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Public Health Expenditure and Health Outcomes in Comoros: An Asymmetric Evidence Using Multiple Threshold Nonlinear ARDL Model

Mohamed Nassur Said Mouinou, Pierre Mendy

Laboratory of Mathematics of Decision and Numerical Analysis, Cheikh Anta Diop University of Dakar, Dakar, Senegal
Email: saidmouinou.nassur@ucad.edu.sn

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Abstract

The objective of this study is to evaluate the effects of major, minor, and moderate changes in public health expenditures on health outcomes in the Comoros. Quarterly data series from 1990Q1 to 2020Q4, obtained from the World Development Indicators (WDI, 2023), were used for the empirical analysis. The estimates show that MTNARDL model provides more robust results than NARDL model. Similarly, the results of this improved framework indicate that the effects of extremely large changes in public health expenditures on health outcomes differ significantly from the effects of extremely small changes. Once again, the results reveal that the positive impacts of health expenditures on health outcomes diminish at the lowest thresholds. Furthermore, the asymmetric effects between health expenditures and outcomes are more pronounced in the long term than in the short term. Therefore, to ensure moderate rates of infant and adult mortality and an increase in life expectancy at birth in the Comoros, policymakers should pay adequate attention to long-term dynamics and ensure that the level of public health expenditure does not trend towards lower thresholds where the positive impacts of health expenditures fade.

Keywords

Public Health Expenditure, Health Outcomes, Multiple Threshold Nonlinear ARDL, Comoros

1. Introduction

The benefits of good health have been recognized in the economic literature. It is

one of the sources of happiness and well-being for individuals, regardless of their status in society. Health also plays a major role in the economic growth and development of countries (Bloom et al., 2004; Gyimah-Brempong, & Wilson, 2004; Boachie, 2017). Thus, even though good health provides utility to the individual and enhances their market value, it also increases national production (Weisbrod, 1966; Grossman, 1972; World Bank, 1993). Consequently, improving the health conditions of the population is considered by policymakers as an important means to enhance human capital, achieve sustainable development, reduce poverty and inequalities, and improve well-being (Grossman, 1972; World Bank, 1993; Von Schirnding, 2005; Sen, 2006). This process requires significant investments in the health sector.

Public health expenditures are one of the government's policy instruments that have been closely scrutinized over the past three decades. The effectiveness of public health expenditures in improving health outcomes has become one of the central issues in health policy, in terms of the role of the government.

The COVID-19 pandemic has shown that investing in the healthcare system is very important and that countries with strong healthcare systems have better managed this enormous health crisis. According to a report published by the World Health Organization in 2019, global health systems have progressed faster than economies until 2018. While global health expenditures grew by 3.9% per year in real terms between 2000 and 2017, the economy grew by 3% per year over the same period. Investing in the health sector provides individuals with a means to improve their health status. Like other investment projects, investing in health requires the mobilization of resources, both financial and non-financial. The amount of expenditures incurred for the preparation and improvement of the population's health is considered health expenditure (World Bank, 2019). This implies that there is a link between health expenditures and health outcomes.

In the Comoros, investments in the health sector are of paramount importance for the socio-economic development of the country. Public health financing directly influences access to care, the quality of medical services, and public health indicators such as life expectancy, infant mortality, and disease prevalence. Furthermore, health status remains low due to malnutrition, high morbidity, and mortality (especially maternal and infant) compared to the global average. Although significant progress has been made in the sector, available data show that maternal and infant mortality (under-five and infant) remain high, and the Comoros is one of the countries that has not been able to achieve most of the Millennium Development Goals (MDGs) (World Bank, 2020). In 2020, the maternal mortality rate was 443 per 100,000 live births, compared to a target of 50 per 100,000 live births, the under-five and infant mortality rates were 55 and 24 per 1,000 live births, respectively, which were above the targets, and life expectancy at birth was 64 years for men and 67 years for women. In other words, despite the progress made, health outcomes remain poor in the Comoros. Besides these

issues, budget allocation to the sector compared to the global average is low and gradually decreasing (World Bank, 2020). In 2015, for example, only 5% of total public expenditure was allocated to health, which represents a decline from previous allocations and is below the 15% target proposed in the Abuja Declaration. These indicators reflect a struggling health system, unable to adequately meet the needs of the population. In this context, examining the relationship between public health expenditures and health outcomes in the Comoros proves to be a central concern.

The study makes several important contributions to the literature. First, it applies the multiple threshold nonlinear ARDL (MTNARDL) model, an advanced econometric approach that allows for separating the major, moderate, and minor effects of public health expenditures on health outcomes. Among the many advantages and preferences of MTNARDL over conventional NARDL is its ability to go beyond verifying only the effects of positive and negative changes in the exogenous variable. Second, it focuses on the Comoros, a context often overlooked in empirical studies, thus offering valuable insights into a low-income country with unique public health challenges. Third, it uses the period 1990Q1-2020Q4, covering health expenditures under six different democratic regimes in the Comoros. Fourth, it explores the policy implications of the results, providing evidence-based recommendations to improve the efficiency of expenditures.

The rest of the article progresses as follows. Section 2 presents the literature review. The research methodology will be detailed in Section 3. Section 4 provides the econometric results and their economic interpretations. Finally, Section 5 gives the conclusion and various policy implications.

2. Literature review

Several empirical studies have explored the relationship between public health expenditures and health outcomes in different contexts. Health expenditures are generally considered to improve health outcomes, such as life expectancy, mortality rate, and infant mortality rate. Previous research has often used linear econometric methods to examine this relationship, with mixed results. A study by Gupta et al. (2002) found that public health expenditures were significantly associated with a reduction in infant mortality in developing countries. Novignon et al. (2012) showed that health expenditures significantly influence health status by improving life expectancy and reducing mortality and infant mortality rates in Sub-Saharan African countries. The results of Mhango and Chirwa (2018) revealed that corruption deteriorates health outcomes and that increased health expenditures reduce infant mortality rates in Malawi. Similarly, Oluyemi and Omola (2019) assert that public health expenditures have a positive impact on reducing infant and newborn mortality in Nigeria. Arthur and Oaikhenan (2017) found that health expenditures have a significant impact on health outcomes in Sub-Saharan Africa. However, other studies find little or no evidence that public health expenditures improve health. Many of these studies, if not all, have questioned the efficiency of public health expenditures. Dollar and Burnside (1999) found a non-

significant relationship between health expenditures and infant mortality in low-income countries. Filmer (1999) also reported an insignificant impact of health expenditures on health outcomes. Yaqub et al. (2012) asserted a significant negative impact of health expenditures on health status due to poor governance quality. Richards and Vining (2016) concluded that despite efforts in health expenditures, they do not significantly impact the under-five mortality rate in low-income countries. Health expenditures are crucial for developing countries, where a large part of the population lacks health infrastructure. In developing countries, the population may face severe health risks due to inadequate healthcare systems. The most common diseases in developing countries are cardiovascular diseases, cancer, diabetes, diarrheal diseases, HIV/AIDS, malaria, strokes, and tuberculosis, among others. According to Bokhari et al., about 11 million children, particularly infants, die each year in developing countries. More recently, studies using nonlinear and asymmetric approaches have shown that the effects of public expenditures can vary depending on expenditure levels and contextual conditions. Akinci et al. (2017) used the NARDL method to analyze the impact of health expenditures on infant mortality in Turkey and found evidence of significant asymmetric effects. Irfan Ullah et al. (2021) explored the effects of health expenditures on health outcomes in Pakistan from 1995Q1 to 2017Q4. After using the QARDL (Quantile Autoregressive Distributed Lag) approach for estimation purposes, they found that public health expenditures improve life expectancy and reduce mortality and infant mortality rates. These nonlinear approaches better capture the complexity of economic relationships and are particularly suited to contexts where changes in democratic regimes can have different impacts depending on their magnitude and direction.

3. Methodology

3.1. Theoretical Framework: Health Production Function

In this paper, the relationship between public health expenditures and health outcomes is examined. To achieve this objective, this study uses three measures of health outcomes, namely life expectancy at birth, the mortality rate, and the infant mortality rate per 1,000 live births. Although there are several measures of health outcomes, these three indicators have been widely accepted to measure the health status of the population. The general hypothesis is that countries with healthy populations have low mortality and higher life expectancy (Boachie et al., 2018).

Following Grossman (1972) and Wagstaff (1986), the health production function is specified as follows:

$$S = f\left(X, M, E\right) \tag{1}$$

where S is a vector of the three measures of health outcomes. X is a vector of socio-economic variables, M represents health system variables, and E represents the vector of environmental factors. The Grossman model is thus modified in accordance with the adopted econometric procedure. Therefore, Equation (1) can be

modified to account solely for public health expenditures:

$$S = f\left(DPS\right) \tag{2}$$

In line with the empirical literature, the logarithmic health production function is as follows:

$$\begin{aligned} LTMI_t &= \alpha_0 + \alpha_1 LDPS_t + \varepsilon_{1t} \\ LTMO_t &= \alpha_0 + \alpha_1 LDPS_t + \varepsilon_{2t} \\ LESP_t &= \alpha_0 + \alpha_1 LDPS_t + \varepsilon_{3t} \end{aligned} \tag{3}$$

where *LTMI*, *LTMO* and *LESP* represents the infant mortality rate, the mortality rate, and life expectancy at birth. *LDPS* refer public health expenditures (in millions of dollars). The coefficients α_i (for $i = 0,1$) represent elasticities, while $\varepsilon_{1t}, \varepsilon_{2t}$ et ε_{3t} are the error terms.

3.2. Econometrics Models

We rely on the seminal contribution by Shin et al. (2014), who propose a nonlinear ARDL model. They suggest a single-threshold approach in which the regressor is decomposed into its positive and negative partial sum components. Consequently, each component captures the influence of either the increase or decrease in the independent variable. Verheyen (2013) extended this single-threshold NARDL model to a two-threshold NARDL model. Pal and Mitra (2015, 2016) further generalized the NARDL technique by setting multiple thresholds for the independent variable, resulting in a Multiple Threshold Nonlinear ARDL (MTNARDL) model.

3.2.1. Nonlinear ARDL Model (NARDL)

To capture the asymmetric effect, Shin, Yu, and Greenwood-Nimmo (2014) proposed a nonlinear ARDL model in which the regressors are decomposed into two partial sums, namely positive and negative. In our study, public health expenditures are decomposed as follows:

$$LDPS_t = LDPS_0 + LDPS_t^+ + LDPS_t^- \tag{4}$$

where $LDPS_t^+$ and $LDPS_t^-$ are partial sums that capture the increase and decrease in the variation of public health expenditures, expressed as follows:

$$\begin{aligned} LDPS_t^+ &= \sum_{i=1}^{t} \Delta LDPS_i^+ = \sum_{i=1}^{t} \max\left(\Delta LDPS_i, 0\right) \\ LDPS_t^- &= \sum_{i=1}^{t} \Delta LDPS_i^- = \sum_{i=1}^{t} \min\left(\Delta LDPS_i, 0\right) \end{aligned} \tag{5}$$

Within the framework of the NARDL approach, the short-term and long-term asymmetric dynamics can be incorporated into the following equation:

$$\begin{aligned} \Delta LS_t = &\sum_{i=1}^{n1} \varphi_{1i} \Delta LS_{t-i} + \sum_{i=0}^{n2} \varphi_{2i} \Delta LDPS_{t-i}^+ + \sum_{i=0}^{n2} \varphi_{3i} \Delta LDPS_{t-i}^- + \theta_1 LS_{t-1} \\ &+ \theta_2 LDPS_{t-i}^+ + \theta_3 LDPS_{t-i}^- + \varepsilon_t \end{aligned} \tag{6}$$

Besides the advantages of the ARDL model, long-term and short-term asymmetry can be tested using the Wald test. For the long term, the null hypothesis is $\theta_2 = \theta_3$. A significant difference between these two values would confirm a long-term asymmetric relationship. Similarly, $\varphi_{2i} = \varphi_{3i}$ would indicate no short-term asymmetry. Furthermore, the existence of co-integration can be assessed using the bounds test, where the null hypothesis ($\theta_1 = \theta_2 = \theta_3 = 0$) means there is no co-integration.

3.2.2. Multiple Threshold Nonlinear ARDL Model (MTNARDL)

The Comorian economy experienced six political regimes during our study period, and the preferences for health expenditures varied and diverged according to these regimes. This can have a diverse impact on health outcomes. Therefore, to capture the dynamic behavior of public health expenditures during different periods, we use the nonlinear ARDL method with multiple thresholds, which could provide more robust results compared to conventional OLS and linear ARDL techniques based on the conditional mean. Our study is primarily focused on the relationship between public health expenditures and health outcomes in Comoros. The main objective is to account for the effects of extreme variations in public health expenditures on health outcomes during the study period and, in particular, to reveal the relevant threshold that provides the most desirable impact.

Drawing on the work of Pal and Mitra (2019), we test the asymmetric impact of public health expenditure shocks on health outcomes using the MTNARDL approach, proposed by Pal and Mitra (2015, 2016), for both the short and long term. Following Verheyen (2013), we introduce two thresholds at the 25th and 75th quantiles to decompose the variation in public health expenditures into three partial sums.

$$LDPS_t = LDPS_0 + LDPS_t^{(\omega_1)} + LDPS_t^{(\omega_2)} + LDPS_t^{(\omega_3)} \tag{7}$$

In specification (7), $LDPS_t^{(\omega_1)}, LDPS_t^{(\omega_2)}$ et $LDPS_t^{(\omega_3)}$ are three partial sums fixed at the 25th and 75th quantiles of health expenditures. Furthermore, the thresholds of each series are represented by τ_{25} et τ_{75}, and calculated as follows:

$$\begin{aligned} LDPS_t^{(\omega_1)} &= \sum_{i=1}^{t} \Delta LDPS_i^{(\omega_1)} = \sum_{i=1}^{t} \Delta LDPS_i^I \left\{ \Delta LDPS_i \le \tau_{25} \right\} \\ LDPS_t^{(\omega_2)} &= \sum_{i=1}^{t} \Delta LDPS_i^{(\omega_2)} = \sum_{i=1}^{t} \Delta LDPS_i^I \left\{ \tau_{25} < \Delta LDPS_i \le \tau_{75} \right\} \\ LDPS_t^{(\omega_3)} &= \sum_{i=1}^{t} \Delta LDPS_i^{(\omega_3)} = \sum_{i=1}^{t} \Delta LDPS_i^I \left\{ \Delta LDPS_i > \tau_{75} \right\} \end{aligned} \tag{8}$$

where $I\{T\}$ is a dummy variable that equals 1 when the conditions specified in { } are met, otherwise it equals 0. The two thresholds of the NARDL model can be specified as follows:

$$\Delta LS_t = \sum_{i=1}^{n1} \varphi_{1i} \Delta LS_{t-i} + \sum_{j=1}^{3} \sum_{i=0}^{n2} \varphi_{ki} \Delta LDPS_{t-i}(\omega_j) + \theta_1 LS_{t-1} + \sum_{j=1}^{3} \theta_k LDPS_{t-1}(\omega_j) + \varepsilon_t \tag{9}$$

where $k = j+1$. Rejection of the null hypothesis of no co-integration $H_0 : \theta_1 = \theta_2 = \theta_3 = \theta_4 = 0$ could confirm co-integration between the variables. Moreover, the Wald test is used to assess short-term asymmetry with the null hypothesis of no asymmetry $H_0 : \varphi_{2i} = \varphi_{3i} = \varphi_{4i}$. Finally, for long-term asymmetry, the null hypothesis is $H_0 : \theta_2 = \theta_3 = \theta_4$. Following the work of Chang et al. (2019) and Pal and Mitra (2019), we first estimate the equations (NARDL, MTNARDL) using the OLS technique. Secondly, we estimate the co-integration relationship using the Wald test and thus obtain the calculated F-statistic, which will be compared to the asymptotic critical value of the upper bound. Finally, the standard Wald test is again applied to determine whether the effect of the variation in public health expenditures is symmetric or asymmetric on health outcomes in both the long and short term.

The main advantage of the MTNARDL model over the NARDL model is that it takes into account the influence of the dependent variable on the extreme positive and negative values of the independent variable and identifies the response to moderate changes in the independent variable (Chang et al., 2019).

4. Data and Empirical Results

4.1. Data

The data used are annual time series from 1990 to 2020, sourced from the World Bank (WDI). These data have been converted to quarterly frequency following Sbia et al. (2018) using the method of quadratic sum of matches. The study period covers from the 1st quarter of 1990 to the 4th quarter of 2020 (1990Q1-2020Q4), totaling 124 observations. This period was chosen because it represents significant global events such as the Millennium Development Goals, currently known as the Sustainable Development Goals (SDGs) and the Abuja declaration in 2001. Both events focused on improving global and regional health. Secondly, most data for Comoros before 1990 are missing due to the absence of reliable and structured data collection systems during this period, which limits the availability and quality of data. Life expectancy at birth, adult mortality rate, and infant mortality rate are used as measures of health outcomes. Public health expenditures (in millions of dollars) are the main variable of interest.

4.2. Empirical Results and Discussion

4.2.1 Descriptive Statistics

Table 1 presents the descriptive statistics of the variables. The standard deviation results show a high variability in public health expenditures compared to other variables. Skewness values indicate that our data are asymmetric. Specifically, except for the TMO variable, the data are skewed to the right. Kurtosis values below 3 indicate platykurtic distributions. However, the Jarque-Bera values for most series indicate that the variables are not normally distributed. Therefore, deviations from normal distribution reveal the variable nature of our data over time, justifying the application of the multiple threshold NARDL model, a time-varying

threshold model (Pal et al., 2015; Chang, 2020). This also provides the necessary justifications for studying the non-linearity and asymmetry in the relationship between public health expenditures and health outcomes in Comoros.

Table 1. Descriptive statistics.

Variable	Mean	Standard Deviation	Skewness	Kurtosis	Jarque-Bera Probability
LTMIQ	1.028	0.057	−0.165	1.901	0.033
LTMOQ	0.575	0.031	0.170	2.265	0.184
LESPQ	1.024	0.010	0.102	2.051	0.087
LDPSQ	0.916	0075	0.095	1.650	0.008

Source: Authors computation based on World Bank (2023) data.

4.2.2. Unit Root Test

The main requirement for time series modeling is to study the order of integration of variables. The application of the MTNARDL model requires excluding I(2) variables. In this study, we used the Zivot-Andrews unit root test (ZA) (Zivot & Andrews, 1992) to extract information regarding the order of integration, and the results are reported in **Table 2**. The results indicate that structural breaks were found for infant mortality rate, adult mortality rate, life expectancy at birth, and public health expenditure in 2001Q2, 1996Q2, 1996Q2, and 2001Q2, respectively. Therefore, the absence of a unit root with structural break reinforces the applicability of the MTNARDL model in our study.

Table 2. Unit root test results (ZA).

Variable	Level	Break Date	First Difference	Break Date
LTMIQ	−4.54	2014Q2	−7.99***	2001Q2
LTMOQ	−2.93	2001Q2	−7.27***	1996Q2
LESPQ	−4.31	2001Q2	−9.53***	1996Q2
LDPSQ	−3.64	2002Q4	−6.76***	2001Q2

Note: ***Significant at 1% level. Source: Authors computation based on World Bank (2023) data.

4.2.3. Cointegration Bounds Test

After confirming the validity of the series for the MTNARDL approach using the Zivot-Andrews unit root test, the cointegration test allows us to examine the existence of a long-term equilibrium relationship. The results from **Table 3** indicate that the Wald F-statistics exceed the upper critical bounds. These findings confirm the presence of a nonlinear (asymmetric) cointegration relationship between the variables in the two-threshold MTNARDL model.

Table 3. Cointegration test results.

	NARDL Model	Two-Threshold MTNARDL Model
Panel A: LTMIQ		
F-Statistic	4.55	3.32
Panel B: LTMOQ		
F-Statistics	4.22	5.43
Panel C: LESPQ		
F-Statistics	3.59	6.16
Panel D: Bounds Critical Values	**99%**	**95%**
	I(1)	I(1)
NARDL	5.58	4.16
Two-Threshold MTNARDL	3.20	3.67

Source: Authors computation based on World Bank (2023) data.

4.2.4. Estimation of NARDL Model

Drawing inspiration from Shin et al. (2014), we obtained the following results from the single-threshold NARDL model (Table A1). Starting with the coefficient of adjustment or error correction term, we observe that across our three estimated models, it is negative and significant, ensuring an error correction mechanism and thus the existence of a long-term relationship between the variables. The asymmetric error terms suggest that 0.2%, 15%, and 18% of any imbalance in infant mortality rate, adult mortality rate, and life expectancy is corrected annually towards equilibrium. In the short term, negative shocks from public health expenditure positively impact the infant mortality rate. Specifically, a 1% increase in health spending increases the infant mortality rate by 0.3%. As for the Panel B and Panel C, we did not find statistical significance of public health expenditures in the short term. In the long term, positive shocks from public health expenditures have both positive and negative impacts on life expectancy and infant mortality rate. Specifically, a 1% increase in health spending would increase life expectancy at birth by 0.1 years and decrease the infant mortality rate by 0.1%.

Table A1 also provides the short-term and long-term asymmetries of the three single-threshold models. Only the model of infant mortality rate suggests a presence of a nonlinear asymmetric relationship in both short and long terms. The model of adult mortality rate suggests asymmetry only in the short term, while the model of life expectancy suggests asymmetry only in the long term.

The dynamic asymmetric multiplier graph (Figure A1) provides a clearer insight into the asymmetric relationship between public health expenditures and health outcomes in the Comoros. It reveals more pronounced adjustments to positive short-term changes in public health expenditures that gradually diminish in the long term.

Post-estimation tests, including serial correlation test, stability test, constant

variance test, and stability test, provide relevant evidence of the non-robustness of the estimates. CUSUM and CUSUMSQ graphs confirm levels of instability in all three models. The observed instability shown by the unstable CUSUMSQ graphs (**Figure A2**) demonstrates the influence of structural breaks in the system that the standard nonlinear ARDL model could not account for. This justifies the application of a more advanced estimation technique (MTNARDL).

4.2.5. Estimation of MTNARDL Model

After using the single-threshold NARDL model where public health expenditures are divided into two series of partial sums, we evaluate the effect of variations in these expenditures by setting the following thresholds: first, the variation in quarterly public health expenditures is divided into three partial sums by setting the thresholds at the 25th and 75th percentiles, respectively (following Verheyen, 2013). The MTNARDL model, employed in this empirical study, should help identify any specific range of variations in public health expenditures that significantly influence the asymmetric response of health outcomes with more precision than the standard NARDL evaluation (see **Table 4**). The decomposition of partial sum series into three parts is based on the quantiles of variations in health spending over the study period.

Starting with Panel A, its adjustment coefficient is negative and significant at the 1% level for the MTNARDL model. The asymmetric correction term shows that 0.2% of any imbalance in infant mortality rate is adjusted towards equilibrium each year.

In the long term, variations in public health expenditures contribute significantly to the reduction in infant mortality rate. At the upper quantile (75th), an increase in public health expenditures leads to a 61% decrease in infant mortality rate. In comparison, at the lower quantile (25th), a variation in public health expenditures has no significant impact on infant mortality rate. Thus, we can observe that the effects are more pronounced in the upper quantile than in the lower quantiles. This implies that policies aimed at reducing infant mortality are most effective at the upper threshold.

In the short term, only the lower quantile of public health expenditures positively and significantly impacts the infant mortality rate in the model. A 1% increase in health spending increases the infant mortality rate by 0.4%. Wald test for asymmetry provides evidence to reject the null hypothesis of absence of short-term and long-term asymmetry for the two-threshold model. In other words, the impacts of public health expenditures on infant mortality rate are asymmetric in both short and long terms.

The adjustment coefficient of Panel B is negative and significant at the 1% threshold. The asymmetric correction term shows that 0.1% of any imbalance in adult mortality rate is adjusted towards equilibrium each year.

In the long term, public health expenditures do not have statistical significance across different quantiles despite their negative impact on adult mortality rate.

In the short term, the lower quantile of the previous year's public health

expenditures has a positive and significant impact, while the upper quantile has a negative and significant impact on adult mortality rate. A 1% increase in the upper quantile of expenditures leads to a 1.9% reduction in adult mortality rate. Wald test for asymmetry suggests the presence of an asymmetric relationship only in the short term.

In Panel C, the asymmetric adjustment coefficient is negative and significant at the 1% threshold, confirming the existence of a long-term asymmetric relationship between public health expenditures and life expectancy.

Based on the results of the two-threshold MTNARDL model, except for the upper quantile, the lower quantiles do not have a significant impact on life expectancy in the long term. Specifically, a 1% increase in the upper quantile of public health expenditures increases life expectancy at birth by 7.5 years. Wald test suggests asymmetry in both short and long terms.

Table 4. MTNARDL model results.

Panel A: LTMIQ	**Coeff**	**Prob**
Long run		
Constant	0.935***	0.000
LDPS (ω_1) (−1)	0.012	0.942
LDPS (ω_2) (−1)	−0.132	0.719
LDPS (ω_3) (−1)	−0.610***	0.000
Short run		
ΔLDPS (ω_1)	0.004***	0.001
ECT (−1)	−0.002***	0.000
W_{SR}	12.278***	0.001
W_{LR}	5.376***	0.006
Panel B: LTMOQ	**Coeff**	**Prob**
Long run		
Constant	0.553***	0.000
LDPS (ω_1) (−1)	−0.143	0.764
LDPS (ω_2) (−1)	−0.246	0.819
LDPS (ω_3) (−1)	−0.325	0.122
Short run		
ΔLDPS (ω_1)	0.014	0.124
ΔLDPS (ω_2)	0.038	0.331
ΔLDPS (ω_3)	−0.019**	0.034
ΔLDPS (ω_1) (−1)	0.051	0.236
ΔLDPS (ω_2) (−1)	0.134***	0.001
ECT (−1)	−0.001***	0.000
W_{SR}	3.337**	0.013
W_{LR}	3.556	0.352

Continued

Panel C: LESPQ	Coeff	Prob
Long run		
Constant	1.021***	0.000
LDPS (ω_1) (−1)	−0.002	0.956
LDPS (ω_2) (−1)	−0.005	0.955
LDPS (ω_3) (−1)	0.075***	0.001
Short run		
ΔLDPS (ω_1)	−0.005*	0.087
ECT (−1)	−0.019***	0.000
W_{SR}	2.616*	0.081
W_{LR}	2.533*	0.084

Note: ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level. W_{SR} and W_{LR} represent the F-statistics used in the Wald test to evaluate short-term and long-term asymmetry, respectively. Source: Authors computation based on World Bank (2023) data.

4.2.6. Specification Tests

The step of verifying hypotheses through various specification tests is crucial for any time series data analysis. The reliability of our results from the three models is checked using the outcomes of different tests presented (**Table A2**). Across the three models in our study, the Jarque-Bera normality test, the LM test for serial correlation by Breusch-Godfrey, and the ARCH test for heteroskedasticity provide relevant evidence of the robustness of the MTNARDL model with two thresholds. However, the CUMUMQ graph indicates some levels of instability for Panel B and Panel C. This instability observed in the CUMUMQ graph demonstrates the influence of structural breaks that the standard NARDL model could not account for.

5. Discussion

This paper explores the impact of public health expenditures on health outcomes in terms of infant mortality rate, adult mortality rate, and life expectancy at birth. The MTNARDL model with two thresholds allowed us to identify thresholds beyond which the effects of public health expenditures on health outcomes change. We obtained interesting results after estimating this model.

The upper quantile of public health expenditures has a negative effect on the infant mortality rate, while the lower quintiles have no significant impact. Increasing public health expenditures lead to a reduction in the infant mortality rate in the Comoros. This result confirms findings from previous studies such as Yaqub et al. (2012), Akinlo and Sulola (2019), and contrasts with the results of Akinkugbe and Mohanoe (2009). It shows that increasing public health expenditures in the Comoros will improve access to and the quality of healthcare. In the upper quintile of public health expenditures, a significant portion of resources is often allocated to higher-quality healthcare infrastructure, advanced medical equipment procurement, and increased qualified medical personnel. This would result in

better capacity to provide prenatal, neonatal, and postnatal care, directly reducing the infant mortality rate. With higher expenditures, vaccination and prevention programs for childhood diseases can be intensified, leading to a significant reduction in preventable diseases contributing to infant mortality.

Public health expenditures have a positive and statistically significant impact on life expectancy at birth. Therefore, increasing public health expenditures can contribute positively to improving life expectancy among the Comorian population. This result is consistent with findings and conclusions from studies such as those by Novignon et al. (2012) and Jakovljevic et al. (2016). This result is not counterintuitive because increasing public health expenditures can help reduce inequalities in access to healthcare, as well as improve healthcare infrastructure and quality of care in rural areas where access is low (according to the WHO report, 2018, one of the main public health issues in Africa is limited access to primary care).

These results could be justified by the fact that the various democratic regimes in the Comoros have implemented several health plans and programs to honor their commitment to improving citizens' health and achieving global health goals set by the United Nations. Among others, we can mention the National Vaccination Program (2004-2024), the Malaria Control Program (2007-2024), the Maternal and Child Health Initiative (2008-2024), the Nutrition and Food Program (2010-2024), and the National Health Policy (2015-2024).

6. Conclusion and Policy Implications

Considering the presence of nonlinearities in the relationship between implemented policies and health outcomes has allowed us to emphasize the heterogeneous dynamics characterizing this relationship and to provide new insights into the impact of public health expenditures on health outcomes in the Comoros between 1990 and 2020.

The estimations have shown that the MTNARDL model with multiple thresholds provides more robust results than the single-threshold NARDL model. The use of the MTNARDL model in this study has highlighted the importance of high levels of health expenditures. The results indicated that the effects of extremely large changes in public health expenditures on health outcomes differ significantly from those of extremely small changes. Specifically, the upper quantile of public health expenditures is associated with significant reductions in infant mortality and increases in life expectancy, due to improved access to and quality of healthcare. Once again, the results reveal that the positive impacts of health expenditures on health outcomes diminish at lower thresholds. This implies that the positive impacts of health expenditures on health outcomes diminish at lower thresholds. However, diminishing marginal returns and asymmetric risks associated with reductions in expenditures underscore the need for careful and strategic management of health resources to maximize benefits and ensure sustainability of public health gains.

Therefore, to ensure satisfactory health outcomes, policymakers should pay

adequate attention to long-term dynamics and ensure that levels of public health expenditures do not trend towards lower thresholds where the positive impacts of health expenditures diminish.

The findings of this study suggest the following policy recommendations: the government should increase health expenditures to optimize health outcomes, especially in regions with inadequate healthcare infrastructure. Secondly, the government should modernize obsolete healthcare infrastructure using the latest health technologies to optimize the country's healthcare system. Thirdly, longevity requires a healthy lifestyle and a cleaner environment, so it is essential to adopt strategies that promote these goals. Such sustainable policy measures can reduce the government's public health burden and improve the overall health outcomes of the country.

In a context of poor economic performance in recent years, the Comorian government has limited room to increase health expenditures. The policy implications of this research suggest that health expenditures significantly increase life expectancy and reduce mortality rates in the country. Therefore, policymakers must explore new avenues for investment in the health sector. By encouraging public-private partnerships and creating an environment conducive to private investment, it is possible to reduce the burden of healthcare expenditures for the government and improve the quality of life for the masses in the country.

However, this research has certain limitations: firstly, it explores the relationship between health expenditures and outcomes in the context of a single country, the Comoros. Secondly, we use time series data from 1990 to 2020 due to data availability constraints. Thirdly, we only use macroeconomic variables in our analysis. Future research directions in this field could expand to multiple countries and regions, such as Indian Ocean countries. Additionally, the data period could be extended to account for different periods and political regimes in the Comoros. Furthermore, microeconomic variables such as household health expenditures could be incorporated in future research for a more comprehensive exploration of the underlying phenomenon.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendices

Table A1. NARDL model results.

Variable	Panel A: LTMIQ		Panel B: LTMOQ		Panel C: LTMOQ	
	Coeff	Prob	Coeff	Prob	Coeff	Prob
Long run						
Constant	0.002**	0.045	0.008**	0.025	0.018**	0.014
$LDPS^{+}$	−0.001***	0.006	−0.002	0.115	0.001***	0.005
$LDPS^{-}$	0.001	0.946	0.001	0.896	0.001	0.833
Short run						
ΔLDP^{+}	0.001	0.647	−0.019	0.153	0.003	0.414
$\Delta LDPS^{+}$ (−1)	−0.002	0.238	−0.001	0.934	−0.001	0.835
$\Delta LDPS^{-}$	0.003***	0.004	0.019	0.113	−0.005	0.136
$\Delta LDPS^{-}$ (−1)	−0.001	0.525	0.006	0.624	−0.001	0.960
ECT (−1)	−0.002**	0.030	−0.015**	0.018	−0.018**	0.015
W_{SR}	3.223*	0.075	4.537**	0.035	1.637	0.203
W_{LR}	48.84***	0.000	1.636	0.204	3.717*	0.056
Specification tests						
Jarque-Bera	9.372	0.009	232.6	0.000	455.5	0.000
Portmanteau	88.290	0.000	123.1	0.000	128	0.000
Breusch-Pagan	0.125	0.725	7.893	0.005	25.790	0.000
Ramsey	2.824	0.042	7.087	0.000	5.902	0.001
CUSUM and $CUSUM^2$	I		I		I	

Note: ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level. Jarque-Bera test H0: Residuals normally distributed; LM test H0: No autocorrelation; Breusch-Pagan H0: Homoskedasticity; ARCH test H0: Homoskedasticity; Ramsey test H0: Model correctly specified; I indicate CUSUM and CUSUMQ graphs are unstable. W_{SR} and W_{LR} represent the F-statistics used in the Wald test to evaluate short-term and long-term asymmetry, respectively. Source: Authors computation based on World Bank (2023) data.

Table A2. Specification tests results.

Panel A: LTMIQ	F-stat	Prob
Jarque-Bera	12.997	0.002
Breusch-Godfrey (LM)	0.039	0.961
Breusch-Pagan-Godfrey	0.452	0.866
ARCH	3.343	0.070

Continued

Ramsey Reset	7.018	0.009
CUSUM	S	
CUSUMQ	S	
Panel B: LTMOQ	**F-stat**	**Prob**
Jarque-Bera	378.204	0.000
Breusch-Godfrey (LM)	0.613	0.543
Breusch-Pagan-Godfrey	2.437	0.011
ARCH	0.165	0.685
Ramsey Reset	0.025	0.980
CUSUM	S	
CUSUMQ	I	
Panel C: LESPQ	**F-stat**	**Prob**
Jarque-Bera	429.138	0.000
Breusch-Godfrey (LM)	0.679	0.509
Breusch-Pagan-Godfrey	3.854	0.001
ARCH	0.667	0.415
Ramsey Reset	0.207	0.836
CUSUM	S	
CUSUMQ	I	

Note: S and I indicates CUSUM and CUSUMQ graphs are stable and unstable. Source: Authors computation based on World Bank (2023) data.

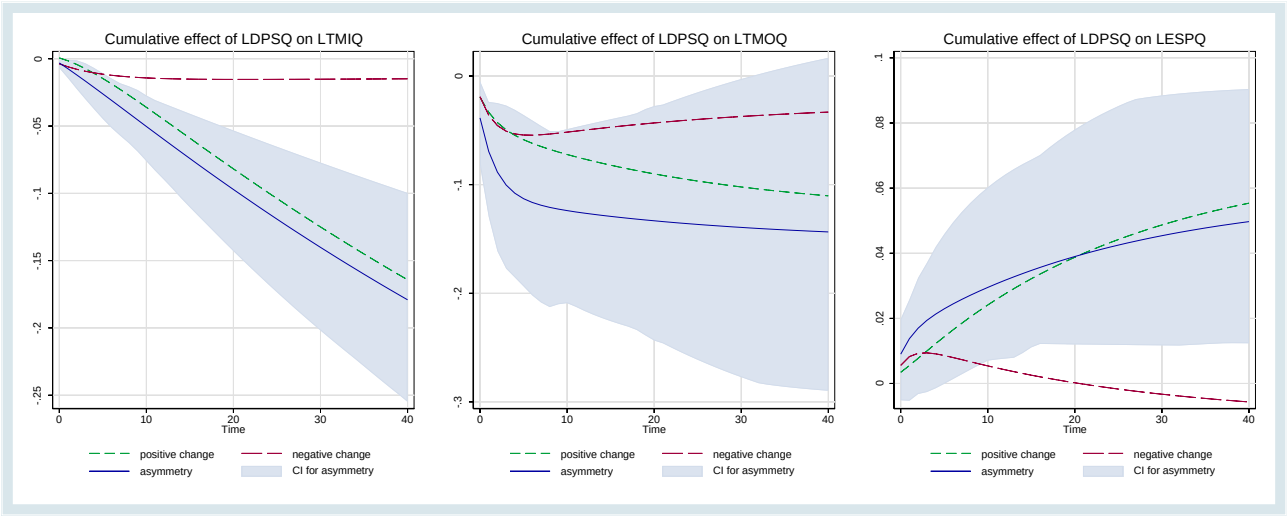

Figure A1. Dynamic multiplier graphs.

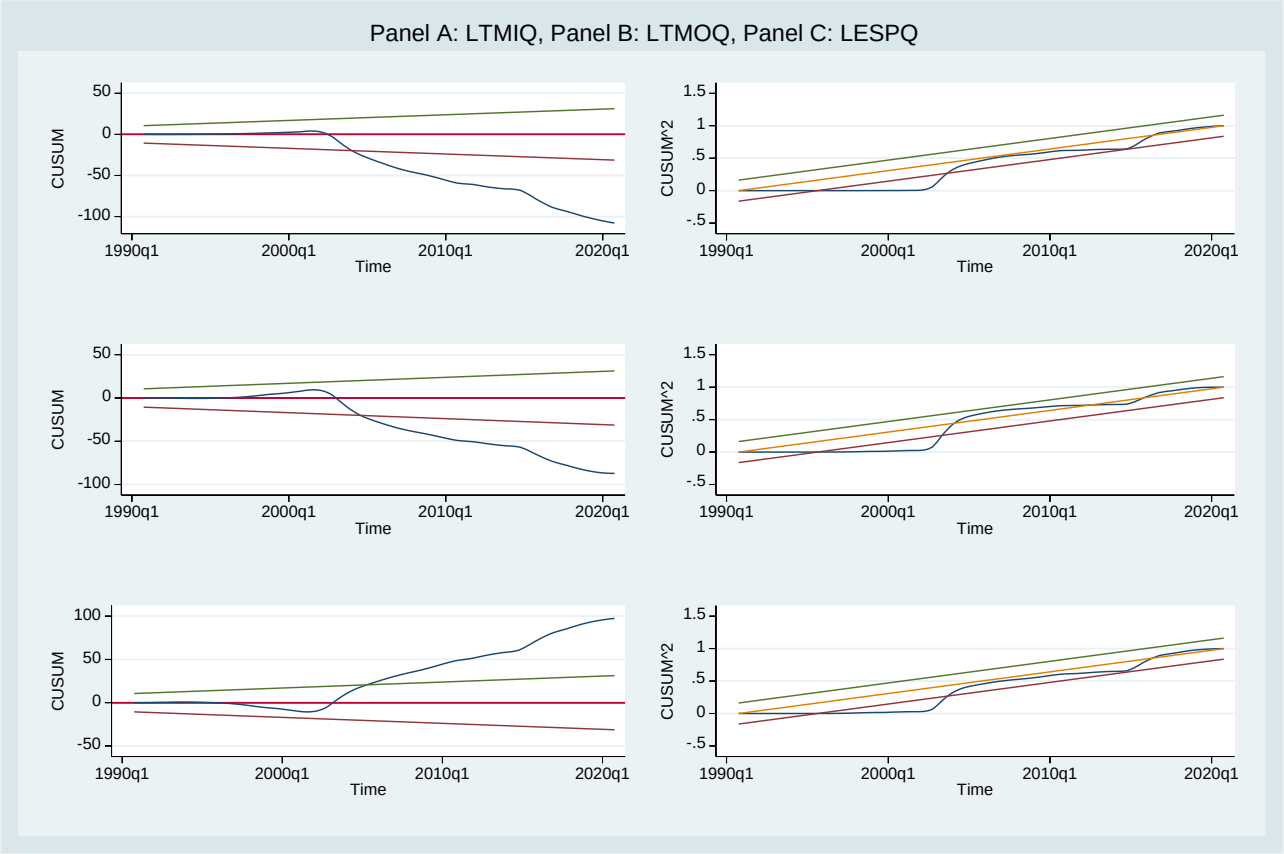

Figure A2. Plots of CUSUM and CUSUMQ for recursive residuals.