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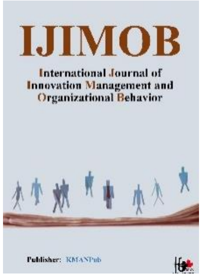

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Threshold Effects of Gross Fixed Capital Formation in the Relationship Between Healthcare Infrastructure and Life Expectancy Index in Iran

Ali. Atashak Maman[1], Lotfali. Agheli[2*], Gholamreza. Abbasi[3]

[1] Department of Economics, SR.C., Islamic Azad University, Tehran, Iran
[2] Department of Economics, Economic Research Institute, Tarbiat Modares University, Tehran, Iran
[3] Department of Economics, CT.C., Islamic Azad University, Tehran, Iran

*** Corresponding author email address**: aghelik@modares.ac.ir

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A B S T R A C T

Objective: The present study aimed to investigate the threshold effects of gross fixed capital formation on the relationship between healthcare infrastructure and the life expectancy index in Iran.

Methods and Materials: This applied and descriptive–analytical study employed an ex post facto design using annual time-series data for Iran covering the period 1986–2023. The empirical analysis was conducted using EViews software. To examine nonlinear dynamics and potential regime-switching behavior, a first-order Logistic Smooth Transition Regression (LSTR1) model was estimated, with gross fixed capital formation serving as the transition variable. Prior to model estimation, Phillips–Perron unit root tests were applied to assess stationarity, and the Johansen–Juselius cointegration approach was used to test for long-run equilibrium relationships among the variables. The model incorporated healthcare infrastructure indicators, including hospital beds, physicians, nurses and midwives, public and private health sector investment, labor force participation, population growth, and literacy rate. Diagnostic tests were performed to assess autocorrelation, heteroskedasticity, parameter stability, and remaining nonlinearity.

Findings: The results indicate that all variables are integrated of order one and cointegrated in the long run. The linearity test rejects the null hypothesis of linearity, confirming the appropriateness of the LSTR1 specification. Gross fixed capital formation exhibits a statistically significant threshold value of −0.211, dividing the model into two distinct regimes. In the nonlinear (high-capital) regime, the coefficients of gross fixed capital formation, hospital beds, physicians, nurses and midwives, and both public and private health sector investment are positive and statistically significant, with greater magnitudes compared to the low-capital regime. Diagnostic tests confirm the absence of autocorrelation and heteroskedasticity, and parameter constancy tests support regime-dependent coefficient variation. The adjusted R^2 of 0.88 indicates strong explanatory power.

Conclusion: The findings demonstrate that the effectiveness of healthcare infrastructure in improving life expectancy in Iran is conditional upon the level of gross fixed capital formation. When capital accumulation surpasses a critical threshold, the impact of healthcare infrastructure intensifies significantly, highlighting the importance of sustained macroeconomic investment in enhancing health outcomes.

Keywords: *Health expenditures; Healthcare infrastructure; Gross fixed capital formation; Life expectancy index; Smooth Transition Autoregressive (STAR) model*

1 Introduction

Health is widely recognized in the economic and management literature as both a fundamental component of human capital and a strategic driver of sustainable development. Beyond its intrinsic social value, health contributes directly to labor productivity, income generation, and long-term economic performance. Empirical evidence consistently indicates that improvements in population health enhance workforce participation, reduce absenteeism, and strengthen human capital accumulation, thereby fostering economic growth (Wu et al., 2021). At the macroeconomic level, public health expenditure is increasingly viewed not merely as a consumption item but as an investment that yields economic returns through improved productivity and social welfare (Hu & Wang, 2024). Consequently, understanding the mechanisms through which health-related investments affect economic and social outcomes has become a central concern for policymakers and scholars in both economics and management sciences.

A substantial body of research has examined the bidirectional relationship between health expenditures and economic growth. Studies focusing on OECD and European Union countries demonstrate that health spending can exert a positive and statistically significant effect on growth, particularly when institutional quality and fiscal capacity are adequate (Ozyilmaz et al., 2022; Ying et al., 2022). Similar findings have been reported in developing contexts, where health indicators and economic growth exhibit long-run causal relationships (Gulzar & Ahmed, 2022; Jalili et al., 2019). In Sub-Saharan Africa, financial development has been shown to influence healthcare expenditure patterns, suggesting that macro-financial conditions shape the allocation and efficiency of health investments (Chireshe & Ocran, 2020). Moreover, quantile-based panel analyses reveal that the relationship between income distribution and healthcare expenditure may vary across different levels of inequality, indicating the presence of nonlinear dynamics (Wang & Nguyen Thi, 2021). These findings collectively underscore the complexity of the health–economy nexus and highlight the need for methodological approaches capable of capturing threshold and regime-dependent effects.

In recent years, attention has increasingly shifted toward efficiency and performance assessment within health systems. Systematic reviews emphasize that health system efficiency depends not only on expenditure levels but also on governance structures, resource allocation mechanisms, and managerial practices (Mbau et al., 2023). Empirical investigations into primary healthcare services demonstrate that efficiency differentials across regions are influenced by infrastructure quality, workforce availability, and fiscal decentralization (Zhao et al., 2023). Within the Iranian context, strengthening primary healthcare has been identified as a strategic priority, requiring structural reforms and better coordination among stakeholders (Mosadeghrad et al., 2021). Budgetary trends and financing mechanisms further shape sectoral performance, as highlighted by operational analyses of Iran's health sector financing (Eisavi & Moayedfard, 2022). These studies suggest that infrastructure and capital formation are critical determinants of health system outcomes and that improvements in physical and institutional capacity can amplify the returns to health expenditure.

Healthcare infrastructure—comprising hospital beds, medical professionals, and technological resources—plays a central role in translating financial inputs into measurable health outcomes. Cross-country analyses indicate that the availability of medical staff and capital-intensive facilities significantly affects health performance indicators (Rezaei et al., 2018). Professional well-being and workforce engagement, particularly among nurses, are also essential for ensuring service quality and organizational resilience in healthcare systems (Ieng Lai et al., 2025). Furthermore, provincial-level assessments of household vulnerability to economic fluctuations reveal that macroeconomic instability can adversely affect access to healthcare services, thereby undermining life expectancy and welfare (Fatemi Zardan &

Fotros, 2021). Equity considerations in health financing are equally important, as disparities in funding distribution may limit the effectiveness of infrastructure investments (Mousavi et al., 2018). Taken together, these findings suggest that both the scale and structure of investment matter in determining health outcomes.

Another critical dimension of the health–development nexus relates to the role of financial development and capital formation. Empirical evidence from Iran indicates that financial development, health expenditures, and renewable energy consumption jointly influence life expectancy (Fathollahi & Jafari, 2024). At the international level, threshold models reveal that the growth effects of public health expenditure may vary depending on income levels and institutional conditions (Hu & Wang, 2024). Such nonlinearities imply that investments in health infrastructure may generate different outcomes depending on the broader macroeconomic environment, particularly the level of gross fixed capital formation. The literature on structural transformation and public finance further highlights how capital allocation decisions influence environmental and economic performance (Wang et al., 2020). Similarly, digital transformation and industrial dynamics have been shown to reshape economic growth trajectories in the post-pandemic era, with implications for healthcare delivery systems (Zhang et al., 2022). These insights reinforce the importance of examining threshold effects and regime shifts when analyzing the relationship between capital formation and health indicators.

From a managerial perspective, financial optimization and cost-efficiency strategies have become increasingly salient in healthcare systems worldwide. The integration of financial operations management (FinOps) frameworks into healthcare organizations has been proposed as a means of enhancing fiscal discipline while maintaining service quality (Olorunyomi et al., 2024). In addition, research on aging populations demonstrates that workplace arrangements, including remote work, can influence mental health outcomes and productivity among older cohorts (Bertoni et al., 2025). These developments highlight the evolving nature of health management challenges and underscore the need for adaptive policy frameworks that align financial resources with health system objectives.

Within emerging economies, structural determinants such as institutional capacity, labor force dynamics, and sectoral investment patterns significantly shape health outcomes. Panel data analyses in Asian regions confirm that improvements in health indicators contribute to economic growth, but the magnitude of this contribution varies across income levels and regional characteristics (Wu et al., 2021). Furthermore, industrial and economic restructuring processes have been linked to changes in healthcare demand and expenditure patterns (Ying et al., 2022). In countries experiencing rapid demographic transitions, the interplay between population growth, labor participation, and health infrastructure becomes particularly salient. This complexity calls for analytical frameworks that move beyond linear specifications and incorporate threshold-based dynamics.

Despite the extensive literature on health expenditure and economic growth, relatively limited attention has been devoted to the potential threshold effects of gross fixed capital formation in shaping the relationship between healthcare infrastructure and life expectancy. Most empirical studies employ linear models that may overlook regime-dependent responses and asymmetric effects. Yet evidence from threshold modeling approaches suggests that economic relationships can change once critical levels of key variables are surpassed (Hu & Wang, 2024). In contexts characterized by structural transformation and fiscal constraints, such as Iran, understanding whether capital formation amplifies or moderates the impact of healthcare infrastructure on life expectancy is of strategic importance.

In Iran, ongoing reforms in health financing and infrastructure development have aimed to enhance service accessibility and efficiency. However, fluctuations in macroeconomic conditions, including investment cycles and fiscal pressures, may alter the effectiveness of these initiatives (Eisavi & Moayedfard, 2022; Fatemi Zardan & Fotros, 2021). Previous studies highlight the significance of financial development and sectoral investment for improving life expectancy (Fathollahi & Jafari, 2024), yet the existence of nonlinear or threshold-based relationships remains underexplored. Given the centrality of capital accumulation in national development strategies, investigating how variations in gross fixed capital formation influence the health–life expectancy nexus constitutes a meaningful contribution to both management and public health literature.

Accordingly, this study seeks to examine the threshold effects of gross fixed capital formation in the relationship between healthcare infrastructure and the life expectancy index in Iran.

2 Methods and Materials

The present study is applied in terms of its objective and has practical implications for the national health sector. In terms of its nature, it is descriptive–analytical and falls within the category of ex post facto research. The statistical population of this study consists of Iran, and due to data availability, the period from 1986 to 2023 was analyzed using EViews software and a Smooth Transition Autoregressive (STAR) model. In line with the studies of Hu and Wang (2024), Mbaou et al. (2023), and Yang et al. (2022), the following model and variables were employed in the regression analysis:

$$LE_t = \alpha_0 + \beta_1 CAP_t + \beta_2 LF_t + \beta_3 POP_t + \beta_4 LR_t + \beta_5 HB_t + \beta_6 P_t + \beta_7 NM_t + \beta_8 PH_t + \beta_9 GG_t + (\theta_1 CAP_t + \theta_2 LF_t + \theta_3 POP_t + \theta_4 LR_t + \theta_5 HB_t + \theta_6 P_t + \theta_7 NM_t + \theta_8 PH_t + \theta_9 GG_t) F(S_t, \gamma, c) + u_t$$

Where gross fixed capital formation (CAP), labor force participation rate (LF), population growth (POP), literacy rate (LR), hospital beds (HB), physicians (P), nurses and midwives (NM), total public sector investment in the health sector (GG), total private sector investment in the health sector (PH), and the life expectancy index (LE) are included as variables in the model.

3 Findings and Results

Initially, to ensure the absence of spurious regression, unit root and cointegration tests were conducted. In this study, the conventional Phillips–Perron unit root test (Phillips & Perron, 1988) was applied.

Table 1

Results of the Phillips–Perron (PP) Test at the Level of Model Variables

Variable Status	Probability	Test Statistic	Variables
---	0.4740	-0.5452	CAP
I(1)	0.0000	-8.8967	D(CAP)
---	0.4522	-0.5078	P
I(1)	0.0000	-11.8039	D(P)
---	0.5545	-0.3434	GG
I(1)	0.0000	-8.2947	D(GG)
---	0.1641	-1.3389	HB
I(1)	0.0000	-7.3635	D(HB)
---	0.1143	-3.1310	LE
I(1)	0.0000	-7.1371	D(LE)
---	0.5547	-0.3429	LF
I(1)	0.0000	-68.5995	D(LF)
---	0.1963	-1.2314	LR
I(1)	0.0000	-4.7081	D(LR)
---	0.6810	0.01447	NM
I(1)	0.0000	-8.8732	D(NM)
---	0.1861	-1.2639	PH
I(1)	0.0000	-15.2172	D(PH)
---	0.5981	-0.2258	POP
I(1)	0.0000	-4.8949	D(POP)

Based on the theoretical foundations of stationarity testing, the null hypothesis (H_0) in these tests assumes the presence of a unit root (non-stationarity). According to the results, all model variables become stationary at the first difference, indicating that they are integrated of order one, I(1) (see Table 1).

Since the variables are integrated of the same order, I(1), the Johansen–Juselius cointegration approach (Johansen, 1988; Johansen & Juselius, 1990) was employed to examine the existence of a long-run equilibrium relationship among the model variables. To implement this test, the number of cointegrating vectors must first be determined. Furthermore, an appropriate specification must be selected with respect to the presence or absence of a deterministic trend and intercept in the cointegration vector. Five alternative specifications are considered: (1) no intercept and no trend; (2) restricted intercept and no trend; (3) unrestricted intercept and no trend; (4) unrestricted intercept and restricted trend; and (5) unrestricted intercept and unrestricted trend. These specifications range from the most restricted (Model 1) to the least restricted (Model 5).

The null hypothesis of no cointegrating vector is tested against the alternative of at least one cointegrating vector, followed by testing the existence of at most one cointegrating vector against two, and so forth, up to n−1 cointegrating vectors (where n represents the number of variables). The summary of the Trace (λTrace) and Maximum Eigenvalue (λMax) test results across the five specifications is presented in Table 2. The results indicate rejection of the null hypothesis of no cointegration, confirming the existence of at least one cointegrating vector among the variables.

Table 2

Summary of Cointegrating Vectors

Model	Model 1	Model 2	Model 3	Model 4	Model 5
Trace Test	4	6	6	3	4
Maximum Eigenvalue Test	3	5	2	5	6

For the estimation of the Smooth Transition Autoregressive model, all variables included in the model were tested as potential transition variables. The variable that most strongly rejects the null hypothesis of linearity was selected as the transition variable. The proposed STAR model based on the selected transition variable was then identified as the optimal specification for estimating the threshold effects of gross fixed capital formation in the relationship between healthcare infrastructure and the life expectancy index in Iran.

The results reported in Table 3 indicate that gross fixed capital formation (CAP) was selected as the transition variable. The null hypothesis of linearity is rejected, and a first-order Logistic Smooth Transition Regression (LSTR1) model is confirmed. Accordingly, the primary emphasis of the study is placed on the nonlinear component of the model.

Table 3

Linearity Test, Selection of Transition Variable, and Model Type

Proposed Model	F Statistic	F4	F3	F2	Variable
LSTR1	0.8958	0.7745	0.5425	0.3896	CAP(t)

In the next stage, a first-order LSTR model (LSTR1), with gross fixed capital formation as the transition variable, was estimated to model the threshold effects in the relationship between healthcare infrastructure and health indicators. Initial values for the threshold parameter (C) and the slope parameter (γ) were selected. Using these initial values and applying the Newton–Raphson algorithm, the model parameters were estimated via maximum likelihood estimation, and the results are reported in Table 4.

The estimation results for the nonlinear component (second regime) indicate that gross fixed capital formation, hospital beds, the number of physicians, nurses and midwives, and both private and public sector investment in health have a positive and statistically significant relationship with the life expectancy index.

Table 4

Estimation of Threshold Effects of Gross Fixed Capital Formation Using the 1LSTR Model

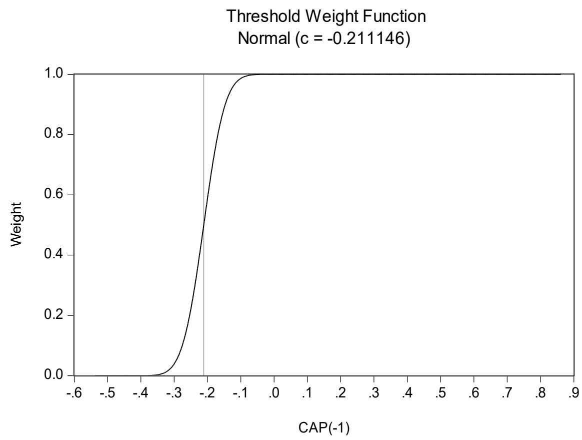
Variable	Coefficient	Probability
Linear Component		
CAP	0.1449	0.0444
LF	0.2389	0.3161
POP	0.0884	0.1593
LR	0.0216	0.0852
HB	0.1446	0.0518
P	0.2129	0.1435
NM	0.0349	0.0442

PH	0.2366	0.0418
GG	0.6524	0.0315
Nonlinear Component		
CAP	0.9617	0.0152
LF	0.0762	0.0117
POP	0.1735	0.0851
LR	0.1445	0.0743
HB	0.1904	0.0122
P	0.2595	0.0107
NM	0.1760	0.0209
PH	0.2004	0.0004
GG	0.6532	0.0009

Threshold (C) = −0.2111 (p = 0.0000)
Slope parameter (γ) = 3.3314 (p = 0.0000)
Adjusted R^2 = 0.88

Figure 1

The Relationship Between the Transition Function and the Transition Variable (Gross Fixed Capital Formation)



The comparison of coefficients across the two regimes is conducted based on the transition variable and its values. The transition variable (gross fixed capital formation) determines the transition function and, consequently, the prevailing regime. Whether the transition variable lies below or above the threshold value generates two distinct regimes in the estimated function.

In the present estimation, CAP is the transition variable, and the estimated threshold value is −0.211. Depending on the deviation of gross fixed capital formation from this threshold, the model follows two different extreme regimes. A comparison of the coefficients across regimes reveals that once gross fixed capital formation surpasses the threshold (−0.211), the responsiveness of the life expectancy index to changes in this variable increases. In particular, the impact of healthcare infrastructure—such as the number of physicians, nurses, and hospital beds—becomes statistically significant and more pronounced when the level of capital formation exceeds the specified threshold.

According to the diagnostic tests, there is no evidence of autocorrelation or heteroskedasticity in the estimated LSTR1 model. Furthermore, the test for no remaining nonlinearity indicates that the LSTR1 specification adequately captures all nonlinear dynamics present in the model (see Table 5).

Table 5

Results of Diagnostic Tests

Test	F-value	P-value
ARCH LM-test	0.9748	0.6525
No remaining nonlinearity test	1.4525	0.4785
Parameters constancy test	1.5414	0.3968

The results of the parameter constancy test across different regimes also suggest rejection of the null hypothesis of parameter stability between the two regimes. This finding implies that the estimated coefficients and parameters of the explanatory variables differ across regimes, supporting the presence of asymmetric effects on the dependent variable, namely the life expectancy index.

Therefore, based on the estimation results and the diagnostic tests performed, the 1LSTR model appears to be an appropriate specification for analyzing the threshold effects of gross fixed capital formation in the relationship between healthcare infrastructure and the life expectancy index. Accordingly, the empirical results derived from this model can be considered reliable and robust.

4 Discussion

The findings of this study provide robust empirical evidence that the relationship between healthcare infrastructure and the life expectancy index in Iran is nonlinear and subject to threshold effects driven by gross fixed capital formation. The Smooth Transition Regression results indicate the existence of two distinct regimes separated by a statistically significant threshold level of capital formation. When gross fixed capital formation remains below the estimated threshold, the responsiveness of life expectancy to changes in healthcare infrastructure variables is relatively moderate. However, once capital formation surpasses this critical level, the magnitude and statistical significance of the coefficients associated with healthcare infrastructure—particularly hospital beds, physicians, nurses and midwives, and both public and private sector health investments—increase substantially. This finding suggests that capital accumulation plays a catalytic role in enhancing the effectiveness of health-related investments.

The positive and significant effect of healthcare infrastructure variables in the high-capital regime aligns with the broader literature emphasizing the productive nature of health expenditure. Empirical evidence from OECD countries demonstrates that public health expenditure exerts stronger growth effects when supported by adequate economic conditions and institutional frameworks (Hu & Wang, 2024). Similarly, panel causality analyses in European Union countries confirm that health expenditures contribute to economic performance, particularly in contexts characterized by structural maturity and fiscal stability (Ozyilmaz et al., 2022). The present results extend this line of research by showing that not only total health spending but also the structural context of capital formation determines the intensity of health infrastructure's impact on life expectancy.

The finding that hospital beds and medical personnel exert a stronger influence in the high-capital regime is consistent with studies highlighting the centrality of healthcare capacity in determining health outcomes. Provincial panel analyses of primary healthcare services in China reveal that infrastructure quality and workforce density significantly influence service efficiency and health indicators (Zhao et al., 2023). In addition, systematic reviews of health system efficiency underscore that resource availability and capital allocation efficiency are key determinants of performance (Mbau et al., 2023). The current study demonstrates that these structural determinants are not uniformly effective across all macroeconomic conditions; rather, their impact intensifies when supported by sufficient capital formation.

The positive and significant role of public and private health sector investment in the nonlinear regime also resonates with previous findings. Evidence from developing and emerging economies indicates that health expenditures and economic growth exhibit a mutually reinforcing relationship (Gulzar & Ahmed, 2022; Jalili et al., 2019). In Iran specifically, financial development and health spending have been shown to contribute to improvements in life expectancy (Fathollahi & Jafari, 2024). However, the present results refine this understanding by demonstrating that the marginal effect of such investments depends critically on the level of capital accumulation. In other words, health infrastructure becomes more productive in improving life expectancy when embedded within a broader environment of economic investment and capital expansion.

The nonlinear pattern identified in this study also corresponds with evidence from quantile and threshold-based analyses in the health–economy literature. Quantile-on-quantile estimations across Asian regions reveal that the impact of health indicators on growth varies across income levels (Wu et al., 2021). Likewise, quantile panel analyses show heterogeneous relationships between income inequality and healthcare expenditure (Wang & Nguyen Thi, 2021). These studies collectively highlight the inadequacy of purely linear models in capturing complex economic dynamics. The Smooth Transition Regression framework employed here confirms that similar heterogeneity exists in the relationship between capital formation and health outcomes in Iran.

From a managerial and governance perspective, the results underscore the importance of aligning fiscal resources with infrastructure development. Budgetary analyses of Iran's health sector demonstrate that financing mechanisms and expenditure composition significantly affect sectoral outcomes (Eisavi & Moayedfard, 2022). Furthermore, the vulnerability of household health expenditures to macroeconomic fluctuations suggests that stable investment conditions are essential for safeguarding long-term improvements in health indicators (Fatemi Zardan & Fotros, 2021). The threshold effect identified in this study implies that insufficient capital formation may limit the returns to health infrastructure investment, whereas sustained capital growth can unlock greater gains in life expectancy.

The results also carry implications for equity and financing considerations. Studies on equity in health financing in Iran highlight disparities in resource distribution across provinces (Mousavi et al., 2018). If capital formation remains uneven across regions, the nonlinear relationship identified here may exacerbate disparities in life expectancy. Conversely, coordinated capital investment strategies may help equalize infrastructure productivity across regions. In Sub-Saharan Africa, financial development has been shown to shape health expenditure dynamics (Chireshe & Ocran, 2020), reinforcing the view that macro-financial conditions serve as enabling factors for health system performance.

The positive association between capital formation and enhanced health infrastructure effectiveness may also reflect broader structural transformation processes. Research on industrial dynamics in OECD countries demonstrates that structural economic changes influence healthcare-related growth pathways (Ying et al., 2022). Similarly, studies on digital transformation and post-pandemic economic strategies emphasize that capital investment can modernize service delivery systems, including healthcare (Zhang et al., 2022). The findings of the present study are consistent with this perspective, suggesting that higher levels of gross fixed capital formation may facilitate technological upgrades, facility expansion, and workforce development, thereby strengthening the relationship between infrastructure and life expectancy.

Another relevant dimension concerns workforce capacity and professional engagement. Cross-sectional evidence on nursing systems indicates that professional benefits and organizational support are crucial for healthcare performance (Ieng Lai et al., 2025). When capital formation exceeds the identified threshold, healthcare systems may possess greater fiscal capacity to invest in human resources, training, and retention programs, thereby amplifying the positive effect of medical staff on life expectancy. This interpretation aligns with realist reviews emphasizing the need for structural strengthening of primary healthcare systems in Iran (Mosadeghrad et al., 2021).

Furthermore, the broader socioeconomic environment influences health outcomes. Studies on working conditions and mental health among older populations highlight the interplay between economic structures and health status (Bertoni et al., 2025). Although focused on a different demographic dimension, such findings reinforce the notion that economic conditions shape health trajectories. The nonlinear association identified here reflects a similar principle: macroeconomic investment levels condition the effectiveness of sectoral infrastructure.

5 Conclusion

Collectively, the empirical evidence suggests that gross fixed capital formation functions as a regime-switching variable that transforms the impact of healthcare infrastructure on life expectancy. When capital accumulation is insufficient, infrastructure investments yield modest improvements. Once a critical investment threshold is reached, however, complementary effects emerge, magnifying the benefits of medical resources and financial allocations. This nonlinear dynamic provides a nuanced understanding of health system performance in emerging economies and offers a valuable contribution to the management and public health literature.

Despite its contributions, this study has several limitations. First, the analysis is confined to a single country, which limits the generalizability of the findings to other institutional and economic contexts. Second, although the STAR model captures nonlinear dynamics effectively, it does not explicitly account for potential structural breaks arising from major policy reforms or external shocks. Third, data constraints may restrict the inclusion of additional explanatory variables such as technological innovation indices or regional inequality measures. Finally, the reliance on aggregated national-level data may obscure subnational heterogeneity in healthcare infrastructure and investment patterns.

Future research could extend the analysis by employing panel data across multiple countries to assess whether similar threshold effects exist in other developing or emerging economies. Incorporating regional or provincial data would allow for examination of spatial heterogeneity and inequality dimensions. Additionally, future studies may integrate environmental, demographic, and technological variables to provide a more comprehensive understanding of the health–investment nexus. The use of alternative nonlinear methodologies, such as panel threshold or regime-switching vector autoregressive models, could further validate and refine the robustness of the results. Longitudinal analyses exploring the long-term sustainability of threshold effects would also contribute to the literature.

From a policy and managerial perspective, the findings highlight the importance of coordinated capital investment strategies to enhance the productivity of healthcare infrastructure. Policymakers should prioritize sustained gross fixed capital formation to create an enabling environment in which health investments can generate maximum returns in terms of life expectancy. Strategic planning should integrate public and private sector investment mechanisms to ensure that infrastructure expansion is aligned with macroeconomic development goals. Strengthening financial management practices, promoting workforce development, and ensuring equitable distribution of resources across regions are also essential. By recognizing the existence of threshold effects, decision-makers can design phased investment strategies that move the economy beyond critical capital levels, thereby amplifying the positive impact of healthcare infrastructure on population health.

Authors' Contributions

A.A.M. conceptualized the study, developed the theoretical framework linking gross fixed capital formation, healthcare infrastructure, and the life expectancy index, and supervised the econometric modeling process. L.A. was responsible for data collection and preparation for the period 1986–2023, conducted the STAR model estimation, and performed diagnostic and threshold tests. G.A. contributed to the interpretation of empirical findings, drafting and revising the manuscript, and ensuring methodological rigor and coherence between theoretical foundations and econometric results. All authors reviewed and approved the final version of the manuscript and accept responsibility for the integrity and accuracy of the study.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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