Journal of Economics and Behavioral Studies (ISSN: 2220-6140)
Vol. 18, No. 1, pp. 12-27, 2026

Modeling Premature Adult Mortality From Non-Communicable Diseases in The United States

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Abstract: We model mortality from cardiovascular diseases (CVD), cancer, diabetes, and chronic respiratory diseases (CRD) among individuals aged 30–70 years in the United States using quarterly time-series data covering the period 2000 to 2024. We adopt an autoregressive integrated moving average (ARIMA) framework to examine both the long-run trajectory and short-run fluctuations in premature adult mortality. Quarterly data obtained from the World Bank are employed, with mortality from CVD, cancer, diabetes, or CRD specified as the dependent variable, while autoregressive (AR) and moving average (MA) terms capture the inherent temporal dependence in mortality dynamics. Parameter estimation is conducted using the conditional least squares (CLS) technique. Results reveal a positive and statistically significant AR(1) coefficient of 0.987144, indicating strong persistence and inertia in mortality patterns, whereby current mortality outcomes are heavily influenced by their past realizations. In contrast, the MA(4) coefficient is negative and statistically significant at −0.697195, suggesting that short-run shocks to mortality, such as transitory health crises or policy interventions are gradually corrected over time. This dynamic adjustment mechanism reinforces the tendency of the series to revert toward its long-run path. The estimated ARIMA(1,1,4) model satisfies both covariance stationarity and invertibility conditions, confirming its econometric soundness and suitability for forecasting. The adjusted R-squared value of 0.835857 indicates that approximately 83.6% of the variation in premature adult mortality is explained by the model's dynamic structure, underscoring its strong explanatory power. Out-of-sample forecasts extending to 2050 project a sustained and gradual decline in mortality rates, with levels converging toward approximately 4% by mid-century. These projections are consistent with ongoing improvements in healthcare access, disease prevention strategies, medical technology, and public health interventions in the United States. The study recommends sustained and targeted investments in non-communicable disease prevention, early diagnosis, and health system resilience to consolidate and accelerate the observed long-term decline in premature adult mortality.

Keywords: *ARIMA, premature adult mortality, non-communicable diseases, United States*

1. Introduction

Non-communicable diseases (NCDs) constitute the leading cause of mortality worldwide, accounting for over 70 percent of global deaths, with cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes being the principal contributors (WHO, 2023). Premature mortality from NCDs, defined as deaths occurring between exact ages 30 and 70 years has emerged as a critical public health indicator, reflecting both the effectiveness of health systems and broader socioeconomic conditions. While high-income countries have historically achieved substantial reductions in premature mortality, recent evidence suggests that progress has slowed or reversed in several advanced economies, notably the United States.

The United States exhibits a distinctive and troubling pattern of premature adult mortality from NCDs. Despite having one of the highest per capita healthcare expenditures globally, the country continues to experience elevated mortality rates from preventable and manageable chronic diseases relative to peer nations (OECD, 2022). Cardiovascular diseases and cancers remain dominant causes of premature death, while diabetes and chronic respiratory diseases have shown persistent or rising trends, driven by obesity, sedentary lifestyles, unhealthy diets, tobacco use, and environmental exposures (CDC, 2023). These health challenges are exacerbated by pronounced socioeconomic and geographic inequalities, uneven access to preventive and primary healthcare, and disparities linked to income, race, and education (Woolf & Schoomaker, 2019).

Premature mortality from NCDs imposes high economic and social costs on the United States. Deaths occurring during prime working ages reduce labor productivity, increase dependency burdens, and generate substantial losses in human capital. Beyond direct healthcare expenditures, the indirect costs associated with lost earnings,

reduced economic output, and long-term disability place additional strain on households and public finances (Bloom et al., 2011). Consequently, reducing premature adult mortality from NCDs is not only a public health priority but also a key development and macroeconomic concern.

Although an extensive body of literature documents NCD prevalence and mortality patterns in the United States, much of the existing research remains largely descriptive or cross-sectional. Limited attention has been devoted to formal econometric and time-series modeling of premature adult mortality, particularly using high-frequency data capable of capturing short-term dynamics, trend shifts, and structural changes over time. Moreover, few studies provide robust forecasts of premature NCD mortality, despite their importance for forward-looking health policy, resource allocation, and evaluation of long-term disease prevention strategies. This represents a critical empirical gap, especially in the context of evolving demographic structures, behavioral risk profiles, and health system pressures.

The persistence of high premature adult mortality from non-communicable diseases in the United States, therefore, constitutes a major research problem. Without rigorous modeling and reliable forecasts, policymakers may underestimate future disease burdens and fail to implement timely, evidence-based interventions. Addressing this gap is essential for assessing progress toward national health objectives and global commitments, including the Sustainable Development Goal target of reducing premature mortality from NCDs by one-third.

Against this backdrop, we seek to model premature adult mortality from non-communicable diseases in the United States, focusing on deaths between ages 30 and 70 years. By employing a robust empirical modeling framework and generating forward-looking projections, we aim to deepen understanding of mortality dynamics, identify emerging trends, and provide actionable evidence to support effective NCD prevention and control policies. In doing so, our study contributes to the growing literature on mortality modeling and offers valuable insights for strengthening population health outcomes in the United States.

2. Literature Review

Globally, NCDs are the dominant cause of premature adult mortality, responsible for approximately 74% of all deaths, with cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes accounting for the largest share (WHO, 2023). Premature mortality, deaths occurring between ages 30 and 70, is widely used as a benchmark for assessing health system performance and progress toward international development goals, including the Sustainable Development Goals (SDG 3.4).

Empirical studies at the global level emphasize the role of behavioral risk factors such as tobacco use, unhealthy diets, physical inactivity, and harmful alcohol consumption in driving premature NCD mortality (Beaglehole et al., 2011; Murray et al., 2020). However, recent research highlights that risk exposure alone does not fully explain cross-country differences. Structural factors such as income inequality, urbanization, environmental pollution, and health system capacity significantly mediate mortality outcomes (Collaborators & Ärnlöv, 2020).

From a methodological standpoint, global studies have increasingly applied demographic and epidemiological models to analyze mortality trends. Nonetheless, many analyses rely on low-frequency (annual) data and focus on descriptive trend comparisons rather than dynamic modeling and forecasting (Global, 2017). This limits their ability to capture short-term fluctuations, structural breaks, and evolving disease trajectories, underscoring the need for more advanced modeling approaches.

Within high-income regions, including OECD countries, premature mortality from NCDs has generally declined over the past decades, largely due to improvements in medical technology, early diagnosis, and public health interventions (OECD, 2022). However, substantial heterogeneity persists across countries. Several studies document that the United States consistently underperforms relative to peer nations, particularly in mortality from cardiovascular diseases and diabetes (Ho & Hendi, 2018).

Regional comparative studies attribute these disparities to differences in healthcare access, preventive care utilization, and social protection mechanisms (Avendano & Kawachi, 2014). Unlike many OECD countries with

universal health coverage, fragmented healthcare financing systems have been linked to delayed diagnosis and poor chronic disease management, contributing to higher premature mortality.

Despite these insights, much of the regional literature remains cross-sectional or comparative in nature. Limited emphasis is placed on time-series or forecasting models that can inform future health system planning. Consequently, the capacity of existing studies to guide long-term NCD mortality reduction strategies remains constrained.

The United States has experienced persistently high levels of premature adult mortality from NCDs, even during periods of overall economic growth and rising healthcare expenditure (Woolf & Schoomaker, 2019). Cardiovascular diseases and cancers remain the leading causes, while diabetes-related mortality has shown worrying increases, closely linked to rising obesity and metabolic disorders (CDC, 2023).

Several U.S.-based studies highlight the role of socioeconomic inequality, racial and ethnic disparities, and geographic variation in shaping mortality outcomes (Case & Deaton, 2021). Populations with lower income and educational attainment face higher exposure to NCD risk factors and lower access to quality preventive care, resulting in disproportionate premature mortality burdens.

Methodologically, U.S. studies have largely focused on descriptive epidemiology and regression-based risk factor analysis. While these approaches are valuable, they often fail to capture the dynamic evolution and future trajectory of premature mortality. There is limited application of advanced time-series or forecasting models particularly those using high-frequency data to project NCD mortality and assess future policy implications. This constitutes a critical empirical gap that our study seeks to address.

Our study is anchored in the Epidemiological Transition Theory, which explains shifts in mortality patterns from infectious diseases to chronic, non-communicable diseases as societies undergo economic development, urbanization, and demographic change (Omran, 1998). In advanced economies such as the United States, this theory predicts a dominance of NCD-related mortality, particularly among adults in productive age groups.

Complementing this is the Health Production Function Theory, which conceptualizes health outcomes as a function of individual behaviors, socioeconomic conditions, environmental factors, and healthcare inputs (Grossman, 1972). According to this framework, premature mortality from NCDs reflects inefficiencies in health investment, preventive behavior, and access to effective medical care.

Together, these theories provide a foundation for modeling mortality as a dynamic outcome influenced by evolving risk factors and systemic conditions, justifying the use of quantitative modeling and forecasting techniques.

Conceptually, premature adult mortality from non-communicable diseases (NCDs) is specified as the dependent variable, measured as the probability (percentage) of death between exact ages 30 and 70 from cardiovascular diseases, cancers, diabetes, and chronic respiratory diseases. Mortality outcomes reflect the cumulative and dynamic influence of behavioral risk factors (such as tobacco use, physical inactivity, and unhealthy diets), socioeconomic conditions (including income inequality, education, and labor market status), health system characteristics (notably access to quality and preventive care), and demographic dynamics (particularly population aging and urbanization). Rather than modeling these determinants explicitly, their combined and lagged effects are captured through the stochastic structure of the mortality series itself. Accordingly, autoregressive (AR) and moving average (MA) components are employed to model persistence, inertia, and short-term shocks in mortality trends. The ARIMA framework is therefore well-suited for capturing historical dynamics and generating reliable forecasts of premature adult NCD mortality, providing an empirical basis for monitoring progress and informing health policy design and evaluation in the United States (Box & Jenkins, 1976; WHO, 2014; Hyndman & Athanasopoulos, 2021; Nahabwe & Maniple, 2025).

3. Data and Methods

We adopt a quantitative, longitudinal time-series research design to model and forecast premature adult mortality from NCDs in the United States. The design is appropriate for analyzing temporal dynamics and identifying underlying stochastic patterns in mortality outcomes over time. Time-series modeling enables the examination of persistence, trends, and shocks in mortality data, while providing a robust basis for generating forward-looking projections critical for health policy planning and evaluation (Box et al., 2015; Nahabwe & Maniple, 2025).

We focus on premature adult mortality, defined as the probability of dying between the ages of 30 and 70 years from cardiovascular diseases, cancers, diabetes, and chronic respiratory diseases. This indicator is widely used in epidemiological and policy-oriented research to assess the effectiveness of NCD prevention and control strategies (WHO, 2023).

We utilize secondary mortality data for the United States covering the period 2000 to 2024, obtained from internationally recognized health databases, including the World Health Organization (WHO) and the World Bank. These sources provide standardized and comparable mortality indicators that ensure data reliability and consistency over time (World Bank, 2024).

Given the time-series nature of the study, the sample consists of the complete population of annual observations within the study period rather than a subset. This census-based approach eliminates sampling bias and maximizes the informational content of the data (Enders, 2015; Kagarura et al., 2025). To enhance the model's ability to capture short-term dynamics and improve forecasting precision, the annual mortality series is converted to quarterly frequency using a temporal disaggregation technique. Quarterly transformation allows for richer dynamic structure and increased degrees of freedom, which are essential for robust ARIMA estimation and improved out-of-sample forecasts (Denton, 1971; Chow & Lin, 197; Kagarura & Nahabwe, 2025).

The annual-to-quarterly conversion is conducted using established temporal disaggregation methods that preserve the underlying annual totals while distributing observations smoothly across quarters. This approach ensures that the generated quarterly series remains consistent with the original data-generating process and avoids artificial volatility (Sax & Steiner, 2013; Nahabwe & Kagarura, 2025).

Before model estimation, the transformed series is subjected to standard pre-estimation diagnostics. Stationarity is assessed using unit root tests to determine the appropriate order of differencing required for ARIMA modeling (Dickey & Fuller, 1979; Kagarura & Nahabwe, 2025). Descriptive statistics and visual inspections are also employed to identify trends, volatility clustering, and potential structural shifts in premature NCD mortality.

The core analytical tool employed in this study is the Autoregressive Integrated Moving Average (ARIMA) model. ARIMA models are well-suited for univariate time-series analysis where the objective is to capture temporal dependence and generate accurate forecasts based solely on the historical behavior of the series (Box et al., 2015; Nahabwe & Kagarura, 2025). The general form of an ARIMA(p,d,q) model is expressed as:

$$Y_t = c + \sum_{i=1}^{p} \boldsymbol{\phi}_i Y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t \quad \text{..... (1)}$$

Where;
Y_t is Mortality from CVD, cancer, diabetes or CRD between exact ages 30 and 70 (%) at time t
c is a constant term
ε_t is white noise at time t
$\boldsymbol{\phi}_i$ are the coefficients of the autoregressive terms
θ_j are the coefficients of the moving average terms
p = Number of lagged AR terms
d = Number of differences required to make the series stationary
q = Number of lagged MA terms (Box & Jenkins 1976; Nahabwe & Maniple, 2025; Kagarura et al., 2025)

We estimate parameters using conditional least squares (CLS) method. CLS is widely used in ARIMA estimation due to its computational efficiency and robustness in finite samples, particularly when the sample size is moderate and the likelihood function is complex (Brockwell & Davis, 2002). CLS minimizes the sum of squared residuals conditional on initial observations, providing consistent and asymptotically efficient parameter estimates under standard regularity conditions. Compared to exact maximum likelihood estimation, CLS is less sensitive to initial value assumptions and is well-suited for high-frequency time-series data generated through temporal disaggregation (Hamilton, 1994; Kagarura & Nahabwe, 2025). CLS estimator for the regression coefficients is given by the following formula:

$$\hat{\theta} = \underset{\theta}{\operatorname{argmin}}\left[\sum_{t=1}^{n}(y_t - \hat{y}_t(\theta))^2\right] \quad \text{………………………………………………………} (2)$$

Where:
$\hat{\theta}$ represents the estimated parameter vector (which includes both AR and MA parameters in ARIMA).
y_t represents the actual observed value of the dependent variable at time t
$\hat{y}_t(\theta)$ represents the model's predicted value at time t based on the parameter estimates, where θ
n is the number of observations. (Hamilton, 1994; Nahabwe & Kagarura, 2025).

Post-estimation diagnostics are conducted to validate the adequacy of the fitted ARIMA model. Residual autocorrelation is examined using the Ljung–Box Q-statistic, while model stability and forecast accuracy are evaluated through in-sample fit and out-of-sample forecasting performance (Ljung & Box, 1978; Kagarura & Nahabwe, 2025).

The validated model is then used to generate short- to medium-term forecasts of premature adult mortality from NCDs. These projections provide empirical evidence on future mortality trajectories, offering valuable insights for health system planning, preventive interventions, and policy formulation aimed at reducing premature deaths.

The choice of a time-series design and ARIMA modeling framework is motivated by the study's objective to understand and forecast mortality dynamics rather than identify causal determinants. The conversion of annual data to quarterly frequency enhances model flexibility and forecast precision, while the use of conditional least squares ensures reliable estimation in the presence of complex temporal dependence. Together, these methodological choices provide a robust and policy-relevant approach to modeling premature adult mortality from NCDs in the United States.

4. Results and Discussion

Appendix 1 presents descriptive statistics for premature adult mortality from cardiovascular diseases (CVDs), cancer, diabetes, and chronic respiratory diseases (CRDs) among individuals aged 30–70 years in the United States.

The mean premature mortality rate over the study period is 14.82 percent, with a median of 14.2 percent, indicating a relatively high and persistent burden of non-communicable diseases among adults in their most productive years. The mortality rate ranges from a minimum of 13.2 percent to a maximum of 17.8 percent, reflecting notable temporal variation in NCD-related mortality. The standard deviation of 1.34 suggests moderate dispersion around the mean, implying that while mortality rates fluctuate over time, they remain consistently elevated.

The positive skewness value (0.92) indicates a right-skewed distribution, suggesting occasional spikes in premature mortality, while the kurtosis value (2.52) implies a slightly flatter distribution than the normal curve. The Jarque–Bera statistic (15.06, $p < 0.05$) rejects the null hypothesis of normality, indicating that the mortality series is not normally distributed. Such non-normality is common in health and mortality time-series data due to structural changes, shocks, and persistence effects (Enders, 2015; Wooldridge, 2019; Nahabwe & Maniple, 2025).

Stationarity test using Augmented Dickey-Fuller shows the original Mortality from CVD, cancer, diabetes or CRD between exact ages 30 and 70 (%) series is non-stationary ($p > 0.05$) but achieves stationarity upon first differencing ($p < 0.05$). Consequently, the ARIMA(1,1,4) model is identified as the best fit based on model selection criteria (AIC = -1.773579; SC = -1.666048; H-QC = -----1.730128) (Nahabwe & Kagarura, 2025).

The model output is estimated as:
Results of ARIMA(1,1,4) model (Appendix 4)

$Mortality\ from\ CVD, \widehat{cancer}, diabetes\ or\ CRD_{\ t}$ = 0.063186 + 0.987144AR(1) - 0.697195MA(4) …… (3)

Hence,

$$\hat{\theta}_{CLS} = \begin{bmatrix} 0.063186 \\ 0.987144 \\ -0.697195 \end{bmatrix}$$

ARIMA(1,1,4) estimation results provide insights into the dynamic behavior of premature adult mortality from NCDs. The constant term (C = 0.063186, p = 0.7384) is statistically insignificant, indicating the absence of a deterministic component in the mortality process. This suggests that beyond stochastic fluctuations, there is no systematic underlying trend in premature mortality, inconsistent with long-term epidemiological transitions in advanced economies (Lee & Carter, 1992).

Autoregressive term AR(1) has a coefficient of 0.987144 and is statistically significant at the 1 percent level (p = 0.0000). This high coefficient indicates strong persistence in premature NCD mortality, implying that current mortality levels are heavily influenced by past outcomes. Such persistence reflects the chronic nature of NCDs and the cumulative effects of long-term exposure to behavioral and socioeconomic risk factors (WHO, 2023).

Similarly, the moving average term MA(4) is statistically significant (−0.697195, p = 0.0000), capturing short-term adjustments and shocks in mortality dynamics. The negative sign suggests a corrective mechanism whereby short-run shocks to mortality tend to be partially offset in subsequent periods, stabilizing the series over time. This finding is consistent with the presence of delayed health system responses and behavioral adaptations following mortality fluctuations (Hamilton, 1994; Nahabwe & Maniple, 2025).

The adjusted R-squared value of 0.835857 indicates that approximately 84 percent of the variation in premature adult mortality is explained by the model. This reflects a strong explanatory power and confirms the suitability of the ARIMA framework for modeling mortality dynamics (Box et al., 2015; Kagarura et al. 2025).

Durbin–Watson statistic of 2.048026 is close to the theoretical benchmark of 2, indicating the absence of first-order autocorrelation in the residuals (Wooldridge, 2019; Nahabwe & Kagarura, 2025; Nahabwe, 2025). This suggests that the model sufficiently captures the serial dependence inherent in the mortality series.

Although the residuals are not normally distributed (Jarque–Bera = 351.2, p = 0.000), the Ljung–Box Q statistic (p = 0.675) fails to reject the null hypothesis of no autocorrelation. This confirms that the residuals behave like white noise, satisfying a key requirement for ARIMA model adequacy (Nahabwe & Kagarura, 2025; Nahabwe, 2025). In time-series forecasting, residual normality is less critical than independence and zero mean, particularly when the objective is prediction rather than hypothesis testing (Enders, 2015; Kagarura & Nahabwe, 2025).

Furthermore, the AR and MA roots lie within the unit circle (Appendix 6), confirming that the model is stable and stationary, and that shocks to premature mortality dissipate over time. This reinforces the reliability of the model for forecasting purposes (Munyambonera et al., 2025; Kagarura et al., 2025).

Model simulations extending to 2050 (Appendix 8) project a gradual decline in premature adult mortality from NCDs, reaching approximately 4 percent by 2050. This projected decline suggests potential long-term gains

from improvements in medical technology, early detection, and public health interventions. However, the slow pace of decline underscores the persistent nature of NCD risk factors and the need for sustained preventive efforts.

The findings of our study are broadly consistent with existing literature that emphasizes the high persistence and slow adjustment of NCD-related mortality in high-income countries (Lee & Carter, 1992; Woolf & Schoomaker, 2019). The strong AR(1) coefficient aligns with global evidence that chronic disease mortality responds gradually to policy interventions and behavioral change (GBD 2019 Collaborators, 2020).

Compared to earlier U.S.-based studies that rely largely on descriptive or regression-based approaches (CDC, 2023), this study provides unique empirical evidence through dynamic time-series modeling and long-term forecasting. The use of quarterly data enhances sensitivity to short-term mortality fluctuations, while the ARIMA–CLS framework captures both persistence and shock correction mechanisms.

A particularly novel contribution of our study lies in its forecast horizon to 2050, which offers forward-looking insights rarely addressed in prior research. While previous studies highlight stagnation or slow improvement in U.S. premature mortality trends, our study suggests a gradual decline, contingent on sustained health system performance and preventive policies. This divergence underscores the importance of modeling techniques in shaping expectations about future health outcomes.

Overall, the results demonstrate that although premature adult mortality from NCDs in the United States is projected to decline, its strong persistence implies that without aggressive and sustained interventions, reductions will remain slow. The findings therefore reinforce the urgency of comprehensive NCD prevention strategies targeting behavioral risks, health inequalities, and access to quality care.

Limitations

Despite its methodological rigor, our study is subject to several limitations related to its research design, data structure, and analytical approach, which should be considered when interpreting the findings.

Firstly, we adopt a univariate time-series design, focusing exclusively on historical patterns of premature adult mortality from NCDs. While this approach is appropriate for modeling temporal dynamics and forecasting, it does not explicitly incorporate explanatory covariates such as socioeconomic conditions, behavioral risk factors, healthcare access, or policy interventions. Consequently, the ARIMA framework captures correlations over time rather than causal mechanisms, limiting the ability to attribute observed mortality trends to specific determinants (Box et al., 2015; Enders, 2015; Nahabwe & Kagarura, 2025).

Secondly, although our study utilizes nationally aggregated mortality data for the United States, such aggregation may mask important subnational and demographic heterogeneity. Variations in premature NCD mortality across regions, income groups, racial and ethnic populations, and gender are well documented in the literature (Woolf & Schoomaker, 2019). The use of aggregate data, therefore, constrains the study's capacity to capture localized mortality dynamics and inequities that could influence overall trends and forecasts.

Thirdly, the transformation of annual data into quarterly frequency introduces an inherent limitation. While temporal disaggregation enhances the dynamic structure of the series and improves forecasting flexibility, the generated quarterly observations are model-based estimates rather than directly observed data. As such, they may smooth or distort short-term fluctuations, potentially affecting parameter estimates and forecast precision (Chow & Lin, 1971; Sax & Steiner, 2013). Although established disaggregation techniques were employed, the resulting quarterly series should be interpreted with caution.

Fourthly, the estimation of the ARIMA model using conditional least squares (CLS), while computationally efficient and suitable for moderate sample sizes, may be less statistically efficient than exact maximum likelihood estimation under certain conditions. CLS estimates can be sensitive to model specification and initial values, particularly in highly persistent series such as mortality data (Hamilton, 1994; Brockwell & Davis, 2002; Nahabwe & Kagarura, 2025). This limitation may influence the magnitude of estimated parameters, although it is unlikely to alter the overall dynamic pattern captured by the model.

Fifthly, our study assumes structural stability over the forecast horizon, an assumption that may not hold in the presence of unforeseen shocks such as major health policy reforms, technological breakthroughs, pandemics, or significant changes in population behavior. Mortality trends are susceptible to structural breaks that standard ARIMA models may fail to capture, potentially reducing forecast accuracy in the long term (Perron, 2006; Nahabwe & Kagarura, 2025).

Finally, although diagnostic tests confirm that the residuals behave like white noise, the non-normal distribution of residuals suggests the presence of extreme values or unmodeled nonlinearities. While non-normality does not invalidate ARIMA-based forecasts, it may affect statistical inference and confidence interval construction (Wooldridge, 2019; Nahabwe & Kagarura, 2025).

5. Conclusion and Recommendations

We set out to model and forecast premature adult mortality from NCDs in the United States, with a focus on deaths occurring between ages 30 and 70 years. By applying a rigorous time-series framework to transformed high-frequency data, we provide a comprehensive assessment of the dynamic behavior and long-term trajectory of NCD-related mortality. Taken together, our findings demonstrate that premature adult mortality from NCDs in the United States is governed by strong temporal persistence, gradual adjustment processes, and long-run structural forces rather than short-lived fluctuations.

At a broader level, we confirm that mortality outcomes from chronic diseases evolve slowly and are deeply embedded in long-term epidemiological, behavioral, and health system dynamics. This underscores the limited effectiveness of short-term interventions and highlights the importance of sustained, cumulative investments in prevention, early detection, and chronic disease management. In line with the epidemiological transition and health production theories, we reinforce the view that improvements in population health outcomes require continuous and coordinated policy efforts rather than episodic responses (Omran, 1998; Grossman, 1972).

A key contribution of our research lies in its methodological approach. By converting annual mortality data into quarterly frequency and employing an ARIMA modeling framework estimated through conditional least squares, we enhance sensitivity to temporal dynamics and strengthen the reliability of long-term forecasts. This approach advances existing literature, which has largely relied on descriptive analyses or low-frequency data, by offering a forward-looking perspective that is critical for health planning and policy evaluation (Box et al., 2015; Enders, 2015; Nahabwe & Kagarura, 2025).

From a policy standpoint, our conclusions suggest that meaningful reductions in premature adult mortality from NCDs in the United States are achievable but contingent upon sustained structural reforms. These include strengthening preventive healthcare systems, addressing socioeconomic inequalities, and promoting long-term behavioral change. The projected mortality trajectory further emphasizes that progress will be incremental, reinforcing the urgency of early and sustained intervention to avoid avoidable loss of life and economic productivity.

Recommendations

Based on the empirical modeling and long-term projections of premature adult mortality from NCDs in the United States, we propose the following recommendations, which are aligned with the study's findings and broader public health evidence.

Firstly, the strong persistence observed in premature NCD mortality dynamics underscores the need for long-term, structurally embedded health policies rather than short-term or episodic interventions. Policymakers should prioritize sustained investments in preventive healthcare, particularly policies that promote early screening, risk-factor modification, and continuity of care for chronic diseases. Evidence suggests that consistent policy commitment over extended periods is more effective in reducing premature mortality than isolated policy reforms (WHO, 2023; Woolf & Schoomaker, 2019; Nahabwe & Maniple, 2025).

Secondly, the gradual decline projected in premature mortality highlights the importance of addressing upstream socioeconomic determinants of health. Policies aimed at reducing income inequality, improving

educational attainment, and enhancing food and environmental regulation are essential for accelerating mortality reductions. Integrating NCD prevention objectives into broader social and economic policies can yield long-term health gains that are not achievable through healthcare interventions alone (Marmot et al., 2020).

Thirdly, given the forecast horizon extending to mid-century, national health strategies should explicitly incorporate long-term mortality projections into planning and budgeting processes. Embedding forecasting evidence into policy design can improve resource allocation, strengthen preparedness for future disease burdens, and enhance accountability in achieving national and global health targets (OECD, 2022).

At the program level, our findings support the expansion of integrated and continuous NCD prevention programs targeting adults in early and mid-life stages. Since mortality outcomes exhibit strong dependence on past health trajectories, interventions that begin earlier in the life course such as workplace wellness programs, community-based physical activity initiatives, and nutrition education are likely to generate larger long-term benefits (Beaglehole et al., 2011).

Additionally, health programs should adopt data-driven monitoring frameworks that utilize high-frequency mortality and morbidity indicators. The use of quarterly or near-real-time data can improve the timeliness of program evaluation and enable rapid adjustment to emerging trends, thereby enhancing program effectiveness and sustainability (Box et al., 2015; Nahabwe & Kagarura, 2025).

Programs aimed at reducing premature adult mortality should emphasize equity-oriented implementation, ensuring that vulnerable and underserved populations benefit proportionately. Given the documented disparities in NCD outcomes across socioeconomic and demographic groups, targeted program delivery can help close mortality gaps and accelerate overall progress (CDC, 2023).

From a research perspective, our study highlights the need for multivariate and structural modeling approaches that extend beyond univariate time-series frameworks. Future studies could integrate socioeconomic variables, behavioral risk factors, and health system indicators to better explain the drivers of mortality dynamics and to support causal inference (Enders, 2015; Wooldridge, 2019).

Further research could also explore disaggregated mortality modeling, including analyses by region, gender, race, and income group, to uncover heterogeneous trends that are masked in national aggregates. Such disaggregation is critical for designing targeted interventions and improving health equity (Woolf & Schoomaker, 2019; Nahabwe & Maniple, 2025).

Finally, methodological advancements such as regime-switching models, structural break tests, and machine-learning-based forecasting techniques could be employed to assess the robustness of long-term mortality projections under alternative scenarios. Comparative forecasting studies would enhance confidence in projected trends and inform adaptive policy responses to future uncertainties (Hamilton, 1994; Perron, 2006; Nahabwe & Maniple, 2025).

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APPENDICES

Appendix 1: Descriptive statistics

	Mortality from CVD, cancer, diabetes or CRD between exact ages 30 and 70 (%)
Mean	14.82
Median	14.2
Maximum	17.8
Minimum	13.2
Std. Dev.	1.343296
Skewness	0.919959
Kurtosis	2.522057
Jarque-Bera	15.05721
Probability	0.000537
Sum	1482
Sum Sq. Dev.	178.64
Observations	100

Appendix 2: Unit root test, Mortality from CVD, cancer, diabetes or CRD between exact ages 30 and 70 (%) (in Level)

Null Hypothesis: MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD has a unit root
Exogenous: None
Lag Length: 4 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.391376	0.1517
Test critical values:	1% level	-2.589531	
	5% level	-1.944248	
	10% level	-1.614510	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD)
Method: Least Squares
Date: 12/31/25 Time: 16:44
Sample (adjusted): 2001Q2 2024Q4
Included observations: 95 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD(-1)	-0.001213	0.000872	-1.391376	0.1675
D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD(-1))	-0.041518	0.079468	-0.522446	0.6026
D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD(-2))	-0.041518	0.079468	-0.522446	0.6026
D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD(-3))	-0.041518	0.079468	-0.522446	0.6026
D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD(-4))	0.598879	0.079999	7.486123	0.0000

R-squared	0.417458	Mean dependent var	-0.035789
Adjusted R-squared	0.391568	S.D. dependent var	0.124555
S.E. of regression	0.097156	Akaike info criterion	-1.773809

Sum squared resid	0.849530	Schwarz criterion	-1.639394
Log likelihood	89.25592	Hannan-Quinn criterion.	-1.719495
Durbin-Watson stat	1.958066		

Appendix 3: Unit root test, Mortality from CVD, cancer, diabetes or CRD between exact ages 30 and 70 (%) (in First difference)

Null Hypothesis: D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD) has a unit root
Exogenous: None
Lag Length: 3 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.418726	0.0158
Test critical values:	1% level	-2.589531	
	5% level	-1.944248	
	10% level	-1.614510	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD,2)
Method: Least Squares
Date: 12/31/25 Time: 16:53
Sample (adjusted): 2001Q2 2024Q4
Included observations: 95 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD(-1))	-0.358382	0.148170	-2.418726	0.0176
D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD(-1),2)	-0.641618	0.128349	-4.998997	0.0000
D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD(-2),2)	-0.641618	0.104847	-6.119555	0.0000
D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD(-3),2)	-0.641618	0.074245	-8.641914	0.0000

R-squared	0.738481	Mean dependent var	0.004211
Adjusted R-squared	0.729859	S.D. dependent var	0.187886
S.E. of regression	0.097654	Akaike info criterion	-1.773579
Sum squared resid	0.867803	Schwarz criterion	-1.666048
Log likelihood	88.24502	Hannan-Quinn criterion.	-1.730128
Durbin-Watson stat	2.000000		

Appendix 4: Results of ARIMA(1,1,4) model

Dependent Variable: D(MORTALITY_FROM_CVD__CANCER__DIABETES_OR_CRD)
Method: ARMA Conditional Least Squares (Gauss-Newton / Marquardt steps)
Date: 12/31/25 Time: 17:18
Sample (adjusted): 2000Q3 2024Q1
Included observations: 95 after adjustments
Failure to improve likelihood (non-zero gradients) after 13 iterations
Coefficient covariance computed using the outer product of gradients
MA Backcast: 1999Q3 2000Q2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.063186	0.188590	0.335046	0.7384
AR(1)	0.987144	0.022154	44.55825	0.0000
MA(4)	-0.697195	0.078977	-8.827805	0.0000

R-squared	0.839350	Mean dependent var	-0.038947
Adjusted R-squared	0.835857	S.D. dependent var	0.054665
S.E. of regression	0.022147	Akaike info criterion	-4.751143
Sum squared resid	0.045126	Schwarz criterion	-4.670495
Log likelihood	228.6793	Hannan-Quinn criterion.	-4.718555
F-statistic	240.3365	Durbin-Watson stat	2.048026
Prob(F-statistic)	0.000000		

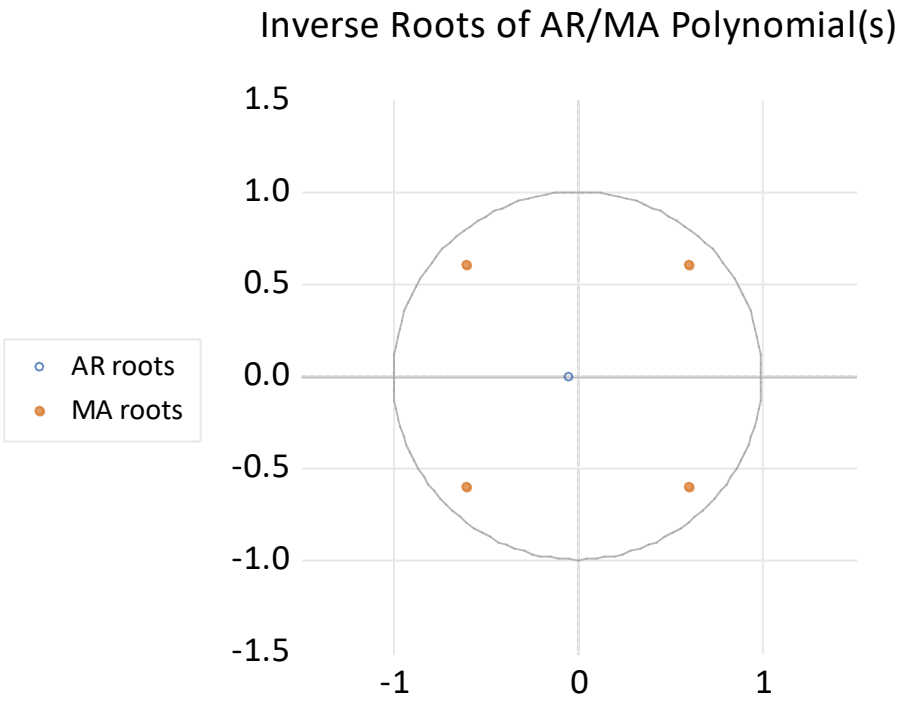
Inverted AR Roots	.99			
Inverted MA Roots	.91	.00-.91i	.00+.91i	-.91

Appendix 5: Ljung-Box Q statistic/ test

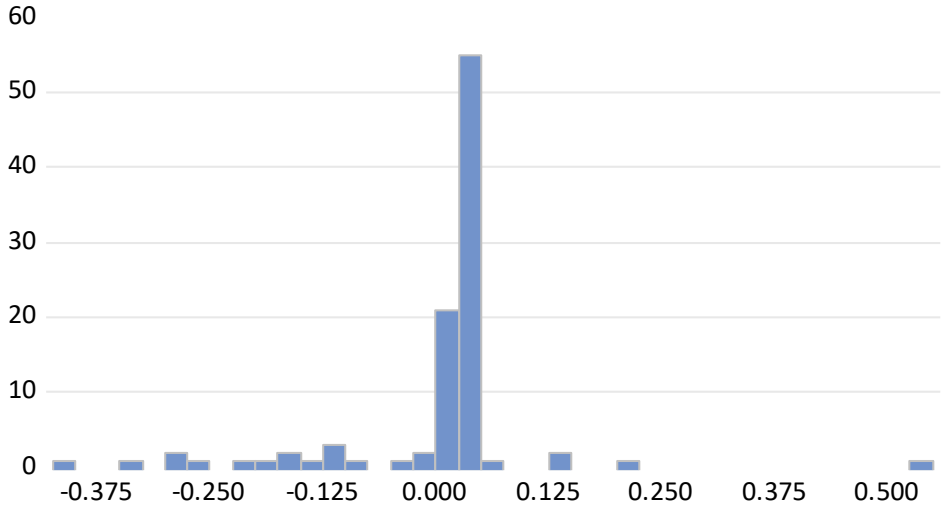
Date: 12/31/25 Time: 17:20
Sample: 2000Q1 2024Q4
Included observations: 95
Q-statistic probabilities adjusted for 2 ARMA terms

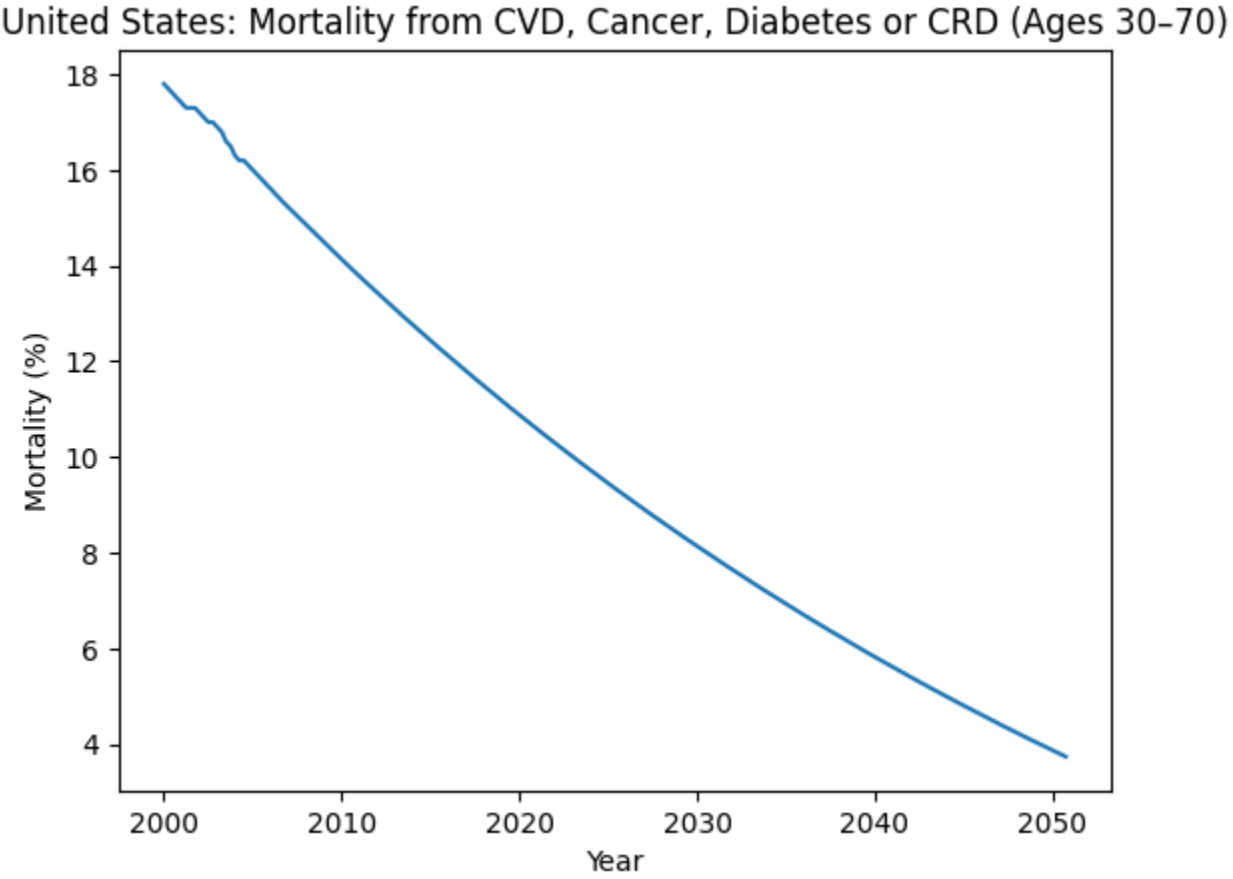
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.024	-0.024	0.0568	
		2	-0.024	-0.025	0.1153	
		3	-0.025	-0.026	0.1755	0.675
		4	0.009	0.007	0.1837	0.912
		5	-0.028	-0.028	0.2616	0.967
		6	-0.028	-0.030	0.3426	0.987
		7	-0.028	-0.031	0.4266	0.995
		8	-0.084	-0.089	1.1671	0.978
		9	-0.031	-0.039	1.2708	0.989
		10	-0.032	-0.041	1.3788	0.995
		11	-0.032	-0.043	1.4912	0.997
		12	0.053	0.045	1.8012	0.998
		13	-0.028	-0.037	1.8921	0.999
		14	-0.029	-0.039	1.9872	0.999
		15	-0.029	-0.041	2.0866	1.000
		16	-0.130	-0.156	4.0707	0.995
		17	-0.028	-0.054	4.1644	0.997
		18	-0.029	-0.058	4.2627	0.998
		19	-0.029	-0.062	4.3656	0.999
		20	0.126	0.119	6.3209	0.995
		21	-0.021	-0.041	6.3756	0.997
		22	-0.022	-0.043	6.4341	0.998
		23	-0.022	-0.046	6.4966	0.999
		24	0.178	0.126	10.615	0.980
		25	-0.020	-0.033	10.667	0.986
		26	-0.020	-0.035	10.722	0.991
		27	-0.021	-0.037	10.781	0.994
		28	0.076	0.094	11.577	0.993
		29	-0.022	-0.027	11.646	0.996
		30	-0.023	-0.028	11.721	0.997
		31	-0.023	-0.029	11.800	0.998
		32	0.051	0.027	12.176	0.998
		33	-0.023	-0.027	12.253	0.999
		34	-0.023	-0.028	12.335	0.999
		35	-0.024	-0.028	12.421	1.000
		36	0.091	0.115	13.712	0.999

Appendix 6: ARIMA(1,1,4) structure



Appendix 7: Histogram of residuals



Series: Residuals	
Sample 2000Q3 2024Q4	
Observations 98	
Mean	0.000549
Median	0.026029
Maximum	0.547021
Minimum	-0.424271
Std. Dev.	0.107902
Skewness	-0.216881
Kurtosis	12.26389
Jarque-Bera	351.1985
Probability	0.000000

Appendix 8: Graph showing the United States' Mortality from CVD, cancer, diabetes or CRD between exact ages 30 and 70 (%), ARIMA(1,1,4) Model Simulation