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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Contents

Abstract

Suicide is a complex worldwide problem that has many causes. This report aims to highlight trends related to country-level measures of suicide globally. The researchers utilize open source data from the World Health Organization and other non-governmental bodies to develop an inferential statistical model. The model considers country level data related to the wealth, culture, and specific efforts to improve mental health. The model is developed through the implementation of a couple of key algorithms and variable transformations.

Based on our analysis we recommend countries consider establishing an authoritative agency that can manage the investigation, formulation, and implementation of a national suicide prevention strategy. Additionally, policy makers should consider implementing measures designed to mitigate the harmful use of alcohol. We also recommend investment in research to better understand potential relationships between income instability, income protection and suicide at the individual level.

An overview of potential limitations of our research in context of the scope of the data we collected, and the methodologies we employed is provided. This overview is meant inform interpretation of key variables of interest in our model, as well as providing commentary on the limitations of using aggregate data to make inferences at local or regional levels.

Research Motivation

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 [4]. 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 [4]. 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 [5]. 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 [6].

Global Trends in Suicide Epidemiology

Suicide is the 15th leading cause of death worldwide, with over 75% of suicides occurring in low-income and middle-income countries [19]. Poverty, particularly in the form of economic status, diminished wealth, and unemployment is often associated with suicide [19]. Poverty may be defined in terms of deprivation across the multiple dimensions of life, such as education, health, or housing [20]. Both chronic poverty and acute economic events, such as crop failure, constitute possible risk factors for suicidal ideations and behaviors [19].

Poverty, unemployment, illiteracy, lack of civic facilities, poor access to health facilities, the absence of health insurance or institutional welfare benefits are factors that adversely impact upon the overall mental health status of the population [21]. In developing countries, the interval between onset of suicidal ideation and the act of suicide is frequently overlooked—partly because of ignorance but also because families and subjects do not know where to seek help. Even when they do realize something is wrong, they lack resources to seek help. [21]

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.

Case Study: Economics - Zimbabwe

Endemic poverty, hyperinflation, and extreme unemployment [7] are among the economic and social problems plaguing Zimbabwe, where political crisis coupled with failed economic policy have led to its decline. 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 100, 000 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, and has one of the highest rates in Africa as visualized below:

Figure 1: Suicide Rate in Africa (annual persons per 100k population)
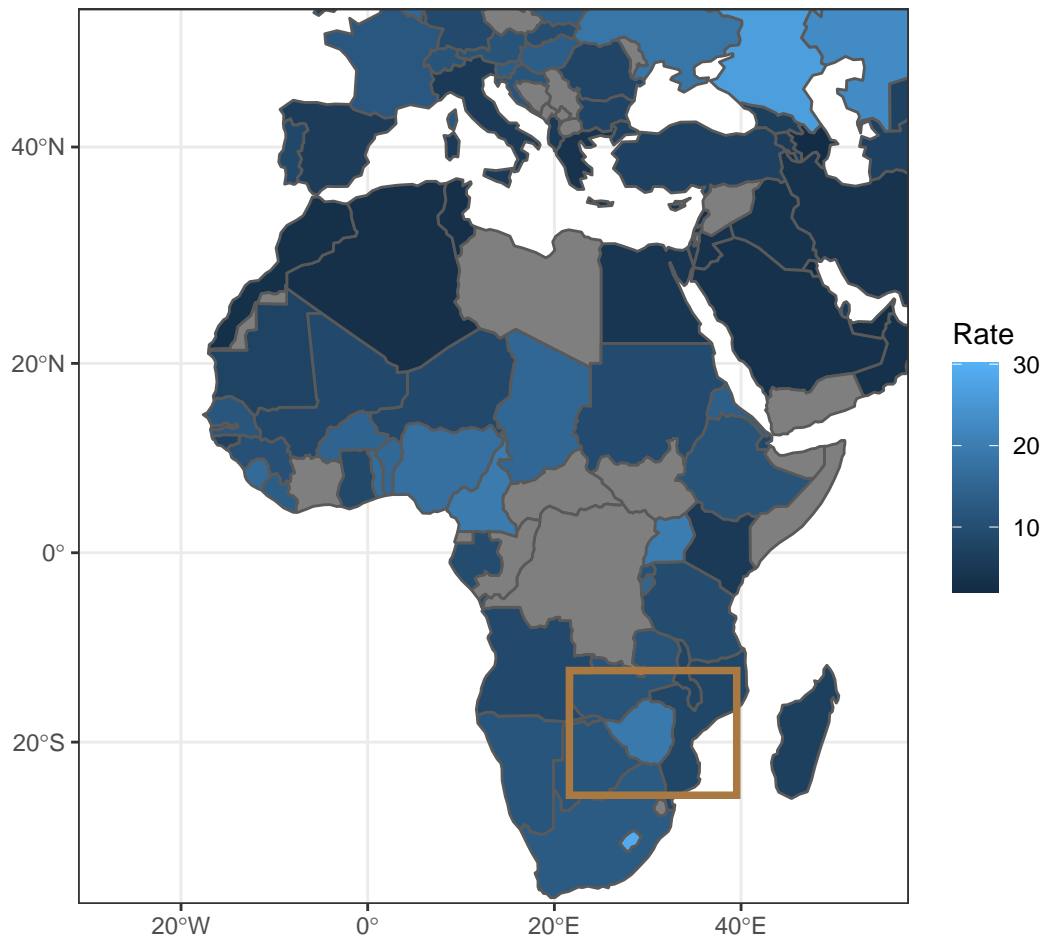
Sourced from the World Health Organization report: "Suicide: Key Facts, 2019" and the WorldBank Economic Profile of the Country of Zimbabwe

Case Study: Alcohol Abuse - Russia

Harmful use of alcohol is often cited as a major risk factor for suicide. A study published in *The Lancet* found that global alcohol consumption saw an increase of about 70% from 1990 to 2017, going from about 21 billion liters of pure alcohol to 35.7 billion liters of pure alcohol [22]. Countries that have higher rates of alcohol use generally also have higher rates of suicide. Current evidence indicates an association between alcohol dependence and impulsive suicide attempts [4].

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. Alcohol intoxication can increase dysphoria, cognitive dysfunction, impulsivity and suicidal ideation. People have approximately seven times increased risk for a suicide attempt soon after drinking alcohol, and this risk further increases to 37 times after heavy use of alcohol [12]. Risk of suicidal ideation, suicidal attempts and completed suicide are each increased by 2–3 times among those with Alcohol Use Disorders (AUD) in comparison with the general population [12].

In Russia, the prevalence of AUD is approximately 5%, meaning that almost 1-in-20 suffer from alcohol dependence [8]. 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 3$^{\text{rd}}$ in the world for suicides per capita, and has higher rates than many of its global neighbors as visualized below:

Figure 2: Suicide Rate in Russia (annual persons per 100k population)
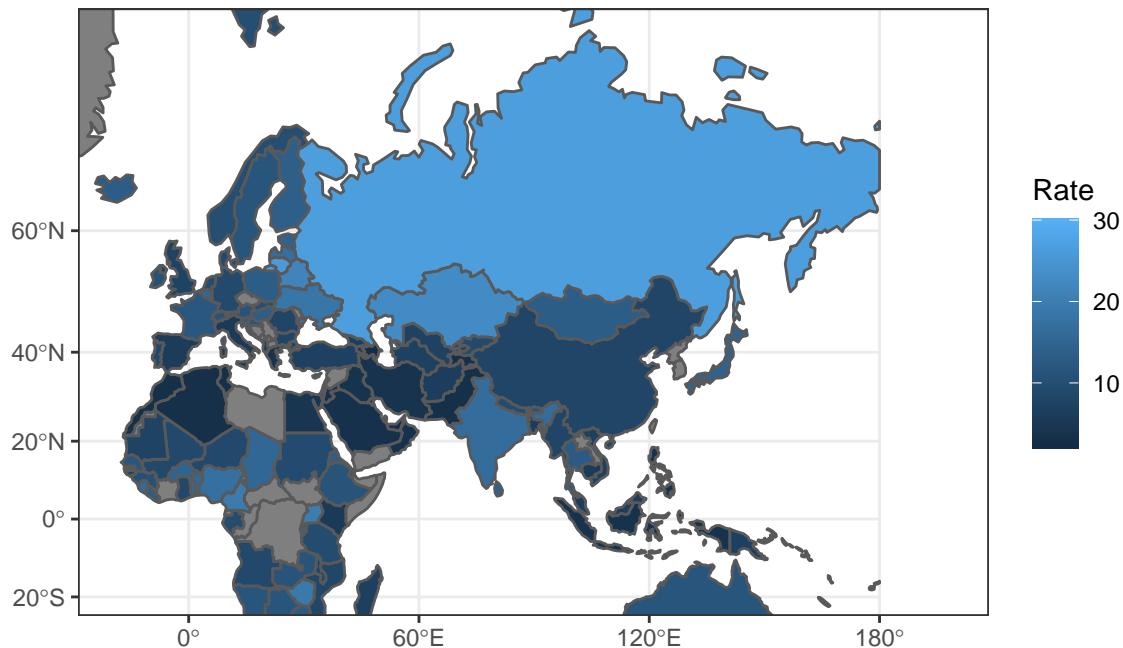
Sourced from the World Health Organization report: Suicide: Key Facts, 2019

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. We also wanted the domains from which we drew the factors to be broad enough to reasonably represent many of the potential causes or mitigators of suicide if possible.

Variables considered came from lifestyle, medical/mental health, economic, and suicide-focused policy domains. The core dataset we plan to rely on comes directly from the World Health Organization [3] (*WHO*). The key measure of interest for our study is the age-standardized suicide rate by country, which is defined as 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, see the Appendix section for details on how this is estimated. Estimates of age-standardized suicide rates were taken in the year with the most recent available data for each country from the *WHO*.

In addition to the core suicide rate statistics provided above, we appended country-level data from ancillary data sources. Health Expenditure was chosen to reflect the resources that a country has its disposal to reduce the suicide rate. GDP per capita was included as a proxy for income or economic well-being. 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 prevalence of a suicide prevention strategy, the number of psychiatrists, and the number of mental hospitals were chosen to reflect how a country has deployed its resources to improve mental health outcomes. The female/male labor participation ratio was included to control for this aspect of a country's culture. The data for these variables along with the suicide rate variable was available for 166 countries.

Below is the full set of considered independent variables with corresponding source:

- Current Health Expenditure as a percentage of GDP: *World Health Organization*
- Labor force participation rate, female to male ratio: *United Nations Development Programme*
- GDP per capita, adjusted by Purchasing Power Parity: *World Bank*
- Liters of Alcohol consumption per capita: *World Bank*
- Presence of a Suicide Prevention Strategy: *World Health Organization*
- Psychiatrists in mental health, per 100,000 population: *World Health Organization*
- Mental hospitals, per 100,000 population: *World Health Organization*

Note that more detailed descriptions of the data and the source links can be found in the *Appendix*.

Modeling & Assumptions

We developed a multiple linear regression model 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.

After conducting some exploratory data analysis, one of the first steps in developing the model was to transform the outcome variable. We utilized the *Box-Cox* transformation to make the outcome variable 'more normal', and it helped to characterize relationships between variables in our data. The next step was to remove outliers. We used regression diagnostics and visual data exploration to identify unusual data points. Brief qualitative research was then conducted on the country represented by each point to confirm whether or not the point should be removed. After the removal of the outlier points, we utilized a stepwise algorithm

to identify which variables should be included in our model. This 'automatic' procedure yielded the set of variables that we would analyze more closely.

The following variables were selected and included in our model: labor force participation rate (female-male ratio), GDP per capita (per-person), liters of alcohol consumption per capita, and the prevalence of a national suicide prevention strategy. The algorithm excluded the following variables from the model: current health expenditure as a percentage of GDP, the number of psychiatrists working in the mental health sector (per 100,000), and the number of mental hospitals (per 100,000).

The final step in the development of our model was to implement an iterative algorithm that adjusted the weights for each of our data points (Iteratively Reweighted Least Squares). This allowed us to further limit the influence of outliers on our data.

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 or individual income. 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.

To develop models utilized in this report we relied on the based functionality provided in the R language. Further details can be found in the appendix.

Quantifying Impact of Measures on Suicide

Our model 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 1: 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 for 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.

Quantifying Impact: Income, GDP per person

A key insight that surfaced during the modeling process was the presence of a significant relationship between a measure of income (here defined as the country-level GDP per person) and country level suicide rates. Countries with lower per person income, tend to have higher incidence of suicide. To explore this relationship further, we look at the impact of income, or per-person GDP, on a country's suicide rate controlling for the other key factors in our model including alcohol consumption, the female-male labor participation rate, and the presence of a country-level suicide prevention strategy.

When controlling for these variables, we found that an approximate 10% increase in income (or GDP per-person) corresponded to a 2% decrease in suicide rate at the country level for the typical country. The following plot highlights the sensitivity of income to suicide rates based on results from our model:

Figure 3: Expected Country-Level Suicide Rate vs. Income (GDP per-person)
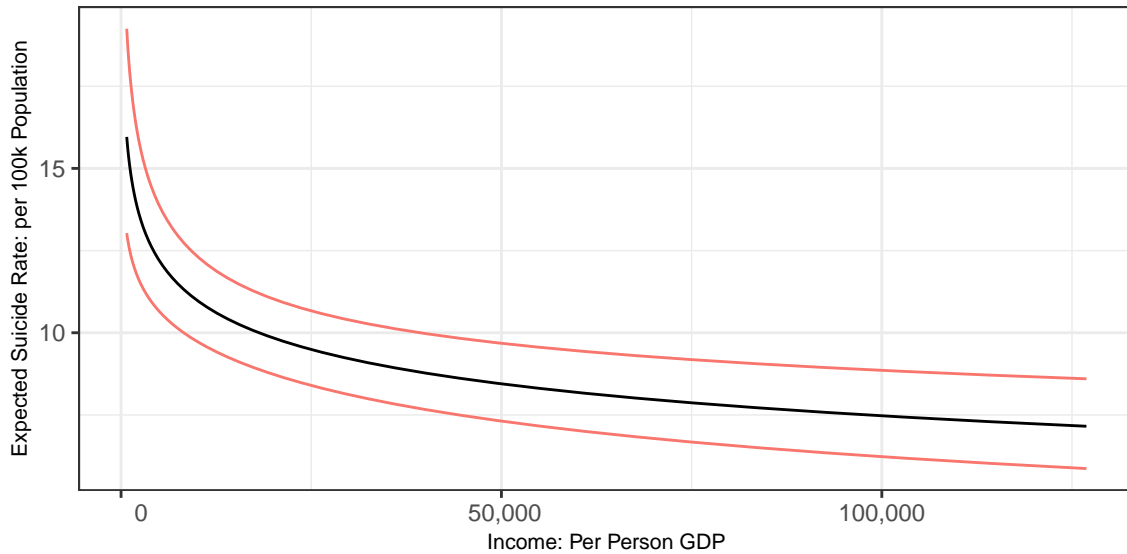
Note: Expected rate with 95% confidence intervals for the typical country (i.e. holding other variables in model identified fixed at the 'sample mean').

Quantifying Impact: Alcohol Consumption

A key insight that surfaced during the modeling process was the presence of a significant relationship between a measure of alcohol abuse, liters of consumption per year, and suicide country level suicide rates. As might be expected, countries with higher levels of alcohol consumption income in our data, tended 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 corresponded to an expected 2% increase in suicide rate for countries where adults, on average, consume more than 4 liters of alcohol per year.

Another thing to note from our data analysis, is that alcohol consumption was the most impactful and significant indicator of country-level suicide rate in our model. The illustrate the estimated impact, the following plot highlights the sensitivity of alcohol consumption to suicide rates based on results from our model:

Figure 4: Expected Country-Level Suicide Rate vs. Liters of Alcohol Consumer Per Year (pp)
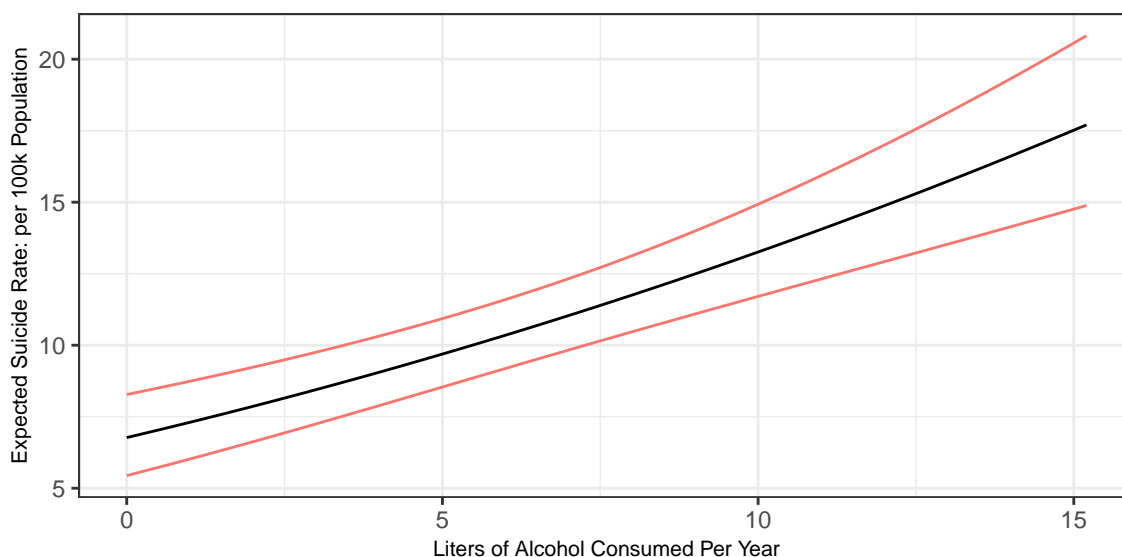

Note: Expected rate with 95% confidence intervals for the typical country (i.e. holding other variables in model identified fixed at the 'sample mean').

This sensitivity analysis highlights the strong relationship between these variables, which isn't an entirely novel relationship we discovered. Our brief case study of suicide in Russia was meant to provide some discussion of the real impact alcohol consumption.

Quantifying Impact: The Presence of A National Suicide Strategy

A key variable we wanted to control for in our model was an indicator of a country having a national suicide prevention strategy in place. Based on data criteria from the *WHO*, we measured the impact of having a stand-alone national suicide prevention strategy. According to the *WHO* the categorical criterion for the presence of a national suicide strategy was that, in order to be considered, as country's planplan have been stand-alone, and not be integrated into another plan.

As we looked at the data, we found that the presence of a suicide prevention strategy was more likely to be associated with countries struggling with suicide prevention overall. Some of these countries included Guyana, Lithuania, Suriname, Belarus and South Korea.

Based on our estimates from our model, countries that have implemented a suicide prevention strategy have a 26% higher incidence of suicide nationally as shown below:

Figure 5: Expected Country-Level Suicide Rate vs. The Presence of A National Suicide Strategy
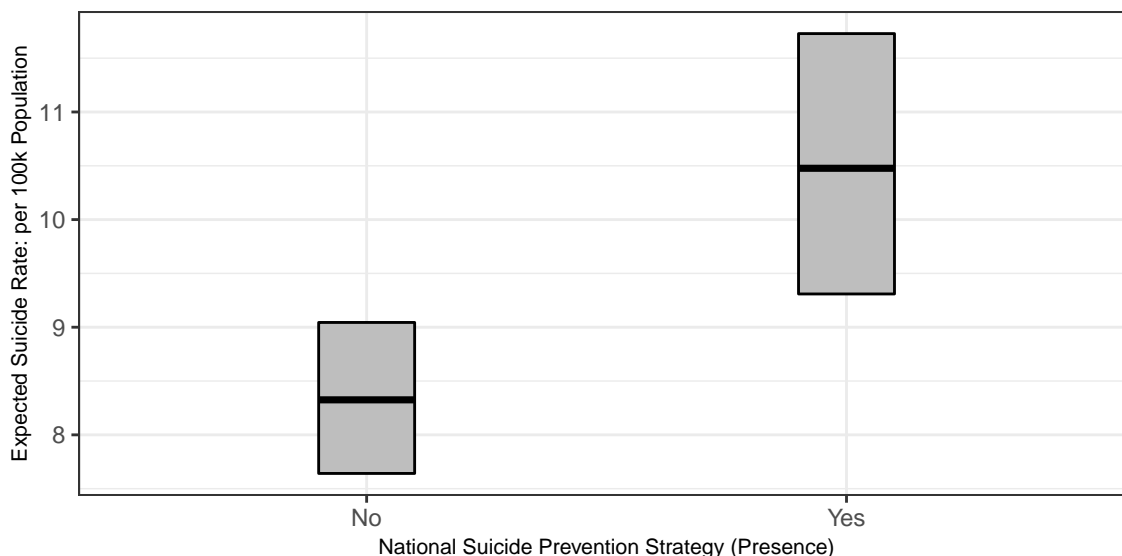
Note: Expected rate with 95% confidence intervals for the typical country (i.e. holding other variables in model identified fixed at the 'sample mean').

While it may seem unintuitive that countries with with a suicide prevention strategy have higher rates, it should not be inferred or interpreted from our model that having a national suicide prevention strategy leads to incidence of suicide rates overall. It may be understood that the institution of this strategy may be a 'reactive' decision, that is, the presence of a strategy has been instituted as a result of high incidence. As a result, we wanted to ensure we were incorporating this variable in our model as both a control for estimating other effect, and for providing context for countries with high rates of suicide otherwise.

Recommendations and Decision Support

Based on the impact and importance of variables included in our model, we want to provide some qualitative recommendations to support policy makers in context of the analysis conducted. The following sections provide an overview of potential strategies employed by some countries around the world, and also recommendations sourced from secondary research specific to the variables we analyzed.

Suicide Prevention Strategy

National Suicide prevention strategies have been implemented in many countries to combat suicide. Many have found their own way of handling the problem, but there was not widespread acceptance and organizational response to the problem until recently. In 1993 The United Nations created a task force which teamed up with the WHO to put together a study on the causes, preventative, and rehabilitative measures of suicide, and which culminated with the release of a report in 1996 called "Prevention of suicide: guidelines for the formulation and implementation of national strategies" [24]. Before this, Finland was the only nation which had a national program for suicide prevention.

These guidelines were followed to varying degrees by different countries or local municipalities. The 1996 study was followed up with another study in 2018 [10] which contained updated recommendations and findings since 1996. For instance, the intersection of biological, psychological, social, environmental, and cultural factors which influence suicide, as well as successfully implemented policies from which countries which had a national suicide prevention program implemented. The 2018 study contained a list of all countries with "a

stand-alone national suicide prevention strategy (NSPSs) adopted by the government" [10]. For our research, the indicator variable was sourced from this list.

We found that countries that have put a national suicide prevention strategy in place, tend to have higher incidence of suicide rates overall, this may be reactionary in nature. If a country has high suicide rates then more attention is paid to the issue and programs are put in place to combat it. Since most National suicide programs have only been emplaced in the last two decades, this may explain the counterintuitive trend observed. However, it is still advised to have a national strategy to address suicide.

Government policy to combat suicide allows for the "development and strengthening surveillance (of at-risk groups), and to provide and disseminate information" [10] on at-risk individuals to inform action. An implementation of a NSPS in Scotland called "Choose Live" decreased suicide rates by 20% over 10 years. This sort of improvement in suicide rates after implementing is implied in the 2018 report and lends to the recommendation that national strategies should be implemented.

Developing countries are recommended to take advantage of online resources for policy planners like MiNDbank a website created by the WHO with recommendations on mental health issues [9]. Countries still should consider establishing an authoritative agency, tasked with the continued investigating, formulating, and implementing of a National Suicide Prevention Strategy. It should follow actions like those below from countries with success in reducing suicide [25]:

- 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

- Promote public awareness campaigns highlighting the prevalence of suicide

National strategies should not replace existing frameworks already in place in local government either. By changing public perceptions, reducing the stigmas associated with seeking help, and coming up with national strategies to combat suicide, the rate of suicide can be reduced.

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. [12] 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. [26]

GDP Per Capita

There is a negative correlation between GDP per capita adjusted for Purchasing Power Parity (PPP) 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. Countries with lower GDPs tend to have higher rates of suicide, which also tend to have lower quality infrastructure, health care, and a plethora of other associated industries. [11] With these lower quality services and access to them, at risk individuals may have higher likelihood of 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.

Research Limitations

In any study there are limitations on what is considered in analysis. Analysis of the topic was limited to the chosen set of inputs. A breakdown of the research limitations of scope, what was considered, and methodology, how it was analyzed, are described below.

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. We used GDP per Capita as a proxy for income. Other measures such as country-level median income should be considered in the future as a more accurate measure of income. This would have given a non-uniform distribution of wealth in the country rather than a uniform distribution, which is not the case due to income inequality. When measuring the liters of alcohol consumed, we assumed a uniform country-wide consumption rate. This study only considered the relationship between alcohol consumption and suicide and did not consider the relationship between substance abuse and suicide. For Suicide Policy (NSPS), the effectiveness of organizational response per country is hard to gauge since local vs federal response is not accounted for in the measurement. We did not consider local/cultural/interactional measures making it difficult to make country-specific inferences in some cases.

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 each other. 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 sophisticated approaches.

Lessons Learned

We had a great experience taking ISyE 6414. Technically, we learned a tremendous amount about how and why different regression techniques are used. However, one of the most important lessons learned is from working on the project. Specifically, we learned about the significance of communicating the details of the project in a format that can be understood and acted on by regular professionals, even if they are not educated in statistics. When presenting a certain piece of information, we tried to consider the perspective of someone who may not have a strong statistical background. Developing this skill was difficult, and we hope to have refined it through reminding ourselves of its important in our future jobs.

Appendix

Variable & Data Sources

The following table describes the the full set of variables we considered and associated data sources:

Table 2: 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 [13]
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 [14]
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 [15]
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 [16]
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 [10]
Psychiatrists in mental health, per 100,000 pop.	Number of Psychiatrists working in the mental health sector, per 100,000 population.	World Health Organization [17]
Mental hospitals, per 100,000 pop.	Number of hospitals dedicated to mental health per 100,000 population	World Health Organization [18]

Defining Suicide Rate

In order to properly analyze and define a model, we must first define suicide. The measure we utilized was 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 (1). To calculate the age standardized rate, denoted ASR see Equation 1 below (2).

Equation 1: Age-Standardized Suicide Rate

$$\text{ASR} = \frac{\sum a_i w_i}{\sum w_i} \quad \text{for } i = 1, ..., n, \text{ where}$$

$$a_i = \text{Age specific rate for group } i$$

$$w_i = \text{The country standard population weight for group } i$$

$$n = \text{The number of age groups considered}$$

The age standardized rate was used instead of crude as it allows for an age normalized view of suicide. In addition, there are no age-related statistics in data inputs considered. Note that this measure was the key outcome of interest for our model.

Model Final Specification

The following notation details the final specification of the model we built. Note that we were able to gather data for $n = 166$ countries around the world across all measures detailed below:

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

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

Y_i : The estimated national suicide rate (per 100k population) for the ith country.(Box-cox transformed $\lambda = 0.4$)

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

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

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

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

Additional Details: Modeling Approach

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. One of our first modeling steps was to conduct visual analysis and explore diagnostic plots to understand how appropriately our model fit the data that we collected. One key tool we used was the normal Q-Q plot, which shows if residuals are normally distributed. In order to correct for this, we employed a Box Cox transformation on Y. Below is the log-likelihood plot to determine the λ value for the Box Cox transformation. In the end a λ 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 .

Outlier Removal Decisions

We relied on quantitative measures of model leverage, and Q-Q plots to identify extreme deviations from normality to identify and countries that we removed from our analysis. However as we identified these countries, we also compiled notes on specific qualititative characteristics of these countries that may put their quantitative outlier status into better context:

Barbados: Caribbean's leading tourism island, transitioned from agricultural to service based economy very successfully and has *very high human development* status in terms of the UNDP's human development index in contrast with an extremely low suicide rate.

Guyana: An extremely poor island country largely made up of agricultural villages. It has very high alcohol and suicide statistics, and the country's ministry of health identifies 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.

Japan: Japan has a notoriously overworked and over stressed population, although the country is very wealthy. Japan has a long cultural history of considering certain types of suicides honorable, and has relatively high cultural tolerance for suicide with a very high suicide rate when compared to other rich nations.

Lesotho: A small, landlocked, mountainous country in Africa with the highest suicide rate in Africa, high levels of child labor, very poor general health outcomes, and the second highest rate of tuberculosis and HIV/AIDS in the world.

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 3: 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 and leverage of remaining outliers on our model. We performed 10 iterations of this algorithm, and final estimates are provided in the next section.

Model Summary Statistics

Table 4: 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

Tools Utilized

We utilized the *R* language to build models and work with the data in this report. More information can be found at https://www.R-project.org. To create the visualizations in the paper, we utilized the *R* package *ggplot2* authored by Hadley Wickham, see https://ggplot2.tidyverse.org for more details. We also utilized the *rmarkdown* package, authored by JJ Allaire, Yihui Xie, Jonathan McPherson, Javier Luraschi , Kevin Ushey,Aron Atkins, Hadley Wickham, Joe Cheng, Winston Chang, and Richard Iannone to simplify the process of compiling this report. More details can be found at https://github.com/rstudio/rmarkdown.

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