Country Level Indicators of Suicide Risk: Data Analysis & Decision Support for Policy Makers

Project Report: Georgia Tech ISyE 6414 - Dr. Yajun Mei

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Abstract

Relying on open source data from the World Health Organization and other non-governmental bodies, we highlight trends and related to country-level measures of suicide globally. A descriptive model is formulated that identifies a set of meaningful factors and measures that highlights some intuitive relationships between country-level suicide rates and other indicators such as income, alcohol consumption, and the presence of a country level suicide prevention strategy.

An initial framework for data-driven decision support for policy makers is presented with recommendations including the identification and ongoing monitoring of meaningful factors and measures related to suicide prevention. The hope is that this can provide some introductory guidance for those managing health related planning activities and priorities related to this topic.

An overview of the sources of data, and process of collection, of data related to suicide at the country level is also described briefly, along with a description of some ancillary datasets that were employed to augment and enrich insights. The intention of these descriptions is to make further research and data analysis on this topic more accessible to other interested researchers and data analysts in the future.

1 Research Motivation

Peter Sort Bib configuration

According to the *World Health Organization*, ("Suicide: One Person Dies Every 40 Seconds" 2019) one person dies every 40 seconds from suicide. It is the second leading cause of death among teenagers and adults aged 15-29 years. Despite the staggering number of suicides happening worldwide, just 38 governments worldwide have a national suicide prevention strategy.

Each of these deaths are tragic, and sadly also preventable. For every suicide, there are many more attempts, and previous suicide attempts are the single most important predictor or risk factor for future suicide attempts. ("Suicide: Key Facts" 2019) 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 in their own nations but also globally.

1.1 Why is suicide such a complex problem?

Suicide is a complex societal problem with multiple social, psychological, biological, and cultural factors. It is one of the top 20 leading causes of death in the world for all ages ("Alcohol-Related Risk of Suicidal Ideation, Suicide Attempt, and Completed Suicide: A Meta-Analysis" 2015). An estimated one million people die annually from suicide, i.e., a global mortality rate of 16 per 100,000, or one death every 40 seconds ("Alcohol-Related Risk of Suicidal Ideation, Suicide Attempt, and Completed Suicide: A Meta-Analysis" 2015). Due to the interactions of so many factors, suicide has no singular cause.

Though it might seem intuitive to categorize suicidal ideation, attempted suicide, and completed suicide as strictly a psychiatric or medical issue or a mental illness, not all who commit suicide are mentally ill. Mental illness is often not clearly distinguishable from normal distress ("Does Suicide Always Indicate a Mental Illness?" 2009). Stressful experiences, such as exposure to trauma, the death of a loved one, a job loss, a change in physical health or relationships and individual characteristics and behaviors are also associated with suicide ("Suicide Prevention Framework" 2016).

To underscore the complex nature of the suicide problem, and to show how causes of suicide can vary between countries, we contrast the situations in Zimbabwe and Russia. Zimbabwe has suffered endemic poverty, hyperinflation, and high unemployment for years. On the other hand, Russia's levels of alcohol consumption are among the highest in the world. Though their underlying conditions appear to be markedly different, both nations suffer from high rates of suicide.

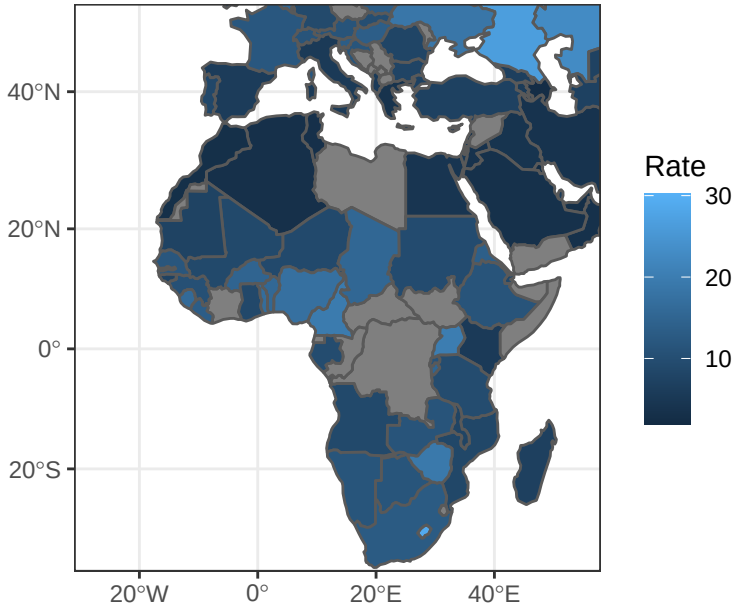
1.2 Examples of the causes of suicide

1.2.1 Economics - Zimbabwe

Political crisis coupled with failed economic policy led to the decline of Zimbabwe's economic output. Over the past few decades, Zimbabwe's economic decline has resulted in endemic poverty, hyperinflation, and an unemployment rate of over 90% ("The Economic Decline of Zimbabwe" 2009). Zimbabwe's economic woes are 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.

The WHO estimates that 19 persons per 100k take their own life deliberately in Zimbabwe per annum (2019). Of the 166 countries in our study, Zimbabwe ranks 13th in the world for suicides per capita.

Figure 1: Suicide Rate in Africa (annual persons per 100k population)



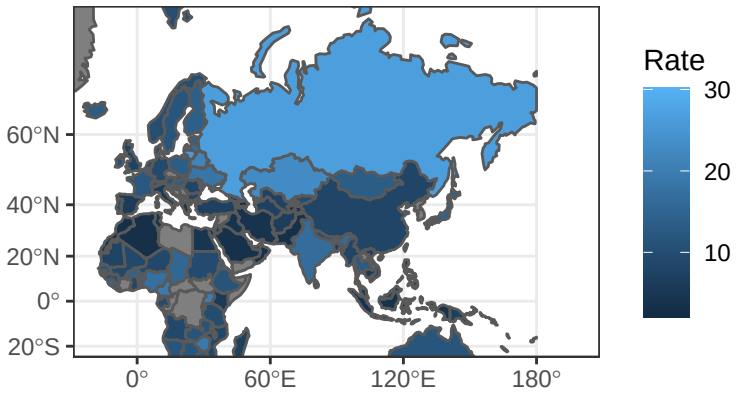
Sourced from the World Health Organization report: "Suicide: Key Facts, 2019" and the WorldBank Economic Profile of the Country of Zimbabwe

1.2.2 Alcohol - Russia

Alcohol use disorder (AUD), defined in the WHO's International Classification of Diseases, is a chronic disease characterized by compulsive alcohol consumption, loss of control over of alcohol intake, and negative emotional state when not consuming alcohol. In Russia, the prevalence of AUD is about 4.7%, meaning that almost 1-in-20 suffer from alcohol dependence ("Alcohol Consumption" 2018). Alcoholism has been a problem because drinking is not only pervasive, but also a socially acceptable behavior in Russian society.

The WHO estimates that 27 persons per 100k take their own life deliberately in Russia per annum (2019). Of the 166 countries in our study, Russia ranks 3rd in the world for suicides per capita.

Figure 2: Suicide Rate in Russia (annual persons per 100k population)



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

1.3 Defining the scope of our research

2 Variables & Data Sources

Due to the sheer number of potential factors associated with suicide and the complex nature of the relationships between them, we wanted to identify those that were best associated with suicide rates at the country level. We chose to limit our study to a small set of factors that could be controlled for and acted upon via policy interventions.

The domains, from which we drew the factors, had to be broad enough to reasonably represent as many of the potential causes or mitigators of suicide as possible. Among the domains in consideration were lifestyle, medical/mental health, economic, and suicide-focused policy.

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. See the table below for a detailed breakdown.

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Table 1: 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 liters 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]

explain (and justify) your proposed methods or models.

3 Modeling & Assumptions

Our model was developed to infer properties about how a handful of socioeconomic and cultural indicators impact suicide rates. An important distinction is that the model is intended to be used for inferential, rather than predictive purposes. Our objective is to discover relationships between variables to inform relevant public policy and future research in the area. The multiple linear regression model was developed using the following steps: 1. Transformation of Key Outcome Variable a. Used to make our outcome variable 'more normal' b. Helped characterize relationships between variables in our data c. 'Box-Cox' transformation applied 2. Outlier Removal a. Using regression diagnostics and visual data exploration we identified unusual data points b. Removal of outlier was additionally informed by qualitative reasoning for each country 3. Variable Selection a. Utilized stepwise regression to identify specific variables for inclusion in our model b. This 'automatic' procedure yielded the set of variables that we would analyze more closely 4. Final

Model Estimation a. Implemented the "Iteratively Reweighted Least Squares" approach to estimate model parameters b. This allowed us to further limit the influence of outliers on our data

The following variables were selected and 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

Below are the variables that were considered but excluded in step 3 of the model development: • 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

In the development of our model, we relied on a few assumptions about the quality of our data. The first is regarding GDP per capita, which is assumed to be an appropriate indicator to reflect the wealth of a country. The second relates to the prevalence of a national suicide prevention strategy. It is assumed that the presence of such a strategy is indicative that the country has taken the time to develop a comprehensive and data driven approach to suicide, based on solid evidence. We also assume that the liters of alcohol consumed per capita reflects the tendency for individuals in the given country to consume excessive amounts of alcohol.

4 Quantifying Impact of Measures on Suicide

The model described allows the data analyst to describe the relationships between country-level indicators and measures and suicide rates globally. Armed with a descriptive model of suicide rates, decision-makers can quantify the relationships between these measures to support insight for their health related planning activities. However, data-driven insights derived from this model and the data sources highlighted in this report should be considered in context of specific country-level impacts not considered in this report. As policy makers infer correlations of country-level measures and indicators with suicide rates there is a need to continue to engage subject-matter-experts in the field to draw on their knowledge and experience. Our intention is to provide some initial context and decision support for policy makers managing health related planning globally and at the country level, but the limitations of our research and methodology highlight the ongoing need for data-driven insights to be utilized in context of other research available, as well as the domain knowledge of practitioners, health professionals, scientists, and policy makers among others.

To highlight the need for a holistic approach to gathering data-driven insights, and incorporating domain knowledge of subject matter experts, we describe a basic framework for potentially incorporating insights from our model into a policy decision-making process:

Table 2: Framework: Identifying, Describing and Monitoring Country Level Indicators to Support Decision-Making

Area of Focus	Decision Support
Identifying & Quantifying Measures and Indicators of Country Level Suicide Rates	Using a model to describe the relationships between country-level indicators and suicide rates to help policy makers identify what variables are important and putting context around how to monitor them
Incorporating Domain Knowledge and Expertise of Subject Matter Experts	Allows policy makers to correlate indicators with country-level suicide related outcomes in context of qualitative insights from experts in the field
Insight Gathering, Analysis and Support Policy Maker Decisions	Integrating data and insights and providing inital context to help policy makers to frame longer term health planning activities and policies

In context of providing exemplary decision-support ofr health related planning activities we discuss some interesting relationships we identified between country-level suicide rates and the descriptor variables we selected in the following sections.

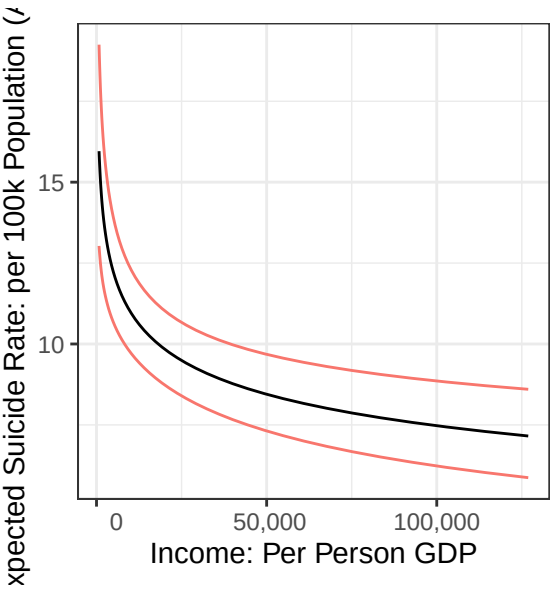
4.1 Quantifying Impact: Income, GDP per person

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



4.2 Quantifying Impact: Alcohol Consumption:

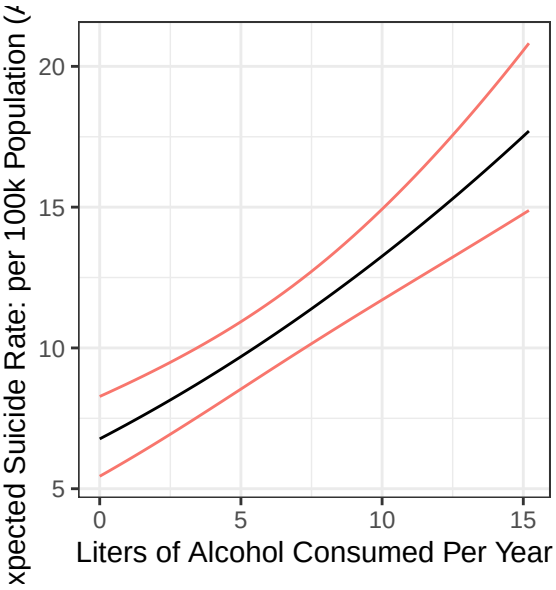
Insights

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



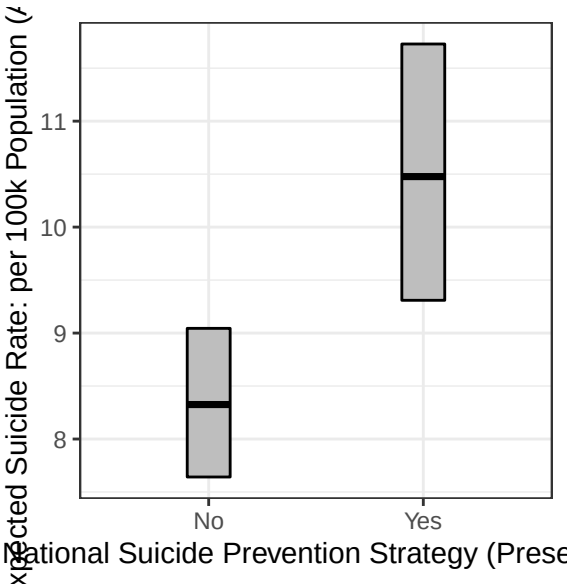
4.2.1 Quantifying Impact: The Presence of A National Suicide Strategy

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



5 Recommendations and Decision Support

For each of the selected model inputs, there are corresponding recommendations. The following sections go over each.

5.1 Suicide Prevention Strategy

Even though countries that have put a national suicide prevention strategy in place, tend to have higher incidence of suicide rates overall, this is in reaction to their already higher suicide rates in general. As such it is still advised to have a national strategy to address suicide. Countries should consider establishing an authoritative agency, tasked with the continued investigating, formulating, and implementing of a National Suicide Prevention Strategy. This strategy can include, but is not limited to, the establishing of a national suicide crisis line as well as suicide prevention and care services. In addition, it is best to follow recommended practices set forth by UN studies which show and help navigate the intersection of biological, psychological, social, environmental, and cultural factors which influence suicide, as well as successful policies which countries which countries which had national suicide prevention programs had implemented. Devolving countries are recommended to take advantage of online resources for policy planners the WHO's website MiNDbank for recommendations on mental health issues ("WHO Mindbank" 2020). Follow actions like those below from countries with success in reducing suicide ("National Suicide Prevention Strategies: Progress, Examples and Indicators" 2018): • Reduce access to means and methods of suicide • View suicide as a psychological mistake • Improve medical, psychological and psychosocial initiatives • Distribute knowledge about evidence-based methods for reducing suicide • Raise skill levels among staff and other key individuals in the care services • Perform "root cause" or event analyses after suicide • Support voluntary organizations

Strategies should not replace existing frameworks already in place in local government Promote public awareness campaigns highlighting the prevalence of suicide. By changing public perceptions and reducing the stigmas associated with seeking help, the rate of suicide can be reduced.

5.2 Alcohol Intake

Suicide is a complex societal problem with no singular cause. However, harmful use of alcohol is among the major risk factors for suicide. Policy makers should consider implementing measures designed to mitigate the harmful use of alcohol as a means of reducing the rate of suicide. According to the WHO, among the policy interventions that have proven effective at reducing the harmful use of alcohol are varied. One is to increase the price of alcohol via taxation, which is implemented successfully in states such as Utah. Another is to enact and enforce restrictions on alcohol advertising (across multiple types of media), out of sight out of mind. And finally, enact and enforce restrictions on the physical availability of retailed alcohol (via reduced hours of sale), for example many "dry states" do not serve alcohol on Sundays ("Global Status Report on Alcohol and Health 2018" 2018). It is not recommended to remove access to alcohol completely, as seen in the disastrous US history lesson in the prohibition era. The increased violence may not have been worth the decrease in suicide ("The Effects of War and Alcohol Consumption Patterns on Suicide: United States, 1910-1933" 1989).

5.3 GDP Per Capita

There is a negative correlation between GDP per capita and suicide rates. While it is unknown why this is, we believe that money should be spent to uncover more about the relationship between income and suicide. An analysis on income of specific income groups would shed more light as to whether low income correlates to higher suicide or not. As such it is recommended Invest in research to better understand potential relationships between income instability, income protection and suicide at the individual level. In addition, governments should pursue measures aimed at poverty reduction and unemployment benefits to support economic well-being.

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5.5 Income & GDP Per Capita

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6 Research Limitations

In any study there are limitations on what is considered in analysis. We only considered a limited set of inputs and analysis measures in the allotted time and would perform more had there been more. A breakdown of the research limitations of scope, what was considered, and methodology, how it was analyzed, are described below.

6.1 Scope

There were issues with some of our inputs, but when drilling down to just the inputs used in the model, we can see room for improvement in data quality. When we used GDP per Capita as a proxy for income, other measures such as country-level median income should have been considered in the future. This would have given a non-uniform distribution of wealth in the country rather than a uniform distribution which is not the case with income inequality. When measuring the liters of alcohol consumed, we assumed a uniform consumption country-wide consumption rate. This doesn't consider incidence of substance abuse. For Suicide Policy (NSPS), the effectiveness of organizational response hard per country is 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.

6.2 Methodology

For our analysis we chose to use a country level scope, however this cannot drill down to local or individual level, essentially limiting our level of fidelity of reflecting on reality. For each country we only used one year, as such our model assumes effects of each input are fixed rather than temporally differing. When considering our inputs, we cannot completely untangle the effect of variable interactions between another. Higher level interactions and additional factors which may influence suicide rates could be considered in the future. Finally, model formulation limited our analysis strength. We chose to use multiple linear regression for inferential and descriptive reasons, but more complicated / non-linear relationships could be characterized better with more complex approaches.

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7 Appendix & References

This section only includes needed documents to support the presentation in the report. Feel free to divide it into several subsections if necessary. Do NOT dump all computer outputs unor-ganized here

7.1 Model Final 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, $\epsilon_i \sim \mathbb{N}(0, \sigma_Y^2)$

for $i = 1, ..., n$ country level measures, where

Y_i : The estimated national suicide rate (per 100k population) for thei^{th} country.(Box-cox transformed $\lambda = 0.4$)
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.

7.2 Model Summary Statistics

Table 3: 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

7.3 Additional Details: Modeling Approach

7.4 Initial Model Choice and Transformation

We developed a multiple linear regression model to infer properties about how a handful of socioeconomic and cultural indicators impact suicide rates. Initial Model, First, we analyzed the diagnostic plots to understand if our model appropriately fits the data that we have. A major red flag here was the Normal Q-Q plot, which shows if residuals are normally distributed. The residuals 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. Below is the log-likelihood plot to determine the lambda value for the Box Cox transformation. A lambda value of 0.4 was chosen.

We also applied log transformation to the variable GDP per capita to better represent the relationship between this variable and the outcome variable based on visual data exploration and resulting effect .

7.5 Outlier Removal Decisions

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The next step in model development was to remove outliers. Points 12, 65, and 88 were identified as outliers on the Residuals vs Fitted, Scale-Location, and Normal Q-Q plots.

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

Points 12, 65, 79, and 88 were removed from the dataset. It is important to note that each of these points also had country specific reasons for being excluded:

After the removal of outliers, we implemented a backwards stepwise algorithm based on AIC to remove variables that were redundant or unnecessary in the model.

7.6 Stepwise Variable Selection Approach

We implemented a backwards stepwise algorithm based on AIC to remove variables based on the AIC criterion, the results and variable inclusion decisions are detailed below:

Table 4: Variable Selection Details: Backwards Stepwise Regression (AIC Criterion)

Variable	Model Inclusion Result
GDP per capita, PPP	Included
Prevalence of a national suicide prevention strategy	Included
Liters of alcohol consumption per capita	Included
Male to Female ratio of the labor participation rate	Included
Health Expenditure as a percentage of GDP	Removed
Psychiatrists working in mental health sector (per 100 000 population)	Removed
Mental hospitals (per 100 000 population)	Removed

The final step in preparing the model was to implement the iteratively weighted least squares algorithm to properly weight each instance in our data. This was more effort to mitigate the effect of outliers on our model. We performed 10 iterations of this algorithm.

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