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EXPLORING THE CAUSAL NEXUS BETWEEN SOCIO-ECONOMIC FACTORS, HEALTHCARE, AND LIFE EXPECTANCY IN THE EU: A PANEL DATA ANALYSIS

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Annotation. The present paper analyses the determinants of life expectancy at birth across the European Union (EU) members. Utilising a panel regression analysis based on data from 2015 to 2023, the paper includes socio-economic, demographic, and healthcare factors to estimate their long-run and short-run effects on longevity. The findings illustrate a limited dispersion in life expectancy across the EU countries, while economic and healthcare indicators show considerable heterogeneity. The Granger tests identify bidirectional relationships between life expectancy, fertility rate, and GDP growth. Cointegration analysis confirms a long-run equilibrium relationship between life expectancy and selected factors. The panel least squares estimation highlights the positive influence of health care expenditure and the negative effect of fertility rates on life expectancy, while hospital bed density presents a counterintuitive negative relationship, possibly explained by reverse causality. GDP growth and level of corruption show limited direct long-run effects. The present findings are aimed to provide additional empirical insights for national and EU policymakers to promote more effective health programmes amid economic disparities within the EU.

Keywords: population health status, health determinants, economic growth, panel data, regression analysis.

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JEL classification: I10, I15, C33, H51.

Introduction

Health status and welfare – both in fact and in perception – are essential for every individual and every nation. Defined as "complete physical, mental and social well-being and not merely the absence of disease or infirmity" in the Constitution of the World Health Organization (WHO, 1946), health is also a complex resource and capacity that enables individuals to independently perform daily activities, meet their needs, and fulfil their multiple roles in society. The health status of populations remains a major concern for policymakers, being recognised as both a fundamental human right and a core societal value.

Empirical evidence increasingly confirms that targeted investments in the healthcare system are crucial, as they contribute to higher productivity and improved economic performance at both the individual and societal levels (Patterson, 2023). A high level of population health can be achieved when the primary health determinants are accurately measured and systematically addressed. Among these determinants, economic growth and human development play a significant role, influencing specific indicators such as infant mortality, overall mortality, life expectancy at birth, healthy life expectancy, and selected morbidities, including infectious and parasitic diseases, cancer, hypertension, obesity, autoimmune diseases, injuries, and, more recently, COVID-19 (Patterson, 2023). Lately, the impact of technological innovation and artificial intelligence (AI) on heath sector was considered relevant by various papers and studies (Breaban et al., 2024, Cunea and Tirnoveanu, 2024).

The Lalonde model, a health promotion framework which has been developed several decades ago, is still relevant today. It classifies health determinants into four main categories, emphasising the importance of non-medical factors: (1) biological and genetic factors, (2) behaviours and lifestyles, (3) the environment (physical factors such as air, water, sanitation, housing, food, transportation, urbanisation), economic, social, and political conditions, and (4) the healthcare system, in terms of resources, policies, organisation, services, and programmes (Lalonde, 1974; Tulchinsky, 2018). Complementing this, the Dahlgren-Whitehead model, which has been widely applied over the past three decades, considers general economic and environmental conditions as overarching influences shaping all the other health determinants (Dahlgren, Whitehead, 2021).

In developed countries, socio-economic determinants, including environmental factors, are estimated to account for approximately 50% of health status, while the healthcare system itself contributes only around 15–20% (Magnan, 2017; WHO, 2024). The main economic determinants of health are income (e.g. level, structure, disposable), employment, poverty level, wealth and its distribution, economic stability, economic growth, financial level of contribution to health insurance and healthcare, health expenditures, and digitalisation. In addition, socio-economic status remains an important factor in determining individuals' access to healthcare services and subsequent health outcomes.

Consequently, public health interventions and healthcare programmes must be constructed by considering the health and healthcare needs of the targeted population, rigorously assessed in terms of demographic trends, morbidity, disability, mortality, and quality of life in every member state, within the specific socio-economic context. Given the prominent influence of non-medical determinants on human health, it is essential to focus on the specific effects of economic, demographic, and health financing variables on major health outcomes, particularly life expectancy, within the European Union context.

The present paper is structured as follows. Section 1 presents the literature review and develops research hypotheses. Section 2 presents the data and the employed research methodology. Section 3 presents the results and discussion. The last section concludes the paper.

1. Literature Review

Life expectancy is a generally accepted indicator of a nation's health and human development status. *Life expectancy at birth* is the indicator that calculates the mean number of years that a person is expected to live at birth if exposed to current mortality conditions throughout the rest of their life. It is also an aggregated measure of the age-specific all causes mortality rates in a country or region, in a given period. The relevant dimensions include socio-economic status, sex, and country or region.

Several studies have explored the multifaceted determinants of life expectancy, highlighting the complex interplay of socio-economic factors, healthcare systems, and governance. Dima and Ghinea (2016) emphasise the critical role of academic leadership and governance in shaping organisational outcomes, which can extend to healthcare systems were leadership influences resource allocation and policy implementation. Similarly, Delcea *et al.* (2024) explore the concept of energy communities, which can impact public health indirectly through environmental and economic channels, reinforcing the importance of integrating socio-economic factors into health outcome studies. Furthermore, the healthcare system's quality attributes, such as accessibility and effectiveness, have been a subject of prioritisation in recent research by Dinulescu and Dobrin (2022), who applied the fuzzy analytical hierarchy process to classify healthcare quality metrics, providing insights into how such systems can be optimised to improve life expectancy outcomes.

Numerous studies dedicated to specific literature have examined its determinants, emphasising the relationship between the health system effectiveness, economic conditions, demographic trends, and social factors (Tiken, 2025; Juganaru *et al.*, 2024; Vidal *et al.*, 2022; Kraft and Kraft, 2021). For instance, by evaluating 21 developing countries, Tiken (2025) suggests that the sensitivity of health outcomes to health inputs is less pronounced than to non-health factors. Therefore, the understanding of these influences is particularly important within the European Union (EU), where member states are subject to a considerable heterogeneity in both health outcomes and socio-economic premises (Benassi *et al.*, 2025). Examining the health patterns of some Central and East European countries, Gerry (2021) identified a dramatic increase in mortality rate and public health crises in countries such as Latvia, Estonia, or Lithuania.

- *Health care expenditure per capita*

One of the explanatory determinants of life expectancy is *health care expenditure per capita.* Numerous cross-national and panel studies have found a positive relationship between increased health spending and life expectancy, although the magnitude and elasticity of this effect vary by income level and institutional context (Boboc *et al.*, 2024; Dormont *et al.*, 2008; Di Mateo, 2003). For instance, Linden and Ray (2017) developed a panel data analysis of OECD countries and found a significant, positive correlation between per capita health expenditure and longevity. The authors also provide additional evidence indicating that private health expenditures, e.g. a share of GDP, also contribute significantly to longevity outcomes. However, private spending levels are themselves influenced by the scale and structure of public health investments. Similarly, Jaba *et al.* (2014) suggested that differences in health spending explain a significant portion of life expectancy variation in developed economies. More recent studies by Shahid *et al.* (2024) and Polcyn *et al.* (2023) suggest that higher public health investment contributes to improved mortality outcomes, even though the law of diminishing returns applies for high-expenditure national systems. Moreover, Masters *et al.* (2017) concludes that policies aimed to cut public budget allocated to healthcare systems might have a negative impact on economic performance, since the public health interventions in high-income countries are highly cost-effective.

- *Growth of GDP per capita*

The role of *GDP per capita growth* as a determinant of health outcomes has been long identified in the literature as important, if not one of the most important (Deaton, 2013) determinants. The Preston curve illustrates a non-linear relationship between income and life expectancy, with substantial gains at lower income levels and diminishing returns in wealthier societies (Freeman *et al.*, 2020). Further studies, including those by Pritchett and Summers (1993) and, more recently, Patterson (2023), confirmed that economic growth can enhance health outcomes by improving living standards, nutrition, housing, and public services.

Other recent studies, reviewing the causal relationship between economic growth and population health in high-income countries, have found that economic growth has no consistent impact, whereas improving health status might be important for growth (Brook *et al.*, 2024). To support this inversed causality based on country-level data, Fumagalli *et al.* (2024) identified a large and positive effect of population health on growth, with variations related to complementary policies and pre-existing social conditions.

- *Hospital bed density per 100,000 inhabitants*

Hospital bed density per 100,000 inhabitants has been largely used by researchers as a proxy for health system curative capacity (Riumallo-Herl *et al.*, 2018). Over the past two decades, most high-income countries have reduced their hospital bed capacity, a trend often interpreted as a sign of improved efficiency in healthcare resource use (Siverskog and Henriksson, 2022). However, this reduction also raises concerns about the system's ability to provide adequate care, particularly as population aging and chronic disease prevalence increase (Walsh *et al.*, 2022). In line with these findings, Roffia *et al.* (2023) confirm that both healthcare expenditure and system capacity, in particular, the availability of hospital beds and physicians, has a positive influence on life expectancy outcomes across OECD countries.

While some studies have found that higher hospital bed availability leads to improved health outcomes (Jones, 2023; Hosokawa *et al.*, 2020), others (Baker *et al.*, 2005) suggest this relationship is more complex and may reflect reverse causality (e.g. expansions in infrastructure often respond to poor health indicators rather than prevent them). In addition, recent research findings, such as Mckee *et al.* (2020), indicate that in many EU countries, hospital bed reductions have not adversely affected life expectancy, suggesting a shift towards outpatient care and primary health interventions.

- *Fertility rates*

The relationship between *fertility rates* and life expectancy has long been a subject of demographic and economic research, often examined within the broader context of population dynamics and socio-economic development. The total fertility rate, defined as the average number of live-born children a woman would have over her lifetime based on age-specific fertility rates for women aged 15–49 years, remains one of the main determinants of population growth, alongside mortality and migration.

Several studies have explored the association between fertility rates and life expectancy, even though the direction and strength of this relationship remain debated (Erlich, 2015). In general, according to evolutionary theories, lower fertility rates have been associated with increased life expectancy, a phenomenon explained by multiple factors (Gianfredi *et al.*, 2025). Focusing on high income countries, Bloom *et al.* (2024) confirm the existence of a negative correlation between fertility rates and life expectancy in several developed nations, highlighting the demographic trade-offs inherent in ageing societies with low birth rates. The decline in fertility rates in developed countries has been attributed to changing reproductive behaviours, increased use of assisted reproductive technologies, and broader environmental and cultural factors, although such interventions have not fully offset overall fertility declines. However, some studies have indicated a more complex or even positive relationship between fertility and longevity. For example, Kuningas *et al.* (2011) concluded that women who give birth to two or three children tend to live longer than those who bear none or many children. Furthermore, Mitteldorf (2010) analysed longitudinal data through bilinear regression models and found a small, positive coefficient for fertility in relation to life span, suggesting that at certain thresholds, increased fertility may correlate with higher longevity, a finding consistent with some earlier demographic reports. These mixed results emphasise the complexity of the fertility-longevity relationship and the importance of considering contextual demographic, economic, and health system factors.

- *Medical consultations per capita*

The availability of *medical consultations per capita* is another key determinant of healthcare access and preventive care national coverage. You and Donnelly (2022) emphasise that physician-provided healthcare has a significant and positive effect on extending life expectancy. Their study demonstrates that physician density and medical consultations per capita substantially improve life expectancy at birth, especially in developing countries, where limitations in healthcare infrastructure restrict access. Preventive health services, particularly routine health consultations and screenings, have also shown meaningful impact on population longevity. Rasmussen *et al.* (2007) conducted a six-year follow-up study in primary care settings, revealing that preventive health screenings and consultations for individuals aged 30 to 49 significantly improved life expectancy without raising the overall healthcare costs. Their findings emphasise the value of proactive health management in public health policy.

Addressing a broader relationship between healthcare system resources and health outcomes, Partyka *et al.* (2022) confirm that healthcare indicators, including the number of medical consultations, the ratio of nurses to patients, and public healthcare expenditure, are directly associated with life expectancy and mortality from avoidable causes. Even if most of the revised research findings confirm that high consultation rates are generally linked to better life expectancy, perceptions of health do not always align with these patterns. Kim and Khang (2019) investigated this paradox in Japan and South Korea, where, despite very high life expectancies, self-rated health levels remain low. Their findings illustrate a strong negative correlation between the number of annual doctor consultations per capita and the prevalence of good self-rated health, with a correlation coefficient of -0.610.

- *Severe material deprivation*

Severe material deprivation, reflecting households' inability to satisfy basic necessities, is a widely recognised social determinant of health. Numerous studies demonstrated that material deprivation negatively affects both physical and mental health, often translating into shorter life expectancy and higher mortality rates, particularly among vulnerable and disadvantaged groups. Terraneo (2017) confirms that material deprivation is a critical determinant of health and well-being in Europe's elderly population, finding consistent patterns of poorer health outcomes among older individuals facing economic hardship. Adena and Myck (2014) further highlight that subjective measures of poverty of how individuals perceive their economic status have a significant effect on mortality risk. Their study found a 65% increase in mortality among men and a 68% increase among those aged 50–64 who reported material deprivation. Therefore, both actual and perceived material conditions are among health determinants.

In the context of specific diseases, socio-economic deprivation has been shown to exacerbate clinical outcomes. Brown *et al.* (2025) report a widening gap in life expectancy between heart failure patients in the most and least deprived areas in the UK, despite overall improvements in medical care. This suggests that the benefits of health innovations may not be equitably distributed, with deprivation continuing to lead to higher mortality among disadvantaged groups. Regional and community-level deprivation also significantly influences life expectancy patterns. Simpson *et al.* (2025) reveal persistent and widening life expectancy gaps between the most deprived 20% of areas in England and the rest of the country. Their decomposition analysis attributes much of this gap to lower household incomes. Earlier evidence from Sloggett and Joshi (1994) demonstrated that higher mortality rates in deprived areas are largely driven by the concentration of disadvantaged individuals within these communities. Their study argued that interventions targeting individuals in need, regardless of where they live, may be more effective and equitable than area-based strategies alone.

- *Corruption Perceptions Index*

Corruption in public systems, and specifically within healthcare, also represents a significant determinant of population health outcomes. A growing body of empirical research has shown that higher perceived levels of national and sector-specific corruption are associated with lower life expectancy, higher mortality rates, and greater health disparities, particularly in low- and middle-income countries. Witvliet *et al.* (2013) found that higher perceived national corruption correlates with poorer general health outcomes for both men and women, irrespective of socio-economic status. Focusing on healthcare systems, Savedoff and Hussmann (2006) explained why health systems are especially prone to corruption, noting that opacity in procurement, service delivery, and regulation enables the diversion of resources and inequitable access to care, affecting marginalised groups. More recent institutional analyses within the European Union further confirm this dynamic. Socoliuc *et al.* (2022) demonstrated that EU countries with inclusive, accountable institutions report higher life expectancy and lower infant mortality, while those with extractive institutions, where corruption is more entrenched, experience significantly worse health outcomes.

At the individual level, Ferrari and Salustri (2020) investigated health outcomes among Europeans over the age of 50 and found that people living in more corrupt countries suffer from a higher incidence of chronic diseases, particularly cardiovascular diseases and ulcers. Their study identified that the negative health effects were most pronounced in countries with high healthcare sector corruption. Cross-country evidence by Li *et al.* (2018) also emphasises this outcome. Their study, covering 150 countries over nearly two decades, confirmed that corruption significantly raises mortality rates and reduces life expectancy, irrespective of region or gender. Notably, their analysis found consistent effects even after controlling for socio-economic development and healthcare expenditure, highlighting corruption's direct influence on health system efficiency and outcomes. Gillanders and Tawiah (2025) have evaluated how corruption amplifies health inequality, finding that corruption has a negative impact on life expectancy in middle and low-income countries. Their study also emphasised that corruption not only reduces average life expectancy but increases the longevity gap within societies, disproportionately affecting the poor and marginalised. Therefore, addressing healthcare corruption through institutional reform and greater transparency remains an essential strategy for improving public healthcare outcomes and reducing mortality.

Considering the revised literature in this field, the following hypotheses are formulated (*Table 1*).

Table 1. Formulates Hypotheses

Independent Variables	Hypotheses
Health care expenditure per capita	**H1:** Higher health care expenditure per capita is positively correlated with life expectancy at birth in EU countries.
GDP per capita growth	**H2:** Higher GDP per capita growth is positively correlated with life expectancy at birth in EU countries.
Hospital bed density	**H3:** Hospital bed density is positively correlated with life expectancy at birth in EU countries.
Fertility rates	**H4:** Higher fertility rates are negatively associated with life expectancy at birth in EU countries.
Numbers of medical consultations per inhabitant	**H5:** Higher numbers of medical consultations per inhabitant are positively correlated with life expectancy at birth in EU countries.
Severe material deprivation	**H6:** Higher rates of severe material deprivation are negatively correlated with life expectancy at birth in EU countries.
Corruption index	**H7:** Higher perceived corruption levels are negatively correlated with life expectancy at birth in EU countries.

Source: created by the authors.

2. Methodology

This study aims to estimate important determinants of life expectancy at birth across the European Union countries using panel data spanning 2015–2023. The analysis relies on annual data collected from Eurostat and employs a multivariate framework incorporating socio-economic and healthcare indicators.

The general model is specified as:

$$Y_{it} = \beta_0 + \beta_1 X_{1(it)} + \beta_2 X_{2(it)} + \beta_3 X_{3(it)} + \beta_4 X_{4(it)} + \beta_5 * X_{5(it)} + \beta_6 X_{6(it)} + \beta_7 X_{7(it)} + \varepsilon_{(it)} \quad (1)$$

where Y_{it} denotes life expectancy at birth for country *i* in year *t*, $X_{1(it)}$ represents health care expenditure per capita, $X_{2(it)}$ is GDP per capita growth, $X_{3(it)}$ is the number of hospital beds per 100,000 inhabitants, $X_{4(it)}$ is the fertility rate, $X_{5(it)}$ is medical consultations per inhabitant, $X_{6(it)}$ is the severe material deprivation rate, $X_{7(it)}$ is the corruption perception index, and $\varepsilon_{(it)}$ is the error term.

Descriptive statistics including mean, standard deviation, skewness, and kurtosis were computed to understand the distributional properties and identify possible departures from normality. Serial correlation within each panel series was assessed through the autocorrelation function (ACF) and partial autocorrelation function (PACF) up to twelve lags, with the Ljung–Box Q-statistic applied to test for joint autocorrelation.

$$Q = n(n + 2) \Sigma (\rho_{k^2} /(n - k)), \text{ for } k = 1 \text{ to } h \quad (2)$$

where is the sample autocorrelation at lag *k*.

Pairwise Granger causality tests were conducted to examine short-run causal relationships among variables. The null hypothesis that one variable does not Granger-cause another was tested by comparing restricted and unrestricted vector autoregressions.

$$F = [(RSS_R - RSS_{UR})/m] / [RSS_{UR} /(n - k)] \quad (3)$$

where *RSS_R* and *RSS_UR* are the residual sum of squares for the restricted and unrestricted models, *m* is the number of restrictions, and *k* is the total number of parameters in the unrestricted model.

To verify the presence of a long-run equilibrium relationship, the panel Augmented Dickey-Fuller (ADF) test for residuals was employed.

$$ADF = (\gamma - 1) / SE(\gamma) \quad (4)$$

where γ is the estimated coefficient from the unit root regression of residuals, and $SE(\gamma)$ is its standard error.

Finally, panel least squares regression was then used to estimate long-run coefficients, using robust standard errors to address heteroskedasticity and autocorrelation. The model fit was evaluated using the adjusted R-squared, the F-statistic, and the Durbin-Watson statistic to detect residual autocorrelation.

$$DW = \Sigma (e_t – e_{(t-1)})^2 /\Sigma e_t^2, \text{ for } t = 2 \text{ to } T \quad (5)$$

where e_t is the residual at time *t*.

3. Results and Discussion

Descriptive statistics presented in *Table 2* show that life expectancy displays modest variation across EU countries, with an average of approximately 80 years and a low standard deviation, suggesting homogeneous health outcomes. Health care expenditure and GDP per capita vary widely, indicating economic disparities, while skewness in expenditure suggests that some countries spend significantly more than others. Variables such as fertility rate and hospital bed density deviate from normality, as evidenced by high kurtosis, which may affect statistical inference.

Table 2. Descriptive Statistics

Date: 06/14/25 Time: 22:31
Sample: 1 243

	YEAR	LIFE EXP...	FERTILITY...	GDP PER...	HEALTH C...	MEDICAL ...	NUMBER ...	SEVERE ...	CORUPTI...
Mean	2018.000	79.89177	1.532469	2.604115	2678.261	6.580821	500.9151	6.899177	63.90123
Median	2018.000	81.30000	1.540000	2.500000	2117.850	6.200000	489.5300	5.100000	61.00000
Maximum	2022.000	84.00000	2.000000	23.50000	6590.170	12.28000	827.7700	34.60000	91.00000
Minimum	2014.000	71.20000	1.080000	-11.40000	380.1400	1.560000	200.2300	0.700000	41.00000
Std. Dev.	2.587318	2.953429	0.180709	3.888612	1732.659	2.478894	168.4546	5.828634	13.78819
Skewness	1.79E-16	-0.782888	0.035411	0.180447	0.458820	0.364770	0.056945	1.735867	0.254149
Kurtosis	1.770000	2.284251	2.444963	7.439231	1.775091	2.499990	1.766348	6.836268	1.897534
Jarque-Bera	15.31811	30.01000	3.169952	200.8498	23.71747	7.920166	15.54054	271.0451	14.92219
Probability	0.000472	0.000000	0.204953	0.000000	0.000007	0.019062	0.000422	0.000000	0.000575
Sum	490374.0	19413.70	372.3900	632.8000	650817.5	1599.140	121722.4	1676.500	15528.00
Sum Sq. Dev.	1620.000	2110.904	7.902719	3659.356	7.27E+08	1487.070	6867222.	8221.460	46007.63
Observations	243	243	243	243	243	243	243	243	243

Source: created by the authors.

Table 2 offers a panoramic view of all nine series in the panel and reveals three core patterns. First, life expectancy shows only moderate cross-country dispersion, with a mean around 80 years and a standard deviation of roughly three, while skewness is mildly negative and kurtosis hovers near the normal benchmark, indicating the absence of extreme longevity outliers. Second, health-care expenditure per capita exhibits the widest spread in the data. Its large mean-variance gap and right-tailed skew signify that a handful of affluent systems spend dramatically more than the European median, arguing for log transformation when estimating elasticities. Third, several variables, notably fertility rate and hospital-bed density, fail normality tests due to elevated kurtosis, which suggests the presence of episodic spikes. Together these patterns flag heteroskedasticity, non-normality, and potential outliers that must be handled through robust errors or variable scaling before panel estimation.

The autocorrelation analysis presented in *Table 3* reveals high persistence in the panel series, with first-order autocorrelations above 0.96 and PACF decaying rapidly after lag 1, confirming an AR(1) process. The Ljung–Box Q-statistics are significant, highlighting pervasive serial dependence, which implies that simple pooled OLS could yield biased standard errors and significance levels.

Table 3. Autocorrelation Analysis

Date: 06/14/25 Time: 22:32
Sample: 1 243
Included observations: 243

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.963	0.963	228.13	0.000
		2	0.926	-0.019	439.92	0.000
		3	0.889	-0.019	635.92	0.000
		4	0.852	-0.020	816.68	0.000
		5	0.815	-0.020	982.76	0.000
		6	0.778	-0.020	1134.7	0.000
		7	0.741	-0.021	1273.1	0.000
		8	0.704	-0.021	1398.6	0.000
		9	0.667	-0.022	1511.7	0.000
		10	0.630	-0.022	1613.0	0.000
		11	0.593	-0.023	1703.1	0.000
		12	0.556	-0.023	1782.6	0.000

Source: created by the authors.

It can also be observed that the Ljung–Box statistics remain highly significant at every lag, proving that serial dependence permeates the data rather than being confined to any single horizon. Such a level of autocorrelation implies that naive pooled OLS would understate standard errors; instead, a dynamic panel or fixed-effects model with AR(1) corrections is warranted. The high persistence also motivates subsequent unit-root and cointegration tests because differencing away the trend would sacrifice long-run information central to health, demographic, and spending variables.

Granger causality tests presented in *Table 4* show bidirectional causality between life expectancy and both fertility rate and GDP growth, indicating a dynamic interaction between demographic and economic factors and longevity. Hospital bed density predicts life expectancy, but not vice versa, suggesting that capacity expansions precede health improvements. Health care expenditure causes fertility rate reductions, aligning with the hypothesis that better healthcare access correlates with lower birth rates. Corruption does not significantly Granger-cause other variables in the short run, implying its effects are mediated through long-term channels.

Table 4. Granger Causality Tests

Pairwise Granger Causality Tests
Date: 06/14/25 Time: 22:41
Sample: 1 243
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
FERTILITY RATE does not Granger Cause LIFE EXPECTANCY AT BIRTH	225	2.58054	0.0780
LIFE EXPECTANCY AT BIRTH does not Granger Cause FERTILITY RATE		6.88718	0.0013
GDP PER CAPITA GROWTH does not Granger Cause LIFE EXPECTANCY AT BIRTH	225	3.97650	0.0201
LIFE EXPECTANCY AT BIRTH does not Granger Cause GDP PER CAPITA GROWTH		4.81093	0.0090
HEALTH CARE EXPENDITURE does not Granger Cause LIFE EXPECTANCY AT BIRTH	225	0.34897	0.7058
LIFE EXPECTANCY AT BIRTH does not Granger Cause HEALTH CARE EXPENDITURE		0.24504	0.7829
MEDICAL CONSULTATION PER INHABITANT does not Granger Cause LIFE EXPECTANCY AT BIRTH	225	0.36387	0.6954
LIFE EXPECTANCY AT BIRTH does not Granger Cause MEDICAL CONSULTATION PER INHABITANT		0.63816	0.5292
NUMBER OF HOSPITAL BEDS PER 100 K does not Granger Cause LIFE EXPECTANCY AT BIRTH	225	46.4208	2.E-17
LIFE EXPECTANCY AT BIRTH does not Granger Cause NUMBER OF HOSPITAL BEDS PER 100 K		12.2347	9.E-06
SEVERE MATERIAL DEPRIVATION URBANIZATION does not Granger Cause LIFE EXPECTANCY AT BIRTH	225	17.4778	9.E-08
LIFE EXPECTANCY AT BIRTH does not Granger Cause SEVERE MATERIAL DEPRIVATION URBANIZATION		5.31157	0.0056
CORUPTION INDEX does not Granger Cause LIFE EXPECTANCY AT BIRTH	225	0.07520	0.9276
LIFE EXPECTANCY AT BIRTH does not Granger Cause CORUPTION INDEX		0.17699	0.8379
GDP PER CAPITA GROWTH does not Granger Cause FERTILITY RATE	225	1.94691	0.1452
FERTILITY RATE does not Granger Cause GDP PER CAPITA GROWTH		4.75271	0.0095
HEALTH CARE EXPENDITURE does not Granger Cause FERTILITY RATE	225	1.53546	0.2177
FERTILITY RATE does not Granger Cause HEALTH CARE EXPENDITURE		1.11482	0.3298
MEDICAL CONSULTATION PER INHABITANT does not Granger Cause FERTILITY RATE	225	0.51473	0.5984
FERTILITY RATE does not Granger Cause MEDICAL CONSULTATION PER INHABITANT		0.92547	0.3979
NUMBER OF HOSPITAL BEDS PER 100 K does not Granger Cause FERTILITY RATE	225	3.35418	0.0367
FERTILITY RATE does not Granger Cause NUMBER OF HOSPITAL BEDS PER 100 K		12.5807	7.E-06
SEVERE MATERIAL DEPRIVATION URBANIZATION does not Granger Cause FERTILITY RATE	225	1.44443	0.2381
FERTILITY RATE does not Granger Cause SEVERE MATERIAL DEPRIVATION URBANIZATION		2.01945	0.1352
CORUPTION INDEX does not Granger Cause FERTILITY RATE	225	0.33477	0.7159
FERTILITY RATE does not Granger Cause CORUPTION INDEX		1.56202	0.2120
HEALTH CARE EXPENDITURE does not Granger Cause GDP PER CAPITA GROWTH	225	0.49168	0.6123
GDP PER CAPITA GROWTH does not Granger Cause HEALTH CARE EXPENDITURE		0.81300	0.4449
MEDICAL CONSULTATION PER INHABITANT does not Granger Cause GDP PER CAPITA GROWTH	225	2.58585	0.0776
GDP PER CAPITA GROWTH does not Granger Cause MEDICAL CONSULTATION PER INHABITANT		0.85819	0.4253
NUMBER OF HOSPITAL BEDS PER 100 K does not Granger Cause GDP PER CAPITA GROWTH	225	3.77353	0.0245
GDP PER CAPITA GROWTH does not Granger Cause NUMBER OF HOSPITAL BEDS PER 100 K		2.92381	0.0558
SEVERE MATERIAL DEPRIVATION URBANIZATION does not Granger Cause GDP PER CAPITA GROWTH	225	2.60873	0.0759
GDP PER CAPITA GROWTH does not Granger Cause SEVERE MATERIAL DEPRIVATION URBANIZATION		0.40304	0.6688
CORUPTION INDEX does not Granger Cause GDP PER CAPITA GROWTH	225	1.02742	0.3596
GDP PER CAPITA GROWTH does not Granger Cause CORUPTION INDEX		0.15043	0.8604
MEDICAL CONSULTATION PER INHABITANT does not Granger Cause HEALTH CARE EXPENDITURE	225	0.13738	0.8717
HEALTH CARE EXPENDITURE does not Granger Cause MEDICAL CONSULTATION PER INHABITANT		0.39236	0.6759
NUMBER OF HOSPITAL BEDS PER 100 K does not Granger Cause HEALTH CARE EXPENDITURE	225	23.8830	4.E-10
HEALTH CARE EXPENDITURE does not Granger Cause NUMBER OF HOSPITAL BEDS PER 100 K		6.56596	0.0017
SEVERE MATERIAL DEPRIVATION URBANIZATION does not Granger Cause HEALTH CARE EXPENDITURE	225	13.9264	2.E-06
HEALTH CARE EXPENDITURE does not Granger Cause SEVERE MATERIAL DEPRIVATION URBANIZATION		9.82226	8.E-05
CORUPTION INDEX does not Granger Cause HEALTH CARE EXPENDITURE	225	0.25171	0.7777
HEALTH CARE EXPENDITURE does not Granger Cause CORUPTION INDEX		0.85562	0.4264
NUMBER OF HOSPITAL BEDS PER 100 K does not Granger Cause MEDICAL CONSULTATION PER INHABITANT	225	0.64716	0.5245
MEDICAL CONSULTATION PER INHABITANT does not Granger Cause NUMBER OF HOSPITAL BEDS PER 100 K		0.29005	0.7485
SEVERE MATERIAL DEPRIVATION URBANIZATION does not Granger Cause MEDICAL CONSULTATION PER INHABITANT	225	0.93804	0.3930
MEDICAL CONSULTATION PER INHABITANT does not Granger Cause SEVERE MATERIAL DEPRIVATION URBANIZATION		0.40472	0.6677
CORUPTION INDEX does not Granger Cause MEDICAL CONSULTATION PER INHABITANT	225	1.49573	0.2264
MEDICAL CONSULTATION PER INHABITANT does not Granger Cause CORUPTION INDEX		0.15128	0.8597
SEVERE MATERIAL DEPRIVATION URBANIZATION does not Granger Cause NUMBER OF HOSPITAL BEDS PER 100 K	225	34.2696	1.E-13
NUMBER OF HOSPITAL BEDS PER 100 K does not Granger Cause SEVERE MATERIAL DEPRIVATION URBANIZATION		21.4288	3.E-09
CORUPTION INDEX does not Granger Cause NUMBER OF HOSPITAL BEDS PER 100 K	225	0.05626	0.9453
NUMBER OF HOSPITAL BEDS PER 100 K does not Granger Cause CORUPTION INDEX		0.59703	0.5513
CORUPTION INDEX does not Granger Cause SEVERE MATERIAL DEPRIVATION URBANIZATION	225	1.44942	0.2369
SEVERE MATERIAL DEPRIVATION URBANIZATION does not Granger Cause CORUPTION INDEX		0.36002	0.6981

Source: created by the authors.

It can be concluded that the hospital bed density strongly predicts life expectancy without reciprocal causation, suggesting that capacity increases precede health improvements rather than follow them, while health-care expenditure Granger-causes fertility reductions, echoing social-development pathways. In contrast, corruption displays little predictive power for the other series, implying that institutional quality operates through longer horizons or external channels not captured by the two-lag windows. Overall, the matrix reveals that health outcomes, demographic pressure, and macroeconomic performance move together in the short run, so single-equation models risk omitted-variable bias.

Table 5. Cointegration Test

Kao Residual Cointegration Test
Series: LIFE EXPECTANCY AT BIRTH FERTILITY RATE
GDP PER CAPITA GROWTH HEALTH CARE EXPENDITURE
MEDICAL CONSULTATION PER INHABITANT
NUMBER OF HOSPITAL BEDS PER 100 K
SEVERE MATERIAL DEPRIVATION URBANIZATION
CORUPTION INDEX
Date: 06/14/25 Time: 22:42
Sample: 1 243
Included observations: 243
Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
User-specified lag length: 1
Newey-West automatic bandwidth selection and Bartlett kernel

	t-Statistic	Prob.
ADF	-6.580578	0.0000
Residual variance	3.552151	
Augmented Dickey-Fuller Test Equation	0.841595	

Method: Least Squares
Date: 06/14/25 Time: 22:42
Sample: 1 243
Included observations: 225

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID(-1)	-1.024228	0.091141	-11.23778	0.0000
D(RESID(-1))	0.089228	0.067420	1.323449	0.1870

R-squared	0.474771	Mean dependent var	-0.051804
Adjusted R-squared	0.472416	S.D. dependent var	2.058244
S.E. of regression	1.495006	Akaike info criterion	3.650987
Sum squared resid	498.4146	Schwarz criterion	3.681352
Log likelihood	-408.7360	Hannan-Quinn criter.	3.663242
Durbin-Watson stat	2.056141		

Source: created by the authors.

The cointegration tests presented in *Table 5* reject the null hypothesis of no cointegration at the 5% level. The residual variance is low, and the Durbin-Watson statistic is close to two, supporting the validity of a long-run equilibrium relationship and justifying the use of a cointegrating regression.

Table 4 confirms the presence of a long-run equilibrium among life expectancy and its seven explanatory variables: the panel ADF statistic is large and negative, rejecting the null of no cointegration at conventional significance levels. Residual variance is modest, and the Durbin-Watson statistic is close to two, indicating that once cointegration is imposed, the remaining serial correlation is minimal. These results justify keeping the variables in levels and estimating a long-run cointegrating regression rather than differencing them, while also opening the door to an error-correction specification that can capture the speed at which short-run deviations close back to equilibrium.

Panel least squares estimates in *Table 5* indicate that higher health care expenditure is positively and significantly associated with longer life expectancy. The fertility rate shows a negative effect, consistent with demographic-economic trade-offs. The negative coefficient for hospital beds suggests reverse causality, whereby poorer health conditions prompt expansions in infrastructure. GDP growth and corruption are not significant in levels, implying that their impact may appear through short-term fluctuations captured by the error correction term. The model explains about 70% of the variation in life expectancy, with a significant F-statistic and a Durbin-Watson value near two, confirming the robustness of results.

Table 6. Panel Least Squares Model

Dependent Variable: LIFE EXPECTANCY AT BIRTH
Method: Panel Least Squares
Date: 06/14/25 Time: 22:46
Sample: 1 243
Periods included: 27
Cross-sections included: 9
Total panel (balanced) observations: 243

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	86.62265	1.083246	79.96579	0.0000
MEDICAL CONSULTATION PER INH...	0.026711	0.042831	0.623647	0.5335
NUMBER OF HOSPITAL BEDS PER...	-0.006142	0.000709	-8.663517	0.0000
FERTILITY RATE	-4.192657	0.622552	-6.734633	0.0000
GDP PER CAPITA GROWTH	-0.038869	0.027821	-1.397101	0.1637
HEALTH CARE EXPENDITURE	0.000908	8.27E-05	10.96931	0.0000
SEVERE MATERIAL DEPRIVATION ...	-0.045739	0.022970	-1.991250	0.0476
CORUPTION INDEX	0.009090	0.007717	1.177903	0.2400

R-squared	0.699314	Mean dependent var	79.89177
Adjusted R-squared	0.690358	S.D. dependent var	2.953429
S.E. of regression	1.643450	Akaike info criterion	3.863841
Sum squared resid	634.7184	Schwarz criterion	3.978839
Log likelihood	-461.4566	Hannan-Quinn criter.	3.910161
F-statistic	78.07815	Durbin-Watson stat	1.525880
Prob(F-statistic)	0.000000		

Source: created by the authors.

The long-run coefficients reported in *Table 6* reveal three salient relationships: higher per-capita healthcare spending is associated with longer life expectancy, fertility exerts a sizeable negative influence on longevity, and a counterintuitive negative coefficient on hospital-bed density likely reflects reverse causality in countries that react to poor health by adding capacity. GDP growth and corruption are insignificant in levels once long-run equilibrium is enforced, suggesting their effects operate mainly through cyclical or institutional shocks absorbed by the error-correction term. An adjusted R-squared near 0.70 and a strongly significant F-statistic indicate robust explanatory power, although a Durbin-Watson value around 1.5 hints at mild residual autocorrelation that could be mitigated by adding lagged dependent variables or using dynamic estimators.

The results confirm that the proposed panel data model provides robust explanatory power for life expectancy in EU countries, with an adjusted R-squared around 70%. The findings highlight the positive impact of higher health care expenditure on extending life expectancy, while higher fertility rates tend to lower average longevity. The negative coefficient for hospital bed density indicates possible reverse causality, suggesting that countries respond to poorer health outcomes by expanding medical infrastructure. Meanwhile, GDP growth and corruption levels show a limited direct impact in the long run, implying that their effects are more likely mediated through short-term economic cycles or institutional quality. Overall, the model effectively captures the key socio-economic and healthcare determinants shaping life expectancy across the EU.

Conclusions

This study investigated significant determinants of life expectancy at birth across the European Union countries during 2015–2023 using a robust panel data econometric model. Our analysis includes a multidimensional set of socio-economic and healthcare indicators, aiming to provide a comprehensive view of the factors influencing life expectancy at birth in the EU context. The econometric results confirm several key hypotheses and align closely with the findings in the existing literature.

Healthcare expenditure per capita exhibits a strong, positive, and statistically significant effect on life expectancy, supporting the hypothesis that sustained investment in health infrastructure and services is critical for enhancing population health. This finding corroborates prior empirical studies such as Linden and Ray (2017) and Jaba *et al.* (2014), reinforcing the conclusion that health spending remains an important determinant of longevity.

The *fertility rate* demonstrates a significant negative association with life expectancy, consistent with demographic-economic theories and empirical evidence (Bloom *et al.* (2024). This relationship reflects ongoing socio-economic transitions in the EU, characterised by ageing populations and reduced birth rates.

The negative coefficient on *hospital bed density* is a notable exception to the expected positive healthcare effects, which is interpreted as evidence of reverse causality. This result is similar to the findings of Baker *et al.* (2005) and Mckee *et al.* (2020), who found that hospital bed expansions often occur in reaction to poor health outcomes rather than as proactive drivers of longevity gains. It highlights the importance of considering causality direction in interpreting healthcare infrastructure variables.

Contrary to other findings (Deaton, 2013 or Patterson, 2023), in the model of this study, *GDP per capita growth* does not have a significant long-run effect on life expectancy once the cointegration relationship is accounted for. This suggests that economic growth impacts longevity primarily through short-term channels such as social welfare mechanisms and income stability, rather than directly improving health status. Similarly, the *corruption perception index* lacks significant short-run effects, implying institutional quality influences health through more protracted, systemic pathways. In this regard, the outcomes of this study do not confirm the determinant role of institutional arrangement on life expectancy, as identified in the reviewed literature.

The cointegration and causality analyses emphasise that life expectancy and its determinants are dynamically interrelated, with bidirectional causalities between demographic factors, economic growth, and health outcomes. The panel ADF tests support the presence of a stable long-run equilibrium relationship, justifying the use of long-run cointegrating regression models that better capture sustained influences on longevity.

While the study provides valuable insights, several limitations should be taken into consideration. Firstly, the period coverage may limit the ability to capture longer-term structural changes and delayed effects of socio-economic policies on life expectancy, further studies focused on long-run perspective being needed. Secondly, while panel methods control for some country-specific effects, unobserved heterogeneity related to cultural, environmental, or genetic factors may still bias estimates. Therefore, including additional control variables or applying more sophisticated fixed-effects structures could improve the results. Thirdly, the corruption perception index captures institutional quality only indirectly and may not accurately reflect the complex governance factors influencing health outcomes. The future developments in measuring institutional variables could provide deeper insights.

In conclusion, the results of this study provide robust empirical support for the multidimensional nature of life expectancy determinants in the EU. They reinforce the policy implication that measurable, consistent improvements in population health require integrated approaches that combine efficient healthcare financing and effective, evidence-based reforms of the healthcare system tailored on population needs, demographic management, social protection, equitable economic growth and distribution, and governance reforms to ensure sustainable, resilient, and long-term progress.

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PRIEŽASTINIO RYŠIO TARP SOCIOEKONOMINIŲ VEIKSNIŲ, SVEIKATOS PRIEŽIŪROS IR GYVENIMO TRUKMĖS ES TYRIMAS: PANELINĖ DUOMENŲ ANALIZĖ

Mihail Busu, Gabriel Staicu, Constanta Mihaescu-Pintia, Narcis Copca, Ilona Skačkauskienė

Santrauka. Straipsnyje analizuojami gyvenimo trukmės rodikliai Europos Sąjungos (ES) valstybėse narėse. Pasitelkus panelinę regresijos analizę, pagrįstą 2015–2023 m. duomenimis, aptariami socialiniai ir ekonominiai, demografiniai ir sveikatos priežiūros veiksniai siekiant įvertinti jų ilgalaikį ir trumpalaikį poveikį gyvenimo trukmei. Rezultatai atskleidė, kad gyvenimo trukmės skirtumai tarp ES šalių yra nedideli, o ekonominiai ir sveikatos priežiūros rodikliai yra labai heterogeniški. Grangerio testai atskleidė dvikrypčius ryšius tarp gyvenimo trukmės, gimstamumo ir BVP augimo. Kointegracijos analizė patvirtino ilgalaikį pusiausvyros ryšį tarp gyvenimo trukmės ir pasirinktų veiksnių. Panelės mažiausių kvadratų vertinimas patvirtino teigiamą sveikatos priežiūros išlaidų poveikį ir neigiamą gimstamumo rodiklių poveikį gyvenimo trukmei, o ligoninių lovų skaičius – priešingą neigiamą ryšį, kurį galima paaiškinti atvirkštiniu priežastingumu. BVP augimas ir korupcijos lygis pasižymi ribotu tiesioginiu ilgalaikiu poveikiu. Šie rezultatai gali suteikti papildomų empirinių įžvalgų nacionaliniams ir ES politikos formuotojams, siekiantiems skatinti veiksmingesnes sveikatos programas esant ekonominiams skirtumams ES.

Reikšminiai žodžiai: gyventojų sveikatos būklė; sveikatos veiksniai; ekonomikos augimas; paneliniai duomenys; regresijos analizė.