AN EVALUATION OF THE IMPACT OF ECONOMIC FACTORS ON LIFE EXPECTANCY

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Abstract

Life expectancy is not only an indicator of the mortality of a given population but can also reflect the economic development of a given country. The relationship between life expectancy at birth and national income per capita is known as the Preston curve. It has been found that people in rich countries live longer on average than those born in poor countries. Extending the relationship of the Preston curve by other economic factors could update its validity and improve its accuracy. This paper confirmed the relationship between life expectancy at birth and national income in the countries of the European Union. Despite the fact that adding mean years of schooling improved the relationship, based on the results, we were not able to argue that as mean years of schooling increase, life expectancy increases. To measure the impact of different educational levels on life expectancy, we computed the life tables by the level (low, middle, high) of education for the years 2001 and 2011. We observed a reduction in the life expectancy gap at the age of 30 between persons with the lowest and highest level of education.

Key words: life expectancy, economic factors, Preston curve, education level

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Introduction

Life expectancy, which expresses the average remaining length of a person's life while keeping mortality rates from the period of construction of the life table, is influenced by various socio-economic factors. In addition to mortality, the indicator is influenced by factors such as the level of the health care system, education, and lifestyle, nutritional habits, the environment and the social, economic or political situation in a given country. As stated in Rogers and Wofford (1989): "*In less developed countries, mortality is primarily influenced by such socio-economic development measures as urbanization, industrialization, and education, and secondarily by such public health measures as access to safe water, physicians, and adequate nutrition*". In contrast, life expectancy is not affected by the age structure of a given population due to the fact that the construction of life tables is based on a stationary population model. As one of the most widely used indicators, it is considered an overall characteristic of the mortality of a given population and is suitable for comparison in time and between territorial units.

When focusing on economic factors affecting life expectancy, mention should be made of the Preston curve, which describes the relationship between life expectancy at birth and national income. Preston (1975) described the effect of the economic factor on mortality as follows: "*A higher income implies and facilitates, though it does not necessarily entail, larger real consumption of items affecting health*". In his article, Preston (1975) presented the evidence evaluating a period of three different decades in the twentieth century. According to Preston (1975), national income is an indicator that reflects the standard of living in a country, as it includes the value of all final products in a certain period of production. National income, as the main economic indicator, is part of growth models from which policy measures are derived.

The Preston curve is often further extended by other socio-economic factors in order to improve the accuracy and validity of the relationship between life expectancy and national income per capita. Socio-economic inequalities in longevity have been found in all European countries (Mackenbach et al., 2019). Better nutrition and greater affordability of health care associated with a higher income have been widely considered as primary determinants of historical and contemporary decline in mortality (Lutz and Kebede, 2018). As stated by Linden and Ray (2017), in their study, the importance of the positive relationship between public health expenditures and life expectancy is present. The longevity gap by socio-economic status is widening due to a faster increase in life expectancy for people with a higher education or income, as many studies show (NASEM, 2015). As data on educational attainment distributions by age and sex have become available, there has been a rapidly increasing body of literature about the effect of education on health-related behaviour and thus on mortality (Lutz et al., 2017; Goujon et al., 2016; Baker et al., 2011; Lutz and Skirbekk 2014; Lutz et al. 2007). Economic development measured by gross domestic product (GDP) per capita, as well as social status measured by the level of education attained, significantly affect life expectancy (Bilas et al., 2014).

1 Methodology and data

Assuming a relationship between life expectancy at birth and national income based on the Preston curve, the macro-model can therefore be specified as (Rodgers, 2002):

$$Y = a + f(x) + bG + \epsilon \,, \qquad (1)$$

where Y is the mortality or the life expectancy, $f(x)$ is a function of mean income, G is a measure of income distribution, and ϵ is an error term.

To estimate the Preston curve, the given relationship can be written into the formula as follows (Shkolnikov et al., 2019):

$$LE_i = a + b \cdot \log(GDP_i) + \varepsilon_i \,, \qquad (2)$$

where index i indicates the country, ε_i is the random error specific to that country, and a and b are parameters to be estimated.

As input for the estimate of the Preston curve, we used the data from the Eurostat database, namely life expectancy at birth and gross domestic product at market prices, in current prices and in Euros. In our analysis, we included the EU and EFTA member states as well as EU candidate countries (with the exception of Kosovo, where data were missing). Please see Tab. 1 for more details. The year 2018 was selected due to the availability of data.

Tab. 1: EU, EFTA member states and EU candidate countries in 2018

EU Members	Belgium	BE	EU Members	Cyprus	CY		Slovakia	SK
	Bulgaria	BG		Latvia	LV		Finland	FI
	Czechia	CZ		Lithuania	LT		Sweden	SE
	Denmark	DK		Luxembourg	LU	EFTA	Iceland	IS
	Germany	DE		Hungary	HU		Liechtenstein	LI
	Estonia	EE		Malta	MT		Norway	NO
	Ireland	IE		Netherlands	NL		Switzerland	CH
	Greece	EL		Austria	AT	EU Candidate	Montenegro	ME
	Spain	ES		Poland	PL		North Macedonia	MK
	France	FR		Portugal	PT		Albania	AL
	Croatia	HR		Romania	RO		Serbia	RS
	Italy	IT		Slovenia	SI		Turkey	TR

Source: Eurostat

To broaden the relationship between life expectancy and national income per capita (GDP), an additional variable representing the average years of education or schooling has been added. To evaluate the relationship, we used input data from the estimation of the first model (life expectancy at birth and national income per capita) as well as data from the UNESCO Institute for Statistics (UIS), which collects data on education. The indicator of mean years of schooling is defined as a percentage of the population (age 25+) by educational attainment. We used the data for the EU and EFTA member states as well as EU candidate countries except for some countries (Iceland, Liechtenstein, Montenegro, North Macedonia, Albania and Croatia) due to a lack of data.

The next part of the paper examines the life expectancy at age 30 by education level in the case of Czechia. The age of 30 was chosen because it is considered to be the age at which people generally have already completed their education. Due to the availability of data from the Czech Statistical Office (CZSO), the years 2001 and 2011 in which the census was held were selected, and it is thus possible to examine the educational structure of the population. The population at risk is equal to the number of usually resident people according to the level of highest educational attainment in a given year. In calculating life expectancy by education, in addition to population and risk data, the numbers of deaths in the given years were also used as input data. However, due to the lack of data on deceased persons in terms of achieved education, we computed the five-year averages for the periods 2001–2005 and 2011–2015. We used standard life table techniques to obtain life expectancy by education level. We calculated in the abridged life tables for both sexes in five age groups from 30–34 years to 80 and more years. None of the life table smoothing method was not used.

2 Main results

The relationship between life expectancy at birth and selected economic factors is estimated using a regression model. Standard testing techniques are used for the statistical inference. The first model describes the relationship between life expectancy at birth and GDP per capita (national income), also known as the Preston curve. For the second model, we added the mean age of schooling as an additional variable. Finally, we computed life expectancy by education level for Czechia.

Life expectancy and GDP

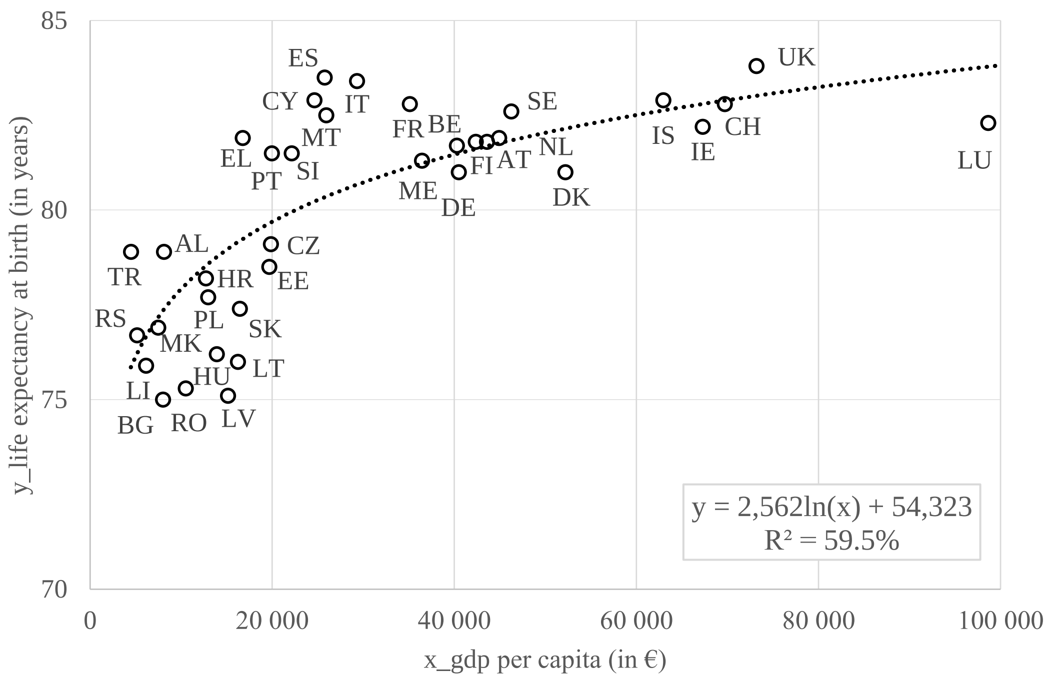
As seen in Fig. 1, we estimated the Preston curve with a simple linear regression model. The dependent variable is life expectancy at birth and the independent variable is GDP per capita (national income) in €. The regression model can be written as follows:

$$Predicted\ Life\ Expectancy\ at\ Birth = 54.323 + 2.562\ \cdot\ \ln(GDP\ per\ capita),$$

where $b_1 = 2.562$ represents the average change of predicted life expectancy at birth by 2.562 years due to the increase in national income by one unit of measure (in €).

We observed the countries with the highest national income as follows: Liechtenstein, Luxembourg and Switzerland, with the life expectancy at birth recorded to be the highest in Switzerland (83.8 years). Liechtenstein was in fourth place in the rankings from the 37 countries with a life expectancy at birth equal to 83.1 years, and Luxembourg took 11th place in the rankings. On the other hand, the countries with the lowest national income were found among the EU candidate countries (Albania, Serbia and North Macedonia). Despite the lowest value of GDP, the life expectancy at birth was higher than in countries such as Bulgaria, Latvia and Romania, with higher national incomes in the rankings.

Fig. 1: Life expectancy at birth and gross domestic product in 37 countries of the EU, EFTA and EU candidate countries, Preston curve, in 2018



Source: Author's calculations and processing based on Eurostat data.

The result of coefficient R^2 is equal to 59.5%, which means that the model explains a total of 59.5 % of the variability of the dependent variable. For the validation of the model, we checked its residues.

To perform the F-test for the model and the t-test for the parameters of the model, the following assumptions to be met were: 1) zero expected value, 2) a constant variance, and 3) independence and normality of the residues. The evaluation and testing of these assumptions using standard visualization and hypothesis techniques did not show us any violation of them. We did not observe any distinct pattern in the residues.

For the model diagnostics, we used the F-test with the null and alternative hypothesis as follows: $H_0: \beta_0 = c, \beta_1 = 0$ (not statistically significant linear dependence), $H_1: non\ H_0$. The model is observed to be significant (p-value = 2.26E-08 < α = 0.01). For the t-test for the parameters, the null hypothesis is $H_0: \beta_i = 0$ and the alternative hypothesis is $H_1: non\ H_0$. The parameters of the model are observed to be significant (for the parameter b_0 the p-value = 7.62E-17 < α = 0.01 and for the parameter b_1 the p-value = 2.2559E-08 < α = 0.01).

Based on our results of the estimation for the year 2018 in selected countries of the EU, EFTA and EU candidate countries, we can therefore confirm the relation between life expectancy at birth and national income as measured by GDP per capita. Despite the results, the other variables discussed above could be tested as input for the model in order to improve the share of the explained variability of the dependent variable.

Life expectancy, GDP and education

In order to examine the impact of other factors on life expectancy, we explicitly considered educational attainment as an additional variable to broadening the perspective. We performed the Preston curve with a multiple linear regression model. The dependent variable is life expectancy at birth and the independent variables, or factors, are GDP per capita (national income) in € and the mean years of schooling (in %). The regression model can be written as follows:

$$Predicted\ life\ expectancy\ at\ birth = 51.514 + 3.936\ \cdot \ln(GDP\ per\ capita) - 0.941\ \cdot\ MYS,$$

where $b_1 = 3.936$ represents the average change of predicted life expectancy at birth by 3.936 years due to the increase in national income by one unit of measure (in €), and $b_2 = -0.941$ represents the average change of predicted life expectancy at birth by -0.941 years due to the increase in mean years of schooling (MYS) by one unit of measure (in %).

The result of modified coefficient R^2 is equal to 74.0%, which means that the model explains a total of 74.0% of the variability of the dependent variable. When comparing the result of the value of the R^2 statistic with the first model, the value of this statistic was found to be higher for the second model. This means that adding another factor, the mean years of schooling, improved the validity and the accuracy of the relationship.

We performed the F-test for the model and the t-test for the parameters of the model. First, the F-test has the null hypothesis $H_0\colon \beta_0 = c, \beta_1 = 0, \beta_2 = 0$ (not statistically significant linear dependence) and $H_1\colon non\ H_0$. We assumed that the following assumptions are met to perform this test as we did not observe any pattern in the residues: 1) zero expected value, 2) a constant variance, and 3) independence and normality of the residues. The model is observed to be significant (p-value = 2.51E-09 < α = 0.01). For the t-test, the null hypothesis is $H_0\colon \beta_i = 0$ and the alternative hypothesis is $H_1\colon non\ H_0$. The parameters of the model are observed to be significant (for the parameter b_0 the p-value = 1.68023E-13 < α = 0.01, for the parameter b_1 the p-value = 4.30436E-10 < α = 0.01, and for the parameter b_2 the p-value = 0.000167558 < α = 0.01).

Although the model increased the accuracy of the model describing the relationship between life expectancy at birth, national income per capita and mean years of schooling, the estimated parameter b_2 cannot be interpreted as we expected. Based on the estimated model, the parameter b_2 says that increasing the mean years of schooling by 1% will reduce life expectancy at birth by 0.9413 years. Despite this fact, however, we consider the relationship between life expectancy at birth and education to be significant. We ascribe the reason for this rather to different types of data coming from different sources (mainly national population censuses; household and / or labour force surveys). In addition, we believe that a higher number of observations of the model could improve the validity.

Life expectancy by education level

In order to demonstrate the difference in life expectancy by education, we calculated the values of this indicator at the age of 30. Life expectancy at the age of 30 by education level and the gap in life expectancy between the highest and lowest education level in Czechia in 2001 and 2011 are shown in Tab. 2. In 2001, we observed a difference in life expectancy at the age of 30 between the highest and lowest educational attainment equal to 9.8 years. Compared to 2011, the gap was reduced to 6.7 years. The life expectancy of people aged 30 with a middle education was very close in value to the overall life expectancy of this age in both periods.

Tab. 2: Life expectancy at the age of 30 by education level and the gap in life expectancy between the highest and lowest education level in Czechia, 2001 and 2011

Education Level	2001	2011	2011/2001
All levels	46.0	50.0	4.0
Low	43.1	47.6	4.5
Medium	46.8	49.8	3.0
High	52.9	54.3	1.4
Gap High/Low	9.8	6.7	-3.1

Source: Author's calculations and processing based on CZSO data.

Conclusion

The relationship between life expectancy and national per capita income expressed by the Preston curve has been confirmed, as many other studies have shown. With a higher level of GDP, a higher average number of expected years to live can be expected for a given person. In addition, there are other known factors that affect life expectancy, as discussed in this paper. As another variable, we considered education, namely mean years of schooling, which turned out to be a statistically significant factor in the model. However, we were unable to confirm, based on the estimated model, that with increasing mean years of schooling, life expectancy at birth increases. On the other hand, the addition of another statistical variable to the model helped to increase its validity and accuracy. In the example of Czechia, life expectancy at the age of 30 by education has shown that persons with the highest level of education live the most years. The difference between the life expectancy at the age of 30 of persons with the highest and lowest education was found to be almost 10 years in 2001, the value of which decreased further as compared to 2011 (6.7 years).

Despite confirming the relationship between life expectancy and other economic factors, further research in this area would be appropriate (for example, on a larger sample of data and after the inclusion of other economic factors). Since the calculation of life tables according to educational categories showed that life expectancy is influenced by the level of education attained, it would be desirable to evaluate life expectancy between men and women as well as over time. We foresee as beneficial the results of the performed decomposition analysis of mortality in the study of the mortality of a given population according to educational categories.

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