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# Advancing Cardiovascular Mortality Trend Analysis: A Machine Learning Approach to Predict Future Health Policy Needs

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**Abstract.** This study investigates the forecasting of cardiovascular mortality trends in Greece's elderly population. Utilizing mortality data from 2001 to 2020, we employ two forecasting models: the Autoregressive Integrated Moving Average (ARIMA) and Facebook's Prophet model. Our study evaluates the efficacy of these models in predicting cardiovascular mortality trends over 2020-2030. The ARIMA model showcased predictive accuracy for the general and male population within the 65-79 age group, whereas the Prophet model provided better forecasts for females in the same age bracket. Our findings emphasize the need for adaptive forecasting tools that accommodate demographic-specific characteristics and highlight the role of advanced statistical methods in health policy planning.

**Keywords.** Cardiovascular Mortality, Forecasting Models, Health Policy Planning, Aging, Machine Learning, Time Series Analysis, Public Health.

## 1. Introduction

The phenomenon of population aging is global, with Greece being one of the fastest-aging countries in Europe [1]. Cardiovascular diseases (CVD) are the leading cause of death in the elderly population, therefore accurate forecasting of CV mortality trends is crucial for health policy planning [2]. Advancements in statistical methods and machine learning have significantly enhanced the capacity to analyze and predict health trends. Among these, the Autoregressive Integrated Moving Average (ARIMA) model has been a staple in time series analysis, providing valuable insights into future disease incidences, hospital admissions, and mortality rates [3]. ARIMA and Prophet have been successfully applied in various public health contexts to forecast disease trends and inform policy

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decisions [5-7]. More recently, the introduction of the Prophet model offers a novel approach by incorporating automatic detection of seasonal patterns, thereby accommodating the complex nature of public health data [4]. Although the Prophet model has been widely used in various domains, its application in public health trends analysis remains relatively unexplored. This study contributes to the literature by applying the Prophet model to forecast cardiovascular mortality trends, demonstrating its potential utility in public health forecasting. Despite the critical importance of forecasting in health policy planning, there is a paucity of research comparing the efficacy of different models. The primary objective of this study is to apply ARIMA and Prophet models to temporal data of CV mortality from 2001-2020 in Greece, forecasting future trends in the elderly population. By comparing the performance of these two models, we seek to identify the most effective tool. By advancing our understanding of CV mortality trend analysis through machine learning approaches, this study adds to the body of literature.

## 2. Methods

The dataset utilized in this study was sourced from the Hellenic Statistical Authority, spanning from 2001 to 2020, and capturing annual mortality figures segmented by gender and age groups (0-64, 65-79, and 80+ years). Data preparation involved converting the 'Year' column to datetime format to facilitate time series analysis. Time series forecasting was performed using two distinct models: the Autoregressive Integrated Moving Average (ARIMA) and Facebook's Prophet model. A non-seasonal ARIMA model was fitted to the data with parameters (5,1,0), based on the Box-Jenkins methodology. The model parameters were chosen to capture the data's characteristics effectively, considering the trends and potential non-stationarity within the time series. The Prophet model was utilized due to its robustness in handling time series data with trends and seasonal effects. It was configured with yearly seasonality to account for potential annual patterns in mortality rates, without weekly or daily seasonality, as it was not pertinent to the annual data frequency. This configuration ensures that the model captures annual patterns in cardiovascular mortality data. Additionally, the `changepoint_prior_scale` parameter was fine-tuned to allow the model to detect significant shifts in trends, which is essential for accurately forecasting long-term data. The gender-based differences observed between the ARIMA and Prophet models may be attributed to the distinct ways each model processes seasonality and trend components.
Forecasts were generated for a 10-year horizon beyond the latest data point in 2020, for each gender and age group. The Python matplotlib library was used for plotting, with special attention to x-axis ticks to ensure clear representation of the yearly data points. The plots provided visual comparisons of actual data against the forecasts from both ARIMA and Prophet models. The forecasting models' accuracy was assessed using the Mean Absolute Error (MAE) and the Root Mean Squared Error (RMSE), calculated over the testing period from 2010 to 2020. These metrics were chosen for their interpretability and ability to quantify the average magnitude of the forecasting errors.

The model evaluation involved comparing the forecasted values against actual data from 2010 to 2020, calculating the MAE and RMSE for both models. This comparison was facilitated by the sklearn.metrics module in Python, which provided functions for error calculations. The performance metrics of the ML techniques that were evaluated in this study were the Sensitivity, Specificity, and Area Under the Receiver Operating Characteristic Curve AUC ROC from prediction scores.

## 3. Results

Table 1 presents the performance the Prophet and ARIMA models for forecasting CV mortality rates, evaluated on the basis of the Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE) metrics. The forecasts were segregated by gender (total, males, females) and age groups (65-79, 80+). The MAE reflects the average magnitude of the errors in a set of forecasts, without considering their direction. The RMSE provides a measure of the magnitude of the forecast error, with higher emphasis on larger errors due to the squaring process. Lower values of MAE and RMSE indicate better forecast accuracy.

**Table 1.** Comparative Performance Metrics of Prophet and ARIMA Models for Cardiovascular Mortality Forecasting Across Different Age Groups and Genders.

| | Age Group | Model | MAE | RMSE |
|---|---|---|---|---|
| Total | 65-79 | Prophet | 163.236 | 188.611 |
| | | ARIMA | 85.895 | 108.456 |
| Total | 80+ | Prophet | 735.271 | 879.238 |
| | | ARIMA | 134.152 | 163.156 |
| Males | 65-79 | Prophet | 241.340 | 274.343 |
| | | ARIMA | 154.563 | 180.718 |
| Males | 80+ | Prophet | 405.386 | 511.938 |
| | | ARIMA | 168.745 | 214.132 |
| Females | 65-79 | Prophet | 49.177 | 53.688 |
| | | ARIMA | 76.797 | 96.989 |
| Females | 80+ | Prophet | 952.480 | 1119.091 |
| | | ARIMA | 274.652 | 305.827 |

In all instances, both metrics are used to assess and compare the accuracy of the forecasts generated by each model. For the total population and males in the 65-79 age group, the ARIMA model demonstrated lower MAE and RMSE values, indicating more accurate forecasts compared to the Prophet model. However, for females in the 65-79 age group, the Prophet model yielded lower values of MAE and RMSE, signifying a more accurate forecast. Notably, the MAE and RMSE are significantly higher for the 80+ age group, indicating more substantial forecasting errors, which could be due to increased volatility or less predictable patterns in mortality rates for this demographic.

Figures 1 & 2 illustrate the time series forecast of deaths due to CV causes among males aged 65-79 (Figure 1) and females (Figure 2) up to 2030. Both models capture the declining trend in mortality rates over time and offers a visual comparison of their future predictions, revealing differing extrapolations. In Figure 1, the Prophet model suggests a slightly steadier decline, whereas the ARIMA model anticipates a steeper decrease followed by a leveling off towards the end of the forecast period. In Figure 2, the Prophet model exhibits a gradually declining trend, suggesting a persistent decrease in mortality rates, whereas the ARIMA model forecasts a sharper decline initially, followed by a period of relative stability in the later years. This visual analysis helps in understanding the models' behavior and assessing their potential reliability for future planning and resource allocation in healthcare services addressing CV issues within this demographic group.

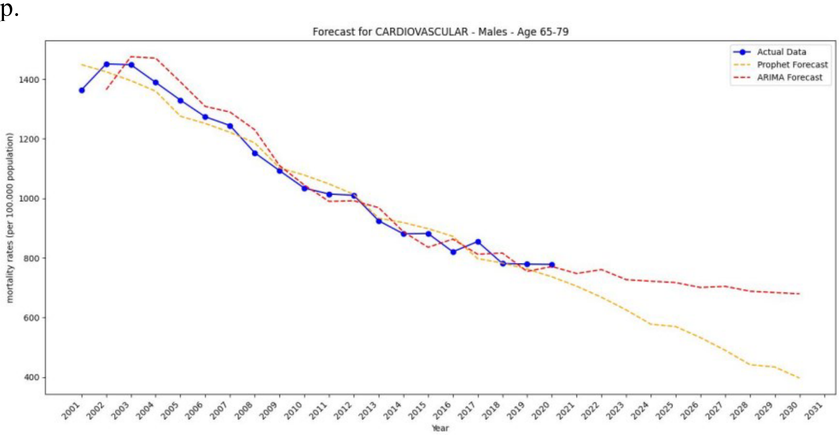


**Figure 1.** Time Series Forecast of Cardiovascular Mortality Rates in Males Aged 65-79: A Comparative Analysis of Prophet and ARIMA Models.

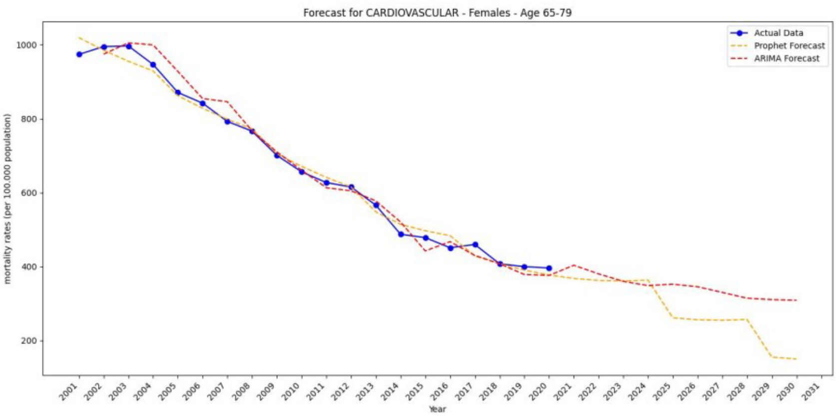


**Figure 2.** Time Series Forecast of Cardiovascular Mortality Rates in Females Aged 65-79: A Comparative Analysis of Prophet and ARIMA Models.

## 4. Discussion

During the past two decades there has been a substantial decrease in the CV mortality rates in all age groups, and both models predicted further decreases from 2020-2030. The ARIMA model, grounded in the Box-Jenkins methodology, has historically provided robust predictions in various fields, including healthcare [3]. In contrast, the Prophet model, with its more recent development, accommodates the seasonality and trends inherent in public health data [4]. Interestingly, the ARIMA model demonstrated superior performance in predicting CV mortality among the total population and males aged 65-79, which suggests that traditional time series methods may still hold significant value in certain demographic segments. Conversely, the Prophet model excelled in forecasting for females in the same age group. These divergent results underscore the necessity of considering demographic-specific characteristics when selecting a forecasting model.

The significant forecasting errors for the 80+ age group across both models indicate the challenges inherent in predicting outcomes for the oldest demographic segment. This finding suggests a potential area for future research, focusing on improving model accuracy for this age group, which is critical given their increasing representation in the population and their substantial healthcare needs. This study has important implications. Firstly, the need for adaptive forecasting tools that can cater to different demographic characteristics is evident. Secondly, health policy interventions should be dynamic, leveraging forecasts to prepare for the changing landscape of healthcare demands. By identifying the most effective forecasting models for different demographic groups, healthcare policymakers can better allocate resources and design targeted interventions. For instance, the superior performance of the ARIMA model for males and the Prophet model for females in the 65-79 age group suggests that tailored strategies could be developed to address gender-specific health trends. Moreover, the identified need for improved forecasting models for the 80+ age group highlights the importance of developing specialized healthcare policies for this vulnerable demographic. Integrating these models into health policy planning could lead to more effective and efficient public health strategies, ultimately improving health outcomes and resource utilization. Finally, forecasting specific CV sub-causes will provide valuable insights for policymakers, targeting their interventions in diseases with predicted increasing mortality trends.

## 5. Conclusions

In conclusion, this study highlights the strengths and limitations of ARIMA and Prophet models in forecasting CV mortality trends. Our findings suggest that while ARIMA may offer more precise predictions for certain demographics, Prophet's capacity to accommodate complex seasonal patterns makes it an invaluable tool in the public health domain. As we advance into an era marked by an aging population, the ability to accurately forecast health trends will be crucial for policymakers and health practitioners.

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