Life Expectancy as an Economic Category: Social, Epidemiological and Macroeconomic Context

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Abstract: The study considers "life expectancy" as a complex category at the intersection of biological, social and economic sciences. The mathematical component of the "life expectancy" indicator is deciphered on the basis of the so-called lifetables. The factors of influence on the economic category dynamics are analyzed and systematized with the subsequent determination of the strength of their relationship through a correlation and regression analysis. The research subjects are Russia, Kazakhstan, the USA and China, which allows assessing the dynamics of life expectancy in developed and developing countries, as well as in transition economies. The correlation and regression analysis revealed that in economically unstable countries (Russia and Kazakhstan), biological factors associated with the spread of HIV and tuberculosis are the most powerful. In developed countries (the USA and China), social factors associated with public health policy and environmental trends come to the fore.

Keywords: life expectancy, mortality table, economic development, correlation and regression analysis.

Introduction

Human life has been dramatically affected by scientific and technological progress, and large-scale medical research and developments. First of all, longevity has increased from 45.7 years in 1950 to 72.6 years in 2019 (United Nations, Department of Economic and Social Affairs, Population Division, 2019). In addition, the quality of life has been significantly improved. Today national welfare is a resource that a country needs to successfully operate in the macroeconomic environment. Despite the subjectivity of the indicator, economists managed to find a way to measure the "level of population happiness". The calculation of life expectancy, representing a digital reflection of human well-being, is an important component in this process.

It can be safely stated that the main goal of each person is to live a long and healthy life. The realities of the modern world make this desire affordable and impossible at the same time. The invention of new medicines is mitigated by an increasing trend towards social inequality. It appears that health depends on the individual genetic predispositions or external climatic

ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)

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conditions, as well as on the level of income and the economic development of the country as a whole.

The relevance of the research is also confirmed by the Rosstat demographic forecast (Federal State Statistic Service, 2019): by 2035, the life expectancy will increase to 79.1 years, while the population will decrease by 134.9 thousand people, and migration growth will remain stable. The global problem of aging of nations is gaining popularity (United Nations, Department of Economic and Social Affairs, Population Division, 2019b), which poses new challenges to states associated with the modernization of healthcare, social protection, and pension systems.

There are studies devoted to this issue that confirm a direct relationship between the growth of life expectancy and an increase in the level of economic development (Bloom & Canning, 2000; Starfield, 2000; Subramanian et al., 2002). There are also works considering macroenvironment parameters and their impact on the health of the nation (Lindström & Lindström, 2006). However, there is almost no information on a comprehensive analysis of "life expectancy" covering its physiological, social and economic components.

Literature review

Life expectancy is an important integral demographic indicator that characterizes the mortality rate of a population (Lemanova, 2016). It is based on a mathematical model – a mortality table (life table) that groups mortality by age intervals. This method of statistical analysis was invented in ancient Rome, but it was scientifically introduced by John Graunt in 1662 (Eschner, 2017). As a rule, the age sample ranges from 0 to 100. The method is based on the principle of multiplying the number of survivors to a certain age by the coefficient of the possibility of surviving to the next age interval. The number of survivors in each age group is formed in the "stepwise" manner; this becomes the basis for predicting life expectancy. In other words, life expectancy is the average number of years that a generation will live provided that the mortality rate remains at the same level.

It is noteworthy that this indicator is calculated separately for men and for women. The fact of the matter is that the statistical age of women over the course of the century has always been higher than that of men (the average difference in the world is 4.6 years (United Nations, Department of Economic and Social Affairs, Population Division, 2019)). There may be several reasons for this: the biological difference between the set of chromosomes, greater addiction of men to alcohol and smoking, social basics (a man is a defender who must protect and support his family), hard and traumatic work, that is jobs "for men", etc. (Ortiz-Ospina & Beltekian, 2018). In addition, women tend to be more concerned about their lifestyle, take care of the health of the child and family. As it can be seen, despite natural disposition, social factors still play a key role.

Life expectancy is a comprehensive concept and a broad social indicator that demonstrates the quality of human capital as one of the country's main resources. It is due to its versatility that it is so popular with scientists and researchers in various fields, ranging from medicine to economics. The simplicity and accessibility of the indicator make it an effective component of various indices and other development indicators. For example, the UN uses it when calculating the Gender related Development Index (GDI) (United Nations, 2020) and the

ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)

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Human Poverty Index (HPI) (United Nations, 2019). The indicator has also been recognized by the evaluators of such a subjective concept as “happiness”, and has become a component of the indicator of Happy Life Expectency (HLE) (Veenhoven, 1996), Life-Quality Index (Pandey & Nathwani, 2014), and the international Happy Planet Index (Happy Planet Index, 2020), etc.

The review of the factors affecting life expectancy is based on the following systematization (Teplykh, 2013):

- natural biological conditions. The category includes all factors affecting the biological component of the indicator: climate, genetics, gender, etc. The main feature of these factors is that they are almost impossible to control. The degree of their effect directly depends on the country's position in the world - more developed and prosperous countries are more likely to block these factors with scientific and medical innovations.

The following sub-factors that require special attention can be distinguished within the factor:

- ecological environment. Access to clean air, fresh water and other natural benefits are essential elements of a healthy living environment. A recent Nigerian study (Agbanike et al., 2019) is a good example. Based on the analysis of autoregressive distributed lags (ARDL), the researchers studied the relationship between environmental pollution due to the development of the oil sector and life expectancy in Nigeria. The results showed that oil export leads to environmental disaster although it provides income necessary to improve the quality of life of the population. As a result, the economic oil upswing is blocked by the negative effects of carbon dioxide (CO2) emissions for a long time.

- nutrition. There are two problems that should be considered: the shortage and low quality of food products in developing countries, and market flooding in developed countries. Although it is well-documented that a balanced diet is the key to a long and healthy life (Miyamoto et al., 2019), the amount of food should not exceed the norms established by national health authorities. These significant differences in eating behavior reflect global social inequality; they lead to the fact that while poor countries are looking for ways to combat hunger, rich countries suffer from obesity. There is a close correlation between infant mortality and nutrition (McQuade et al., 2019), which explains high infant mortality rates in countries with the lowest per capita income.

- economic and social development. Economic growth has a positive effect on life expectancy and vice versa – a decrease in mortality leads to the prosperity of a country. This method is equally effective in the South African region (Biyase & Malesa, 2019) and among the G7 countries (G7 - Group of Seven) (Shafi & Fatima, 2019). Economic development is closely linked to education and healthcare that support human vitality through their well-coordinated activities. That is why developed countries are characterized by high standards of living, social stability, and public safety, that support the economy at the required level. However, there is also an opinion that life expectancy contributes to economic growth until a certain threshold level is achieved. Any further increase will have a reverse effect (Sirag et al., 2019).

ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)

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Setting Objectives

The purpose of the study is to analyze "life expectancy" as a complex category at the intersection of biology, sociology and macroeconomics.

The following tasks have been set to achieve the goal:

- to seize the essence of the studied concept and determine its use;
- to analyze the main factors affecting the concept to be further used in calculations;
- to track the dynamics and forecasts of life expectancy among the male and female population of Russia, Kazakhstan, China, and the USA;
- to conduct a correlation and regression analysis of the relationship between life expectancy at birth and a group of economic, social and biological factors, followed by a description of the closest relationships.

Methods and materials

To identify the features of the "life expectancy" indicator in differently developed countries, the sample of the study consists of developed (the USA) and developing countries (China), as well as countries with economies in transition (Russia, Kazakhstan). The comparison of the dynamics of the studied category in different age groups and the subsequent correlation and regression analysis are based on statistical data. There are two variables (X and Y) in the analysis.

The resulting indicator (Y) is life expectancy. Given the studied category is divided by age groups, it was decided to use data on newborns as they are the most common in the world scientific community.

The novelty of the study is the fact that it proves the complexity of the concept of "life expectancy" and its correlation with the physiological, social and economic aspects of human life. To do this, we created a system of factors of influence (X), taking into account each aspect (Fig. 1).

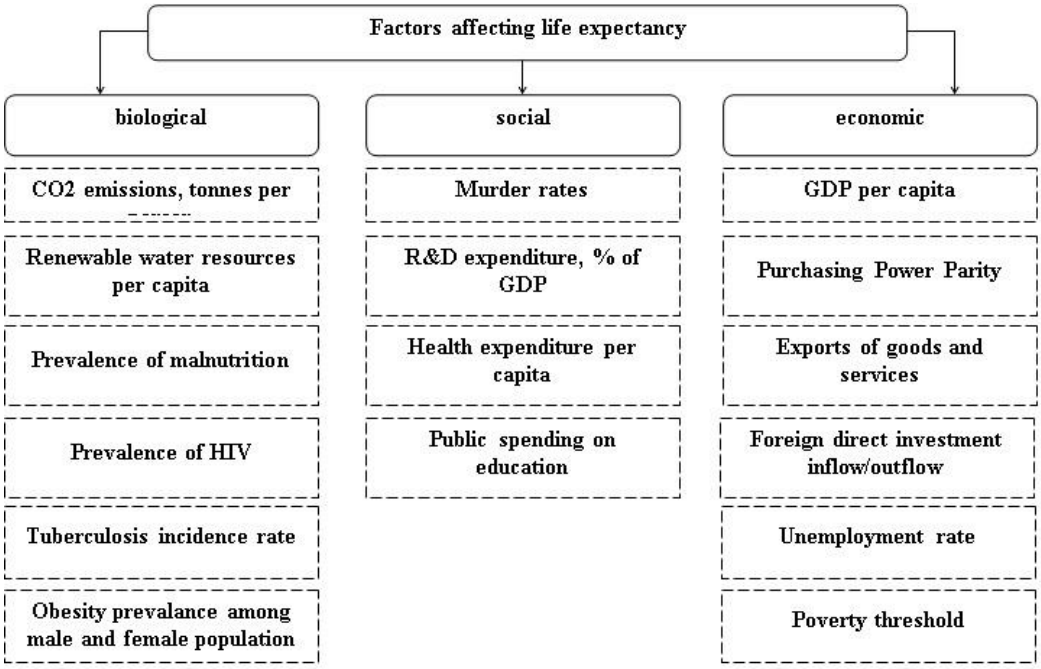

Figure 1. Factors affecting life expectancy.

ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)

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The most successful models that demonstrate a high degree of interconnectedness will be described in the RESULTS section.
The study is based on the official statistics from the United Nations (United Nations, Department of Economic and Social Affairs, Population Division, 2019) and the World Bank (2020), as well as the Knoema (2020). The MS Excel Data Analysis ToolPak is used to perform calculations.

Results

Despite the fact that global trends indicate a widespread increase in life expectancy at birth (216 deaths per 1000 children aged 0-5 in 1950 compared to current estimations of 38.9 deaths; in developed countries, there are only isolated cases, which take only a few ppm in the proportion (United Nations, Department of Economic and Social Affairs, Population Division, 2019)), it is necessary to track local changes in the dynamics of this category to identify national characteristics and differences (Fig. 2).

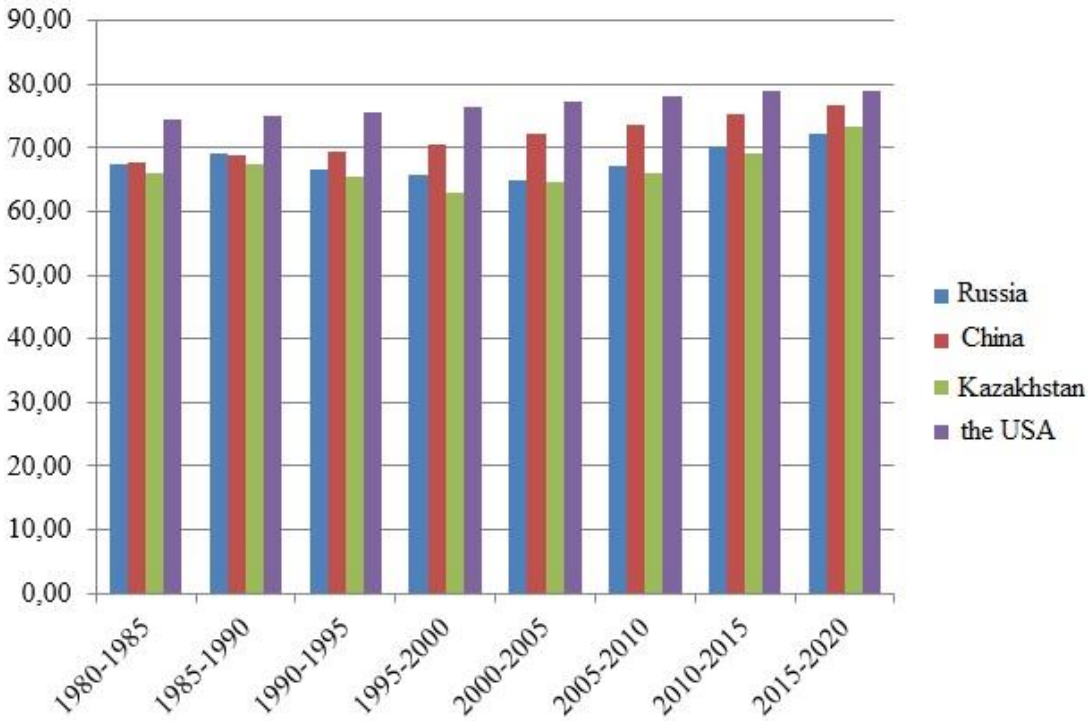

Figure 2. Life expectancy at birth in the countries participating in the study, 1980 - 2020.

As it can be seen, in the period from 1990 to 2000, there was a decrease in life expectancy in Russia and Kazakhstan caused by the dissolution of the Soviet Union and subsequently destabilized economic development of these countries. However, positive dynamics has been observed since 2006. In many respects, this is due to economic (access to global markets, foreign investment, etc.) and social (new social policy) changes. Healthcare structure modernization has contributed to the availability of modern medical care. In other respects, there are no significant differences between developed and developing countries. UN experts suggest that this trend will continue over the next 15 years (United Nations, Department of Economic and Social Affairs, Population Division, 2019) (Fig. 3).

ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)

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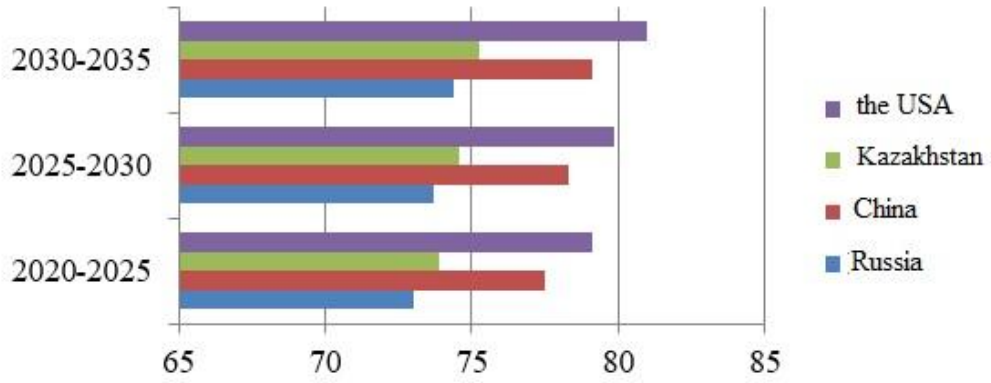

Figure 3. Forecast of life expectancy at birth in the countries participating in the study, 2020 – 2035

The increase in life expectancy poses new challenges to the state shifting the focus from quantity to quality. Thus, the quality of life becomes as important as its length. It is physical and spiritual well-being that allows people to remain able-bodied for as long as possible working for the good of society.

The indicator of life expectancy at age 60 deserves special attention as it demonstrates successful prevention and treatment of chronic diseases, as well as the general improvement of the quality of life (Fig. 4).

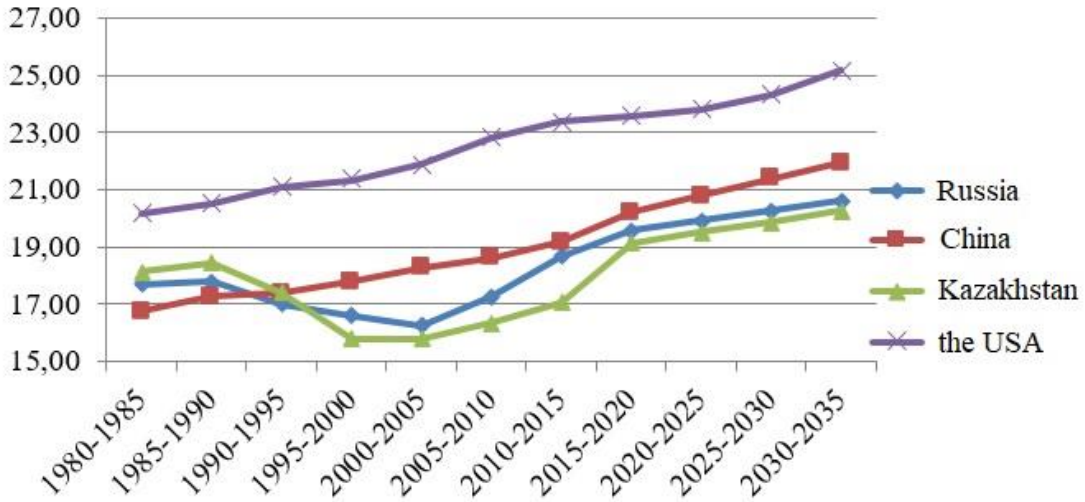

Figure 4. Life expectancy at age 60, 1980-2035

The situation is similar and it is possible to track the difference in the progress of countries with stable economic growth (the USA and China) and the former post-Soviet republics. Thus, in Russia and Kazakhstan, there has been a sharp decline in the life expectancy of retirement-age people since 1985, which peaked in 1995-2005. As it has been noted, the main cause is the historical events that led to global economic changes in both countries.

Let us now turn to the assessment of factors affecting the analyzed dynamics. Having carried out a correlation and regression analysis of all the identified factors (see the methods and materials section), we concluded that life expectancy in countries with different levels of

ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)

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economic development depends on various factors. Thus, the correlation and regression analysis showed that in Russia there is a close correlation between life expectancy and the prevalence of HIV and tuberculosis, rates of murder and poverty (Table 1).

Table 1. Correlation and regression analysis of the impact of social, biological and economic factors on life expectancy (the Russian Federation)

	Life expectancy	Prevalence of HIV	Tuberculosis incidence rate	Murder rates	Unemployment rate	Poverty rate
Life expectancy	1					
Prevalence of HIV	0.975759	1				
Tuberculosis incidence rate	-0.983502	-0,986811	1			
Murder rates	-0.879015	-0.835498	0.810963	1		
Unemployment rate	-0.616661	-0.636750	0.708760	0.252596	1	
Poverty rate	-0.736038	-0.687623	0.672870	0.854556	0.274618	1

A positive correlation between life expectancy and the prevalance of HIV can be explained by the fact that improvements in the provision of medical services contribute to the timely detection of the virus. It is not the number of patients that is increasing, but the number of officially registered cases.

The accuracy and consistency of this model emphasize the high regression and determination coefficients - 0.98 and 0.99, respectively, implying a 99% probability of a correlation between the calculated indicators.

In the regression analysis, the following equation was obtained:

$$Y = 82{,}7 - 1{,}22X_1 - 0{,}14X_2 - 0{,}12X_3 + 0{,}1X_4 - 0{,}26X_5 \quad (1)$$

It follows that despite the close correlation between the studied indicators, their mutual influence is insignificant.

In respect to Kazakhstan, the analysis revealed similar patterns: the correlation coefficient between life expectancy and the poverty level of the population was -0.914997. In addition, there is also a significant reduction in the number of tuberculosis patients (from 162 patients per 100,000 people in 2007 to 68 - in 2018), which also led to the high indicator (-0.987160).

The analysis of China and the United States revealed completely different correlations (Table 2 and 3).

Table 2. Correlation and regression analysis of the impact of social, biological and economic factors on life expectancy (China)

	Life expectancy	CO2 emissions,	Health expenditure	Obesity prevalance	Obesity prevalance

ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)

		tonnes per person		among male population	among female population
Life expectancy	1				
CO2 emissions, tonnes per person	0.931047	1			
Health expenditure	0.974507	0.919009	1		
Obesity prevalance among male population	0.998511	0.91988	0.973737	1	
Obesity prevalance among female population	0.998915	0.929862	0.965893	0.996995	1

The feature of these factors is that they have a cumulative effect and the mathematical model is not able to see their negative consequences in the current period. The only fact is that every year carbon dioxide emissions, as well as the percentage of people suffering from obesity, which is a premonitory symptom of chronic diseases, are increasing pro rata with the increase in the life expectancy of the Chinese population.

Table 3. Correlation and regression analysis of the impact of social, biological and economic factors on life expectancy (the USA)

	Life expectancy	CO2 emissions, tonnes per person	Health expenditure	Obesity prevalance among male population	Obesity prevalance among female population
Life expectancy	1				
CO2 emissions, tonnes per person	-0.65768	1			
Health expenditure	0.763629	-0.78331	1		
Obesity	0.676857	-0.87482	0.883618	1	

ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)

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prevalance among male population					
Obesity prevalance among female population	0.708739	-0.87877	0.86654	0.992732	1

In the United States, recent tough environmental policies have produced results: CO2 emissions have decreased significantly, which allows the United States to maintain leadership in clean air and water. However, President Donald Trump's new policy on reviving industry combined with radical decisions such as withdrawal from the Paris Agreement on Climate Change and mitigation of environmental protection measures (Garusova & Kuryanova, 2019) may lead to unexpected results.

Discussion

A close correlation between CO2 emissions and healthy life expectancy (healthy life expectancy, HALE), an indicator of the number of years lived without serious chronic illness, was identified in the study (Mohmmed et al., 2019). The authors studied carbon dioxide emission factors in 10 leading countries (China, the USA, India, the Russian Federation, Japan, Germany, South Korea, Iran, Canada, and Saudi Arabia) based on the method of logarithmic differentiation (LMDI). The research results showed that changes in CO2 emissions significantly affect population and income, especially in China and the United States. CO2 emissions are expected to increase by 2030. This requires immediate government intervention and the introduction of policies aimed at creating a safe environment.

Life expectancy is growing in most social groups (Steiner et al., 2020). This is especially evidenced by better health of the elderly which is achieved through the biological age reduction. In 2001, there was a study conducted in Denmark, which involved 238 women and 144 men, whose average age was 75.5 years. Expert groups of different age categories were shown the photographs of the participants, who confirmed the real age of the participants with an error of six months. The experiment was repeated in 2012 in order to identify changes in the subjective perception of age against the background of a world-wide increase in life expectancy. As a result, the same people in the photographs seemed to be 2-3 years older.

Retirement-age people are one of the most socially sensitive social groups requiring constant support. A specific indicator of life expectancy was modeled for this group: disability-adjusted life years (DALYs), taking into account the presence of diseases such as diabetes, cardiovascular disorders and other age-related chronic processes. There was an American study which counted the years lost due to disability. The study involved 18,000 participants with the above-mentioned problems; it was revealed that there were 902,033 years lost (McGrath et al., 2019).

World Health Organization (2020) has proven that adult obesity significantly increases the risk of adverse health effects; however there was no quantitative evidence of its effect on life expectancy. Therefore, the Australian study (Lung et al., 2019) that demonstrates how life

ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)

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expectancy is shortened by obesity is of practical significance. The presented estimates are quite significant: depending on the degree of obesity, life expectancy loss varies between 5.6–7.6 years and 8.1–10.3 years. Overweight and obesity are associated with premature mortality at all ages for both men and women. The authors make valuable recommendations on the development of a coherent, sustainable and cost-effective strategy to prevent overweight and obesity, especially among young men.

At an independent expert meeting featuring Teresa Marto, Secretary of State for Health and Welfare in England, four key issues preventing the increase in life expectancy in quantitative and qualitative terms were identified (Mytton et al., 2019). Their minimization will increase life expectancy by 15 years by 2035. Despite the fact that the issue was considered in the context of the British population, the described risks and possible solutions are universal and applicable to any country. The first two problems are excessive consumption of alcohol and smoking. Speakers suggest using a comprehensive methodology for their solution reviewing both the tax policy of the state and the marketing tools of each individual company. An increase in the legal age to purchase tobacco and alcohol products from 18 to 21, as well as a decrease in the blood alcohol content for drivers to 50 mg/100 ml are also considered. In addition, the abundance of junk food in the regular diet of the population and sedentary lifestyle give rise to serious concerns. It is proposed to initiate active efforts to replace advertisements of sweets and fast food with their healthier alternatives, as well as to create special reports on proper nutrition benefits, etc. In addition, it is also proposed to provide needy families with state support which includes monthly deliveries of fresh vegetables and fruits or set social prices for these products, reduce food delivery portions and close down fast food restaurants in shopping centers. Activity can be increased by improving local infrastructure, setting prices for the use of roads at certain hours, organizing mass events, charity races, etc.

Conclusions

The feature of the “life expectancy” indicator is that it is an adequate generalizing characteristic of socio-economic development and the mortality rate in each age group. It is affected by a number of biological, social and economic factors ranging from the environment status to the policy of a particular state. This is an element of the analysis of the “quality” of life that is required for the development of competitive human capital.

The correlation and regression analysis revealed similar patterns in developing and developed countries. Thus, in Russia and Kazakhstan there is a high correlation between life expectancy at birth and poverty rates, prevalence of HIV and tuberculosis, as well as murder rates. In addition, the study demonstrated a sharp decrease in the indicator dynamics in the 1990s as a result of the collapse of the Soviet Union.

In economically stable countries, social and environmental factors move to the forefront. The US position as an environmental leader allows it to reduce carbon dioxide emissions while increasing life expectancy. However this is not the case in China.

In general, the results of the study prove the versatility of life expectancy as an economic category and confirm its value. It is life expectancy that makes it possible to identify hidden vulnerabilities of different age groups, track the difference in the lifestyle of male and female

ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)

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population, as well as improve social policy based on these data. The analysis of the indicator involves the discussion of important issues: the fight against obesity and environmental pollution.

Acknowledgments

Maria Egorova was supported by the Russian Science Foundation (project №19-18-00300).

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ISSN 1869-0459 (print)/ ISSN 1869-2885 (online)