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IMPACT OF HUMAN CAPITAL LOSSES IN IT ENTREPRENEURSHIP ON THE POST-WAR RECOVERY OF UKRAINE'S ECONOMY

The article is devoted to substantiating the causal impact of human capital losses in IT entrepreneurship due to migration processes on the post-war recovery of the Ukrainian economy based on a multi-criteria model of indicators and the interpretation of lag variables. It is identified that the migration crisis in IT is escalating, which directly affects the prospects for economic growth and complicates the recovery of the national economy in the post-war period. A two-vector concept of the impact of human capital losses in IT entrepreneurship is established: (1) migration outflow to the sector abroad (emigration) with a projection on IT development indicators; (2) the existing economic potential of the state with a projection on post-war recovery. The following indicators of the development of the IT segment are substantiated: economic potential, human capital, innovative investments as an information-analytical basis of the study based on the principles of dynamism and integrity. The results of dynamic modeling of economic potential and post-war recovery of Ukraine for 2018-2023 proved the thesis that indicators of economic potential have a complementary lag interaction. It was established that the strength of the impact of migration of IT specialists on economic potential increases in a time lag of 2-3 years. It is proven that an increase in the balance of migration of IT specialists by 1% leads to a weakening of economic potential by 0.15%. It is substantiated that in the absence of an effective policy for managing migration processes and ensuring re-emigration of the population, the economic effect of using migration transfers will not exceed the economic losses from weakening potential, especially at the stage of post-war recovery of the Ukrainian economy.

Ключові слова: *IT entrepreneurship, economic potential, human capital, innovative investments, post-war recovery.*

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1. STATEMENT OF THE PROBLEM IN A GENERAL APPEARANCE AND ITS CONNECTION WITH IMPORTANT SCIENTIFIC OR PRACTICAL TASKS

Since the beginning of the war, IT has been the only sector of the economy in Ukraine that continues to develop, create new jobs, implement new projects, and attract investments. Today, the IT sector is a highly intellectual industry in Ukraine, employing almost 300,000 specialists and growing by 25-30% annually. One IT specialist creates an average of 2.8 additional jobs in related industries. In 2023, this figure was 2.7. In total, the sector provides 663,000–668,000 jobs [1].

In 2024, IT entrepreneurship continues to be the backbone of Ukraine and may become one of the main drivers of post-war development in the future. The IT industry currently accounts for 4.4% of Ukraine's GDP. It is expected that the total volume of IT services exports will be 6.3–6.45 billion dollars in 2025 [2].

One of the biggest challenges for IT entrepreneurship has been to retain customers and maintain a skilled workforce due to migration processes. Currently, the IT sector has a very high level of dependence on human capital, as it is an integral part of the global creative economy and directly depends on the talents, knowledge and skills of specialists working in this field.

Accordingly, the outflow of personnel as a result of migration processes has a devastating impact on the economy during the war, since the IT sector has already become a key sector supporting the Ukrainian economy in the first years of the war. In addition, the loss of human capital in IT entrepreneurship destructs positive forecasts for the implementation of innovative processes and attracting venture capital for the needs of post-war economic recovery.

2. ANALYSIS OF LATEST RESEARCH AND PUBLICATIONS

The study of the impact of human capital losses in IT entrepreneurship is currently relevant and is in the circle of research by economists from Ukraine, since it has a target vector of orientation in view of the military situation in Ukraine. The information basis for understanding trends and challenges in the field of IT entrepreneurship are operational reports and interim studies with the participation of IT Cluster, the DOU programmer community and the Ministry of Digital Transformation of Ukraine.

From the side of scientists, an overview of the IT market situation was carried out in the studies: Barvinok V. [3], Bozhinsky S. and Synyavsky O. [4], Zhuravlev O. and Simachov O. [5], key trends in the Ukrainian IT industry were highlighted in the works of Altynpara A. and Korogodova O. [6], Dovgan L. and Malik I. [7], Tymoshenko N. and Ronsky B. [8], strategic imperatives for the development of the industry in the work of Breus R. [9] and Vasyltsiv T. [10].

3. SELECTION OF PREVIOUSLY UNSOLVED PARTS OF THE GENERAL PROBLEM TO WHICH THIS ARTICLE IS DEDICATED

Currently, there is an objective need to assess the impact of human capital losses in IT entrepreneurship on the economic potential of post-war recovery of Ukraine through such projections on the circle of IT specialists: human resources and migration movement. It is obvious that the analysis of trends, the development situation of the industry and approaches to the development of strategic vectors is insufficient. A significant gap is the lack of research on the impact of human capital losses in IT entrepreneurship from migration processes on

macroeconomic indicators in the short and long term.

4. FORMULATION OF THE PURPOSES OF THE ARTICLE

The aim of the article is to substantiate the causal impact of human capital losses in IT entrepreneurship on the post-war recovery of the Ukrainian economy based on a multi-criteria model of indicators and the interpretation of lag indicators of variables.

5. PRESENTATION OF THE MAIN MATERIAL OF THE RESEARCH WITH FULL JUSTIFICATION OF THE OBTAINED SCIENTIFIC RESULTS

Despite the flexibility and resilience demonstrated by the IT market at the initial stage of a full-scale war, at the end of 2023, disappointing signals began to arrive regarding the deterioration of a number of indicators of recruitment, business activity and the financial condition of the information technology market [11]. The Ukrainian IT sector faced such serious challenges as the mobilization of workers into the ranks of the army, recession and the unpredictability of regulatory decisions of the military economy, which affect the export of services and their taxation.

In 2025, according to the forecast of Lviv IT Cluster [12], further globalization of Ukrainian IT companies and an increase in migration of specialists abroad are expected. In such a situation, the obvious trend is the leaching of human capital from the IT sector and the loss of the intellectual and innovative potential of the Ukrainian economy. In order to substantiate the causal impact of human capital losses in IT entrepreneurship on the post-war recovery of the Ukrainian economy, a multi-criteria model of indicators for assessing the effects and interpreting lag indicators of variables [13] was chosen. The proposed model is based on the following principles:

- the presence of connections and interdependence;
- reflection in the indicators of strategic indicators of economic development;
- information accessibility and transparency of indicators;
- quantitative expression of indicators;

- relevance of the assessment, which consists in choosing a single period for calculating indicators [14].

The selected indicative approach assumes an orientation towards the strategic development of the Ukrainian economy in the post-war perspective. In accordance with the approach to forming a system of indicators for assessing the effects of human capital losses in IT entrepreneurship is based on the achievement of such key indicators of macroeconomic assessment as the state's GDP and exports of services from the IT segment.

To identify the impact of human capital losses on the country's post-war recovery potential, two research vectors were selected: (1) migration outflow to the overseas sector (emigration) → indicators of IT segment development, (2) the economic potential of the state → post-war recovery.

To build a model of post-war economic growth, a hypothetical progress in the growth of indicators described by the variables in Table 1 is assumed. Therefore, the information-analytical

basis of the study is the indicators of the development of the IT segment, grouped according to the principles of complementarity, dynamism and integrity.

Based on the modeling of lag indicators of the variables «Emigration outflow - Economic potential» to determine the impact of migration on the change in the share of computer service exports in Ukraine's service exports, a short-term moderate relationship was identified. Fig. 1 shows the share of computer service exports in services exports has increased by 35.3 percentage points, accounting for 4% of GDP [15].

Thus, migration causes a reverse impact on the indicator «Economic Potential» in the third and fourth lags (-0.18% and -0.35%, respectively), which is presented in Table 2. In particular, an increase in the migration balance by 1% contributes to an increase in economic potential by an average of 0.25%, which is explained by an increase in the volume of migration transfers to Ukraine, but a decrease in the share in the export of services.

Table 1

Comparability of variables and indicators for lag modeling*

№	Variables	Indicators	Unit
1	Economic potential	Share of IT services export in GDP	%
2	Human capital	Number of employees in the IT industry	Person / Thousand
3	Innovative investments	Venture capital	USD / Million

* developed by the author

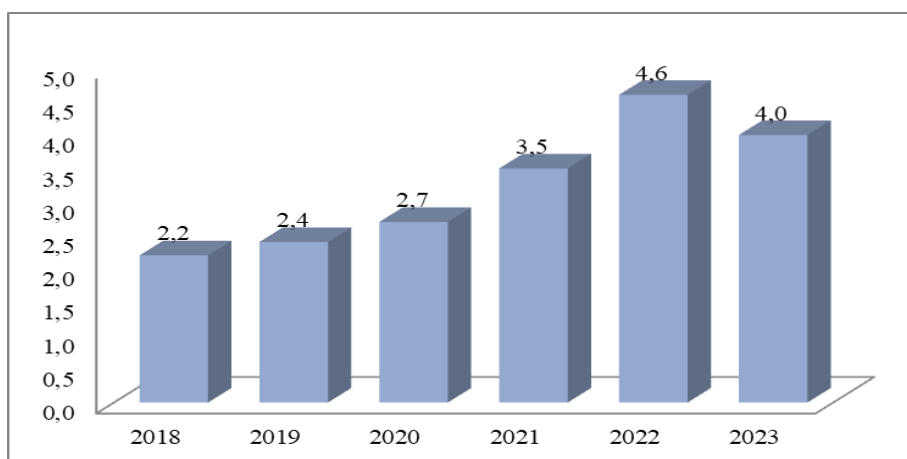


Fig. 1. Share of computer service exports in GDP (%), 2018-2023 [15]

Table 2

Modeling lag indicators of variables «Emigration outflow - Economic potential»*

Lags	Impact coefficient	Indicators of statistical significance		
		Standard error	Student's t-test	p-level
lag ¹	0,53144	0,19877	2,00518	0,03315
lag ²	-0,73758	0,28863	-1,91661	0,03818
lag ³	-0,17983	0,23717	-0,56867	0,36188
lag ⁴	-0,34916	0,24639	-1,06282	0,16170

* developed by the author

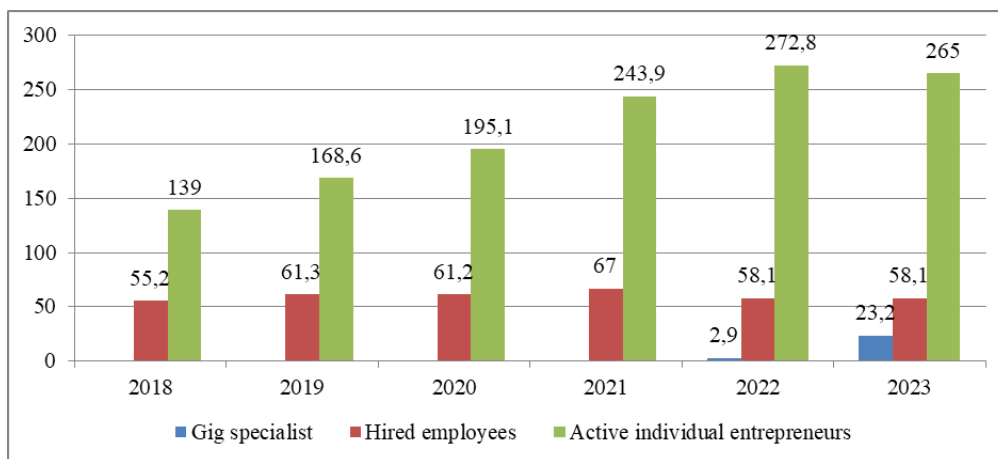


Fig. 2. Number of employees in the IT industry in Ukraine, 2018-2023*[16]

*one IT specialist can be an individual entrepreneur, an hired employee and a gig specialist at the same time

Table 3

Modeling lag indicators of variables «Emigration outflow - Human capital»*

Lags	Impact coefficient	Indicators of statistical significance		
		Standard error	Student's t-test	p-level
lag ¹	0,44385	0,24154	1,37818	0,00869
lag ²	0,39336	0,36847	0,80066	0,02451
lag ³	2,04114	0,43191	0,93966	0,01927
lag ⁴	3,00027	0,32672	1,72226	0,00461

* developed by the author

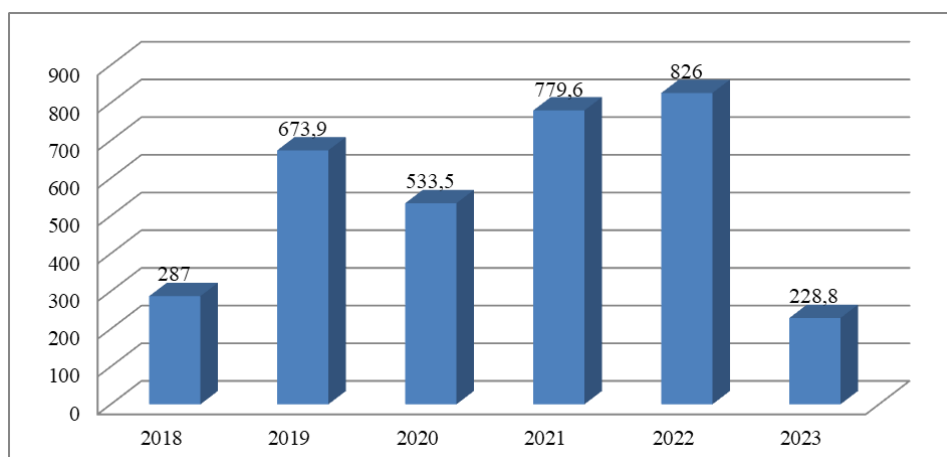


Fig. 3. Volume of venture capital deals in the Ukrainian IT market, 2018-2023 [17; 18]

Table 4

Modeling lag indicators of variables «Emigration outflow - Innovative investments»*

Lags	Impact coefficient	Indicators of statistical significance		
		Standard error	Student's t-test	p-level
lag ¹	-0,10159	0,20297	-0,37539	0,04741
lag ²	-0,17747	0,15692	-0,84825	0,02215
lag ³	-0,41854	0,18412	-0,17736	0,06149
lag ⁴	-0,45670	0,15043	-2,27689	0,00143

* developed by the author

In Ukraine, an IT specialist can cooperate with companies in three ways, each of which has its own characteristics of cooperation and advantages for both the IT specialist and the IT company. Given that work in the IT industry is more project-oriented, most IT specialists prefer

to work with companies as individual entrepreneurs, rather than as full-time employees. Accordingly, the assessment of migration losses of IT specialists was carried out in terms of combining three categories: gig specialist, hired

employees and active individual entrepreneurs (Fig. 2).

Based on the implementation of primary calculations, it was found that the migration outflow of IT specialists to the sector abroad does not have a significant impact on the indicator «Human Capital» in the first time lag (the impact coefficient is -0.44%). The nature and strength of the impact of migration of IT specialists on resource potential and labor productivity changes and increases from the second lag (Table 3). Thus, a decrease in the balance of youth migration by 1% leads to a decrease in labor productivity from 0.39% to 3.0% (the second and fourth lags, respectively).

The migration of highly qualified specialists in the IT segment, as the most creative segment of the economically active population, affects the provision of innovative development by

attracting investments in innovations based on venture financing (Fig. 3).

Significant migration of IT specialists leads to an increase in the shortage of personnel and causes the formation of a personnel famine in the process of innovative developments and the organization of startups. The increase in migration of IT workers is the reason for the decrease in the «Innovative investments» indicator, and as a result, the loss of economic potential for post-war recovery.

The impact of IT industry migration on the «Innovative investments» indicator can be traced in four lags. Losses of venture capital due to the startup crisis have a reverse impact on the resource potential of «Innovative investments» in all time lags, the strength of the impact of which increases with each year (Table 4); for example, the impact coefficient in the first lag is 0.102%, and in the fourth – 0.457%.

Table 5

**Modeling lag indicators of variables
«Emigration outflow – Economic potential – Post-war recovery potential»***

Lags	Impact coefficient	Indicators of statistical significance		
		Standard error	Student's t-test	p-level
Economic potential				
lag ¹	-0,37633	0,12818	-2,20197	0,00188
lag ²	-0,67735	0,15783	-1,79311	0,00308
lag ³	-1,11544	-0,61093	-2,94108	0,00143
lag ⁴	-1,41646	-0,58127	-2,53221	0,00098
Post-war recovery potential				
lag ¹	-0,14637	0,05759	-1,90620	0,00143
lag ²	-1,14214	0,06487	-4,53347	0,00008
lag ³	-1,22734	0,06971	-4,87167	0,00008
lag ⁴	-1,48478	0,08434	-5,89351	0,00008
Statistical significance coefficients				
Coefficient of determination				0,607149
Adjusted coefficient of determination				0,559532
Statistical error				9,56298
Fisher's F-test				0,00021
DW statistics				1,724669

* developed by the author

The migration crisis and the deterioration of the demographic, social and economic situation as a result of the war have created serious challenges for ensuring the sustainability of the business sector of Ukraine. The intensification of external migration processes has led to significant losses of the workforce, which directly affects the entrepreneurial potential and the ability of businesses to further develop. The results of the study are not unambiguous, since among the determinants of the potential of post-war recovery is the scaling of business migration

processes abroad through relocation. Business relocation allows developing the business sector in the future, thereby preserving jobs and ensuring the tax stability of the territory. However, the migration of business units leads to significant losses for the national economy due to the weakening of economic security and the development of regional asymmetry.

Currently, the migration crisis in IT has reached critical proportions, which directly affects the prospects for economic growth and complicates the recovery of the national economy

in the post-war period. The impact of migration on the decline in exports of services from the IT sector is increasing in dynamics (Table 5). Thus, an increase in migration losses by 1% leads to a decrease in the economic potential of exports in the first lag by 0.5 pp. and by 1.9 pp. in the fourth lag. The same situation is observed with the impact of migration losses on the pace of post-war recovery in Ukraine, which increases from 0.2 pp. (first lag) to 2.0 pp. (fourth lag). The statistical significance of the results obtained is 99%.

The results of dynamic modeling of economic potential and post-war recovery of Ukraine for 2018-2023 proved the thesis that indicators of economic potential have a complementary lag mutual influence. Migration processes even before the war had a significant impact on the performance indicators of the IT segment. There are two channels of influence - the outflow of human capital, in particular IT specialists, and the receipt of remittances from migrants. Therefore, remittances play a key role in ensuring the economic stability of regions in the short term, especially in the first months of the war. However, without an effective policy of managing migration processes and ensuring the re-emigration of the population, the economic effect of using migration transfers will not exceed the economic losses from weakening potential, especially at the stage of post-war recovery of the Ukrainian economy.

6. CONCLUSIONS FROM THIS RESEARCH AND PROSPECTS FOR FURTHER EXPLORATION IN THIS DIRECTION

According to the results of the modeling of the causal impact of human capital losses in IT entrepreneurship on the post-war recovery of the Ukrainian economy, it was found that the impact of IT specialist migration on economic potential increases in the time period of 2-3 years. The outflow of human capital has a negative effect on the indicator «Economic Potential» in the first and second periods (-0.37% and -0.68%, respectively), a direct positive effect in the third and fourth periods due to a significant increase in remittances from migrants. Thus, it was identified that an increase in the volume of remittances from emigrants to Ukraine will contribute to an increase in financial potential by an average of 0.5%. It was found that an increase in the balance of IT specialist migration by 1% leads to a weakening of economic potential by 0.15%. The impact of migration on venture capital is already visible from the first lag, which indicates a high degree of adaptability of the business sector to structural changes in the labor market.

Further scientific research in this area will focus on analyzing and assessing the socio-economic effect of the IT specialists' integration for the needs of post-war reconstruction of Ukraine, with an emphasis on improving migration policy for digital nomads and their taxation.

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Анотація

ДУМАНСЬКА Ілона

Вплив втрат людського капіталу в IT-підприємстві на поствоєнне відновлення економіки України

Стаття присвячена обґрунтуванню причинно-наслідкового впливу втрат людського капіталу в IT підприємстві від міграційних процесів на поствоєнне відновлення економіки України на основі багатокритеріальної моделі показників та інтерпретації лагових змінних. Ідентифіковано, що міграційна криза в IT масштабується, що безпосередньо впливає на перспективи економічного зростання та ускладнює відновлення національної економіки у пост воєнній перспективі. Встановлено двовекторну концепцію впливу втрат людського капіталу в IT підприємстві: (1) міграційний відтік у сектор закордон (еміграція) з проєкцією на індикатори розвитку IT; (2) наявний економічний потенціал держави з проєкцією на пост воєнне відновлення. Обґрунтовано такі індикатори розвитку IT сегменту: економічний потенціал, людський капітал, інноваційні інвестиції як інформаційно-аналітичний базис дослідження на основі принципів динамізму та цілісності. Результати динамічного моделювання економічного потенціалу і пост воєнного відновлення України за 2018-2023 рр. довели тезу, що індикатори економічного потенціалу мають комплементарний лаговий взаємовплив. Встановлено, що сила впливу міграції IT спеціалістів на економічний потенціал посилюється у часові лази 2-3 років. Доведено, що збільшення сальдо міграції IT спеціалістів на 1 % призводить до послаблення економічного потенціалу на 0,15 %. Обґрунтовано, що за відсутності ефективної політики управління міграційними процесами і забезпечення рееміграції населення, економічний ефект від використання міграційних трансфертів не буде перевищувати економічні втрати від послаблення потенціалу, особливо на етапі поствоєнного відновлення економіки України.

Key words: IT підприємство, економічний потенціал, людський капітал, інноваційні інвестиції, поствоєнне відновлення.

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