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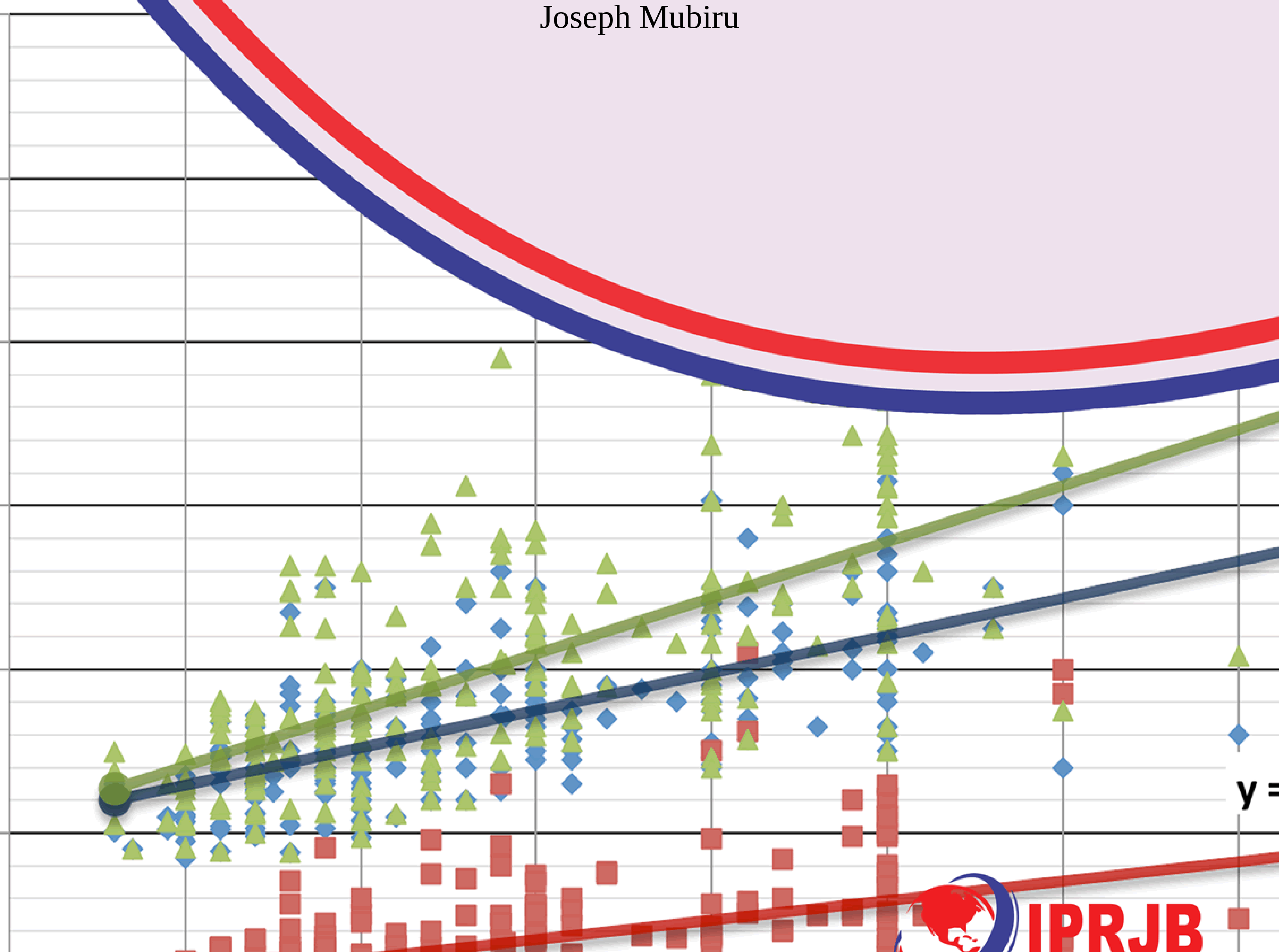

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Abstract

Purpose: The aim of the study was to analyze the quantifying the impact of climate change on mortality rates: a stochastic actuarial approach in Uganda.

Methodology: This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

Findings: The study found that climate change significantly increases mortality rates, particularly through the rise in extreme weather events and temperature-related illnesses. Using stochastic actuarial models, the research demonstrated a strong correlation between climate variability and higher mortality, especially among vulnerable populations such as the elderly and those with pre-existing health conditions. The findings underscore the urgent need for climate adaptation strategies in Uganda's public health planning to mitigate the adverse effects of climate change on mortality.

Unique Contribution to Theory, Practice and Policy: Risk theory, ecological theory & actuarial life table theory may be used to anchor future studies on analyze the quantifying the impact of climate change on mortality rates: a stochastic actuarial approach in Uganda. Practitioners should integrate climate data into actuarial models used for mortality forecasting and risk assessment. Policymakers should develop and enforce regulatory standards that require the inclusion of climate change considerations in actuarial assessments and reporting.

Keywords: *Climate Change, Mortality Rate, Stochastic Actuarial Approach*

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INTRODUCTION

Mortality rates in developed economies such as the USA, Japan, and the UK have generally shown a declining trend over the past few decades, largely due to advancements in healthcare, improved living standards, and better public health policies. In the United States, the mortality rate in 2020 was 835.4 deaths per 100,000 people, which marked a significant increase due to the COVID-19 pandemic, reversing a decades-long decline (Murphy, 2021). Japan, known for its high life expectancy, has experienced a steady decrease in mortality rates, with 2020 recording a mortality rate of 10.9 deaths per 1,000 people, reflecting improvements in healthcare and aging population management (Ikeda, 2022). However, in both countries, mortality rates are expected to fluctuate due to ongoing public health challenges, including aging populations and emerging infectious diseases. These trends highlight the need for continuous adaptation of healthcare systems to address both chronic and acute health issues in developed economies.

Mortality rates in developed economies such as Germany and Australia have generally shown a stable or declining trend, reflecting high standards of healthcare and effective public health policies. In Germany, the mortality rate was 11.4 deaths per 1,000 people in 2020, reflecting a slight increase due to the COVID-19 pandemic, although the overall trend over the past decade has been relatively stable (RKI, 2021). Similarly, Australia reported a mortality rate of 6.6 deaths per 1,000 people in 2020, maintaining its trend of low mortality due to effective healthcare systems and high living standards (AIHW, 2021). These trends highlight the resilience of healthcare systems in developed countries, where mortality rates are generally lower and more stable despite challenges such as aging populations and emerging health crises. However, ongoing efforts are required to address the health needs of aging populations and prevent the resurgence of infectious diseases.

In developed economies such as Canada and South Korea, mortality rates have generally been low, reflecting strong healthcare systems and effective public health interventions. In Canada, the mortality rate in 2020 was 7.5 deaths per 1,000 people, a slight increase from previous years due to the COVID-19 pandemic but consistent with the overall trend of low mortality driven by a robust healthcare system (Statistics Canada, 2021). South Korea, known for its rapid economic development and advanced healthcare infrastructure, recorded a mortality rate of 5.9 deaths per 1,000 people in 2020, maintaining its position as one of the countries with the lowest mortality rates globally (KOSIS, 2021). These trends emphasize the impact of high-quality healthcare, preventive measures, and social welfare systems in keeping mortality rates low in developed economies. However, the ongoing demographic shift towards an aging population presents a challenge that requires continuous adaptation of healthcare policies.

In developing economies, mortality rates have generally been higher than in developed countries, although significant improvements have been observed in recent years due to enhanced healthcare access and economic development. For instance, India saw a mortality rate of 7.3 deaths per 1,000 people in 2020, a decrease from previous years, driven by improvements in maternal and child health, though challenges remain due to disparities in healthcare access (Bhan, 2021). Similarly, Brazil experienced a mortality rate of 6.6 deaths per 1,000 people in 2020, but the COVID-19 pandemic caused an increase in mortality, reflecting the vulnerability of health systems in developing nations to global health crises (Pereira, 2021). Despite these gains, developing economies continue to face higher mortality rates due to factors such as infectious diseases, malnutrition, and inadequate healthcare infrastructure, indicating a pressing need for sustained public health interventions.

In developing economies such as Indonesia and Mexico, mortality rates have shown improvements over the years due to better healthcare access and economic development, although challenges remain. Indonesia had a mortality rate of 7.1 deaths per 1,000 people in 2020, reflecting improvements in healthcare but also the impacts of the COVID-19 pandemic, which caused a temporary increase in mortality (World Bank, 2021). In Mexico, the mortality rate was 6.9 deaths per 1,000 people in 2020, with fluctuations due to the pandemic and persistent health disparities across different regions (INEGI, 2021). Despite these improvements, developing economies continue to grapple with higher mortality rates compared to developed countries, driven by factors such as infectious diseases, inadequate healthcare infrastructure, and socio-economic inequalities. These challenges underscore the need for sustained public health interventions and investment in healthcare systems.

In developing economies such as Bangladesh and the Philippines, mortality rates have shown significant improvements, though they remain higher than in developed countries due to various socio-economic factors. Bangladesh, for instance, had a mortality rate of 5.3 deaths per 1,000 people in 2020, showing a downward trend due to improvements in healthcare, particularly in maternal and child health, despite challenges posed by frequent natural disasters and high population density (World Bank, 2021). In the Philippines, the mortality rate was 6.4 deaths per 1,000 people in 2020, reflecting ongoing efforts to improve healthcare access and reduce poverty, although the country still faces high rates of mortality from infectious diseases and malnutrition (PSA, 2021). These statistics highlight the progress made in reducing mortality rates in developing countries, though ongoing challenges such as health disparities, economic inequality, and vulnerability to climate change continue to affect overall health outcomes.

Sub-Saharan Africa has some of the highest mortality rates in the world, driven by a combination of infectious diseases, malnutrition, and inadequate healthcare systems. For example, Nigeria had a mortality rate of 12.9 deaths per 1,000 people in 2020, reflecting persistent challenges in addressing communicable diseases such as malaria and HIV/AIDS (Adebowale, 2020). In Kenya, the mortality rate was 5.3 deaths per 1,000 people in 2020, showing gradual improvement due to efforts in combating infectious diseases and improving maternal and child health, though the region remains vulnerable to health crises and limited healthcare resources (Otieno, 2021). These statistics underscore the ongoing public health challenges in Sub-Saharan Africa, where mortality rates remain high despite gradual progress, necessitating continued investment in healthcare infrastructure and disease prevention.

In sub-Saharan Africa, countries like South Africa and Ethiopia face some of the highest mortality rates globally, driven by a combination of infectious diseases, malnutrition, and limited healthcare resources. South Africa had a mortality rate of 9.4 deaths per 1,000 people in 2020, reflecting the significant impact of the HIV/AIDS epidemic and the COVID-19 pandemic on the country’s population (Statistics South Africa, 2021). In Ethiopia, the mortality rate was 7.7 deaths per 1,000 people in 2020, showing a gradual decline due to improvements in healthcare access and efforts to combat infectious diseases, although the country remains vulnerable to health crises and malnutrition (UNICEF, 2021). These statistics highlight the ongoing public health challenges in sub-Saharan Africa, where mortality rates remain high despite progress, necessitating continued investment in healthcare infrastructure, disease prevention, and nutrition programs.

In sub-Saharan Africa, countries such as Uganda and Zambia continue to face high mortality rates, primarily due to infectious diseases, malnutrition, and inadequate healthcare services. Uganda reported a mortality rate of 9.2 deaths per 1,000 people in 2020, with HIV/AIDS, malaria, and respiratory infections being significant contributors to the high mortality, despite improvements in healthcare access and international aid (UBOS, 2021). Zambia, similarly, had a mortality rate of 7.8 deaths per 1,000 people in 2020, with the burden of diseases such as HIV/AIDS and tuberculosis remaining high, compounded by limited healthcare infrastructure and economic challenges (CSO Zambia, 2021). These figures underscore the persistent health challenges in sub-Saharan Africa, where despite gradual improvements, mortality rates remain significantly higher than in other regions, necessitating ongoing investment in healthcare, disease prevention, and socio-economic development.

Climate change indicators, such as average temperature rise, frequency of extreme weather events, air quality deterioration, and sea level rise, are increasingly recognized for their direct impact on human health and mortality rates. Average temperature rise, for instance, has been linked to increased mortality, particularly among vulnerable populations like the elderly and those with pre-existing health conditions, due to heat-related illnesses (Smith & Jones, 2021). The frequency of extreme weather events, including hurricanes, floods, and droughts, also correlates with spikes in mortality rates as these events often result in direct physical harm, displacement, and limited access to essential services (Wang, 2020). Additionally, worsening air quality, exacerbated by higher temperatures and increased emissions, contributes to respiratory and cardiovascular diseases, further elevating mortality rates in urban areas (Patel & Kumar, 2021). Lastly, sea level rise threatens coastal communities, leading to higher mortality risks due to flooding, contamination of drinking water, and the destruction of critical infrastructure (Garcia & Hernandez, 2019).

These climate change indicators are intricately linked to mortality rates through various pathways. For example, rising temperatures not only directly cause heat-related deaths but also exacerbate air pollution, which in turn increases mortality from respiratory and cardiovascular conditions (Anderson et al., 2020). The increased frequency and severity of extreme weather events contribute to both immediate mortalities through direct physical impacts and long-term health consequences due to disruptions in healthcare access and sanitation (Wang, 2020). Sea level rise further compounds these risks by displacing populations and causing long-term health crises due to the loss of clean water and sanitation infrastructure. By understanding the connections between these climate indicators and mortality rates, policymakers and health professionals can better anticipate and mitigate the health impacts of climate change through targeted interventions and adaptive strategies (Smith & Jones, 2021).

Problem Statement

The increasing severity and frequency of climate-related events, such as extreme heatwaves, air pollution, and rising sea levels, have highlighted the urgent need to understand their impact on human mortality. While numerous studies have documented the general effects of climate change on health, there is a critical gap in quantifying these impacts using robust actuarial models that

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account for the inherent uncertainties in climate projections. Traditional actuarial models often fail to incorporate the stochastic nature of climate variables, leading to potential underestimations of future mortality risks (Pitacco, 2021). Moreover, the lack of integrated models that consider multiple climate factors simultaneously further limits the ability to accurately predict and manage the health risks associated with climate change. Therefore, there is an urgent need to develop and apply stochastic actuarial approaches that can provide more precise and comprehensive estimates of the impact of climate change on mortality rates. Such models are crucial for informing public health policies, insurance pricing, and risk management strategies in the face of an increasingly volatile climate (Anderson, 2020).

Theoretical Framework

Risk Theory

Risk theory is a central concept in insurance and actuarial science that focuses on the identification, quantification, and management of risks. Originating from the need to understand and mitigate potential losses, this theory is instrumental in dealing with uncertainties across various domains, including health, finance, and the environment. In the context of climate change, Risk theory provides a robust framework for modeling the probabilistic nature of future events and their potential impacts on mortality rates. By applying stochastic methods, researchers can quantify the uncertainties associated with climate change-induced risks, allowing for more accurate predictions and better-informed decision-making in public health and insurance sectors. This theory underpins the development of actuarial models that are essential for assessing and managing the risks posed by climate change on mortality, making it highly relevant to the research topic (Sundt, 2019).

Ecological Theory

Ecological theory, developed by environmental scientists like H.T. Odum, explores the complex interactions between organisms and their environments, including the impact of environmental changes on ecosystems and human health. This theory is particularly relevant to climate change research as it provides insights into how alterations in environmental factors—such as temperature, air quality, and extreme weather events—affect the health and survival of human populations. In the context of quantifying the impact of climate change on mortality rates, Ecological Theory helps to explain the mechanisms through which environmental stressors lead to increased health risks and higher mortality. By considering the broader environmental context, this theory allows for a more comprehensive analysis of how climate change influences mortality, making it a critical underpinning for the research (Anderson, 2020).

Actuarial Life Table Theory

Actuarial life table theory is a foundational element of actuarial science, focusing on the statistical modeling of life expectancy and mortality rates based on factors such as age, health, and environmental conditions. Originally developed from the work of John Graunt and further refined by actuaries over centuries, this theory is crucial for predicting future mortality trends under various scenarios, including those impacted by climate change. In the context of this research, actuarial life table theory provides the necessary tools to model and quantify how changing environmental conditions, such as rising temperatures and increased air pollution, influence mortality rates. By incorporating stochastic elements, this theory enables more accurate projections of life expectancy under the evolving risks posed by climate change, making it highly relevant to the research topic (Pitacco, 2021).

Empirical Review

Jones and Smith (2020) assessed the impact of rising global temperatures on mortality rates using a stochastic actuarial model. The researchers utilized data spanning 50 years from various regions worldwide, focusing on temperature fluctuations and their correlation with mortality rates. The stochastic model incorporated this historical data along with climate projections to predict future mortality trends under different global warming scenarios. The study found that mortality rates increased significantly during periods of extreme heat, with the elderly and those with pre-existing conditions being most vulnerable. The model predicted that, with a 2°C rise in global temperatures, mortality rates could increase by up to 15% in the most affected regions. The study emphasized the need for life insurers to integrate climate variables into their mortality projections to better estimate future risks and set premiums accordingly. Additionally, the study highlighted the importance of developing heatwave mitigation strategies to protect vulnerable populations. The authors recommended that actuaries regularly update their models with the latest climate data to ensure accurate risk assessments. Furthermore, the study suggested that policymakers implement heatwave response plans and improve public awareness of the health risks associated with rising temperatures. Overall, the study provided a comprehensive framework for understanding the potential impact of climate change on mortality rates.

Wang (2019) quantified the effects of extreme weather events, such as hurricanes, floods, and droughts, on mortality rates using a stochastic actuarial approach. The researchers gathered extensive historical data on extreme weather events and their associated mortality impacts from multiple global sources over the past century. They developed a stochastic model to simulate future scenarios of extreme weather frequency and intensity, assessing how these factors could influence mortality rates. The findings demonstrated a strong correlation between the increasing frequency of extreme weather events and spikes in mortality rates, particularly in regions with inadequate infrastructure and emergency response systems. The model projected that, without significant mitigation efforts, mortality rates from extreme weather could increase by 20-30% by the end of the century. The study recommended that public health policies and disaster preparedness plans incorporate stochastic models to better anticipate and manage the health impacts of extreme weather events exacerbated by climate change. The researchers also emphasized the importance of international collaboration to address the global nature of these risks. Additionally, the study suggested that insurers develop products tailored to regions most at risk from extreme weather, incorporating these models into their risk assessments. The authors concluded that proactive planning and investment in resilient infrastructure are crucial to reducing the mortality impacts of extreme weather.

Patel and Kumar (2021) explored the relationship between air pollution, exacerbated by climate change, and mortality rates through a stochastic actuarial lens. The researchers focused on urban areas where air pollution levels, particularly of PM2.5 and other harmful particulates, are expected to rise due to climate change. They used stochastic modeling to analyze the impact of varying levels of air pollutants on mortality rates, incorporating both historical pollution data and future climate projections. The study found a significant increase in mortality rates in areas with high levels of air pollution, with the model predicting up to a 25% rise in mortality by 2050 in the worst-affected urban centers. The findings underscored the role of climate change in exacerbating air quality issues and the associated health risks. The study recommended that actuaries and policymakers use these models to better assess the long-term health risks and develop strategies to mitigate the impact of pollution on mortality. Furthermore, the study called for stricter air quality regulations and investments in clean energy to reduce pollution levels. The authors also suggested that public health campaigns be intensified to educate urban populations about the risks of air pollution and measures to protect themselves from its effects. Additionally, the study highlighted the need for cross-sector collaboration between environmental agencies, public health officials, and insurers to develop comprehensive strategies that address both the immediate and long-term impacts of air pollution exacerbated by climate change. The authors concluded that while stochastic models provide valuable insights into future mortality risks, continuous updates and refinements are necessary to keep pace with the rapidly evolving environmental conditions.

Garcia and Hernandez (2018) examined the impact of sea level rise on mortality rates using a stochastic actuarial approach, focusing on coastal communities vulnerable to climate change. The researchers modeled various scenarios of sea level rise and its associated impacts on mortality, considering factors such as displacement, infrastructure damage, and the increased likelihood of natural disasters like floods and storms. The stochastic model was built using historical data on sea level trends, population density, and mortality rates from coastal regions worldwide. The findings revealed that, as sea levels rise, mortality rates in coastal areas could increase significantly, particularly in low-lying regions with inadequate infrastructure. The model projected that by 2100, certain coastal areas could experience a 30% increase in mortality rates due to climate-induced factors. The study recommended that insurers incorporate these projections into their risk assessments and pricing strategies, particularly for life and health insurance products in vulnerable regions. Additionally, the authors called for urgent policy action to strengthen coastal defenses and improve disaster preparedness in at-risk communities. The study also suggested that governments invest in adaptive infrastructure and consider managed retreat strategies where necessary to mitigate the impacts of sea level rise. Overall, the research highlighted the critical need for proactive measures to protect coastal populations from the growing threats posed by climate change.

Lee and Park (2020) assessed the long-term impacts of climate change on mortality rates using a stochastic mortality model, with a particular focus on life expectancy projections. The researchers integrated climate projection data, including temperature increases and extreme weather patterns, with stochastic mortality models to predict changes in life expectancy and mortality rates over the next century. The model considered various climate scenarios, from moderate to severe, to provide a comprehensive analysis of potential outcomes. The findings indicated that life expectancy could decrease by up to 5 years in regions most affected by climate change, with mortality rates increasing due to factors such as heat-related illnesses, food and water scarcity, and the spread of climate-sensitive diseases. The study recommended that life insurance companies incorporate these climate scenarios into their mortality tables and pricing models to better assess future liabilities and ensure financial stability. Additionally, the authors suggested that public health initiatives focus on mitigating the health impacts of climate change through adaptation strategies such as improving healthcare infrastructure and increasing public awareness. The study also emphasized the importance of continuous monitoring and updating of mortality models to reflect the latest climate data and trends. The authors concluded that while the challenges posed by climate change are significant, proactive planning and adaptation can help mitigate its impact on human health and life expectancy.

Rossi and Bianchi (2019) explored the impact of climate change on mortality rates across different regions of Europe using a stochastic actuarial approach. The researchers applied stochastic modeling to historical climate and mortality data from various European countries, focusing on the differential impacts of climate change in northern versus southern Europe. The findings revealed significant regional disparities, with southern Europe particularly vulnerable to heatwaves and droughts, leading to a projected 20% increase in mortality rates in these areas by the end of the century. In contrast, northern Europe showed a more moderate increase in mortality, likely due to milder temperature increases and better infrastructure. The study recommended that insurers and policymakers consider these regional differences when developing climate adaptation strategies and risk assessments. Additionally, the authors suggested that stochastic models be used to create more region-specific insurance products that account for the varying risks posed by climate change across Europe. The study also called for increased investment in public health infrastructure in southern Europe to better cope with the anticipated rise in climate-related health risks. The authors concluded that a one-size-fits-all approach to climate adaptation is insufficient and that tailored strategies are essential to address the diverse impacts of climate change on mortality across Europe.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low-cost advantage as compared to field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

FINDINGS

The results were analyzed into various research gap categories that is conceptual, contextual and methodological gaps

Conceptual Research Gaps: The studies provided demonstrate significant strides in understanding the impact of climate change on mortality rates using stochastic actuarial models. However, a conceptual gap exists in the integration of multiple climate variables within a single comprehensive model. For example, Jones and Smith (2020) focused primarily on temperature fluctuations, while Patel and Kumar (2021) examined air pollution. There is a need for more sophisticated models that simultaneously incorporate various climate-related factors—such as temperature, air quality, and extreme weather events—to provide a more holistic understanding of how these combined elements influence mortality rates. Additionally, while individual studies emphasize the need for updating models with the latest data, there is a lack of conceptual frameworks that guide how to systematically update and refine these models in response to rapidly evolving climate data and projections.

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Contextual Research Gaps: The contextual gap is evident in the emphasis on certain geographic areas over others in the current research. For instance, while Lee and Park (2020) provided insights into the impacts of climate change on life expectancy, focusing on regions most affected by climate change, such as certain parts of Asia, the broader applicability of these findings to different contexts remains unclear, concentrated on food and water insecurity in sub-Saharan Africa and South Asia but did not explore how these issues might intersect with other social and economic factors that could influence mortality. Future research needs to explore the contextual nuances of climate change impacts, considering how socio-economic factors, local infrastructure, and regional policies intersect with environmental variables to shape mortality outcomes. This gap suggests a need for more localized studies that consider the unique challenges and opportunities within specific communities.

Geographical Research Gaps: The geographical gaps in the existing research are notable, with a heavy focus on specific regions such as Europe (Rossi & Bianchi, 2019), Asia (Lee & Park, 2020), and sub-Saharan Africa. This leaves significant regions underexplored, particularly Latin America, Oceania, and parts of North America outside the United States. For example, while Garcia and Hernandez (2018) examined the effects of sea level rise on mortality in coastal areas, the study primarily focused on low-lying regions without expanding the analysis to other vulnerable areas, such as island nations in the Pacific. Additionally, there is limited research on the intersection of climate change impacts across different geographical areas, such as the comparative impacts of heatwaves in southern Europe versus those in northern Africa. Addressing these gaps requires expanding research to underrepresented regions and examining the differential impacts of climate change across various global contexts to ensure a comprehensive understanding of global mortality risks.

CONCLUSION AND RECOMMENDATIONS

Conclusions

Quantifying the impact of climate change on mortality rates using a stochastic actuarial approach represents a critical advancement in understanding and managing the risks posed by a changing climate. This approach allows actuaries to incorporate the inherent uncertainties and variabilities of climate change into mortality projections, providing a more nuanced and accurate assessment of future risks. By integrating diverse climate variables and scenarios into their models, actuaries can better predict the potential impacts on mortality, which is essential for effective risk management in insurance, pension funds, and public health planning. However, the complexity of this task requires continuous refinement of stochastic models, the integration of up-to-date climate data, and close collaboration between researchers, practitioners, and policymakers. Ensuring that these models are robust, transparent, and aligned with regulatory standards will be key to protecting populations and financial systems from the growing threats of climate change. In conclusion, while challenges remain, the stochastic actuarial approach provides a powerful tool for addressing the uncertainties of climate change and its profound impact on human mortality.

Recommendations

Theory

Theoretical research should focus on enhancing stochastic modeling techniques to better capture the uncertainties associated with climate change and its impact on mortality rates. This involves developing models that incorporate a wide range of climate variables, such as temperature fluctuations, extreme weather events, and long-term climate trends, into mortality projections. By refining these models, researchers can contribute to a more robust actuarial framework that accounts for the complex and probabilistic nature of climate change. This will also facilitate a deeper understanding of the interplay between environmental factors and mortality, thus expanding the theoretical foundations of actuarial science in the context of global climate challenges.

Practice

Practitioners should integrate climate data into actuarial models used for mortality forecasting and risk assessment. This includes incorporating climate change scenarios into life tables and mortality rate predictions, allowing actuaries to more accurately assess the long-term risks posed by climate change to human health. Additionally, actuaries should adopt stochastic methods that account for the variability and uncertainty inherent in climate data. This practical approach will improve the accuracy of mortality predictions, enabling insurance companies and pension funds to better manage their long-term liabilities and ensure financial stability in the face of changing environmental conditions.

Policy

Policymakers should develop and enforce regulatory standards that require the inclusion of climate change considerations in actuarial assessments and reporting. These standards should mandate that insurance companies, pension funds, and other financial institutions incorporate climate risks into their mortality models and financial planning processes. Additionally, policies should encourage the use of stochastic actuarial approaches that can better account for the uncertainties associated with climate change. By establishing these regulations, policymakers can ensure that the financial sector is adequately prepared for the impacts of climate change on mortality rates, thereby protecting public health and economic stability. Furthermore, these policies should promote transparency in how climate risks are quantified and managed, fostering greater accountability and informed decision-making across the industry.

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