

VISUALIZATION CAPABILITIES OF SIMULATION OF ECONOMIC PROCESSES

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Abstract. *Educational experience shows that during the research process researchers perceive graphical information better than analytical relationships. Many economic courses operate with models that were previously available only in mathematics and physics disciplines. As a possible solution, there could be the use of the package Matlab Simulink in the realization of different algorithms both for engineering disciplines and economic studies. The article substantiates the usefulness of implementing the simulation models during the early stage of the research, when in parallel to acquiring analytical relations, simulation models may be introduced. The aim of the article is to show Matlab Simulink suitability for the purpose of visualizing simulation models of various economic disciplines. To reach the aim, the following research tasks have been set: identification of Matlab Simulink possibilities for simulation of economic processes; demonstrate visualization models on the basis of examples; visualization of time series model using Latgale unemployment rate data. The article presents examples of using simulation modeling in the economic research processes - optimal tax rate searching and time series application. Common research methods are used in this research: descriptive research method, statistical method, mathematical modeling.*

Keywords: *Matlab Simulink, modeling, simulation, teaching, visualization.*

JEL code: *C63*

Introduction

The classification of general economic models is based on the scope of the economic system under study. From this point of view, the models can be divided into three major groups: the models of firms, industry models and macroeconomic models.

The model should be based on solid empirical basis. However, this information is usually not available for developers of economic models. The management of companies simply do not wish to give their business details to the third person. This is especially true for companies operating in the face of strong competition.

The aim of the research study on different simulation models is the formation of a researcher's theoretical knowledge and practical skills in the use of simulation modeling techniques in research of solving specific problems in modeling of real economic applications. During the course, researchers get acquainted with the means of simulation modeling processes of functioning systems, master the simulation modeling

methods and typical stages of modeling process that form the “chain”: the construction of the conceptual model and its formalization – model algorithmization and its computer implementation – simulation experiment and interpretation of the results of the modeling; acquire practical skills for implementation of modeling algorithms for studies of characteristics and behaviour of complex economic systems (Kay, 1984; Karel & Tomas, 2015).

Simulation - the most powerful and versatile method for studying and evaluating the effectiveness of systems, the behaviour of which depends on the influence of random factors.

The implementation of such opportunities in the universal programming language is a difficult task. Currently, there is quite a lot of software that allows to model processes. However, now there is a product that allows solving these problems quite effectively – the MATLAB package (Kiusalaas, 2016; Siau & Bayern, 2015; Smith, 2013) containing a visual simulation tool – Simulink (<http://se.mathworks.com/products/simulink/>). Simulink - a tool that allows you to simulate the system quickly, get the indexes of expected effect and compare them with the amount of effort required to achieve them (Karel & Tomas, 2015; Xue & Chen, 2013).

The article substantiates the usefulness of implementing the simulation models during the early stage of the research, when in parallel to acquiring analytical relations, simulation models may be introduced.

The main aim of the article is to show Matlab Simulink suitability for the purpose of visualizing simulation models of various economic disciplines.

To reach the aim, the following research tasks have been set:

- identification of Matlab Simulink possibilities for simulation of economic processes;
- demonstrate visualization models on the basis of examples;
- visualization of time series model using Latvian unemployment rate data.

A study was carried on using Matlab Simulink capabilities in the optimal tax rate modeling and in the application of time series analysis possibilities with the help of Simulink.

To demonstrate the practical use of a time series with the help of Matlab, data on the unemployment rate in Latvia in the years 1996-2015 from the Latvian Central Statistical Bureau was taken.

Common research methods are used in this research: descriptive research method, statistical method, mathematical modeling.

Possibilities of the software package Matlab Simulink

Of particular interest for simulation is a Simulink tool designed specifically for modeling dynamical systems. It has a library of standard graphics units with built-in mathematical functions. It is sometimes called a tool of visual modeling (Shiflet & Shiflet, 2014; Silva, 2009).

Although Simulink is designed mainly to solve engineering and scientific- technical problems, the possibilities of its use are almost unlimited. The input of initial parameters is made interactively by graphics assembly of elementary blocks circuit diagram, resulting in a model of the studied system. The blocks included in the model relate to each other both in information and in management. The type of connection depends on the type of the block and the logic of the model.

The Simulink program is an application to the MATLAB package. The simulation, using Simulink, implements the principle of visual programming whereby the user on the screen creates a model of a structure, process or system from standard blocks of the library, and performs calculations. In this case, unlike in classical ways of modeling, the user does not need to study the programming language and numerical mathematics methods thoroughly, there is enough to have some general knowledge required when working on the computer, and, of course, knowledge on the subject area in which he works.

Creating a model in this way, and then launching it, it is possible to see the results of modeling. In the simulation, the user can choose the method for solving equations, as well as the way to change the model time (with a fixed or variable step). During the simulation, it is possible to monitor the processes happening in the system. To this purpose, special viewing devices that are part of the Simulink library are used. The simulation results can be presented in the form of graphs or tables.

Series of research were carried out in order to demonstrate the Simulink suitability for simulation model visualization purposes in different engineering disciplines. It should be noted that often the analytical solution is much simpler than the visual Simulink model, but in perspective, it gives an understanding of such models usefulness.

Figure 1 shows the used blocks' description and its explanation given in the examples.

The **Discrete Time Integrator** block (Commonly Used Blocks) performs discrete-time integration or accumulation of a signal. We use this block in discrete-time systems instead of the Continuous Integrator block in continuous-time systems. The block can integrate or accumulate using the Forward Euler, Backward Euler, and Trapezoidal methods.

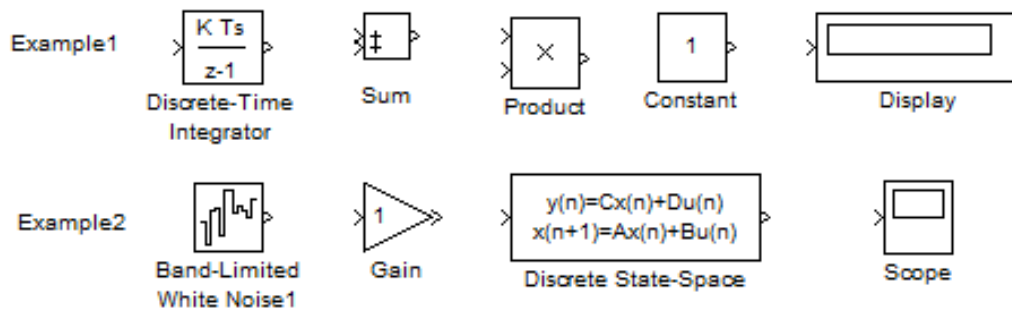


Figure 1. Blocks used in the examples (*Source: author's construction*)

The **Product** block (Commonly Used Blocks) block performs multiplication or division of its inputs. This block produces outputs using either element-wise or matrix multiplication, depending on the value of the Multiplication parameter.

The **Sum** block (Commonly Used Blocks) performs addition or subtraction on its inputs. This block can add or subtract scalar, vector, or matrix inputs.

The **Constant** block (Sources) is used to define a real or complex constant value.

The **Display** block (Sinks) shows the output value at the end of the simulation time.

The **Band Limited** block (Sources) is an implementation of white noise into Zero-Order Hold block.

The **Gain** block (Commonly Used Blocks) multiplies the input by a constant value (gain). The input and the gain can each be a scalar, vector, or matrix. We specify the value of the gain in the Gain parameter.

The **Discrete State-Space** block (Discrete) implements the system described by the equations: $x[n + 1] = Ax[n] + Bu[n]$ $y[n] = Cx[n]$.

Research part

Example 1. Optimal Tax Rate searching

The aim of the experiment: to study the dependence of budget revenues on the tax rates. The author used the (Cisar, 2004) study results.

The state announces the income tax rate and receives funds from the companies to the budget. Companies have their own capital, get profit, and pay funds to the budget according to the tax rate. After-tax profit as retained earnings is fully included in the company's own capital. Dividends are not paid out, no other deductions from income are done. All profit is divided only into two flows: to the budget and the rest-to the equity.

Budget revenues for a certain period of time will be the greatest not at the maximum but at the optimum tax rate for the budget. That is, with

the growth of the tax rate, the revenues to the budget will increase and then decrease.

The amount of tax revenues from enterprises for the simulated period is stored in the fiscal accounts, and is represented by the integral:

$$BD(t) = \int_{t=tb}^{t=tf} PRF(t) \cdot TXRT \cdot dt \quad (1)$$

where $BD(t)$ – amount of funds received in the budget from the beginning of the simulation till the moment t , euro;

$PRF(t)$ – pretax profit, derived by an enterprise at the moment t , euro/year;

$TXRT$ – income tax rate;

t – current time, year.

tb – beginning moment of simulation;

tf – final moment of simulation.

A profit balance capitalized by an enterprise during the simulation time:

$$CP(t) = \int_{t=tb}^{t=tf} PRF(t) \cdot (1 - TXRT) \cdot dt \quad (2)$$

Profit at time t :

$$PRF(t) = CP(t) \cdot RN \quad (3)$$

where RN - profitability of the enterprise capital. It is set as a parameter of the enterprise, initial data.

The model of such a process is shown in Figure 2.

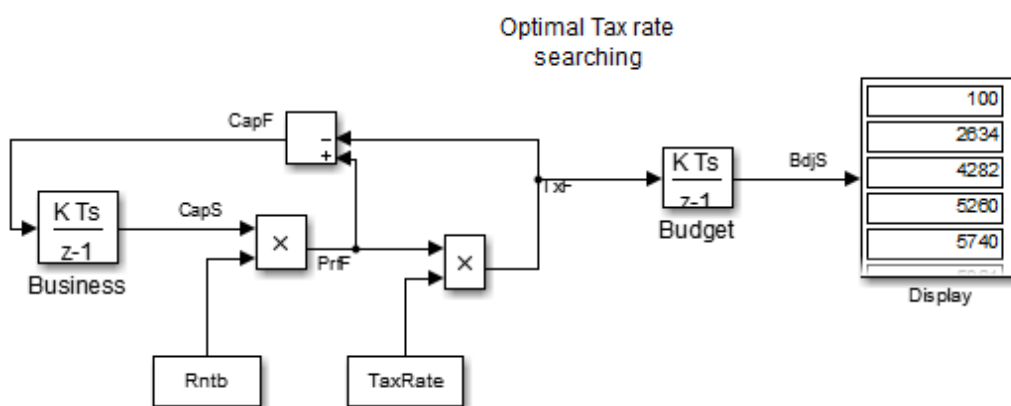


Figure 2. Optimal tax rate searching model

(Source: author's construction - adapted from Cisar, 2004)

In the scheme block **Business**, there is presented the hoarder of the equity of the enterprise, it is taken from the library of elements as a block

Integrator of discrete time. The investment flow **CapF** enters on the block input. It is after-tax, retained profit. It is accumulated by a business and increases its equity capital. Block **Out** - is the amount of capital in business **CapS**. Profitability is defined by a block with the name **Rntb**. The next block works out the multiplication of the profit flow on the tax rate **Tax Rate**. This is the flow of deductions from profits to the state budget **TxF**. The tax rate is set with the name **Tax Rate**. The block **Budget** is represented by the integrator. It accumulates tax revenues **TxF** for the simulation period as a variable **BdjS**. The block **Display** reflects numerical values of **BdjS**.

The optimal tax rate modeling result is shown in Figure 3.

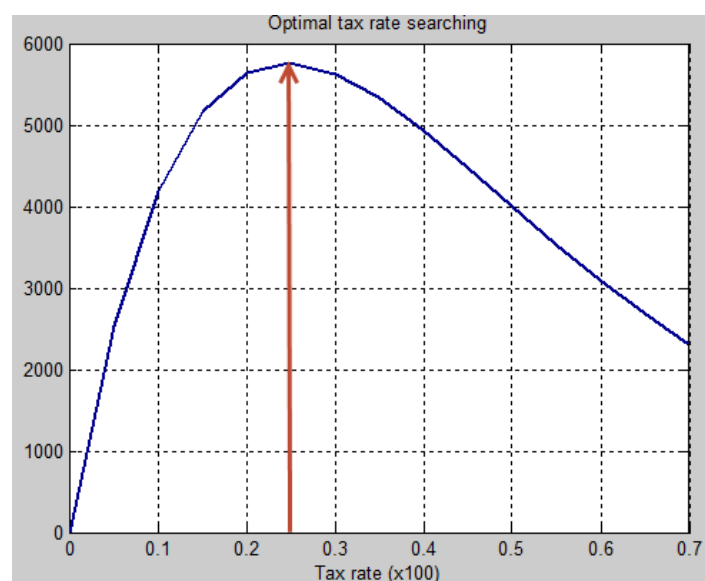


Figure 3. Optimal tax rate (*Source: author's construction*)

With increasing rates, the revenues to the budget increase and then decrease. There is a strongly marked maximum, i.e., the optimal tax rate for the budget. The higher the profitability of the enterprise is, the more pronounced the optimal tax rate is. With the growth of the profitability, the optimal rate is reduced (shifted to the left), aiming at a fixed value, on our charts, approximately, to 23 - 25%.

Example 2. Economic time series data modeling

A time series is a sequence of real numbers that represent the measurements of a real variable at equal time intervals, whereas a time series database is a collection of time series (Kirchgassner and Wolter, 2007; Lutkepohl, 2005; Tsay, 2002; Montgomery et. al., 1988). Time series data can be analysed in many different ways. For instance, to perform this task various mathematical models can be used.

Time sequences appear in many applications, to be more precise, in any applications that involve a value that changes over time. There is one problem concerning the time sequences has been paid a lot of attention to recently, i.e., the problem of similarity retrieval of time sequences in databases, or the so called “query by example” (Vlachos and Gunopulos, 2004).

The ARMA model is offered (Montgomery et. al., 1988) with the help of following equation:

$$y_n = 10 + 0.6 y_{n-1} + u_n + 0.9 u_{n-1} \tag{4}$$

where $\sigma^2 = 4$.

The matrices for the discrete state-space representation of the disturbance are as follows: (Nembhard and Nembhard, 1996):

$$A = \begin{bmatrix} 0.6 & 0.9 \\ 0 & 0 \end{bmatrix} \quad B = \begin{bmatrix} 1 \\ 1 \end{bmatrix} \quad C = [1 \ 0] \quad D = [0]$$

The theoretical time series simulation model (Nembhard and Nembhard, 1996) is shown in Figure 4 and Figure 5.

The following graph illustrates that simulation methods can be used in time series analysis. It can be used as an example to demonstrate Simulink possibilities in changing various parameters of simulation model. It should be noted that the use of real data in this model is quite unwieldy.

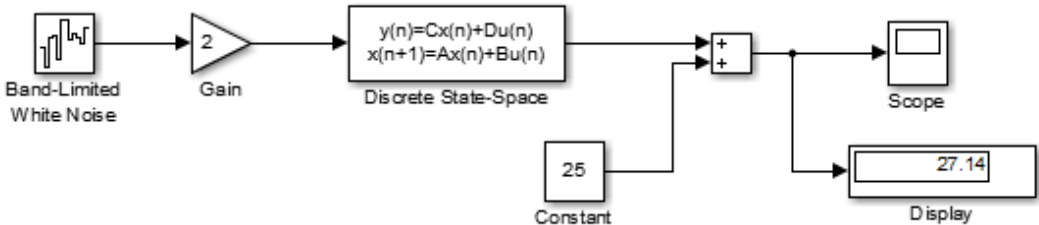


Figure 4. Time series ARMA process simulation model
 (Source: author’s construction - adapted from Nembhard and Nembhard, 1996)

To demonstrate the practical use of a time series with the help of Matlab, data on the unemployment rate in Latgale in the years 1996-2015 (see Table 1) from the Latvian Central Statistical Bureau was taken.

In graphical form it is shown in Figure 6. This data time series is shown in Figure 7.

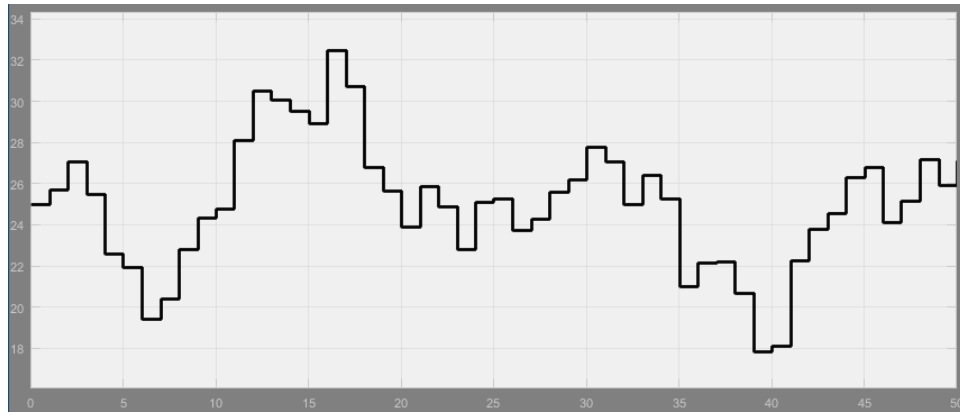


Figure 5. Realization of the ARMA random stream process
 (Source: author's construction - adapted from Nembhard and Nembhard, 1996)

Table 1

Unemployment rate in Latgale (Source: CSB, 2016)

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Level (%)	23.4	16.7	17.0	21.9	20.9	20.8	18.5	18.0	14.6	14.5

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Level (%)	11.6	8.7	9.6	18.0	19.5	19.0	20.9	17.3	17.3	19.0

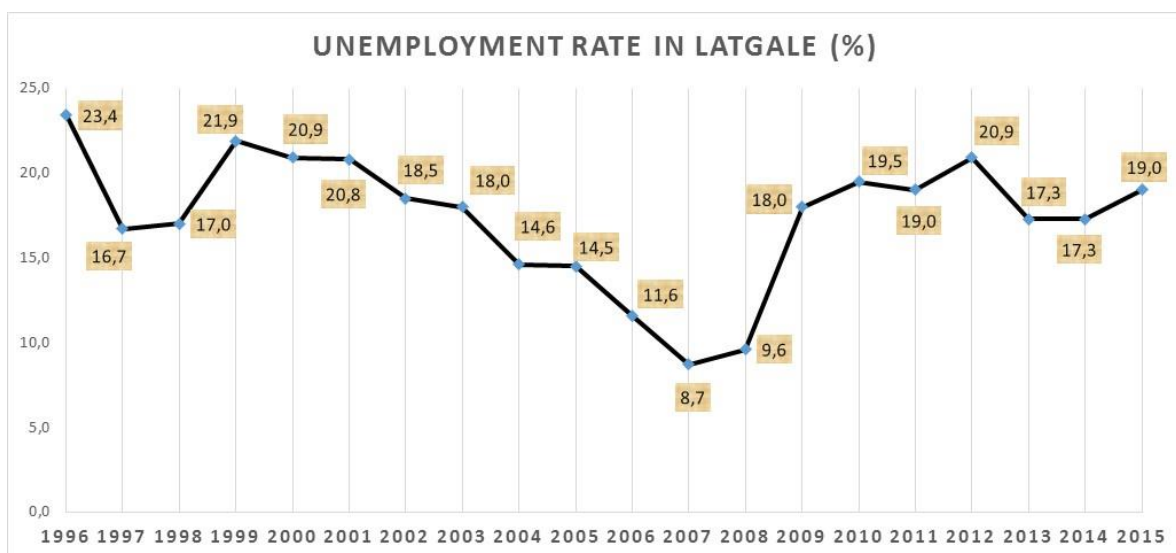


Figure 6. The unemployment rate over the years
 (Source: author's construction)

Although in this case, the visual model may seem complicated, but its further understanding makes it possible to create complex system models - not only in engineering, but also in economics, environmental sciences, sociological studies, and so on (Anderson, 2005; Cerný, 2009; Chapra & Canale, 2015).

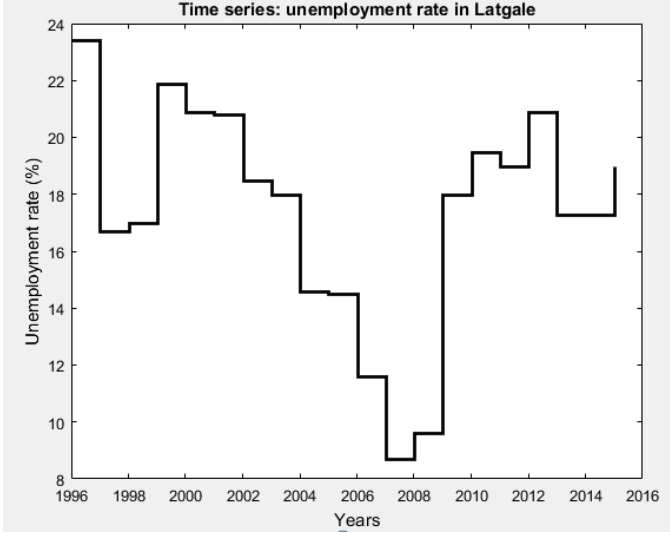


Figure 7. Time series graph (Source: author's construction)

Conclusions

In this article the author substantiates the usefulness of introduction of a simulation model for the economics studies. It gives researchers the opportunity to visualize different correlations in graphical form.

In study part the possibilities of simulation modeling for economic studies are demonstrated - optimal tax rate searching and time series application. As a practical example, the time series acquisition from data on the unemployment rate in Latgale is shown. In further studies, the author intends to focus on time series forecasting.

The author is assured that the use of simulation models makes it possible to raise a researcher' horizon and gives an idea of the potential uses of such models.

Thus it can be concluded that the Matlab Simulink tool is a very suitable tool not only in engineering calculations, but also can serve as a simulation model visualization tool in various science fields.

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EKONOMISKO PROCESU MODELĒŠANAS VIZUALIZĀCIJAS IESPĒJAS

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Kopsavilkums

Pieredze rāda, ka pētnieki izziņas procesā daudz labāk uztver grafisko informāciju, nevis analītiskās sakarības. Daudzi kursi operē ar modeļiem, kas agrāk bija pieejami tikai matemātikas un fizikas disciplīnās. Kā iespējamais risinājums būtu paketes Matlab Simulink izmantošana dažādu algoritmu realizācijā gan inženierzinātņu disciplīnās, gan arī ekonomiskajos pētījumos.

Tika veikta pētījumu sērija, lai demonstrētu Matlab Simulink piemērotību dažādu ekonomisko disciplīnu simulācijas modeļu vizualizācijas nolūkā. Jāatzīmē, ka bieži vien analītiskais risinājums ir daudz vienkāršāks, nekā vizuālais Simulink modelis, taču perspektīvā tas dod sapratni par šādu modeļu izmantošanas lietderīgumu. Lai arī šajā gadījumā vizuālais modelis varētu likties sarežģīts, taču tā izpratne turpmāk dod iespēju veidot kompleksus sistēmu modeļus – ne tikai inženierzinātnēs, bet arī ekonomikā, vides zinātnēs, socioloģiskajos pētījumos utt.

Šajā pētījumā autors pamato simulācijas modeļu ieviešanas lietderību jau sākotnējā pētījumu procesā, kad paralēli analītisko sakarību apgūšanai var ievest arī simulācijas modeļus.

Pētījumu daļā tiek demonstrētas modelēšanas iespējas ekonomiskajos pētījumos – optimālās nodokļu likmes skaitļošanā un laikrindu analizē. Kā praktisks piemērs ir parādīta laikrindu iegūšana no datiem par bezdarba līmeni Latgalē. Turpmākajos pētījumos autors plāno pievērsties laikrindu prognozēšanai.

Tādējādi var secināt, ka Matlab Simulink ir ļoti piemērots rīks ne tikai aprēķinu veikšanai, bet arī var kalpot kā simulācijas modeļu vizualizācijas rīks dažādās zinātņu jomās.

Atslēgas vārdi: Matlab Simulink, modelēšana, simulācija, vizualizācija.