Scientific Annals of Economics and Business
71 (4), 2024, 641-662
DOI: 10.47743/saeb-2024-0028

Income-Based Economic Determinants of Life Expectancy in Four Groups of Countries Classified by their Levels of Income

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Abstract: This study seeks to determine the role of per capita value added in the main sectors of; agriculture, industry, services, plus per capita GDP, on life expectancy at birth in the four groups of countries classified internationally by; high income, upper middle income, lower middle income, and low-income countries, during the period 1990-2022. Panel data analysis adopted for each group countries, where CS-ARDL approach is used to measure the effect of the independent variables (sector's value-added per capita income) on the dependent variable (life expectancy at birth). The findings indicate that the per capita values provided by the sectors of industry and services are important factors in increasing life expectancy in high-income countries. Whereas, increases in per capita GDP would significantly extend life expectancy in countries ranging from upper-middle to lower-middle and low-incomes.

Keywords: life expectancy at birth; agriculture; industry; services; per capita GDP; CS-ARDL.

JEL classification: E10; C33; I15.

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Article history: Received 9 August 2024 | Accepted 29 October 2024 | Published online 19 December 2024

To cite this article: Abdulrahman, I. M., Chawsheen, S. A. (2024). Income-Based Economic Determinants of Life Expectancy in Four Groups of Countries Classified by their Levels of Income. *Scientific Annals of Economics and Business*, 71(4), 641-662. https://doi.org/10.47743/saeb-2024-0028.

1. INTRODUCTION

Human life expectancy at birth (LEB) is the expected average number of years living at a given age (at birth). Life expectancy has upsurged in the four groups of countries classified by the world bank according to income as; low income, lower middle income, upper middle income, and high income, from 49.7 to 62.5, 59 to 66.9, 67.6 to 74.7, and 75.3 to 79.9, respectively, during the period under study 1990-2022 (WB, 2024). These figures tell that there are discrepancies among the four groups life expectancy, approximately more than 15 years between low-income and high-income countries. This gap, and the factors behind the high level of life expectancy in high-income countries, have prompted researchers in various scientific fields to investigate its reasons.

Investigating the factors affecting life expectancy has received great importance from different fields of study. The factors were classified under: economic, social, political, and environmental (Aigheyisi, 2020). This study examines the impact of the primary components of the economy on life expectancy by considering the value added per capita in agriculture, forestry, and fisheries, the value added per capita in industry, and the value contributed per capita in services, in addition to GDP per capita. Any difference in the added value of these sectors demonstrates structural changes that happened over the inquiry period, whereas per capita GDP reflects economic growth. The added value in any of these areas refers to a feature of life that contributes to expanding life expectancy, whether the rise is in the proper direction to support health and the environment, or, on the contrary, it affects the direction of rising life expectancy. Considering the average per capita GDP reveals the individual's ability to access sufficient and healthy food, obtain life-sustaining goods, good health, and educational and recreational services.

The main economic sectors are the sectors that provide the population with necessary and luxury goods and services. Access to adequate food is an essential goal for achieving well-being and human development. The United Nations has set access to food and eliminating poverty among the main sustainable development goals, as the agricultural sector is the one that accomplishes this mission (Herforth, 2015). Achieving progress in the sector of agriculture in many countries is an important step in achieving economic development, reducing poverty and hunger, and thus liberation from the restrictions of poor and backward agriculture (Alexandratos, 1999). On the other hand, agriculture is one of the entities responsible for secreting large quantities of gases and harmful substances to the environment that negatively affect the quality of life and life expectancy (FAO, 2024).

Industrialization transforms the production process from labor-intensive production to capital-intensive production, and this transformation creates a major leap in the quantity and quality of production. As a result, the potential of getting goods and services grows significantly, thereby improving people's well-being (Szreter, 2004). Successive industrial revolutions provided great assistance to the prosperity of agriculture through the development of modern agricultural methods, providing sufficient food for the growing population. In addition, industrial development has created a revolution in the field of transportation, delivery of goods, provision of services, and energy (Liu *et al.*, 2020). The industrial sector also provides many job opportunities with higher wages, which helps increase income (Helper *et al.*, 2012). On the other hand, industry is responsible for causing harm to the environment by releasing many gases and wastes into the air, soil and water, which has serious consequences for health (Sardar *et al.*, 2013).

In regard to services, it is the sector that includes numerous offerings, such as medical services that have significant impacts on life expectancy (Tackie *et al.*, 2022). Also, educational services contribute to increasing people's interest in health (Hahn and Truman, 2015), in addition to other entertainment services that may support life expectancy. Without a doubt, services sector consumes materials and energy to accomplish its works, which may also have negative effects on the environment. For example, health sector is responsible for 4.6% of greenhouse gas (MacNeill *et al.*, 2020).

In addition to mentioning the importance of measuring the impact of the main above-mentioned sectors, per capita GDP was added to the independent variables under study, because per capita GDP largely reflects the level of well-being and social welfare that affect the life expectancy (Boo *et al.*, 2016).

As mentioned previously, there is a number of researches that has dealt with the factors determining life expectancy, some of which have focused on socio-economic factors, some of which have dealt with political and security factors, and Others have focused on health and environmental issues. Some of these studies were related to a specific country, others to a specific region, or a group of countries, such as developed and developing countries, and even brought together almost all countries of the world in one research. This study examines the impact of four economic factors on life expectancy at birth (LEB) for four-classified groups of countries by income around the world, selected depending on data available by the WB (2024). Therefore, this study attempts to answer the following questions:

1- Do increases in per capita value added in the sectors of agriculture, industry, and services lead to increased life expectancy at birth, and does this impact differ among the four groups of countries?

2- How would per capita GDP affect life expectancy at birth within the four groups of countries?

2. LITERATURE OVERVIEW

WB (2024) has defined life expectancy as "The average number of years that a newborn could expect to live, if he or she were to pass through life exposed to the sex and age-specific death rates prevailing at the time of his or her birth, for a specific year, in a given country, territory, or geographic area". Ortiz-Ospina and Roser (2017) defines life expectancy as, the number of years a group of people is expected to live.

The relationship between the agricultural sector and life expectancy is broad and includes: food security and proper nutrition, contribution to comprehensive economic development, negative and positive impacts of agriculture on the environment, as well as migration from the countryside to the city. Agricultural researchers presented both effects positive and negative, on life expectancy. On the one hand, it offers food and raw resources. On the other hand, it causes the release of certain gases that affect global warming and the atmosphere over a long period of time, as reported by Aigheyisi (2020) and Kabir (2008). While, in the short run, this is contradictory to the findings of Saidmamatov *et al.* (2024) and Aigheyisi (2020). According to Saidmamatov *et al.* (2024) agricultural production had a positive and significant connotation with life expectancy, and access to healthy and sufficient food contributors to a better and longer livelihood. Also, Pramita (2017) discovered that agriculture, forestry, and fisheries contribute significantly to economic growth, which influences life expectancy by increasing income and enhancing nutrition and health services.

Therefore, in this study the authors enter the per capita value added in the sector of agriculture, fisheries, and forestry, as one main factor that influence life expectancy.

Even though agriculture utilizes natural resources, the way these resources are used has an impact on people's quality of life and life expectancies. According to Cavusoglu and Gimba (2021) there is a positive relationship between food production and life expectancy in the long-term in Sub-Saharan Africa countries. The study of Aigheyisi (2020) exposed increases in agricultural output have a short-term advantageous effect on life expectancy since they allow for the acquisition of additional nutrients and the enhancement of the diet. However, the long-term outcomes were reversed, since this enhancement might have an adverse effect on life expectancy if calories and cholesterol are consumed excessively. In this context Madreimov and Li (2019) discovered an inverted U-shaped link between natural resource consumption and life expectancy, implying when greater natural resources are used, life expectancy declines. Lin *et al.* (2012)) calculated nutrition contributes 2.79% - 5.14% to life expectancy gains in less developed countries during 1970-2004. Kabir (2008) found a significant negative impact of undernourished on life expectancy in developing countries with high life expectancy.

Fish and other aquatic creatures help to increase global food production and eliminate hunger, both of which are essential aims of the UN's Sustainable Development aims (SDGs 2 and 3). Fish consumption account for almost 20% of the average per capita animal protein intake for approximately three million people. Furthermore, fish contain omega-3, which is necessary for the prevention of many illnesses, helping to increase life expectancy (Siregar, 2021). Therefore, sustainable fisheries management is critical for maintaining food security, which has a favorable influence on life expectancy (Mainguy *et al.*, 2023).

Forests play a crucial role in conserving ecosystems by storing carbon and moderating global warming. They also provide beauty and environmental benefits for human health. Ciocanel and Pavelescu (2015) discovered increasing forest area by ten units might reduce the frequency of mortality by 1297 people. Also, Kerdprasop and Kerdprasop (2017)) observed a significant relationship between forest acreage and GDP growth in the Mekong Pool, which had a positive impact on long life.

Industry is another vital and important sector that has a wide-ranging impact on many aspects of life, including: contributing to the population's food supply through the agricultural developments, contributing to the development of health care by building advanced infrastructure for health services and providing medicines, and connecting regions with roads, transportation, and communication. In addition, industrialization brings about urbanization and technical progress. Thus, industrialization may have a positive effect on life expectancy. On the other hand, increased industrial activities result in pollution in the air, water and soil, which has negative consequences on life expectancy. Fuel consumption on the other hand is the main driver of industrialization, where Hendrawaty *et al.* (2022) discovered that a 1% increase in fuel use reduces life expectancy by 0.15% in Asian countries. Pathirathne and Sooriyarachchi (2019) argued technological progress and increased urbanization have a negative impact on life expectancy, due to increases in pollution.

Jafrin *et al.* (2021) discovered that a growth in urban population has a negative and substantial influence on life expectancy at birth in five nations out of eight in the South Asian Association for Regional Cooperation (SAARC). But Kabir (2008) didn't find the impact of urbanization on life expectancy in developing countries, and the use of internet and mobile phone have not had any significant impacts on life expectancy at birth.

The sector of services provides a wide range of impact on life expectancy, which may be classified into several different groups, the most important of which are health, education, and recreation services. This sector provides; 1- Effective health care that lowers mortality rates, increase life expectancy; 2- A healthy workforce enhances productivity, which eventually raises production and per capita income. 3- Education is regarded as a necessary public service that provides the opportunity to earn a higher income and a greater interest in health, so contributing to a longer life expectancy. 4- Entertainment, hospitality, tourism, and recreational services all assist in creating a comfortable and happy lifestyle, which may help to extend life expectancy.

Radmehr and Adebayo (2022) employed the approaches of FMOLS, DOLS, and FE-OLS of long-run estimators. They observed an increasing in health expenditures by 1% lead to increase in life expectancy in the Mediterranean countries by 0.018%, 0.025%, and 0.057%, respectively, other factors been constant. Also, Owumi and Eboh (2021) discovered that $1% increase in the domestic general government health expenditure would lead to 6% increase in life expectancy, $1% increase in out-of-pocket health expenditure would lead to 63% enhancement in life expectancy, and 1% increase in external health spending as a percentage of existing health care spending will result in an 11%-year increase in average life expectancy at birth in Nigeria. However, other scholars such as Rahman *et al.* (2018) found that overall health spending does not boost life expectancy in SAARC-ASEAN countries. In addition, Rahman *et al.* (2022) discovered no short-term causal relationship between health spending and life expectancy in most of examined countries.

The results of 13 studies conducted on eight different groups indicated that recreational and regular physical activity increases life expectancy by 0.4 to 6.9 years. It also reduces the risk of death among physically active people by 20% to 30% compared to those who are inactive (Reimers *et al.*, 2012). Mueller *et al.* (2019) examined the relationship between county-level spending on parks and recreation activities and all-cause mortality in the United States between the years 1980 and 2010. The study shows parks and recreational activities had a favorable influence on all-cause death rates, including female-specific mortality rates. According to their estimated models for female and overall all-cause age-standardized mortality, when all other factors were equal, a $100 increase in per capita parks and recreation operational expenditures, in 2010 dollars, was associated with an average 3.9% decrease in mortality rate, or 3.4 deaths per 100,000 persons. Esfahani *et al.* (2018) found a significant positive relationship between public sports participation and life expectancy. Also, recreational activities support the social life of the elderly and improve their well-being and life satisfaction, improves their physical health and increases their resistance to diseases (Zhang *et al.*, 2021).

Concerning the relationship between education and life expectancy, Joshi *et al.* (2017) emphasize the positive role of education in life expectancy. Literacy had a significant impact on increasing life expectancy in less developed countries, where the impact ranged between 23.7-38.1 during 1970-2004. Lin *et al.* (2012) and Jafrin *et al.* (2021) found the average number of years of schooling positively impacts the life expectancy in five SAARC nations. Also, Kabir (2008) found a negative relationship between adult illiteracy and life expectancy in the developing countries that had longer life expectancy. Also, lack of access to health and education services is one of the reasons leading to low life expectancy in low-income countries (Aigheyisi, 2020).

In general, rich countries have a higher life expectancy than poor countries (Freeman *et al.*, 2020). The influence of per capita GDP on life expectancy varies by country, with some having a positive effect and others having a negative effect. For example, out of six Asian nations, the effect of per capita GDP was significant only in two countries: Japan and Bangladesh, with negative and positive impacts, respectively (Summoogum and Fah, 2016). Gürler and Özsoy (2019) discovered that a unit increase in income per capita leads to an increase of nearly 0.05 units in life expectancy at birth for 56 developing countries, this means that nearly 8.108 USD increase in per capita income, for 56 developing countries, causes nearly 3.27 years increase in life expectancy on average.

Increases in per capita GDP improve access to health and education services, as well as beneficial nutrition. According to the WB (2024) extending life expectancy (WHO, 2024)by 10% leads to economic growth of 0.3% to 0.4% (Colantonio *et al.*, 2010). Cervellati and Sunde (2005) proposed a large empirical evidence to support that a high level of economic development is associated with a higher level of life expectancy. Radmehr and Adebayo (2022) adopted the econometric methods of FMOLS, DOLS, and FE-OLS estimators, and found that a 1% improvement in economic performance contributed to raise life expectancy by 0.13%, 0.17%, and 0.15%, respectively, other factors remained unchanged. Also, Saidmamatov *et al.* (2024) found a direct and significant relationship between per capita GDP and life expectancy, with each 1% rise in per capita GDP result in a 0.014% increase in lifespan in five Central Asian countries. Therefore, per capita GDP may have a significant impact on happiness and life satisfaction, that eventually affect life expectancy, similar to Boo *et al.* (2016) confirmed a direct and significant relationship between the size of income with both happiness and life satisfaction.

3. DATA SCOPE AND METHODOLOGY

This study relied on the WB (2024) classification of the countries, according to income, into four groups countries (2024):

- High income, includes 48 countries.
- Upper middle income, includes 44 countries.
- Lower middle income, includes 41 countries
- Low income, includes 16 countries.

The time span of this study is 33 years starting from year 1990 to 2022. And the studied variables notations are:

- Life expectancy at birth, total years denoted by (L_E), dependent variable.
- Agriculture, forestry, and fishing, annual per capita value added in constant 2015 US$, (AFF).
- Industry including construction, annual per capita value added in constant 2015 US$, (IND).
- Services annual per capita value added in constant 2015 US$, (SER).
- Annual GDP per capita in constant 2015 US$, (GDP_PC).

STATA17 software was adopted for the empirical analysis.

Frequently panel data units or countries will be affected by common factors result in cross section dependency across the units (countries). In order to avoid the biasness impacts of slope heterogeneity, and the endogeneity problem between the variables, which lead to inconsistent estimates using conventional panel regression estimates, also, to develop long-term and short-term impacts, this study adopts Common Correlated Effects (CCE) approach, known by Cross Section Autoregressive Distributed Lags (CS-ARDL).

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

The average of life expectancy was 76.8 years in high income countries. While in group of upper middle-income countries the average of life expectancy was 70.3 years. This average reduced to 63.9 years in group of lower middle-income countries. Also, the average reduced further in group of lower income countries to 55.3 years, see Table no. 1.

Table no. 1 – The Descriptive statistics

Countries	Variable	Mean	Std. dev.	Min	Max	Obs.
High income	Countries	-	-	1	48	1584
	Year	-	-	1990	2022	1584
	L_E	76.8058	4.168465	62.415	84.56	1536
	AFF	571.897	460.7976	16.7886	3781.528	1484
	IND	7508.6	5796.316	648.9524	44437.46	1478
	SER	18903.3	14560.69	970.6112	89538.94	1477
	GDP_PC	29473.9	20105.43	2386.057	112417.9	1546
Upper middle income	Countries	-	-	1	44	1452
	Year	-	-	1990	2022	1452
	L_E	70.334	5.151	50.632	80.116	1408
	AFF	427.154	198.747	92.67	1288.37	1422
	IND	1526.097	972.939	212.53	7156.735	1419
	SER	3198.222	1711.672	262.808	9061.698	1402
	GDP_PC	5604.936	2603.624	791.647	14200.27	1437
Lower middle income	Countries	-	-	1	41	1353
	Year	-	-	1990	2022	1353
	L_E	63.93726	7.854374	41.957	79.729	1312
	AFF	280.0389	143.3071	39.18747	865.9799	1333
	IND	501.2045	383.2536	42.92058	2127.698	1332
	SER	1015.895	906.5837	99.73121	6661.377	1300
	GDP_PC	1934.743	1291.454	353.9566	9037.086	1348
Low income	Countries	-	-	1	16	528
	Year	-	-	1990	2022	528
	L_E	55.39514	6.731896	14.098	67.545	512
	AFF	222.0811	165.6891	62.8988	947.8558	507
	IND	158.2017	208.4829	16.13141	1349.249	493
	SER	314.7578	270.3306	47.6915	1601.468	488
	GDP_PC	703.0122	513.6541	190.35	2547.64	528

Source: researchers' calculations

The average of per capita value added for the sector of agriculture, forestry, and fishing, had the highest figure 571.897$, in high income countries. Concerning the upper middle countries recorded 427.154$, while lower middle countries witnessed 280.0389$. As for low-income countries record was the lowest figure 222.0811$.

Concerning per capita value added for the sector of industry including construction, recorded 7508.6$ in high income countries, while in upper middle-income countries 1526.097$, then this figure reduced to almost to less than a quarter of this figure in upper middle countries to reach 1526.097$, in lower middle-income countries recorded more reduction 501.2045$, while low-income countries evidenced minimum industry per capita valued added with the mean of 158.2017$.

The highest average of per capita value added in the sector of services was 18903.3$ in high income countries. This statistic reduced to 3198.222$ in upper middle-income countries, then reduced further to 1015.895$ in lower middle-income countries, while it recorded its lowest figure 314.7578$ in low-income countries.

Observing the average of GDP per capita in high income countries was quite high 29473.9$, then it lowered to 5604.936$, 1934.743$, and 703.0122$, in upper middle-income countries, lower middle-income countries, low-income countries, respectively.

4.2 Cross-Sectional Dependence Test

As commonly understood, a panel dataset consists of N countries or groups and T time (years, months…etc.), where a linear panel data model would take the following formula:

$$Yit = \alpha i + \beta Xit + Uit \quad (1)$$

for i=1, …, N, and t=1, …, T

Xit is a k×1 vector of regressors, β is a k×1 parameters to be estimated, αi is individual time invariant nuisance parameters. Uit is the model residuals, assumed independent and identically distributed (iid) across sections and over periods under the null hypothesis. And, correlated across units under the alternative hypothesis, but the assumption of no serial correlation remains.

In panel data usually the residuals are correlated due to common factors between the countries or across sections. To assess the existence of cross section dependence (CSD) between a panel data (Pesaran, 2004) CD test is employed in this study.

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1} . \sum_{j=i+1}^{N} \rho ij\right) \quad (2)$$

Where ρ_{ij} is the pairwise correlation of the residuals. $\hat{U}_{it}$ is the estimated U_{it} in (1)

$$\rho ij = \rho ji = \frac{\sum_{t=1}^{T} \hat{U}it\, \hat{U}jt}{\left(\sum_{t=1}^{T} \hat{U}it^2\right)^{1/2} \left(\sum_{t=1}^{T} \hat{U}jt^2\right)^{1/2}} \quad (3)$$

H0*: Cov (uit, ujt) = 0, for all t, i ≠ j, or the panels are cross sectionally independent.*

H1*: Cov (uit, ujt) ≠ 0, for all t, i ≠ j, or the panels are cross sectionally dependent.*

The results of CD test are illustrated in Table no. 2.

Table no. 2 – CD Test for the Four Groups Countries

Countries	CSD Test	L_E	AFF	IND	SER	GDP_PC
High income	Pesaran CD	179.261	6.213	56.026	148.757	137.898
	P-value	0.000	0.000	0.000	0.000	0.000
Upper middle income	Pesaran CD	118.9	29.45	76.48	140.84	126.5
	P-value	0.000	0.000	0.000	0.000	0.000
Lower middle income	Pesaran CD	120.22	38.39	37.91	125.46	96.43
	P-value	0.000	0.000	0.000	0.000	0.000
Low income	Pesaran CD	52.42	-1.43	11.39	13.56	12.39
	P-value	0.000	0.154	0.000	0.000	0.000

Notes: Under the null hypothesis of cross-section independence, CD ~ N (0,1) P-values close to zero indicate data are correlated across panel groups.

Source: researchers' calculations

Notice that all variables are cross sectionally dependent for each panel countries. As the CD tests p-values are less than 0.05, therefore, we reject the H0, and accept ***H1***, except for variable AFF in low-income countries, we accept ***H0***.

4.3 Series Stationarity (Unit Root) Test

Following the CD test results in Table no. 2, to examine the series stationarity (non-existence of unit root), the second-generation unit root test of Pesaran (2007) is used, which is known as Cross Sectional Augmented Dicky Fuller (CADF) test, the hypotheses are as the following:

H0: *the variable is non-stationary (the series contains a unit root),*
H1: *the variable is stationary (the series doesn't contain a unit root).*

Retrieving from Westerlund *et al.* (2015) the CADF statistic is:

$$\text{CADF}i = \frac{y'i, -1M_X \Delta y_i}{\sigma\epsilon, i\sqrt{y'i, -1M_X y_{i,-1}}} \quad (4)$$

where:

$M_X = I_{T-1} - x(x'x)^{-1}x',\ x = (\Delta\bar{y}, \bar{y}-1),\ \Delta y_i = (\Delta yi, 2, \dots, \Delta y_{i,T})',\ y_{i,-1} = (y_{i,1}, \cdots, y_{i,T-1})',$

$\Delta\bar{y} = N^{-1}\sum_{i=1}^{N} \Delta\, y_i$ with a similar definition of $\bar{y}-1$, and $\sigma^2\epsilon, i = T^{-1}(\Delta y_i)'^{M_X}\Delta y_i$.

Table no. 3 – Series Unit Root Test CADF

Countries	variable	Constant		constant and trend		Stationary at
		CADF	p-value	CADF	p-value	
High income	L_E	-2.1680	0.0020	-2.1880	0.8850	I(0)
	AFF	-2.4770	0.0070	-1.397	0.0810	I(0)
	IND	-9.7720	0.0000	-7.641	0.0000	I(1)
	SER	-8.8370	0.0000	-6.3470	0.0000	I(1)
	GDP_PC	-9.4830	0.0000	-6.978	0.0000	I(1)
Upper middle income	L_E	-2.267	0.0000	-2.642	0.0110	I(0)
	AFF	-16.382	0.0000	-14.661	0.0000	I(1)
	IND	-4.061	0.0000	-1.0210	0.1540	I(0)
	SER	-1.978	0.0240	2.934	0.9980	I(0)
	GDP_PC	-3.885	0.0000	1.139	0.8730	I(0)
Lower middle income	L_E	-2.246	0.0011	-2.185	0.8700	I(0)
	AFF	-16.365	0.0000	-14.640	0.0000	I(1)
	IND	-1.710	0.0440	-0.5290	0.2980	I(0)
	SER	-8.421	0.0000	-7.2610	0.0000	I(1)
	GDP_PC	-7.374	0.0000	-6.087	0.0000	I(1)
Low income	L_E	-2.6230	0.0000	-2.0310	0.9200	I(0)
	AFF *	0.3205	0.6257	-4.0853	0.0000	I(0)
	IND	1.6520	0.9510	-2.9230	0.0020	I(0)
	SER	-5.7520	0.0000	-6.1090	0.0000	I(1)
	GDP_PC	-3.6020	0.0000	-4.2000	0.0000	I(1)

Note: * Im–Pesaran–Shin (IPS) unit-root test for AFF due to the variable cross section independence as show in Table no. 2. The statistic of Z-t-tilde-bar is considered for CADF test, as the series has some gaps with one year lag.

Source: researchers' calculations

The results in Table no. 3 show that the series are stationary at the original level I(0) and first difference I(1). As their CADF statistics P-values are less than 0.05, therefore we reject H0 and accept H1, so we conclude that the series under investigation is stationary in the long run and doesn't contain a unit root for each (i) country (group).

4.4 Testing Model Slope Heterogeneity

The general form of this study's Four panel models high income countries (M1), upper middle-income countries (M2), lower middle-income countries (M3), and low-income countries (M4), for each group of countries is:

$$L\_E_{it} = \alpha_i + \beta_{1i}AFF_{it} + \beta_{2i}IND_{it} + \beta_{3i}SER_{it} + \beta_{4i}GDP\_PC_{it} + U_{it} \quad (5)$$

In this study Pesaran and Yamagata (2008) test of a model slope heterogeneity is adopted for testing the following hypothesis:

H0: *slope coefficients are homogenous.*

H1: *slope coefficients are heterogenous.*

or

H0: $\beta_{1i} = \beta_1,\ \beta_{2i} = \beta_2,\ \beta_{3i} = \beta_3,\ \beta_{4i} = \beta_4,$ *for i= 1, 2, …, N*

H1: $\beta_{1i} \neq \beta_1,\ \beta_{2i} \neq \beta_2,\ \beta_{3i} \neq \beta_3,\ \beta_{4i} \neq \beta_4,$ *for some i.*

Table no. 4 – Panel Model Slope Heterogeneity Test

Statistics	M1 High income countries		M2 Upper middle-income countries		M3 Lower middle-income countries		M4 Low-income countries	
	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value
Delta	44.019	0.000	35.572	0.000	39.935	0.000	21.638	0.000
adj. Delta	49.245	0.000	39.629	0.000	44.508	0.000	24.325	0.000

Source: researchers' calculations

Results in Table no. 4 indicate that the slopes of the specified models aren't homogenous for each of M1, M2, M3, and M4. As Delta and adjusted Delta statistics p-values are less than 0.05 for all four models. Therefore, we reject H0, and infer that the slops are heterogenous for each model.

4.5 CS-ARDL Approach

Cross-sectionally augmented autoregressive distributed lags model (CS-ARDL) of Chudik and Pesaran (2015), and Chudik *et al.* (2016) was developed in this research, both long-term and short-term assessments were estimated. In comparison to the mean group (MG), pooled mean group (PMG), common correlated effect mean-group (CCEMG), and augmented mean group (AMG), CS-ARDL require far less time and effort (Wang *et al.*, 2021). Based on another definition, this method solves seemingly undiscovered issues of endogeneity, non-stationarity, mixed-order integration, slope heterogeneity SH, and cross section dependency CSD (Chudik *et al.*, 2016).

The CS-ARDL derived from panel ARDL approach of Pesaran *et al.* (1999), where the dynamic panel model with heterogeneous slopes and an unobserved common factor (f_t) and a heterogeneous factor loading (γ_i) is:

$$y_{i,t} = \lambda_i \, y_{i,t-1} + \beta_i \, x_{i,t} + u_{i,t} \quad (6)$$

where

$u_{i,t} = \gamma`_i \, ft + e_{i,t}$

$\beta MG = 1/N \sum_{i=1}^{N} \beta i$, $\lambda MG = 1/N \sum_{i=1}^{N} \lambda i$, i = 1, ..., N, and t = 1, ..., T (Pesaran et al. 1999).

A more extended description of equation (6) with additional lags of the dependent and independent variable in the form of an ARDL (py, px) model is:

$$y_{i,t} = \sum_{j=1}^{p_y} \lambda_{j,i} y_{i,t-j} + \sum_{i=0}^{p_x} \beta_i x_{i,t-i} + u_{i,t} \quad (7)$$

where

p_y and p_x is the lag length of y and x.

The long run coefficient of β and the mean group coefficient are:

$$\theta_i = \frac{\sum_{i=0}^{p_x} \beta_{i,i}}{1 - \sum_{j=1}^{p_y} \lambda_{j,i}}, \quad \hat{\theta}MG = \frac{1}{N} \sum i = 1^N \widehat{\theta_\iota}$$

Chudik *et al.* (2016) proposed the cross-sectionally augmented ARDL (CS-ARDL) estimator as:

$$y_{i,t} = \sum_{l=1}^{p_y} \lambda_{l,i} y_{i,t-l} + \sum_{l=0}^{p_x} \beta_i x_{i,t-l} + \sum_{l=0}^{p_T} \gamma'_i \bar{z}t - l + ei,t \quad (8)$$

where the mean group estimates:

$$\hat{\theta}CS - ARDL, i = \frac{\sum_{l=0}^{p_x} \widehat{\beta}i}{1 - \sum_{l=1}^{p_y} \widehat{\lambda_{l,\iota}}} \quad , \quad \theta \,\hat{}\, MG = \sum_{i=1}^{N} \widehat{\theta_\iota}$$

And the Error Correction Model (ECM) transformation:

$$\Delta y_{i,t} = \phi_i [y_{i,t-1} - \theta_i x_{i,t}] - \sum_{l=1}^{p_y - 1} \lambda_{l,i} \Delta y_{i,t-l} - \sum_{l=1}^{p_x} \beta_i \Delta_l x_{i,t} + \sum_{l=0}^{p_T} \gamma_{i,l} \Delta \bar{z} i, t + ui, t \quad (9)$$

where:

$$\Delta \text{l} = \text{t} - \text{t} - \text{l}, \ \Delta x_{i,t} = x_{i,t} - x_{i,t-1}$$

$$\varphi\hat{}\ i = -(1 - \sum_{l=1}^{py} \lambda\hat{}\ l, i) \ , \ \theta_i = \frac{\sum_{l=0}^{p_x} \beta_{l,i}}{\phi\hat{}\ i} \ , \theta \,\hat{}\, MG = \sum_{i=1}^{N} \widehat{\theta_\iota}$$

where φˆ i is the error correction term (ECT), also known as the speed of adjustment, refers to the pace at which the model corrects itself in the long run, given a short run disequilibrium. Ideally, we anticipate the ECT to be statistically significant and range between -1 and 0, ensuring that the system returns to equilibrium.

4.6 The Estimated Models

The general formula for our four estimated models is as the following:

$$L\_E_{it} = \beta_0 + \beta_1 L\_E_{it-1} + \beta_2 AFF_{it} + \beta_3 IND_{it} + \beta_4 SER_{it} + \beta_5 GDP\_PC_{it} + U_{it} \quad (10)$$

where β’s are the estimated coefficients, L_E_{it-1} is lag dependent variable (life expectancy at birth), AFF_{it}, IND_{it}, SER_{it}, and GDP_PC_{it}, are the independent variables described previously at time t related to country i. Table no. 5 shows the estimated model for each group contraries denoted by M1, M2, M3, and M4.

Table no. 5 – The Estimated Models of Life Expectancy in Four Groups of Countries

CS-ARDL Model	M1			M2			M3			M4		
	Coef.	St. Err.	Z. Sta.	Coef.	St. Err.	Z. Sta.	Coef.	St. Err.	Z. Sta.	Coef.	St. Err.	Z. Sta.
Long-run Models												
AFF	-0. 02834	0.029	-0.960 (0.335)	-0. 00243	0.005	-0.500 (0.619)	-0.0352	0.0207	-1.70 (0.090)	-0.0642	0.0331	-1.9400 (0.0520)
IND	0. 00147	0.001	2.920 (0.004)	-0. 00572	0.003	-1.870 (0.061)	-0.0203	0.0113	-1.80 (0.072)	-0.0647	0.0302	-2.1500 (0.0320)
SER	0. 00131	0.000	2.670 (0.008)	-0. 00266	0.002	-1.740 (0.081)	-0.0205	0.0116	-1.75 (0.079)	-0.0639	0.0321	-1.9900 (0.0460)
GDP_PC	-0. 00132	0.000	-3.470 (0.001)	0. 00228	0.001	1.570 (0.117)	0.02199	0.0109647	2.01 (0.045)	0.0653	0.0286	2.28 (0.0220)
Constant	23.4625	59.2896	0.40 (0.692)	304.5222	266.211	1.14 (0.253)	-5.2477	25.1868	-0.21 (0.835)	7.5720	8.4464	0.9 (0.3700)
ECT	-0.956	0.081	-11.810 (0.000)	-0.839	0.080	-10.500 (0.000)	-0.4613	0.07481	-6.17 (0.000)	-0.7456	0.0891	-8.3700 (0.0000)
Short-run Models												
Lag L_E	0.04368	0.081	0.540 (0.590)	0.161	0.080	2.020 (0.043)	0.5386	0.07481	7.20 (0.000)	0.2544	0.0891	2.86 (0.0040)
AFF	-0. 000085	0.001	-0.090 (0.932)	0.00170	0.002	0.700 (0.482)	-0.0106	0.0061	-1.71 (0.087)	-0.0435	0.0212	-2.0500 (0.0400)
IND	0. 00075	0.000	2.740 (0.006)	-0. 00133	0.001	-0.980 (0.328)	-0.0105	0.0059	-1.76 (0.078)	-0.0560	0.0287	-1.9500 (0.0510)
SER	0. 00096	0.000	3.740 (0.000)	-0. 00114	0.001	-0.810 (0.420)	-0.0086	0.00537	-1.62 (0.10)	-0.0463	0.0204	-2.2700 (0.0230)
GDP_PC	-0. 00075	0.000	-3.500 (0.000)	0. 00120	0.001	0.940 (0.347)	0.0096	0.0052	1.83 (0.067)	0.0503	0.0204	2.47 (0.0140)
Constant	-1.0666	13.07207	-0.08 (0.935)	14.41935	32.95571	0.44 (0.662)	-16.6277	20.9009	-0.80 (0.426)	4.4391	7.2402	0.61 (0.5400)
Trend	-	-	-	.0669479	.0765283	0.87 (0.382)	-	-	-	-	-	-
Statistics												
Obs.		1310			1293			1211			450	
groups		48			44			40			16	
Avg. Obs. per group (T)		27			29			30			28	
cross-sectional lags		2			2			1			1	
R-squared		0.54			0.16			0.37			0.37	
R-squared (MG)		0.98			0.99			0.97			0.96	
Residuals CSD test		0.36 (0.7203)			1.51 (0.1321)			5.63 (0.0000)			-0.14 (0.8896)	

Note: P-values are between parentheses.
Source: researchers' calculations

5. COINTEGRATION TEST

The presence of long-run cointegration among panels is one of reliability checks for the estimated models, therefore, we employed the first-generation cointegration test of Neal (2014), and the second generation cointegration test of Westerlund *et al.* (2015), which assumes cross-sectional independence among the panels. The hypothesis being tested are:

H0: *panels aren't cointegrated.*

H1: *panels are cointegrated.*

Table no. 6 – Panel Cointegration Test

Test	M1 High income		M2 Upper middle income		M3 Lower middle income		M4 Low income	
	Constant	Constant and trend	Constant	Constant and trend	Constant	Constant and trend	Constant	Constant and trend
Westerlund	0.7183 (0.2363)	-1.3911 (0.0821)	-1.0671 (0.1430)	2.2702 (0.0116)	1.7966 (0.0362)	4.1196 (0.0000)	-0.6289 (0.2647)	0.2371 (0.4063)
Pedroni: Modified Phillips Perron t	1.7165 (0.0430)	1.9182 (0.0275)	4.1191 (0.0000)	4.3527 (0.0000)	2.9814 (0.0014)	2.3008 (0.0107)	1.3884 (0.0825)	2.5158 (0.0059)
Phillips–Perron t	-2.7241 (0.0032)	-2.3904 (0.0084)	2.2150 (0.0134)	2.2123 (0.0135)	-0.9748 (0.1648)	-2.5596 (0.0052)	-1.8687 (0.0308)	2.2039 (0.0138)
Augmented Dickey–Fuller t	-1.1726 (0.1205)	-1.8921 (0.0292)	2.6864 (0.0036)	2.3300 (0.0099)	0.0590 (0.4765)	-1.6221 (0.0524)	-0.5079 (0.3058)	3.3931 (0.0003)

Source: researchers' calculations

The results in Table no. 6 indicated long run cointegration among the series (variables) for each estimated model, as the calculated p-values are less than 0.05, generally with constant and trend. Therefore, we reject the ***H0*** and accept ***H1*** and conclude all countries (panels) for each estimated model are cointegrated (Neal, 2014).

6. THE ECONOMIC INTERPRETATION OF THE RESULTS

6.1 High income countries

The results of M1 in Table no. 5 show the existence of a positive relationship between an individual's yearly share of services, and life expectancy, at 1% significance level, in countries with high incomes. Therefore, as SER increases by $100, L_E will extend in the long run and the short run by 0.131, and 0.096 years, respectively, ceteris paribus. This might be attributed to an increase in health, education, water, and sewage services. This finding is compatible with economic theory, as well as the findings of Joshi *et al.* (2017); Esfahani *et al.* (2018); Radmehr and Adebayo (2022).

The results revealed a direct relationship between the individual's share of the value added in the sector of industry including construction, and the expected life span. So, as IND increases by $100, L_E will extend by 0.147, and 0.075 years, in long run and short run, respectively, ceteris paribus. Because in high income countries, the positive effects of industrial development are greater due to persistent improvements in the production process, transportation and communication.

Commonly an increase in the individual's share of GDP is expected to increase people's ability to access goods and services, which contributes to an increase in life expectancy. But the results of M1 are showing the opposite, thus as GDP_PC increases by $100, L_E will decrease by 0.132, and 0.075 years, in long run and short run, respectively, ceteris paribus. According to Freeman et al. (2020) similar result was appeared in Japan, which is the opposite with most studies of previous generations. Similarly, an inverse relationship was observed between the per capita share of AFF, and L_E, but with insignificant impact, because the associated P-value of the AFF coefficient is exceeding 10% significance level.

A one-year lag of L_E, represented as (L_Et-1), has a positive and weak impact on the current value of L_E. Therefore, if L_Et-1 extended by one year, L_E rises by 0.0436 years, assuming all other variables remain constant.

The coefficient of error correction term (ECT) is the rate which disequilibrium among variables adjusts back to their long-run equilibrium by a shock within a certain period of time. The value of ECT=-0.956, significant at the 1% level and has a negative sign, indicating that all estimated variables are cointegrated across time. This statistic indicates that 95.6% of the disequilibrium among variables has been adjusted to their long-run equilibrium during the current year at a convergence rate of 95.6%. However, for 100% adjustments to occur, 1/0.956 =1.046, or one year, four days, and six hours would be required. This means the value of life expectancy will be equal in both short and long periods within one year.

6.2 Upper Middle-Income Countries

The estimated model M2 of upper middle-income countries shows significant inverse relationship between each of IND, SER, and L_E in the long timeframe at 10% significant level. Therefore, as IND increases by $100, L_E will reduce by 0.57 years in the long run, ceteris paribus. Regarding SER, if it increases by $100, L_E will decrease by 0.26 years in the long run, ceteris paribus. These results are telling that both industry and services are contributing negatively to environmental pollution, urban migration and urban sprawl. the increased adverse effects, due to the misuse of economic resources as the disadvantages of these sectors are way more than their advantages on the expected lifetime, as the process of progress and change was a long-term process. As per Azodi *et al.* (2019) the negative relationship between services and life expectancy in this group is attributed to several reasons, including: the shortcomings in the provision of public health services, as the inefficient allocation of public funds hinders the provision of health services, which reduces life expectancy despite increased spending. Additionally, unequal income distribution lowers life expectancy. According to Wilkinson (2018) growing economic inequality has a negative influence on health and psychological well-being, reducing life expectancy. The indirect relationship is also in line with the findings of Pathirathne and Sooriyarachchi (2019). Moreover, increased spending has the potential to affect the ecosystem, resulting in reduced life expectancy (Fahlevi *et al.*, 2023; Vladimirskaya and Kolosnitsyna, 2023).

There is a week (insignificant at 10% level) positive relationship between the individual share of agricultural value added and expected life in the short term, but it has changed in the long term. This inverse relationship can be attributed to the use of toxic pesticides and chemical fertilizers, which cause pollution as it will have a negative impact on the expect age.

The impacts in long and short run time frames showed that GDP_PC has a positive relationship with L_E, as an increase in the individual's share of national product leads to an increase in life expectancy. As an outcome, when GDP_PC increases by $100, L_E extends by 0.226 and 0.12 years in the long and short terms, respectively, assuming that all other factors remain constant. Although this result is consistent with the economic theory and the results of most previous studies but the effect is insignificant as the associated p-values are bigger than 10% significance level in both long- and short-time frames.

A one-year lag of L_E, denoted as (L_Et-1), has a notable and positive influence on the present value of L_E at the 5% level. As a result, if L_Et-1 expands by one year, L_E rises by 0.161 years, providing all other variables stay constant.

The error correction coefficient of M2 is (-0.839), which is significant at the 1% level, and has a negative sign, implying that all estimated variables are cointegrated across time. Inferring the current year witnessed an 83.9% convergence rate in bringing variables back to their long-run equilibrium. We may conclude that the model achieves equilibrium with a 100% convergence rate within 1.19 years, that is, one year, one month, and nine days, meaning that the value of life expectancy will be 100% identical in both the short and long periods after 1.19 years.

6.3 Lower Middle-Income Countries

Observing M3 in Table no. 5 which is the estimated model for lower middle-income countries, the short- and long-term consequences of comparison are largely similar to those in high-middle income countries, however M3 shows the increase in the share of the individual services, industry and agriculture will lead to a significant reduction in life expectancy, at 10% significance level. The long run findings show as each of AFF, IND, and SER increases disjointedly by $100, L_E decreases by 3.52, 2.03, and 2.05 years, respectively, ceteris paribus. While the short run impact for these three variables showed reduction in the L_E by 1.06, 1.05, and 0.86 years, respectively. This negative impact may be attributed to lack of expertise and improper use of the available resources. As Madreimov and Li (2019) explained the relationship between the use of natural resources and life expectancy is in the form of an inverted U shape, and given that these countries are experiencing high population growth, the increase in the use of natural resources in these sectors (services, industry, agriculture) may have negative consequences over the environment and individual health, reducing life expectancy. Some industries, particularly those in developing nations, have a detrimental influence on the environment by increasing greenhouse gas emissions, which leads to increased sickness and mortality and, eventually, a decrease in life expectancy (Siddique and Kiani, 2020; Aslam *et al.*, 2023).

Per capita GDP has a significant positive impact on life expectancy at 5% significance level, which is greater than that of the upper middle income group countries. Thus, in the long term, M3 shows that when GDP_PC increases by $100, L_E increases by 2.19 years, assuming every other factor remains constant. In the short run, L_E would increase by 0.96 years for every $100 increase in GDP_PC, if all other factors remained constant. These outcomes align with the economic theory and the results of the majority of previous studies.

The effect of a one-year lag of L_E, i.e. (L_Et-1) on the current value of L_E is significant and positive at the 1% level. As a result, if L_Et-1 expanded by one year, L_E increases by 0.5386 years, assuming all other factors remain constant.

M3 error correction coefficient (-0.4613) is significant at the 1% level and has a minus sign, indicating the current year witnessed an 46.13% convergence rate in bringing variables back to their long-run equilibrium. Therefore, life expectancy model for group of lower middle-income countries reaches to equilibrium by a 100% convergence rate within 2.16 years.

6.4 Low Income Countries

M4 in Table no. 5 illustrates significant negative impact of per capita value added in the sectors of agriculture, industry, and services at 5% significance level. These consequences are more potent in both periods, when compared to the rest estimated models M1, M2, and M3, because growth in these economic sectors is usually slower while the negative consequences exceed the positive ones. The long run results show as each of the variables AFF, IND, and SER increases disjointedly by $100, then L_E reduces by 6.42, 6.47, and 6.39 years, respectively, ceteris paribus. Considering the short run results, we observe L_E reduces by 4.35, 5.60, and 4.64 years for $100 increase to these variables, ceteris paribus.

It is worth noting health services in this category countries have issues because they only provide certain treatments, and this fragmentation makes it difficult to provide comprehensive care, such as care for chronic diseases such as vascular and heart disease, so increasing health spending does not result in an increase in life expectancy (Reddy, 2001; Dudley and Garner, 2011). Also, inadequate sanitary infrastructure may impede the effectiveness of water purification processes, resulting in the spread of various illnesses and a decrease in life expectancy.

Per capita GDP has a greater positive impact on life expectancy in low-income countries comparing with the other three groups of countries. The results show a $100 increase in GDP_PC increases L_E by 0.65 years, if all remaining variables remain constant in the long run. accordingly, if GDP_PC increases by $100, then L_E extends by 5.03 years, all other factors being constant in the short run. This outcome is compatible with economic theory, because any rise in personal income in these nations will have a large influence on the provision of fundamental requirements of life, hence contributing to enhance life expectancy.

The effect of one year lag of L_E (L_Et-1) is significant and positive on the present value of L_E at 1% significant level. Therefore, if L_Et-1 increased by one year then L_E increased by 2.54 years, ceteris paribus.

The error correction coefficient is (-0.7456), which is significant at 1% level, showing the current year had a 74.56% convergence rate in adjusting the variables to their long-term equilibrium. Thus, to establish long-term equilibrium with a 100% convergence rate, low-income countries would take 1.34 years, or one year, three months, and four days.

7. CONCLUSIONS

As a result of measuring the impact of each of annual per capita value added in the sectors of agriculture fisheries and forestry, industry including construction, services and per capita GDP in constant 2015 US$ on life expectancy at birth, only the group of high-income countries experiences increases in life expectancy with increments in individual share of industry and services, unlike the other groups. Concerning the groups of upper middle income, lower middle income, and low-income countries, only the factor of per capita GDP increases life expectancy, this result is parallel to Cervellati and Sunde (2005); Gürler and Özsoy (2019); Radmehr and Adebayo (2022). While the remaining variables individual share in agriculture, industry, and services, decrease life expectancy.

The negative impact of per capita value added in the sectors of agriculture, industry and services, and the positive impact of the individual's share of the national product have witnessed a greater magnitude in the group of lower income countries.

The findings of the per capita value added in the sectors of agriculture, industry, and services in the higher, lower, and low-income countries, revealed negative relationships, which contradict with the economic theory. Reasons were provided for these contradictions and comparable outcomes from earlier studies, such as Cervellati and Sunde (2005); Pathirathne and Sooriyarachchi (2019); Radmehr and Adebayo (2022). The findings indicate to inefficiency in the management of these countries' resources, such as the presence of political, financial, and administrative corruption, income inequalities, and the agricultural, services, and industrial production being directed for export or for products that may harm health and life expectancy, such as global warming, tobacco, eco-pollution, noises, harmful radiations …etc.

In summary, the results showed that per capita GDP is a crucial component that is rising in scale as we move from upper-middle-income to lower-middle-income and low-income countries with regard of life expectancy. While per capita value added generated by the sectors of industry and services is an essential component in extending life expectancy in high-income countries. The speed of adjustment to reach long term equilibrium as a result of one shook in the short term is faster in high income countries comparing to the other groups of countries.

8. LIMITATIONS AND RECOMMENDATIONS

Due to the lack of complete data for a long period of time, we were forced to choose the period (1990-2022), but structural changes in economic sectors require a longer time. On the other hand, the data were intermittent for some countries in the four groups, so we removed a number of countries from the measurement, which may affect the measurement results. Therefore, we suggest that researchers, if more data would be available, repeat the research for a longer period of time and include other countries that were not studied in this research. In this study, the independent variables used are a set of parts, for example, the per capita share of added value in the agricultural sector, which includes agriculture, forestry and fisheries, as well as for industry and services. Researchers can divide these variables into smaller variables and then measure their impact on life expectancy.

We recommend other variables, such as culture, social values, working environment, political, security, and international relations stability, may have an influence on life expectancy at birth, plus those under inquiry. Thus, including such factors into future studies may result in more richer findings.

We advocate the authorities particularly in developing countries to reconsider their political and administrative plans, and seek to establish the foundations that are suitable to preserve public funds and direct them in the right direction, including: health spending to areas related to people's lives and maintaining their health, establishing an educational system with a tangible return, developing skills that meet the needs of the labor market, paying attention to agriculture and construction. And directing their efforts towards reaching sustainable development goals that suit the demands of the current generation while conserving resources for future generations.

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