ECONOMIC CYBERNETICS

An Equation-Based Modeling and Agent-Based Modeling Approach

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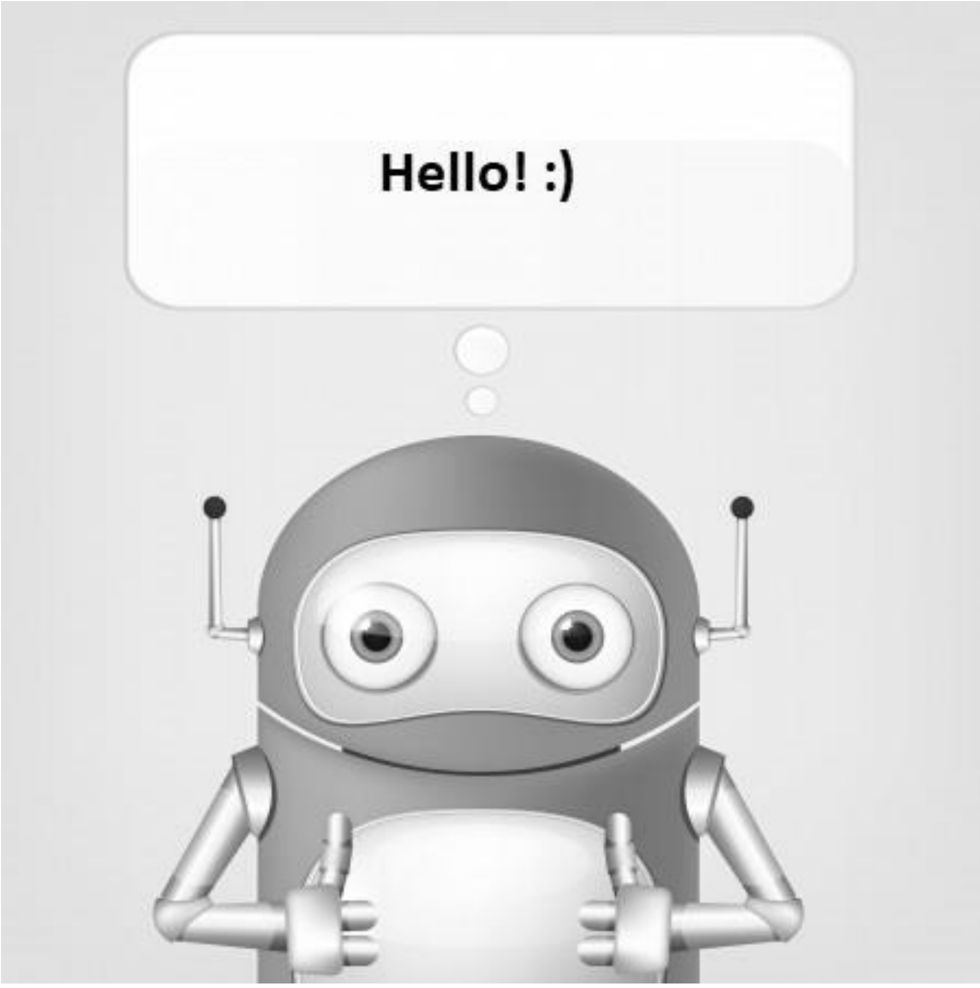
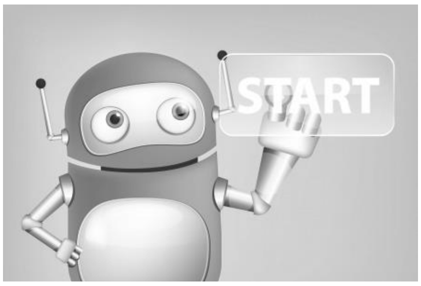


COCO will guide you through this book, making your adventure more comfortable.

INTRODUCTION



The present book is intended to come to the attention of the researchers, teachers, practitioners, students or any other persons interested in fields such as: cybernetics, systems science, economics, modelling, forecasting, etc. due to the fact that it provides the necessary framework and tools for the knowledge and understanding of the aggregate phenomena that one may encounter in economic real-life situations.

The first chapter of the book is focusing on the economic modelling and it starts with a discussion on the similarities and differences between the simple and complex systems. Based on these, the authors are presenting the types of variables implied in the modeling process and the criteria needed to be satisfied by model in order to be valid.

The second chapter is dealing with the equation based modelling and, considering the literature, several models used over time in economic cybernetic modelling are presented step-by-step, such as Harrod's growth model, Solow model, Black box, Malthus and Verhulst. A series of numerical applications are proposed here for a better understanding of the selected models.

The third chapter is moving to the agent-based modelling done with the NetLogo 6.0. software. Here, the types of agents are explained and the distinction between randomness and determinism is discussed and analysed based on the existing literature.

The forth chapter is continuing the agent-based modelling with NetLogo 6.0. by presenting the interface and the code sections provided by the software. More, a large review of the models created in NetLogo is provided based on a series of papers indexed in ISI Thompson database. Additionally, a model created in NetLogo by the authors is brought to the readers' attention. This model uses one of the newest intelligent-artificial technique, namely the grey systems theory for shaping the variables and the relation between the agents.

The fifth chapter is dealing with the parallel between the equation-based modelling and agent-based modelling. For this, the authors are considering some examples solved with both methods with the purpose of showing the advantages and disadvantages brought by each of the considered methods. In the end, a short summary of pros and cons is presented along with some suggestions about how to decide which method is better considering the situation one decide to model.

The book ends with a discussion and quizzes section and references.

Hoping that you will find the material useful, we wish you a pleasant reading!

Acknowledgements:

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1st Chapter

ECONOMIC MODELING

1.1. Simple vs. Complex Systems

Erdi (2007) describes a system as “a delineated part of the universe which is distinguished from the rest by a real or imaginary boundary” which wield a particular influence on the environment and, in the same time, is influenced by the environment (Érdi, 2007)– see Figure 0.1.

Figure 0.1 The relation between a system and its environment

On the other hand, the International Council of Systems Engineering (INCOSE) suggests that a system is a construct or collection of different elements that together produces results not obtainable by the elements alone. The elements can include: people, hardware, software, facilities, policies, documents, etc. (“Wiley,” n.d.)

Some examples of systems: the Romanian economy, the solar system, the human body, a household, the market for apples, the flow and distribution of water in the Danube delta, the person reading this book is a system, so is everyone else, etc.

In general, we can have the following types of systems:

- Physical or notional with regard to the existence or inexistence of such a system;
- Open or closed systems when considering the interactions such system can have with the environment. Ludwig von Bertalanffy (Bertalanffy and Sutherland, 1974) believes that the majority of biological and social systems are open systems. Also, thinking on the great majority of systems that surround us, we can easily see that most of them are open. Let’s take for example a piece of stone. First, we can say that its shape is preserved by the inner sub-systems force and can be disintegrated by rupture. Further, let’s consider that the piece of stone has the same shape no matter what happens in the environment. Do you think that in this case the stone is a closed system? (when making the answer, you should keep in mind that even though the shape of the stone stays the same over the time, the

stone possess even other characteristics than the shape, such as the temperature and chemical composition. Do you think that the chemical composition is changing over time? What about its temperature? Does it depends on the environment? Can we say that the piece of stone is in thermal equilibrium all the time?);

- Simple or complex systems – and here is much to discuss:

According to (Érdi, 2007) the properties of a simple system can be summarized as in Table 0.1 The properties of a simple systemTable 0.1.

Table 0.1 The properties of a simple system

Single cause and single effect	
	When analysing a system a single cause and a single effect is considered.
A small change in the cause implies a small change in the effect	
	This small change is not similar all the time to a linear relationship between the cause and the effect, but it rather suggest that the causality between the cause and the effect won't be surprising. Also, small changes in the structure of the system or in the parameters, if we speak about economic systems for example, do not qualitatively alter the system's behaviour, so, in more fancy terms we can say that our system is "structurally stable".
Predictability	
	As we are not surprised by the outcome of the small change we have spoken above, we can say that the behaviour of the system is predictable.

More, the complex systems possess the characteristics in Table 0.2.

Table 0.2 The properties of a complex system

Circular causality	
	Or, in simple words: the output influence the input. For example, we can have A causes B causes C causes D which modifies or causes A again.
Feedback loops	
	A feedback loop can be seen as a channel or pathway formed by an output returning to the system as an input and generating either more or less of the same effect. In practice, we can have two types of feedback loops: positive and negative.

	The positive feedback loop has a reinforcing effect on the system by driving the change of that system, while the negative feedback loop is balancing, dampening or moderating the system, offering stability. Figure 0.2 is presenting the general schema for a feedback loop.
Logical paradoxes	
Strange loops	
Small change in the cause implies dramatic effects	
	The expression “butterfly effect” became well-known, even in the popular culture.
Emergence	
	Emergence is the process that creates new order together with self-organisation. According to (Goergen et al., 2010): “Emergence in a human system tends to create irreversible structures or ideas, relationships and organizational forms, which become part of the history of individuals and institutions and in turn affect the evolution of those entities.”
Unpredictability	
	As in this case we are surprised by the outcome of the small change which produce dramatic effects in the output, the behaviour of the system is unpredictable.

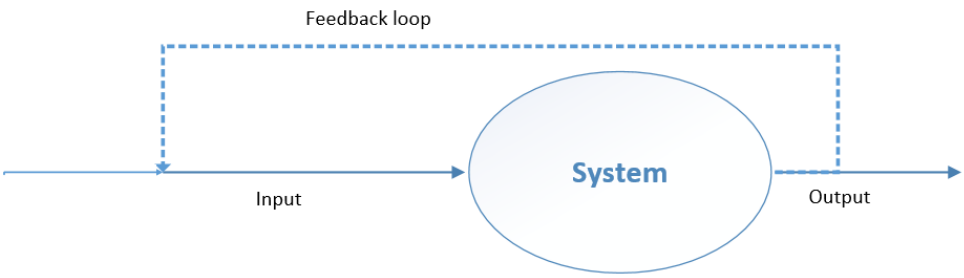
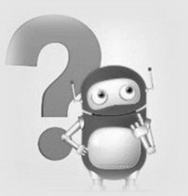


Figure 0.2 The feedback loop



What type of feedback can be identified in the following example? Please explain.
Let us consider a central heating system placed in a house. The system possess a thermostat which monitors the temperature in the entire house, and when the temperature is below 20 degrees, an adjusting mechanism is set in motion, which turns the heating on until the desired temperature is attained. In the same way, when the temperature rises above 20 degrees, the heating is switched off until the temperature falls below the desired level.

In this situation, due to the thermostat and to the adjusting mechanism, the gap between the desired and the actual temperature is thus closed. Therefore, we are facing a negative feedback.
On the other hand, the positive feedback would progressively widen the gap. Instead of reducing or cancelling out the deviation, positive feedback would amplify it.

Have you heard of “the butterfly effect”? Can you explain it in few words? Do you think that it really exists in the reality? Can you give an example?

The butterfly effect

Let’s start with the story behind the butterfly effect: it is known that while working on a weather prediction problem back in 1961, Edward Lorenz used a computer to run a 12 equations model on the weather. At a certain point, he decided to run the model from the middle rather than from the beginning and by using just three decimal places instead of the normal six. The result was fantastic: the weather patterns evolved differently which made him believe that the small change he has made is as trivial as the beating of a butterfly’s wing.

The butterfly effect

The equations Lorenz used to simulate the motion of the air were:

$$\frac{dx}{dt} = \sigma\,(y - x) \qquad (1)$$

$$\frac{dy}{dt} = x\,(\rho - z) - y \qquad (2)$$

$$\frac{dz}{dt} = xy - \beta z \qquad (3)$$

Where dx/dt refers to the variable x rate of change as a function of time; x, y and z represents the systems state; t is the time; and β, σ and ρ are the system's parameters.

The best way to present the butterfly effect is by using the Lorenz attractor. Such a simulation can easily be done by any of us through accessing the web-page: http://fractalfoundation.org/OFC/OFC-7-1.html

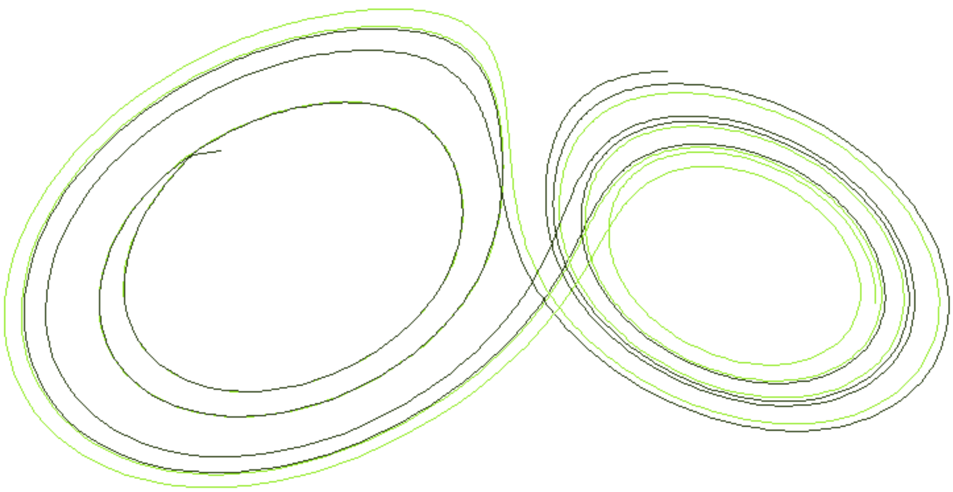


Figure 0.3 Lorenz attractor (1)

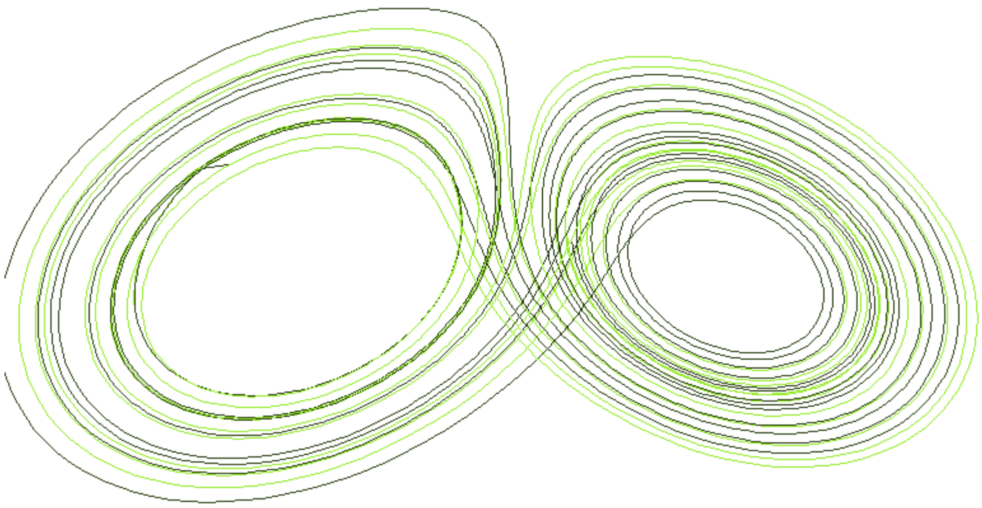


Figure 0.4 Lorenz attractor (2)

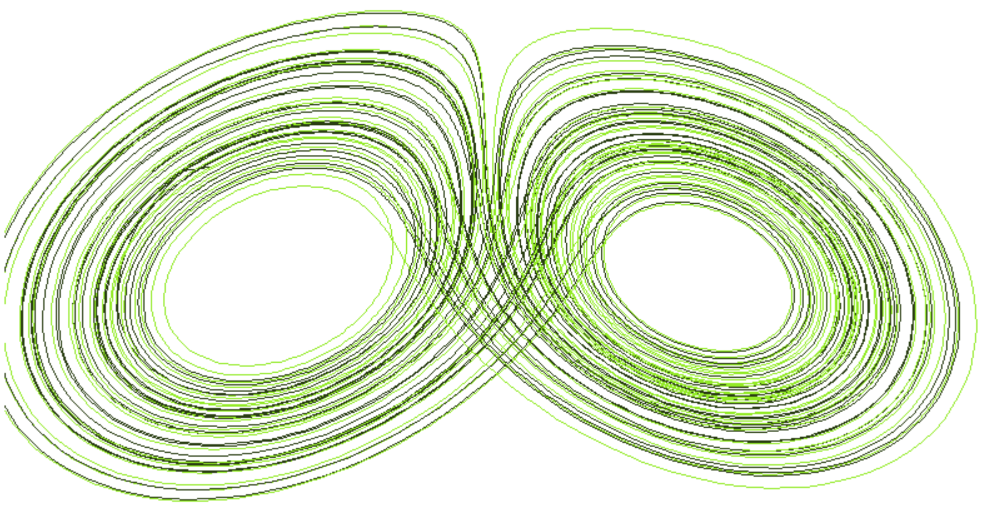


Figure 0.5 Lorenz attractor (3)

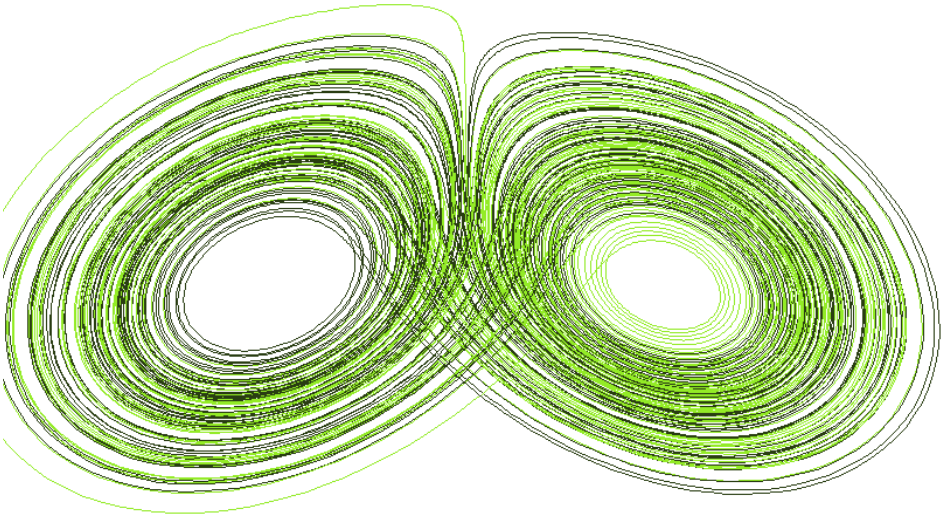


Figure 0.6 Lorenz attractor (4)

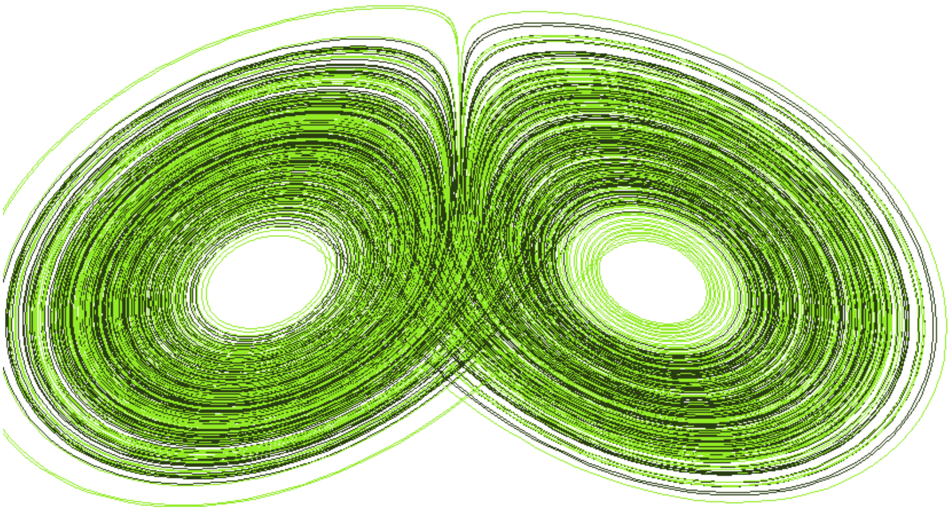


Figure 0.7 Lorenz attractor (5)

First of all, let's define an attractor. So, the attractor is the solution or the pattern of behaviour that a system can reach. To that extent, we can find either simple attractors (for example a pendulum which will move back and forward when released until it reaches a fix point right in the middle and stops) or strange attractors (such as the Lorenz attractor which derives from the Lorenz's equations for the weather and behaves as in Figure 0.3 to Figure 0.7).

In 1972 during a session on Global Atmospheric Research Program of the American Association for the Advancement of Science meeting, Edward

Lorenz presented a lecture on the theme of "Predictability: Does the Flap of a Butterfly's Wings in Brazil set off a Tornado in Texas?" showing that some of the dynamical systems have a "sensitive dependence on initial conditions" and that small errors are subject of dramatic amplification (Érdi, 2007). This is one of the reasons why the effect of a flap in real life can be associated to a round-off error in the Lorenz's weather model.

Even though the "butterfly effect" is more like a hypothesis, it had multiple variations over the time (see Figure 0.8) and it has been used in real life to explain the political events of the stock market crashes.

Geographic variations:

- The flap of a Butterfly's Wings in Brazil sets off a Tornado in Texas.
- A butterfly flapping its wings in Kansas could trigger a typhoon in Singapore or a downpour on your summer party.
- A man sneezing in China may set people to shoveling snow in New York.
- A butterfly flaps its wings in Asia, the action may eventually alter the course of a tornado in Kansas.
- A butterfly flapping its wings in Tokyo could cause a cyclone in the Caribbean.
- A butterfly flapping its wings in South America can affect the weather in Central Park.
- The possibility of large storm in New England may be caused by a butterfly wing flap in China.

Figure 0.8 Geographic variations on the "butterfly effect"

Considering the political events, the Palm Beach County Butterfly Ballot Controversy is one of the most well-known butterfly effect - Figure 0.9 summarizes the events (if interested in reading more please go to http://www.authentichistory.com/1993-2000/3-2000election/3-dispute/).

The Palm Beach County Butterfly Ballot Controversy

Wednesday morning brought the first specific reports of voting irregularity in Florida. Attention soon focused on the design of the ballot in Palm Beach County, which many voters found confusing. This ballot design used 2 pages for voting on a single office. The candidates were staggered one on the left page, then one on the right page, and then back to the left page again. The name corresponded to holes that ran down the center between the 2 pages. These punch-card style voting machines required the voter to pick up a pointed stylus, line it up with the hole corresponding to his candidate of choice, and to push it down into the hole and through the voter card underneath the ballot booklet. Some voters found the left, right, left, right design confusing. George Bush and Al Gore were the first two candidates listed on the left side, but the hole corresponding to Al Gore's name was the third one down, not the second one. The second hole belonged to Pat Buchanan, whose name was the first one listed on the right side of the ballot. Ironically, this ballot design was chosen in part because it allows for larger print, and it was an attempt to accommodate the county's large elderly population.

Unfortunately, as many as 3,000 voters who intended to vote for Al Gore ignored the right side of the ballot and punched the second hole down and thus accidentally voted for Pat Buchanan (The punch card itself is slipped in beneath this ballot from above). Voters in Palm Beach County were sent a sample ballot by mail, but it did not show the holes down the center.

Figure 0.9 Summary on the Palm Beach County Butterfly Ballot Controversy (see http://www.authentichistory.com/1993-2000/3-2000election/3-dispute/ for the whole story)

1.2. What is modeling?

Modeling is defined as the process of creating mathematical and conceptual frameworks for describing economic phenomena. In other words, the result of a modeling process is a conceptual or mathematical framework that describes how various concepts in economics actually work, all gathered within a model.

Therefore, a model is a simplified representation of the world (see Figure 0.10). Or, in other words, we can say that models are approximations of the real world.

The model shouldn't be seen as something fixed and unchangeable, but rather like a continuous change process, where, as a result of repeated observation, simulation and analysis, one can draw some conclusions and verify and validate his/hers research. Also, based on these conclusions one can make various recommendations in order to improve the actual state of the system.

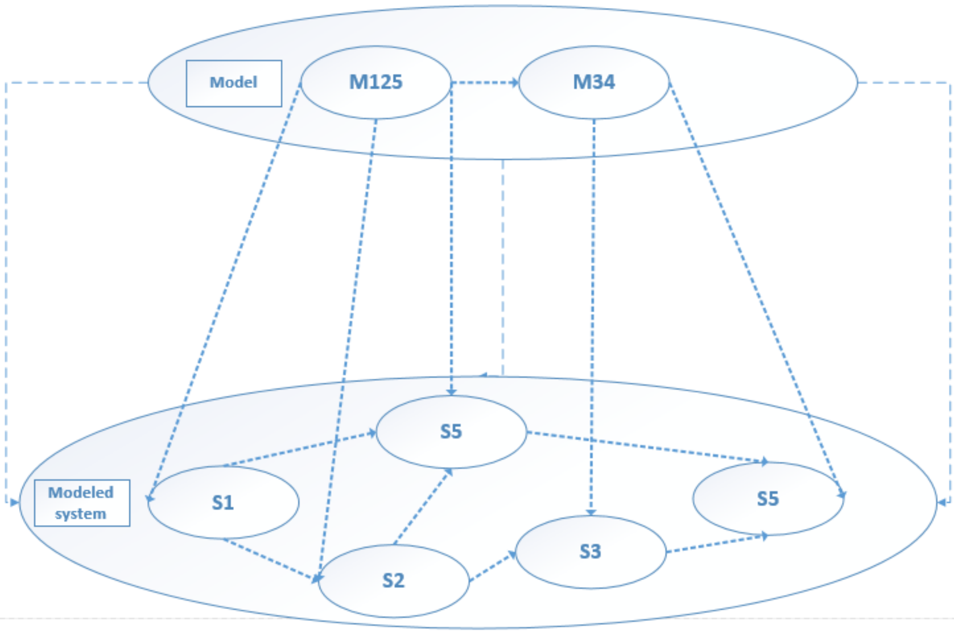


Figure 0.10 A system and its model

Let's see in the following what we should do for creating a model of a system.