

Health Expenditures, Education and Longevity in Algeria : An Empirical Analysis Using the VECM Model

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Abstract :

This paper investigates the relationship between health expenditures, education, and life expectancy in Algeria over the period 1990–2023 using a Vector Error Correction Model (VECM). Contrary to theoretical expectations, the findings reveal a paradox: both education and health expenditures are negatively associated with longevity. In the short run, only education contributes to correcting disequilibria, while health expenditures primarily respond to changes in life expectancy. These results highlight the importance of enhancing the quality and efficiency of education and health policies in order to foster longevity and promote sustainable human development.

Keywords : Health expenditure, education, longevity, VECM, Algeria.

Jel classification : I15, H51, H52, C22.

1. Introduction

Life expectancy is a key indicator of human development, simultaneously reflecting the performance of the health system, access to education, and overall living conditions. In developing countries, where budgetary and social constraints often limit public policies, examining the determinants of longevity becomes particularly relevant. Among these

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determinants, education encourages preventive behaviors and promotes an efficient use of health services, while health expenditures signal government commitment to improving both the supply and the quality of care. A joint analysis of these three dimensions—life expectancy, education, and health expenditure—thus provides an avenue to assess their respective roles and their interactions in fostering well-being and sustainable development.

A substantial body of empirical research accentuates the positive impact of schooling on life expectancy. Education enables individuals to adopt healthier behaviors, achieve higher incomes, and access better living conditions, while also facilitating access to healthcare. Women's education, in particular, contributes to reducing infant mortality and improving maternal health. These mechanisms confirm that schooling constitutes an essential determinant of population longevity.

The objective of this study is to empirically analyze the relationship between health expenditures, education, and longevity in Algeria by employing a Vector Error Correction Model (VECM). The article seeks to address the following research question: to what extent do education and health expenditures influence longevity in Algeria, both in the short run and in the long run?

2. Literature review

The review of prior research constitutes a fundamental step in situating the present study within its theoretical and empirical framework. It provides an opportunity to shed light on the major contributions of the literature, to identify the methodological approaches adopted, and to underscore both the convergences and divergences observed regarding the relationships between the examined variables.

-Cutler, D. M., & Lleras-Muney, A. (2012). Education and Health : Insights from International Comparisons. NBER Working Paper No. 17738.

The literature review investigates the education–health nexus across countries, showing robust empirical evidence of a positive correlation between educational attainment and health outcomes. Education is linked to lower malnutrition rates and healthier behaviors, though the effects exhibit heterogeneity : in developed economies, schooling is negatively correlated with BMI, while in developing contexts the correlation is often positive. Such differences reflect the role of socioeconomic environments in shaping health behaviors. Beyond correlation, the review emphasizes issues of causality, highlighting the need to address endogeneity through econometric strategies and identifying key transmission mechanisms-income, information efficiency, and preventive actions-through which education influences health.

-Galama, T. J., Lleras-Muney, A., & van Kippersluis, H. (2018). The Effect of Education on Health and Mortality: A Review of Experimental and Quasi-Experimental Evidence. NBER Working Paper No. 24225. Several studies have confirmed the existence of a strong correlation between education, health, and longevity, but the causal nature of this relationship remains controversial. Drawing on a human capital framework, some studies have examined the effects of education on mortality and on two of its leading preventable causes : smoking and obesity. Evidence from randomized trials, twin studies, and quasi-experiments shows no convincing effect of education on obesity, while impacts on smoking emerge only when school reforms alter the educational track pursued or the peer group, but not when education is limited to extending years of schooling. Regarding mortality, the effect of education appears to be context-dependent and seems to be contingent on gender, labor market returns, the quality of education, and the way education influences peer composition.

-Fletcher, J., & Nohganibehambari, H. (2021). The Effects of Education on Mortality : Evidence Using College Expansions. NBER Working Paper No. 29423.

A study using U.S. mortality data from the Social Security Administration (1988–2005), combined with 1940 census data, analyzed the impact of education on longevity. Exploiting variations in the availability of higher

education institutions across local cohorts, the authors showed that access to one additional four-year college around age 17 was associated with a 0.13-month increase in life expectancy. Estimates focusing on individuals directly affected suggested larger gains, ranging from 1 to 1.6 years of longevity. Robustness checks confirmed that these results were not due to pre-existing trends, endogenous migration, or other local time-varying factors. This contribution aligns with the literature documenting the health and social benefits of education.

-Issolah, F., Djemaci, B., & Kertous, M. (2021). Education, Health, and Economic Growth in Algeria : An Econometric Study Using the ARDL Model. *Dirassat Journal Economic Issues*, Vol. 12, No. 1. The objective of this study is to analyze the impact of human capital development on economic growth in Algeria, through a discussion of various empirical works and an econometric analysis based on the ARDL models, covering the period 1986–2017. The findings highlight a positive association between primary and secondary schooling and economic growth, whereas health expenditures are found to exert a negative effect on the latter.

-Kouassi, Y. A. G. (2021). Analysis of the Effects of Health Capital on Economic Growth in Côte d'Ivoire. *International Journal of Financial Accountability, Economics, Management, and Auditing*, No. 3. This study analyzes the effect of health capital, proxied by life expectancy, on economic growth in Côte d'Ivoire over the period 1974–2014. The analysis relies on a Vector Error Correction Model (VECM), complemented by the sequential application of the Granger non-causality test. The results reveal a unidirectional causal relationship, both in the short and long run, running from health capital to economic growth. These findings underscore the need to strengthen health programs to stimulate Ivorian economic growth and call for an increase in the budget allocated to the health sector in order to boost its long-term contribution to national economic development.

-Michel, J. P., Barriguete-Melendez, A., et al. (2023). Report 23-04. Inter-Academic Report : Educational Trajectories, Health, and Longevity. Bulletin of the French National Academy of Medicine, 207. The joint report by the French and Mexican Academies of Medicine stresses that education, beginning in early childhood, profoundly shapes health and longevity through mechanisms related to epigenetics, as well as family, socio-economic, and educational contexts. In this regard, acquiring adequate health literacy is key to adopting health-promoting behaviors and preventing chronic diseases. Noting that less-educated populations live shorter lives and spend more years with disability, the group therefore recommends targeted educational interventions for children and families, health professionals, and the elderly, with the indispensable support of public and academic authorities.

-Bonnin, A., Rives, N., & Lévi, Y. (2024). Report and Recommendations of the ANM Report 24-04. On Health-Prevention Education for Young Citizens. Bulletin of the National Academy of Medicine, 208. While the French health system is distinguished by high-quality care, it suffers from underdeveloped preventive measures, leading to health inequalities and adverse outcomes, including lower healthy life expectancy and higher obesity rates. In this context, the National Academy of Medicine emphasizes that strengthening prevention is both a major public health challenge and a prerequisite for the sustainability of health expenditures. Recognizing that education is a central determinant of health, an analysis of school curricula in France reveals limited and inconsistent consideration of preventive health topics. To address this gap, the Academy recommends an alliance between the education and health sectors to integrate, starting from preschool, a “health-prevention education for young citizens,” comparable to moral and civic education, with the aim of instilling healthy behaviors from an early age, both at the individual and collective levels.

Aris, S., Gorham, A. P., & Ji, J. (2024). Schooling and Longevity. Canadian Institute of Actuaries (CIA).

A study of U.S. populations revealed that the gap in life expectancy

between those with higher education and those without widened from 1990 to 2018. The author observed that although racial differences in life expectancy have narrowed, the schooling gap has grown between Black and White populations. This growing gap in life expectancy, attributable to differences in educational attainment, indicates that education has now become a more important differentiating factor in life expectancy than race.

Contribution of the Study

This study provides an innovative contribution by placing longevity at the core of the analysis, in contrast to previous research in Algeria that has primarily focused on economic growth. From a methodological standpoint, the use of the Vector Error Correction Model (VECM) enables the examination of both the short- and long-term relationships between health expenditures, education, and longevity. Finally, by focusing on the Algerian case, the study addresses an empirical gap in the African and Maghreb literature, which has paid relatively limited attention to the determinants of public health and longevity.

3. Theoretical Framework of the Relationship between Education, Health Expenditure, and Longevity

The scientific literature underscores the importance of the interactions between education, health expenditures, and life expectancy in analyzing the determinants of human development. Beyond its traditional role in skill accumulation and the enhancement of professional prospects, education increasingly appears as a structuring factor of health behaviors and the quality of life. At the same time, the efficient allocation of health expenditures constitutes a key determinant of the quality of care, prevention, and ultimately, life expectancy.

A. Education as a Determinant of Health and Longevity

The work of Cutler and Lleras-Muney (2012) demonstrates that education is generally correlated with better health, although the effects vary depending on the economic and social context. For instance, in developed countries, more educated individuals tend to adopt health-promoting

behaviors such as maintaining a lower Body Mass Index (BMI), whereas in some developing countries, a higher educational level may be associated with a higher BMI, reflecting differing nutritional contexts. Education, therefore, influences health not only through differentiated behaviors but also via the acquisition of health literacy.

This perspective is reinforced by the joint France–Mexico inter-academic report (Michel et al., 2023), which emphasizes the influence of educational trajectories from early childhood through epigenetic, familial, and socio-economic mechanisms. Education is thus seen as a cumulative resource that promotes prevention and delays the onset of chronic diseases. Similarly, Bonnin, Rives, and Lévi (2024) emphasize that preventive health education should be integrated into the school system in order to reduce health inequalities and improve healthy life expectancy.

Finally, a study by the Canadian Institute of Actuaries (Aris et al., 2024) reveals that the longevity gap by educational level widened in the United States between 1990 and 2018, to the point of becoming a stronger determinant than race. This illustrates the increasing importance of education as a key determinant of health and longevity trajectories.

B. The Causality Question : Education, Behaviors, and Mortality

Although the correlation between education and health is well documented, the causal mechanisms remain debated. The work of Galama, Lleras-Muney, and van Kippersluis (2018) shows that the effect of education on mortality is context-dependent and influenced by factors such as gender, the quality of schooling, and peer effects. Their results suggest that education does not mechanically translate into better health but operates through intermediate social and economic channels.

Complementing this, Fletcher and Noghanibehambari (2021), exploiting a natural experiment linked to college expansions in the United States, provide robust evidence of a positive effect of education on longevity, with gains in life expectancy of up to 1.6 years. These findings reinforce the

view that expanded access to higher education serves as a significant lever for improving public health outcomes.

C. The Education–Health–Economic Growth Nexus

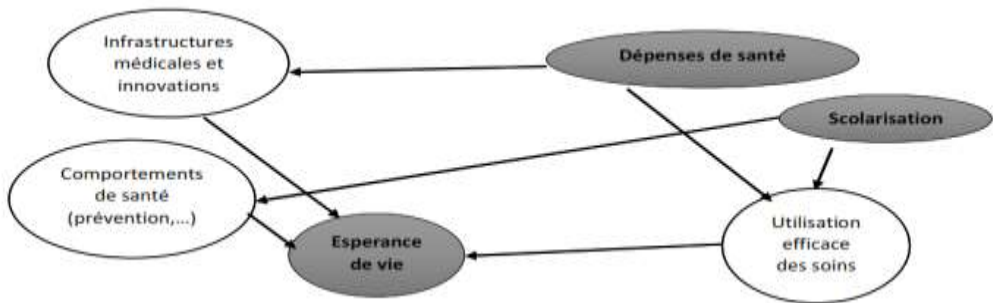
Beyond its direct effects on health, education contributes to economic growth through human capital. In Algeria, the study by Issolah, Djemaci, and Kertous (2021) demonstrates a positive relationship between primary and secondary schooling and economic growth, although health expenditures may exert a negative effect on growth when not allocated efficiently.

Similarly, in Côte d'Ivoire, Kouassi (2021) shows that health capital, measured by life expectancy, demonstrates a unidirectional causality toward economic growth, both in the short and long term. This implies that improving public health through education and health investments serves as a driver of sustainable economic development.

The relationship between life expectancy, schooling, and health expenditures can thus be understood through several theoretically and empirically established mechanisms. Education fosters the acquisition of health literacy and behaviors—such as prevention, hygiene, and improved nutritional practices—that reduce the prevalence of diseases and enhance overall quality of life. Moreover, higher educational attainment increases employment opportunities and income, thereby facilitating access to medical care and a balanced diet and strengthening the capacity to finance health expenditures. These expenditures, in turn, play a central role in extending longevity, as they determine the quality, efficiency, and availability of healthcare services. Finally, education and health investment generate positive externalities at the societal level, diffusing beneficial health and social norms across the population. Hence, the synergy between schooling and health expenditures represents a fundamental determinant in improving life expectancy.

Here is a conceptual diagram illustrating the theoretical framework of the relationship between life expectancy, schooling, and health expenditures. These variables interact through multiple channels and converge toward the enhancement of life expectancy.

Figure 1. The Triplet: Life Expectancy, Education, and Health Expenditures



4. Methodology

This section outlines the methodological approach applied to investigate the relationship between health expenditures and life expectancy in Algeria. It specifies the utilized data sources, the selected variables, and the applied econometric approach.

4.1. Definition of the Study Variables

- **Health Expenditures** : Health expenditures represent the total financial resources mobilized to provide prevention, medical care, rehabilitation, and the management of the healthcare system. They encompass both public funding (state, social security) and private contributions (households, insurance), reflecting the level of a country's commitment to preserving health and improving the well-being of its population.

- **Education**: Education refers to the process through which individuals acquire knowledge, skills, and values. At the macroeconomic level, it is generally measured through enrollment rates and educational attainment levels, thereby serving as an indicator of human capital that directly

contributes to economic and social development through productivity and innovation.

• **Longevity:** Longevity refers to the average lifespan of a population, most often measured by life expectancy at birth. It reflects the overall health status and quality of healthcare services, while also capturing the influence of socioeconomic factors such as educational attainment and living conditions.

4.2. The Econometric Model

VECM specification for the variables: Life Expectancy, Education, and Health Expenditures

- **LESPt:** life expectancy (log-transformed or in levels, depending on specification),
- **DLEDUt:** education (first-differenced log to achieve stationarity),
- **LGHEt:** health expenditures (log-transformed).

The Vector Error Correction Model (VECM) allows for modeling both short-run and long-run relationships among non-stationary but cointegrated variables. In this case, the three variables examined are life expectancy (LESP), education (DLEDU), and health expenditures (LGHE).

-Vector of Variables

We consider the following vector of endogenous variables:

$$Y_t = \begin{pmatrix} LESPt \\ DLEDUt \\ LGHEt \end{pmatrix}$$

- General Form of the VECM

The VECM of order p can be written in the following form:

$$\Delta Y_t = \alpha \beta Y_{t-1} + \sum_{i=1}^p \Gamma_i \Delta Y_{t-i} + \varepsilon_t$$

Where:

- β contains the cointegration vectors (long-term relationships),

- α contains the adjustment coefficients (speeds of adjustment to disequilibria),
- Γ_1 represent the short-term dynamics.

- Explicit expression for our variables :

Considering a VECM (2) model, we have :

$$[\Delta \text{LESP}_t, \Delta \text{DLEDU}_t, \Delta \text{LGHE}_t]' = \alpha \beta' [\text{LESP}_{t-1}, \text{DLEDU}_{t-1}, \text{LGHE}_{t-1}]' + \Gamma_1 [\Delta \text{LESP}_{t-1}, \Delta \text{DLEDU}_{t-1}, \Delta \text{LGHE}_{t-1}]' + \varepsilon_t$$

- Expanded form of the equations

a) Equation for life expectancy (LESP):

$$\Delta \text{LESP}_t = \alpha_1(\beta_1 \text{LESP}_{t-1} + \beta_2 \text{DLEDU}_{t-1} + \beta_3 \text{LGHE}_{t-1}) + \gamma_{11} \Delta \text{LESP}_{t-1} + \gamma_{12} \Delta \text{DLEDU}_{t-1} + \gamma_{13} \Delta \text{LGHE}_{t-1} + \varepsilon_{1t}$$

b) Equation for education (DLEDU):

$$\Delta \text{DLEDU}_t = \alpha_2(\beta_1 \text{LESP}_{t-1} + \beta_2 \text{DLEDU}_{t-1} + \beta_3 \text{LGHE}_{t-1}) + \gamma_{21} \Delta \text{LESP}_{t-1} + \gamma_{22} \Delta \text{DLEDU}_{t-1} + \gamma_{23} \Delta \text{LGHE}_{t-1} + \varepsilon_{2t}$$

c) Equation for health expenditures (LGHE):

$$\Delta \text{LGHE}_t = \alpha_3(\beta_1 \text{LESP}_{t-1} + \beta_2 \text{DLEDU}_{t-1} + \beta_3 \text{LGHE}_{t-1}) + \gamma_{31} \Delta \text{LESP}_{t-1} + \gamma_{32} \Delta \text{DLEDU}_{t-1} + \gamma_{33} \Delta \text{LGHE}_{t-1} + \varepsilon_{3t}$$

Here:

- $\beta_1, \beta_2, \beta_3$ describe the long-term cointegration relationship (e.g., how life expectancy structurally depends on education and health expenditures).
- $\alpha_1, \alpha_2, \alpha_3$ indicate the speed of adjustment toward equilibrium.
- γ_{ij} represent the short-term effects.

5- Results

The construction of the VECM model in this study is based on the following steps:

- Stationarity tests (ADF and PP).

- Johansen cointegration test to verify the existence of long-term relationships.
- Estimation of the VECM to capture both short- and long-term dynamics.
- Granger causality test.
- Analysis through impulse response functions (IRF) and variance decomposition (VDC).

The use of the VECM is justified by the need to account for both short-term adjustments and long-term structural relationships among the variables.

5.1. Stationarity Test of the Time Series

The following table presents the results of the Phillips-Perron (PP) unit root test for each series.

Table 1. Stationarity Test of the Time Series

Variables	Models	Level	First diff	Decision
lesp	Intercept	0.7819	0.0000	I(1)
	Trend and Intercept	0.7413	0.0000	I(1)
	None	0.9978	0.0000	I(1)
lghe	Intercept	0.7729	0.0000	I(1)
	Trend and Intercept	0.3744	0.0001	I(1)
	None	0.9428	0.0000	I(1)
dledu	Intercept	0.2212	0.0000	I(1)
	Trend and Intercept	0.4826	0.0000	I(1)
	None	0.2239	0.0000	I(1)

Examining the probabilities across the different specifications reveals that all variables exhibit a unit root in all cases at the level, but become stationary after applying the first difference, which classifies them as I(1).

5.2. Johansen Cointegration Test to Verify the Existence of Long-Term Relationships

Since all the series are non-stationary and integrated of order 1, it is therefore appropriate to perform a cointegration test in order to investigate the existence of long-term relationships among the variables used in our study, which we aim to estimate.

Table 2. Results of the Johansen Cointegration Test (Trace Statistic)

Null hypothesis	Eigenvalue	Trace statistic	Critical value (5%)	p-value	Result
No cointegration	0.389	31.54	29.79	0.031	Reject H0
At most 1 cointegration	0.363	16.26	15.49	0.038	Reject H0
At most 2 cointegrations	0.071	2.29	3.84	0.129	Do not reject H0

The results indicate the existence of cointegration, with at least two cointegrating relationships among longevity, education, and health expenditures in Algeria at the 5% significance level.

Table 3. Normalized Cointegration Vectors

Variables	Relation 1	Relation 2
LESP (life expectancy)	1.000	0.000
DLEDU (education)	11.24	1.000
LGHE (health expenditures)	-0.066	0.0025

The econometric analysis highlights a positive and robust long-term effect of health expenditures on life expectancy, confirming their role as a structural determinant of longevity. In contrast, the impact of education appears more nuanced: although negative in certain short-term specifications, it tends to become positive in the long run, suggesting that its structural benefits gradually materialize through improvements in health and life duration.

Table 4. Adjustment Coefficients (alpha)

Dependent variable	Eq. 1	Eq. 2
ΔLESP	-0.016	0.260

Δ DLEDU	0.151	-0.612
Δ LGHE	6.502	-3.075

The results indicate that the adjustment to long-term disequilibria is primarily driven by health expenditures and education, which appear as the most responsive variables in the model's dynamics. Conversely, life expectancy exhibits relative rigidity, reflecting low sensitivity to short-term shocks and slow adjustment toward long-term equilibrium. Therefore, public policy should focus on strengthening health expenditures and fostering synergies with education to achieve sustainable improvements in life expectancy.

5.3. Lag Length Determination

Before estimating the VECM model, it is essential to select the appropriate lag length in order to prevent error autocorrelation, which could undermine the validity and robustness of the results. Table (5) reports the values chosen by the different lag selection criteria.

Table 5. Lag Length Determination According to Several Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	154.6664	NA	5.75e-09	-10.45975	-10.31831	-10.41546
1	215.9994	105.7465	1.57e-10	-14.06893	-13.50315*	-13.89173
2	224.1208	12.32215	1.70e-10	-14.00833	-13.01822	-13.69824
3	243.7946	25.77942*	8.66e-11	-14.74446	-13.33001	-14.30147
4	257.7569	15.40668	6.92e-11*	-15.08668*	-13.24791	-14.51080*

The choice of a lag length of 4 proves to be appropriate, as indicated by the FPE, AIC, and HQ criteria.

5.4. Estimation of the VECM cointegration model

Table 6. Cointegration Relation (Long Term)

Variable	Coefficient	Std. Error	t-Statistic
LESP(-1)	1.000000	—	—

DLEDU(-1)	-7.8265	(1.8396)	[-4.254]
LGHE(-1)	-0.1954	(0.0254)	[-7.691]
Constant (C)	-3.8602	—	—

The table reports the cointegration equation extracted from the VECM, which captures the long-term relationship among life expectancy, education, and health expenditures. The coefficient associated with the differenced education variable DLEDU(-1) is negative and significant (-7.8265; $t=-4.254$), suggesting that an increase in educational attainment is correlated, within this model, with a decrease in life expectancy in the long run. This paradoxical finding may be attributed to structural specificities of the context under study, such as the low quality of the education system or a mismatch between schooling and direct health outcomes.

Similarly, the coefficient for health expenditures LGHE(-1) is also negative and highly significant (-0.1954; $t=-7.691$), indicating that, in the long term, an increase in health expenditures is associated with a reduction in life expectancy. This counterintuitive relationship may reflect inefficiencies in resource allocation, a large share of spending devoted to curative rather than preventive care, or even reverse causality (i.e., expenditures rising when health deteriorates).

Finally, the negative constant (-3.8602) reflects a structurally unfavorable baseline level of longevity in the absence of improvements in education and health.

In summary, the equation indicates the existence of a significant long-term relationship, though with paradoxical effects, as both education and health expenditures appear negatively associated with life expectancy. This unexpected result underlines the need to focus more on the quality and effectiveness of investments in these sectors rather than their sheer volume. It may be explained by inefficiencies in the education and health systems, reverse causality mechanisms, or budget reallocations unfavorable to other key determinants of well-being.

Table 7. Error Correction Mechanism (Short Term)

Variable	Δ LESP	Δ DLEDU	Δ LGHE
CointEq1	0.0708	0.1435***	0.2469
	(0.0589)	(0.0310)	(0.4912)
	[1.201]	[4.622]	[0.503]
Main regressors (extracts)	...	...	...

The estimation of the error correction term shows that only the equation related to education (Δ DLEDU) reacts significantly to long-term disequilibria, with a positive and highly significant coefficient (0.1435; $t = 4.622$). This underscores a central adjustment role of education in the dynamics of the system. In contrast, life expectancy (Δ LESP) and health expenditures (Δ LGHE) display non-significant coefficients, suggesting a low short-term sensitivity to deviations from the long-term equilibrium.

Table 8. Model Validation Statistics

Indicator	Δ LESP	Δ DLEDU	Δ LGHE
R^2	0.228	0.753	0.884
Adjusted R^2	-0.490	0.524	0.776
F-statistic	0.317	3.290	8.198
AIC	-5.923	-7.205	-1.682
SC	-5.257	-6.539	-1.016

The analysis of the diagnostic statistics reveals notable differences across the model's equations. The equation for the variation in life expectancy (Δ LESP) exhibits a very weak explanatory power ($R^2 = 0.228$, negative adjusted R^2) and an insignificant Fisher statistic, indicating that the explanatory variables do not meaningfully contribute to the short-term dynamics of longevity. By contrast, the education equation (Δ DLEDU) displays a satisfactory R^2 (0.753) and an acceptable overall significance, reflecting a stronger sensitivity of education to disequilibria. As for the health expenditures equation (Δ LGHE), it stands out with a high explanatory power ($R^2 = 0.884$, adjusted $R^2 = 0.776$) and a strong Fisher statistic, confirming that this variable constitutes one of the main adjustment channels.

These results suggest that, within the VECM framework, the adjustment to long-term disequilibria relies primarily on education and health expenditures, whereas life expectancy remains relatively rigid and adjusts more slowly.

5.5. LM Test for Residual Autocorrelation

To ensure the validity of the econometric results, it is essential to verify the absence of autocorrelation in the model's residuals. For this purpose, the LM test (Lagrange Multiplier Test) is employed to detect the potential presence of serial correlation among the errors. The null hypothesis states the absence of autocorrelation, while its rejection would indicate model misspecification or the need to adjust the lag structure.

Table 9. LM Test for Residual Autocorrelation

Lags	LM-Stat	Prob
1	4.153315	0.9010
2	9.554866	0.3877
3	10.37909	0.3207
4	1.900634	0.9929
5	12.58819	0.1821
6	3.508160	0.9407
7	13.08337	0.1589
8	7.803199	0.5541
9	18.98319	0.0253
10	6.050765	0.7348
11	10.88285	0.2838
12	3.901039	0.9178

The LM test of serial correlation in the residuals confirms the absence of autocorrelation up to lag 12, with the exception of lag 9, which shows a significant probability. Overall, the VECM model is properly specified and does not exhibit any major issue of serial correlation.

5.6. White Test for Heteroskedasticity

To ensure the validity of the econometric results and eliminate the risk of non-constant variance in the residuals, the White test for heteroskedasticity was applied. The results allow assessment of the presence or absence of heteroskedasticity in the estimated model.

Table 10. Results of the White Heteroskedasticity Test

Indicator	Chi ²	df	Prob.
Global test	159.8845	156	0.3991

Individual components

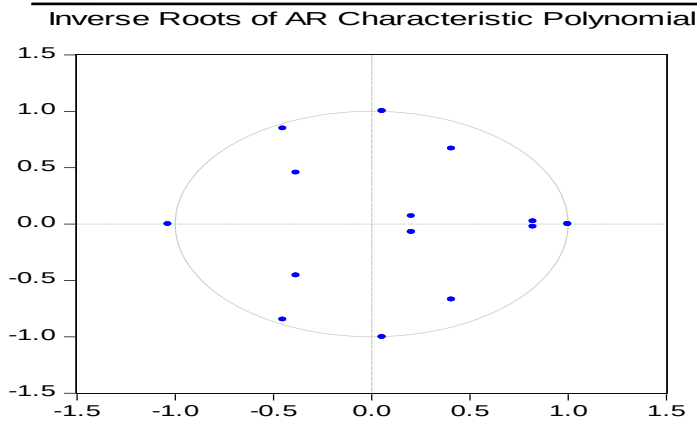
Dependent	R ²	F(26,1)	Prob.	Chi ² (26)	Prob.
res1*res1	0.807224	0.161053	0.9806	22.60227	0.6553
res2*res2	0.999981	2019.818	0.0176	27.99947	0.3585
res3*res3	0.987162	2.957504	0.4341	27.64054	0.3764
res2*res1	0.995539	8.582519	0.2644	27.87508	0.3646
res3*res1	0.864642	0.245686	0.9459	24.20999	0.5640
res3*res2	0.996886	12.31327	0.2221	27.91281	0.3628

The null hypothesis of homoskedastic residuals is not rejected, either by the global test ($p = 0.399$) or at the level of the individual components (all p -values > 0.05). The VECM model therefore does not suffer from heteroskedasticity issues, which confirms the robustness of the estimates.

5.7. Inverse Roots of the AR Characteristic Polynomial Test

As part of validating VAR/VECM models, it is indispensable to verify their dynamic stability. This verification is carried out using the inverse roots of the autoregressive (AR) characteristic polynomial test.

Figure 02. Stationarity Test



The model is considered stable and correctly specified as long as all the inverse roots of the autoregressive polynomial lie strictly within the unit circle in the complex plane.

5.8. Analysis of the model's variance

Table 11. Forecast Error Variance Decomposition (FEVD)

Horizon	Dependent Variable	LESP (%)	DLEDU (%)	LGHE (%)
1	LESP	100.0	0.0	0.0
5	LESP	95.0	0.9	4.1
10	LESP	86.1	2.9	11.0
1	DLEDU	0.1	99.9	0.0
5	DLEDU	18.5	57.6	23.9
10	DLEDU	33.8	24.5	41.8
1	LGHE	5.0	0.6	94.4
5	LGHE	57.6	2.1	40.3
10	LGHE	64.1	2.4	33.5

The variance decomposition results reveal that:

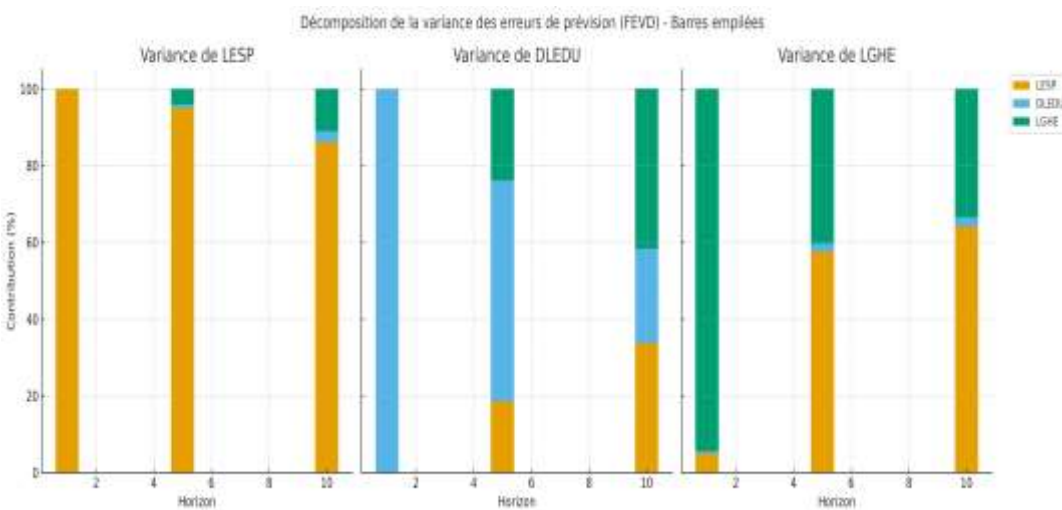
- The evolution of LESP (life expectancy) is mainly explained by its own innovations ($\approx 86\%$ at the 10-period horizon), but the contribution of health expenditures (LGHE) gradually becomes significant ($\approx 11\%$).

- The fluctuations of DLEDU (education) are increasingly influenced by LGHE and LESP (around 42% and 34% respectively at the 10-period horizon), which highlights a strong interdependence.
- The variance of LGHE is explained in the long run by LESP ($\approx 64\%$) and by its own dynamics ($\approx 34\%$), reflecting a feedback relationship between health expenditures and life expectancy.

Thus, the results confirm a dynamic interdependence between life expectancy, education, and health expenditures. Life expectancy remains largely endogenously determined but is influenced by health expenditures. Education, in turn, becomes increasingly sensitive to health and longevity over time. Finally, health expenditures appear to be strongly determined by the evolution of life expectancy, which points to a feedback mechanism between improved longevity and the intensification of health investments.

The figure below illustrates the results of the forecast error variance decomposition (FEVD) obtained from the VECM. This decomposition quantifies the relative contribution of each variable to the fluctuations of the others across different forecast horizons.

Figure 03. Forecast Error Variance Decomposition (FEVD) for LESP, DLEDU, and LGHE



5.9. Estimation of Impulse Response Functions

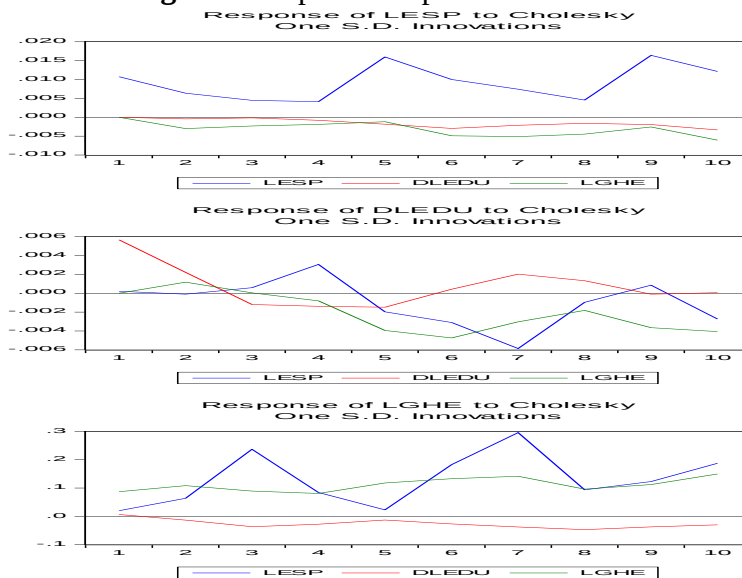
The following table reports the estimated impulse response functions, which allow the observation of the dynamic reaction of each variable in response to a shock affecting the others.

Table 12. Results of the Impulse Response Function Estimation

Shock Variable →	Response of	Period 1	Period 5	Period 10
LESP	LESP	0.0107	0.0160	0.0121
	DLEDU	0.0000	-0.0018	-0.0034
	LGHE	0.0000	-0.0012	-0.0061
DLEDU	LESP	0.0002	-0.0020	-0.0027
	DLEDU	0.0057	-0.0015	0.00006
	LGHE	0.0000	-0.0039	-0.0041
LGHE	LESP	0.0200	0.0230	0.1876
	DLEDU	0.0066	-0.0130	-0.0300
	LGHE	0.0870	0.1180	0.1500

Based on the estimates reported in the previous table, the following figure graphically illustrates the impulse response functions, allowing the visualization of the dynamic impact of shocks on the different variables through time.

Figure 4. Impulse Response Functions



Based on the impulse response functions, several findings can be drawn. First, life expectancy (LESP) reacts positively to its own shock, with a persistent and significant effect over a ten-period horizon. This pattern indicates a strong dependence of the variable on its own dynamics, while exogenous shocks originating from education (DLEDU) and health expenditures (LGHE) generate negligible and statistically insignificant responses, suggesting the absence of short-term effects within this model.

Second, a positive shock to education (DLEDU) produces a dynamic characterized by high volatility: the variable responds positively up to the seventh period before subsequently declining. By contrast, shocks originating from life expectancy (LESP) and health expenditures (LGHE) exert a negative effect on education, particularly pronounced between the second and sixth periods. These results imply that the dynamics of DLEDU are largely self-sustained, while an unexpected rise in life expectancy or health expenditures tends to constrain educational outcomes, possibly through resource reallocation mechanisms or macroeconomic pressures.

Finally, health expenditures (LGHE) respond strongly to a shock to life expectancy (LESP), with a positive and persistent effect, punctuated by notable peaks around the third and sixth periods. Conversely, exogenous shocks from education (DLEDU) generate a slightly negative and enduring effect. As for shocks specific to LGHE, they induce a moderately positive response that increases over time. These results suggest that improvements in life expectancy translate into sustained and notable increases in health expenditures, while education exerts a somewhat constraining effect, and the endogenous dynamics of LGHE simultaneously contribute to its growth.

Conclusion

The empirical analysis reveals a paradoxical long-term relationship, in which education and health expenditures appear negatively associated with life expectancy. This result, at odds with theoretical expectations, is likely explained by structural inefficiencies in the education and health systems, by reverse causality effects, or by budgetary reallocations at the expense of

other key determinants of well-being. In the short run, only education helps correct disequilibria, while longevity depends primarily on its own dynamics. Health expenditures, for their part, respond strongly to changes in life expectancy, confirming the presence of reverse causality, whereas education tends to become increasingly shaped by health and longevity over the long term.

These findings suggest the existence of bidirectional causality between longevity and health expenditures, with education playing a secondary but increasingly important role. They further underscore that longevity does not depend solely on the volume of investments in health and education, but rather on their quality and effectiveness.

Situating our results in the context of prior research reveals both convergences and divergences. Most studies conducted in different contexts—such as those of Cutler and Lleras-Muney (2012), Galama, Lleras-Muney and van Kippersluis (2018), Fletcher and Noghanibehambari (2021), Michel et al. (2023), Bonnin, Rives and Lévi (2024), and Aris et al. (2024)—confirm a positive relationship between education, health, and longevity, stressing the crucial role of human capital in improving health behaviors, prevention, and reducing mortality. These conclusions contrast with our results, where education and health expenditures appear negatively correlated with life expectancy in the long run, pointing to structural specificities inherent to the Algerian case.

Nevertheless, our results converge with certain studies that highlight paradoxes or context-dependent effects. Galama et al. (2018), for instance, emphasize the non-systematic and sometimes limited nature of the causal effect of education on mortality and risk-related behaviors. Similarly, the study by Issolah, Djemaci and Kertous (2021) identifies a negative effect of health expenditures on economic growth in Algeria, which is consistent with our findings regarding the potential inefficiency of the health system. In a similar vein, Kouassi (2021) shows that in the Ivorian case, the health–growth dynamic is marked by unidirectional causality, echoing the reverse

causality hypothesis raised in our analysis, whereby life expectancy exerts a stronger influence on health expenditures than the reverse.

Ultimately, our results deviate from the dominant literature confirming the positive role of human capital for longevity, but they resonate with more recent and contextualized studies underscoring that the impact of education and health is not automatic and may strongly depend on institutional quality, the allocation of expenditures, and the broader socio-economic context.

In light of these findings, and given the divergences observed with respect to international literature, it appears crucial to formulate recommendations aimed at enhancing the effectiveness of educational and health policies in Algeria, with an emphasis on the quality of services rather than their sheer volume, so as to transform such investments into effective levers of longevity and human development.

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