

## The interstate development of human capital accounting: Assessment and modeling of the economic effect



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### ABSTRACT

The aim of the article is to develop a methodology for determining the effectiveness and accounting of human capital in the context of interstate comparison. The article notes the importance of systematic accounting for the interstate development of human capital. It is emphasized that there is no relevant methodology in the scientific world for determining the effectiveness and human capital accounting in the context of interstate comparison. Taking into account the above, the authors proposed a method of human capital accounting using the information resource of the UN statistical database. In the article, for the first time in the scientific world, the comparative interstate human capital accounting with the use of the modified first principal component analysis is carried out. The method proposed by the authors involves the use of a variety of socio-economic and demographic indicators of 29 countries of the world and the modeling of a single integral indicator of human capital accounting. The integral indicator made it possible to take into account and compare the level of human capital development in different countries in the dynamics. The proposed method will allow interested stakeholders to systematically record, evaluate and compare the state of human resource development with other countries of the world.

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### 1. Introduction

Human capital is an important strategic resource for the development of a progressive economy based on knowledge and innovation. Unique human abilities, intelligence, experience, professional skills, creativity of thinking arise as important factors of global transformational changes and civilizational progress. Under the current conditions of market economy development, the leading countries of the world continue to adjust and improve the paradigm of human capital accounting. Countries that have information on the real state of human resource

development have competitive advantages in the formation of long-term staffing policies for the knowledge-based economy. At the same time, extensive methodological approaches to the human capital accounting in scientific sources, migration, changes in the labor market conditions give grounds to realize the multidimensionality and complexity of this issue. The modern development of information technology makes it possible to use a wide range of tools for human capital accounting. At the same time, there is a need to improve the modeling of interstate human capital accounting, which will make it possible to quickly make management decisions, to form a state personnel policy in the context of competition and variability of the external environment. An important issue is to determine the set of socio-economic, demographic indicators of the human capital accounting and modeling of an integral indicator that will make it possible to compare the level of human capital development in different countries in the dynamics. In addition,

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there is a need to identify factors affecting the state of human resource development. The solution of these issues actualizes the need to improve the accounting, assessment and modeling of the economic effect of interstate development of human capital.

## 2. Literature review

Taylor and Martin (2001), Erdogan (2002), Abeyssekera and Guthrie (2005), Bozbura et al. (2007), Fleisher et al. (2010), Guthrie et al. (2012), Artuc et al. (2015), and other scientists have thoroughly investigated the problem of assessing, accounting and determining the economic effect of human capital development. The effectiveness of human capital in order to increase socio-economic well-being, accumulation of the country's income is considered in the works of Asteriou and Agiomirgianakis (2001), Coulthard et al. (2011), Teixeira and Queirós (2016), Hanushek and Woessmann (2020), and Alvarado et al. (2021). A separate group of authors approached the accounting and assessment of the economic effect of human capital development from the standpoint of measuring its productivity, which is reflected in the works of Tosi et al. (2000), Bronzini and Piselli (2009), Guillaumont et al. (2017), and Ghosh and Parab (2021). Modeling the assessment of the economic effect of human capital development in entrepreneurship, its impact on the success of business growth and the development of new ideas are analyzed in the works of Davidsson and Honig (2003), Skuras et al. (2005), Unger et al. (2011), Martin et al. (2013), Fayolle and Liñán (2014), Brush et al. (2017), Gryshko et al. (2018), Hnatenko et al. (2020; 2021), Semenov et al. (2021), Gryshchenko et al. (2021), Zos-Kior et al. (2021), Mayovets et al. (2021), and Rossokha et al. (2021). The importance of interstate accounting and determining the relevant set of indicators of human capital effectiveness is raised in the research of Bassanini and Scarpetta (2002), Baldacci et al. (2008), Chiswick and Miller (2009), Hanushek (2013), and Samir and Lutz (2017). An important study in the modern conditions of the development of the world economy has the work of Yarovaya et al. (2021), which raised the impact of COVID-19 on human capital and assessed the effectiveness of its development in a pandemic. Determination of the effectiveness of human capital in the labor market, taking into account migration trends, the specifics of the accumulation and distribution of human resources are analyzed in the works of Wang et al. (2020), and Bobba et al. (2021). A significant number of scholars have studied the role of investment in the effective development of human capital and emphasized that highly professionals encourage investment in the country's economy (Noorbakhsh et al., 2001; Kalemli-Ozcan et al., 2000; Guo et al., 2021). Management aspects of modeling the required level of human capital, its evaluation and accounting are disclosed in the works of Gratton

and Ghoshal (2003), Belout and Gauvreau (2004), Cho et al. (2006), Tarique and Schuler (2010), Lengnick-Hall et al. (2011), and Kiando et al. (2017). Assessment of the adaptability of human capital to crises in the labor market, unemployment and other turbulent phenomena of the market environment is violated in the works of Pelling and High (2005), McArdle et al. (2007), and Below et al. (2012). Assessment of the effectiveness of human capital in the context of active digitalization, the development of artificial intelligence and scientific and technological progress are analyzed in the works of Nowak and Grantham (2000), Batjargal (2007), and Andreev et al. (2021). The method of accounting for human capital in an innovative economy and stimulating innovation using a group of indicators is studied in the works of Hsu and Fang (2009), Danquah and Amankwah-Amoah (2017), and You et al. (2021).

Emphasizing the importance and necessity of scientific works of these scientists to improve the accounting of interstate development of human capital, some problems should be noted. In particular, the extensive methodological apparatus for assessing, determining the effectiveness and human capital accounting proposed by scientists is characterized by fragmentation, complexity, inconsistency and obsolescence. In addition, the group of indicators proposed by scientists does not allow their use in interstate accounting of human capital due to the difficulty of comparing them between countries and the lack of the necessary input information base. Therefore, it is important to develop a relevant and adequate method with individual statistical indicators that would allow obtaining reliable and up-to-date information on the current state of human capital development in different countries in the dynamics. The developed method should serve as a basis for choosing a further management strategy for human capital development, taking into account the internal resources of a particular country.

## 3. Materials and methods

We propose to carry out accounting of human capital in the country using a variety of socio-economic and demographic indicators. On their basis, it is possible to determine a single integral indicator, which will make it possible to compare the level of human capital in different countries and assess its dynamics. Let us denote by  $P$  a set of initial indicators, on the basis of which the specified integral indicator of accounting for human capital is determined. This set can be represented as a union  $P = P_1 \cup P_2$ , where  $P_1 = \{p_{1j}\}_{j=1}^{m_1}$  - a set of economic and social indicators that affect the level of human capital development, and  $P_2 = \{p_{2j}\}_{j=1}^{m_2}$  - a set of demographic indicators. For the integral indicator, the following indicators were selected:

- $p_{11}$  - GDP per capita (in US dollars)

- p<sub>12</sub>–the percentage of unemployed in relation to the working-age population
- p<sub>13</sub>–balance of payments (in million US dollars)
- p<sub>14</sub>–health care spending (as a percentage of GDP)
- p<sub>15</sub>–education expenditures (as a percentage of GDP)
- p<sub>21</sub>–average annual population growth rate
- p<sub>22</sub>–total fertility rate
- p<sub>23</sub>–life expectancy at birth
- p<sub>24</sub>–international stock of migrants (percentage of the total population)
- p<sub>25</sub>–number of refugees
- p<sub>26</sub>–infant mortality rate

Indicators p<sub>11</sub>, p<sub>13</sub>, p<sub>14</sub>, p<sub>15</sub>, p<sub>21</sub>, p<sub>22</sub>, p<sub>23</sub> are stimulants, their increase leads to an increase in the integrated indicator of human capital accounting. Indicators p<sub>12</sub>, p<sub>24</sub>, p<sub>25</sub>, p<sub>26</sub> are disincentives, their increase leads to a decrease in this integrated indicator.

On the basis of these indicators, integral assessments of the socio-economic and demographic components of the country's human potential are determined, and then these assessments are combined into a single integral indicator for accounting for human capital.

The information base of the integral indicator of human capital accounting is the values of indicators from the set P for 2010, 2015 and 2020 in 29 countries (Ukraine, Poland, Armenia, Azerbaijan, Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Austria, Belgium, Germany, Greece, Denmark, Ireland, Spain, Italy, Cyprus, Luxembourg, Malta, France, Sweden). Input indicators for human capital accounting in these countries are obtained from the information resource of UN databases (<https://data.un.org/>). To denote the year, we introduce the variable t: 2010 corresponds to the value t=1, 2015–to the value t=2, 2020–to the value t=3. To denote the country, we use the variable k. The value of p<sub>ij</sub> in the t-th year in the k-th country is denoted as p<sub>ij</sub><sup>k</sup>(t).

To determine the integrated indicator of socio-economic and demographic components of human potential, it is necessary to normalize the indicators p<sub>ij</sub>, i.e. to match these indicators dimensionless indicators q<sub>ij</sub>, which would vary from 0 to 1. For stimulus indicators, the normalization is performed by Eq. 1:

$$q_{ij} = \frac{p_{ij} - \min_{k,t} p_{ij}^k(t)}{\max_{k,t} p_{ij}^k(t) - \min_{k,t} p_{ij}^k(t)} \quad (1)$$

For indicators-disincentives – by the Eq. 2:

$$q_{ij} = \frac{\max_{k,t} p_{ij}^k(t) - p_{ij}}{\max_{k,t} p_{ij}^k(t) - \min_{k,t} p_{ij}^k(t)} \quad (2)$$

where  $\max_{k,t} p_{ij}^k(t)$  and  $\min_{k,t} p_{ij}^k(t)$ –respectively, the maximum and minimum value of p<sub>ij</sub> for all years considered in all countries studied.

All normalized indicators q<sub>ij</sub> are stimulators, and the best value of the indicator p<sub>ij</sub> corresponds to the value q<sub>ij</sub> = 1, and the worst one corresponds the value q<sub>ij</sub> = 0.

The integral indicator of accounting for the socio-economic component is determined from the equality:

$$G_1 = \sum_{j=1}^{m_1} \alpha_j q_{1j}, \quad (3)$$

The integral indicator of accounting for the demographic component – from equality:

$$G_2 = \sum_{j=1}^{m_2} \beta_j q_{2j}, \quad (4)$$

where α<sub>j</sub> and β<sub>j</sub>–weights of indicators q<sub>1j</sub> and q<sub>2j</sub> in the corresponding integral assessments.

To determine the weighting factors, we use the method of the modified first principal component. To do this, we define the covariance matrices A<sub>i</sub> = (a<sub>ij</sub><sup>i</sup>), i = 1, 2, the elements a<sub>ij</sub><sup>i</sup> of which are the covariance coefficients between the exponents q<sub>ij</sub> and q<sub>ir</sub>. The weighting factors α<sub>j</sub> are proportional to the squares of the components of the eigenvector of the matrix A<sub>1</sub> = (a<sub>ij</sub><sup>1</sup>), which corresponds to its maximum eigenvalue, and satisfy the equality  $\sum_{j=1}^{m_1} \alpha_j = 1$ . Similarly, the weights β<sub>j</sub> are determined using the matrix A<sub>2</sub> = (a<sub>ij</sub><sup>2</sup>).

For many socio-economic indicators, the maximum eigenvalue of the covariance matrix is 0.0745, and the eigenvector corresponding to this value is the vector V<sub>1</sub>=(0.478; 0.197; 0.182; 0.663; 0.510). Therefore, the weights in the integrated indicator of the socio-economic component of human capital are as follows: α<sub>1</sub>=0.228, α<sub>2</sub>=0.039, α<sub>3</sub>=0.033, α<sub>4</sub>=0.440, α<sub>5</sub>=0.260. Thus, the integral indicator of accounting for the socio-economic component of human capital in the t-th year in the k-th country is determined by the Eq. 5:

$$G_1^k(t) = 0.228q_{11}^k(t) + 0.039q_{12}^k(t) + 0.033q_{13}^k(t) + 0.440q_{14}^k(t) + 0.260q_{15}^k(t) \quad (5)$$

where q<sub>1j</sub><sup>k</sup>(t) is the value of the normalized indicator q<sub>1j</sub> in the k-th country for the t-th year.

For a set of demographics, the maximum eigenvalue of the covariance matrix is 0.1111, and the eigenvector corresponding to this value is the vector V<sub>2</sub>=(0.074; 0.311; 0.742; 0.283; 0.117; 0.503). So, the weighting factors of the integral indicator of accounting for the socio-economic component of human capital are β<sub>1</sub>=0.005, β<sub>2</sub>=0.097, β<sub>3</sub>=0.551, β<sub>4</sub>=0.080, β<sub>5</sub>=0.014, β<sub>6</sub>=0.253. Thus, the integral indicator of accounting for the socio-economic component of human capital in the t-th year in the k-th country is determined by the Eq. 6:

$$G_2^k(t) = 0.005q_{21}^k(t) + 0.097q_{22}^k(t) + 0.551q_{23}^k(t) + 0.080q_{24}^k(t) + 0.014q_{25}^k(t) + 0.253q_{26}^k(t) \quad (6)$$

where  $q_{2j}^k(t)$  is the value of the normalized indicator  $q_{2j}$  in the  $k$ -th country for the  $t$ -th year.

The general indicator of accounting for the country's human capital is defined as a linear combination of integral assessments of the socio-economic and demographic components, that is, there is equality:

$$G = \gamma_1 G_1 + \gamma_2 G_2 \tag{7}$$

The weighting factors  $\gamma_1$  and  $\gamma_2$  are determined by a modified method of the first principal component. The covariance matrix  $A$  of the integral assessments  $G_1$  and  $G_2$  has the form:

$$A = \begin{pmatrix} 0.023 & 0.016 \\ 0.016 & 0.029 \end{pmatrix} \tag{8}$$

Eigenvalues of this matrix  $\lambda_1=0.0096$ ,  $\lambda_2=0.0425$ . The maximum eigenvalue of 0.0425 corresponds to the eigenvector  $V=(0.637; 0.771)$ . So, the weighting

factors in the integral accounting indicator  $G$  are  $\gamma_1=0.405$ ,  $\gamma_2=0.595$ . Thus, the integral indicator of accounting for human capital in the  $t$ -th year in the  $k$ -th country is determined by Eq. 9:

$$G^k(t) = 0.405G_1^k(t) + 0.595G_2^k(t) \tag{9}$$

The modeling proposed by the authors provided an opportunity to take into account the interstate development of human capital and consider its importance in the dynamics.

#### 4. Results and discussion

As a result of approbation of the method proposed by the authors, we obtained an integral indicator of accounting for human capital and its socio-economic and demographic components in 29 countries of the world (Table 1).

**Table 1: Integral indicator of accounting for human capital and its components**

Country	Socio-economic component accounting			Demographic component accounting			Integral indicator		
	2010	2015	2020	2010	2015	2020	2010	2015	2020
Ukraine	0.448	0.387	0.376	0.335	0.417	0.453	0.381	0.405	0.422
Poland	0.350	0.345	0.356	0.632	0.679	0.735	0.518	0.543	0.581
Armenia	0.390	0.421	0.461	0.465	0.507	0.562	0.434	0.472	0.521
Azerbaijan	0.183	0.284	0.263	0.239	0.301	0.431	0.216	0.294	0.363
Belarus	0.310	0.319	0.312	0.425	0.532	0.602	0.378	0.446	0.485
Bulgaria	0.331	0.396	0.404	0.530	0.562	0.603	0.449	0.495	0.522
Croatia	0.403	0.342	0.362	0.634	0.677	0.702	0.541	0.541	0.564
Czech Republic	0.358	0.435	0.443	0.691	0.734	0.772	0.556	0.613	0.639
Estonia	0.355	0.368	0.384	0.569	0.659	0.728	0.482	0.541	0.588
Georgia	0.402	0.285	0.340	0.420	0.480	0.554	0.412	0.401	0.467
Hungary	0.395	0.369	0.380	0.558	0.604	0.666	0.492	0.508	0.550
Kazakhstan	0.094	0.101	0.105	0.271	0.374	0.563	0.199	0.263	0.377
Kyrgyzstan	0.387	0.401	0.362	0.308	0.426	0.477	0.340	0.416	0.430
Latvia	0.319	0.326	0.333	0.473	0.553	0.612	0.410	0.461	0.499
Lithuania	0.365	0.328	0.335	0.507	0.582	0.644	0.449	0.479	0.519
Moldova	0.667	0.539	0.428	0.304	0.393	0.431	0.451	0.452	0.430
Austria	0.640	0.635	0.651	0.764	0.790	0.803	0.714	0.727	0.742
Belgium	0.644	0.657	0.672	0.769	0.796	0.821	0.718	0.739	0.761
Germany	0.655	0.667	0.686	0.751	0.774	0.797	0.712	0.731	0.752
Greece	0.493	0.384	0.398	0.768	0.798	0.831	0.657	0.630	0.655
Denmark	0.770	0.721	0.772	0.751	0.789	0.811	0.759	0.761	0.795
Ireland	0.654	0.450	0.476	0.782	0.809	0.852	0.730	0.663	0.699
Spain	0.485	0.466	0.476	0.816	0.844	0.875	0.682	0.691	0.713
Italy	0.498	0.479	0.473	0.821	0.848	0.873	0.690	0.699	0.711
Cyprus	0.444	0.433	0.458	0.724	0.752	0.778	0.611	0.623	0.648
Luxembourg	0.532	0.447	0.480	0.727	0.756	0.778	0.648	0.631	0.657
Malta	0.515	0.530	0.599	0.765	0.795	0.814	0.663	0.688	0.727
France	0.668	0.667	0.665	0.824	0.853	0.867	0.761	0.777	0.785
Sweden	0.595	0.752	0.769	0.829	0.852	0.867	0.735	0.811	0.827

The best indicators of human capital development in 2020 are observed in Sweden (0.827), Denmark (0.795), France (0.785), Belgium (0.761), and Cyprus (0.648). Countries with a low efficiency score include Kyrgyzstan (0.430), Moldova (0.430), Ukraine (0.422), Kazakhstan (0.377), and Azerbaijan (0.363). The ratio of the integral indicator of human capital accounting in 2020 between countries of the world is shown in Fig. 1.

The dynamics of the integral indicator of human capital accounting and its components in Ukraine are shown in Fig. 2.

According to the results of accounting for the component of human capital in Ukraine in 2020, there is a dominance of the demographic component,

which indicates the availability of human resources in the country needed to make positive changes in the economy. At the same time, the decline in the socio-economic component over the study periods indicates the need to review government policies to improve human resource support by increasing investment in education and health care.

To assess the impact of socio-economic indicators  $p_{1j}$  on the integrated indicator  $G_1$  of the socio-economic component of human capital, the correlation coefficients  $\rho_{1j}$  between these indicators and this integral indicator is determined by the Eq. 10:

$$\rho_{1j} = \frac{\sum_{k=1}^{29} \sum_{t=1}^3 (p_{1j}^k(t) - \overline{p_{1j}})(G_1^k(t) - \overline{G_1})}{\sqrt{\sum_{k=1}^{29} \sum_{t=1}^3 (p_{1j}^k(t) - \overline{p_{1j}})^2 \sum_{k=1}^{29} \sum_{t=1}^3 (G_1^k(t) - \overline{G_1})^2}} \quad (10)$$

where  $\overline{p_{1j}}$  and  $\overline{G_1}$  are average values of  $p_{1j}$  and  $G_1$  for all considered countries for the three considered years.

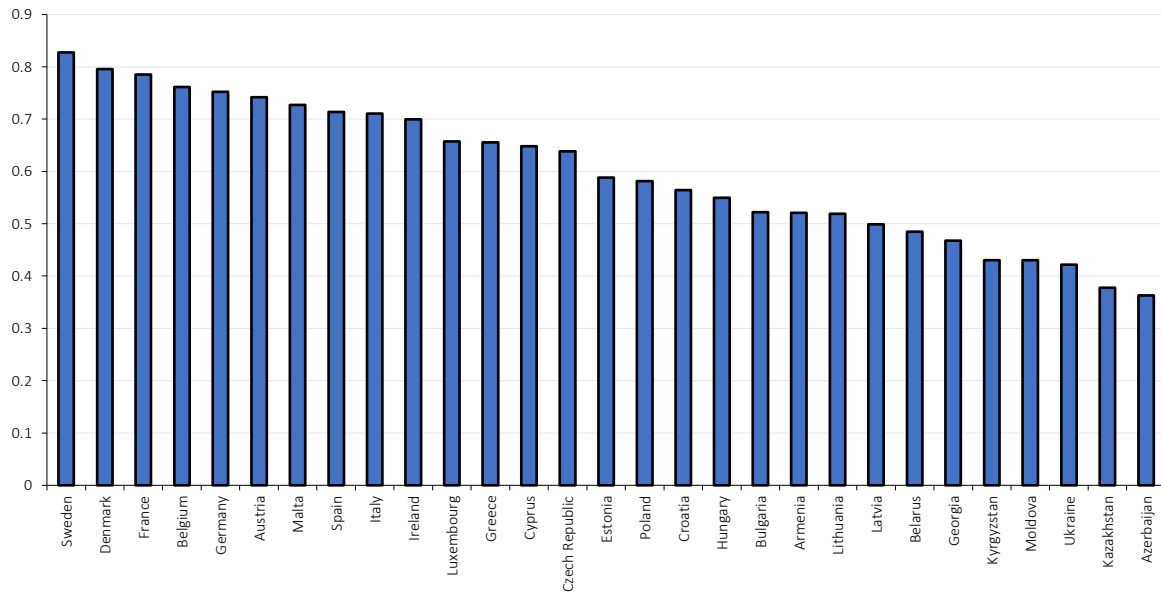


Fig. 1: Integral indicator of human capital accounting in 2020

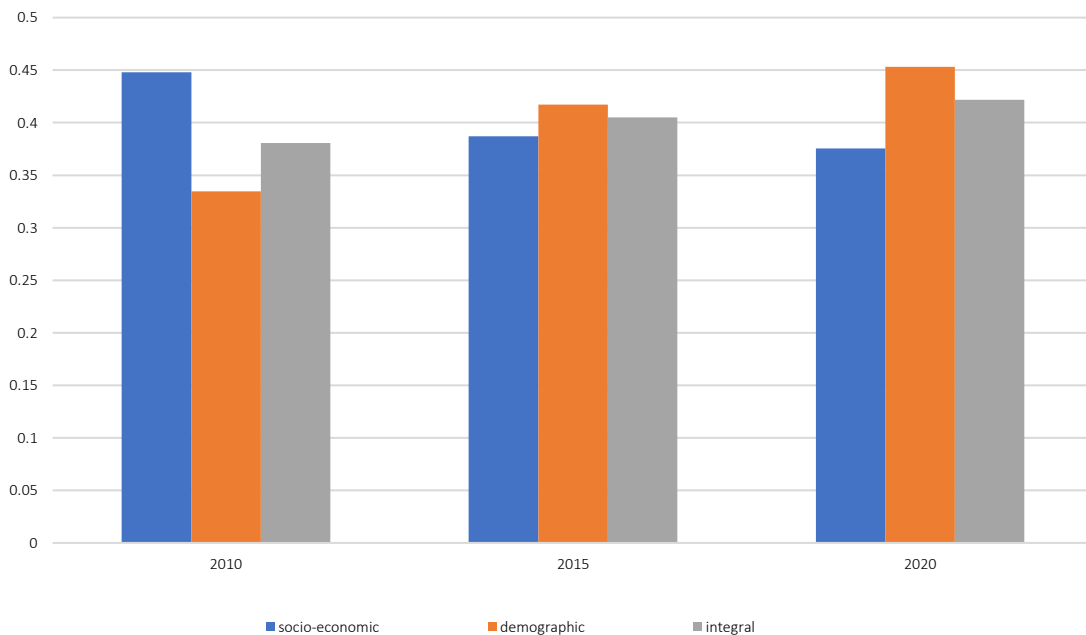


Fig. 2: Dynamics of the integral indicator of human capital accounting and its components in Ukraine

The significance of the determined correlation coefficients was checked by Student's criterion. If the actual value of the Student's criterion is:

$$t(\rho_{1j}) = \frac{\rho_{1j}}{\sqrt{1-\rho_{1j}^2}} \sqrt{N-2} \quad (11)$$

where N is the number of known values of the indicator  $p_{1j}$ , modulo exceeds the corresponding

critical value of this criterion, the correlation coefficient  $\rho_{1j}$  is considered significant.

As a result of calculations, it was found that the correlation coefficients between the integral indicator of accounting for the socio-economic component of human capital and indicators of GDP per capita (correlation coefficient  $\rho_{11} = 0.585$ ), government spending on health care (correlation coefficient  $\rho_{14} = 0.878$ ), government spending on education ( $\rho_{15} = 0.660$ ) are significant.

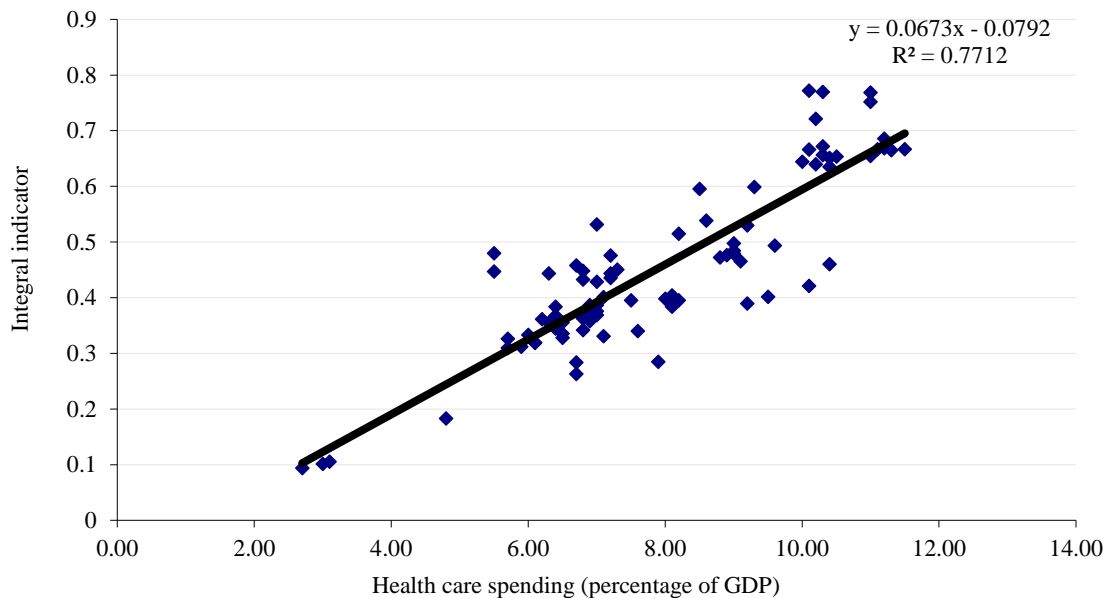
Let us define a pairwise linear regression equation that reflects the dependence of the integral indicator of accounting for the socio-economic component of human capital on government

spending on health care. This equation has the form  $G_1=a_1p_{14}+b_1$ . Coefficients  $a_1$  and  $b_1$  are determined from the system of equations:

$$\begin{cases} a_1 \sum_{k=1}^{29} \sum_{t=1}^3 (p_{14}^k(t))^2 + b_1 \sum_{k=1}^{29} \sum_{t=1}^3 p_{14}^k(t) = \sum_{k=1}^{29} \sum_{t=1}^3 p_{14}^k(t) G_1^k(t) \\ a_1 \sum_{k=1}^{29} \sum_{t=1}^3 p_{14}^k(t) + 87b_1 = \sum_{k=1}^{29} \sum_{t=1}^3 G_1^k(t) \end{cases} \quad (12)$$

Having solved this system, we get  $a_1=0.0673$ ,  $b_1=-0.0792$ . Therefore, the regression equation has the form  $G_1=0.0673p_{14}-0.0792$ . The adequacy of this equation is confirmed by Fisher's criterion. The

dependence of the integral indicator of accounting for the socio-economic component of human capital on government spending on health care is shown in Fig. 3.



**Fig. 3:** Dependence of the integral indicator of accounting for the socio-economic component of human capital on government spending on health care

To assess the impact of demographic indicators  $p_{2j}$  on the integral indicator  $G_2$  of accounting for the demographic component of human capital, we determine the correlation coefficients  $\rho_{2j}$  between these indicators and this integral indicator. The values of birth rate (correlation coefficient  $\rho_{22}=-0.411$ ), life expectancy at birth (correlation coefficient  $\rho_{23}=0.98$ ), international stock of migrants (correlation coefficient  $\rho_{24}=0.463$ ) and infant mortality rate (correlation coefficient  $\rho_{26}=-0.796$ ) are most closely related to the integrated indicator  $G_2$ .

Let us define the equation of paired linear regression, reflecting the dependence of the integral indicator of accounting for the demographic component of human capital, life expectancy at birth. This equation has the form  $G_2=0.0371p_{23}-2.1969$ , its adequacy is confirmed by Fisher's criterion.

The dependence of the integral indicator of accounting for the demographic component of human capital on life expectancy at birth is shown in Fig. 4.

To assess the impact of socio-economic and demographic factors on the overall integral indicator  $G$  for accounting for human capital, the correlation coefficients  $\rho_1$  and  $\rho_2$  were determined between the integral indicator  $G$  and the integral indicators  $G_1$  of

the socio-economic component and  $G_2$  of the demographic component, respectively. These coefficients are significant and equal to  $\rho_1=0.877$  and  $\rho_2=0.935$ .

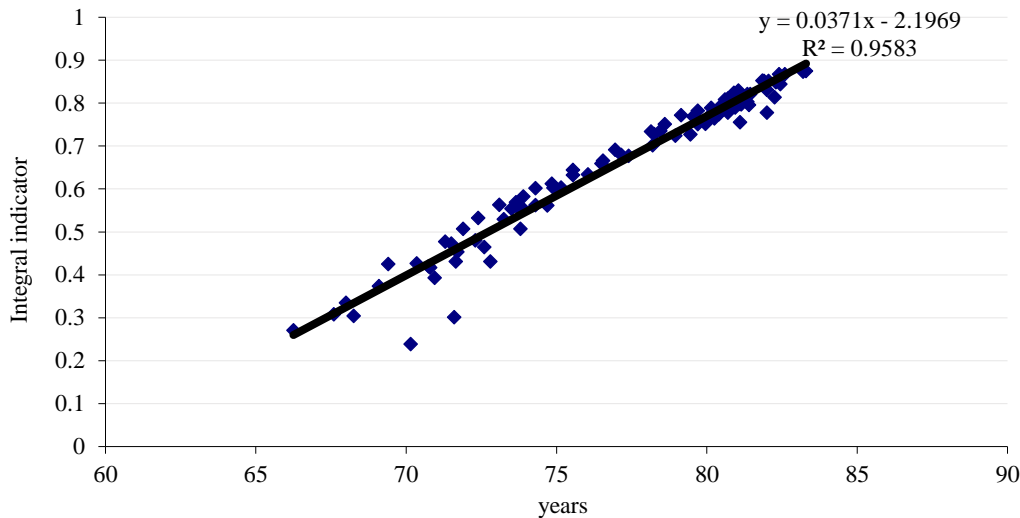
The study of the dynamics of the integral indicator of human capital accounting showed that in all the countries under consideration, with the exception of Moldova, Ireland and Greece, there is an increase in this indicator in 2020 compared to 2010. But the indicator of the socio-economic component in 2020 decreased compared to 2010 in 13 of the 29 countries studied. In Ukraine, it decreased by 16.2%. At the same time, the indicator of the demographic component increased for all the countries under consideration.

**5. Conclusion**

Accounting for human capital is a necessary state measure towards the formation of a competitive, innovative and progressive economy. The results of accounting for socio-economic and demographic indicators of human capital development and the calculation of the integral indicator made it possible to carry out interstate comparisons of the state of human capital. Based on the use of the UN statistical database, taking into account the proposed modeling

of the integral indicator of accounting for human capital, the countries are leaders and outsiders. The countries of the leaders include Sweden, Denmark, France, Belgium, and Cyprus. The outsiders are Kyrgyzstan, Moldova, Ukraine, Kazakhstan, and Azerbaijan. Obviously, outsider countries should pay more attention to the state of the human resource, which is an indispensable element in the formation of an economy based on knowledge and

technological progress. The method proposed by the authors for modeling the integral indicator of human capital accounting was developed for the first time in the scientific world. Calculation and testing in practice of the proposed method will allow each country to compare the state of human capital development relative to other countries and form investment, innovative or social measures that will improve the situation of human resources.



**Fig. 4:** Dependence of the integral indicator of accounting for the demographic component of human capital on life expectancy at birth

### Compliance with ethical standards

### Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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