

Country Level Indicators of Suicide Risk:

Data Analysis and Decision-Making Support for Policy Makers

Team 25: ISyE 6414 Spring 2020

Team Members: Team 25



Osman Ghandour
BS in ISyE

From Columbia, SC
Hobbies: Fitness & Podcasts



Samuel Garcia
MS in Statistics
(Part-time - ISyE)

From San Juan, PR
Hobbies: Software Development
and Linux



Michael Szostak
MS in Aerospace
Aerospace Systems Design Lab

From Austin, TX
Hobbies: Running & Mtn Biking



Peter Williams
MS in Statistics
(Part-time - School of Math)

From Atlanta, GA
Hobbies: Running & Board Games

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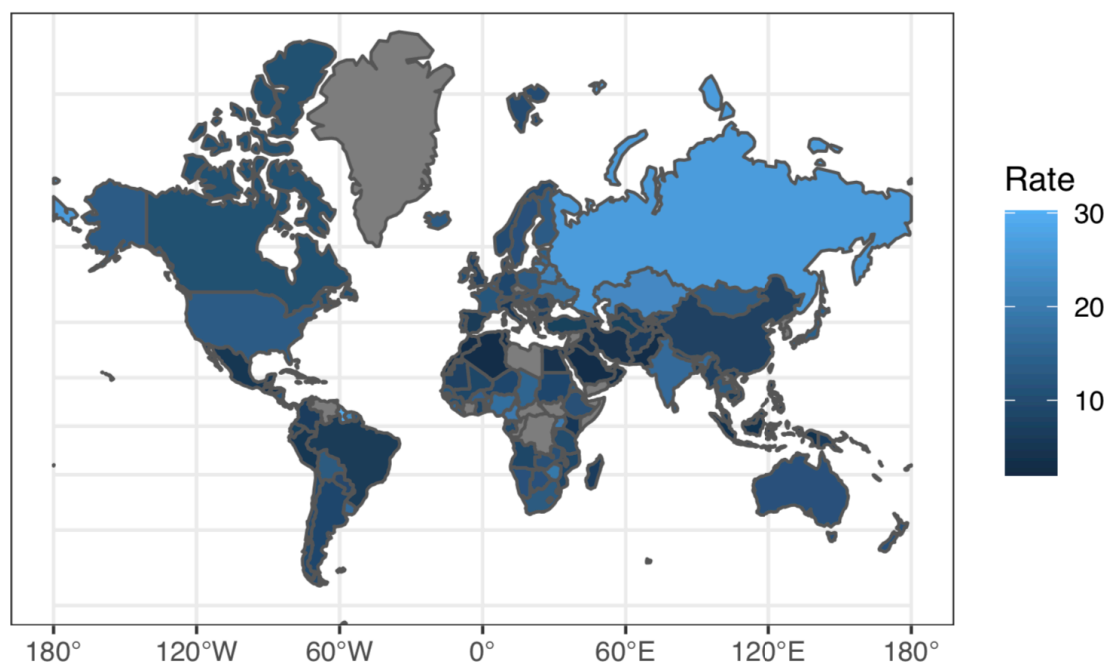
Research Motivation

Background and Motivation – Why We Chose This Topic

- Prevalence:
 - “I'm the girl nobody knows until she commits suicide. Then suddenly everyone had a class with her.”
— Tom Leveen, [Party](#)
- Global Relevance:
 - Suicide is an international problem, with tragic outcomes
- Preventable:
 - The possibility of prevention and the scale of the problem highlight the need for policy makers, at the national level, to understand the factors that contribute to suicide not only locally but also in neighboring countries

Suicide is a Global Problem With Significant Effects

Worldwide Suicide Rate by Country (per 100,000 persons)



Key Insights*

- One person dies every 40 seconds from suicide
- Suicide is the 2nd leading cause of death among persons 18-29
- Only 38 governments worldwide have a national suicide prevention program
- Sadly, many deaths attributed to suicide are preventable

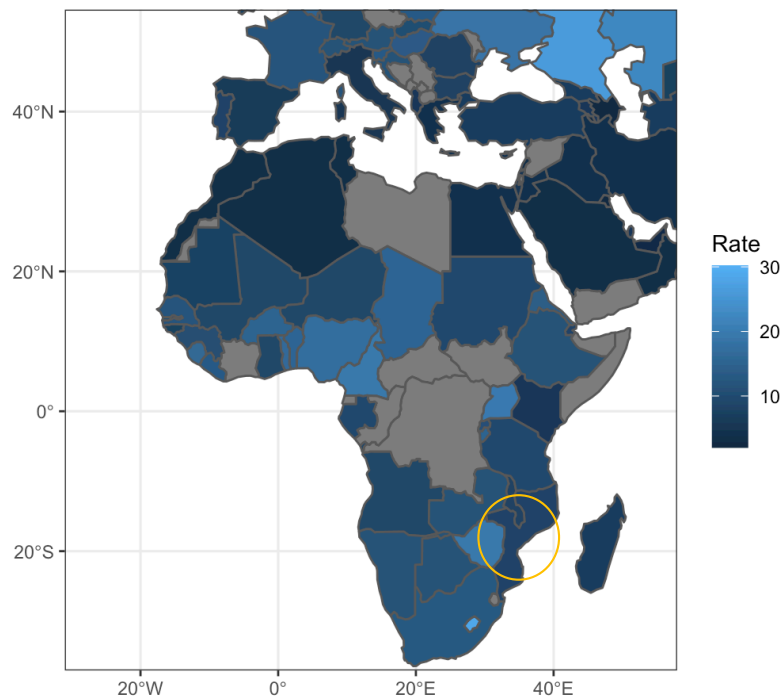
*Sourced from the World Health Organization report: "Suicide: Key Facts, 2019"

Suicide Is A Complex Problem For A Number of Reasons

- No singular cause: psychological, social, biological, cultural, and environmental dimensions
- Not all who commit suicide do have an existing mental illness
- Stressful experiences, such as exposure to trauma, the death of a loved one, job loss, change in physical health or relationships...are also associated with suicide [2].

Case Study: Faltering GDP, Economic Instability & Poverty Contribute to Suicide in Zimbabwe

Africa: Suicide Rate by Country (per 100,000 persons)



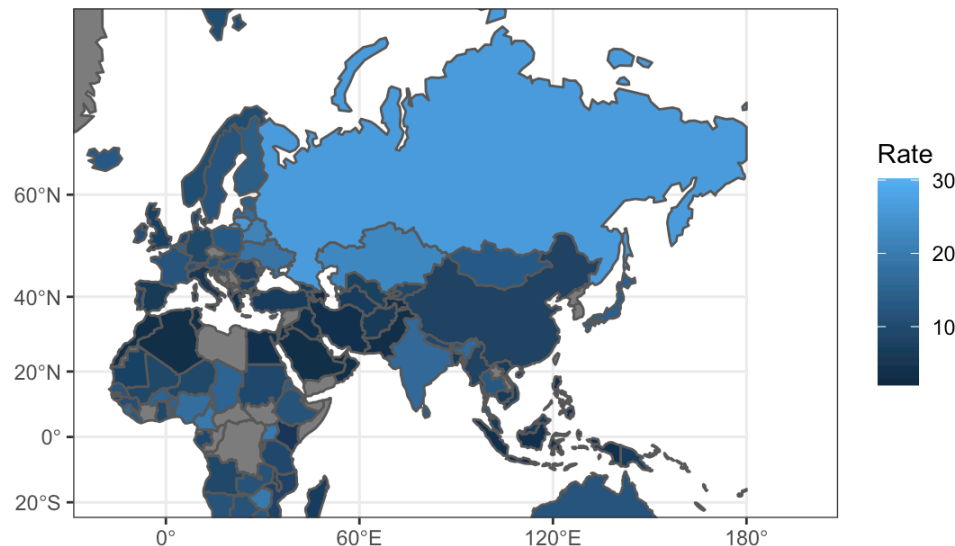
Key Insights*

- The WHO estimates that 19 persons per 100k take their own life deliberately in Zimbabwe per annum (2019)
- Zimbabwe has dealt with issues of endemic poverty, unemployment and hyperinflation for years which is often attributed to the policies of former dictator Robert Mugabe
- Post Mugabe, Zimbabwe continues to deal with debt issues, difficulty attracting foreign investment, and currency instability which continue to contribute to systemic unemployment and poverty nationwide

*Sourced from the World Health Organization report: "Suicide: Key Facts, 2019" and the WorldBank Economic Profile of the Country of Zimbabwe

Case Study: Alcohol Dependence and Abuse May Contribute to Suicide in Russia

Russia: Suicide Rate by Country (per 100,000 persons)



Key Insights*

- The WHO estimates that 27 persons per 100k take their own life deliberately in Russia per annum (2019)
- Among the general populace in Russia, almost 1-in-20 adults suffer from alcohol dependence
- Alcoholism has been a problem because drinking is not only pervasive, but also a socially acceptable behavior in Russian society
- Of the 166 countries in our study, Russia ranks 3rd in the world for suicides per capita.

**Sourced from the World Health Organization report: "Suicide: Key Facts, 2019" and the WorldBank Economic Profile of the Country of Zimbabwe*

Defining the Scope of Our Research

- We wanted to identify available measures/indicators that were best associated with suicide rates at the country level
- We made a conscious choice to limit the study to a set of factors, from which to draw inferences, that could be controlled for and acted upon via policy interventions
- Factors from different domains such as lifestyle, medical/mental health, economic, and suicide-focused policy were considered

Variables & Data Sources

Defining Our Key Outcome Of Interest

- **Key Outcome of Interest:** Suicide Rate, per 100,000 population
- **Definition:** The suicide rate is age-standardized, meaning that it is a weighted average of the age-specific mortality rates per 100,000 persons, where the weights are the proportions of persons in the corresponding age groups of the WHO standard population.
- **Source:** World Health Organization [1] (see appendix for link)

Variables We Considered For Testing and Analysis

- **Health Expenditure** and **GDP per capita** were chosen to reflect the resources that a country has its disposal to reduce the suicide rate
- **Liters of Alcohol per capita** was chosen to account for an aspect of culture (alcohol consumption) that the media often links to mental health outcomes
- The **presence of a suicide prevention strategy**, the **number of psychiatrists**, and the **number of mental hospitals** were also chosen to reflect how a country has deployed its resources to improve mental health outcomes
- The **female/male labor participation ratio** was also included to control for trends or changes related to gender labor participation rates

Data Sources

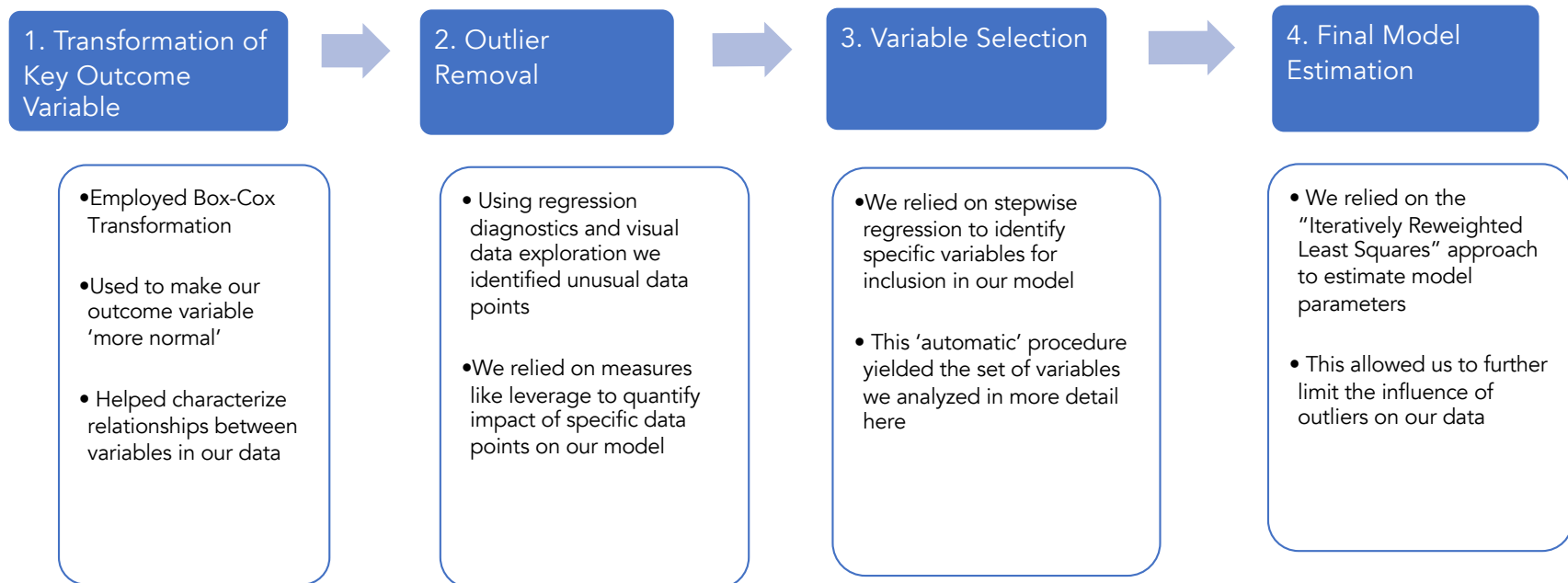
Input	Data Description	Source
Current Health Expenditure as a Percentage of GDP	This data provides an indication on the level of resources channeled to health relative to other uses. It shows the importance of the health sector in the whole economy and indicates the societal priority which health is given measured in monetary terms.	World Health Organization [2]
Labor force participation rate (female-male ratio)	Ratio of female to male of proportion of a country's working-age population (ages 15 and older) that engages in the labor market, either by working or actively looking for work, expressed as a percentage of the working-age population.	United Nations Development Programme [1]
GDP per capita, PPP	Gross Domestic Product converted to international dollars using purchasing power parity (PPP) rates and divided by total population. This data is in terms of PPP in order to account for differences in the cost of living between countries.	World Bank [1]
Liters of Alcohol per capita	Total (sum of recorded and unrecorded alcohol) amount of alcohol consumed per person (15 years of age or older) over a calendar year, in litres of pure alcohol, adjusted for tourist consumption.	World Bank [2]
Suicide Prevention Strategy	Countries which are known have a stand-alone national suicide prevention strategy are included as 1s, else 0. Note that the plan must be stand-alone, and may not be integrated into another plan, in order to count in the dataset.	World Health Organization [3]
Psychiatrists in mental health, per 100,000 pop.	Number of Psychiatrists working in the mental health sector, per 100,000 population.	World Health Organization [4]
Mental hospitals, per 100,000 pop.	Number of hospitals dedicated to mental health per 100,000 population	World Health Organization [5]

Modeling & Assumptions

Modeling Objective: Inferential vs Predictive

- Our model is intended to be used for inferential, rather than predictive purposes
- The model was developed to infer properties about how a handful of socioeconomic and cultural indicators impact suicide rates
- Our objective is to discover relationships between variables to inform relevant public policy and future research in the area

Analysis Approach: Multiple Linear Regression Model Development Steps



Results: Variable Testing & Inclusion

Variables Selected & Included In Our Model

- Labor force participation rate (female-male ratio)
- GDP per capita, PPP
- Liters of Alcohol consumption per capita
- Prevalence of a Suicide Prevention Strategy

Variables Considered But Not Included

- Current Health Expenditure as a Percentage of GDP
- Number of Psychiatrists working in the mental health sector, per 100,000 population
- Number of Mental Hospitals, per 100,000 population

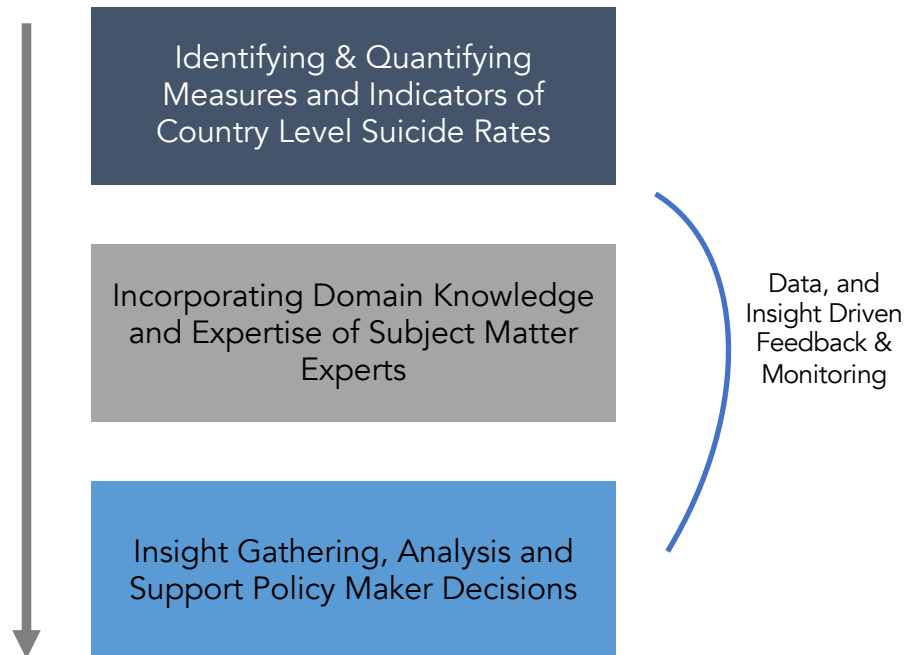
Some Modeling Assumptions

- **GDP per capita** is an appropriate indicator to reflect the wealth of a country
- The **prevalence of a national suicide prevention strategy** is indicative that the country has taken the time to develop a comprehensive and data driven approach to suicide, based on solid evidence
- **Liters of Alcohol consumed per capita** reflects the tendency for individuals in the given country to consume excessive amounts of alcohol

Quantifying the Impact of Measures on Suicide

Identifying, Describing and Monitoring Country Level Indicators Is Critical for Effective Decision-Making Support

Providing Decision Support for Policy Makers

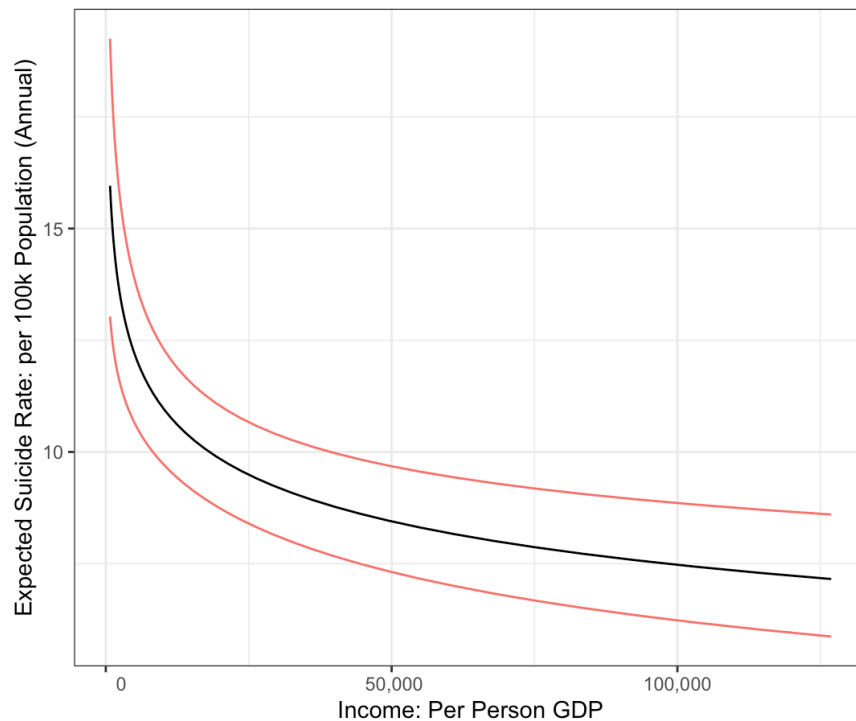


Topline

- Using a model to describe the relationships between country-level indicators and suicide rates can help quantify the impact of measures
- This allows policy makers to correlate indicators with country-level suicide related outcomes
- Our intention is to provide some initial context and decision support for policy makers managing health related planning activities

Income, GDP per person: Quantifying Impact & Monitoring

Income vs. Expected Suicide Rate (per 100k Population)



Note: Expected country level suicide rate, with 95% confidence interval. Units 'back-transformed' to original scale.

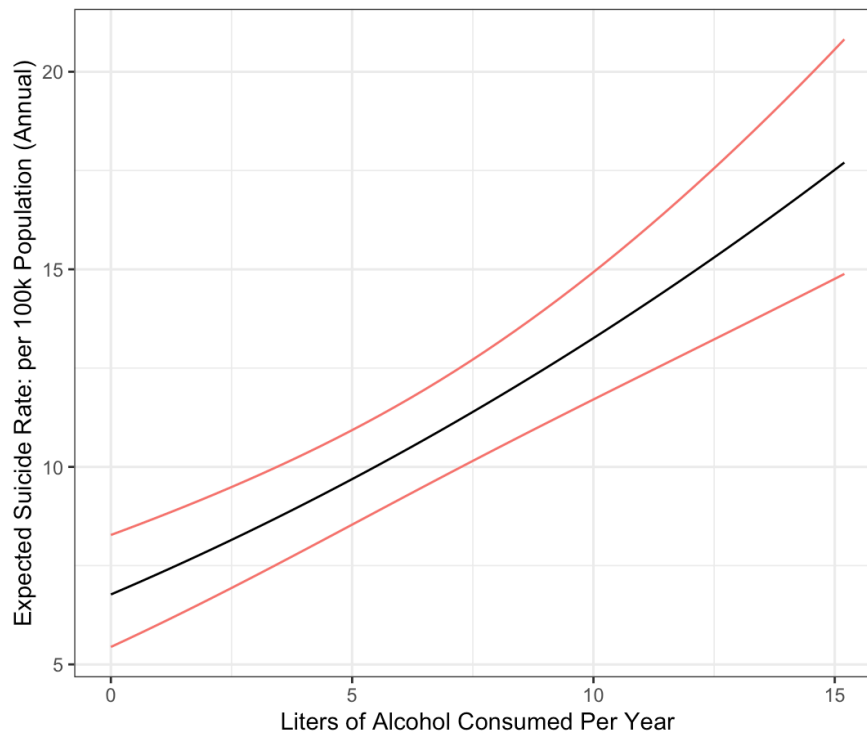
*Other variables controlled for include **Liters of Alcohol Consumption**, The Presence of a **National Suicide Strategy Prevention Program**, and the **Female/Male Labor Participation Rate**.

Insights

- Our model indicates the presence of a significant relationship between a measure of income (country-level GDP per person) and suicide
- Countries with lower per person income, tend to have higher incidence of suicide when controlling for other variables in our model*
- Based on our estimates, an approximate 10% increase in income corresponds to a 2% decrease in suicide rate at the country level for the typical country

Alcohol Consumption: Quantifying Impact & Monitoring

*Alcohol Consumption vs. Expected Suicide Rate
(per 100k Population)*



Note: Expected country level suicide rate, with 95% confidence interval. Units 'back-transformed' to original scale.

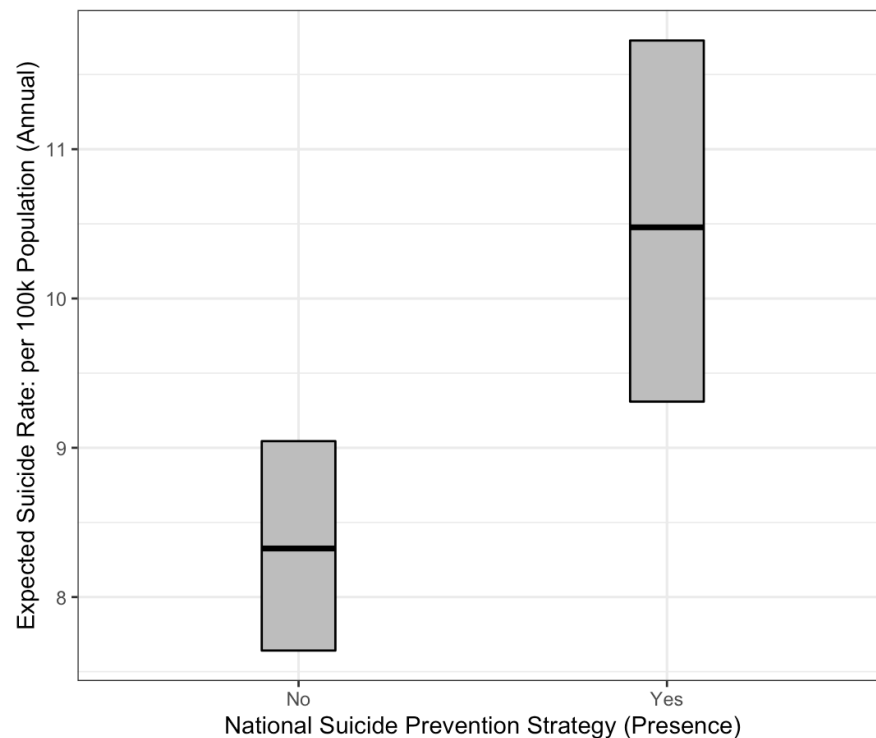
*Other variables controlled for include **Income (GDP per person)**, The Presence of a **National Suicide Strategy Prevention Program**, and the **Female/Male Labor Participation Rate**.

Insights

- Our model indicates the presence of a significant relationship between a measure of alcohol consumption (liters per year)
- Countries with higher levels of alcohol consumption income, tend to have higher incidence of suicide when controlling for other variables in our model*
- Based on our estimates, an approximate **4%** increase in alcohol consumption corresponds to a **2%** increase in suicide rate at the country level for the typical country (>4 liters per year)
- Alcohol consumption was the most impactful and significant indicator of country-level suicide rate in our analysis

The Presence of A National Suicide Strategy: Quantifying Impact & Monitoring

National Suicide Strategy vs. Expected Suicide Rate (per 100k Population)



Note: Expected country level suicide rate, with 95% confidence interval.

*Other variables controlled for include **Income (GDP per person)**, **Liters of Alcohol Consumed**, and the **Female/Male Labor Participation Rate**.

Insights

- Our model indicates that countries that have put a national suicide prevention strategy in place, tend to have higher incidence of suicide rates overall
- Based on our estimates, countries that have implemented a suicide prevention strategy have a 26% higher incidence of suicide nationally
- However, to put this in context, it appears that the institution of a suicide prevention strategy by countries struggling with suicide prevention overall, including Guyana, Lithuania, Suriname, Belarus and South Korea are driving this estimate

Recommendations & Decision Support

Recommendation I: Implement Ongoing Measurement of Key Indicators

Identify Measures & Indicators

- Our initial analysis indicates the presence of significant relationships that describe suicide at the country level
- Income (GDP per person), Alcohol and substance abuse, as well as the presence of a national suicide strategy should be considered in context of policy decision making and support

Implement Strategies to Quantify and Monitor

- In order to support decision makers, we recommend policy makers collect data and monitor these identified indicators
- We recommend engaging subject matter experts as data monitoring and measurement processes are developed

Inform Policy Making Decisions

- Insights provided by the measures highlighted in this analysis are only one facet of an informed policy decision making strategy
- We recommend ongoing engagements between health, policy and data experts and to support building a holistic suicide prevention strategy



Recommendation II: Inform Policy Across These Areas of Focus

Suicide Prevention Strategy

- Establish an agency, tasked with implementing a National Suicide Prevention Strategy which doesn't replace local government frameworks
- Follow UN recommendations, and emulate successful policies of other countries
- Take advantage of online resources like MiNDbank [1]

Implement Policies to Mitigate Alcohol Abuse

- Increase the price of alcohol via taxation
- Enact and enforce restrictions on alcohol advertising (across multiple types of media)
- Enact and enforce restrictions on the physical availability of retailed alcohol (via reduced hours of sale)

Invest in Research to Uncover More About The Relationship Between Income and Suicide

- Invest in research to better understand potential relationships between income instability, income protection and suicide at the individual level
- Pursue measures aimed at poverty reduction and unemployment benefits to support economic well-being



Research Limitations

Research Limitations: Identifying Potential Shortcomings

Scope of Measurement

- We used GDP per Capita as a proxy for income, but other measures such as country-level median income should be considered in the future
- Measuring the liters of alcohol consumed: assumes uniform consumption country-wide and doesn't consider incidence of substance abuse
- Suicide Policy (NSPS): effectiveness of organizational response hard to gauge since local response vs federal not accounted for in measurement
- We did not consider local/cultural/interactional measures making it difficult to make country-specific inferences in some cases

Methodology

- Country level scope: cannot drill down to local or individual level, our model assumes effects are fixed
- Interactions between variables: higher level interactions and additional factors which may influence suicide rates could be considered in the future
- Formulation: we chose to use multiple linear regression for inferential and descriptive reasons but more complicated / non-linear relationships could be discovered with more complex approaches

Appendix

Final Model Specification & Model Results Summary

Final Model Specification

$Y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \epsilon_i$, where we assumed, $\epsilon_i \sim \mathcal{N}(0, \sigma_Y^2)$

for $i = 1, \dots, n$ country level measures, where

Y_i : The estimated national suicide rate (per 100k population) for the i^{th} country.

x_{1i} : The estimated national labor participation rate (percentage) for the i^{th} country.

x_{2i} : The log-transformed estimated per-person gross domestic product (GDP) (income) for the i^{th} country.

x_{3i} : An estimate of the national per-person average of liters of alcohol consumed annually for the i^{th} country.

x_{4i} : A binary indicator of the 'presence of a national suicide prevention strategy' in 2019 for the i^{th} country.

This yields fitted regression model:

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 x_{1i} + \hat{\beta}_2 x_{2i} + \hat{\beta}_3 x_{3i} + \hat{\beta}_4 x_{4i}$$

where,

$\hat{\beta}_0$, $\hat{\beta}_1$, $\hat{\beta}_2$, $\hat{\beta}_3$, and $\hat{\beta}_4$ were estimated by the method of iterative re-weighted least squares.

Model Estimates & Results

Table 1: Regression Model Summary

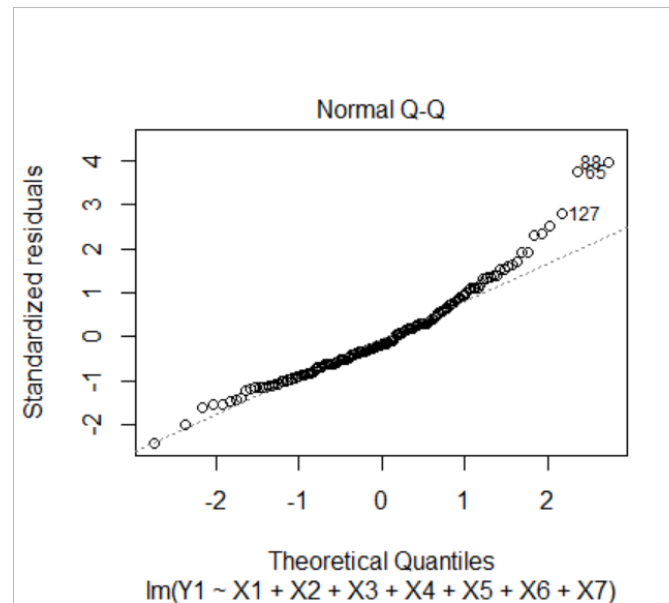
	Dependent variable:
	Suicide Rate (Box-Cox Transformed $\lambda = 0.4$)
Income (pp GDP) - Log Transformed	-0.404*** (0.080)
Liters of Alcohol Consumed	0.166*** (0.026)
Suicide Prevention Strategy (Binary)	0.562*** (0.185)
Labor Participation Rate	1.031** (0.472)
Constant	5.420*** (0.828)
Observations	162
R ²	0.412
Adjusted R ²	0.397
Residual Std. Error	1.272 (df = 157)
F Statistic	27.475*** (df = 4; 157)
Note:	*p<0.1; **p<0.05; ***p<0.01

References

- World Health Organization [1] : <https://apps.who.int/gho/data/node.main.MHSUICIDEASDR?lang=en>
- World Health Organization [2] : [https://www.who.int/data/gho/data/indicators/indicator-details/GHO/current-health-expenditure-che-as-percentage-of-gross-domestic-product-gdp-\(-\)](https://www.who.int/data/gho/data/indicators/indicator-details/GHO/current-health-expenditure-che-as-percentage-of-gross-domestic-product-gdp-(-))
- World Health Organization [3] : <https://apps.who.int/iris/handle/10665/279765>
- World Health Organization [4] <https://apps.who.int/gho/data/node.main.MHHR?lang=en>
- World Health Organization [5] : <https://apps.who.int/gho/data/node.main.MHFAC?lang=en>
- United Nations Development Programme [1] : <http://hdr.undp.org/en/content/labour-force-participation-rate-female-male-ratio>
- World Bank [1] : <https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD>
- World Bank [2] : <https://data.worldbank.org/indicator/SH.ALC.PCAP.LI>

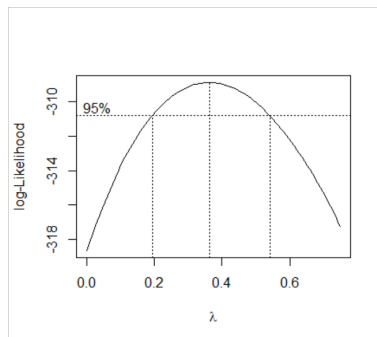
Model Development Notes: Initial Model, Multiple Linear Regression

- $Y \sim X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7$
- Normal Q-Q plot shows that the points deviate from the reference line at the higher quintiles. In order to correct for this, our next step was to try a Box Cox transformation on Y.



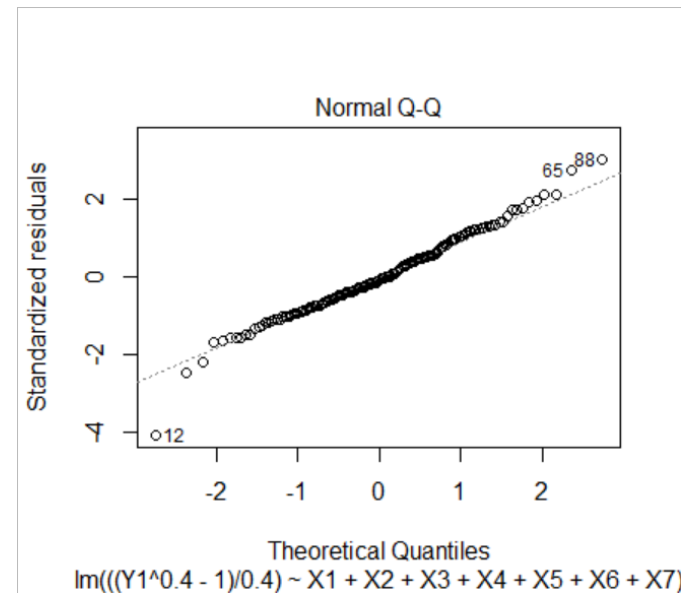
Model Development Notes: Box-Cox Transformation

- $\frac{Y^{.4}-1}{.4} \sim X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7$



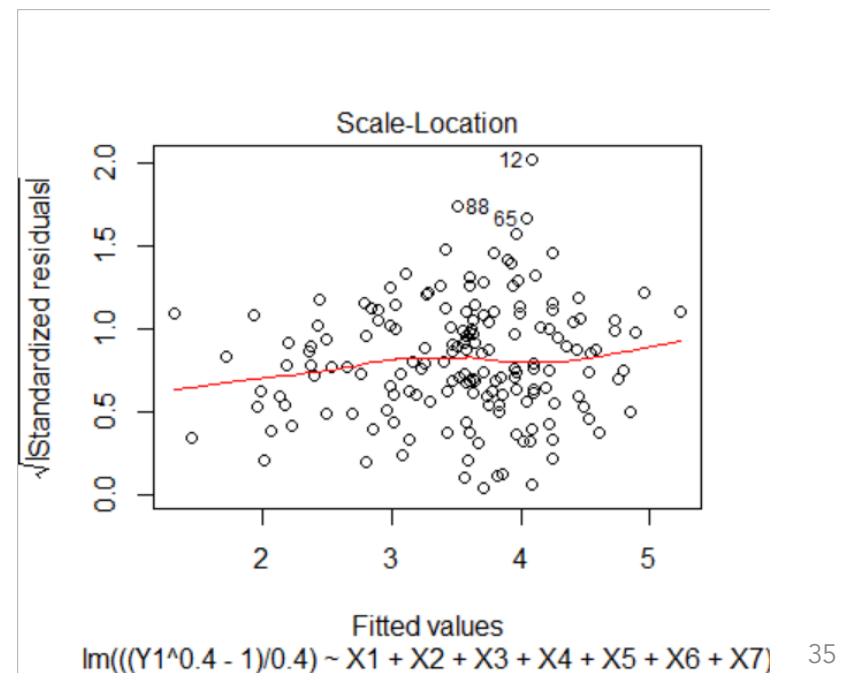
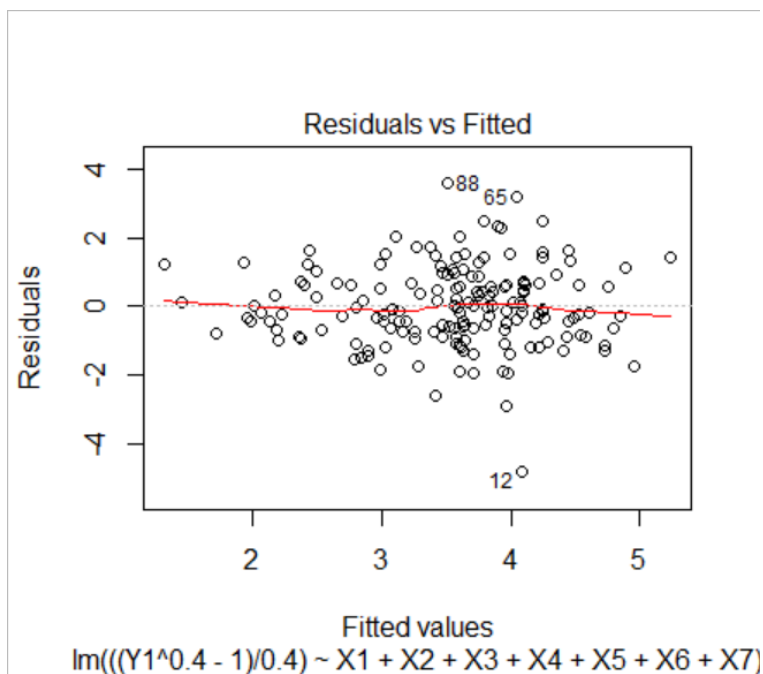
- After transformation, the points in the Normal Q-Q plot are much closer to the reference line

- Box Cox transformation on $\lambda = 0.4$ seems to be appropriate



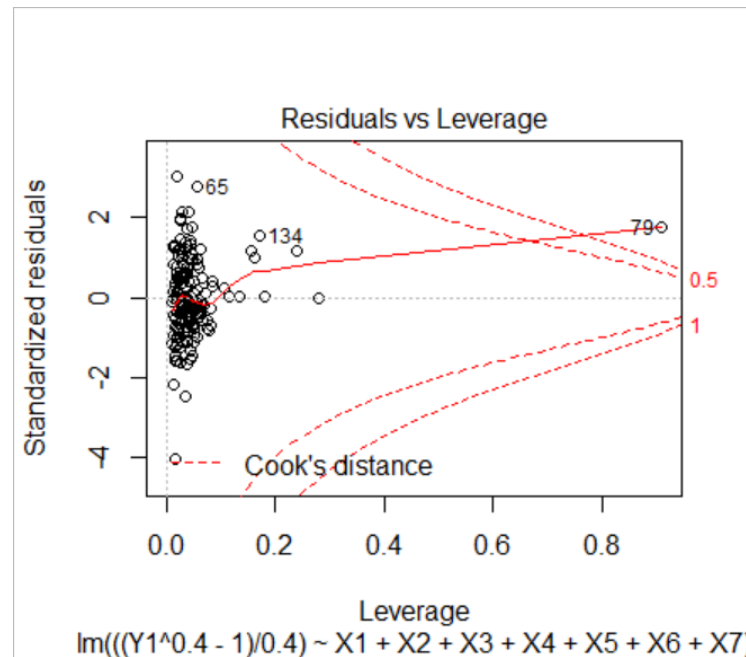
Model Development Notes: Outlier Removal

- Points 12, 65, and 88 were identified as outliers on the Residuals vs Fitted, Scale-Location, and Normal Q-Q plots (refer to previous slide)



Model Development Notes: Outlier Removal

- In addition, point 79 was identified as an outlier that should be removed, as it had very high leverage in the model



Model Development Notes: Outlier Removal

- Points 12, 65, 79, and 88 also had country specific reasons for being removed from the data set
- 12 – Barbados:
 - Caribbean's leading tourism island, transitioned from agricultural to service based economy very successfully
 - “very high human development” status in terms of the UNDP’s human development index
 - Extremely low suicide rate
- 65 – Guyana:
 - Extremely poor island country largely made up of agricultural villages.
 - Very high alcohol and suicide statistics
 - Ministry of health identified poverty, pervasive stigma about mental illness, access to lethal chemicals, alcohol misuse, interpersonal violence, family dysfunction and insufficient mental health resources as key factors causing one of the highest suicide rates in the world.
- 79 – Japan:
 - Notoriously overworked and over stressed population, although the country is very wealthy
 - Long cultural history of considering certain types of suicides honorable, relatively high cultural tolerance for suicide
 - Very high suicide rate when compared to other rich nations
- 88 – Lesotho:
 - Small, landlocked, mountainous country in Africa
 - Highest suicide rate in Africa
 - High levels of child labor
 - Very poor general health outcomes, ex. second highest instances of tuberculosis and HIV/AIDS in the world

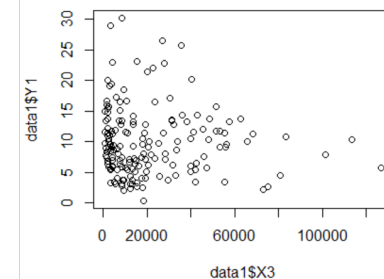
Model Development Notes: Variable Selection

- Next step was to remove the variables that were redundant or unnecessary in our model. We used the step function which removes variables based on AIC.
- Removed Variables:
 - X1 – Health Expenditure as a percentage of GDP
 - X6 – Psychiatrists working in mental health sector (per 100 000 population)
 - X7 – Mental hospitals (per 100 000 population)
- Model After Variable Reduction: $\frac{Y^{.4}-1}{.4} \sim X_2 + X_3 + X_4 + X_5$

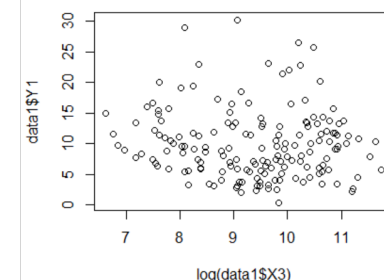
Model Development Notes: Variable Transformation

- After removal of variables based, further analysis was performed to decide whether a predictor transformation may be appropriate.
- We discovered that a log transformation of GDP per capita (X3) would better represent the relationship between this predictor and the outcome variable

Before transformation



After transformation



- Model After Predictor Transformation: $\frac{Y^{.4}-1}{.4} \sim X_2 + \log(X_3) + X_4 + X_{5_{39}}$

Model Development – IWLS and Final Model

- Final step was to implement iteratively weighted least squares
- Performed 10 iterations
- To the right is the summary of the final model after IWLS

Weighted Residuals:

Min	1Q	Median	3Q	Max
-2.9885	-0.9233	-0.0513	0.8235	4.3666

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)	
(Intercept)	5.42041	0.82797	6.547	7.93e-10	***
X2	1.03107	0.47182	2.185	0.03035	*
X3	-0.40426	0.08027	-5.036	1.29e-06	***
X4	0.16572	0.02594	6.388	1.82e-09	***
X5	0.56202	0.18527	3.034	0.00283	**

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.272 on 157 degrees of freedom

Multiple R-squared: 0.4118, Adjusted R-squared: 0.3968

F-statistic: 27.48 on 4 and 157 DF, p-value: < 2.2e-16