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RESTORING THE SCIENTIFIC POTENTIAL OF UKRAINIAN SCIENCE: NECESSITY AND REAL PROSPECTS

The urgent necessity of restoring the human potential of Ukrainian science has been substantiated. A method for forecasting the evolution of human capacity of science has been developed based on consideration of the relationship and interdependence of adjacent age groups of scientists. The possible options for human capacity recovery in Ukraine have been estimated for two decades. Provided the recent trends remain fixed, the number of researchers by 2035 has been showed to decrease 4.5 times as compared with 2015, unless the government cardinally changes the attitude towards science. At the same time, even if significantly increasing salary and improving working conditions of researchers lead to a 25% growth in the inflow of young researchers to science every 5 years and provided the number of researchers over 30 years who leave the R&D sector does not exceed 1%, at best, it will enable to stabilize the human potential of Ukrainian science, but is still not enough to essentially enlarge it. The option of stimulating a 40% increase in the inflow of young researchers is also not sufficient.

Only the implementation of measures that would ensure doubling inflow of young researchers every 5 years can give an opportunity to reach by 2035 the number of researchers close to that in the early 1990s, i.e. to get their ratio per 1 million comparable to the EU countries. Moreover, it is necessary to start implementing this policy immediately: if it is postponed until 2020, such an accelerated rate of escalating the inflow of young people to science will not enable to reach in 20 years the number of researchers Ukraine had in the not-so-successful 2010.

Keywords: forecast of evolution of number of researchers, age structure of researchers, preservation of scientific personnel, innovation development of the economy, and restoration of research personnel capacity.

The fact that in the present-day world, the scientific development is the only way to the innovative economic growth has been repeatedly stated. Its rationale has been recognized by the world, its authors have been awarded with Nobel Prize and honorary titles. However, in recent years, researchers' attention has been increasingly focused on finding optimal relationships between science and economics as well as quantitative characteristics through which one could characterize the ability of country or its regions to innovate. For example, having studied the peculiarities of innovative development of certain regions of the United States, R. Florida concludes that only the states with a sufficient representation of the «creative class» whose core, according to him, is researchers and engineers, have prospects for intensive innovation development, while those which have not created favorable conditions for the life and creativity of this category are rapidly losing their scientific potential, pace of economic growth, and, consequently, a chance to withstand a sharp competition [1].

The prospects for innovation transformation of the economy are directly proportional to the number of researchers in the European Union: in 2013, on average, EU Member States had over 33 000 researchers per 1 million population (2.6 times more than in the today's Ukraine). The European Union leadership concluded that this was not enough

to provide an innovative breakthrough and undertook to attract, at least, 3 million researchers more to the European scientific community.

This is in line with the global trend. According to UNESCO [2], from 2007 to 2013, the number of researchers in the world increased by 21.2% and reached 7.8 million.

In 2013—2014, in Ukraine, the researchers made up only 0.49% of the total number of working population (as compared with 1.16%, in 1990). So, Ukraine leveled down the least advanced economies, such as Romania (0.46%) and Cyprus (0.71%). Finland and Denmark had this index at 3.2%, Switzerland at 2.66%, Norway at 2.56%, and Slovenia at 2.27%. In addition, in recent years, it has been growing quite rapidly in these countries. On average, in the EU this index is 5—6 times higher than in Ukraine.

The fact that the research staff dynamics in Ukraine has a completely different trend is an anomaly indicating that, despite declaring attempts to follow the European standards, our state is going to the opposite direction.

Almost all neighboring countries, even those whose science previously was significantly behind the Ukrainian one, in particular, Turkey, Poland, and Romania, are constantly increasing their scientific potential (not to mention an unprecedented pace of R&D growth in the countries aiming to catch up with advanced rivals such as Japan, South Korea, China, etc.).

If not to tolerate the prospect of Ukraine's final transformation into a third world country and a raw material appendage of advanced economies with very low living standards and cheap labor force, one of the most urgent tasks should be the revival of research potential, without which none can dream about innovative development of the economy.

Studying the poor dynamics of the personnel in Ukrainian science, everyone can be convinced that it can be destroyed quickly, but it is not so easy to build it up.

A skilled worker can be trained for 1—2 years, a teacher or an engineer for 4—5 years, while the formation of researcher takes much longer. Several decades may not be enough to create an effective team. After all, its capabilities are determined not only by personal qualities of individual researchers, but also by a proper distribution of roles and functions and a harmonious combination of researchers representing different generations.

Table 1

Accepted Numeration of Age Groups

Group number, *n*	1	2	3	4	5	6	7	8	9	10	11
Age, years	≤24	25—29	30—34	35—39	40—44	45—49	50—54	55—59	60—64	65—69	≥70

Table 2

Dynamics of the Number of Researchers in the Age Groups in Ukraine, 2011—2015*

	Номер групи, *n*										
	1	2	3	4	5	6	7	8	9	10	11
2011, researchers	3382	8210	7591	5853	4967	6130	7961	8624	7699	4168	5793
2015, researchers	1605	5972	6430	5766	4598	4093	5310	5847	5293	4547	4374
Researchers who left science, %			26.9	28.95	25.25	20	13.75	29.56	43.81	44.64	55.7

* The share of researchers who left science for other better paid activities or retired is calculated by formula (1).

The peculiarity of science is that the formation of researcher occurs only within the very science, in research team. Therefore, the research staff can be replenished only due to involvement of young people. Adult people happen to come to science, but they are isolated. Notwithstanding all hardships, the arrival of young people in science until recently has even slightly increased, which was the reason for some restrained optimism about its revival in the future, despite the fact that a significant share of young and middle-adult researchers having received certain qualifications, left science in search of a higher remuneration for their labor [3].

However, since 2012, the researcher profession has lost its prestige in the eyes of young people, and arrival of young researchers to science started to decrease.

To understand further prospects for evolution of the personnel potential capacity of Ukrainian science, a forecasting method [4] has been developed. It enables to assess the main benchmarks to be addressed by the government policy for its revival.

The method is based on consideration of deep interconnection and interdependence of neighboring age groups of researchers, which can be used to predict the evolution of both structure and changes in numerical indicators of the personnel potential of science. This becomes possible due to the fact that the science is a relatively closed system which can be replenished from outside with younger age groups (up to 30 years). The number of researchers in other groups depends on «migration» of representatives of younger groups who reach the corresponding age and those who leave the science for other activities or depart abroad. This process, at least, for the age group over 30 years, can be described by relatively simple formulas:

$$D_n^k = D_{n-1}^{k-i} - P_{n-1}^{k-i} - N_{n-1}^{k-i}, \qquad (1)$$

where D_n^k is number of researchers in the n-th age group in k-th year; i is age range determining the group's width; P_{n-1}^{k-i} is number of researchers in $(n-1)$ age group, in $(k-i)$ year, who have left the science for other activities during i years; N_{n-1}^{k-i} is number of researchers in $(n-1)$ age group, in the same $(k-i)$ year, who are likely to die for i years, based on average mortality rate statistics.

Group number n in calculations correspond to Table 1.

N_{n-1}^{k-i} is calculated based on mortality rate dependence on age for Ukraine given in [5].

The total number of researchers in the k-th year (D_s^k) is equal to:

$$D_s^k = \sum_{n-1}^{11} D_n^k. \qquad (2)$$

The number of researchers in the two youngest groups D_1^k and D_2^k cannot be calculated by formula (1), since it depends on inflow of young people from outside. Until recently, this indicator was easily controlled — it was enough to open more vacancies in order to increase it. Despite all challenges the inflow of young researchers grew up, which gave reason for optimistic prognosis of self-reproduction of Ukraine's research staff potential. However, since 2012, the situation changed drastically as profession of researcher dropped its prestige in the eyes of young people and the number of those who desired to work as researcher decreased significantly. At the same time, the so-called science optimization that was reduced mainly to cut of its financial support created additional problems with job places. As a result, the number of researchers in the youngest groups started to go down [6] (Table 2).

Based on the presented data, several scenarios for building up R&D human resources in Ukraine for the next 20 years and a spontaneous evolution scenario (all trends reported from 2011 to 2015 remain fixed) have been elaborated. Table 3 shows basic indicators for the most realistic scenarios..

The main difference between these scenarios is rate of increasing the number of researchers in the young groups for five years: 25%, in scenario 1; 40%, in scenario 2; and duplication, in scenarios 3 and 4. The R&D support that stimulates rising researcher career prestige and motivates researchers not to leave R&D institutions is assumed to

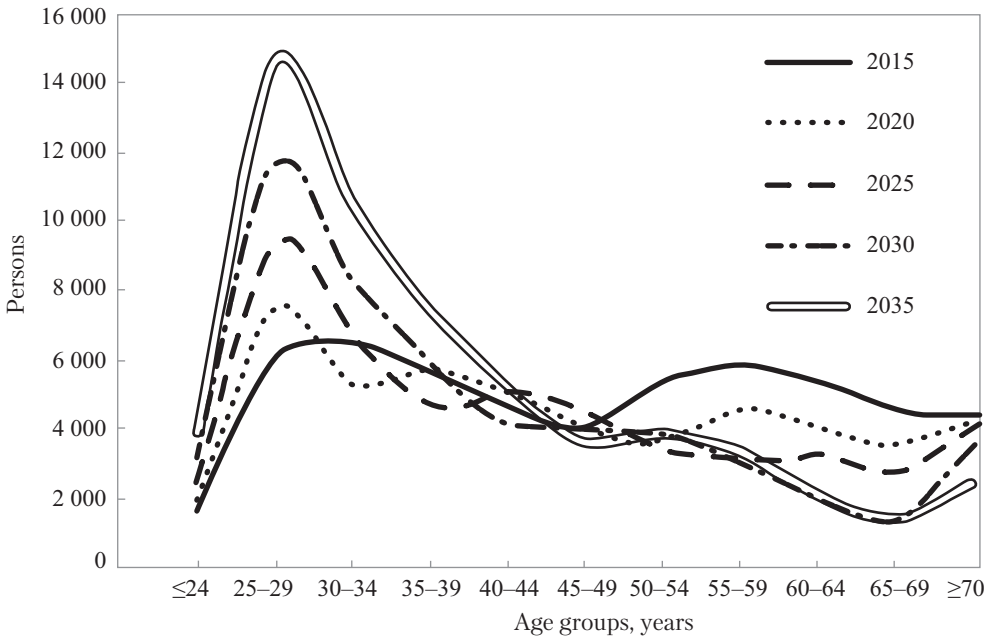

Fig. 1. Forecasted changes in age structure of Ukraine's researchers for the case when inflow of young researchers to age groups 1 and 2 grows by 25% every 5 years, while outflow is limited to, at most, 5% from age groups 3—8 and 25% from groups 9—11 (scenario 1)

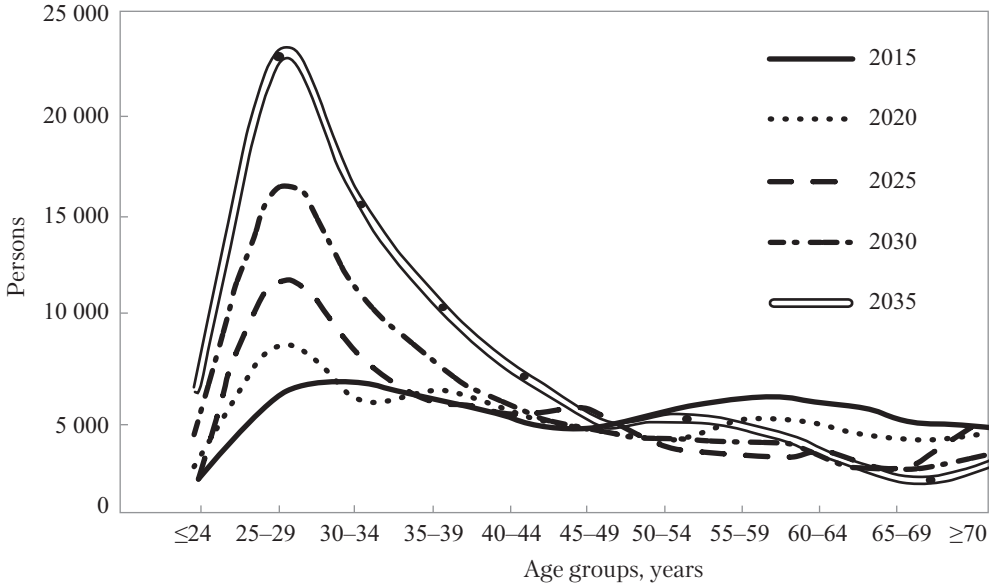

Fig. 2. Forecasted changes in age structure of Ukraine's researchers for the case when inflow of young researchers to age groups 1 and 2 grows by 40% every 5 years, while outflow is limited to, at most, 5% from age groups 3—8 and 25% from groups 9—11 (scenario 2)

have different scales. The assumptions that less than 5% researchers of the most productive age will leave R&D for other activities (i.e. less that 1% annually) and less than 25% researchers of pension age will retire (as compared with data in the last line of Table 2) are not realistic.

Fig. 1 shows the results of calculations for scenario 1. In this case, a gradual increase in the number of researchers in the young groups and widening of the first maximum in the age structure towards the elder groups are expected. However, this leads to a lack of researchers aged 40—60 years: in 2020, a minimum corresponding to 35—34 years appears, it grows up till 2025 and shifts towards 35—39. At the same time, their total number till 2025 will remain almost fixed and

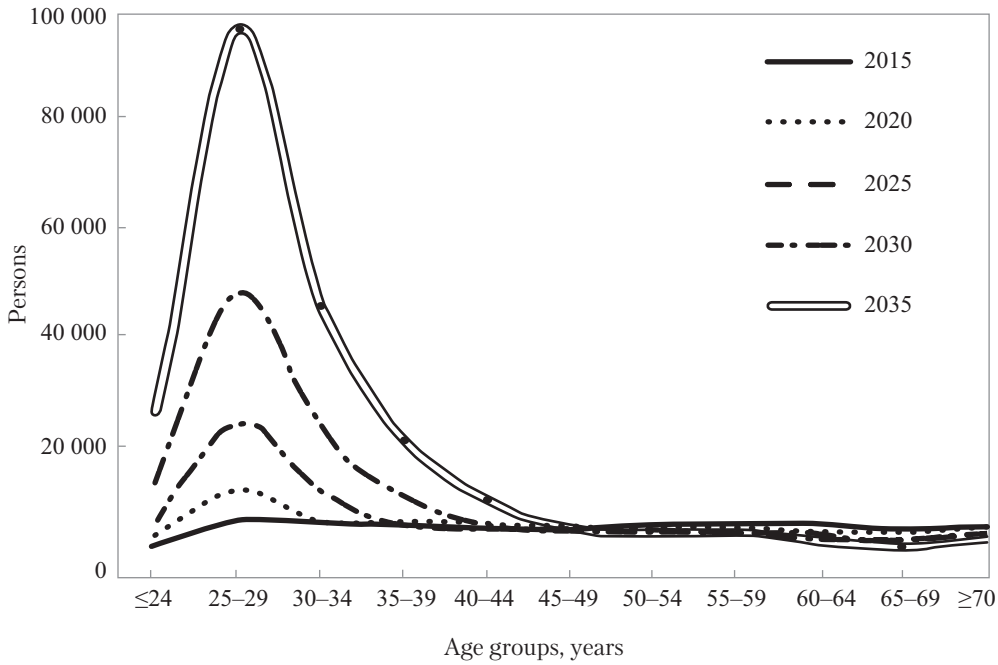

Fig. 3. Forecasted changes in age structure of Ukraine's researchers for the case when inflow of young researchers to age groups 1 and 2 is duplicated every 5 years, while outflow is limited to, at most, 5% from age groups 3—8 and 25% from groups 9—11 (scenario 3)

further will grow at a quite slow pace: in 2035, it will be less than in 2010 (Fig. 4). Hence, it is a stabilization scenario rather than a replenishment one. Fig. 2 shows that scenario 2 does not accelerate the replenishment so much, with the number of young researcher inflow increasing by 40% every 5 years.

More radical and, surely, the most desired and necessary is the scenario that would enable doubling the inflow of young researchers to the R&D every 5 years. The corresponding evolution of age structure is showed in Fig. 3.

However, its optimality is to be discussed since this kind of «rejuvenation of science» and significant lack of researchers aged 35—60 years will not contribute to the formation of phase dynamics of roles and functions in researcher teams [7—10], which slows down the creative growth of young researchers and complicates preservation of existing and formation of new scientific schools. Proceeding from the existing situation, unfortunately, this cannot be avoided. At the same time, this is just that scenario which in 20 years can allow the country to come close to the level of provision of innovation-driven development with researchers, which, at least, approach those typical for European countries and world advanced economies.

Fig. 4 shows a comparison of dynamics of researcher number for various scenarios of government policy development in the sphere of R&D personnel support. In addition, this Figure features also the results of calculations for the scenario 4, i.e. in the case when in the view of hard times the implementation of scenario 3 (duplication of young researcher inflow every five years) is decided to postpone till 2020. One can see, in this case, to reach the level of European standards it is necessary, at least, 10 years, i.e. in the most optimistic case, this can happen as early as in 2045 (!).

Hence, the calculations with the use of proposed method for forecasting the evolution of R&D human resources in Ukraine have confirmed that the government attitude towards science aimed at replenishing the R&D capacity shall be radically changed immediately. The longer the government postpones addressing this problem the more costs are required for it. The specific features of R&D system and of the forma-

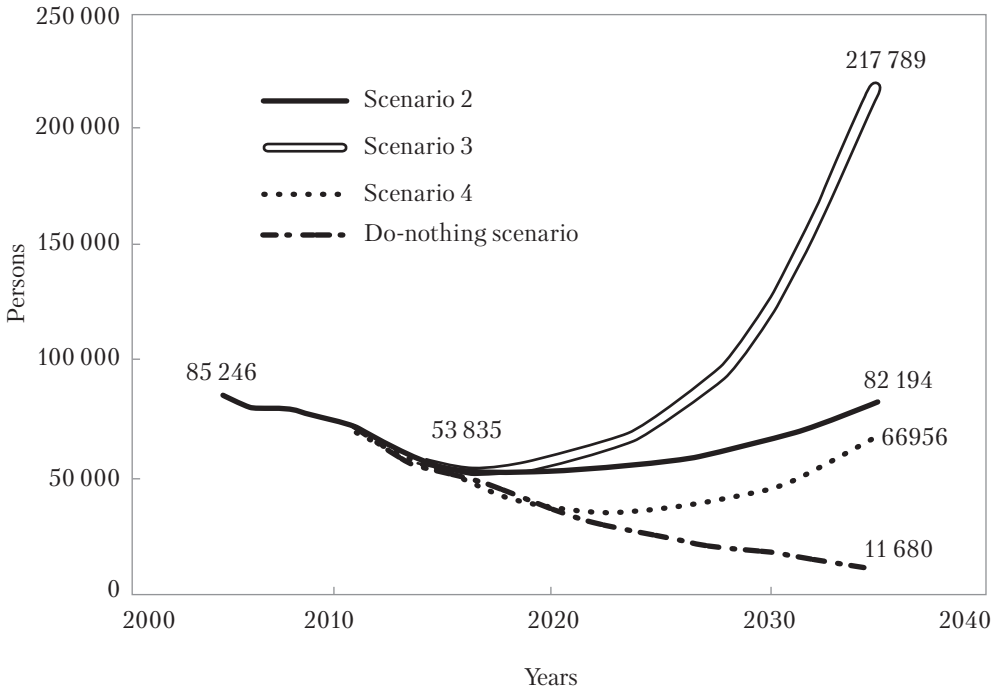

Fig. 4. Comparison of forecasted changes in the number of Ukrainian researchers for the considered scenarios of policy aimed at replenishing R&D human resources in Ukraine

Table 3

Researchers Migration Indices Underlying the Considered Scenarios for the Policy Towards Building Up R&D Human Resources

Option (scenario)	Age groups, years										
	≤24	25—29	30—34	35—39	40—44	45—49	50—54	55—59	60—64	65—69	≥70
1	+25%	+25%	—5%	—5%	—5%	—5%	—5%	—5%	—25%	—25%	—25%
2	+40%	+40%	—5%	—5%	—5%	—5%	—5%	—5%	—25%	—25%	—25%
3	×2	×2	—5%	—5%	—5%	—5%	—5%	—5%	—25%	—25%	—25%
4	×2	×2	—5%	—5%	—5%	—5%	—5%	—5%	—25%	—25%	—25%

tion and work of its human resources make impossible its rapid buildup and control. This process is long-term and quite expensive. However, trying to save on this sphere leads to the necessity to pay more in the future.

The leaders of many countries understand this clearly. Almost all neighboring countries, even those whose science previously yielded to the Ukrainian one, do not spare money to build up the R&D capacity. The countries that really want to escape from the Third World and to take a lead in the economic development, such as China or India, have taken extraordinary measures that require high financial costs: for example, huge money has been spent to return the researchers who left the country and worked abroad and to attract foreign young researchers and students. In China, over the past 15 years, researcher salary has increased 24 times. Poor India has built a city for researchers and IT developers.

Nowadays, when the R&D development accelerates at a high pace, if Ukraine ignores these global trends, it risks to lose its chance for innovative development for many decades.

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ВІДНОВЛЕННЯ НАУКОВОГО ПОТЕНЦІАЛУ УКРАЇНСЬКОЇ НАУКИ: НЕОБХІДНІСТЬ І РЕАЛЬНІ ПЕРСПЕКТИВИ

Обґрунтовується нагальна необхідність відновлення кадрового потенціалу української науки. На основі розробленого авторами методу прогнозування еволюції кадрового потенціалу науки, що базується на врахуванні взаємозв'язку і взаємообумовленості сусідніх вікових груп науковців, розраховано можливі варіанти його відновлення в Україні протягом двох десятиліть. Показано, що при відсутності кардинальних змін у ставленні до науки з боку держави та при збереженні тенденцій останніх років, до 2035 року чисельність дослідників у країні зменшиться в 4,5 рази порівняно з 2015 роком. Водночас, навіть у випадку, якщо істотне збільшення заробітної плати та умов праці науковців призведе до збільшення притоку молоді в науку на 25 % протягом кожних 5 років і не буде допускатися того, щоб більше 1 % дослідників старших 30 років щороку залишали наукові колективи, істотно збільшити кадровий потенціал української науки не вдасться — в кращому випадку, відбудеться його стабілізація. Недостатнім виявляється і варіант політики, який мотивує збільшення приходу молоді на 40 %.

Тільки реалізація політики, яка забезпечить подвоєння поповнення молодого покоління науковців кожні 5 років, може дати можливість довести число дослідників у 2035 році до рівня, близького тому, який був на початку 90-х років, і, тим самим, наблизитись до такого їх співвідношення на 1 млн. населення, яка є сьогодні в країнах ЄС. Причому розпочинати реалізацію такої політики слід негайно: якщо ж відкласти цей процес до 2020 року, то й такий форсований темп нарощування приходу молоді в науку не дозволить і за 20 років досягти тієї кількості дослідників, яку мала Україна навіть у не надто благополучному 2010 році.

Ключові слова: прогнозування еволюції чисельності дослідників, вікова структура дослідників, закріплення наукових кадрів, інноваційний розвиток економіки, відновлення кадрового потенціалу науки.

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ВОССТАНОВЛЕНИЕ НАУЧНОГО ПОТЕНЦИАЛА УКРАИНСКОЙ НАУКИ: НЕОБХОДИМОСТЬ И РЕАЛЬНЫЕ ПЕРСПЕКТИВЫ

Обосновывается настоятельная необходимость восстановления кадрового потенциала украинской науки. На основе разработанного авторами метода прогнозирования эволюции этого потенциала, базирующегося на учете взаимосвязи и взаимообусловленности соседних возрастных групп ученых, рассчитано возможные вари-

анты его восстановления в Украине на протяжении двух десятилетий. Показано, что при отсутствии кардинальных изменений в отношении к науке со стороны государства и при сохранении тех тенденций, которые наблюдались в течение последних лет, к 2035 году численность исследователей в стране уменьшится в 4,5 раз по сравнению с 2015 годом. В то же время, даже в случае, если существенное увеличение заработной платы и условий труда ученых приведет к увеличению прихода молодежи в науку на 25 % в течение каждых 5 лет и не будет допускаться того, чтобы более 1 % исследователей старше 30 лет ежегодно оставляли научные коллективы, существенно увеличить кадровый потенциал украинской науки не удастся — в лучшем случае, произойдет его стабилизация. Недостаточным оказывается и вариант политики, который мотивирует увеличение прихода молодежи на 40 %.

Только реализация мер, которые обеспечивали бы удвоение пополнения молодого поколения ученых каждые 5 лет, может дать возможность довести число исследователей в 2035 году до уровня, близкого тому, которое было в начале 90-х годов, а тем самым приблизиться к их числу на 1 млн. населения, имеющемуся сегодня в странах ЕС. Причем начинать реализацию такой политики необходимо немедленно: если же отложить это до 2020 года, то столь форсированный темп наращивания прихода молодежи в науку не позволит за 20 лет достичь того количества исследователей, которое имела Украина даже в не слишком благополучном 2010 году.

Ключевые слова: прогнозирование эволюции численности исследователей, возрастная структура исследователей, закрепление научных кадров, инновационное развитие экономики, восстановление кадрового потенциала науки.