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## SIMULATION MODELLING OF THE AIRPORT PASSENGER SERVICE PROCESS

The article is devoted to the study of the efficiency of operation of the registration and checking system of passengers at Boryspil airport, using the theory of mass service. The state of passenger air transportation at Boryspil airport was analysed. The model of the operation of the registration and checking system of passengers is considered, its simulation model is developed, as well as on the basis of the model, recommendations are given to increase the capacity of the Boryspil airport passenger check-in and checking system.

The main attention is paid to the problem of the functioning of airport passenger terminals as a complex multichannel mass service system. The results of the study will facilitate the adoption of managerial decisions regarding the improvement of the airport's operations, namely, optimization of the structure of passenger services.

**Key words:** efficiency, system, simulation modelling, mass service theory, airport capacity.

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## SYSTEM DYNAMICS APPROACH TO MODELING OF MIGRATION IN UKRAINE

The article investigate the dynamics of migration processes in Ukraine based on the system dynamics approach. The simulation model that takes into account the factors of wage differences, GDP, unemployment and living standards in Ukraine and neighboring countries has been constructed. The simulation results showed that the main factors of migration for Ukrainian labor migrants was to improve their standard of living and the prospect of higher salaries. However, incomes from other countries are not the only factor of the motivation for migration. The decision-making process includes non-financial variables such as social benefits and cultural values.

**Key words:** migration, system dynamics, labor force, unemployment, simulation model, labor market.

У статті проведено дослідження динаміки міграційних процесів в Україні на підставі підходу системної динаміки. Побудовано імітаційну модель, що враховує чинники відмінностей у заробітній платі, ВВП, рівня безробіття та прожиткового мінімуму в Україні та країнах-сусідах. Результати моделювання показали, що основними факторами міграції для українських трудових мігрантів є поліпшення їх рівня життя та перспектива вищих зарплат. Проте доходи від інших країн не є єдиним фактором мотивації для міграції; процес прийняття рішення включає нефінансові змінні, такі як соціальні переваги та культурні цінності.

**Ключові слова:** міграція, системна динаміка, робоча сила, безробіття, імітаційна модель, ринок праці.

System dynamics is a technique for strategic and policy simulation modeling based on feedback systems theory. This approach was invented by J. Forrester who was a pioneer in engineering and computer design. Since then, SD has developed as its own field, distinct from the larger fields of operations research and management science to which it is related. System dynamics is a powerful methodology and computer simulation modeling technique for framing, understanding, and discussing complex issues and problems. Originally developed to help corporate managers improve their understanding of industrial processes, system dynamics is currently being used throughout the public and private sector for policy analysis and design.

Expanding the analytical toolbox of system dynamics constitutes a third research stream. Methods for estimation of dynamic models (e.g. derivatives of maximum likelihood and indirect inference), optimization and control of these systems (e.g. approximate dynamic programming), formalizing the links between model structure and behavior (e.g. eigenvalue analysis), and decision analysis (e.g. decision trees) using these models are common research targets [1]. This type of research can be heavily analytical and often closely interacts with literature in control theory, econometrics, operations research and decision analysis, among others.

From organizational transformation, project management and process improvement to macroeconomics and economic cycles, climate change, epidemiology, body weight dynamics, and the evolution of ecosystems, system dynamics research have deepened our understanding of the origin of dynamics, tested hypotheses empirically, and informed policy analysis. In our research, we use system dynamic method in purpose to investigate the migration in Ukraine.

Ukraine has the second largest migration corridor in the world (the US-Mexico corridor being the largest). Keeping this in mind Ukraine had and continues to have the difficult task of building migration systems with large and frequently used borders. Ukraine's demographic mosaic is set by relatively high mortality rates (especially for males), falling fertility rates and significant net migration outflows. For example, the population fell from 51,944,000 million persons in 1991 to 45,533,000 million persons in 2013. There has been a total population decrease in Ukraine over many decades. It is caused by two factors. The first one is the deterioration of the overall macroeconomic situation in Ukraine. It leads to aggravation of contradictions in the social and labor sphere, the enhancement of these contradictions is caused by the lack of effective employment structural

changes [2], constriction of employment opportunities, incomplete usage of employed labor force, decrease of actual employment income and the demographic factor as well. Economic and demographic differences have influenced the shape of labor mobility and migration across Europe during the last decade. Rich societies in Europe are experiencing rapid population aging and in the last decade, many of these countries have been confronted with stagnation and a decline of their native labor forces. Labor shortages, especially in the low skilled labor market segment, have increased rapidly [3]. Statistics shows population ageing will continue to grow. Many countries have addressed labor shortage and aging society problems through a strategy of migration and foreign labor mobility. As shown in the population pyramid. Ukraine is experiencing an aging population with a high percentage of the population falling in the 35-95 age categories. A lot of population in the age category 20-66 are becoming labor migrants.

#### **Literature review.**

Migration is an important demographic factor that influences economic activity and unemployment rate in every country. Ukrainian researchers substantiate the presence of socio-demographic, informational, structural, market, territorial and gender asymmetry in the labor market [4; 5] that have impact on internal migration in national labor market as well as emigration. Scientists emphasize the significant dependence of the economy on inconsistent policy decisions, the aging of productive assets due to the lack of the production sector financing [6; 7]. The limited effect of foreign direct investment and asymmetry in the depletion of productive forces [8; 9], underutilization of labor resources and non-optimal distribution [10], significant unemployment [11], low wages and problems in the informal sector of employment are important causes that have influence on migration. Thus, the scientific investigation of migration flows need to leverage the system dynamics views and methods.

**The research goal** of this work is to analyze the phenomenon of labor migration in Ukraine and its impact on the country's economic development by means of system dynamics approach. Among this, we examine the negative effects of the reduction of the population of Ukraine and the instability of its social security system.

#### **Data and Methodology.**

The theoretical basis of empirical modeling of interactions between factors of immigration will serve some modifications of a macroeconomic economic-mathematical model of migration. The theoretical model covers the modeling of emigration from Ukraine through such indicators as average wages, unemployment rate and GDP

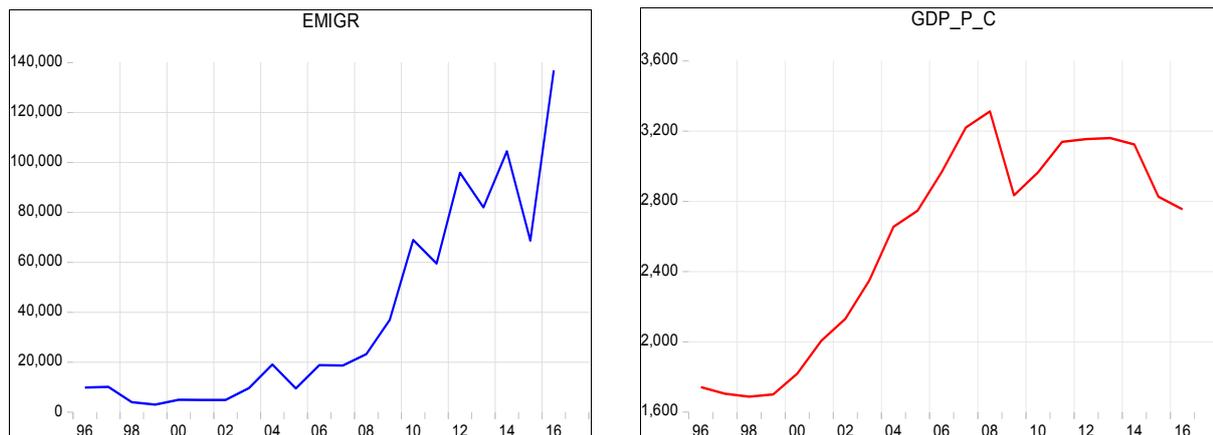
per capita. Rows of data of these indicators are named accordingly: emigration from Ukraine – *emigr*, average wage – *avr\_wage*, unemployment rate – *unempl\_r*, GDP per capita – *gdp\_p\_c*. In other words, we consider the phenomenon of migration as a function of these factors  $emigr = f(avr\_wage, unempl\_r, gdp\_p\_c)$ . All data are presented from 1996 to 2016.

While closely related to simulation research in management science and beyond, the system dynamics approach to modeling has a few distinctive features. It is characterized by a focus on endogenous explanations for dynamic phenomena. Dynamics are explained as arising primarily endogenously within the boundary of a model from the interactions among the elements and actors in the system, rather than from exogenous inputs. Every attempt is made to represent these causal processes realistically, consistent with the available empirical evidence, and robust to extreme inputs outside of the historically observed range. System dynamics researchers strive to capture the causal processes at play and the representation of these should correspond

to the real-world processes in the system under study, be consistent with the available empirical evidence, and be robust to extreme inputs outside of the historically observed range. These considerations require SD modelers to draw on a wide range of qualitative and quantitative data. System dynamics modelers not only use traditional econometric methods to estimate model parameters using quantitative data, but also routinely augment those methods with qualitative research methods including the use of archival documents, interviews, and ethnographic methods and direct observation of decision making and organizational processes. Model testing involves quantitative assessment of the ability of the model to reproduce the behavior of the system of interest, and a wide range of additional tests including structure assessment, dimensional consistency, extreme condition, behavior reproduction, surprise behavior, sensitivity analysis, and system improvement tests, among others [1].

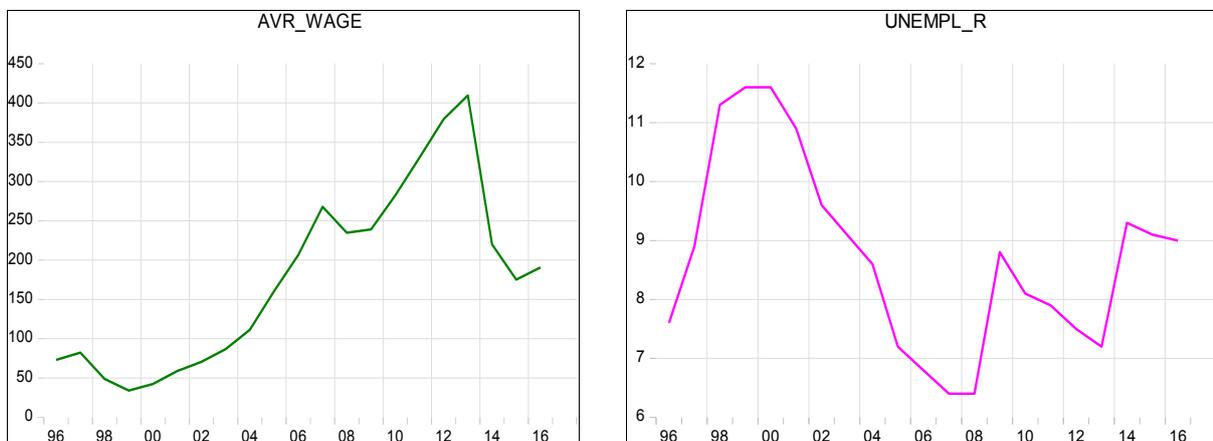
#### Empirical modeling and results.

At first, we considered a simple model of the population by adding two flows (Figure 3). Inflow



**Fig. 2. Time series plot of the long-term labor emigration and GDP per capita**

Source: data of the State Statistics Service of Ukraine, elaborations of the authors.



**Fig. 3. Time series plot of the average wage and unemployment rate**

Source: data of the State Statistics Service of Ukraine, elaborations of the authors.



emigration through *Fraction of emigration*. We also assumed that these all effects have an impact on return Ukrainian from abroad. They affect *Emigrants return* through *Percentage of return*.

To obtain the *Effect of wage difference on emigration* we calculate it as the ratio between *Ukraine to world wage* and the *Normal difference in wage* and consider *Ukraine to world wage* as the ratio between *Ukraine's average wage* and *world wage*. The calculation of *Ukraine's average wage* is defined by the ratio between *Nominal wage* and *Employment*. *Nominal wage* is a product of *GDP* and *Labor income share*.

Important is *Effect of difference in the unemployment rate* that determined as a ratio between *Ukraine to world unemployment rate* and the *Normal difference in the unemployment rate*. *Ukraine to World unemployment rate* is calculated as the ratio between *unemployment rate in Ukraine* and in the world. The *Ukraine's unemployment rate* as a ratio of *Unemployment* and *Labor force*. *Unemployment* is a product of *Labor force* and *Unemployment ratio*. The *Labor force* is formed as a product of the population ages 15 and older that is economically active and *Labor force participation*.

The last effect that we considered is *Effect of the average cost of living on emigration*. We calculated it as the ratio between *Ukraine to world-price wage ratio* and the *Normal difference in average cost of living*. *Ukraine to world price-wage ratio* we calculated as the ratio between *Ukraine to world price ratio* and *Ukraine to world wage* (a ratio that is already in our model).

The Figure 4 represents a System Dynamics model of emigration from Ukraine.

The objective of system dynamics method is to find the conditions under which a system under study will evolve and in what direction.

It aims at considering the interrelationships between the components of an organization or environment rather than looking at each component in isolation.

#### Conclusions.

In building system dynamics models is the importance of modeling a problem rather than an entire system. Focusing on a particular problem provides a boundary to the modeling process and forces the modeler to consider only system variables that relate specifically to the problem in question.

Migration management in Ukraine had to meet big challenges in the past and until now. To investigate the problem we built system dynamics model that explain what can make people leave their country. The modeling results proved that main cause of emigration is that the average migrant wage abroad is several times higher than the average salary in Ukraine. The main migration push factors for Ukrainian labor migrants are the improvement of their living standards and the prospect of higher salaries. However, income differentials are not the sole motivation factor for migration; the decision process includes non-fiscal variables such as social preferences and cultural values. In the model, we assumed that people take into account such factors as the difference in wages, the difference in cost of living, the difference in unemployment rates and the difference in GDP per capita.

Constructing a unified theoretical framework based on the SD perspective will significantly contribute to an understanding of the underlying structure behind the rapid growth of emigration from Ukraine. On the other hand, it will provide an understanding of the fundamentals of the underlying feedback structure that drive migration phenomena in general.

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System dynamics is a technique for strategic and policy simulation modelling based on feedback systems theory. Expanding the analytical toolbox of system dynamics includes the methods of dynamic models estimation, system optimization and control, formalizing the links between model structure and behaviour, decision analysis. The article investigates the dynamics of migration processes in Ukraine based on the system dynamics approach. Ukraine has the second largest migration corridor in the world. Keeping this in mind Ukraine had and continues to have the difficult task of building migration systems with large and frequently used borders. Ukraine's demographic mosaic is set by relatively high mortality rates, falling fertility rates and significant net migration outflows. The theoretical basis of empirical modelling of interactions between factors of immigration will serve some modifications of a macroeconomic economic-mathematical model of migration. The theoretical model covers the modelling of emigration from Ukraine through such indicators as average wages, unemployment rate, and GDP per capita. The developed simulation model that takes into account the factors of differences in wage, GDP, unemployment rate, and living standard in Ukraine and neighbouring countries has been constructed. The simulation results showed that the main factors of migration for Ukrainian labour migrants were to improve their standard of living and the prospect of higher salaries. However, incomes from other countries are not the only factor of the motivation for migration. The decision-making process includes non-financial variables such as social benefits and cultural values.

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