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Suggested Citation: Chakroun, Mohamed (2024) : Health and economic growth: new evidence from a panel threshold model, Cogent Economics & Finance, ISSN 2332-2039, Taylor & Francis, Abingdon, Vol. 12, Iss. 1, pp. 1-13,
<https://doi.org/10.1080/23322039.2024.2331010>

This Version is available at:

<https://hdl.handle.net/10419/321464>

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To cite this article: Mohamed Chakroun (2024) Health and economic growth: new evidence from a panel threshold model, Cogent Economics & Finance, 12:1, 2331010, DOI: [10.1080/23322039.2024.2331010](https://doi.org/10.1080/23322039.2024.2331010)

To link to this article: <https://doi.org/10.1080/23322039.2024.2331010>



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Health and economic growth: new evidence from a panel threshold model

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ABSTRACT

The paper examines the relationship between health and economic growth using a dynamic panel with threshold effect and endogeneity. The study uses a sample of 136 countries over the period of 1965–2015 and the results indicate that the relationship between health and economic growth is nonlinear. The findings suggest that the impact of health on economic growth is only positive in countries that have attained minimum benchmarks of health improvement. These findings carry significant policy implications. Low-income countries need a comprehensive approach, encompassing multiple factors, such as education enhancement, productivity boost, and entrepreneurship promotion, that go beyond health promotion to foster substantial economic growth. In countries already attaining satisfactory health outcomes, policies prioritizing improved health outcomes, through directing investments towards Research and Development can serve as an effective means to promote sustainable economic growth.

IMPACT STATEMENT

The paper provides an in-depth analysis of the relationship between health and economic growth. By explicitly examining potential non-linearities and thresholds, the study offers insights into how variations in health status may influence economic growth differently across different thresholds or stages of development. By identifying the key health thresholds, the research provides policymakers with actionable insights to allocate resources effectively. This guidance is critical for crafting targeted policies that maximize the impact of health investments on economic development.

ARTICLE HISTORY

Received 23 October 2023
Revised 22 January 2024
Accepted 10 March 2024

KEYWORDS

Health; economic growth; threshold models; instrumental variables; life expectancy

JEL CLASSIFICATION CODES

I10; O47; C22

REVIEWING EDITOR

Goodness Aye, University of Agriculture, Makurdi, Nigeria

SUBJECTS

Health & Development; Economics; Econometrics

1. Introduction

The nexus between human capital and economic growth constitutes a longstanding focal point in economic inquiry. The trajectory set by new growth theory underscores the pivotal role of human capital accumulation as a fundamental catalyst for a nation's wealth and prosperity (see for instance: Barro, 1991; Benhabib & Spiegel, 1994; Romer, 1990).

While macroeconomists widely acknowledge the contribution of human capital to economic growth, their empirical inquiries predominantly gauge human capital through the prism of education (Bloom et al., 2001). Notwithstanding, insights from early thinkers, such as Bentham (1789) and Marx (1867) accentuated the significance of health as a pivotal component of human well-being and reproduction. Similarly, scholars like Mushkin (1962) and Schultz (1961) underscored that health constitutes a form of human capital as crucial as education.

However, it was only in the 1980s and 1990s, concomitant with the development of endogenous growth theories and the emergence of health economics as a distinct field of study, that a substantial resurgence of interest in health investment, financing, and their repercussions on economic growth materialized.

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

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Presently, the role of health in economic growth garners wide acceptance across both theoretical and empirical realms. In conjunction with education, health emerges as a sector encompassing the principal drivers of endogenous growth, including research and development, human capital, and public expenditure (Barro & Sala-i-Martin, 1995; Lim, 1996).

Despite the growing consensus on the role of health in economic growth, a pronounced discrepancy persists between theoretical propositions and empirical investigations. Recent theoretical literature increasingly acknowledges a non-linear correlation between health and economic growth. However, this theoretical insight has not been fully translated into empirical investigations, as existing studies predominantly rely on linear models to explore the relationship between health and economic growth. This discrepancy highlights a notable gap in the current research paradigm, with the inherent complexities and potential thresholds in this relationship remaining largely unexplored or inadequately addressed in empirical studies. This underscores the necessity for more advanced methodological approaches to bridge the gap between theory and empirical exploration.

In this paper, we use a panel threshold model that addresses this research gap by acknowledging and exploring nonlinearities in the relationship between health and economic growth. The advantage of such a model is that it allows for heterogeneity in the convergence and divergence regimes, in terms of growth rates and levels. It suggests that economies that differ in their initial conditions may not converge. Such an approach, considering the existence of multiple equilibria, is thus useful to allow heterogeneity in the specification of convergence equations (Bernard & Jones, 1996).

Considering threshold effects in the relationship between health status and economic growth is noteworthy for several compelling reasons: different countries may exhibit varying relationships between health and economic growth. Threshold effects could differ based on initial health conditions, institutional setups, and stages of economic development. Investigating these heterogeneities helps comprehend why some countries experience rapid economic growth with incremental health improvements, while others may not, thereby providing tailored policy recommendations for different contexts.

The contribution of this study to the existing literature is 3-fold. Firstly, it addresses a critical research gap prevalent in earlier empirical studies by utilizing a panel threshold model, diverging from the dominant use of linear models. Secondly, by employing this innovative approach, the paper delves deeper into the health-economic growth nexus, offering a nuanced comprehension. This exploration of potential nonlinearities and thresholds grants insights into how diverse health statuses influence economic growth, varying across distinct developmental thresholds. Such an analysis augments the existing literature by transcending oversimplified linear assumptions, enriching understanding with nuanced complexities. Thirdly, the study's findings carry substantial policy implications by pinpointing health thresholds with significant impacts on economic growth. By illuminating these critical junctures, the research equips policymakers with actionable insights to optimize resource allocation effectively, thereby guiding the formulation of targeted and efficient policy interventions for promoting economic development through strategic health investments.

The rest of the paper is organized as follows: [Section 2](#) critically examines the current body of literature concerning the nexus between health and economic growth. [Section 3](#) delineates the econometric model and estimation technique employed in this study. [Section 4](#) presents and discusses the results. Finally, [Section 5](#) summarizes the key findings, and provides recommendations for policymakers.

2. Literature review

Conceptually, health can be viewed as a factor of production (Lucas, 1988; Mankiw et al., 1992). Thus, at the macro-level, it is the accumulation of health, i.e. an increase in life expectancy, that may cause economic growth. Conversely, health can be viewed as a stock (Nelson & Phelps, 1966). Consequently, it is the level of health, i.e. the average level of life expectancy, that may influence real output.

Health's impact on economic growth has been extensively explored in theoretical and empirical studies, revealing a complex and nuanced relationship. While prevailing literature often indicates a positive link between health and growth, conflicting findings challenge this consensus.

Empirical examinations of the impact of health on growth often utilize cross-sectional and panel data, involving the regression of the growth rate of real GDP per capita against the level of health (Bloom & Canning, 2005).

Seminal literature commonly establishes a positive correlation between health status, measured by life expectancy at birth and/or adult survival rates, and economic growth (Aghion et al., 2008, 2010; Barro & Lee, 1994; Barro & Sala-i-Martin, 1995; Bloom et al., 2001, 2003, 2004, 2014; Jamison et al., 2005; Knowles & Owen, 1995, 1997; Li & Huang, 2009; Mayer, 2001a, 2001b; Mayer et al., 2001; McDonald & Roberts, 2002; Lorentze et al., 2008; Sachs & Warner, 1995, 1997; Sala-i-Martin, 1997, 2005; Sala-i-Martin et al., 2004; Ridhwan et al., 2022).

Recent empirical inquiries, utilizing state-of-the-art econometric methodologies, consistently validate the positive nexus between health indicators and economic growth.

Munir and Shahid (2020) used annual panel data of four South Asian countries, from 1980 to 2018 and applied the panel ARDL model to analyze the long run and short run impact of life expectancy on economic growth. They reported a positive and significant relationship. Their results are confirmed by Ahmad and Nayyab (2021).

He and Li (2020) examined the long- and short-term linkages between life expectancy and economic growth across 65 countries from 1980 to 2014. Employing panel cointegration analysis and causality tests, the estimations unveiled significantly positive long-run relationships between life expectancy and GDP per capita. However, these relationships exhibited variations across aging levels, with a stronger positive impact of life expectancy on economic growth observed in groups with higher levels of aging.

Lawanson and Umar (2021) investigated the interplay between life expectancy, poverty incidence, and economic growth in Nigeria, utilizing the fully modified ordinary least squares method. The results underscored a positive contribution of health to economic growth.

Alternative studies focused on the impact of health investments on economic growth rather than examining the correlation between health accumulation and growth. Unsurprisingly, most of these studies conclude a positive association between healthcare expenditure and economic growth.

For instance, Gyimah-Brempong (1998) and Gyimah-Brempong and Wilson (2004) found a positive and significant causal relationship between public spending on health and economic growth in African countries. This result is supported by Heshmati (2001, 2018) and Rivera and Currais (1999a, 1999b, 2003, 2004) for developed countries.

Ye and Zhang (2018) scrutinized the causal relationship between healthcare expenditure and economic growth across 31 countries spanning 1986–2007, employing panel regression analysis to reveal a stimulating effect of healthcare expenditure growth on economic growth.

However, recent studies investigating heterogeneity and asymmetry in the relationship between health expenditure and economic growth have challenged this positive correlation.

Wu et al. (2021) used a quantile-on-quantile approach to analyze the dynamics between the quantiles of healthcare expenditure and economic growth in a pooled sample of 40 Asian countries. Their results indicate that an elevation in healthcare expenditure quantiles across these nations does not ensure a proportional escalation in the influence of healthcare expenditure on economic growth.

Similarly, Zhou et al. (2021) employed a Time-Varying Parameter model to investigate the influence of healthcare expenditure on economic growth in China. The results indicate a negative relationship in the short run and a positive association in the long run, accompanied by notable heterogeneity across distinct levels of economic development within China.

Indeed, the positive and monotonic association between health and growth has been challenged extensively by Acemoglu and Johnson (2007), Bhargava et al. (2001), and Hartwig (2010).

Bhargava et al. (2001) found large positive effects of adult survival rates on growth rates for poor and developing countries. Conversely, for highly developed countries, the estimated effect of adult survival rates on growth rates was negative.

Acemoglu and Johnson (2007) regressed per capita GDP growth against the growth in life expectancy using a sample of 59 countries, from Western Europe, Oceania, the Americas, and Asia, over the period 1940–1980. They found no evidence that the increase in life expectancy led to faster growth of income per capita.

Hartwig (2010) argued that, based on OECD data, there is no evidence supporting the notion that the formation of health capital through healthcare spending or the rise in life expectancy exerts a positive Granger-causal impact on per capita GDP growth.

Bloom et al. (2009) contended that the proposition suggesting a decline in income per capita due to health enhancements is counterintuitive. However, they believe that the income response to health improvements is not instantaneous but involves a time lag. Accounting for this temporal delay results in positive estimations for both the influence of prior health status and the effects of health improvements on the growth of per capita income.

Becker et al. (2005) argued that countries starting with better health status are likely to grow faster than countries with a lower initial health level. Nevertheless, this relationship is subject to diminishing returns. Such an idea has been adopted by other researchers (Aghion et al., 2010; Bloom et al., 2014) who assume decreasing returns to health investments at the macro level. Decreasing returns are even advanced as a plausible explanation to the findings of Acemoglu and Johnson (2007) and Bhargava et al. (2001).

Recent literature recognizes that the relation between health and economic growth changes over time (Weil, 2014) and across the process of economic development (Bloom et al., 2019; Ngwen & Kouty, 2015).

A substantial body of theoretical literature posits a non-linear relationship between health and economic growth. Boucekkine et al. (2002), Cipriani (2000), De la Croix and Licandro (1999), Fuster (1999), and Tabata (2005) have derived, based on overlapping generation models, an inverted U-shaped relationship between life expectancy and economic growth. Blackburn and Cipriani (2002) developed an overlapping generation model in which the economy exhibits multiple equilibria. They conclude that there exists a critical level of human capital below which the economy ends up plunging into a poverty trap. Aísa and Pueyo (2006) demonstrate the existence of a differentiated impact of health government expenditure on economic growth. This impact appears to be positive in developing countries, while it is negative in developed countries. Kuhn and Prettnner (2016) developed a growth model with overlapping generations to examine the conditions under which expanding healthcare enhances growth and welfare. They demonstrate that healthcare increases productivity, but it also diverts labor away from production and R&D. On the other hand, Reinhart (1999) derives a negative relationship between public spending on health and growth, even though the link between growth and life expectancy seems to be rather positive.

The existence of such non-linearities has been highlighted in the empirical literature (Berthélemy, 2008; Kelley & Schmidt, 1995; Sachs & Warner, 1997). Sachs and Warner (1997) found that the impact of health on economic growth is positive but decreases with the stock of health capital. Similarly, Berthélemy (2008), based on a multiple regime model, shows that health is among the main factors that have contributed to keeping African countries in a poverty trap. This result is supported by Aghion et al. (2008) who consider that the low growth of developing countries is mainly due to their low initial level of life expectancy. Similarly, Bloom et al. (2009) reported that, over the period 1940–2000, countries initially characterized by high life expectancy also showed faster growth in per capita income.

Cervellati and Sunde (2011) contribute to this discourse by examining the causal impact of life expectancy on per capita income growth, finding a non-monotonic effect. They assert that health improvements do not stimulate economic growth unless a country has undergone the demographic transition from high to low rates of fertility and mortality.

Sirag et al. (2020) reinforce this perspective with their dynamic panel threshold methodology, highlighting a non-linear correlation between life expectancy and economic growth. They posit that life expectancy positively influences economic growth up to a certain threshold level.

Yıldırım et al. (2020) applied cluster and panel threshold analyses to scrutinize the relationship between life expectancy and economic growth across 12 OECD countries during 1999–2016. The findings indicated that an increase in life expectancy at birth in countries characterized by higher health status yielded no significant impact on economic growth. However, for countries with lower health status, such an increase positively influenced economic growth.

In conclusion, the literature presents a nuanced and intricate relationship between health and economic growth, marked by conceptual divergences, conflicting empirical findings, and a growing body of evidence supporting a non-linear association. These complexities necessitate a critical lens when interpreting the broader implications for health policies and economic development.

3. Empirical framework

In the cross-country growth models, it has become a common practice to test the empirical linkages between growth and health using the following standard linear growth equation:

$$Growth_i = \alpha + \beta Health_i + \delta'X_i + \varepsilon_i \quad (1)$$

where $i = 1, 2, \dots, N$ is the country indicator and ε_i is an error term. Growth denotes the growth rate of real GDP per capita, Health is the measure of health improvements and X_i represents a vector of control variables.

To allow for nonlinearity in the relationship, we extend Equation (1) into a threshold regression model that takes the following general form:

$$y_i = \theta'_1 z_i I(q_i \leq \gamma) + \theta'_2 z_i I(q_i > \gamma) + \varepsilon_i \quad (2)$$

where $y_i = Growth_i$, $z_i = (Health_i, X_i')'$, $\theta_j = (\beta, \delta')'$, $j = 1, 2$. $I(\cdot)$ represents an indicator function that takes the value 1 if the argument in parenthesis is valid, and 0 otherwise. q_i is an exogenous threshold variable used to split the data into different regimes or groups. The threshold parameter is $\gamma \in \Gamma$, where Γ a strict subset of the support of q_i . This model allows the regression parameters θ_1 and θ_2 to switch between regimes depending on whether q_i is smaller or larger than the unknown threshold value γ .

Equation (2) can be rewritten in more detailed form as follows:

$$Growth_i = \beta_1 Health_i I(q_i \leq \gamma) + \beta_2 Health_i I(q_i > \gamma) + \delta_1' X_i I(q_i \leq \gamma) + \delta_2' X_i I(q_i > \gamma) + \varepsilon_i \quad (3)$$

Assuming that all explanatory variables are exogenous, Hansen (2000) suggests Equation (2) to be estimated using Ordinary Least Square. Conditional on the above estimators, we then can estimate the threshold value by minimizing the concentrated sum of squared errors function (SSE).

However, the threshold estimation method proposed by Hansen (1999, 2000) is not suitable when one or more explanatory variables are endogenous. Since we consider that the health variable is highly likely to be endogenous, we rather choose to estimate Equation (3) by applying the Caner and Hansen (2004) instrumental variable threshold regression model (IVTR).

The reduced form of the endogenous variable can be defined as follows:

$$Health_i = g(s_i, \pi) + u_i \quad (4)$$

where π is an unknown parameter vector, g is a linear function and u_i is a random error. The vector s_i represents a set of instrumental variables that are not included in the growth regression, along with other exogenous variables of the model. After replacing the endogenous variable by its reduced form, Equation (3) can be written as follows:

$$growth_i = \beta_1 g(s_i, \pi) I(q_i \leq \gamma) + \beta_2 g(s_i, \pi) I(q_i > \gamma) + \delta_1' X_i I(q_i \leq \gamma) + \delta_2' X_i I(q_i > \gamma) + v_i \quad (5)$$

where $v_i = \beta_1 u_i I(q_i \leq \gamma) + \beta_2 u_i I(q_i > \gamma) + \varepsilon_i$

The parameters are estimated sequentially. First, we estimate the reduced form parameter π and obtain the predicted value $\widehat{Health}_i = \hat{g}_i = g(s_i, \hat{\pi}) = \hat{\pi}'s_i$. Second, we turn to the estimation of the threshold parameter γ which is chosen to minimise the sum of squared residuals from a sequence of regressions of growth on the predicted value of the health variable. Third, we estimate the slope parameters $(\beta_1, \beta_2, \delta_1, \delta_2)$ by 2SLS or GMM on the split sample implied by $\hat{\gamma}$.

To test the existence of the threshold effect, Caner and Hansen (2004) suggest the Supremum Wald test statistic. First, we fix $\gamma \in \Gamma$ to any value and the equation (19) is estimated by GMM. Then, for the fixed value of γ , the Wald statistic under H_0 is constructed as follows:

$$w_n(\gamma) = [\hat{\theta}_1(\gamma) - \hat{\theta}_2(\gamma)]' [\hat{V}_1(\gamma) + \hat{V}_2(\gamma)]^{-1} [\hat{\theta}_1(\gamma) - \hat{\theta}_2(\gamma)] \quad (6)$$

Repeating the calculation for all $\gamma \in \Gamma$, we can obtain the Sup statistic as the greatest value of the calculated w_n :

$$Sup W = \sup_{\gamma \in \Gamma} w_n(\gamma) \quad (7)$$

The asymptotic distribution of this statistic is not standard because of the presence of the nuisance parameter γ . For this reason, Caner and Hansen (2004) use a bootstrapping procedure to get the p -value.

3.1. Data description

Equation (5) is estimated for 136 countries observed over the period 1965–2015. All data are averaged over periods of five years. Given that the IV threshold model doesn't tolerate unbalanced samples, all missing observations have been dropped, reducing the sample total number of observations from 1496 to 1075 observations.

Data on population, income, and physical capital are from the Penn World Tables (Feenstra et al., 2022). Health variables are from the United Nations (2022). In line with Bloom et al. (2022), health stock is proxied by adult survival rates, which measure the probability of surviving from age 15 to 60. For robustness check purposes, we use life expectancy as an alternative measure of health improvements. Data on education are from Barro and Lee (2001). Education is proxied by years of secondary schooling for the working-age population 15–64. Table A1 in Appendix A reports descriptive statistics for the estimation sample, and Table A2 reports the correlation matrix.

4. Empirical results and discussion

4.1. The linear model

Table 1 reports parameter estimates of the linear IV GMM model. The results are in line with Bloom et al. (2022). Adult survival rate has the expected positive impact on economic growth and the estimated coefficient is significant at the 1% significance level. Using life expectancy as an alternative measure or population health or GDP per worker as an alternative dependent variable doesn't alter the findings. As discussed previously, the validity of such findings relies on the fundamental assumption that the relationship between health and economic growth is basically linear. We proceed next to test this assumption using the methodology proposed by Caner and Hansen (2004).

4.2. Linearity tests

The first step before estimating the threshold model is to select among the candidate threshold variables the one that most strongly rejects the linearity hypothesis. Therefore, three variables were selected: initial survival rate ($SURV_0$), initial life expectancy (LEX_0), and initial GDP (GDP_0). The choice of the first

Table 1. The macroeconomic return to health: linear GMM estimates.

Dependent variable	Growth rate of income per capita		Growth rate of income per worker	
	(1)	(2)	(3)	(4)
Log income per capita (–1)	–0.5097*** (0.1646)	–0.5981*** (0.1924)		
Log income per worker (–1)			–0.5807*** (0.1873)	–0.6913*** (0.1768)
Survival rate	0.04919*** (0.01356)		0.06238*** (0.01751)	
Life expectancy		0.06522*** (0.01850)		0.08637*** (0.02266)
Secondary schooling	0.4551*** (0.1381)	0.5923*** (0.1659)	0.4507*** (0.1374)	0.5988*** (0.09965)
Growth of working age population	0.8923*** (0.08162)	0.9448*** (0.07922)	–0.1015 (0.08151)	–0.05101 (0.08484)
Population growth rate	–0.1967 (0.1381)	–0.0008222 (0.1573)	–0.1848 (0.1395)	
Growth of capital per worker	0.4638*** (0.04674)	0.5166*** (0.04529)	0.4660*** (0.04678)	0.5365*** (0.04604)
Observations	1075	1075	1075	1075
Countries	136	136	136	136
J-test p -value	0.2654	0.3806	0.7128	0.9086

Note: *** indicates statistical significance at the 1%, respectively. Standard errors are in parentheses.

two variables is primarily intended to test the hypothesis of decreasing marginal returns of health. Thus, we would like to test whether health improvements are less likely to translate into higher growth rates in countries initially characterized by better population health conditions. The third threshold variable (GDP_0) has been chosen to test the hypothesis that the impact of health on economic growth changes between countries that differ in their initial economic conditions. Rejecting the linearity hypothesis ultimately means that economies that differ in their initial stock of health or in economic conditions, may not converge and may therefore be on different growth trajectories.

As we can obviously observe from Tables 2 and 3, the null hypothesis of a linear relationship between economic growth and health is rejected at the 1% significance level for all the considered threshold variables. The threshold estimates for $SURV_0$ and LEX_0 are 78.8 and 58.4, respectively. For GDP_0 , the estimated threshold is \$ 2152.

Table 2. The macroeconomic return to health: IV panel threshold estimates.

Threshold variable	Dependent variable: growth rate of GDP per capita					
	$SURV_0$		LEX_0		GDP_0	
Sup W	46.4394*** (0.000)		71.2090*** (0.000)		33.657*** (0.000)	
Estimated threshold ($\hat{\gamma}$)	87.82		58.36		2152.16	
	$q_i \leq \hat{\gamma}$	$q_i > \hat{\gamma}$	$q_i \leq \hat{\gamma}$	$q_i > \hat{\gamma}$	$q_i \leq \hat{\gamma}$	$q_i > \hat{\gamma}$
GDPCAPITA (−1)	–	–	–	–	0.0122*** (0.0048)	−0.0007*** (0.0002)
LOG_GDP per capita (−1)	−0.4412 (0.4912)	−0.4835*** (0.1737)	0.0353 (0.2045)	−0.2370*** (0.0925)	–	–
Survival rate	0.0087 (0.0403)	0.0508*** (0.0151)	–	–	0.0990 (0.0665)	−0.1025** (0.0358)
Life expectancy			−0.0008 (0.0322)	0.0408*** (0.0132)	–	–
Secondary schooling	0.9520** (0.4274)	0.3513*** (0.1275)	0.1765 (0.3329)	0.1984** (0.0956)	2.7262*** (0.8517)	6.1859*** (1.8373)
Growth of physical capital	0.9068*** (0.1414)	0.9643*** (0.0875)	0.5689 (0.0736)	0.5269*** (0.0489)	0.6629* (0.3935)	1.1025*** (0.2566)
Population growth	0.6086 (0.4462)	−0.3369*** (0.1173)	0.0305 (0.1721)	0.0220 (0.0862)	1.6913*** (0.4778)	3.5181*** (1.1828)
Growth of working population	0.6941*** (0.0911)	0.4959*** (0.0481)	−0.0553 (0.4985)	−0.2781*** (0.1131)	0.4172*** (0.1171)	0.5445*** (0.0953)
Observations	245		830		205	

Note: Asterisk *, **, *** indicate statistical significance at the 10, 5, and 1%, respectively. Standard errors are in parentheses.

Table 3. The macroeconomic return to health: IV panel threshold estimates.

Threshold variable	Dependent variable: growth rate of GDP per worker			
	$SURV_0$		LEX_0	
Sup W	48.1945*** (0.000)		71.2090*** (0.000)	
Estimated threshold ($\hat{\gamma}$)	87.82		58.36	
	$q_i \leq \hat{\gamma}$	$q_i > \hat{\gamma}$	$q_i \leq \hat{\gamma}$	$q_i > \hat{\gamma}$
LOG GDP per worker (−1)	−0.4771 (0.5360)	−0.5494*** (0.1985)	0.0353 (0.2045)	−0.2370*** (0.0132)
Survival rate	0.0175 (0.0500)	0.0633*** (0.0195)	–	–
Life expectancy	–	–	−0.0008 (0.0322)	0.0408*** (0.0132)
Secondary schooling	0.9494** (0.4276)	0.3416*** (0.1253)	0.1765 (0.3329)	0.1984** (0.0956)
Growth of physical capital	0.6969*** (0.0920)	0.4962*** (0.0481)	0.5689*** (0.0736)	0.5269*** (0.0489)
Growth of working population	−0.0811 (0.1400)	−0.0267 (0.0867)	0.0305 (0.1721)	0.0220 (0.0862)
Population growth	0.6266 (0.4525)	0.3324*** (0.1164)	−0.0553 (0.4985)	−0.2781*** (0.1131)
Observations	245		205	

Note: Asterisk **, *** indicate statistical significance at the 10, 5, and 1%, respectively. Standard errors are in parentheses.

4.3. The threshold model

The rejection of the null hypothesis of a linear relationship between economic growth and health implies that the total sample will be split into two distinct groups, indicating the existence of multiple equilibria. Furthermore, each country's growth path is determined by its initial condition relative to the identified critical threshold.

Table 2 indicates that while the impact of health on economic growth is positive in the lower regime, this effect is insignificant. Most of the control variables have the expected signs and are significantly correlated with the growth rate of real GDP per capita. The best results are however obtained when $SURV_0$ is used as a threshold variable.

The coefficient estimates obtained from the panel threshold model offer valuable insights into the connection between improved health and economic growth. Irrespective of whether we use $SURV_0$ or LEX_0 as a threshold, the first lag coefficient estimate for real GDP per capita is both negative and statistically significant at the 1% level. This suggests a negative correlation between the current quarter's real GDP growth rate and the growth rate of the previous quarter. These negative coefficient estimates align with the expectation that sustainable growth should occur over time. In other words, higher growth rates in the previous period correspond to higher growth rates in the current period.

The estimated coefficient for adult survival is 0.05, and it is statistically significant at the 1% level. This means that a 10% increase in adult survival would result in a 0.5% increase in real per capita GDP growth. This finding supports previous research that demonstrates the positive impact of improved health on economic growth.

Similarly, the coefficient estimate for secondary education is also positive and significant at the 1% level. Therefore, a 10% increase in secondary education is associated with a 3.5% increase in real GDP per capita growth. These findings emphasize the importance of secondary education in promoting economic growth by equipping individuals with the necessary skills for the labor market and contributing to overall economic development.

The coefficient estimate for capital growth per employee indicates that a 10% increase in capital growth per employee leads to a substantial 9.6% increase in real GDP growth per employee. This result highlights the significance of investing in physical capital to stimulate economic growth, as it enhances the productive capacity of the economy.

On the other hand, the coefficient estimate for the population growth rate is negative and significant at the 1% level. This suggests that population growth can exert pressure on the economy and limit its growth potential. However, the coefficient estimate for labor force growth is positive and statistically significant at the 1% level. Overall, the coefficient estimates from the upper bound of the panel threshold model provide evidence of a positive association between health improvement and economic growth. All the explanatory variables are statistically significant at the 1% level, indicating that improvements in adult survival, post-secondary education, capital growth rate per worker, and labor force growth rate can have a positive impact on real GDP per capita growth. These results emphasize the importance of policies that promote health and education, as well as investments in physical capital, to stimulate economic growth.

It is important to note that according to the panel threshold model results, improved health status does not necessarily result in higher growth rates unless a minimum health status threshold is met. The estimated threshold of 87.8 years suggests that countries with adult survival rates below this threshold will not experience significant benefits from improved health. In such countries, the healthcare sector does not play a significant role in stimulating or boosting economic growth.

In the lower regime, where the initial adult survival rate falls below the threshold, improvements in health status have a positive yet modest influence on economic growth. Within this specific context, the factors of secondary education and increased capital per worker stand out as significant drivers of economic growth. These findings suggest that in countries with lower levels of health, the pivotal role in promoting economic growth is assumed by education and investments in physical capital.

The results emphasize the crucial role of attaining a minimum level of health for the health sector to exert a substantial influence on fostering and facilitating economic growth. Hence, policymakers in countries with

poor health conditions should not solely concentrate on enhancing the health sector but should also consider other factors, such as investments in education and physical capital, to augment economic growth.

Significantly, employing the growth rate of real GDP per worker instead of real GDP per worker as the dependent variable does not yield substantial alterations to the outcomes of the panel threshold model (Table 3). The findings persistently demonstrate a non-linear relationship between health and economic growth, rejecting the null hypothesis of a linear association between growth and health at the 1% significance level. The adult survival threshold remains unchanged at 87.8 years. Within the sub-regimes, secondary education and growth in capital per worker continue to be the sole significant variables, exerting a positive and significant impact on economic growth. This implies that investments in education and physical capital remain the primary drivers of economic growth in countries with subpar health conditions.

The coefficient estimates for adult survival are slightly higher in the upper regime compared to the reference model, indicating a marginally stronger correlation between health and economic growth in this particular regime. This supports the conclusion that improved health can significantly affect economic growth in countries that attain the minimum health threshold.

Therefore, utilizing the growth rate of real GDP per worker as the dependent variable does not bring about substantial changes to the outcomes. Furthermore, the assertion that health improvements leading to higher growth rates necessitate a minimum level of health remains valid.

5. Conclusion and policy implications

Based on the empirical evidence presented in the paper, it becomes evident that the relationship between health and economic growth exhibits a non-linear pattern. The positive influence of health on economic growth is solely observed in countries that have attained minimum benchmarks of health improvement. Notably, countries with initial poor health conditions may not experience substantial economic growth even with enhanced health outcomes, as highlighted in the paper.

These findings carry significant policy implications, particularly for low-income countries that still struggle to achieve basic health outcomes. They imply that focusing solely on improving health outcomes may not be sufficient to generate significant economic growth in these countries. Instead, a comprehensive approach encompassing multiple factors, such as education enhancement, productivity boost, and entrepreneurship promotion may be necessary.

Furthermore, Policymakers in low-income countries need to strategically allocate resources to interventions that contribute to surpassing the health threshold. This may involve prioritizing investments in healthcare infrastructure, preventive measures, or public health campaigns that specifically target conditions preventing the nation from reaching the minimum health threshold.

The paper suggests that in countries already attaining satisfactory health outcomes, policies prioritizing improved health outcomes can serve as an effective means to promote sustainable economic growth. For these countries, policy focus may shift towards improving the overall quality of life for their populations and fostering long-term sustainable growth.

In this context, the recommended policy approach for these countries involves directing investments towards research and development (R&D) to support innovation and cultivate emerging industries. This can result in the creation of new technologies, products, and services that not only drive economic growth but also enhance the well-being of citizens. Specifically, investments in R&D can support the advancement of health-related innovations, such as personalized medicine and digital health to further enhance health outcomes.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

No funding was received.

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Mohamed Chakroun is a professor of economics specializing in health economics. With numerous publications in reputable journals, he is recognized for his expertise in exploring the intersection of health and the economy.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, MC, upon reasonable request.

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Appendix A

Table A1. Descriptive statistics.

Variable	Mean	Median	<i>SD</i>	Min	Max
Growth rate of real GDP per capita	1.81	1.98	3.73	−25.2	24.4
Growth rate of real GDP per worker	1.49	1.64	3.68	−25.4	24.2
Survival rate	0.900	0.904	0.0396	0.435	0.973
Life expectancy	65.5	68.5	10.9	12.0	84.3
Growth of physical capital	1.94	1.68	3.14	−15.5	20.8
Population growth	1.77	1.77	1.57	−5.48	17.0
Growth of working population	0.332	0.249	1.21	−5.15	6.15
Secondary schooling	2.25	1.93	1.57	0.000	7.92

Table A2. Correlation matrix.

	Growth rate of real GDP per capita	Survival rate	Life expectancy	Growth of physical capital	Population growth	Growth of working population	Secondary schooling
Growth rate of real GDP per capita	1						
Survival rate	0.0343	1					
Life expectancy	0.0190	0.9066	1				
Growth of physical capital	0.3814	−0.0496	−0.0731	1			
Population growth	−0.1525	−0.0506	−0.0756	−0.2118	1		
Growth of working population	0.2301	0.0467	0.0456	−0.2685	0.0996	1	
Secondary schooling	0.0570	0.3326	0.3570	−0.0789	−0.4449	0.0582	1