# Analysis and Forecasting of Two Time Series Models for Respiratory Infectious Diseases

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**Abstract.** The global impact of the COVID-19 pandemic has heightened attention on respiratory diseases and medical infrastructure across the globe. This study focuses on the comparison of healthcare systems in Japan, a developed country, and Brazil, a developing nation, to explore how differences in medical systems affect the distribution of healthcare resources and outcomes in respiratory disease management. Given the more extensive medical coverage in Japan compared to Brazil, this research investigates whether Japan demonstrates better outcomes in terms of lower mortality rates for respiratory diseases. Utilizing data from the World Health Organization (WHO), this study conducts a time series analysis for upper and lower respiratory tract infections, applying and comparing various predictive models. The Exponential Triple Smoothing (ETS) model showed superior fit and forecasting accuracy. The results indicate that Japan consistently maintains lower mortality rates compared to Brazil, suggesting that disparities in healthcare systems significantly influence disease outcomes. These findings underscore the importance of robust healthcare infrastructure in managing respiratory diseases, particularly in the context of a global pandemic.

**Keywords:** COVID-19, respiratory diseases, healthcare systems, Japan, Brazil, time series analysis, ETS model, WHO data.

## 1 Introduction

During the COVID-19 pandemic, unprecedented advancements in diagnostic technologies at both genotypic and phenotypic levels were achieved. These advancements transformed the diagnostic paradigms for infectious respiratory diseases, enhancing the accuracy and efficiency of diagnoses. Throughout the pandemic, there was an unparalleled effort in generating and sharing the genetic sequences of SARS-CoV-2 globally [1]. This effort significantly boosted the monitoring and research of respiratory diseases, providing invaluable data and experience for managing future similar pandemics [1].


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### 1.1 Literature Review

In the literature "Advances in diagnostic tools for respiratory tract infections: from tuberculosis to COVID-19 – changing paradigms?" [1], it is mentioned that after the pandemic, humanity has gained more understanding of various respiratory diseases and has improved diagnostic techniques for respiratory tract infections, especially tuberculosis and COVID-19. This article integrates various studies, such as those on drug-resistant bacteria or microorganisms related to pneumonia and chronic obstructive pulmonary disease (COPD), population density data of Japan and Brazil, the background of healthcare policies in both countries, current research on respiratory diseases in Japan and Brazil, and offers recommendations for future responses.

### 1.2 Research objectives

Japan and Brazil, as representatives to show the mortality rates caused by respiratory tract infections in developed and developing countries respectively. To rigorously predict the future, it is essential first to compare the fitting accuracy of the two models on respiratory disease data and then split the data into training and test sets to evaluate the prediction accuracy. Therefore, using two prediction models, Exponential Smoothing State Space Model (ETS) and Auto Regressive Integrated Moving Average (ARIMA) model are used to predict the mortality rates of respiratory tract infections in Japan and Brazil. This study focuses on the performance of respiratory diseases in Japan and Brazil in recent years and makes future predictions. It further analyzes and summarizes various aspects such as national healthcare policies, healthcare expenditure, and the national economy.

### 1.3 Research Significance

Following the experience of COVID-19, respiratory diseases have garnered increased attention. Humanity has gained a deeper understanding of respiratory diseases and developed more methods for their treatment and management. This enhanced knowledge and capability may potentially lead to a corresponding decrease in the global mortality rate of respiratory diseases. To verify this hypothesis, further analysis is required, which will be presented in the subsequent sections.

### 1.4 Outline

The following parts of this paper are organized as follows: Section 2 discusses data sources, Section 3 introduces the models, and Section 4 presents the ARIMA and ETS analyses by country and respiratory disease category. Section 5 is about the analysis of respiratory tract deaths in different age groups in the two countries. Section 6 is about the comparison of healthcare policy systems in the two countries. Section 7 discusses future trends and the factors that may affect respiratory diseases. Section 8 is the final conclusion.

# 2 Empirical Model

## 2.1 Data Collection

Data used in this paper comes from World Health Organization [2]. Data is obtained on respiratory tract infections in Japan and Brazil from 1979 to 2022 (including upper respiratory tract infection, lower respiratory tract infection, and otitis media, The total number of deaths in each year, the number of deaths in each age group, and the number of deaths per 100,000 Human mortality rate and number of deaths from specific causes as a percentage of total deaths). Time series analysis is conducted on more than 40 years of data from Brazil and Japan from 1979 to 2022, using two models, ETS and ARIMA, to fit and predict future annual data.

## 2.2 Empirical Model

The ETS model is a family of time series forecasting models that includes three components: error, trend, and seasonality. These components can be combined in different ways to capture various patterns in time series data.

Model:

$$y_t = l_{t-1} + b_{t-1} + s_{t-m} + \epsilon_t \quad (1)$$

The ARIMA (Auto Regressive Integrated Moving Average) model is a popular and widely used statistical method for time series forecasting. It combines three components: autoregression (AR), differencing (I), and moving average (MA).

Model:

$$y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \ldots.. + \phi_p Y_{t-p} + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \ldots. + \theta_q \varepsilon_{t-q} + \varepsilon(t) \quad (2)$$

## 2.3 Model Selection & Explanation

Before making further predictions, first select the appropriate models for different countries and diseases to compare their fitting accuracy and choose the optimal model. Therefore, split the data into training and test sets. Next, as shown in Fig.1 and Fig.2, the data imported into the models, and eight plots will be created to compare the predictions with the test sets.

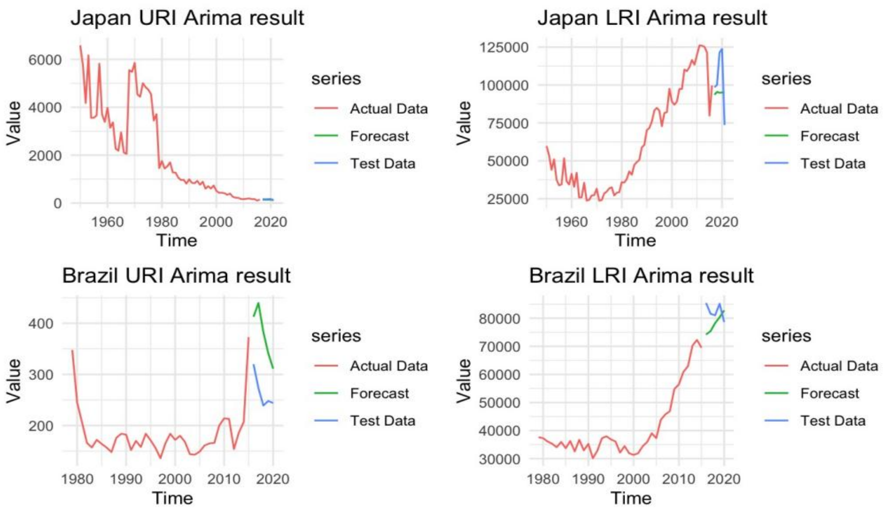


**Fig. 1.** ARIMA model fit prediction graphs (Photo credit: Original)

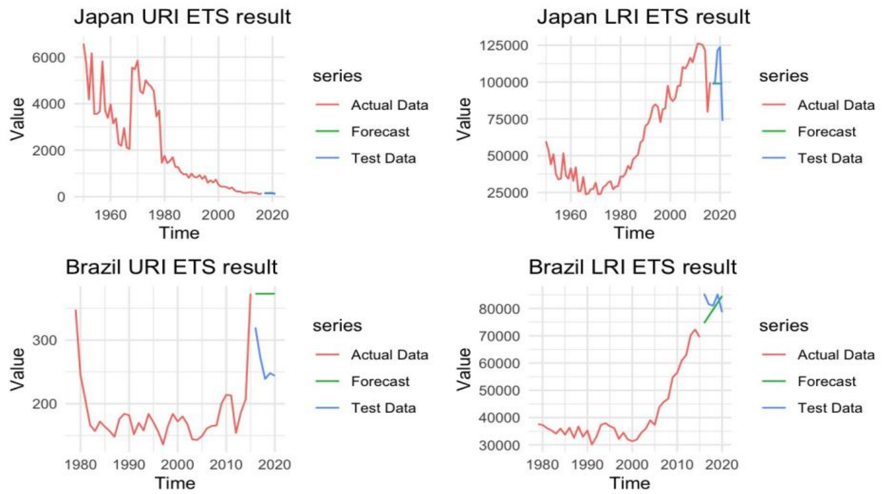


**Fig. 2.** ETS model fit prediction graphs **(**Photo credit: Original**)**

Common upper respiratory tract diseases such as the common cold and pharyngitis generally do not pose a threat to life. However, virus like Syncytial Virus (RSV), Influenza Virus (Type A and B), Parainfluenza Virus, Adenovirus, Human Metapneumovirus (hMPV), Coronavirus, these are also the reasons that can lead to lower respiratory tract infections [3]. Therefore, the number of deaths due to upper respiratory tract infections in both countries is significantly lower than that due to lower respiratory tract infections. If only focus on the original data, what can be infered? It is not difficult to notice that the number of deaths from URI in Japan is higher than in Brazil, but overall, it is on a downward trend and reached a comparable level to Brazil in 2020. A similar pattern is observed for LRI: although the overall number of deaths in Japan is higher than in Brazil, by 2020, the number of deaths had nearly reached the same level. So, what do these numbers signify? Simply comparing the number of deaths is not enough; other aspects must also be considered. Given the differences in scale and population density between the two countries, a rigorous analysis is required. From the World Bank database, it was found that in 2020, Japan's population density was approximately 347 people per square kilometer, while Brazil's population density was about 25 people per square kilometer [4]. Japan's population density is 13.88 times that of Brazil. Given the population base of both countries, the number of deaths from this disease in Japan is still considerable. A significant portion of upper and lower respiratory tract infections are caused by infectious diseases. Research indicates that the transmission rate of infectious diseases is significantly higher in densely populated communities compared to low-density ones. This suggests that, given Japan's higher population density compared to Brazil, the number of infections would also be relatively higher [5]. However, only look at the mortality rate, it is obvious that Brazil is facing a more severe challenge.

### 2.4 Age Distribution of Lower Respiratory Deaths in 2020 for Two Countries

From Fig. 3, it is evident that Japan has a higher overall death count compared to Brazil, with the mortality rate from lower respiratory diseases particularly concentrated among those aged 59 to over 85 years in 2020 (Data From WHO) [2].

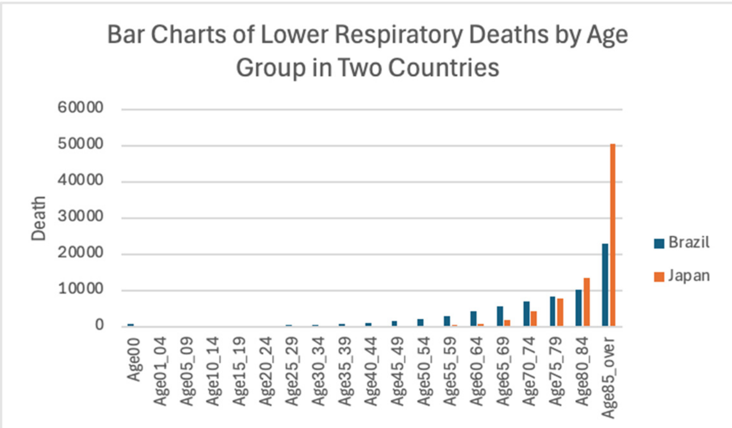


**Fig. 3.** Bar Charts of 2020 Lower Respiratory Deaths by Age Group in Two Countries (Photo credit: Original)

### 2.5 The Healthcare Policy Backgrounds of the Two Countries

Since 1961, Japanese citizens have enjoyed universal health insurance coverage, receiving a wide range of medical services with low co-payment. The government has balanced the benefits across different professions and communities by providing subsidies to financially weaker groups, ensuring that people's health needs are largely met [6]. Brazil's Unified Health System (SUS) has also made significant progress in recent years, promoting universal health coverage (UHC) [7]. However, Brazil faced severe challenges in 2014 with the worst economic recession in its history, leading to a decline in GDP, rising unemployment, and substantial cuts in health and education budgets [7]. After 2015, public health expenditure declined, and the burden on health services increased [7]. Although improvements are being made, health inequalities persist, reflecting internal wealth disparities [7]. Similarly, Japan faces comparable issues, with a significant increase in the proportion of the population aged 65 and over in recent years, and rising healthcare costs for the elderly, which reached $108.5 billion in 2014, accounting for 35.4% of total healthcare expenditure [6]. This figure continues to rise, leading to financial pressure and uneven resource distribution. Due to the higher number of elderly people in Japan and the significantly higher medical costs for this age group compared to younger populations, this effectively explains why there are more deaths from lower respiratory diseases among the elderly in Japan. However, in both Brazil and Japan, only lower respiratory tract infections were on a significant upward trend, especially around 2020 when the COVID-19 pandemic broke out, with the number of infections rising sharply. By April 29, 2020, global reported cases had reached 3,018,681 with 207,973 deaths, a mortality rate of 6.9% [8]. It was also during this special period that the number of deaths from lower respiratory tract infections in both countries peaked.

## 3 Forecast

Above are the corresponding RMSE data (see Table 1). Although some combinations of countries and diseases have smaller values, it is evident that the RMSE values using the ETS model are significantly smaller overall compared to those of the ARIMA model.

**Table 1.** RMSE calculation results

| | | | |
|---|---|---|---|
| Japan URI (ARIMA)29.5 | Japan LRI (ARIMA)20163.7 | Japan URI (ETS)29.3 | Japan URI (ETS)18790.3 |
| Brazil URI (ARIMA)118.6 | Brazil LRI (ARIMA)6522.4 | Brazil URI (ETS)112.3 | Brazil LRI (ETS)6056.0 |

Above are the results of the Ljung-Box test p-values (Table 2). A higher p-value indicates a better fit of the model to the data. From the chart, it is evident that the Ljung-Box test p-values obtained using the ETS model are generally higher, with the only exception being Japan URI, which is relatively low. There is sufficient evidence to suggest that the ETS model is more suitable for respiratory diseases. Therefore, the upcoming predictions will use the ETS model to forecast data for the next ten years.

**Table 2.** Ljung-Box Test p-value

| | | | |
|---|---|---|---|
| Japan URI (ARIMA) 0.6273 | Japan LRI (ARIMA) 0.9061 | Japan URI (ETS) 0.9705 | Japan URI (ETS) 0.3294 |

| | | | |
|---|---|---|---|
| Brazil URI (ARIMA) 0.6667 | Brazil LRI (ARIMA) 0.9382 | Brazil URI (ETS) 0.9705 | Brazil LRI (ETS) 0.954 |

In the next ten years, the overall predicted range of the number of deaths from upper and lower respiratory tract infections in both countries is like the data in 2020. However, it can be noted that the number of deaths from lower respiratory tract infections in Brazil will have a slightly upward trend, this is also in line with the trend during the period from 1980 to 2020 (see Fig. 4).

Previously, it was mentioned that pneumonia can lead to lower respiratory tract infections. However, with the advancement of medical technology, treating pneumonia is not a major issue. But two bacterial strains, MRSA and PRGNB, present unique challenges for pneumonia patients [9]. Research indicates that MRSA and PRGNB often exhibit high levels of antibiotic resistance [9]. Specific data shows that PRGNB accounts for 7.1% (95% CI 5.9% to 8.3%) of all pneumonia cases, while MRSA accounts for 40.7% (95% CI 29.0% to 52.4%) of cases [9]. It is evident that MRSA has a higher infection rate and prevalence. Therefore, the presence of these two resistant bacteria makes pneumonia increasingly difficult to treat in the future. The example of pneumonia serves as a warning for the future challenges to the word with lower respiratory tract diseases. It is not just pneumonia; other diseases can also lead to similar situations, causing lower respiratory tract infections and subsequently increasing mortality among those affected. The microbiome in the respiratory system contains a set of resistance genes that affect the action of antibiotics. When attempting to treat respiratory diseases, particularly chronic respiratory diseases such as cystic fibrosis, chronic obstructive pulmonary disease (COPD), and bronchiectasis with antibiotics, it may lead to multiple drug resistance, thereby affecting the effectiveness of antibiotics in the future [10].

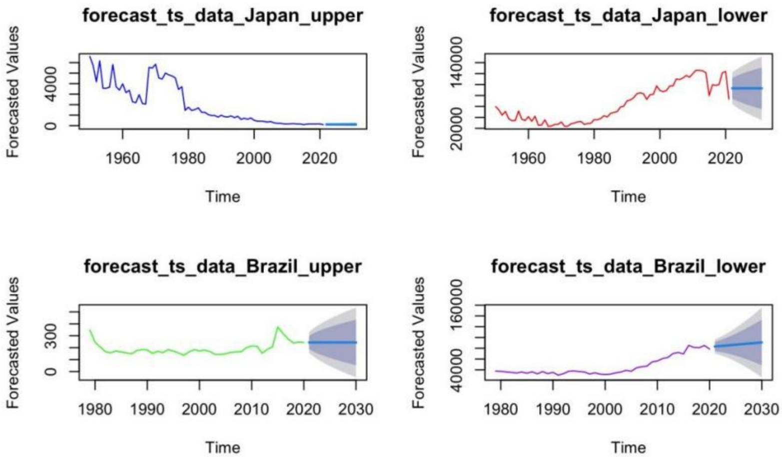


**Fig. 4.** ETS Ten-Year Forecast Chart **(**Photo credit: Original**)**

# 4 Conclusion

Mankind have experienced one of the most severe pandemics in human history, which has made human more aware of upper and lower respiratory tract diseases. Not only have we learned lessons from this pandemic, but we have also made various medical advancements, providing us with more experience to handle similar issues in the future. By studying Brazil and Japan as representatives of developing and developed countries respectively, the trends in respiratory disease mortality in different national contexts were analyzed. This includes considerations of national backgrounds and healthcare policies to explain the trends in respiratory-related deaths in both countries.

Although Japan has significantly higher numbers of respiratory disease cases compared to Brazil, when considering the population size differences, Brazil appears to be more severely impacted. Despite efforts by both countries to develop healthcare policies, inequalities in the distribution of medical resources persist. In Japan, this is reflected in the increasing number of elderly people and the rising medical costs for this age group, while in Brazil, it is more evident in the inequality between rich and poor regions.

For the future development of respiratory diseases, the predictions brought by the ETS model can only serve as a reference. The specific future situation will vary in each country. In addition to considering updated and more comprehensive healthcare policies, efforts should also be made to address the infections caused by highly resistant bacterial strains that lead to more respiratory tract infections. It is important to note that older age groups are particularly vulnerable; as age increases, immunity tends to decline, and data from both groups in 2020 show that the proportion of deaths from lower respiratory tract diseases is significantly higher among the elderly. Therefore, healthcare policies should be more focused on the elderly, especially in aging societies like Japan.

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