only visionary to imagine a giant scaled data bank which gathers information about individuals, families and enterprises, performing all kinds of calculations, and for the public benefit.

If the problem of confidentiality is solved and large scale information systems are implemented, there will be vast possibilities for economic research, which is impossible at present. Let us consider the case, for example, that the Employment Security Section and the Education Section plan in their respective ways to collect some data about the same inhabitants. If we could compare these two groups of data with each other, interesting interrelations between them could be extracted from them. A computer is the most suitable instrument to do this work, because it extracts the results from personal data according to the instruction which was given. It never has personal interests.

It is only a slight difference that many unified information systems are made for government offices and that some private enterprises or individuals use them. The research staff of enterprises do not only gain the statistical data as soon as possible but also use the data items individually, that is, perform simulation of replicative type. It will be possible to construct a model which bears no resemblance to those of the past. That is, by putting an appropriate sized sample, which is taken out of an individual's data, into buffer storage—for example, in tapes—and by specifying operations characteristics for each type of individual unit, it will be possible to carry out the simulation experiments.

G. H. Orcutt and his team, the pioneers of this type model, suggest as follows: "Predictions about aggregates are needed, but they should be obtained by aggregating behavior of elemental units rather than by attempting to aggregate behavioral relationships of these elemental units. That is, aggregates should be obtained from a simulation of the real system in a fashion analogous to the way a census or survey obtains aggregates relating to real socio-economic systems."

In general, the work called economic forecasting is divided into two parts—collecting and processing of data, and designing and building of predictive models. we propose to concentrate and mechanize the former part as possible, and to entrust the choice of model design to each governmental or private institution, firm or individual. Those various decision makers should have not only freedom but also obligation in order to choose their own way of prediction about future. This is the crucial point which we wish to stress here.

Effort for Linguistic Extension

By the way, what kind of norm is expected of individuals and enterprises in the coming "computerized" society, where "time distance" will be shortened for the circulation of material and information? As it is well known, the ancestors of our profession developed the standards of conduct for individuals in the modern industrial society. And they asserted that we were able to entrust the private individual with important economic decisions. Their conclusion is that, it is possible to realize a collective purpose which is never the intention of each individual as far as he does his best to pursue his own gains. It would be a matter of concern in every society to think out the conditions for individuals and enterprises to make rational decisions even though laying aside that classical harmonization theory of an invisible hand.

The question of making rational decisions is nothing but the question of reasonable prediction of the future, whatever meaning we are to assign the word, "rational". And a prediction about a social development depends upon the understandings of social rules. But there is a great distance between the understandings by the classical social scientists about the characters of the social rules and the current understandings.

It is clearly explained in a paragraph in the book by a famous Japanese scholar of economic doctrines, Dr. Yoshiya Takashima. "Natural scientists intended to discover an order which governs celestial objects and living creatures. The classical economists took the same manner. They intended to know what kind of rules governing there···Adam Smith did not regard the society as an organism, but observed it by regarding as an exquisite clock···And his eyes focused to one point whatever is natural in the society, that is the natural order of economy." This passage shows well the intellectual atmosphere of the era when the classical social sciences—political economy, jurisprudence, sociology—were born one after the other. If the economists in the 18th or 19th centuries had come across words like "Social Engineering", what kind of study could they have imagined? They might have imagined the final state in which man had at last hit upon the fundamental mechanism of human society and had succeeded in controlling its movement at his will.

However, we, descendants of them, never venture to establish the fundamental law of socio-economic system. We know it is impossible to hope that many people will agree about what is the "fundamental" rule which governs the social development. From a modern view point this agreement is not only impossible but also unneccessary for well-being of a society.

The job of classical social scientists was to discover an "objective" law of human society, but the job of social engineers in the 20th century is to design and to construct a "subjective" simulator or model for us to help understand social circumstances. Social engineers are not passive observers, but belong to a sort of tribe as active "designers". And, we might add to this, what they are going to design is "linguistic" as well as "organizational" construction.

Broadly speaking, there are three ways to solve economic problems for human society. One is "silent repetition". That is to keep our ancestral manners strictly and to obey the customs and the traditions without argument. A variant of this method, assignment by inherited social status, played a central role in the history of mankind. The second method is to let "things" have the role of "words". That is, to make a symbol, which is made of gold or silver, works as an intermediary among individuals and help them to make economic decisions. When we exchange goods and services with the help of money, we follow this second way. When classical economists argued the workability of the price-mechanism, they defended this second method against the first one. As the third type, there is a solution by conversation. By communication through words, we solve the problems like what and how much we are going to produce within our capabilities, and how and when to consume it. Although our daily languages are useful enough for the discussion of utmost 10 to 20 persons, they are useless to exchange the opinions of hundreds or thousands of people. Because, our daily languages are too vague and too multivocal to convey the precise contents of any economic plan or program. Therefore, we believe it is better to create the variety of systems of "symbolic and artificial" languages that is expected to carry out the role which money has been taking in order to solve society's economic problems.

Those symbolic and artificial languages are, in a way, a realization of the dream of "Ars Combinatoria" or "Mathesis Universalis", which was once conceived as an ideal of language by Descartes and Leibnitz. Our endeaver toward "replicative" simulation is akin to their efforts. For, building up a new type of model is nothing but to invent an artificial language. There are a lot of difficult and unsolved problems before our goal. But we are desirous of proceeding step by step with hope.

References

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2. The Author's Papers in "Sūrikagaku", April, 1967 and January, 1970.