Exploratory Model Building

Toward Agent-Based Economics

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"The social process is really on indivisible whole.
Out of its great stream the classifying hand of the investigator artificially extracts economic facts.
The designation of a fact as economic already involves an abstraction,
the first of the many forced upon us by the technical conditions of mentally copying reality.
A fact is never exclusively or purely economic."
——— *Joseph A. Schumpeter [1]*

1 Introduction

The economic model is always an abstraction from the real economy, and will not be perfectly completed as long as any kind of models. There is possibility to deny the model by new observations at any moment, because of the nature of scientific models that are just valid to the past experience[2][3]. Especially in the social science, the models are exposed to the fact that individuals and society, which are targets to be modeled, make changes very often. It is caused by the abstraction at high level in social science. At the viewpoint of systemics, the rules on the layer would be changed by the emergence occurred from the lower layer. Thus, the economic model should be well pliant to change as the target changes.

On the basis of the above, we are now developing a platform that provides the extensible economic model. It is called "Boxed Economy Model", which is an artificial economy model for the agent-based economic simulation to make predictions and explanations of the real economic movements in the entire economy [1].

In this paper, we outline the procedure of model building method for the agent-based economic simulation, especially for Boxed Economy Model. The argument is based on the agent-based model, but it can be also applied to other social simulations.

2 Exploratory Model Building

To make a social model, the detail of the target model is understood during the process of making and simulating the behaviors on the computer, because of the complexity of the target. This incremental approach by trial and error is called *constructive method* in the science of complex systems[6]. In many cases, most parts of social models are not always understood and proven. Thus the researchers should build *ad-hoc* models and then improve them better and better. In consequence, the hypotheses, which are contradicted each other, often coexist for long time in social science [7].

The researchers would choose some simulation models by exploring in all possible combinations of the alternative model components, before they make the simulation for the prediction and the analysis. As a beginning, we would like to suggest that we should divide simulations study into the model building process and the application process, while many studies deal with them together. In this paper, we focus on the model building process, and name it *Exploratory Model Building*.

Exploratory Model Building is divided into the four phases after the fundamental procedure of conventional econometrics: model building, model specification (specification of initial settings), parameter estimation, and model validation[2]. What is important here is that the iterations of the whole phases are necessary for the Exploratory Model Building. After the confirmation of the model to some degree through these phases, we can apply it to the prediction, the structural analysis, the experiment on the computer. In the following sections, we would like to consider these four phases.

[1] See the reference[4][5] and our www page (http://www.novel.mag.keio.ac.jp/boxed-economy/) about the detail and the engineering aspect, for example object-oriented modeling and framework design for reuse and extension in the agent-based economic simulation (*boxed-economy@novel.mag.keio.ac.jp*).

[2] To test the fitness of the model to the reality is called "validation" here by course of simulations study, while it is called "verification" in economics. In the usage in simulations study, "verification" means testing the correct coding from the model to the computer program.

3 Model building

The simulation model is divided into module components at some levels in Boxed Economy Model. First, the economy model is composed of *Agent Model Components* and *Relation Model Components*. Agent Model Components are the models of economic actors, for example, consumers, corporations, banks, and government. Relation Model Components describe the relations among the agents, for example, personal networks, corporation networks, goods markets, and labor markets.

Second, the Agent Model Components and Relation Model Components are composed of *Algorithm Model Components*, *Meta-Algorithm Model Components*, and *Adaptive Components*. Algorithm Model Components are modeled the concrete actions of the agents. Meta-Algorithm Model Components describe the procedure to call the concrete algorithm. Adaptive Components are for learning modules like neural networks and artificial intelligence.

4 Model specification

Model specification is the phase to set the initial values at known parameters by the surveyed data and experimental data. There is no realistic constraint in the simulation world. Due to this, we have to assign the realistic limitations that exist in the real economy.

5 Parameter estimation

In the standard method of conventional econometrics, the relations among the parameters are estimated by the regression analysis. The coefficients are assumed by the quantities of the observed values (Figure 1: Left). It can be called *inductive estimation*.

On the other hand, in the method of simulational econometrics, the parameters are estimated through the enormous number of simulation runs with different settings. We can observe the behavior of the model by setting the concrete initial value temporarily, although it is difficult to understand analytically the complex subjects. This way to understand has grown out of the science of chaos, complex systems, and computer simulations. The combination of parameters to generate similar behaviors to the real economy is selected after the simulation (Figure 1: Right). It can be called *deductive estimation* [3]. As well as the parameters, the models can be obtained by the deductive estimation. There are an enormous number of the combinations among the models and the parameters. The criterion of the validation is discussed in the next section.

[3]See the reference [8] [9] [10] about the example of deductive estimation. It is estimated the relation between the local and the global influences for the agents to choose the video format.

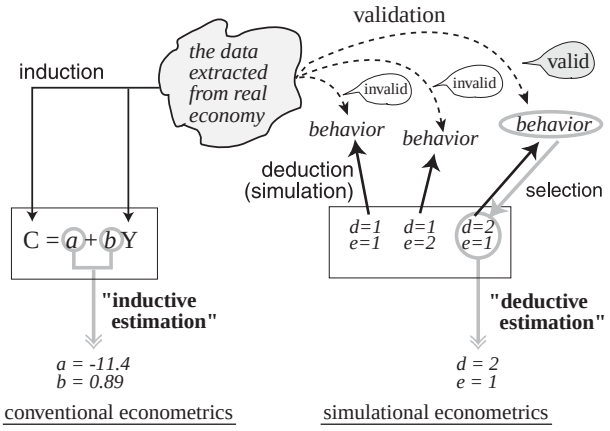

Figure 1: The parameter estimation method of the conventional and simulational econometrics

6 Model validation

Lots of methods about the model validation are studied so far, because there is no direct measure of the distance between the model and real world [11]. Three methods of validation are shown here:

- Comparison with observed data

In the context of economics, the predictability is often used as the validation by interpolation and extrapolation test of time-series trajectories. Because it is necessary to trace the past, especially time-series trajectories, in order to make the prediction of the real economy. The examples of time-series trajectories are gross domestic product (GDP), consumer price index, production index, producers' inventory index, wage index, savings rate, unemployment rate , Engel coefficient, and so on.

- Comparison with other economic theories

Another kind of validation method is compared with the other simpler models known in economics [11]. We can apply the macroeconomic analysis to our artificial economy as well as the real economy. For example, the coefficients of the consumption function and the production function can be estimated and compared with those of real economy in order to validate the model.

- Comparison with empirical tendencies

Little attention has been given to the validation by empirical tendencies of the real economy, for example fractal structures, chaotic behaviors, and self-organized criticality. They are studied in the science of complex systems and "econophysics" [12]. The power law distribution, for example, is observed at the relation between the size of corporation and its rate of growth[13]. And a part of the personal income dis-

tribution is described as the power distributions [14]. The relation between the size and the rank of citis is known as self-organized criticality. In economics, Gini coefficient, Lorenz curve, Phillips curve are also known as the economic tendencies .

7 Total Flow of Exploratory Model Building

We are now ready to look at the total flow of Exploratory Model Building process in order of time (Figure 2).

1. The researchers prepare for several kinds of model components.
2. The researchers assign the combinations of components and each descriptions about the parameter ranges and the increments.
3. The researchers prepare for the data set for model specification and model validation. And they assign the ranges and increments of the each parameter and the random seed.
4. Agent and Relation Model Components are built by combining a Meta-Algorithm Model Component and some Algorithm Model Components. Here is the start of the model composition loop [**Model building I**].
5. A social model is built by composing the Agent and Relation Model Components [**Model building II**].
6. The parameters are set at the corresponding observed data as the initial values. The model and these parameters are temporally fixed during the model composition loop [**Model specification**].
7. The unknown parameters are temporally set at the values within the assigned ranges. The round-robin match of all possible combination is processed as the parameter estimation loop. The parameters are temporally fixed during the parameter estimation loop [**Parameter estimation**].
8. The random seed for pseudo-random number series is set at the values within the assigned ranges. The random seed loop is started from this step.
9. The simulation with settings assigned above is executed.
10. The model validations are executed [**Model Validation**].
11. Go back to step 8, if the random seed loop is not finished.
12. Go back to step 7, if the parameter estimation loop is not finished.
13. Go back to step 4, if the model composition loop is not finished.

The 5th to 13th steps can be executed automatically, even if the researcher prepares for the assignations at the 1st to 3rd steps. Through the Exploratory Model Building process, the models and the parameters that are valid to the assigned conditions are obtained.

8 Conclusion

In this paper, we proposed the Exploratory Model Building process for the agent-based economic simulation. The agent-based economic simulations have the possibility for a novel forecast technique, which combines the macroscopic and the microscopic dynamics of economy [9]. In other words, we can estimate the micro-level parameters from the macro-level parameters, and vice versa, because the artificial economy is actually built on the computer. In this paper, we discussed the method for building models before the application process.

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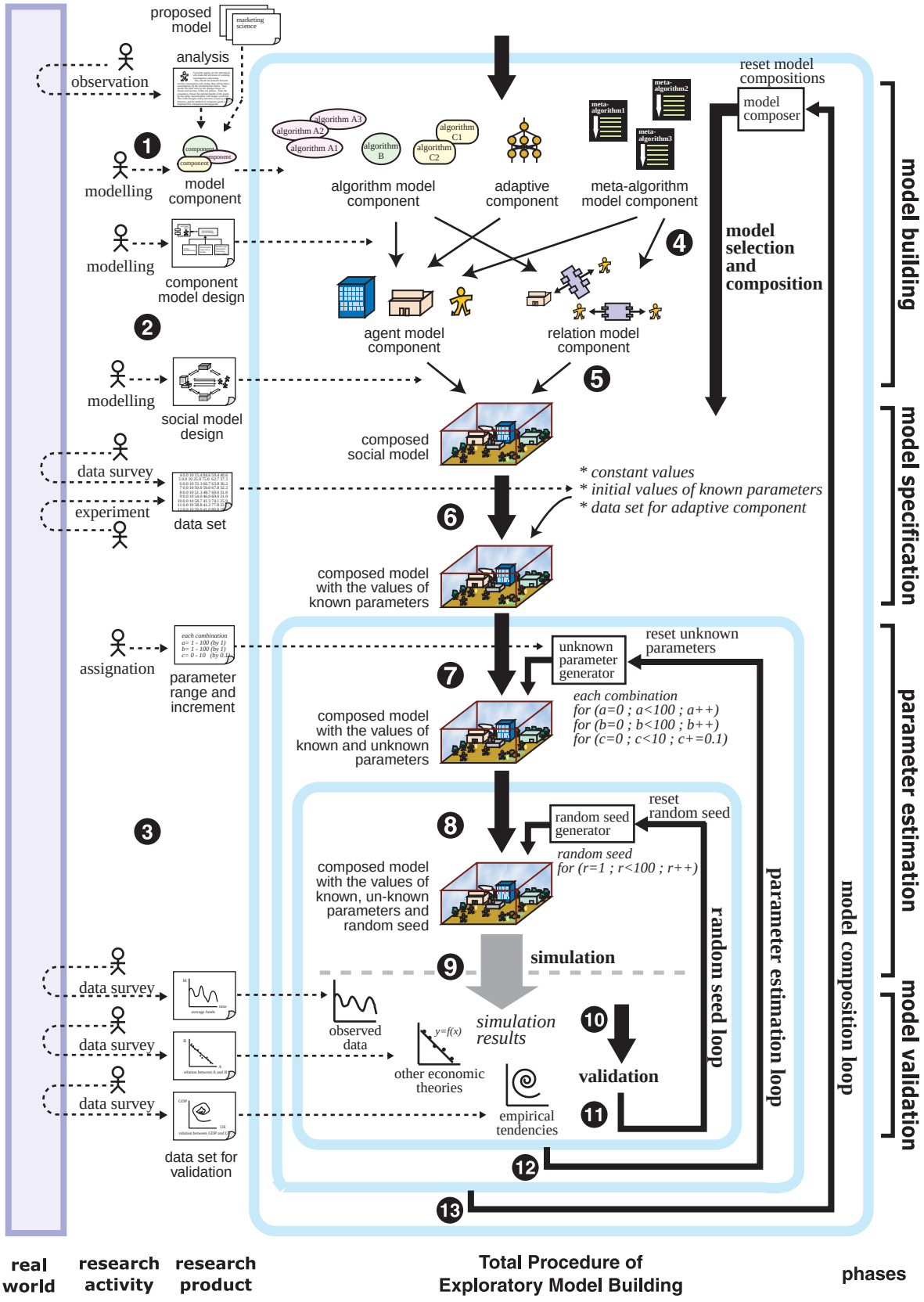

Figure 2: Exploratory Model Building Process