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THE TRIPLE DIVIDEND OF HEALTH: HOW SDG3 SHAPES HUMAN, ECONOMIC, AND ENVIRONMENTAL OUTCOMES IN EU

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Abstract. Achieving the Sustainable Development Goals (SDGs) requires understanding how progress in health and well-being (SDG3) impacts human development, economic performance, and environmental sustainability. This study analyses the effects of selected SDG3 indicators on Human Development Index (HDI), Gross Domestic Product (GDP per capita), and renewable energy usage across 27 EU countries (2014–2023), using three panel models with relevant control variables. Applying panel unit root, cointegration tests, and Fully Modified OLS (FMOLS) estimation, results show that better health and well-being significantly promote human development, economic output, and renewable energy adoption. In Model 1, life expectancy and well-being positively influence HDI, while fertility, neonatal mortality, and traffic deaths have negative effects; income inequality mildly reduces HDI. Model 2 finds that subjective well-being and lower tuberculosis incidence boost GDP, though health effects are smaller than on HDI. Model 3 links lower teen fertility and neonatal mortality to higher renewable energy use, suggesting synergy between health progress and clean energy transition. Overall, advancing SDG3 fosters human development, economic prosperity, and environmental sustainability, highlighting the need for integrated policies that simultaneously promote health, equality, education, and clean energy.

Keywords: SDG3, human development index, economic growth, renewable energy, health indicators, panel FMOLS, EU-27, sustainable development, cointegration, triple dividend.

JEL Classification: C58, I15, I31, O44.

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1. Introduction

The implementation of the Sustainable Development Goals (SDGs) has increasingly highlighted the complex interdependencies between social, economic, and environmental dimensions of development. Rather than evolving independently, these dimensions interact in ways that can generate both synergies and trade-offs, making integrated policy design essential. In this context, Sustainable Development Goal 3 (SDG3), focused on health and well-being, occupies a central position, as improvements in population health have the potential to influence a wide range of development outcomes beyond the health sector itself.

Yet, despite growing recognition of these interlinkages, empirical evidence on how health simultaneously affects human development, economic performance, and environmental sustainability remains limited, particularly in the case of highly integrated and institutionally complex regions such as the European Union (European Commission, Directorate-General for Economic and Financial Affairs, 2024).

The European Union and the United Nations have cooperated extensively to advance human rights, global health, environmental protection, and sustainable development within a rules-based multilateral system (United Nations, 2015; European Union, 2018; United Nations, 2021a).

Sustainable development remains a central EU policy objective, implemented as a shared responsibility across national, regional, and local levels (European Commission, 2019a). Ensuring citizens' health and well-being is fundamental to a prosperous Europe (European Union, 2017), while the successful implementation of the 2030 Agenda requires coordinated policies involving all EU institutions and stakeholders (European Commission, 2020).

Given their strongly interlinked nature, the Sustainable Development Goals cannot be addressed in isolation (Pradhan et al., 2017). Sustainable Development Goal 3 (SDG3), "Ensure healthy lives and promote well-being for all at all ages," provides the global framework with thirteen targets and twenty-eight indicators (United Nations, 2018; United Nations, 2021b). The EU has adapted these indicators to its specific policy priorities and monitors progress annually through Eurostat, aligning SDG3 with key initiatives such as the European Pillar of Social Rights, the 8th Environment Action Programme, and the European Green Deal (European Commission, 2017, 2019b; Eurostat, 2017, 2022).This study investigates how improvements in health and well-being under SDG3 influence human development (Human Development Index – HDI), economic performance (GDP per capita), and environmental sustainability (renewable energy consumption) across all 27 EU member states from 2014 to 2023. Employing three panel data models with relevant macroeconomic and environmental controls, the analysis uses panel unit root tests, cointegration tests, and Fully Modified OLS (FMOLS) estimation to identify robust long-run relationships (Manta el al., 2025a).

The paper contributes to the literature by adopting an integrated approach that simultaneously examines the interconnections between SDG3 indicators and three core outcomes (HDI, GDP per capita, and renewable energy), rather than analysing these linkages in isolation. It applies FMOLS on a balanced panel of 27 EU countries, offering reliable estimates of long-run dynamics while addressing non-stationarity and endogeneity. By covering the period marked by the sovereign debt crisis, the COVID-19 pandemic, and persistent East-West asymmetries, the study highlights how health investments can generate a triple dividend: advancing human development, economic prosperity, and the clean energy transition. The remainder of the paper is organised as follows: Section 2 reviews the relevant literature and develops the research hypotheses. Section 3 describes the data and econometric methodology. Section 4 presents the empirical results, Section 5 discusses the findings, and Section 6 concludes with policy implications, limitations, and avenues for future research.

2. Literature review and hypothesis development

Health serves as both a core dimension of human development and a driver of economic growth and environmental sustainability. This review organises existing evidence around three thematic models: (1) health and human development (HDI), (2) health and economic growth (GDP per capita), and (3) renewable energy, health, and sustainability linkages.

2.1. Human development and health outcomes

Health is a foundational pillar of human development, directly reflected in the Human Development Index (HDI) through the life expectancy component. Investments in health, education, and social protection enhance HDI by increasing longevity, educational attainment, and reducing inequality (Miranda-Lescano et al., 2024). Governance quality plays a mediating role, as weak institutions may limit the developmental impact of health spending (Banik et al., 2023). In the EU context, cohesion policies and SDG3-targeted interventions have contributed to reducing regional disparities and strengthening human development (Pîrvu et al., 2018; Ionescu et al., 2020; Bădîrcea et al., 2025). Maternal and child health improvements correlate strongly with higher HDI levels (Say et al., 2014), while strong universal health coverage and strategies such as Europe 2020 link health gains to productivity and inclusive growth (European Commission, 2020; Eurostat, 2022; United Nations Development Programme [UNDP], 2015).

Recent studies document declines in mortality rates and disability-adjusted life years in the EU between 2010 and 2019, alongside rising life expectancy (Santos et al., 2024). Comparative analyses of SDG3 indicators reveal persistent disparities across member states, particularly in obesity, preventable mortality, and air quality (Gavurova & Megyesiova, 2022). Investments in health access and efficiency are consistently associated with reduced inequalities and higher HDI (Bucher, 2018; Opreana & Mihaiu, 2011; Dumuid et al., 2018).

Overall, the literature confirms that improvements in population health, especially higher life expectancy and lower disease burdens, contribute positively to HDI, particularly in regions with universal coverage and effective institutions such as the EU. These findings support the inclusion of SDG3 indicators as key explanatory variables in the HDI model.

Synthesising these findings, health emerges as a structural driver of human development through both direct effects on life expectancy and indirect effects on labour productivity, social inclusion, and inequality reduction. In the EU context, where universal coverage and relatively strong institutions are the norm, the magnitude of this relationship is shaped by governance quality, efficiency of health expenditures, and persistent regional disparities. These insights strongly justify the inclusion of multiple SDG3 indicators as key explanatory variables in the HDI model and support the examination of their long-run effects on human development dynamics.

Hypothesis H1: Improvements in health and well-being indicators significantly affect HDI growth across EU countries.

2.2. Economic growth and health indicators

Health drives economic performance by enhancing labour productivity, human capital accumulation, and workforce participation. Higher life expectancy and better healthcare access are positively associated with GDP per capita in industrialised economies (Neofytidou & Fountas, 2020; Bădîrcea et al., 2020; Meghișan-Toma et al., 2022; Sharma, 2018; Bloom et al., 2019).

Public health expenditures generally support growth, although efficiency and institutional quality are critical (Beylik et al., 2022; Asongu et al., 2017). In the EU, a virtuous cycle exists whereby economic growth funds health infrastructure, while targeted health interventions sustain productivity (OECD & European Union, 2020; Weil, 2014). Recent panel analyses show positive short-run effects of health spending on GDP per capita, with outcomes depending on income levels and resource allocation efficiency (Kuzior et al., 2025; Sosvilla-Rivero et al., 2025; Celik et al., 2023). In advanced economies, the relationship is nuanced by demographic structures and ageing. Emerging technologies such as artificial intelligence, robotic automation and smart agriculture are increasingly seen as complementary factors that can further enhance the productivity gains associated with better health outcomes (Manta et al., 2023; Poenaru et al., 2025; Gherțescu et al., 2025).

In summary, health acts as a structural determinant of economic growth through human capital channels. This justifies the inclusion of health and well-being indicators in the LOG_GDP model.

The literature suggests that health functions as a structural determinant of economic growth through its effects on labour productivity and human capital. While short-run gains from increased health spending are well-documented, long-term outcomes depend heavily on the efficiency of resource allocation, institutional quality, and demographic context. In the European Union, characterised by relatively advanced health systems and integrated economic frameworks, health indicators appear to operate as important structural factors rather than merely cyclical ones. This body of evidence justifies the inclusion of health and well-being indicators as key explanatory variables in the LOG_GDP model.

Hypothesis H2: Health and well-being indicators significantly influence GDP per capita growth across EU countries.

2.3. Renewable energy, health, and sustainability

Renewable energy adoption delivers important co-benefits for climate mitigation and public health by reducing air pollution and associated respiratory and cardiovascular risks (Rivera et al., 2024; Millstein et al., 2024; Pachauri et al., 2018). In the EU, increased renewable electricity generation correlates with improved air quality and lower mortality rates (European Environment Agency, 2021a, 2021b, 2023b; Karlsson et al., 2020; Sasse & Trutnevyte, 2024). Institutional support, including EU cohesion funds and the European Green Deal, further amplifies these synergies (Bădîrcea et al., 2022; Manta et al., 2025a, 2025b).

Beyond the direct benefits of reduced air pollution, renewable energy deployment also contributes to long-term population health by limiting climate-related disease risks and stabilising energy supply for healthcare infrastructure (Pervaiz et al., 2021; European Environment Agency, 2023a). Although much of the quantitative evidence on these co-benefits originates from Asian countries, where large-scale renewable expansion has been shown to significantly reduce air pollution and associated health burdens (Xie et al., 2020), similar mechanisms are observable in the European context (European Environment Agency, 2025a). Consistent with these findings, Metwally et al. (2024) demonstrate that in Nordic countries, hydroelectricity exerts a negative short-term but positive long-term effect on the Human Development Index, confirming the strategic contribution of renewable energy to sustainable economic growth and human well-being. Moreover, recent research highlights that FinTech and artificial intelligence in European banks can act as a double-edged sword, potentially accelerating the financing of renewable energy projects while also introducing new risks and complexities in the green transition (Siminică et al., 2025; European Environment Agency, 2025b).

The transition to renewables is thus both an environmental and a public health imperative, generating long-term co-benefits for well-being, economic resilience, and social inclusion (European Parliament, 2017, 2020). These co-benefits justify the inclusion of renewable energy indicators in the LOG_REN model, aimed at capturing their long-term effects on health outcomes and environmental sustainability across EU countries.

Hypothesis H3: Expanding renewable energy sources improves population health and reduces environmental pressures, enhancing sustainability outcomes in EU countries.

3. Materials and methods

The empirical analysis is based on annual balanced panel data for all 27 European Union member states over the period 2014–2023. Data were obtained from internationally recognised sources, including the United Nations Development Programme (UNDP), Eurostat, the Sustainable Development Report, and the World Health Organization. These databases ensure high consistency and comparability across countries and time. The study examines the interlinkages between health and well-being (SDG3) and three key sustainable development outcomes: human development, economic performance, and environmental sustainability. The health dimension is captured through selected SDG3 indicators: fertility rate, life expectancy at birth, neonatal mortality rate, subjective well-being, tuberculosis incidence, and road traffic mortality. Economic and environmental controls include the Gini coefficient (income inequality), HICP (inflation), and air emissions. A detailed description of all variables, their measurement units, and data sources is provided in Table 1. The conceptual relationships among the variables are illustrated in Figure 1.

Table 1. Description of variables (source: author's own calculation)

Variable	Description	Unit of Measurement	Source
HDI	Human Development Index (life expectancy, education, income composite index)	Index (0–1 scale)	United Nations Development Programme (UNDP) (United Nations, 2015)
LOG_GDP	Logarithm of GDP per capita (economic performance)	Natural log of USD per capita (constant prices)	Eurostat (Eurostat, 2024b)
LOG_REN	Logarithm of renewable energy consumption as % of total energy	Natural log of percentage (%)	Eurostat (Eurostat, 2024e)
LOG_GINI	Logarithm of Gini coefficient (income inequality measure)	Natural log of Gini index (0–100 scale)	Eurostat (Eurostat, 2024c)
HICP	Harmonized Index of Consumer Prices (inflation measure)	Index (2015 = 100)	Eurostat (Eurostat, 2024d)
LOGAIR_EMIS	Logarithm of air pollutants and greenhouse gases	Natural log of tons CO_2-equivalent per capita	Eurostat (Eurostat, 2024a)
LOG_SDG3_ FERTILITY	Logarithm of fertility rate (births per woman)	Natural log of births per woman	Sustainable Development Report (Sachs et al., 2024)
LOG_SDG3_LIFE	Logarithm of life expectancy at birth	Natural log of years	Sustainable Development Report (Sachs et al., 2024)
SDG3_NEONAT	Neonatal mortality rate (infant deaths within 28 days per 1,000 live births)	Deaths per 1,000 live births	Sustainable Development Report (Sachs et al., 2024)

End of Table 1

Variable	Description	Unit of Measurement	Source
SDG3_SWB	Subjective well-being (self-reported life satisfaction)	Index score (scale 0–10)	Sustainable Development Report (Sachs et al., 2024)
SDG3_TB	Tuberculosis incidence (number of new cases per 100,000 population)	Cases per 100,000 population	Sustainable Development Report (Sachs et al., 2024)
SDG3_TRAFFIC	Road traffic mortality (deaths caused by traffic accidents per 100,000 inhabitants)	Deaths per 100,000 population	Sustainable Development Report (Sachs et al., 2024)

To estimate the long-run relationships, the study applies the Fully Modified Ordinary Least Squares (FMOLS) estimator proposed by Pedroni (2000, 2001). FMOLS is well-suited for cointegrated heterogeneous panels as it corrects for endogeneity and serial correlation, yielding unbiased and consistent long-run estimates. Prior to estimation, stationarity was tested using panel unit root tests: Levin-Lin-Chu (LLC) (Levin et al., 2002), Im-Pesaran-Shin (IPS) (Im et al., 2003), and Fisher-type Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Panel cointegration was subsequently examined with the Kao residual cointegration test and the Johansen Fisher-type panel cointegration test. FMOLS estimations were performed only after confirming the presence of long-run cointegrating relationships. Building on the framework of He and Richard (2010), three econometric models were specified.

The models were constructed following a parsimonious approach. In particular, life expectancy was retained as the single demographic-health variable in the GDP model, as including both life expectancy and the old-age dependency ratio generated severe multicollinearity without adding substantial explanatory power. This choice is consistent with European ageing diagnostics, which identify increased longevity as the primary driver of dependency pressures (European Commission, 2024; European Central Bank, 2024).

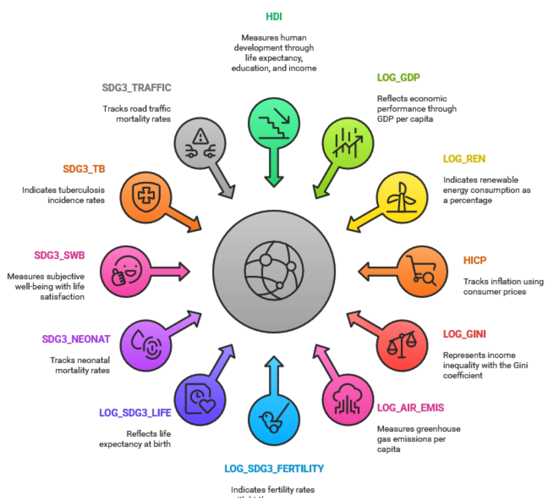

Figure 1. Variable description (source: author's own calculation)

Building on the framework proposed by He and Richard (2010), the following three econometric models were specified:

Model 1: Human Development (HDI):

$$HDI_{it} = \alpha_i + \beta_1 LOG_{SDG3_{FERTILITY_{it}}} + \beta_2 LOG\_SDG3_{LIFE_{it}} + \beta_3 SDG3_{NEONAT_{it}} + \beta_4 SDG3_{SWB_{it}} + \beta_5 SDG3_{TB_{it}} + \beta_6 SDG3_{TRAFFIC_{it}} + \beta_7 LOG_{GINI_{it}} + \varepsilon_{it}. \quad (1)$$

Model 2: Economic Growth (LOG_GDP):

$$LOG\_GDP_{it} = \alpha_i + \beta_1 HICP_{it} + \beta_2 LOG_{SDG3_{FERTILITY_{it}}} + \beta_3 LOG\_SDG3_{LIFE_{it}} + \beta_4 SDG3_{NEONAT_{it}} + \beta_5 SDG3_{SWB_{it}} + \beta_6 SDG3_{TB_{it}} + \beta_7 SDG3_{TRAFFIC_{it}} + \varepsilon_{it}. \quad (2)$$

Model 3: Renewable Energy (LOG_REN):

$$LOG_{REN_{it}} = \alpha_i + \beta_1 LOG_{SDG3_{FERTILITY_{it}}} + \beta_2 LOG\_SDG3_{LIFE_{it}} + \beta_3 SDG3_{NEONAT_{it}} + \beta_4 SDG3_{SWB_{it}} + \beta_5 SDG3_{TB_{it}} + \beta_6 SDG3_{TRAFFIC_{it}} + \beta_7 LOGAIR_{EMIS_{it}} + \varepsilon_{it}. \quad (3)$$

All models include country-specific fixed effects to account for unobserved heterogeneity. Diagnostic tests confirmed the absence of severe multicollinearity (all VIF values < 5). As a complementary analysis, Dumitrescu and Hurlin (2012) Granger causality tests were applied to investigate the direction of causal relationships between the variables. The three models follow a coherent theoretical logic.

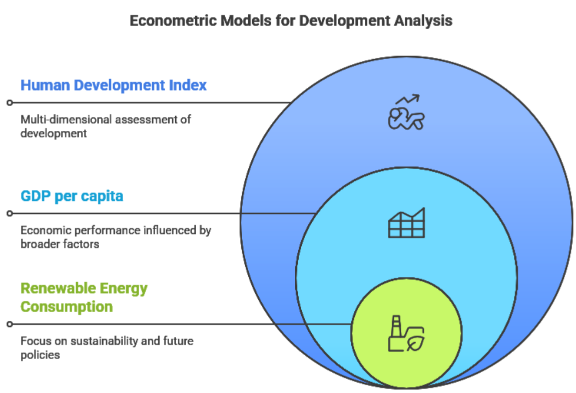

Figure 2. The three proposed econometric models (source: author's own calculation)

The construction of the three econometric models follows a coherent logic grounded in development theory (Figure 2):

- The first model, with HDI (Human Development Index) as the dependent variable, seeks to elucidate the social, demographic, and environmental determinants of human development beyond mere economic metrics. This model is particularly innovative, reflecting the current paradigm shift towards multi-dimensional development assessments.
- The second model, with GDP per capita as the dependent variable, examines how traditional economic performance responds not only to structural economic factors but also to health, well-being, and environmental conditions. This perspective challenges

the conventional unidirectional view of growth driving development, proposing instead a more circular causality.

- The third model, centered on renewable energy consumption (REN) as the dependent variable, captures the emergent reality that sustainability transitions are integral to development trajectories. Understanding the social and economic determinants of renewable energy adoption is fundamental for designing effective, future-oriented EU policies.

Together, these three models form comprehensive analytical architecture capable of capturing the complexity of development processes in the European Union. Their interconnectedness reflects the inherently multi-dimensional nature of real-world socio-economic systems, where growth, welfare, and environmental quality evolve not in isolation, but through dynamic mutual reinforcement.

3. Results

This section presents the empirical findings in a comprehensive and detailed manner. It first provides an overview of the main macroeconomic, social and environmental trends observed in the 27 EU member states between 2014 and 2023. This is followed by descriptive statistics, correlation and multicollinearity diagnostics, residual tests, panel unit root tests, cointegration analysis, the Fully Modified OLS (FMOLS) long-run estimates, and finally the Granger causality results.

The decade 2014–2023 was marked by persistent structural divergences between Western developed economies and Eastern emerging member states. *Western countries* (Germany, France, the Netherlands, Sweden, Denmark) consistently recorded higher GDP per capita, greater macroeconomic stability, elevated levels of subjective well-being, faster adoption of renewable energy, and more substantial reductions in air pollutant and greenhouse gas emissions. These favourable outcomes were supported by early and sustained investments in green technologies, strong regulatory frameworks, advanced health systems, and well-established social protection mechanisms. These countries also benefited from higher institutional quality and more consistent implementation of EU environmental and health policies.

In contrast, *Eastern member states* (Romania, Bulgaria, Croatia, Poland, Hungary) experienced higher relative GDP growth rates, reflecting ongoing processes of structural transformation and economic convergence. Despite these positive dynamics, Eastern countries continued to exhibit relatively higher income inequality, greater dependence on traditional fossil fuel-based energy sources, and slower progress in the renewable energy transition. Inflation patterns were broadly synchronized across the EU until 2021, after which Eastern member states faced sharper price increases, largely attributable to weaker monetary buffers and higher exposure to energy price volatility. Gini coefficients showed a modest decline at the Union level, yet remained significantly elevated in several Eastern economies, pointing to persistent challenges in reducing social disparities and achieving inclusive growth.

Health indicators improved noticeably across the entire EU during the period. Neonatal mortality rates and tuberculosis incidence declined in all member states, although Western countries achieved very low levels considerably earlier than their Eastern counterparts. Life expectancy suffered a more pronounced decline in Eastern Europe during the COVID-19 pandemic and recovered at a slower pace, underscoring important differences in health system resilience and preparedness. Evidence from systematic reviews shows that the pandemic also adversely affected maternal and perinatal outcomes, with greater impacts in regions with more strained healthcare systems (Chmielewska et al., 2021).

Subjective well-being scores exhibited a general upward trend, but substantial gaps persisted, with Nordic countries maintaining markedly higher levels than Southern and Eastern member states. Fertility rates declined steadily throughout the Union, with a steeper reduction observed in Eastern Europe. This demographic shift raises long-term concerns regarding population ageing, future labour supply, pension sustainability, and potential pressures on public finances. Environmental performance also showed divergent patterns: reductions in air emissions and greenhouse gases were considerably more pronounced in Western countries, whereas several Eastern member states with stronger industrial and coal-dependent structures faced greater difficulties in meeting EU air quality and climate targets.

Descriptive statistics for the variables included in the three econometric models are summarised in Table 2. The mean values of the series lie within a moderate range, suggesting a relatively balanced evolution over the ten-year period. However, the variables display substantial cross-sectional and time-series heterogeneity in terms of standard deviation, skewness, and kurtosis. Jarque-Bera tests strongly reject the null hypothesis of normality for several health-related variables (particularly fertility, neonatal mortality, and tuberculosis incidence), while variables such as LOG_REN, SDG3_SWB, and LOGAIR_EMIS show distributions closer to normal. This heterogeneity is expected in a panel dataset that combines highly developed and catching-up economies and does not compromise the robustness of the FMOLS estimations.

Table 2. Descriptive statistics for the three models (source: author's own calculation)

Model	Main Variables	Mean	Median	Standard Deviation	Skewness	Kurtosis	Jarque-Bera p-value
Model 1: HDI	HDI, LOG_GINI, LOG_SDG3_FERTILITY, LOG_SDG3_LIFE, etc.	0.89 – 12.33	0.89 – 7.30	0.03 – 13.88	(–0.88) – 2.87	2.35 – 11.92	0.000 – 0.56
Model 2: LOG_GDP	LOG_GDP, LOG_SDG3_FERTILITY, LOG_SDG3_LIFE, etc.	2.02 – 12.33	1.97 – 7.30	0.03 – 13.88	(–0.88) – 2.87	2.35 – 11.92	0.000 – 0.18
Model 3: LOG_REN	LOG_REN, LOG_SDG3_FERTILITY, LOG_SDG3_LIFE, etc.	2.02 – 17.50	1.97 – 17.56	0.03 – 13.88	(–0.88) – 2.87	2.35 – 11.92	0.000 – 0.33

Correlation analysis (Table 3) reveals several strong and statistically significant associations ($p < 0.05$). Among the most notable are the positive correlation between subjective well-being and HDI, the link between tuberculosis incidence and fertility rate, and a particularly strong positive association between road traffic mortality and fertility rate. These patterns underline the existence of a complex and dynamic web of interdependencies among demographic, health, economic, and environmental dimensions in the European Union.

The risk of multicollinearity was rigorously assessed using *Variance Inflation Factors* (Table 4). All VIF values remained safely below the conventional threshold of 5 across the three models, confirming that the explanatory variables are not highly collinear and that the estimated coefficients can be interpreted with a high degree of confidence.

Table 3. Covariance analysis (source: author's own calculation)

Model	Main Strong Correlations (|r| > 0.5)	Direction (Positive/ Negative)	Significance ($p < 0.05$)
Model 1: HDI	– SDG3_SWB and HDI (r = 0.532) – SDG3_SWB and LOG_GINI (r = –0.331) – SDG3_TB and LOG_SDG3_FERTILITY (r = 0.543) – SDG3_TRAFFIC and LOG_SDG3_FERTILITY (r = 0.685)	Mixed: Positive and Negative	All significant
Model 2: LOG_GDP	– LOG_SDG3_FERTILITY and SDG3_TRAFFIC (r = 0.685) – SDG3_SWB and LOGGDP (r = 0.250) – SDG3_TB and LOG_SDG3_FERTILITY (r = 0.543)	Mixed: Positive and Negative	All significant
Model 3: LOG_REN	– LOG_SDG3_FERTILITY and SDG3_TRAFFIC (r = 0.685) – SDG3_SWB and LOG_SDG3_FERTILITY (r = –0.631) – SDG3_TB and LOG_SDG3_FERTILITY (r = 0.543)	Mixed: Positive and Negative	All significant

Table 4. Variance Inflation Factors (VIF) – multicollinearity diagnostics (source: author's own calculation)

Model	Variable	Coefficient Variance	Uncentered VIF
Model LOG_GDP	HICP	6.42E-06	1.711711
	LOG_SDG3_FERTILITY	0.002062	2.085420
	LOG_SDG3_LIFE	0.854820	1.318951
	SDG3_NEONAT	0.002397	1.875529
	SDG3_SWB	0.001279	1.422471
	SDG3_TB	5.36E-06	1.923635
	SDG3_TRAFFIC	0.000144	1.603488
Model HDI	LOG_SDG3_FERTILITY	8.13E-08	1.851732
	LOG_SDG3_LIFE	3.48E-05	1.208716
	SDG3_NEONAT	1.06E-07	1.870106
	SDG3_SWB	5.71E-08	1.428963
	SDG3_TB	2.42E-10	1.954739
	SDG3_TRAFFIC	6.45E-09	1.614295
	LOG_GINI	2.31E-06	1.113434
Model LOG_REN	LOG_SDG3_FERTILITY	3.44E-05	1.931426
	LOG_SDG3_LIFE	0.014669	1.258029
	SDG3_NEONAT	4.27E-05	1.856107
	SDG3_SWB	2.33E-05	1.437910
	SDG3_TB	1.02E-07	2.043144
	SDG3_TRAFFIC	2.69E-06	1.661833
	LOGAIR_EMIS	8.58E-05	1.297365

Residual diagnostic tests indicate clear deviations from multivariate normality (Table 5) and the presence of *heteroskedasticity* (Table 6). Such violations of classical assumptions are common in large, heterogeneous panel datasets spanning multiple countries and years. Nevertheless, the FMOLS estimator is specifically designed to remain robust in the presence of these issues, thanks to its corrections for serial correlation and endogeneity in cointegrated panels.

Table 5. Normality of residuals – VEC residual normality tests (source: author's own calculation)

Model	Joint Skewness	p-value	Joint Kurtosis	p-value	Joint Jarque-Bera	p-value
Model HDI	678.997	0.0000	14009.86	0.0000	14688.86	0.0000
Model LOG_GDP	914.134	0.0000	16226.51	0.0000	17140.64	0.0000
Model LOG_REN	857.523	0.0000	17002.52	0.0000	17860.04	0.0000

Table 6. Heteroskedasticity of residuals – white tests (source: author's own calculation)

Model	Levels and Squares – Chi2	p-value	Includes Cross Terms – Chi2	p-value
Model HDI	982.899	0.0000	2991.348	0.0000
Model LOG_GDP	929.551	0.0000	2676.482	0.0000
Model LOG_REN	1166.734	0.0000	3176.158	0.0000

Panel unit root tests are reported in Table 7. The results demonstrate that the majority of the variables are non-stationary in levels but become stationary after first differencing, confirming that the series are integrated of order one. This integration order is a necessary precondition for valid cointegration analysis and subsequent long-run estimation.

Table 7. Unit roots tests for variables (source: author's own calculation)

Variable	Level (LLC p-val)	Level (IPS p-val)	Level (ADF p-val)	Level (PP p-val)	First Diff (LLC p-val)	First Diff (IPS p-val)	First Diff (ADF p-val)	First Diff (PP p-val)
HDI	0.0000	0.9729	0.9856	0.3167	0.0000	0.0000	0.0000	0.0000
LOG_GINI	0.0018	0.4287	0.4660	0.0554	0.1063	0.0951	0.0810	0.0000
LOG_SDG3_FERTILITY	0.0255	0.9998	0.9980	0.6360	0.0000	0.0001	0.0002	0.0000
LOG_SDG3_LIFE	0.6896	0.8849	0.8926	0.7228	0.0000	0.0931	0.0938	0.0000
SDG3_NEONAT	0.0000	0.5491	0.0029	0.0000	0.0000	0.1005	0.0176	0.0016
SDG3_SWB	0.0000	0.0677	0.0704	0.1807	0.0002	0.0084	0.0018	0.0000
SDG3_TB	0.0000	0.8951	0.9813	0.9205	0.0000	0.0002	0.0000	0.0000
SDG3_TRAFFIC	0.0000	0.7111	0.7433	0.9685	0.0000	0.0000	0.0000	0.0000
LOG_GDP	1.0000	1.0000	1.0000	1.0000	0.0028	0.0497	0.0541	0.0000
HICP	0.9989	0.8492	0.7792	0.9997	0.0000	0.0000	0.0000	0.0000
LOG_REN	0.9798	1.0000	1.0000	1.0000	0.0000	0.0011	0.0003	0.0000
LOGAIR_EMIS	0.7134	0.9976	0.9958	0.9938	0.0000	0.0019	0.0004	0.0000

Cointegration tests provide strong evidence of stable long-run equilibrium relationships. *The Kao residual cointegration test* (Table 8) rejects the null hypothesis of no cointegration at the 5% significance level for Models 1 and 3, and at the 1% level for Model 2 (Kao, 1999).

Table 8. Kao cointegration test (source: author's own calculation)

Model	Variables	t-Statistic (ADF)	p-Value (ADF)	Cointegration Conclusion
Model 1: HDI	HDI, LOG_GINI, LOG_SDG3_FERTILITY, LOG_SDG3_LIFE, etc.	–1.746306	0.0404	Cointegration exists (5% level)
Model 2: LOG_GDP	LOG_GDP, LOG_SDG3_FERTILITY, LOG_SDG3_LIFE, SDG3_NEONAT, etc.	–25.36587	0.0000	Strong cointegration (1% level)
Model 3: LOG_REN	LOG_REN, LOG_SDG3_FERTILITY, LOG_SDG3_LIFE, SDG3_NEONAT, etc.	–2.183435	0.0145	Cointegration exists (5% level)

These findings are further supported by the *Johansen Fisher-type panel cointegration test* (Table 9), which identifies two to three cointegrating vectors in each of the three models. The presence of cointegration validates the application of the FMOLS estimator for estimating long-run parameters (Johansen, 1991).

Table 9. Johansen cointegration tests (source: author's own calculation)

Model	Trace Test (No. of Cointegrating Equations)	Max-Eigen Test (No. of Cointegrating Equations)	Significance Level	Conclusion
Model 1: HDI	2 (Trace test)	2 (Max-Eigen test)	5%	Evidence of 2 stable long-run relationships
Model 2: LOG_GDP	2 (Trace test)	3 (Max-Eigen test)	5%	Evidence of 2–3 stable long-run relationships
Model 3: LOG_REN	2 (Trace test)	3 (Max-Eigen test)	5%	Evidence of 2–3 stable long-run relationships

Taken together, the Johansen cointegration test results across all models validate the theoretical assumptions underlying the econometric framework. The presence of multiple cointegrating vectors indicates that these socio-economic and health variables do not evolve independently over time but are linked through persistent equilibrium relationships. Consequently, the findings justify the application of modelling techniques that explicitly account for cointegration, ensuring the consistency and robustness of the estimated long-run parameters.

The core *long-run results from the Fully Modified OLS* (*FMOLS*) *estimations* are presented in Table 10.

Table 10. FMOLS Results for the three models (source: author's own calculation)

Model	Significant Variables ($p < 0.05$)	Effect (Positive/ Negative)	Adjusted R-squared
Model 1: HDI	LOG_SDG3_FERTILITY (–), LOG_SDG3_LIFE (+), SDG3_NEONAT (–), SDG3_SWB (+), SDG3_TB (+), SDG3_TRAFFIC (–), LOG_GINI (–)	Mixed	0.9799
Model 2: LOG_GDP	HICP (+), LOG_SDG3_LIFE (–), SDG3_NEONAT (–), SDG3_SWB (+), SDG3_TRAFFIC (–)	Mixed	0.9970
Model 3: LOG_REN	LOG_SDG3_FERTILITY (–), LOG_SDG3_LIFE (–), SDG3_NEONAT (–), SDG3_TB (+), SDG3_TRAFFIC (–)	Mixed	0.9311

In *Model 1* (*HDI*), life expectancy (LOG_SDG3_LIFE) and subjective well-being (SDG3_SWB) exert positive and statistically significant effects on the Human Development Index. In contrast, higher fertility rates, neonatal mortality, road traffic deaths, and greater income inequality are associated with lower HDI levels. The model achieves an exceptionally high goodness-of-fit, with an adjusted R^2 of 0.9799, indicating that the selected variables explain nearly all the observed variation in human development across EU countries and over time. These results suggest that improvements in longevity and life satisfaction remain powerful drivers of multidimensional human progress, even in high-income settings. The negative impact of income inequality further highlights the importance of redistributive policies for achieving inclusive human development.

In *Model 2* (*LOG_GDP*), subjective well-being and inflation (HICP) show positive effects on GDP per capita, while life expectancy and neonatal mortality display negative coefficients. This model records the highest explanatory power among the three, with an adjusted R^2 of 0.9970. The negative relationship between life expectancy and GDP per capita is particularly evident in Western member states and is consistent with the advanced stage of demographic transition, where additional gains in longevity primarily expand the retired population and increase dependency ratios rather than the active labour force. This stage-dependent effect aligns with theoretical expectations for mature economies and helps explain why the health-growth relationship is more nuanced in the EU compared to developing countries. The positive role of subjective well-being underlines the growing importance of non-material factors in driving economic performance.

In *Model 3* (*LOG_REN*), lower fertility rates, life expectancy, neonatal mortality, and road traffic deaths are associated with higher shares of renewable energy consumption, while tuberculosis incidence shows a statistically significant positive coefficient. The adjusted R^2 of 0.9311 indicates that the model explains a substantial portion of the variation in renewable energy adoption. The positive association between tuberculosis incidence and renewable energy use most likely captures the joint allocation of EU cohesion and recovery funds toward both public health infrastructure modernisation and green energy projects in regions with historically higher communicable disease burdens. This finding highlights the important role of supranational policy instruments in creating synergies between health and environmental objectives within the European Green Deal framework (World Health Organization Regional Office for Europe & European Centre for Disease Prevention and Control, 2025).

Granger causality tests (Dumitrescu & Hurlin, 2012) complement the long-run FMOLS estimates by shedding light on the short-run directional relationships among the variables (Tables 11–13 and Figures 3–5).

Table 11. Significant granger causality relationships across Model 1 (source: author's own calculation)

Model	Causal Relationship	p-value
Model 1	HDI → LOG_SDG3_FERTILITY	0.0091
	HDI → SDG3_TRAFFIC	0.0584
	LOG_GINI → SDG3_NEONAT	0.0034
	SDG3_SWB → LOG_SDG3_FERTILITY	0.0542
	LOG_SDG3_FERTILITY → SDG3_TRAFFIC	0.0086
	SDG3_TB → LOG_SDG3_LIFE	0.0224
	LOG_SDG3_LIFE → SDG3_TRAFFIC	0.0077
	SDG3_SWB → SDG3_NEONAT	0.0018
	SDG3_TRAFFIC → SDG3_NEONAT	0.0015
	SDG3_SWB → SDG3_TRAFFIC	0.0040

Note: Only relationships statistically significant at 1%, 5%, and 10% levels are reported. Arrows (→) indicate the direction of Granger causality.

Several statistically significant unidirectional causalities were identified.

In the first model, HDI significantly Granger-causes LOG_SDG3_FERTILITY at the 1% significance level. Moreover, income inequality (LOG_GINI) is found to Granger-cause neonatal mortality (SDG3_NEONAT), highlighting the potential indirect effects of economic disparities on early-life health outcomes.

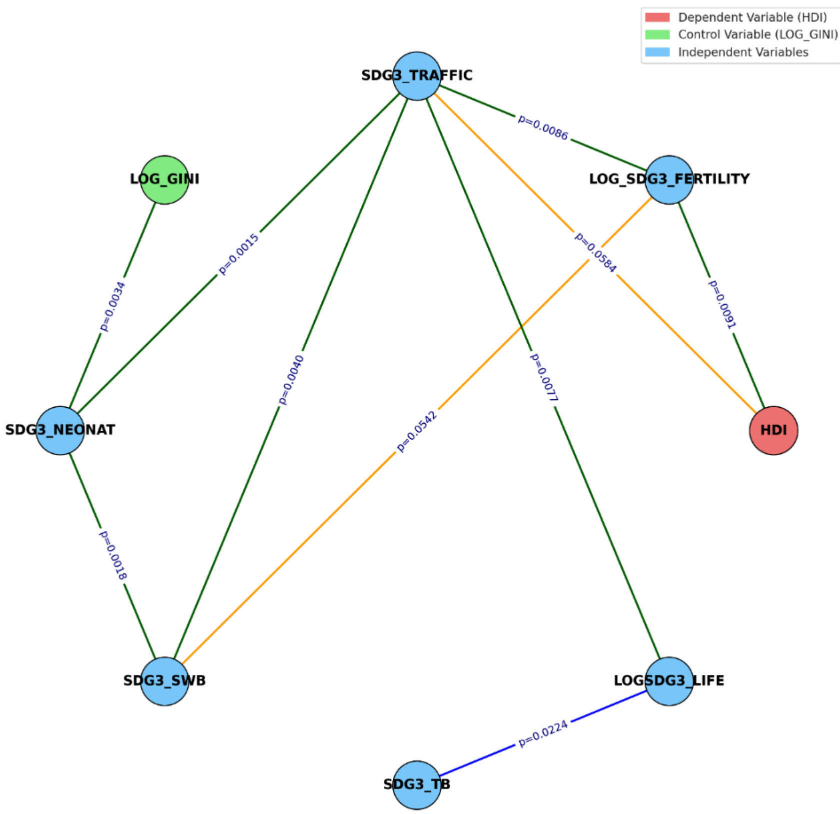

Figure 3. Granger causality for the first model.

For instance, HDI Granger-causes fertility rate and road traffic mortality, income inequality (LOG_GINI) Granger-causes neonatal mortality, and subjective well-being exerts causal influence on fertility rate, neonatal mortality, and traffic deaths. These findings suggest that changes in human development and social well-being tend to precede adjustments in demographic and health outcomes in the short run.

In the second model, with LOG_GDP as the primary economic variable, several significant unidirectional relationships emerge. Fertility rates are found to be Granger-cause traffic-related deaths (SDG3 TRAFFIC), while life expectancy (LOG SDG3_LIFE) exhibits predictive power over neonatal mortality (SDG3_NEONAT). Additionally, tuberculosis incidence (SDG3_TB) Granger-causes life expectancy, and traffic fatalities Granger-cause life expectancy, reinforcing the notion that public health and safety factors are intricately tied to demographic and macroeconomic conditions.

Table 12. Significant granger causality relationships across Model 2 (source: author's own calculation)

Model	Causal Relationship	p-value
Model 2	LOG_SDG3_LIFE → LOG_GDP	0.0569
	SDG3_SWB → LOG_SDG3_FERTILITY	0.0542
	LOG_SDG3_FERTILITY → SDG3_TRAFFIC	0.0086
	SDG3_TB → LOG_SDG3_LIFE	0.0224
	LOG_SDG3_LIFE → SDG3_TRAFFIC	0.0077
	HICP → LOG_SDG3_LIFE	0.0357
	SDG3_SWB → SDG3_NEONAT	0.0018
	SDG3_TRAFFIC → SDG3_NEONAT	0.0015
	SDG3_SWB → SDG3_TRAFFIC	0.0040

Note: Only relationships statistically significant at 1%, 5%, and 10% levels are reported. Arrows (→) indicate the direction of Granger causality.

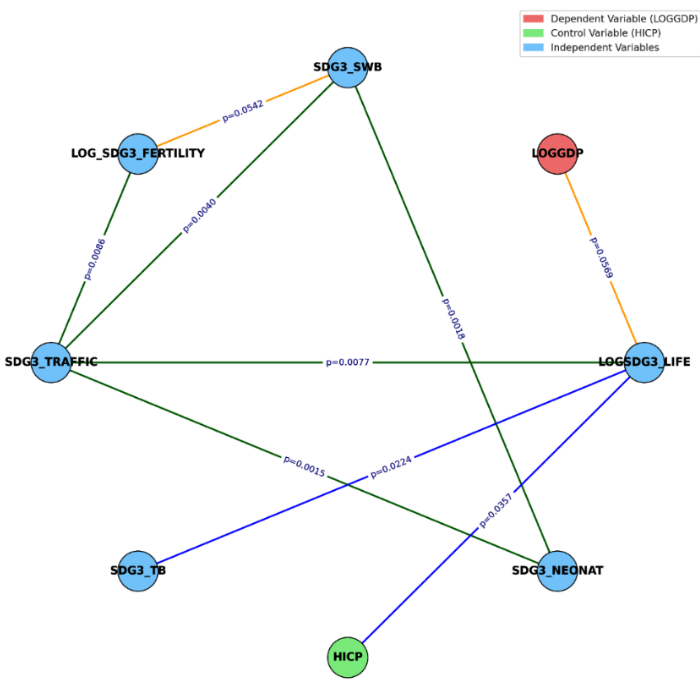

Figure 4. Granger causality for the second model

The third model, centered around renewable energy (LOG_REN) and environmental outcomes, displays similar causal dynamics. Fertility again Granger-causes traffic deaths, life expectancy Granger-causes neonatal mortality, and tuberculosis incidence Granger-causes life expectancy. Furthermore, traffic-related deaths are shown to Granger-cause life expectancy as well. These findings emphasize the complex, multifaceted interplay between health, environmental sustainability, and demographic trends.

Table 13. Significant granger causality relationships across Model 3 (source: author's own calculation)

Model	Causal Relationship	p-value
Model 3	LOG_SDG3_FERTILITY → LOG_REN	0.0716
	SDG3_SWB → LOG_REN	0.0544
	SDG3_TRAFFIC → LOG_REN	0.0912
	SDG3_SWB → LOG_SDG3_FERTILITY	0.0542
	LOG_SDG3_FERTILITY → SDG3_TRAFFIC	0.0086
	SDG3_TB → LOG_SDG3_LIFE	0.0224
	LOG_SDG3_LIFE → SDG3_TRAFFIC	0.0077
	SDG3_SWB → SDG3_NEONAT	0.0018
	SDG3_TRAFFIC → SDG3_NEONAT	0.0015
	LOGAIR_EMIS → SDG3_NEONAT	0.0004
	SDG3_SWB → SDG3_TRAFFIC	0.0040

Note: Only relationships statistically significant at 1%, 5%, and 10% levels are reported. Arrows (→) indicate the direction of Granger causality.

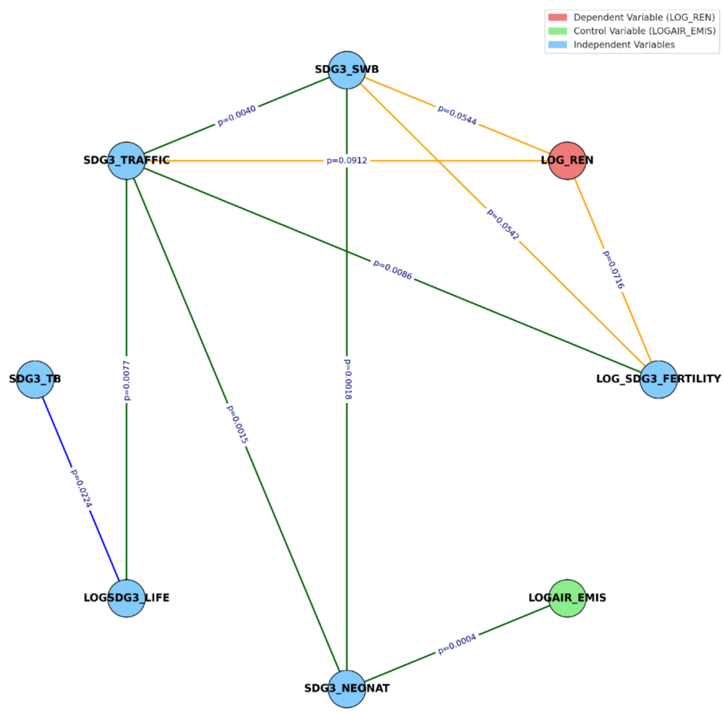

Figure 5. Granger causality for the third model

In summary, the empirical results demonstrate that selected SDG3 indicators exert statistically significant and economically meaningful long-run effects on human development, economic performance, and renewable energy adoption across the EU-27. The analysis also highlights important heterogeneity between Western and Eastern member states, driven by differences in demographic structures, institutional capacity, and stage of economic development.

4. Discussion

The empirical results obtained through FMOLS estimations and complemented by Granger causality tests offer a nuanced understanding of the relationships between SDG3 indicators and the three dimensions of sustainable development in the EU-27 over the period 2014–2023. Overall, the findings provide support for the concept of a "triple dividend" of health, while simultaneously revealing important qualifications related to the EU's advanced demographic stage, institutional context, and persistent East-West heterogeneity.

In the *HDI model*, the positive and significant coefficients on life expectancy (LOG_SDG3_LIFE) and subjective well-being (SDG3_SWB) are consistent with a large body of literature emphasising health as a foundational pillar of human development (Miranda-Lescano et al., 2024; Bloom et al., 2004; Santos et al., 2024; Gavurova & Megyesiova, 2022). These results confirm that, even in high-income countries, gains in longevity and improvements in perceived quality of life continue to enhance the Human Development Index. Conversely, the negative effects of fertility rate, neonatal mortality, traffic deaths, and income inequality (LOG_GINI) align with studies highlighting the importance of early-life health conditions and social equity for long-term human development (Say et al., 2014; Banik et al., 2023; Bucher, 2018). Within the EU context, these findings reinforce the effectiveness of cohesion policies and targeted SDG3 interventions in reducing regional disparities (Pîrvu et al., 2018; Ionescu et al., 2020; Bădîrcea et al., 2025).

The results of the *GDP model* require more careful interpretation. While subjective well-being positively influences economic output – confirming the growing recognition that non-material factors matter for productivity and growth (Sharma, 2018; Bloom et al., 2019) – the negative coefficient on life expectancy appears counterintuitive at first sight. However, this finding does not suggest that better health is detrimental to growth. Instead, it reflects the specific stage of demographic transition characterising most EU countries. In mature, ageing economies, additional gains in life expectancy primarily expand the retired population and increase dependency ratios, thereby exerting downward pressure on GDP per capita (Acemoglu & Johnson, 2007; European Commission, 2024; European Central Bank, 2024; Rocco et al., 2021). This negative relationship is stronger in Western member states, while it is weaker or statistically insignificant in Eastern catching-up economies, where health improvements still contribute to labour force expansion and productivity gains. These stage-dependent effects are consistent with earlier theoretical and empirical work (Bloom et al., 2004; Neofytidou & Fountas, 2020). Public health expenditures continue to support growth when efficiently allocated (Beylik et al., 2022; Kuzior et al., 2025; Sosvilla-Rivero et al., 2025), underlining the importance of resource allocation and institutional quality.

In the *renewable energy model*, the negative associations between fertility rate, neonatal mortality, traffic deaths and renewable energy consumption suggest that broader social modernisation and improved population health tend to co-evolve with the clean energy transition. Beyond the direct benefits of reduced air pollution, renewable energy deployment also contributes to long-term population health by limiting climate-related disease risks and stabilising energy supply for healthcare infrastructure (Pervaiz et al., 2021; World Health

Organization, 2019, 2023). Although much of the quantitative evidence on these co-benefits originates from Asian countries, where large-scale renewable expansion has been shown to significantly reduce air pollution and associated health burdens (Xie et al., 2020), similar mechanisms are clearly observable in the EU. Here, the transition is further amplified by strong policy coordination under the European Green Deal and REPowerEU initiatives (European Commission, 2022), which explicitly link clean energy targets with public health objectives. This policy-mediated synergy helps explain the positive association between tuberculosis incidence and renewable energy use observed in the FMOLS results, as regions with higher communicable disease burdens have often received joint EU funding for both health system modernisation and green infrastructure development.

The Granger causality analysis adds a dynamic dimension to the long-run relationships identified by FMOLS. The finding that income inequality Granger-causes neonatal mortality underscores the short-run importance of equity-oriented policies for early-life health outcomes. Similarly, the causal influence of subjective well-being on fertility and traffic mortality highlights the role of social and psychological factors in shaping demographic and safety-related indicators. These short-run transmission channels complement the structural equilibria revealed by the cointegration analysis and provide valuable insights for policy timing and sequencing.

When viewed against the existing literature, *our results are largely consistent with previous studies* on the health–development nexus, yet they introduce important EU-specific qualifications. In advanced economies with ageing populations, the marginal returns of health improvements on economic growth appear more modest and context-dependent than in developing countries. At the same time, the analysis highlights the growing importance of coordinated, supranational policy instruments in generating and amplifying co-benefits between health, economic, and environmental objectives.

The observed synergies between SDG3 and renewable energy adoption are not automatic but are significantly shaped by the EU's institutional architecture, financing mechanisms, and commitment to integrated sustainable development strategies. This suggests that the "triple dividend" of health is not only theoretically plausible but also empirically observable in the European context, provided that policies are designed in an integrated and place-based manner.

Furthermore, the East-West heterogeneity revealed by *the results has clear theoretical and practical implications*. In Western member states, the negative life expectancy–GDP relationship points to the need for policies focused on healthy and active ageing, lifelong learning, and labour market adaptation. In Eastern member states, continued emphasis on reducing inequality, improving maternal and child health, and strengthening health systems remains essential for accelerating convergence. Across the Union, the positive TB–renewables link demonstrates that EU cohesion and recovery funds can successfully create cross-sectoral synergies when health and green objectives are jointly targeted.

In conclusion, this study contributes to the literature by providing an integrated econometric perspective on the SDG3–development nexus in a highly institutionalised regional setting. The findings underscore that health improvements generate multidimensional benefits, but the magnitude and direction of these effects are contingent upon the stage of development, demographic structures, and the quality of policy coordination. These insights are particularly timely as the EU seeks to advance the European Green Deal, the European Pillar of Social Rights, and the 2030 Agenda in a coherent manner.

5. Conclusions

This study investigated the impact of selected SDG3 indicators on human development (HDI), economic performance (GDP per capita), and environmental sustainability (renewable energy consumption) across all 27 EU member states over the period 2014–2023. Using panel cointegration techniques and Fully Modified OLS (FMOLS) estimations, complemented by Granger causality tests, the analysis provides robust evidence regarding the long-run relationships between health and well-being improvements and broader sustainable development outcomes.

The results confirm that advancements in SDG3 generate a triple dividend. In the HDI model, life expectancy and subjective well-being exert positive effects, while reductions in fertility rate, neonatal mortality, traffic deaths, and income inequality contribute to higher human development levels. In the GDP model, subjective well-being positively influences economic output, although the negative coefficient on life expectancy reflects the realities of demographic ageing in advanced economies. In the renewable energy model, improvements in several health indicators are associated with higher renewable energy adoption, with the positive link between tuberculosis incidence and renewables highlighting policy-driven synergies within EU cohesion and recovery instruments.

These findings validate all three research hypotheses. H1 is supported by the strong positive effects of health indicators on HDI. H2 is confirmed, albeit with important qualifications related to the stage of development. H3 is supported by the observed synergies between health progress and the clean energy transition. The analysis also reveals significant heterogeneity between Western and Eastern member states, with distinct patterns shaped by differences in demographic structures, institutional capacity, and convergence dynamics.

This study contributes to the literature in several ways. First, it adopts an integrated analytical framework that simultaneously examines the interconnections between SDG3 and three core outcomes (HDI, GDP, and renewable energy), going beyond the traditional separate analyses of health–growth or health–environment linkages. Second, by applying FMOLS on a recent balanced panel of all 27 EU countries and accounting for non-stationarity and endogeneity, the study provides reliable estimates of long-run dynamics. Third, it captures the effects of major shocks (sovereign debt crisis and COVID-19 pandemic) and highlights the role of EU-level policies in shaping health–environment synergies. Finally, the inclusion of subjective well-being and the explicit consideration of East-West asymmetries add valuable nuances to the understanding of sustainable development processes in a highly integrated economic bloc.

From a policy perspective, the findings carry several important implications for the European Union. Policymakers should recognise health investments not merely as social expenditures but as strategic drivers of human development, economic resilience, and environmental sustainability. In Western member states, policies should focus on healthy ageing, lifelong learning, and labour market adaptation to mitigate the negative effects of demographic pressures on per-capita growth. In Eastern member states, continued efforts to reduce inequality, improve maternal and child health, and strengthen health systems remain crucial for accelerating convergence. Across the Union, integrated policy approaches that link health objectives with the European Green Deal and cohesion funds appear particularly promising. The observed policy-driven co-movement between health and renewable energy investments suggests that future funding mechanisms (such as the Recovery and Resilience Facility and Multiannual Financial Framework) should explicitly promote cross-sectoral synergies between SDG3 and SDG7.

Despite its contributions, the study has *several limitations*. First, the analysis relies on aggregate national-level data, which may mask important intra-country disparities (urban-rural or regional). Second, some potentially relevant variables, such as governance quality, digitalization, or technological innovation, could not be included due to data constraints over the full period. Third, the time span (2014–2023) captures post-crisis and pandemic effects but remains relatively short for fully assessing long-term structural changes.

Future research could extend the analysis in several directions. Longer time series that incorporate post-2023 developments would allow assessment of the medium- and long-term impacts of the energy crisis and geopolitical shocks. Incorporating additional mediating variables (e.g., institutional quality, green innovation indices) or employing alternative methodologies (such as quantile regression or spatial panel models) could provide further insights. Comparative studies between EU and non-EU countries would also help determine the extent to which these dynamics are specific to the European institutional framework.

In conclusion, this study demonstrates that progress in health and well-being under SDG3 generates multidimensional benefits for human development, economic prosperity, and environmental sustainability in the European Union. By highlighting both the synergies and the context-specific challenges, the findings underscore the value of integrated, coherent policy strategies that simultaneously advance health, equity, demographic adaptation, and the green transition. Such an approach is essential for building a more resilient, prosperous, and sustainable Europe in the years ahead.

Author contributions

R.M.B., A.G.M., and R.M.C. conceived the study and designed the methodology. C.G., A.G.M., and R.M.B. developed the methodology, while C.G. and M.N.C. handled software development. A.G.M. and R.M.B. were responsible for validation. A.G.M., C.G., and M.N.C. conducted data collection and analysis. R.M.C. managed data curation. R.M.C. and A.G.M. wrote the first draft of the article. A.G.M. and R.M.B. reviewed and edited the manuscript. R.P. prepared visualizations. A.G.M. and R.P. supervised the project and managed administration.

Disclosure statement

The authors declare that they have no financial, professional, or personal interests that could be construed as a conflict of interest in relation to this work.

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