

# System Dynamics Modeling in a Ukrainian Secondary School

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## Abstract

*Since 2012, the System Dynamics Group at the University of Bergen in Norway and the Finance Department at the National University of Kyiv-Mohyla Academy in Ukraine have been collaborating in a project called "Learning Economics with Dynamic Modeling." The project's primary educational purpose is building system dynamics modeling capacity in Ukraine, thereby improving economics education and research. Over the next four years, the project will be enlarged and extended to include SD-based research in collaboration with economists at Ukraine's central bank, plus an initiative to engage a select number of Ukrainian secondary school teachers and students in SD-based teaching and learning of economics. This paper describes an initial effort by two of the co-authors to engage secondary students in SD-based learning. Findings suggest that system dynamics-based education can contribute to student learning at the secondary school level in Ukraine, in addition to being an effective modeling tool for research at that level.*

## Introduction

Since 2012, the System Dynamics Group at the University of Bergen in Norway (UiB) and the Finance Department at the National University of Kyiv-Mohyla Academy (NaUKMA) in Ukraine have been collaborating in a project called "Learning Economics with Dynamic Modeling." The project's primary educational purpose is building system dynamics (SD) modeling capacity at NaUKMA, thereby improving economics education and research in Ukraine. Under this program to date, NaUKMA has sent 12 master and PhD students and 3 professors to Bergen to gain in-depth training in SD modeling, including macroeconomic modeling and policy design and implementation. Funding for the project has been provided by the Norwegian Centre for International Cooperation in Education and the Norwegian Foreign Ministry.<sup>1</sup>

In 2016, we received a three-fold increase in funding to enlarge and extend the project. We have also received new exchange-student funding from the European Union's 'ErasmusPlus' program. Over the next four years, about 65 *additional* Ukrainian students and professors will develop SD modeling skills in Norway. More importantly, they are sustaining this university-level education initiative by developing new SD courses while enhancing other economics and finance courses in their home university. On the research side, collaboration has begun with economists at Ukraine's central bank. One of the new initiatives involves reaching out to secondary schools in Ukraine, where workshops, conferences, and model-based 'science fairs' for teachers and students will be organized.

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<sup>1</sup> For more information, see Stelmashenko et al. (2015). In addition, a five-minute video with student interviews highlights the project (<http://www.uib.no/en/rg/dynamics/81245/learning-economics-dynamic-modelling>). See Davidsen et al. (2014) for an overview of system dynamics teaching and research at the University of Bergen.

The organizing principle for the entire project is ‘training the trainers.’ In addition to gaining modeling skills and experience, NaUKMA students and professors develop SD-based teaching, supervision, and mentoring skills. Along those lines, this paper describes an unexpected outcome of the first phase of our collaboration; it occurred even before our new secondary schools initiative was formalized and funded. One of us (PhD student Dadashova) received SD training in Bergen and, after returning to Ukraine, introduced SD to another co-author (secondary student Ganina). The rest of this paper describes how that mutual teaching and learning experience evolved.

### **University Engagement with Secondary Schools**

The quality of a university education depends not only on the university’s internal capacity for instruction, but also on students’ capacity for learning. When students enroll at a post-secondary institution, their capacity to learn depends, in part, on their basic stock of accumulated knowledge and skills. Just as important, however, is their ability to think logically and critically. Moreover, those of us trained in SD believe that ‘thinking systemically’ should be on any list of learning skills. Needless to say, universities should always be striving to improve their instructional capacities. At NaUKMA, we believe a university should also be engaged in efforts to help young students prepare themselves for the university educational experience.

Ways that universities can be engaged with secondary schools include making modern methodologies accessible to teachers and students and mentoring those who show an interest in learning to use those methods. In Ukraine, this engagement is fostered by university professors’ participation in secondary students’ research projects for the annual National Scientific Academy Research Contest. In this competition, students have opportunities to conduct research in various spheres and present it to a professional evaluation committee. While conducting and presenting the research, each student is supervised by one teacher from the secondary school and one scholar from a university. In 2015-2016, Kateryna Ganina entered the national competition and NaUKMA supported her initiative with professional support and supervision. She was the winner at the city-level and placed high in the regional competition.

### **Choosing a Research Topic and Methodology**

To be competitive in the Ukrainian contest, the student must start with a research topic that is distinguishable from the topics that are common in student research at the secondary level and even at the undergraduate level at universities: simple theoretical paraphrases. The key principle is to take one particularly important issue and address it in a simplified yet novel way, and discover practical implications. Therefore, the selection criteria for the research topic were:

- importance of the issue,
- identification of the main problem to be addressed,

- availability of data and clarity of the theory in the model structure,
- possibility to produce results with practical implications.

Initially, therefore, Kateryna created a list of possible topics with these criteria in mind. There were topics related to the tax system and discipline in Ukraine, the shadow economy, educational efficiency, and the competitiveness of business procedures at the micro level. However, to make the research really practical and important, it was necessary to identify not only an interesting topic, but also the way it can be investigated and research results demonstrated. She organized her topics in a comparative way, as displayed in Table 1.

Table 1  
*Preliminary topics of the research analysis*

No	Issue to address	Research questions	Methods	Possible results
1	Tax efficiency	Do people in Ukraine feel the benefits from taxes they pay?	Surveys, data analysis.	Visualization of real net benefits from taxes, evidence of importance of tax discipline.
2	Education as economic growth factor	Does educational level influence economic efficiency and provide growth?	Data analysis	Substantiation of the education importance of economic development
3	Pension system efficiency	What policy decisions can really improve the pension system efficiency in Ukraine?	Simulation modeling, data analysis	Visualization of the policy implementation results, explanation of the interrelations that are responsible for the pension system development
4	Business plan of an enterprise	How can small enterprises in Ukraine be created?	Data analysis	Plan of establishing a small enterprise in Ukraine

All the topics in Table 1 are significant for Ukraine's development. Personal behavior influences the economy through tax evasion and avoidance, high levels of shadow activities, and extreme dollarization. Public perception of these issues also influences their significance. The financial crisis that grew out of a political crisis at the beginning of 2015 was caused not only by objective financial and economic conditions, but also by public panic and non-rational behavior (Lukianenko & Dadashova, 2016). The budget imbalance in Ukraine is connected not only to excessive spending, but also 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 the shadow economy according to the ministry of finance and the World Bank is nearly 50 % of Ukraine's total output.

The typical behavior is directly connected to the fact that people do not see the real results of their actions. Although the general educational level of Ukrainians is relatively high, the level of basic economic education is rather low. This can be explained by the fact that basic economics

began to be taught in secondary schools only 15 years ago. Therefore, lack of familiarity with basic economic concepts creates additional disturbances for the economy. So the issues of economic education and tax discipline were important to address in the research. The question for Kateryna was how to merge educational elements into her research design.

At that point, her key decision was to choose a research method to achieve the scientific results (e.g., replication of historical pension system behavior) but also to enable understanding and communication of the reasons for those results (i.e., structure underlying that behavior). It is important that the chosen method give both the young researcher and her audience a chance to deepen their understanding of the research problem and to infer substantiated conclusions based on clear thinking about that problem.

Kateryna chose system dynamics (SD) as her research method. The advantages of SD can be separated into two categories: those for the modeler and those for the target audience (Figure 1). For the modeler--a secondary school student—SD was preferable because it demands good understanding of the structure responsible for the problematic behavior. Therefore, SD motivates studying to gain deeper knowledge. At the same time, this method is relatively easy to learn, compared to most macro-economic modeling tools. And 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 side, the audience--while not familiar with SD methodological details—can still understand the modeling outcome when behavior-over-time simulation results are explained with the aid of structured illustrations that rely on stock-flow and causal-loop diagrams.

	<b>Modeler</b>	<b>Target audience</b>
<i>Method Features</i>	<ul style="list-style-type: none"> <li>• Need for the object structure knowledge,</li> <li>• Simplicity of modeling,</li> <li>• Wide range of testing options,</li> <li>• Low demand for data,               <ul style="list-style-type: none"> <li>• Visualization possibility,</li> <li>• Real time simulation and forecasts possibilities.</li> </ul> </li> <li>• Availability of user friendly interface.</li> </ul>	
<i>Results</i>	<ul style="list-style-type: none"> <li>• Understanding the underlying structure that creates the interesting behavior,</li> <li>• Understanding the impact of decisions on the system's behavior,</li> <li>• Forecasts of system behavior under different conditions.</li> </ul>	

Figure 1. Methodological features of system dynamics and the advantages for participants

With SD, it was feasible for Kateryna to include all the desired aspects into her research: choose an important issue with problematic behavior, investigate and represent its structure, make numerical analysis, and create the research outcome (model) that can contribute to the economic

education of different groups. In order to make the last point even more explicit, it was decided to emphasize 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 a desire to reach practical results. That culminated in Kateryna’s research goal: to create a model of the pension system in Ukraine in order to explain its principles to secondary school students.

### Modeling Results

The next phase of the research after the goal formulation and method selection was to create the necessary model that would represent the structure of the pension system in Ukraine that could explain the reasons for its imbalance during the period under investigation. The deficit of the pension system, the resulting debt, and the burden on the governmental budget became the core issues for the model to explain. Figure 2 displays the pattern of historical behavior for these issues.

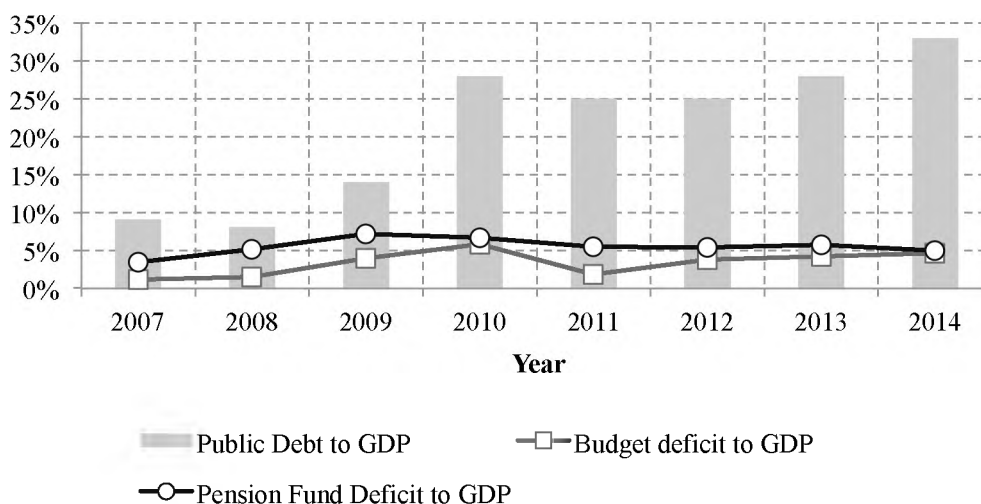


Figure 2. Pension fund deficit dynamics in context of budget deficit and public debt accumulation.

In order to explain the problematic behavior, it was necessary to represent the pension system structure in the model. The pension system in Ukraine is completely financed by the government. It provides pensions to all citizens that reach the pension age (60 years for man and 55 for women). The pension is paid once a month and the amount depends somewhat on the working experience. The pensions are paid from a special governmental fund named Pension Fund of Ukraine. The fund is created from the social contributions of the working population in the form of a 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 the current working population pays contributions which are used to pay pensions to current pensioners. Under this system, 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 a deficit of such resources, the government covers the gap with its special transfers from the budget. As it can be seen from Figure 2, this annual coverage is a significant fraction of the budget expenditures and contributes to the imbalance of the budget. The only available source for the budget deficit coverage during recent years in Ukraine has been debt financing. The connection between the pension fund imbalance, budget imbalance, and debt accumulation causes the problem for the Ukrainian fiscal system and the overall financial sector.

The first modeling task was to represent the interrelationships that produce the problematic behavior associated with the pension fund. The model's population aging chain allows for the computations of the working age population and pensioners. 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 improves understanding of the interrelations that drive the main economic indicators. The model structure is presented in the Figure 3. The model is calibrated with actual data for Ukraine in 2007-2014.

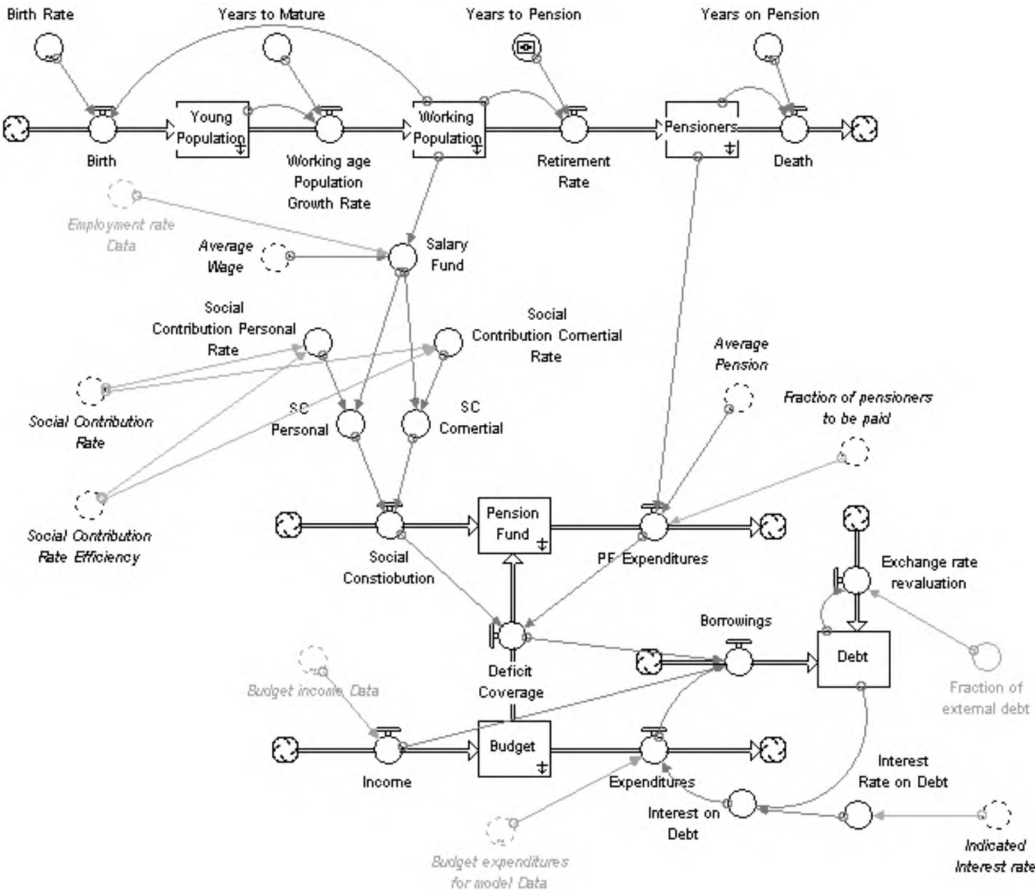


Figure 3. The structure of the pension system of Ukraine model

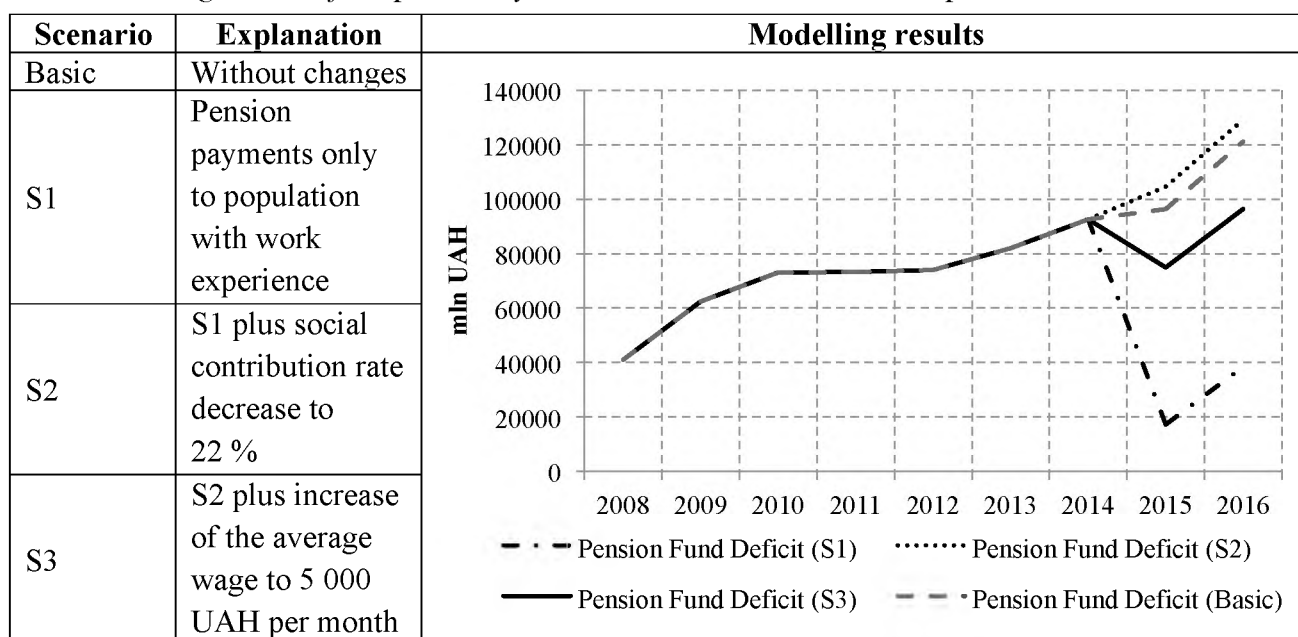
Because the model was to be used for educational purposes, Kateryna included a large set of testing possibilities in order to illustrate the impact that different policies can make on the pension system. It was assumed that visualization of the impact of different policies contribute to the understanding of the underlying principles that define pension system behavior and various proposals for changing it. It is possible to test the changes of such indicators:

- average pension,
- pension age,
- tax rate that is paid to pension fund,
- efficiency of the social contribution rate,
- average wage,
- limitation of the categories that receive pension,
- interest rate on government 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 2.

Table 2

*Modeling results of the pension system behavior under alternative policies, 2015-2016.*



### Using the Findings to Improve Learning

Since one of the main purposes of the research was educational, it was necessary to do more than develop a forecasting model. It was also important to develop easy-to-understand, interesting, and visually attractive materials that would explain the principles of the pension system in Ukraine. The model was used to explain the pension system in Ukraine to secondary school students, and different scenarios were developed to make the principles of pension program budgeting more explicit. For this purpose, an hour-long workshop was conducted.

The audience for the workshop consisted of students in the 10<sup>th</sup> and 11<sup>th</sup> years at the Irpin Specialized School No. 2 with Advanced Study of Economics and Law. The students had already taken several classes of basic economics, so they were ready to accept the material. During the workshop, Kateryna used her model to explain to the other students the structure of Ukrainian pension system. She explained why the current imbalance is important for everyone, proposed different options for changing the pension system, and allowed students to see what would happen in 2015-2016 with the pension fund, budget, and debt for each policy tested. Then the students were encouraged to suggest a combination policy scenario that would permit reaching desirable pension system conditions without creating additional budget burden. The students actively used the model to create different policy combinations and recommend the 'best' possible way to manage the pension system.

To measure the educational workshop effects, two surveys were conducted. Students were asked to answer the same question before and after the workshop; namely, “What you would like to change in the Ukrainian pension system?” The number of populist answers decreased after the workshop; moreover, the majority of students selected options that would increase the pensioners’ wealth together with those that could balance the pension fund budget without additional borrowings. That suggests the visualization of existing problems and possible outcomes of policy changes are able to improve the students' understanding of economic processes.

Our co-author--Kateryna--was confident and well prepared while presenting the forecasting results under different scenarios. She could explain all behavioral changes and how they were produced by the model structure. That would have been impossible without the experience of modeling that gave her a deep understanding of the systemic structure she had represented.

After the workshop, students were asked to evaluate the educational efficiency of the modeling process. Nearly two-thirds (64 percent) of the students said model testing makes the process of understanding easier, and 80 percent said that it's clearer to use SD to study the pension system. The survey results are presented in Figure 4. Also, it is important that more than half of the students said they would like to study system dynamics.

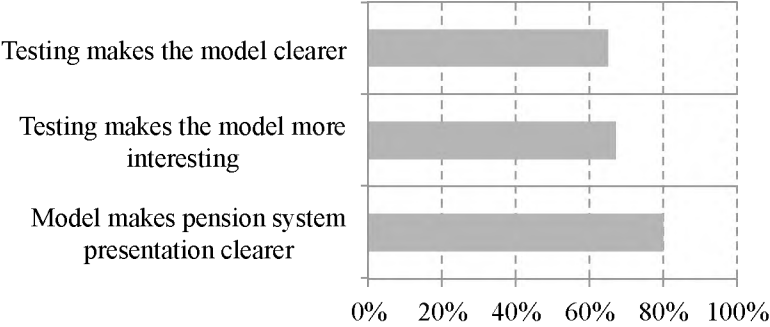


Figure 4. Results of the student survey conducted after the workshop



## Conclusions

To provide high quality post-secondary education, a university should improve its own instructional capacity, as NaUKMA has been doing in its collaborative project with the University of Bergen. But universities can do more; they can also help secondary students prepare for the university-level educational experience. The NaUKMA initiative to help a secondary school student with her research was driven by this idea.

Using Kateryna's model in the student workshop also appeared to be an effective teaching strategy. After the workshop, knowledge of the pension system was higher. Moreover, the majority of students proposed relevant and balanced measures aimed to 'fix' the broken pension system. About 80 percent of the students found the model to be a useful way to explain economic issues, and more than half are now interested in learning more about system dynamics. Therefore, we conclude that system dynamics modeling can contribute to the educational process at the secondary school level in Ukraine, in addition to being an effective tool for research at that level.

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