INTERNATIONAL JOURNAL OF ECONOMIC STUDIES

ULUSLARARASI EKONOMİK ARAŞTIRMALAR DERGİSİ

June 2024, Vol:10, Issue:1 Haziran 2024, Cilt:10, Sayı:1
e-ISSN: 2149-8377 p-ISSN: 2528-9942
journal homepage: https://dergipark.org.tr/tr/pub/ead

Exploring Determinants of Life Expectancy: A Comprehensive Analysis of Health, Socioeconomic, and Environmental Factors in European Countries

Serdar AYDIN
Clinical Assistant Professor, Georgia State University, Institute of Health Administration, Robinson College of Business, saydin@gsu.edu
Eunice MULENDA
Georgia State University, Institute of Health Administration, Robinson College of Business, , emulenda1@student.gsu.edu

ARTICLE INFO

Article History:
Received 25 April 2024
Received in revised form 15 May 2024
Accepted 30 June 2024

Keywords:
Life expectancy, socioeconomic and health factors, public health, European countries

ABSTRACT

This paper aims to construct a comprehensive conceptual model for understanding and assessing the variables influencing life expectancy in European countries. A systematic review of relevant literature was conducted, analyzing 53 European countries and exploring the impact of health, socioeconomic, environmental, and demographic factors on life expectancy. The relationship between life expectancy and these factors were analyzed using univariate analysis which examined key statistics, bivariate analysis, which was used to identify relationships among variables. A linear multivariate regression analysis was used to construct a model that reveals the effect of the different variables on life expectancy. Life expectancy is a multi-dimensional construct influenced by current health expenditure, death rate, GNI, and fertility rate. The study revealed significant correlations, with health spending and GNI positively affecting life expectancy, while higher fertility rates and death rates are associated with decreased life expectancy. The conceptual model proposed requires empirical validation. The study predominantly focused on developed countries, and findings may not be universally applicable, particularly in diverse cultural contexts. The findings offer valuable insights for policymakers, emphasizing the need for strategic investments in healthcare and targeted interventions to balance fertility rates. The nuanced relationships identified provide a basis for evidence-based public health policies. This paper consolidates and examines recent findings on life expectancy determinants in European countries, presenting a comprehensive conceptual model. By synthesizing diverse research, it offers a holistic view of factors impacting life expectancy, contributing to the understanding of population health.

INTRODUCTION

Public health plays a crucial role in the development of a country.[1] A strong public health system improves the quality of life for individuals and reduces suffering by aiding and prolonging life. More importantly, it is also associated with the long-term productivity of a country's economy. A healthy population is a crucial driver of labor productivity, capital investment, and consistent economic growth. The efficacy of a country's public health can be assessed by many indicators; One of the key indicators is life expectancy at birth. It gauges the overall health of a community by measuring the health status across all age groups. Therefore, it more objectively reflects the viability of the population. Furthermore, it allows comparison within and across societies worldwide. Medical and socioeconomic research have been extensively investigating life expectancy and its determinants looking to find methods of increasing it. Researchers emphasize that good health is linked to various socioeconomic preconditions, including the reduction of poor education levels, unemployment, insecurity, and the improvement of life conditions. Life expectancy at birth has risen over the past century [2] due to an evolution of technology, evidence-based medical practices, and lifestyle changes. People are healthier, wealthier, and living longer today than 30 years ago.[3] The average global life expectancy at birth is estimated to increase by 7 years from 1998 to 2025, with 26 countries having a life expectancy at birth above 80 years.[3] Predicting various countries' life expectancy and comparing them allows researchers and policymakers [4] to better understand what influences them and how to improve those variables to increase life expectancy overall. Thus, identifying determinants of life expectancy and their level interaction is crucial.

This study delves into the intricate interplay of various factors—namely, health expenditure, death rate, fertility rate, GNI per capita, CO_2 emissions, prevalence of current tobacco use, unemployment, and GDP per capita—on the life expectancy at birth in 53 European countries. Given the multifaceted influences shaping life expectancy, encompassing healthcare access, lifestyle, environmental conditions, and social policies, the primary objective is to discern the significance of these factors and develop a foundational understanding of their relationships. It is essential to acknowledge that attributing life expectancy solely to selected factors oversimplifies this complex concept. Recognizing its multi-dimensional nature, this study postulates the existence of statistically significant relationships with the aforementioned factors. Specifically, we anticipate a positive correlation with health expenditure, GNI per capita, and GDP per capita, while expecting an inverse correlation with death rate, fertility rate, CO_2 emissions, prevalence of current tobacco use, and unemployment.

The subsequent sections of the paper follow a structured approach. The literature review, theoretical framework, and empirical evidence are presented in the next section. Methodological considerations, dataset overview, and variable explanations are outlined in the third section. Results and analyses are presented in subsequent sections, leading to the paper's conclusion, where open issues for future research are identified.

1.Theoretical Framework

Several studies, investigations, and research have been conducted regarding life expectancy and its determinants and diverse model approaches and countries have been used. The influence of socioeconomic, health, environmental, demographic, and geographic factors on life expectancy has been extensively investigated through different methods throughout the year. Factors such as national income[5–7], education, urbanization, health care spending[5,8] and inputs such as number of physicians, access to safe drinking water, nutritional outcomes, and a country's location[8] appeared to be statistically significant. Mondal and Shitan[9] carried out a detailed analysis of life expectancy determinants of 91 low- and lower-middle-income countries within a multiple regression framework. They analyzed the effect of education (mean years of schooling), GNI per capita, total fertility rate, HIV prevalence rate, and physician density. The chosen determinants were significantly correlated with life expectancy. Mean years of schooling, total fertility rate, and HIV prevalence rate had significant direct and indirect effects on life expectancy. The total effect of higher physician density was to increase life expectancy.

Many researchers have investigated the relationship between income to life expectancy. There are abundant works of literature that have identified income as the most important determinant of life expectancy[4,7,10]. They associate higher gross national income (GNI) and GDP with higher life expectancy at birth. However, after a certain income threshold, there is no change in life expectancy as income increases.[11] Swift[5] used Johansen multivariate cointegration analysis to investigate the relationship between life expectancy and GDP over the past two centuries, covering periods from 1820 – 2001 to 1921- 2001 across 13 OECD countries. A consistent, long-term cointegrating relationship was identified between life expectancy and both total GDP and GDP per capita for all the countries examined. These relationships exert a significant impact on both total GDP and GDP per capita in the majority of the countries assessed. She found that a 1% increase in life expectancy was associated with an average 6% rise in total GDP in the long run and a 5% increase in GDP per capita. Furthermore, total GDP and GDP per capita significantly influence life expectancy in most countries. The study found no evidence of changes in these relationships for any country over the estimated periods, suggesting that shifts in major causes of illness and death over time do not seem to have affected the connection between health and economic growth.

Total healthcare spending is believed to wield a significant influence on life expectancy as it directly contributes to the reduction of mortality and morbidity. A cross-province investigation uncovered that lower healthcare spending is linked to a statistically significant rise in infant mortality and a decline in life expectancy in Canada. Notably, this relationship remained independent of various economic, socio-demographic, nutritional, and lifestyle factors, as well as the provincial specificity of the time trend[12]. There may also exist a correlation between per capita income and health expenditure, as higher per capita income could result in increased per capita health expenditure. Simultaneously, a higher per capita income enhances a nation's ability to acquire the necessary goods and services that foster health. The poverty level within societies is causally linked to the poor health of those societies[13]. Achieving overall good health levels may require a certain level of healthcare expenditures. One might anticipate a positive relationship between healthcare spending and health status if increased resources imply an enhancement in the level and quality of health services provided to the population. However, there might be diminishing returns to scale beyond a certain expenditure level. Hitiris and Posnet[14] using cross-country time series data discovered a small negative relationship between health spending and mortality rates.

A trend can be observed across all countries. There is a decline in the total fertility rate (TFR). Cheng et al.[15] investigated the global trends in total fertility rate and its relation to national wealth, life expectancy, and female education using distributed-linear models (DLNMs). Within the range of reproductive age, TFR increased as life expectancy increased. Outside that range, TFR significantly negatively correlated with life expectancy at birth.[15] However, the trend was not consistent for all regions and all age cohorts. High fertility can potentially exert a negative impact on life expectancy. Families with high fertility rates often face resource constraints per child, and shorter intervals between births may reduce breastfeeding, jeopardizing the nutritional well-being of infants. Mondal and Shitan[9] found that TFR exhibited a significant inverse correlation with income and education. Additionally, life expectancy showed an inverse correlation with TFR. TFR had a notable direct effect on life expectancy.[16] Adolescents globally encounter heightened reproductive health risks, with over 14 million aged 15 to 19 giving birth annually. This adolescent fertility is linked to adverse maternal and child health outcomes, including complications during labor, low birth weight, fetal growth issues, and elevated infant and maternal mortality. Greater adolescent fertility contributes to increased sexual activity among unmarried girls, exposing them to unplanned pregnancies, unsafe abortions, and sexually transmitted diseases, including HIV. Delayed reproduction is associated with improved survivorship, a phenomenon observed globally. Studies have indicated that adolescents expecting a shorter lifespan tend to reproduce at an earlier age compared to those anticipating a longer life.[16]

The emission of carbon dioxide (CO_2) is recognized as a powerful factor in environmental deterioration. As global efforts toward achieving higher economic growth continue, there is a concurrent rise in the concentration of CO_2 in the atmosphere, raising significant concerns that extend beyond national borders.[17] Numerous research studies on the intricate relationships between climate change and health and economic welfare have shown that there is a potential connection between life expectancy to both production and pollution. [18] Increased production leads to higher income, potentially positively impacting health, particularly in underdeveloped economies. On the other hand, pollution is more likely to contribute to higher morbidity, lower quality of life of populations, and a potential reduction in life expectancy.[18,19] Rasoulinezhad et al.[18] conducted a study examining the interplay between economic growth, fossil fuel consumption, mortality, and environmental pollution. Employing the generalized method of moments estimation technique, the research concluded that CO_2 was a crucial variable contributing to mortality, particularly from diseases such as cardiovascular disease (CVD) and cancer, in the Commonwealth of Independent States (CIS) regions during the period 1993–2008. Also, Murthy et al.[20], in their investigation of the relationship between CO_2, economic growth, and life expectancy in the D-8 countries during the study period 1992–2017, noted a negative impact of CO_2 on life expectancy. However, contrasting findings were observed in several research studies, particularly in underdeveloped regions. For instance, Amuka et al.[21] conducted a study on the relationship between climate change and life expectancy for the period 1995–2013, using CO_2 emission as a proxy for climate change. They identified a positive and significant relationship between CO_2 emission and life expectancy in Nigeria. The current literature on the relationship between carbon emissions and life expectancy does not provide a clear universal conclusion applicable to all nations. Instead, it is imperative to examine this linkage in the context of country-specific situations separately.[17]

The pursuit of maintaining, expanding, and improving the health of human populations is considered a key policy for sustainable development at the macro level. The rise of urbanization and industrialization along with advances made in medicine, improvements in the level of the population's hygiene, and a rise in the standard of living brought about the fall in crude death rate due to the decrease in infant and child mortality.[22] Although the crude death rate has seen a decline overall, some countries are doing better than others. This difference is tied to their economic growth. [23] Research has shown that life expectancy is linked to the average age at death within a population and is inversely related to death rates at that time. High life expectancy is often associated with low infant and child death rates and access to high-quality care. Furthermore, the death rate is dependent on many factors such as age, sex, national income, education, access to healthcare, urbanization, etc.[24–27] The impact of smoking on health is well-known. Smoking is linked with increasing risks for lung and other cancers, diseases of the respiratory system, diseases of the circulatory system, and other diseases that lead to death. 25% of deaths among men and 18% among women in Denmark in 1995 were attributable to smoking.[28] Brønnum-Hansen and Juel[28] estimated life expectancy between smokers and non-smokers in Denmark using Sullivan's method. They found that non-smoker Danes lived longer than smokers with women living longer in both cases.

2.Methods

The study focused on examining variables that were identified in prior research as having the most notable impact on life expectancy. Life expectancy indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life. The variables examined in this study along with their definitions are shown in Table 1 in the appendix. The list of the European countries studied is also provided in Table 2 in the appendix. The factors influencing life expectancy are categorized into 4 main groups: health, socioeconomic status, environmental, and demographic indicators. The health factor was the prevalence of current tobacco use; the socioeconomic variables were GNI per capita and GDP per capita; the environmental factor was CO_2 emission per capita, and the demographic variables were fertility rate, death rate, and population growth. All data were sourced from the World Bank database. [29]

Univariate analysis examined key statistics such as maximum, minimum, mean, and median values and standard error of the mean (SE mean) and SD. In bivariate analysis, Pearson correlation analysis was used to identify relationships among variables. Finally, a linear multiple regression analysis was used to construct a model that reveals the effect of the different variables on life expectancy. In the model, life expectancy was the dependent variable, countries were used as categorical variables, and health, socioeconomic, environmental, and demographic factors were used as continuous predictors. Some countries had missing data which were excluded from the model. All statistical analysis was done using SPSS software (version 29; IBM Corporation, Chicago, IL, USA).

Linear multiple regression analysis is a statistical method used to examine the relationship between a dependent variable and two or more independent variables. It aims to model and quantify the linear association between the variables. In this analysis, the dependent variable is assumed to be influenced by the independent variables linearly.[30]

The general form of a multiple regression model is:

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + \ldots + b_nX_n + \varepsilon$$

Where:

-$\hat{Y}$ is the dependent variable,

- b_0 is the intercept,

- b_1, b_2, ..., b_n are the coefficients representing the relationship between the independent variables X_1, X_2, ..., X_n and the dependent variable,

- ε is the error term.

The analysis estimates the coefficients,b_0, b_1, b_2, ..., b_n, that best fit the data and describes how changes in the independent variables are associated with changes in the dependent variable.

The method is widely used in various fields, including economics, social sciences, and health research, to understand and predict the impact of multiple factors on a particular outcome. The significance of each coefficient, as well as the overall model fit, is assessed to draw meaningful conclusions from the analysis. In this study, it helped predict life expectancy at birth based on various factors.

3.Results

3.1.Univariate analysis

The key statistics for both predictor and response variables are presented in Table 3. Notable variations were observed across countries, emphasizing the diverse nature of the variables.

Table 1: Descriptive statistics for dependent and independent variables

Variable	No.	Minimum (Country)	Maximum (Country)	Mean	Std. Deviation
Life expectancy at birth ($\hat{Y}$)	50	70.5 (Moldova)	83.8 (Turkey)	78.9	3.7
Current health expenditure (X_1)	46	1.6 (Monaco)	11.5 (Germany)	7.8	2.1
Death rate (X_2)	53	4.4 (Andorra)	15.4 (Bulgaria)	9.9	2.7
GNI per capita (X_3)	47	2750.0 (Ukraine)	83460.0 (Isle of Man)	29699.9	24873.1
Fertility rate (X_4)	50	1.3 (Spain, Cyprus, & Ukraine)	2.5 (Faroe Islands)	1.6	0.2
CO_2 emissions per capita (X_5)	45	1.9 (Albania)	15.3 (Luxembourg)	5.9	2.7
Prevalence of current tobacco use (X_6)	43	12.6 (Iceland)	40.1 (Serbia)	27.7	6.3
Unemployment (X_7)	44	2.2 (Czechia)	21.2 (North Macedonia)	7.8	4.7
GDP per capita (X_8)	52	3096.6 (Ukraine)	194287.1 (Monaco)	39255.2	40128.7

Life expectancy in Europe ranged from 70.5 years in Moldova to 83.8 years in Turkey. The mean LE was 78.9 years, with a spread of 13.3 years. Current health expenditure as a percent of GDP ranged from 1.6 in Monaco to 11.5 in Germany with a mean of 7.8% with a spread of 9.9%. Death rate ranged from 4.4 per 1000 people in Andorra to 15.4 per 1000 people in Bulgaria with a mean of 9.9 and a spread of 11 per 1000 people. GNI per capita ranged from 2,750 USD in Ukraine to 83,460 USD in the Isle of Man with a mean of 29,699.9 USD and a spread of. The fertility rate ranged from 1.3 in Spain, Cyprus, and Ukraine to 2.5 in the Faroe Islands with a mean of 1.6 and a spread of 1.2. CO_2 emissions per capita ranged from 1.9 in Albania to 15.3 in Luxembourg with a mean of 5.9 and a spread of 13.5. Prevalence of tobacco use ranged from 12.6 in Iceland to 40.1 in Serbia with a mean of 27.7 and a spread of 27.5. The unemployment rate ranged from 2.2% in Czechia to 21.2% in North Macedonia with a mean of 7.8% and a spread of 19%. GDP per capita ranged from 3096.6 USD in Ukraine to 194,287.1 USD in Monaco with a mean of 39,255.2 and a spread of 191,190.5 USD.

3.2.Bivariate analysis

Table 2: Pearson correlation coefficients between variables

	$\hat{Y}$	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Life expectancy at birth ($\hat{Y}$)	1								
Current health expenditure (X_1)	0.61[a]	1							
Death rate (X_2)	-0.55[a]	0.01	1						
GNI per capita (X_3)	0.77[a]	0.54[a]	-0.46[a]	1					
Fertility rate (X_4)	-0.10	-0.08	-0.18	0.113	1				
CO_2 emissions per capita (X_5)	0.24	-0.04	-0.08	0.38[b]	-0.17	1			
Prevalence of current tobacco use (PCTU) (X_6)	-0.43[a]	-0.29	0.49[a]	-0.62[a]	-0.02	-0.15	1		
Unemployment (X_7)	-0.06	-0.01	0.04	-0.40[a]	-0.22	-0.33[b]	0.42[a]	1	
GDP per capita (X_8)	0.63[a]	-0.01	-0.48[a]	0.98[a]	0.06	0.28	-0.59[a]	-0.39[a]	1

[a]$P < 0.01$, [b]$P < 0.05$.

Table 2 present the correlation coefficients of the variables under investigation which underscored significant relationships Life expectancy showed significant positive correlations with health expenditure, income, and GDP. Additionally, it exhibited a positive correlation with CO_2 emissions. Conversely, it demonstrated an inverse correlation with the death rate, fertility rate, PCTU, and unemployment percentage. Health expenditure displayed an inverse correlation with fertility rate, CO_2 emissions, PTCU, unemployment percentage, and GDP. It also significantly positively correlated with income and exhibited a positive correlation with death rate.

Death rate was positively correlated with PTCU, and unemployment, while inversely correlated with GNI, fertility rate, CO_2 emissions, and GDP. GNI showed significant positive correlations with GDP and a positive correlation with fertility rate and CO_2 emissions. It demonstrated an inverse correlation with PCTU, unemployment, and population. Fertility rate exhibited positive correlations with GDP, while inversely correlated with CO_2 emissions, PCTU, and unemployment. CO_2 emissions were positively correlated with GDP and inversely correlated with PCTU and unemployment. PTCU showed a positive correlation with unemployment and an inverse correlation with GDP. Unemployment was inversely correlated with GDP.

3.3.Linear regression analysis

Table 3 shows the regression coefficients of all the independent variables along with their p-values. The full model had an F-value of 15.3, a p-value of <0.001, and an R^2 of 0.81. However, the model had 3 significant variables and 5 insignificant variables. The statistically significant variables were death rate, GNI per capita, and fertility rate with p-values of 0.001, 0.003, 0.12, and 0.06, respectively. The statistically insignificant variables were current health expenditure, CO_2 emission, prevalence of current tobacco, unemployment, and GDP per capita with p-values of 0.073, 0.29, 0.29, 0.19, and 0.44, respectively. The model summary and ANOVA results are shown in Table 7 in the appendix.

Table 3: Full linear regression model: coefficients.

	Unstandardized B	Coefficients Std. Error	Standardized Coefficients Beta	t	Sig. (p)
Constant (b_0)	79.15	3.848		20.57	<.001
Current health expenditure (X_1)	0.473	0.256	0.254	1.851	0.073
Death rate (X_2)	-0.523	0.161	-0.374	-3.253	0.003
GNI per capita (X_3)	0	0	0.954	1.589	0.122
Fertility rate (X_4)	-3.122	1.569	-0.163	-1.989	0.055
CO_2 emissions per capita (X_5)	0.147	0.136	0.107	1.078	0.289
Prevalence of current tobacco use (PCTU) (X_6)	0.071	0.066	0.121	1.076	0.29
Unemployment (X_7)	0.126	0.094	0.145	1.342	0.189
GDP per capita (X_8)	-5.88E-05	0	-0.43	-0.79	0.435

The final model was refined by eliminating statistically insignificant variables one at a time with the worst one (highest p-value) first. After dropping GDP, the p-values of CO_2 emission, prevalence of current tobacco, and unemployment did not improve while current health expenditure became significant with a p-value of 0.006. They were still insignificant. CO_2 emission, prevalence of current tobacco, and GDP per capita were all dropped one regression at a time. After dropping CO_2 emissions, the remaining variables were still significant. The final p-values for current health expenditure, death rate, GNI per capita, and fertility rate were 0.001, <0.001, <0.001, and 0.02, respectively as shown in Table 2. The model F-value improved and changed from 17.72 to 33.40 and the R^2 decreased from 0.81 to 0.78. The model summary and ANOVA results are shown in Table 8 in the appendix.

Table 4: Final linear regression model: coefficients.

	Unstandardized B	Coefficients Std. Error	Standardized Coefficients Beta	t	Sig. (p)
Constant (b_0)	83.105	3.119		26.646	<.001
Current health expenditure (X_1)	0.619	0.176	0.334	3.524	0.001
Death rate (X_2)	-0.506	0.133	-0.361	-3.811	<.001
GNI per capita (X_3)	6.47E-05	0	0.414	3.714	<.001
Fertility rate (X_4)	-3.694	1.468	-0.194	-2.516	0.016

All statistically insignificant variables were dropped one at a time with the worst one (highest p-value) first. After dropping GDP, the p-values of CO_2 emission, prevalence of current tobacco, and unemployment did not improve while current health expenditure became significant with a p-value of 0.006. They were still insignificant. CO_2 emission, prevalence of current tobacco, and GDP per capita were all dropped one regression at a time. After dropping CO_2 emissions, the remaining variables were still significant. The final p-values for current health expenditure, death rate, GNI per capita, and fertility rate were 0.001 <0.001, <0.001, and 0.02, respectively. The model F-value improved and changed from 17.72 to 33.40 and the R^2 decreased from 0.81 to 0.78.

With the aforementioned information, the final regression model goes as follows:

$$\hat{y} = 83.11 + 0.619\,\mathbf{X_1} - 0.506\,\mathbf{X_2} + 0.00006466\,\mathbf{X_3}, - 3.694\,\mathbf{X_4}$$

Where:

- $\hat{y}$: Life expectancy (years)
- X_1: Current health expenditure as a percent of GDP (%)
- X_2: Death rate, crude per 1,000 people
- X_3: GNI per capita (U.S. $)
- X_4: Fertility rate, total (births per woman)

DISCUSSION

The bivariate analysis highlighted significant associations between life expectancy and current health expenditure, death rate, and GNI in European countries. However, it indicated a weak association with fertility rate. In the multivariate linear regression analysis, current health expenditure, death rate, GNI, and fertility rate emerged as significant contributors to life expectancy. These findings underscore the intricate interplay of health, policy, and economics on a national scale, offering valuable insights into global health policy trajectories.

Examining the relationship between health spending and life expectancy, our model aligns with existing literature that demonstrates a linear association between the two. [4,7,9,10] Specifically, a 1% increase in healthcare expenditure in 2018 corresponded to a 0.619-year rise in life expectancy, holding other variables constant. . Similarly, a positive association between life expectancy and GNI per capita was observed [9], although the contribution was relatively small (0.00006466 years per 1% increase). This suggests diminishing gains in life expectancy at higher income levels, a phenomenon noted in previous research. [9,11] These findings have implications for policymakers, emphasizing the role of economic development in societal improvement and increased life expectancy.[9]

Furthermore, the model revealed a negative relationship between fertility rate and life expectancy. A 3.69-year decrease in life expectancy occurred with an increase in the fertility rate, aligning with the inverse correlation observed in bivariate analysis. This negative association is consistent with the notion of a trade-off between fertility and lifespan proposed by evolutionary theories of aging. While evidence supporting this hypothesis is lacking for historical human populations, contemporary data indicate a potential trade-off, necessitating further exploration. [31]

The inverse relationship between death rate and life expectancy, where decreasing mortality or death rates correspond to increased life expectancy, is in line with established literature. The model indicated that a one-unit increase in death rate led to a 0.509-year decrease in life expectancy at birth. However, the complex nature of the mortality-life expectancy relationship, influenced by economic factors, healthcare systems, public health measures, social conditions, and lifestyle factors, emphasizes the need for comprehensive investigations.

CONCLUSION

This investigation elucidates critical determinants impacting life expectancy across European nations, delineating the complex interplay between health metrics, policy frameworks, and socio-economic variables. Through rigorous multivariate analyses, the study identified salient factors—namely, current health expenditure, death rate, Gross National Income (GNI), and fertility rate—that significantly influence life expectancy. These insights have profound implications for both public health strategies and economic policy formulation.

From a public health perspective, the research underscores the necessity of strategic investments in healthcare infrastructure. A demonstrable positive correlation between health expenditure and life expectancy accentuates the potential dividends of channeling resources towards enhancing healthcare facilities, preventive healthcare, and overall health promotion endeavors. This evidence empowers policymakers to devise health policies that not only elevate health outcomes but also extend life expectancy, thereby promoting a healthier populace. Furthermore, the inverse relationship observed between fertility rates and life expectancy underscores the imperative for robust family planning and reproductive health initiatives. Policies that facilitate family planning are pivotal, not merely for individual health but for ameliorating the collective health and longevity of the community. The insights gleaned from this study facilitate the crafting of targeted public health interventions and the informed execution of health policies.

On the economic front, the analysis reaffirms the significant role of economic prosperity in enhancing societal health metrics. Although a positive correlation exists between GNI per capita and life expectancy, the phenomenon of diminishing returns at elevated income levels necessitates a reevaluation of economic strategies. This finding prompts policymakers to extend their focus beyond mere income augmentation, advocating for holistic societal enhancements and equitable resource distribution to optimize life expectancy gains.

The outcomes of this study furnish policymakers with a nuanced framework to navigate the intricate nexus of health, policy, and economics. By acknowledging these interconnected domains, decision-makers are better equipped to implement precise interventions that not only foster increased life expectancy but also amplify the collective welfare of their constituencies. This research contributes a pivotal resource for shaping evidence-based policies that aim to cultivate healthier, more sustainable societies in Europe and potentially across the globe.

Appendix

Table 5: Variables definitions

Variable	Definition
	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.
Current health expenditure	Current expenditures on health per capita in current US dollars. Estimates of current health expenditures include healthcare goods and services consumed during each year.
Death rate	Crude death rate indicates the number of deaths per 1,000 midyear population.
Fertility rate	The total fertility rate represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children per age-specific fertility rates of the specified year.
GDP per capita	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for the depreciation of fabricated assets or for the depletion and degradation of natural resources. Data are in current U.S. dollars
GNI per capita	GNI per capita (formerly GNP per capita) is the gross national income, converted to U.S. dollars using the World Bank Atlas method, divided by the midyear population. GNI is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. GNI, calculated in national currency, is usually converted to U.S. dollars at official exchange rates for comparisons across economies, although an alternative rate is used when the official exchange rate is judged to diverge by an exceptionally large margin from the rate actually applied in international transactions.
Life expectancy at birth	Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.
Prevalence of tobacco usage	The percentage of the population ages 15 years and over who currently use any tobacco product (smoked and/or smokeless tobacco) on a daily or non-daily basis. Tobacco products include cigarettes, pipes, cigars, cigarillos, waterpipes (hookah, shisha), bidis, kretek, heated tobacco products, and all forms of smokeless (oral and nasal) tobacco. Tobacco products exclude e-cigarettes (which do not contain tobacco), "e-ci
Unemployment	Unemployment refers to the share of the labor force that is without work but available for and seeking employment. Definitions of labor force and unemployment differ by country.

Table 6: Countries list and data

Country	Life expectancy at birth, total (years)	Current health expenditure (% of GDP)	Death rate (per 1,000 people)	GNI per capita (US$)	Fertility rate (births per woman)	CO2 emissions (metric tons per capita)	Prevalence of current tobacco use (% of adults)	Unemployment (% of total labor force)	GDP per capita (US$)
Switzerland	83.8	11.4	7.9	82470.0	1.5	4.4	25.7	4.7	85216.6
Spain	83.4	9.0	9.1	29330.0	1.3	5.5	28.1	15.3	30379.7
Italy	83.3	8.7	10.5	33850.0	1.3	5.4	23.3	10.6	34622.2
Liechtenstein	83.0		7.2		1.6	3.7			175286.6
Iceland	82.9	8.4	6.4	67770.0	1.7	4.8	12.6	2.7	74452.2
Norway	82.8	10.0	7.7	80970.0	1.6	7.3	17.1	3.8	82792.8
France	82.7	11.2	9.1	41170.0	1.9	4.6	33.6	9.0	41557.9
Faroe Islands	82.6		7.7	62940.0	2.5				62576.8
Sweden	82.6	10.9	9.1	55700.0	1.8	3.5	24.8	6.4	54589.1
Luxembourg	82.3	5.3	7.1	79770.0	1.4	15.3	21.6	5.6	116786.5
Gibraltar	82.2		8.2		1.9				
Ireland	82.2	6.9	6.4	59350.0	1.8	7.7	21.4	5.7	79250.4
Greece	81.8	8.1	11.2	19080.0	1.4	6.1	34.5	19.3	19757.0
Netherlands	81.8	10.0	8.9	50540.0	1.6	8.8	22.6	3.8	53044.5

Austria	**81.7**	**10.3**	**9.5**	**48980.0**	**1.5**	**7.1**	**27.1**	**4.9**	**51466.6**
Finland	**81.7**	**9.0**	**9.9**	**48210.0**	**1.4**	**8.0**	**22.2**	**7.4**	**49987.6**
Belgium	**81.6**	**10.8**	**9.7**	**46060.0**	**1.6**	**8.2**	**23.9**	**6.0**	**47545.0**
Channel Islands	**81.4**		**8.7**		**1.4**			**6.9**	**62316.2**
Cyprus	**81.4**	**6.8**	**6.6**	**27410.0**	**1.3**	**5.9**	**35.5**	**8.4**	**29419.9**
Slovenia	**81.4**	**8.3**	**9.9**	**24650.0**	**1.6**	**6.8**	**22.3**	**5.1**	**26123.7**
Portugal	**81.3**	**9.4**	**11.0**	**22060.0**	**1.4**	**4.8**	**25.3**	**7.0**	**23562.6**
United Kingdom	**81.3**	**9.7**	**9.2**	**42180.0**	**1.7**	**5.4**	**16.1**	**4.0**	**43306.3**
Denmark	**81.0**	**10.1**	**9.5**	**61260.0**	**1.7**	**5.7**	**18.1**	**5.1**	**61591.9**
Germany	**80.9**	**11.5**	**11.5**	**47490.0**	**1.6**	**8.5**	**22.5**	**3.4**	**47939.3**
Isle of Man	**80.6**		**10.1**	**83460.0**	**1.6**				**89425.9**
Albania	**79.2**	**6.7**	**8.3**	**4860.0**	**1.4**	**1.9**	**23.0**	**12.3**	**5287.7**
Czechia	**79.0**	**7.5**	**10.6**	**20560.0**	**1.7**	**9.7**	**30.9**	**2.2**	**23424.5**
Kosovo	**78.7**		**5.5**	**4300.0**	**1.6**				**4384.2**
Estonia	**78.2**	**6.7**	**11.9**	**21180.0**	**1.7**	**11.9**	**30.5**	**5.4**	**23165.8**
Croatia	**78.1**	**6.8**	**12.9**	**14330.0**	**1.5**	**4.0**	**36.7**	**8.4**	**15003.1**
Poland	**77.6**	**6.3**	**10.9**	**14180.0**	**1.5**	**8.2**	**24.7**	**3.9**	**15504.5**
Turkey	**77.6**	**4.1**	**5.1**	**10470.0**	**2.1**	**5.0**	**30.9**	**10.9**	**9400.8**
Slovak Republic	**77.3**	**6.7**	**10.0**	**18400.0**	**1.5**	**6.1**	**31.5**	**6.5**	**19486.4**
Bosnia and Herzegovina	**77.1**	**8.9**	**12.1**	**5700.0**	**1.4**	**6.7**	**35.5**	**18.4**	**6024.5**
Montenegro	**76.8**	**8.3**	**10.5**	**8450.0**	**1.8**	**4.0**	**31.8**	**15.2**	**8850.4**
North Macedonia	**76.6**	**6.5**	**9.5**	**5500.0**	**1.4**	**3.3**		**21.2**	**6108.7**
Hungary	**76.1**	**6.6**	**13.4**	**14980.0**	**1.6**	**5.0**	**32.2**	**3.7**	**16425.2**
Serbia	**75.9**	**8.5**	**14.6**	**6410.0**	**1.5**	**6.6**	**40.1**	**12.7**	**7252.4**
Lithuania	**75.7**	**6.5**	**14.1**	**17470.0**	**1.6**	**4.2**	**32.3**	**6.2**	**19186.4**
Romania	**75.4**	**5.6**	**13.6**	**11520.0**	**1.8**	**3.9**	**28.4**	**4.2**	**12494.4**
Armenia	**75.1**	**10.0**	**9.8**	**4410.0**	**1.6**	**2.0**	**25.8**	**13.2**	**4391.9**
Bulgaria	**75.0**	**7.3**	**15.4**	**8540.0**	**1.6**	**5.8**	**39.4**	**5.2**	**9451.9**
Latvia	**74.8**	**6.2**	**15.0**	**16560.0**	**1.6**	**4.0**	**37.2**	**7.4**	**17865.0**
Belarus	**74.2**	**5.5**	**12.7**	**5730.0**	**1.4**	**6.3**	**30.9**	**4.8**	**6360.1**
Georgia	**73.3**	**7.1**	**13.0**	**4460.0**	**2.1**	**2.6**	**31.7**	**12.7**	**4722.0**
Azerbaijan	**72.8**	**3.6**	**5.8**	**4080.0**	**1.7**	**3.3**	**24.2**	**4.9**	**4739.8**
Russian Federation	**72.7**	**5.4**	**12.5**	**10250.0**	**1.6**	**11.5**	**27.1**	**4.9**	**11287.4**

Greenland	**71.9**		**8.7**		**2.0**				**54545.3**
Ukraine	**71.6**	**7.5**	**14.8**	**2750.0**	**1.3**	**4.2**	**26.2**	**8.8**	**3096.6**
Moldova	**70.5**	**6.6**	**13.3**	**3850.0**	**1.8**	**3.2**	**28.7**	**2.9**	**4157.0**
Andorra		**7.4**	**4.4**			**6.6**	**32.0**		**42904.8**
Monaco		**1.6**	**6.6**						**194287.1**
San Marino		**8.5**	**7.1**	**42250.0**					**48464.5**

Table 7: Full model summary and ANOVA

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	.901[a]	0.811	0.765	1.8055
a. Predictors: (Constant), GDP per capita (US$), Fertility rate (births per woman), Unemployment (% of total labor force), Current health expenditure (% of GDP), CO_2 emissions (metric tons per capita), Death rate (per 1,000 people), Prevalence of current tobacco use (% of adults), GNI per capita (US$)				

ANOVA[a]					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	462.124	8	57.765	17.719	<0.001[b]
Residual	107.58	33	3.26		
Total	569.704	41			
a. Dependent Variable: Life expectancy at birth, total (years)					
b. Predictors: (Constant), GDP per capita (US$), Fertility rate (births per woman), Unemployment (% of total labor force), Current health expenditure (% of GDP), CO_2 emissions (metric tons per capita), Death rate (per 1,000 people), Prevalence of current tobacco use (% of adults), GNI per capita (US$)					

Table 8: Full model summary and ANOVA

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	.882[a]	0.779	0.755	1.829
a. Predictors: (Constant), Fertility rate (births per woman), GNI per capita (US$), Death rate (per 1,000 people), Current health expenditure (% of GDP)				

ANOVA[a]					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	446.94	4	111.735	33.401	<0.001[b]
Residual	127.12	38	3.345		
Total	574.06	42			
a. Dependent Variable: Life expectancy at birth, total (years)					
b. Predictors: (Constant), Fertility rate (births per woman), GNI per capita (US$), Death rate (per 1,000 people), Current health expenditure (% of GDP)					

REFERENCES

Bai R, Wei J, An R, et al. Trends in Life Expectancy and Its Association with Economic Factors in the Belt and Road Countries-Evidence from 2000-2014. *Int J Environ Res Public Health*. 2018;15(12). doi:10.3390/ijerph15122890

Kinsella K. Changes in life expectancy 1900–1990. *Am J Clin Nutr*. 1992;55(6):1196S-1202S. doi:10.1093/ajcn/55.6.1196S

Bulled NL, Sosis R. Examining the Relationship between Life Expectancy, Reproduction, and Educational Attainment. *Human Nature*. 2010;21(3):269-289. doi:10.1007/s12110-010-9092-2

Miladinov G. Socioeconomic development and life expectancy relationship: evidence from the EU accession candidate countries. *Genus*. 2020;76(1):2. doi:10.1186/s41118-019-0071-0

Swift R. The relationship between health and GDP in OECD countries in the very long run. *Health Econ*. 2011;20(3):306-322. doi:10.1002/hec.1590

OECD. *Life Expectancy at Birth*.; 2017. doi:doi:https://doi.org/10.1787/health_glance-2017-6-en

Shafi R, Fatima S. Relationship between GDP, Life Expectancy and Growth Rate of G7 Countries. *Int J Sci*. 2019;8(06):74-79. doi:10.18483/ijSci.2085

Jaba E, Balan CB, Robu IB. The Relationship between Life Expectancy at Birth and Health Expenditures Estimated by a Cross-country and Time-series Analysis. *Procedia Economics and Finance*. 2014;15:108-114. doi:10.1016/S2212-5671(14)00454-7

Mondal MNI, Shitan M. Relative importance of demographic, socioeconomic and health factors on life expectancy in low-and lower-middle-income countries. *J Epidemiol*. 2014;24(2):117-124. doi:10.2188/jea.JE20130059

Life expectancy at birth. In: ; 2017:48-49. doi:10.1787/health_glance-2017-6-en

Kabir M. *Determinants of Life Expectancy in Developing Countries*. Vol 41.; 2008.

Crémieux PY, Ouellette P, Pilon C. Health care spending as determinants of health outcomes. *Health Econ*. 1999;8(7):627-639. doi:10.1002/(SICI)1099-1050(199911)8:7<627::AID-HEC474>3.0.CO;2-8

Subramanian S V., Belli P, Kawachi I. The Macroeconomic Determinants of Health. *Annu Rev Public Health*. 2002;23(1):287-302. doi:10.1146/annurev.publhealth.23.100901.140540

Hitiris T, Posnett J. The determinants and effects of health expenditure in developed countries. *J Health Econ*. 1992;11(2):173-181. doi:10.1016/0167-6296(92)90033-W

Cheng H, Luo W, Si S, et al. Global trends in total fertility rate and its relation to national wealth, life expectancy and female education. *BMC Public Health*. 2022;22(1):1346. doi:10.1186/s12889-022-13656-1

Mondal MNI, Shitan M. Relative importance of demographic, socioeconomic and health factors on life expectancy in low- and lower-middle-income countries. *J Epidemiol*. 2014;24(2):117-124. doi:10.2188/jea.je20130059

Das S, Debanth A. Impact of CO2 emission on life expectancy in India: an autoregressive distributive lag (ARDL) bound test approach. *Future Business Journal*. 2023;9(1):5. doi:10.1186/s43093-022-00179-9

Rasoulinezhad E, Taghizadeh-Hesary F, Taghizadeh-Hesary F. How Is Mortality Affected by Fossil Fuel Consumption, CO2 Emissions and Economic Factors in CIS Region? *Energies (Basel)*. 2020;13(9):2255. doi:10.3390/en13092255

Martins F, Felgueiras C, Smitkova M, Caetano N. Analysis of Fossil Fuel Energy Consumption and Environmental Impacts in European Countries. *Energies (Basel)*. 2019;12(6):964. doi:10.3390/en12060964

MURTHY U, SHAARI MS, MARIADAS PA, ABIDIN NZ. The Relationships between CO2 Emissions, Economic Growth and Life Expectancy. *Journal of Asian Finance, Economics and Business*. 2021;8(2):801-808. doi:10.13106/jafeb.2021.vol8.no2.0801

Amuka JI, Asogwa FO, Ugwuanyi RO, Omeje AN, Onyechi T. International Journal of Economics and Financial Issues Climate change and Life Expectancy in a Developing Country: Evidence from Greenhouse Gas (CO 2) Emission in Nigeria. *International Journal of Economics and Financial Issues*. 2018;8(4):113-119.
http:www.econjournals.com

Arltová M, Langhamrová J, Langhamrová J. Development of life expectancy in the Czech Republic in years 1920-2010 with an outlook to 2050. *Prague Economic Papers*. 2013;(1):125-143. doi:10.18267/j.pep.444

Awe O, Ayeni O, Sanusi G, Oderinde L. A comparative time series analysis of crude mortality rate in the BRICS countries. *BRICS Journal of Economics*. 2021;2(2):17-32. doi:10.38050/2712-7508-2021-2-2

Cutler D, Deaton A, Lleras-Muney A. *The Determinants of Mortality*.

Chetty R, Stepner M, Abraham S, et al. The association between income and life expectancy in the United States, 2001-2014. *JAMA - Journal of the American Medical Association*. 2016;315(16):1750-1766. doi:10.1001/jama.2016.4226

Aburto JM, Villavicencio F, Basellini U, Kjærgaard S, Vaupel JW. Dynamics of life expectancy and life span equality. *Proceedings of the National Academy of Sciences*. 2020;117(10):5250-5259. doi:10.1073/pnas.1915884117

Preston SH. The Changing Relation between Mortality and Level of Economic Development. *Popul Stud (NY)*. 1975;29(2):231. doi:10.2307/2173509

Brønnum-Hansen H, Juel K. Abstention from smoking extends life and compresses morbidity: a population based study of health expectancy among smokers and never smokers in Denmark. *Tob Control*. 2001;10:273-278. doi:10.1136/tc.10.3.273

World Bank. World Development Indicators. https://databank.worldbank.org/Popular-Indicators/id/1ff4a498.

Aiken LS, West SG, Pitts SC. Multiple Linear Regression. In: *Handbook of Psychology*. Wiley; 2003:481-507. doi:10.1002/0471264385.wei0219

Kuningas M, Altmäe S, Uitterlinden AG, Hofman A, van Duijn CM, Tiemeier H. The relationship between fertility and lifespan in humans. *Age (Dordr)*. 2011;33(4):615-622. doi:10.1007/s11357-010-9202-4