CAUSES OF DISPARITIES IN LIFE EXPECTANCY AMONG COUNTIES IN USA

STATISTICAL DATA MINING PROJECT REPORT

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# EXECUTIVE SUMMARY

## 1.1 PROBLEM SUMMARY

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| The disparity in life expectancy between States in America has been at its widest point in the past 40 years. Most Americans will live to be 78 years old, but if they were born in different areas, they may pass away more than ten years sooner. We wanted to look deep into the reasons for this disparity and understand how various socio-economic factors effect life expectancy in the United States. |

## 1.2 DATA

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| The data was collected for all the counties in the US for the years 2019 to 2023. Here is a list of variables collected from different sources.  Variables:  Demographics - age, gender, race/ethnicity, socioeconomic status, education, and occupation.  Health behaviors - smoking, alcohol consumption, physical activity, and nutrition.  Health outcomes - chronic diseases, mental health conditions, and infant mortality.  Environment - air/water quality, green spaces, and exposure to toxins.  Healthcare access - availability of providers, insurance coverage, and preventative care.  Social determinants - poverty, income inequality, and community safety.  Control variables:  Demographics - family size, marital status, immigration status, and location.  Health behaviors - access to healthy food, recreational facilities, and media exposure.  Health outcomes - healthcare access, insurance coverage, and preventative care.  Environment - weather patterns, location, and industrial activity.  Healthcare access - distance to facilities, transportation options, and cost of healthcare.  Social determinants - education level, employment status, and family structure. |

## 1.3 ANALYSIS

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| Two models were used to analyze life expectancy data with different levels and time: a linear fixed effect model and an LMER model. The linear model accounted for individual-level factors, while the LMER model considered county-wide and state-wide variations. The analysis showed the importance of considering multiple levels and dimensions in understanding life expectancy variations, with implications for public health policies and interventions. |

## 1.4 KEY FINDINGS

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# PROBLEM DEFINITON AND SIGNIFICANCE

High-level summary of each category below (a total of 2 pages max)

## 1.1 TARGET CLIENTS

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| The target clients for the statistical analysis on the causes of disparities in life expectancy among US counties may include public health officials, researchers, government agencies, non-profit organizations, and the general public. |

## 1.2 BUSINESS PROBLEM

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| Estimate the impact of each factor on life expectancy for States and see how they vary across the United States. |

## 1.3 PROBLEM SIGNIFICANCE

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| Life expectancy disparities among US states have widened in the past 40 years, with some Americans dying over ten years earlier depending on where they live. Despite advances in medicine and quality of life, many Americans have not benefited equally. This disparity is illustrated in a graphic below. |

# PRIOR LITERATURE

## 3.1 PREDITCORS USED IN THE PAPERS

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| * Geographic area (e.g., region, urban-rural status), socioeconomic status (e.g., income, education), household structure (e.g., family type, household size), and household composition (e.g., age and sex of household members) * Economic factors: Gross domestic product (GDP) per capita, income inequality, and poverty rates. * Health factors: Access to health care services, vaccination coverage, and HIV prevalence. * Demographic factors: Age structure, fertility rates, and literacy rates. * Environmental factors: Water and sanitation facilities, air pollution, and access to clean energy. * Political factors: Political stability, government effectiveness, and corruption levels.​ * Income, Pollution, Obesity, Smoking, %Black, %Hispanic, Median age, %over 65 yrs. and indicator variables for the nine census division areas.​ * Age group, Total County population, median income quartile indicators, population density quartile indicators, proportion of individuals with a 4-year degree, PRCSDA status and census region indicators. |

## 2.1 PAPER 1: PREMATURE MORTALITY IN THE US: THE ROLES OF GEOGRAPHIC AREA, SOCIOECONOMIC STATUS, HOUSEHOLD STRUCTURE, AND HOUSEHOLD COMPOSITION

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| PREDICTORS:  The predictors used in the study include geographic area (e.g., region, urban-rural status), socioeconomic status (e.g., income, education), household structure (e.g., family type, household size), and household composition (e.g., age and sex of household members)  Y – Life expectancy (LE)  MODELS:  logistic regression models, Cox proportional hazards models, and random-effects Poisson regression models  KEY FINDINGS:  Mortality rates vary geographically in the US, with certain regions having higher rates. Lower socioeconomic status is strongly associated with premature mortality. Household structure and composition also affect mortality rates, with non-traditional structures and living alone being linked to higher rates.  The effects of household structure on mortality are largely mediated by socioeconomic status.  Geographic area, socioeconomic status, and household structure together explain a large portion of the variation in premature mortality rates in the US. |

## 2.2 PAPER 2: DETERMINANTS OF LIFE EXPECTANCY IN DEVELOPING COUNTRIES

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| PREDICTORS:  Economic factors: Gross domestic product (GDP) per capita, income inequality, and poverty rates.  Health factors: Access to health care services, vaccination coverage, and HIV prevalence.  Demographic factors: Age structure, fertility rates, and literacy rates.  Environmental factors: Water and sanitation facilities, air pollution, and access to clean energy.  Political factors: Political stability, government effectiveness, and corruption levels.  Y – Life expectancy (LE)  MODELS:  It primarily uses descriptive statistics and correlation analysis to identify the determinants of life expectancy in developing countries.  KEY FINDINGS:  The results suggest that factors such as access to safe water, education, per capita income, and health expenditure are positively associated with life expectancy.  In contrast, infant mortality rates, prevalence of HIV/AIDS, and the proportion of the population living in urban areas are negatively associated with life expectancy.  The study highlights the importance of investing in public health infrastructure, education, and poverty reduction programs to improve life expectancy in developing countries. |

## 2.3 PAPER 3: HOW IMPORTANT ARE HEALTH CARE EXPENDITURES FOR LIFE EXPECTANCY? A COMPARITIVE, EUROPEAN ANALYSIS BY WIM. J.A VAN DEN HEUVEL PHD

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| PREDITORS:  Does not focus on specific predictors, but instead examines the relationship between health care expenditures and life expectancy in European countries. The paper compares life expectancy and health care expenditures across 27 European countries, and also looks at other factors that may affect life expectancy, such as income and education.  Y – Life expectancy (LE)  MODELS:  The paper uses multiple linear regression models and structural equation modeling to analyze the data.  KEY FINDINGS:  The study compares the relationship between health care expenditures and life expectancy across 27 European countries.  The results show a positive association between health care expenditures and life expectancy, but the relationship is weak and non-significant in some countries.  Other factors such as socioeconomic conditions, lifestyle, and environmental factors have a stronger impact on life expectancy.  The study suggests that investing in health care alone may not be enough to improve life expectancy, and a comprehensive approach that addresses social determinants of health is needed. |

## 2.3 PAPER 4: SOCIAL DETERMINANTS OF HEALTH INEQUALITIES INTERNATIONAL CENTRE FOR HEALTH AND SOCIETY, UNIVERSITY COLLEGE LONDON, 1–19 TORRINGTON PLACE, LONDON WC1E 6BT, UK PROF MICHAEL MARMOT

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| PREDITORS:  Social and economic factors, such as income, education, employment, and housing. Political and social factors, including government policies and social norms. Structural factors, such as discrimination, racism, and gender inequality.  Y – Life expectancy (LE)  MODELS:  The paper is a literature review and discussion of the social determinants of health inequalities.  KEY FINDINGS:  There is a strong association between social determinants such as income, education, and occupation and health outcomes, including life expectancy and mortality rates.  Health inequalities are not just a result of individual choices and behaviors but are shaped by broader social, economic, and political factors.  Interventions and policies aimed at reducing health inequalities need to address the social determinants of health, such as poverty, social exclusion, and unequal access to education and employment opportunities.  The paper advocates for a broader approach to health policy that includes not just health care interventions but also upstream interventions that address the social determinants of health. |

## 2.3 PAPER 5: IMPACT OF SOCIO-HEALTH FACTORS ON LIFE EXPECTANCY IN THE LOW AND LOWER MIDDLE-INCOME COUNTRIES

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| PREDITORS:  Income, Education, Health Expenditure, Physicians Density, Sanitation, Clean Water Access, Malnutrition, HIV/AIDS, Tuberculosis, Malaria, Cardiovascular Diseases  Y – Life expectancy (LE)  MODELS:  Multiple Regression Models  KEY FINDINGS:  The study found that income, education, health expenditure, physician density, sanitation, and access to clean water were positively associated with life expectancy in low and lower-middle income countries. On the other hand, malnutrition, HIV/AIDS, tuberculosis, malaria, and cardiovascular diseases were negatively associated with life expectancy. The authors suggest that interventions aimed at improving education, healthcare access, and sanitation can have a positive impact on life expectancy in these countries. Additionally, addressing the burden of communicable diseases can also improve life expectancy. |

## 2.3 PAPER 6: COUNTERVAILING EFFECTS OF INCOME, AIR POLLUTION, SMOKING, AND OBESITY ON AGING AND LIFE EXPECTANCY: POPULATION-BASED STUDY OF U.S. COUNTIES

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| PREDITORS:  Y – Life expectancy (LE) / Exceptional Aging (EA)  X variables – Income, Pollution, Obesity, Smoking, %Black, %Hispanic, Median age, %over 65 yrs and indicator variables for the nine census division areas.  MODELS:  Multiple Regression Models  KEY FINDINGS:  An interesting finding from the study was that policy on one factor alone like reducing air pollution isn't a strong enough tool to increase life expectancy. When comparing the tradeoffs with the other variables, this study found that a 10 μg/m 3 reduction in PM2.5 and a $5,000 increase (adjusted for inflation, base year 2000) in real, per-capita income corresponded to the same increase in Life expectancy.  Additionally, they also found that while greater income does increase life expectancy, a bend in the relationship between income and longevity occurs at about 40,000$, indicating that beyond this level increases in income are associated with smaller increases in longevity. |

## 2.3 PAPER 7: COUNTY-LEVEL LIFE EXPECTANCY CHANGE: A NOVEL METRIC FOR MONITORING PUBLIC HEALTH ARUNA CHANDRAN 1,\*,†, RITIKA PURBEY 1, KATHRYN M. LEIFHEIT 2, KIRSTEN MCGHIE EVANS 1, JOCELYN VELASQUEZ BAEZ 1 AND KERI N. ALTHOFF

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| PREDITORS:  Annual death counts were grouped into 25-34, 35-44 and similar age groups.  A Negative Binomial model was fitted with variables: Age group, Total County population, median income quartile indicators, population density quartile indicators, proportion of individuals with a 4-year degree, PRCSDA status and census region indicators to **calculate the estimated death counts (for counties with <5 3 year averaged observed deaths)**  A Linear Regression model was used to estimate the average change in life expectancy per year for each county and counties were categorized as having increased, decreasing or no change in LE.  Y – Life expectancy (LE)  MODELS:  Multinomial Regression Models and Poisson Models.  KEY FINDINGS:  Linking the County health rankings data was a good move by these researchers since it adds an additional layer to this analysis to help health officials in resource allocation.  It was found that counties with increasing LE between 2011-2016 had significantly lower COVID mortality compared to no-change counties. However, counties with decreasing LE had similar mortality rates to counties with no change for reasons unanswered.  Higher rates of smoking, obesity, unemployment, children in poverty and single parent households understandably led to a decrease in LE. However, binge drinking, motor vehicle crash mortality and preventable hospital stays did not impact LE. |

# DATA SOURCE AND PREPARATION

## 4.1 SOURCES

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| * The County Health Rankings, a program of the University of Wisconsin Population Health Institute, measures the health of nearly all counties in the nation and ranks them within states. The Rankings are compiled using county-level measures from a variety of national and state data sources. These measures are standardized and combined using scientifically informed weights. * Counties in each of the 50 states are ranked according to summaries of a variety of health measures. Those ranking in the healthiest 75-100% of counties are the “healthiest.” Counties are ranked relative to the health of other counties in the same state. * County wise health ranking data <https://www.countyhealthrankings.org/> * United States Mortality Rates and Life Expectancy by County, Race, and Ethnicity 2000-2019 * (<https://ghdx.healthdata.org/record/ihme-data/united-states-life-expectancy-by-county-race-ethnicity-2000-2019>) |

## 4.2 DATA PREPARATION

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| * Population data was acquired from <https://data.census.gov/> * Combined and merged the county wise data from 2019-2023. * Missing values in certain columns (e.g. -food environment index) were filled in using the county-wise data from <https://datausa.io/> |

# PREDICTOR TABLE

## 4.1 VARIABLES, ESTIMATED EFFECT ON LE AND RATIONALE

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| |  |  |  | | --- | --- | --- | | **Predictor** | **Expected Effect** | **Rationale** | | **Year** | + | With increasing years, causes of increasing LE should be identified and action  is likely to be taken to reduce them | | **State** | ? | Policy and laws by each state can influence LE depending on how strict/lax  their regulations are. | | **County** | +/- | Different counties can have different laws, population distributions and  environmental factors which can affect LE | | **% of people under frequent physical distress** | - | Greater physical distress/ a greater number of distressed individuals can  affect LE negatively. | | **% of people under frequent mental distress** | - | More people under mental distress can lower the LE for an area. | | **% of diabetic individuals** | - | Although diabetes is not a fatal disease by itself, it can be hypothesized that  those with diabetes might be relatively unhealthier than healthy individuals and  can lower the LE of an area. | | **% of food insecure individuals** | - | Food insecurity can lead to malnutrition and lower LE | | **% of people getting insufficient sleep** | - | Insufficient sleep can impair the body’s normal functions and can affect LE in  the long term. | | **No. of uninsured adults +**  **No. of uninsured children** | - | Uninsured people are likely to visit the doctor less frequently due to fear of  hefty medical bills and might miss obvious signs of  illness. However, it can also be said that they might  take better care of themselves knowing that they can’t afford hefty fees.  Regardless, the expected effect is likely a negative impact to LE. | | **Household income** | + | Greater income leads to a better quality of life which can improve LE | | **No. of households with severe cost burden** | - | Severe money issues can cause mental stresses, inadequate nutrition, and  little to no preventative medical care, likely leading to reduced LE | | **Population** | +/- | Greater population likely indicates a more urban city and can provide better  access to food, more varied housing and better healthcare facilities leading to  improve LE however, can also contribute negatively due to increased  pollution, greater mental stress, and other factors. | | **% of population under 18 +**  **% of population over 65** | +/- | The skew in population distribution can affect LE positively or negatively as a  larger youth population can lead to increase LE due to better access to  healthcare, environment and vaccinations compared to individuals over 65  who would not have had the same amenities growing up. | |

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| |  |  |  | | --- | --- | --- | | **Predictor** | **Expected Effect** | **Rationale** | | **Year** | + | With increasing years, causes of increasing LE should be identified and action is  likely to be taken to reduce them. | | **State** | ? | Policy and laws by each state can have an effect on LE depending on how  strict/lax their regulations are. | | **% of people under frequent physical distress** | - | Greater physical distress/ a greater number of distressed individuals can affect LE  Negatively. | | **% of people under frequent mental distress** | - | More people under mental distress can lower the LE for an area | | **% of diabetic individuals** | - | Although diabetes is not a fatal disease by itself, it can be hypothesized that those  with diabetes might be relatively unhealthier than healthy individuals and can  lower the LE of an area | | **# of food insecure individuals** | - | Food insecurity can lead to malnutrition and lower LE | | **% of people getting insufficient sleep** | - | Insufficient sleep can impair the body’s normal functions and can affect LE in the  long term | | **No. of uninsured adults**  **No. of uninsured children** | - | Uninsured people are likely to visit the doctor less frequently due to fear of hefty  medical bills and might miss obvious signs of illness. However, it can also be said  that they might take better care of themselves knowing that they can’t afford  hefty fees. Regardless, the expected effect is likely a negative impact to LE. | | **Household income** | + | Greater income leads to a better quality of life which can improve LE | | **No. of households with severe cost burden** | - | Severe money issues can cause mental stresses, inadequate nutrition, and little to  no preventative medical care, likely leading to reduced LE | | **Population** | +/- | Greater population likely indicates a more urban city and can provide better  access to food, more varied housing and better healthcare facilities leading to  improve LE however can also contribute negatively due to increased pollution,  greater mental stress, and other factors. | | **% of population under 18 +**  **% of population over 65** | +/- | The skew in population distribution can affect LE positively or negatively as a larger  youth population can lead to increase LE due to better access to healthcare,  environment and vaccinations compared to individuals over 65 who would not  have had the same amenities growing up. | |

# DATA VISUALIZATIONS AND DESCRIPTIVE ANALYSIS

## 6.1 VISUALIZATIONS

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| A graph of life expectancy  Description automatically generated with medium confidence  **Life Expectancy for all the counties from 2019-2023**  The histogram shows us that the distribution of life expectancy is roughly normal, with a peak around 75-80 years. |

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| **Household Income Vs Life Expectancy (Year-Wise)**  The scatterplot shows us that there is a positive correlation between household income and life expectancy.  Counties with higher household incomes tend to have higher life expectancies. |

## 6.2 CORRELATION ANALYSIS

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| High correlation between percent of frequent physical distress and average number of physically unhealthy days. Dropped average number of physically unhealthy days as it was captured by the other variable.  High correlation between number of households with severe cost burden and population. The population was dropped from the analysis because it was not a strong predictor of life expectancy compared to the latter.  High correlation between number of primary care physicians and mental health providers. Removed the number of mental health providers from the analysis as primary care physicians is more considerable for the analysis. |

# MODELING

## 1.1 MODELS AND THEIR RATIONALE

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| Since Life expectancy is approximately normal, we can run linear models. But the data has different levels (County and State) along with a time dimension.  Hence, we ran 2 models starting with the Linear one, which is a fixed effect model, followed by LMER model to account for county-wide and state-wide variations in life expectancy. |

## 1.2 MODEL SELECTION

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| The outputs of the models seem to differ widely in terms of the estimated effect of each predictor. This is since the linear model does not account for the statewide differences and the multi-level model takes those effects into account. Hence, the model we would choose to make recommendations is the multi-level model. |

## 1.4 QUALITY CHECKS

#LMER models are robust to Linearity, Normality and Equality of variances assumptions. But we still need to perform tests on multi-collinearity and Independence.

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| 1.4.1. Correlation Test - Passed  > vif(re)  Df GVIF^(1/(2\*Df))  year 4 1.565004  percent.frequent.physical.distress 1 2.814840  percent.diabetic 1 1.317145  percent.food.insecure 1 3.086380  percent.adult.uninsured 1 2.565204  household.income 1 1.686660  no.households.with.severe.cost.burden 1 2.697548  percent.65.and.over 1 1.197579  percent.african.american 1 1.577684  percent.american.indian.alaskan.native 1 1.705880  percent.asian 1 1.786593  percent.hispanic 1 2.042741  percent.non.hispanic.white 1 2.060404  percent.female 1 1.781031  percent.smokers 1 2.438270  percent.adults.with.obesity 1 1.386307  food.environment.index 1 1.273367  percent.excessive.drinking 1 1.402807  no.primary.care.physicians 1 3.039596  percent.rural 1 1.341041  average.daily.pm2.5 1 1.224935  presence.of.water. violation 1 1.011646  1.4.2. Durbin-Watson Test – Passed  > residuals <- resid(re)  > durbinWatsonTest(residuals)  [1] 1.959945  The result is 1.959945, which is close to the ideal value of 2, indicating that there is no significant autocorrelation present in the residuals. |

# RECOMMENDATIONS

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| * Governments can reduce physical distress by ensuring access to quality healthcare, implementing public health initiatives, promoting occupational health and safety, protecting the environment, providing social welfare programs, investing in infrastructure, supporting mental health services, and fostering research and innovation. * Governments can support mentally unhealthy people through accessible mental health services, awareness campaigns, social welfare programs, crisis intervention, policy and legislation, workforce development, collaborative partnerships, and research and innovation. * Government action for poor food index counties: food assistance, rural dev., nutrition ed., food safety, community gardens, public-private partnerships, policy advocacy, health/nutrition services, empowerment/capacity-building. * Government strategies to reduce smoking population: tobacco taxation, advertising regulations, tobacco control policies, cessation programs, health education campaigns, supportive social policies, enforcement of tobacco laws, stakeholder collaboration, and monitoring/evaluation. |

# REFERENCES

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| --- |
| Harvard T.H. Chan School of Public Health. (2019, September 24). Significant disparities in U.S. life expectancy found at census tract level. Retrieved from <https://www.hsph.harvard.edu/news/press-releases/significant-disparities-in-u-s-life-expectancy-found-at-census-tract-level/> |