ECONOMIC EDUCATION USING SYSTEM DYNAMICS

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Annotation

System thinking is one of the most important transferable skills that can be developed by education, whichin economic field strongly depends on the ability of system representation through models. Therefore, modelling experience in general and system dynamics in particular becomes a necessary element of the economic education. This paper is devoted to the presentation of the educational research project performed with the use of system dynamics as an example of its advantages as educational tool.

Keywords: system dynamics, economic education, university, secondary school.

Introduction

In 2012, the project named “Learning economics with Dynamic Modeling” commenced. The main conceptual idea for the cooperation between theSystem Dynamics Group at Norwegian University of Bergen (UiB) and the Finance Department at Ukrainian National University of Kyiv-Mohyla Academy (NaUKMA) was to build the system dynamics modeling school in Ukraine through the principle “train the trainers”. Idea of the project is based on the ability of students and professors trained at UiB to share their knowledge and implement them in economic education and research in Ukraine.The mentioned project has already been performed with one extension. During the three-year period, 12 master and PhD students and 3 professors from NaUKMA visited Bergen and completed three basic courses that allowed them to gain knowledge in system dynamics. Moreover, under the project extension the 4 PhD student visits were funded to give them possibility to improve skills in model-based policy design and implementation. The mentioned concept realization was fulfilledat NaUKMA through the implementation of the system dynamics into the curriculum. Cases with the system dynamics elements were inbuilt into the business processes modeling and reengineering topics in Financial Controlling course, models of the banking system were used in Financial Services Market and Financial Market courses, modeling of the accounting elements and financial flows became a part of the Corporate Finance and Insurance Services courses. These achievements together with the “System Dynamics Methods in Finance” course introduction at NaUKMA in 2014, 2 published monographs and more than 15 papers allow for conclusion about the success of the project.

The next step in cooperation between NaUKMA and UiB was student mobility granted by Erasmus+, and in 2016 the new grant from SIU was received. Under this new project, the extended concept will be realized, which is focused on the enforcement of the cooperation between higher educational institutions and schools, and the improvement of school education with the use of system dynamics for systems thinking training. NaUKMA and System Dynamics group are going to perform several workshops for school teachers to allow them to implement system dynamics into school courses that will ensure better understanding of the material. This extension of the project target audience coincided with the NaUKMA idea of deeper collaboration with schools. Thus, the first example of such cooperation was performed before the official start of the new international project.

1. System Dynamics in Economic Education

System dynamics in modern understanding was developed from system thinking concept of Forrester which was grounded in 1950s in engineering. Richmond (1994) in his article arrive at conclusion that system thinking is the art and science of making consistent conclusions about behaviour by developing a deep understanding of structure that produces such behaviour. These ideas were the basis for Forrester's works on system dynamics. The first models were dedicated to the production management including issues of inventory, workforce regulation, and demand volatility. The general aim of such models is to understand the reasons of problematic behaviour of the system, which includes the overall system condition investigation. The important term in system dynamics is "mental model", which means that models represent the human understanding of the real systems (Reichel, 2004).

The main idea that lies in the basement of this method is that any behaviour of the system is generated by the peculiarities of its structure. The investigation of internal structure allow for understanding the dynamics of system indicators. Despite the external influences, the system will sustain the behaviour that is defined by the structure. This emphasis on the internal structure promotes the concept of endogeneity. And there are causal relations between elements of the systems. Usually, this causality is viewed to be dual, which lead to the concept of feedback causality.

Feedback causality in models is presented through the feedback loops. These loops are constructed of variables. The first type of variables represents an accumulation process of physical or informational value (stock), whereas the second type represents the changes in the levels (flows). Both types of variables are strictly distinguished and have their peculiarities (Meadows, 1980). Moreover, the delays and nonlinearities can be modelled with this method. Depending on the direction of interconnections between variables the loops can be either positive (reinforcing) that increases both growth and the fall, or negative (balancing), which counteract the external and internal shocks and lead to the goal achievement. The combinations of different loops with different power are able to produce exponential growth, decay, and various complex types of behaviour. The complexity of systems and their behaviour caused the emergence of special tools for modelling, such as iThink, Vensim, PowerSim, Stella, etc.

The general process of modelling in system dynamics consists of several phases: conceptualization, model formulation, model testing, and implementation/representations. The modern approaches also detail the first stage as analysis and design (Keating, 1999). The analysis means problem formulation, whereas the design includes variables selection and model scopes identification. After that the formulation involves construction of model by itself, and testing allow for validation, behaviour and policies testing. Implementation means presentation of the results to the users with further their usage in order to solve the problem.

The fact that system dynamics as modelling method deals first of all with the system structure and demand deep understanding of the research object it can be very useful for the educational purposes. Modelling process allow students to understand the internal reasons of the economic laws. Therefore in NaUKMA the system dynamics is taught to bachelor and master students in two special courses. Moreover, the system dynamics models are used by students to perform their term research papers and by teachers to explain some topics in basic courses. Thus it is possible to conclude that system dynamics became an important and inseparable part of the higher economic education in NaUKMA.

2. Research Topic and Methodology Selection

The level of education that Universities provide depends strongly not only on the internal potential of these institutions, but also on the level of school students' preparation, their basic knowledge, and,what is even more important, on the ability of logical systematic thinking. The possible waysof how Universities can contribute to the school education development is to provide modern methodological approaches, share experience in advanced pedagogical practices, train teachers and students. One direction of the mentioned training process is the universities professors' participation in the school students' research work. Therefore, in 2015 the system dynamics method was used to perform school student's investigation under supervision of the NaUKMA teacher.

Itshould be noted thatin Ukraine personal behavior of people influences economy a lot through tax evasion and avoidance, high level of shadow activities, enormous dollarization and its importance perception by the population.According to the research, the financial crisis aggravation in the beginning of 2015 was connected not only to objective reasons, but also to the panic and irrational behavior (Lukianenko& Dadashova, 2016).The budget imbalance in Ukraine is also highly connected not only to the excessive spending, but to the enormously high level of tax evasion on all levels. Thus, effective rates of the main taxes and social payments in Ukraine were about 36 % lower than the nominal level during the last 15 years, and the level of shadow economy according to the Ministry of finance and the World Bank is 49,7% in Ukraine.

Described behavior is directly connected to the fact that people do not see the real results of their actions. Despite the general educational level of Ukrainians is rather high, which can be proved by the World Bank high value of the education pillar in the Knowledge Economic Index (30) and the education pillar in the Global Competitiveness report (33), the level of basic economic education is rather low. It can be explained by the fact that basic economics began to be taught in schools only 15 years ago. Therefore, not always rational and not balanced behavior of people who are not familiar with the basic economic concepts creates additional disturbances for the economy. So the issues of economic education and tax discipline were important to address under the cooperation of NaUKMA with schools. The question was how it was possible to implement educational elements into the investigation results. When talking about the educational goal it is important to provide both young researcher and her or his audience with the possibility to deepen their understanding of the topic and make substantiated conclusions about their personal behavior, develop systematic thinking.

System dynamics in this regard was chosen as the most useful approach for the research reciprocally by the student and supervisor.The advantages of system dynamics in this case can be separated into two categories: for the modeler and for the target audience. For the modeler, who is a school student, system dynamics is preferable as it demands good understanding of the object interconnections and structure, therefore, motivates for better study and deeper knowledge. At the same time,despite this method is quite simple comparing to the majority of macro modeling tools, it provides high visualization and testing possibilities. Moreover, the availability of supporting technical materials and software was an additional important benefit of the approach.On the other hand, the audience which is not familiar with the methodological features still can understand the modeling outcome due to the availability of structure stock-flow and causal-loop diagrams, while real time simulation and forecasts make the model even more attractive.

Due to all mentioned features of the system dynamics, it became feasible to include all the desired aspects into the research: chose important issue with problematic behavior, investigate and represent its structure, make numerical analysis, create the research outcome

(model) that can contribute to the economic education of different groups. In order to make the last point even more implicit, it was decided to realize the educational potential of the created model within the research process.

Hence, the topic selection and the research idea by itself was a complex process that included the urgency of the addressed issues, researcher interests, methodological considerations and desire to reach practical results. All the abovementioned led to the goal that can be stated as to create the model of pension system in Ukraine in order to explain its principles to the school students.

3. Modeling Results

The next phase of the research after the goal formulation and method selection was to create the necessary model which would be able to represent the pension system structure in Ukraine and explain the reasons for its imbalance during the investigated period. The problem that became the core issue to model is the deficit of the pension system and the burden on the governmental budget produced by it that after all created indebtedness.

In order to explain the described problem it was necessary to recreate the pension system structure in the model. The pension system in Ukraine is completely financed by the government. It provides pension to all citizens that reach the pension age (60 years for man and 55 for women). The pension is paid once a month and its amount depends on the working experience, but does not vary a lot for the majority of categories. The pensions are paid from the special governmental fund named Pension Fund of Ukraine. The fund is created from the social contributions of the working population in the form of monthly paid fraction of the labor income (wages and salaries). The pension system in Ukraine is based on the pay-as-you-go (PAUG) principle which means that current working population pays contributions which are taken to pay pensions to current pensioners. As under this system for the long period the amount of collected income does not allow for full financing of therequired expenditures, there is little possibility for any investment and interest income for the pension fund. Therefore, the social contribution is actually the only source of money for the pension provision. In the case when there is lack of such resources, the government covers the gap with its special transfers from the budget. As it can be seen from the Fig. 2, this annual coverage is a significant fraction of the budget expenditures and contributes a lot to the imbalance of the budget. The only available source of the created budget deficit coverage during several last years in Ukraine has been the debt financing. The direct relation between the pension fund imbalance, budget imbalance, and debt accumulation causes the problem for the Ukrainian fiscal system and financial sector in overall.

The first model task was to represent the mentioned interrelations and problematic behavior of the pension fund and debt as a result. Model starts from the aging chain that allows for the computations of the working age population and pensioners amount under the different conditions which is necessary for the further pension fund income and spending determination. The pension fund budget calculations are included. Its income in the model depends on the social contribution rate, working population amount and average wage as a base for the social contribution. Pension fund expenditures are calculated as the average pension multiplied by the amount of pensioners. The pension fund budget gap in the model is the same as in the real economy and is covered from the budget. The remaining budget expenditures and income are exogenous. Additionally, the governmental debt accumulation is presented in the model. In this simplified version it is only possible to analyze the pension fund deficit impact on debt ceteris paribus. Nevertheless, it gives better understanding of the interrelations that drive main economic indicators. The model structure is presented in the Fig. 1. The model is built on the real data for Ukraine in 2007-2014.

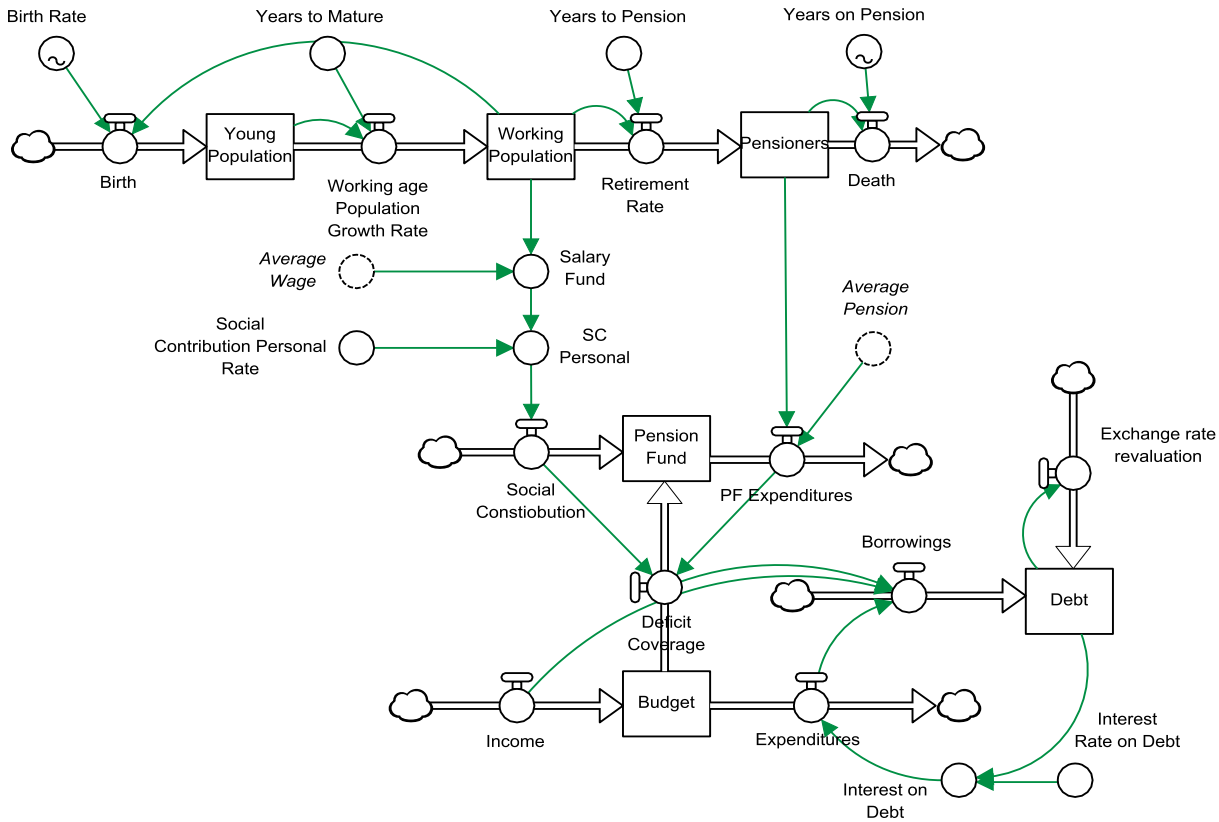


Fig. 1.The structure of the pension system of Ukraine model

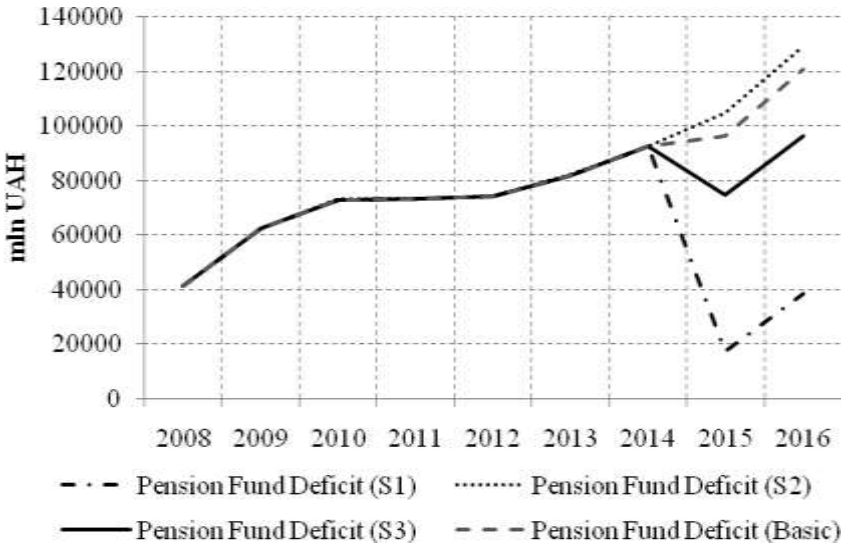
As the developed model had to be used for educational purposes, it was decided to include a large set of testing possibilities in order to illustrate the impact which different policies can make on the pension system. It was assumed that visualization of the different actions impact can contribute to the understanding of the underlying principles that define pension system behavior. It is possible to test the changes of such indicators:

- Average pension,
- Pension age,
- Social contribution rate (rate of tax that is paid to pension fund),
- Efficiency of the social contribution rate (as approximation of the tax preferences and ineffective social contribution collection that decrease the amount of pension fund income),
- Average wage,
- Limitation of the categories that receive pension,
- Interest rate on governmental debt.

The testing and sensitivity analysis can be made both by changing separate indicator values and by combining available options into complex policy decisions. The illustration of the several forecasts under the different scenarios is presented in Table 1.

Table 1

Modeling results of the pension system behavior under possible policies implementation in 2015-2016.

Scenario	Explanation	Modelling results
Basic	Without changes	
S1	Pension payments only to population with work experience	
S2	S1 plus social contribution rate decrease to 22 %	
S3	S2 plus increase of the average wage to 5 000 UAH per month	

4. Implementation of the Findings into the Education Process

As one of the main purposes of the research was educative, obviously, it was necessary to prepare adequate model, but it was even more important to propose easy, interesting, and visually attractive materials that would explain the principles of the pension system in Ukraine. The model was used to explain school students the pension system in Ukraine, and different scenarios were developed to make the principles of its budgeting more explicit. For this purpose an hour workshop was conducted. The audience for the workshop was students of the 10th and 11th forms of the Irpin Specialized Economic School No. 2. The students had already taken several classes of the basic economics, so they were ready to accept proposed material. During the workshop Kateryna Ganina told colleagues about the structure of Ukrainian pension system, explained it on the base of her model, argued why it is important for everyone that this system is not balanced now, proposed different options of the pension system change and allowed students to see what will happen in 2015-2016with the pension fund, budget, and debt in the case of each change implementation. After that students were proposed to create a combined scenario that will allow them to reach desirable pension system conditions without creating additional budget burden. The students were active in choosing different combinations and selection of the best possible way to manage the pension system with the use of its model.

In order to be able to measure the workshop results two surveys were conducted. Students were asked to answer the same question before and after the workshop which is:“what you would like to change in Ukrainian pension system”. It was noticed, that amount of populist answers after the workshop decreased, moreover, the majority of students chosen options that will increase the pensioners’ wealth together with those that can balance the PF budget without additional borrowings. So the visualization of existent problems and possible outcomes of decisions are able to improve the students understanding of economic processes. One more important point to be mentioned is that Kateryna while she was presenting the forecasting results under different combined scenarios was confident and ready to explain all changes and their reasons that arise from the modeled object structure, which would not be

possible without the experience of modeling and respective deep understanding of the modeled processes. One more question that was asked to students after the workshop is about how they can evaluate the efficiency of the modeling usage in educational process. 64 % of students responded that testing makes the process of understanding easier and 80 % responded that study something with models is clearer.It is also important than more than half of the students answered that they would like to study system dynamics.

Conclusions

To provide the high level of education for the Universities it is important to contribute not only to the higher education development, but to support the school education. The NaUKMA incentive to help with the research to the school student was driven by this idea and the goal of deepen collaboration between different educational institutions in Ukraine and abroad. During the first stage of the investigation it was decided to select the topic that is not only important regarding the current economic situation, but also will allow for additional educational and practical results. In this regard not only the research object was important but the method that provide with possibility to reach the stated aim. Due to its specific features such as simplicity of modeling, vide range of testing options, visualization possibility, real time simulation and forecasts possibilities, and user friendly interface, the system dynamics were chosen as the basic method. Hence, the goal of the research was stated as to create the model of pension system in Ukraine in order to explain its principles to the school students.

The desired research results achievement demanded to build the model of the pension system of Ukraine. Final model includes the aging chain that allows for the evaluation of the working age population and pensioners amount under the different conditions. The pension fund budget calculations are also represented. Pension fund income in the model depends on the social contribution rate, working population amount, and average wage. Pension fund expenditures are calculated as the average pension multiplied by the amount of pensioners. The pension fund deficit is covered by the budget expenditures. The model represents pension system of Ukraine in 2007-2014 and can produce forecast for 2015-2016 under different policy implications.

Usage of the built model as the basic in the workshop for the school students was proven to be effective. After the workshop the level of knowledge about the pension system increased. Moreover, the majority of students was involved into the process of policy for the pension system future development creation and proposed relevant and balanced measures. The results of the survey that was conducted after the workshop showed that 80 % of students found the model useful way to explain economic issues. Moreover, more that 50 % of students were also interested in learning more about the system dynamics. Therefore, it is possible to conclude that system dynamics can contribute a lot to the educational process in the school, and it can be used not only as effective modeling tool for specific research, but also as good visual material for the basic courses.

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