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The Dynamic Inter-dependency among Macroeconomic and Physical Health Variables and Their Effects on Suicide Rates in the United States.

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Abstract

We study how suicide rates in the United States respond to economic determinants such as unemployment rates and median salary, and how selected determinants evolve dynamically with diseases related to COVID-19. Our project is inspired by threats of an imminent recession and our concern regarding its secondary health outcomes. We seek to investigate a potential need for investment in preventative measures by governments such as mental health support, counselling, and greater individual support for those in the labor force. We aim to avoid a complete shift of governmental focus away from health issues once the pandemic subsides, as there are risks associated with the economic downturn that will surely follow. We extract data from a wide range of online government databases to conduct multi-variate analysis using a random effects logistic model and a vector auto-regressive model. We show that unemployment and salary have significantly positive and negative time-invariant impacts on suicide rate, respectively. We also estimate that the effect of an exogenous shock from pneumonia deaths on insured unemployment rate lasts beyond 52 weeks. Policy implications of our findings are discussed, along with our proposals for effective policies to prevent a critical rise in suicide rates.

Keywords Suicide, recession, pandemic, public policy

1 Introduction

As a consequence of the COVID-19 pandemic and the resulting public health response, the US economy officially entered recession territory in February 2020, marking the end of 128 months of expansion[3]. The US government is diverting large sums of money to mitigate economic and immediate health impacts. However, it is also important to remember long-term individual outcomes. Suicide is the second leading cause of death in the US for ages 10-34 and its burden falls largely on the working-age population. Not only this, the working-age population shoulders a disproportionate share of the burden of recessions[49]. A systemic analysis of the underlying causes and the interactions between economic recessions and suicide rates can facilitate better understanding of how to mitigate suicide risk for vulnerable populations in the coming months and years.

Our research is centered on the following question: "To what extent would the rise in unemployment and loss of earnings as a result of the COVID-19 pandemic impact suicide rates in the United States?" The focus on unemployment rate and median annual salary is motivated by their close relationships with the economic condition of a country. They can also directly impact mental well-being, as the loss of a job can induce great anxiety and depression, while financial strain due to a reduction in salary can also decrease mental wellness[57].

The confounding of multiple risk factors including health factors, environmental factors, and historical factors makes it difficult to explain a population-level rise in suicide rates. However, by looking at the major pathway and plugging back-doors, we may be able to tease out a causal relationship. It is clear that an economic downturn leads to higher suicide rates. A meta-analysis of studies on suicide rates during the 2007-09 recession found 31 studies that showed a positive association between the economic recession and suicide rates[55]. This positive association is further lent credibility by the existence of similar trends across different countries[53, 11, 12, 32]. Our research offers unique insight into the determinants of suicide by studying recent pandemic-induced economic downturns in contrast to recessions caused by systematic financial institution failure.

However, it is still important to recognize the intermediate pathways between recessions and suicide rates in general. They are summarized by research on the individual roles of (i) socioeconomic changes, (ii) alcoholism, and (iii) mental health. The relationship between socioeconomic changes induced by economic recessions and suicide rates has been extensively studied and not just in the context of the 2007-09 recession. Deaths from suicide have risen sharply since 2000 among white, middle-aged Americans, particularly in rural communities. Termed "deaths of despair", this sharp increase coincides with declines in farming and manufacturing jobs over the past couple of decades and deteriorating economic and social well-being for this sub-population[10]. This insight is also supported by research that counties with higher poverty rates have higher suicide rates[36] and that weaker social bonds leads to higher suicide rates[52].

A factor that frequently interacts with socioeconomic changes and is important in its own right is alcoholism: a strong positive association exists between alcoholism and suicide rates[59, 54]. While there is some variation in the magnitude of this effect by gender and age, it is clear that alcoholism is an important predictor of suicide[49]. Other factors such as financial loss, bankruptcy, and home repossession are factors that may lead directly or indirectly to mental problems such as depression, anxiety, and binge drinking and then to suicidal behavior[30].

We ground our investigation on the vast empirical findings we have discussed. We advance the literature by analyzing most of the determinants of suicide collectively with unemployment and salary, and by subsequently delving into the dynamic inter-dependencies of selected determinants of suicide in the context of the COVID-19 pandemic. By answering our research question, we generate useful insights that are informative of policy-making in light of the repercussions of the COVID-19 pandemic.

Since the 2008 Great Recession, multiple policies have been proposed and passed into law in regards to the topics that here concern us. In its study, we divide our focus between two separate categories of bills. First, we examine the proposed legislation regarding the healthcare system and its efficiency in supporting those individuals struggling with mental health. We begin by examining the bill H.R.2345 "National Suicide Hotline Improvement Act of 2018", which created a commission to investigate allegations of inefficiency within the public service, as well as the potential introduction of a 3-digit dialing code to replace the current 10-digit dialing code for the hotline[18].

Then, we investigate the proposed bill H.R.2464 "Helping Families in Mental Health Crisis Act of 2016", which was stopped at the Senate. This bill was motivated by the rising mental health crisis and it was aimed at providing greater government support to facilities and programs through assistance and grants, in order to achieve greater efficiency in treatments and recovery. Certain sections of the bill received criticism for its encouragement of regressive treatment methodology, which ultimately stopped its development[17].

We move onto discussing some of the economic policies that affect one of our studied predictor variables, unemployment rate. We examine H.R.266 "Paycheck Protection Program and Healthcare Enhancement Act", which was passed into law this year. The bill provided temporary funding for small businesses in the form of relaxed debt regulation and tax cuts, in order to support continued business operation and thus minimize unemployment. It also granted extra funding for healthcare and testing facilities, for the duration of the present fiscal year[19]. Finally we discuss Public Law 111-5 "American Recovery and Reinvestment Act of 2009". This legislation was approved in the face

of the Great Recession and provided tax cuts, among other economic reliefs, to palliate the severity of the financial situation[16].

2 Materials & Methods

Data was drawn from various online government sources. Relevant components were selected to form two data sets for panel and longitudinal analyses. Summary plots were generated for general insights into the data before more complex methods were employed.

The panel data contains 9 variables from years 2002 to 2017 (inclusive) at an annual frequency, across four races and two genders[1]. The response variable is suicide counts per 100,000 resident population[23], and the main explanatory variables are unemployment rate (percent)[41] and median annual salary (in thousands of USD)[42]. The control variables are the number of deaths due to influenza and pneumonia per 100,000 resident population[22], the percentage of population below poverty[8], the Economic Policy Uncertainty Index[61], drug-induced deaths[24], alcohol-induced deaths[25], and deaths from chronic liver disease and cirrhosis[22]. All deaths are the number deceased each year per 100,000 resident population due to the corresponding diseases or causes. These mortality rates are proxies for the prevalence of drug abuse, alcoholism, and chronic diseases respectively, which are strong determinants of suicide tendency. We assume that actual rates of abuse and infection are non-decreasing in their mortality rates. Liver disease and cirrhosis is intended to improve control for alcoholism as it has alcohol-related causes. Mortality data was used as controls as they were more available than records of actual substance abuse or infection counts.

We conducted regression analysis based on a generalized linear mixed model (GLMM). The outcome variable suicide rate was modelled as the number of positive cases, while 100,000 subtracted from the suicide count is the number of negative cases. A logistic link was used to confine the fitted suicide proportion to 0 and 1. Covariates are all of the aforementioned controls[2], with Male as the reference category for gender.

Race was interacted with unemployment and median salary to reveal any heterogeneous effects of the two economic variables by race. The solitary term for Race was excluded from the model specification so that Race was only allowed to affect suicide rate through unemployment and salary. Year random effects was included in attempt to capture effects of idiosyncratic 'shocks' on suicide rates in each year and as a time control. A back-step algorithm was used on the initial model to determine the nested model that minimizes the Akaike Information Criterion (AIC). Results of the likelihood-ratio test between the initial model and the adjusted were drawn upon as evidence for the insignificance of the dropped variables.

After establishing unemployment rate and median annual salary as significant determinants of suicide rates, we modelled how unemployment rate evolve dynamically based on the assumption of serial correlation, to gain insights into future suicide trends. The longitudinal data comprises of seven economy-wide non-seasonally adjusted time series at a weekly frequency[3] from 2013 Week 40 to 2020 Week 22. The series are: percent of deaths due to pneumonia[31], percent of deaths due to influenza[31], the Economic Policy Uncertainty Index[61], the Chicago Board Options Exchange Volatility Index (VIX)[60], the insured unemployment rate[62][4], savings deposits at all commercial banks (in billions)[63], and counts of NICS firearms background check[34].

Percentages of deaths due to influenza and pnuemonia were treated as exogenous variables, the shocks of which would directly impact the endogenous variables. The primary endogenous variables is the insured unemployment rate, a proxy for unemployment. The six other series are the secondary endogenous series that represent the macroeconomic and socioeconomic conditions that might influence insured unemployment rate. They are selectively included to improve modelling accuracy.

[1] View appendix A for details

[2] Data for firearms background checks[34] and number of bankruptcy filings[33] (constant across gender and race) were added initially, but they resulted in non-convergence in the estimation algorithm.

[3] Weeks are ending on Wednesdays. Series that did not conform to this are matched to the data by trimming-off additional weeks within a year.

[4] The percentage of labor force receiving unemployment insurance[65].

A vector auto-regressive (VAR) model was employed to capture any dynamic inter-dependency among the endogenous trends conditional on the external regressors: percent of deaths due to pneumonia and influenza. We took a more mechanical approach in selecting the secondary endogenous series. A short iteration algorithm was developed to test the stationarity and extract the AIC and MAPE of the model for every combination of endogenous and exogenous variables, contemporaneous and lagged[5].

The first step involves selecting all the combinations of external regressors that give the lowest AIC, for each *stationary* combination involving insured unemployment rate and at least one of the two economic indices. The second step selects the model with the least number of endogenous series (most parsimonious), because AIC cannot be compared across different combinations of series. A uni-variate SARIMA model was fitted on insured unemployment using an automatic algorithm and its Mean Absolute Percentage Error (MAPE) is used as a benchmark.

Co-integration tests using the Johansen procedure were conducted. The results of the tests are drawn-upon together with cross-correlation plots of the series and Granger-causality tests to support the design of the final model that we selected for analysis and forecasting. The impulse response function of insured unemployment on itself is plotted. Auto-correlation plots and time series of residuals are used to assess model validity. 26-weeks ahead forecasts are generated for insured unemployment rate, conditioned on two scenarios: the external regressors remaining constant at the most recent values and at the worst (highest) values since the beginning of 2020.

3 Results

Table 1 gives the estimated standard deviation of the distribution for the year random effects in the initial GLMM model, which follows the specification mentioned in the methods section. The value is negligibly small. The likelihood ratio test of the initial model against the model without random effects has a p-value of 0.9997, so we do not reject the insignificance of the random effects at the 1% level, against the alternative that it is significant. The back-step algorithm that minimizes AIC drops deaths from liver diseases and drug-induced deaths from the controls. We adjust the initial model by dropping these two variables but keeping the random effects.

Table 1: Year Random Effects Variance

Groups	Name	Std.Dev.
Year	(Intercept)	3.6282e-06

Table 2 presents the estimates from the adjusted model. Females have *lower* suicide odds by a factor of 0.32151 than males. Increasing alcohol deaths by 1 per 100,000 is significantly associated with an *increased* suicide odds by a factor of 1.05059 at the 5% level. An increase in 1% of deaths due to influenza/pneumonia and an increase in 1% of population below poverty are estimated to *decrease* odds of suicide by factors of 0.97753 and 0.95164 respectively, at the 5% significance level. The Economic Policy Uncertainty Index does not have a significant impact on suicide rates at the 5% level.

Table 2: 95% CI of Exponentiated Coefficients - Adjusted Model

	2.5%	97.5%	Estimate	
(Intercept)	0.00026	0.00131	0.00058	***
GenderFemale	0.26321	0.39273	0.32151	***
AlcoholDeath	1.03464	1.06679	1.05059	***
FluPneuDeath	0.96942	0.98571	0.97753	***
Poverty	0.92887	0.97496	0.95164	***
Uncertainty	0.99916	1.00003	0.9996	.
Unemploy:White	1.00182	1.03858	1.02003	*
Unemploy:Asian	0.97989	1.04025	1.00962	
Unemploy:Black	1.00288	1.04136	1.02194	*
Unemploy:Hisp-Lat	1.00484	1.0584	1.03127	*
Salary:White	0.97714	0.9982	0.98761	*
Salary:Asian	0.97056	0.99122	0.98084	***
Salary:Black	0.95945	0.98938	0.9743	***
Salary:Hisp-Lat	0.94277	0.97585	0.95917	***

Significance codes for p-values of estimates:
$0 < *** \leq 0.001 < ** \leq 0.01 < * \leq 0.05 < . \leq 0.1$

The exponentiated estimates are the change in odds relative to the baseline odds (the intercept value), of one suicide case occurring given 1 unit change in the corresponding covariate.

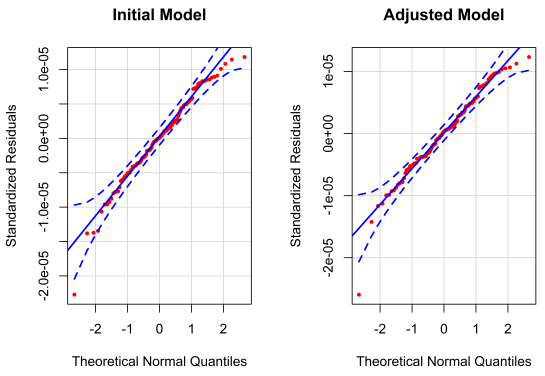
A 1% increase in unemployment rate is significantly associated with *increased* odds of suicide for the White, Black, and Hispanic or Latino racial groups at the 5% level. However, there are no significant heterogeneous unemployment effects by race, since the 95%

[5]We lagged the endogenous variables up to order 10, while the exogenous regressors are lagged up to order 2 with contemporaneous trends present in each combination. We restricted the lags due to computational limitations arising from algorithm design inefficiencies.

confidence intervals of salary estimates overlap in every pair-wise comparison. The increase in salary is significantly associated with *decreased* odds of suicide for all races at the 5% level. However, there are no significant heterogeneous salary effects by race, other than between the White and Hispanic or Latino groups. The upper bound of the 95% interval of salary estimates for the Hispanic or Latino racial group is 0.00129 lower than the 95% lower bound of salary estimate for the White racial group.

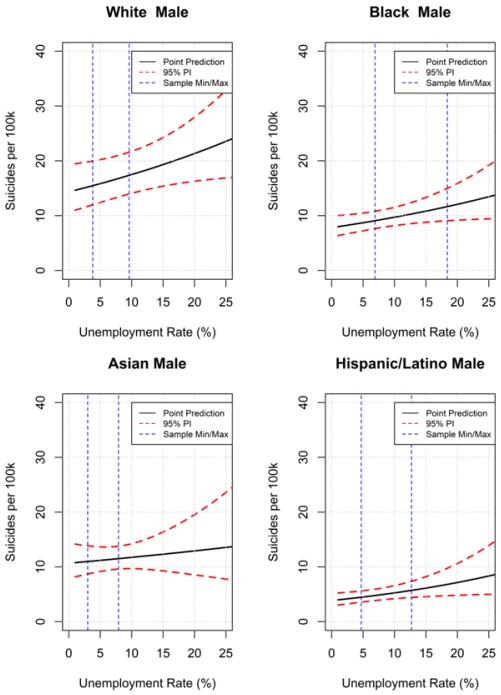
Next, we evaluate the fit of the adjusted model. Figure 1 shows that the adjusted model slightly improves residual normality. In the left panel, some residuals of the initial model are touching the borders of the intervals of the theoretical normal quantiles at the second lower quantile, while they recede from the bounds in the right panel. Overall, the plot shows conformity to the normality assumption with the exception of one residual.

Figure 1: Normal QQ plot of Standarized Residuals.



We present predictions using our adjusted model. Suicide rates are predicted over a continuous range of unemployment rates, by the four races for the male gender. Other covariates are held constant at their respective sample means. In Figure 2, the slopes of the predicted trends and their 95% prediction intervals are positive on the range of unemployment rates for all races except for Asians or Pacific Islanders males.

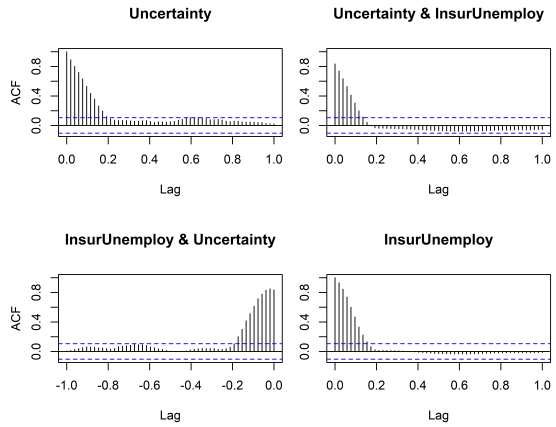
Figure 2: Prediction of Suicide Rates on Increasing Unemployment Rates



The following sections are results from the Vector Auto-regression (VAR) model. The iterative algorithm we used for model selection finds that of all the stationary models containing insured unemployment rate, the model that minimizes AIC uses the Economic Policy Uncertainty index as the other endogenous series. Its external regressors are contemporaneous series of percent of deaths due to pneumonia and percent of deaths due to influenza. Although the algorithm found stationary models containing NICS background checks, none of which included insured unemployment rate as the other endogenous series.

Figure 3 shows significant auto-correlation for both series up to a considerable number of lags (each spike occurs at a week). This is strong evidence of non-stationarity. Strong cross-correlations are also observed for many lags, indicating dynamic inter-dependencies. From the Johansen test, we reject that there exists no co-integrating relations at the 1% significance level. From the Granger-causality tests, we reject at the 5% level both null-hypotheses that the uncertainty index does not Granger-cause insured unemployment and vice-versa.

Figure 3: Auto/Cross-correlations Functions of Endogenous Series



Each spike represents a weekly auto/cross-correlation. A total of 52 weeks are displayed.

From Table 3, a 1% increase in percent of deaths due to pneumonia in the current week is associated with an *increase* in contemporaneous insured unemployment rate by 0.18219%. A 1% increase in percent of deaths due to influenza leads to a *decrease* in current-week insured unemployment rate by 0.23352%. Both effects are significant at the 1% level.

Table 3: Significant Estimates - Insured Unemployment Rate (Weekly)

height	Estimate	P-value	
Uncertainty.l1	0.00184	0.00003	***
InsurUnemploy.l1	1.01007	0.00000	***
Uncertainty.l2	0.00131	0.00696	**
Uncertainty.l3	-0.00132	0.00738	**
InsurUnemploy.l3	-0.75517	0.00000	***
Uncertainty.l4	0.0014	0.00528	**
InsurUnemploy.l4	0.76993	0.00000	***
Uncertainty.l5	-0.0014	0.00601	**
InsurUnemploy.l5	-0.33659	0.02536	*
Uncertainty.l8	-0.0013	0.01235	*
InsurUnemploy.l9	0.39401	0.02645	*
InsurUnemploy.l10	-0.4077	0.00062	***
const	-1.23265	0.00000	***
trend	0.00059	0.03845	*
PneuDeath	0.18219	0.00000	***
FluDeath	-0.23352	0.00000	***
Adjusted R-squared	0.988		
Global F-test P-value	$<$ 2.2e-16		
MAPE	7.24%		

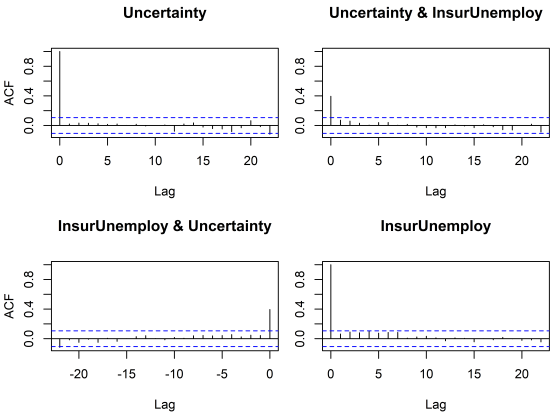
Significance codes for p-values of estimates:
$0 < *** \leq 0.001 < ** \leq 0.01 < * \leq 0.05 < . \leq 0.1$

Both insured unemployment and the uncertainty index are lagged up to and including lag 10, but only estimates significant at least at the 5% level are displayed in Table 3.

Table 3 also shows that insured unemployment rate depends significantly on past values of itself and the uncertainty index as far back as 10 weeks. The Mean Absolute Percentage Error (MAPE) for the insured unemployment series is 7.24%. This is much lower than 20.27%, the MAPE of our benchmark model[6].

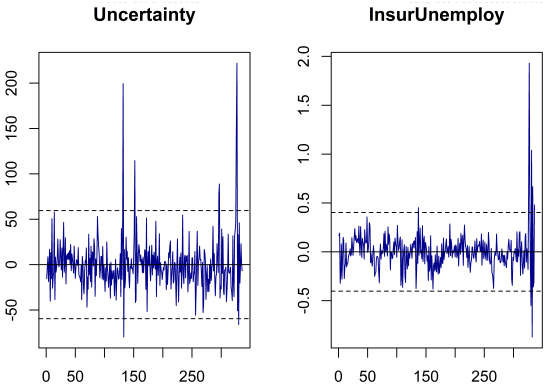
Figure 4 shows there are no significant auto or cross-correlations in the residuals of the VAR. This indicates that the model captured most of the dynamic inter-dependencies between the two series.

Figure 4: Residuals Auto-correlation Functions



In both panels of figure 5, the residual series have constant zero means and do not exhibit heteroskedasticity apart from a few obvious spikes that greatly exceeds the two standard deviation bounds. We identified the outlying residuals and found that most correspond to weeks after the first case was confirmed in the United States (after about 2020 week 3).

Figure 5: Residuals Time Series

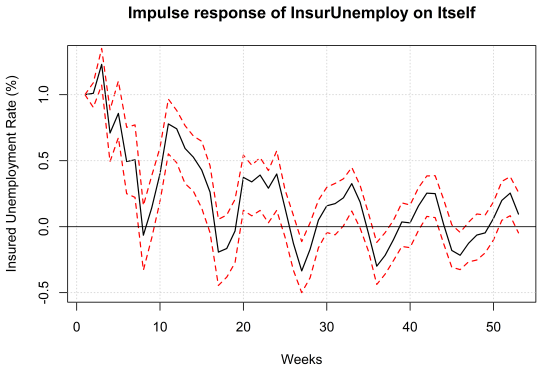


Horizontal dotted lines demarcate two standard deviations from the mean of the series.

[6] View appendix B for details.

Figure 6 shows the impulse response of insured unemployment from a 1% increase in itself due to an exogenous shock, holding all else constant. The full extent of the shock is greater than the initial increase a few weeks later. The effects are indistinguishable from zero on weeks where the 95% intervals cross the x-axis, but it is clear that the impulse responses are significantly positive on many other weeks and do not completely diminish after 52 weeks.

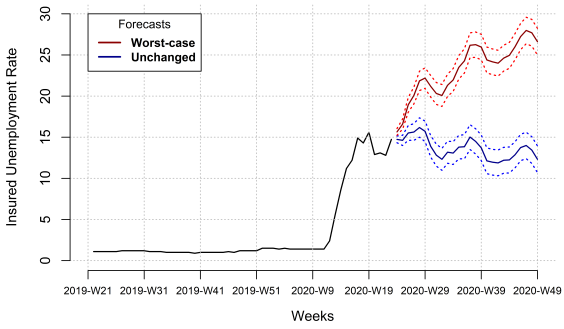
Figure 6: Impulse Response of Insured Unemployment Rate on Itself - 52 weeks ahead



Red dashed lines demarcate 95% confidence intervals, generated using the bootstrap method.

Figure 7 forecasts insured unemployment rate under hypothetical conditions. Under the worst-case, insured unemployment is projected to rise continually to reach about 27% near the end of 2020, while it will fluctuate around the current level under the 'unchanged' assumption.

Figure 7: 26-Week Ahead Forecast for Insured Unemployment



*Solid lines are point prediction and dotted lines are 95% prediction intervals.

The 'worst-case' assumes external regressors remain constant for the next 26 weeks at the worst (highest) value since the start of 2020 (occured on 2020 week 15 and 2020 week 11 for percentages of deaths due to pnuemonia and influenza, respectively). The 'unchanged' scenario assumes external regressors stabilizes at their most recent value (week 22 of 2020).

4 Discussion

We are interested in finding the extent to which disruptions in unemployment and earnings due to COVID-19 would impact suicide rates in the United States. The key findings from our panel analysis is that unemployment rate and median salary have significantly positive and negative time-invariant impacts on suicide rate, respectively. Using time series data while focusing on insured unemployment rates, our results warn of sluggish recovery of unemployment rate from shocks of the pandemic, and potential for devastating levels of unemployment if the pandemic worsens. This translates into dire implications for suicide rates in the near future. Thus, our findings serve as evidence to drive the much needed changes to suicide-related policies that can prevent large-scale unnecessary loss of life.

We first discuss in detail results from our logistic GLMM. Studies have shown significant heterogeneity by time period in suicide rates, by month of year[29, 48], by day of week[48], and by the four seasons[13]. The insignificant time random effects of our GLMM is evidence of no significant heterogeneity by year from 2002 to 2017. This also means our model comprises of a good set of predictors that captures systematic variation in suicide rates well, and leaves no significant yearly idiosyncratic 'shocks'. We also refer to the highly normal residuals observed in Figure 1 to support the validity of our GLMM.

Our adjusted GLMM model estimates that percentage of population below poverty *negatively* predicts suicide rates. As we expected this impact to be positive, we suspect presence of omitted variable biases. The estimate of the effect of poverty on suicide could have been biased downwards due to omitting gun ownership. A possible causal path is that poverty lowers gun ownership due to affordability issues, and lower gun ownership is in turn associated with lower suicide rates[43]. However, the demand for firearms is elastic, and a 1% change in price (or cost of firearms relative to income) induces

a change in quantity demanded by more than 1%[6]. This means that it only takes changes in earnings to affect gun ownership, and not poverty. Since we have controlled for salary in our model, we can reasonably rule out such causal link between poverty and gun ownership. Thus, we cannot pin-point the source of bias. To ensure this source of bias do not also affect our main variables, unemployment and salary, future studies should analyze any changes of our estimates after adding gun ownership and other relevant controls if data are available.

The significant positive associations between suicide and unemployment rate for all races confirm the widely documented impact of unemployment on suicide[4, 58, 7]. But many of such studies focused on heterogeneity of the unemployment effect by gender and age group[29, 7, 44]. Thus, our estimates provide evidence to the literature that no significant heterogeneity by race exists for the unemployment effect on suicide rates. The significance of the estimates for unemployment and median annual salary, while poverty and alcohol-induced deaths are controlled, also provides additional evidence of significant direct impact of unemployment and salary on suicide rates. That is, job losses or loss of income lead to suicidal tendencies directly, not only through mediators such as poverty (extreme loss of income) or alcoholism[36]. The meaning of having a 'direct' impact should be interpreted with care. We are only concerned with the large-scale associations of unemployment and salary with suicide rates for policy purposes, but we recognize there exist more intricate causal mechanisms on a micro scale. We encourage future works to expand upon our analysis by using individual-level data where available, to either validate macroeconomic associations of variables on the individual scale and to potentially identify heterogeneity by individual characteristics.

Our panel analysis culminates in Figure 2, which provides an intuitive illustration of the unemployment effect on suicide. Our investigation into salary as a determinant of suicide ends here due to lack of data, but we continue to investigate unemployment in context of our research question. A different approach is required to more accurately judge the future trend of suicide rates during the current pandemic where determinants of suicide are fluctuating dramatically. Concerns for serial correlation motivated our time series approach. Evidence of co-integration between our endogenous variables as indicated by Figure 3, the Johansen test, and the Granger-causality test further warrants the use of multi-variate time series, which would help improve estimation over a uni-variate model. This is further evidenced by the fact that the MAPE for our VAR model is 13% lower than the benchmark minimum AIC uni-variate forecast. Since we observe no significant heterogeneity by race for the unemployment effect, our use of nation-wide economic trends and indices without a race dimension does not diminish the external validity of our forecasts in this sense.

The final VAR model our algorithm has selected uses insured unemployment rate as a proxy for total unemployment rate, in which insured unemployment rate is the number of people currently receiving unemployment insurance as a percentage of labour force. It is an obvious proxy because of it's close set-wise relation to the total population of unemployed individuals. From an article written by Stephen Williamson, insured unemployment rate contains a more visualized action (filing for unemployment insurance) than a much more blurred action of actively searching for work. However, we must remain cognizant of the implicit bias in using it as a proxy given the marginally different populations at play (insured workers vs. uninsured workers). The former are often holding stable positions with robust contracts that are much harder and more costly to break in the case of a termination. The latter, on the other side, tend to hold starting level and temporary positions much more often. This puts them at a higher risk for termination and thus we expect the unemployment rate within the uninsured population to be higher than that of the insured population. Although using the insured population as a proxy might be meaningful and easier to analyse since data is more readily available, we must recognize that it is likely to underestimate the true population unemployment level.

The other endogenous series in the selected VAR model is the Economic Policy Uncertainty Index. This serves to capture the broad range of macroeconomic factors. Figure 3 shows significant inter-dependency over time between uncertainty index and insured unemployment rates, and the tests suggest they are highly co-integrated. Although these are evidence that the index helps to explain variations in insured unemployment rate, we admit that our model can be vastly improved using a a few more

specific series that capture different aspects of the economy or even health instead of just a broad index. An extension to our project may also include trends by each state to identify state effects.

Despite potential areas of improvement, our diagnostics show that our model would perform adequately in forecasting. We see no significant auto and cross-correlations in our model residuals in Figure 4. This is evidence that our model adequately captures dynamic relationships in our endogenous variables, and robust predictions can be made. Our model also satisfies homoskedasticity assumptions as seen in Figure 5. This means that the t-tests on estimated coefficients are valid and the variables shown in 3 are indeed significant. We note that there are a few deviating residuals from the two-standard deviations bounds for residuals near the time of COVID-19's initital outbreak. Thus, we encourage future explorations to incorporate more data during the pandemic to calibrate the model to the more volatile series during the pandemic and to make better forecasts.

We were hoping to model relationships between unemployment and NICS firearms checks. However, our iteration algorithm found no stationary models that include insured unemployment with NICS firearms background checks with any other combination of endogenous or exogenous series, and the Johansen test found no co-integrating relationship between the two. This suggests a more complex relationship between unemployment distress or insecurity and the intention to purchase firearms.

We used deaths from pnuenomia and deaths from influenza as external regressors as it is more befitting of our research question, which asks how our endogenous variables evolve conditional on the level of pandemic. This setup also avoids over-simplifying the disease dynamics that involves many other factors such as mass-immunization and isolation[14] of which we lack data. But this specification could lead to simultaneity bias if they are not truly exogenous. For example, unemployment could reduce access to healthcare, which would increase influenza activity[20]. We verified the degree of exogeneity by conducting a Johansen test and Granger-causality test. At the 1% level, we do not reject the null-hypothesis that there exists no co-integrating relations between the two external regressors and the two endogenous ones. Also, both endogenous variables do not Granger-cause deaths from influenza at the 5% significance level. However, they do significantly Granger-cause deaths from pneumonia at the 1% level. We recognize this potential source of simultaneity bias, but retained our model in favor of a parsimonious one. We argue that the causal relationship of unemployment on deaths from pneumonia would take many lags to capture and thus would strain the estimation of parameters. This is important as we do not have a large data set (our data spans only 346 weeks). Future studies can compare our model with a model that treats the diseases as endogenous and evaluate their predictive performance.

As expected, Table 3 shows that deaths from pneumonia as external regressors has highly significant positive impact on insured unemployment rate. This is evidence that COVID-19 is directly impacting employment. It is interesting to find that the best model by minimum AIC criterion uses contemporaneous series for deaths from pneumonia as external regressors. This provides evidence that pneumonia infection rates affect insured unemployment within a short time frame of a week. It is also interesting to note that deaths from influenza has significant negative association with insured unemployment, which is consistent with our findings from our panel analysis.

As seen in Figure 6, insured unemployment's significant serial correlation with itself warns of sluggish recovery from the pandemic. The figure shows that insured unemployment will not break loose from the effects of exogenous shocks such as pneumonia deaths due to COVID-19, for as long as 52 weeks. Moreover, we've shown from our results from Table 3 that the unemployment trend will continue to receive feedback from economic uncertainty from as far back as eight weeks, which would contribute to slow recovery.

Figure 7 puts all cumulative and simultaneous effects into perspective. The worst-case prediction colorized in red shows insured unemployment will soar beyond the historical high of about 25% during the Great Depression[15]. This is conditional on the COVID-19 situation (as measured by percentage deaths from pnuemonia and influenza) reverting to its highest value between since the outbreak and remains

so till the end of 2020. We rationalize the use of sustained pneumonia deaths at its all-time high since outbreak to predict the worst-case scenario as a more conservative approach. In reality, if deaths from pneumonia hit the previous record high, it will likely set off subsequent weeks of rapid ascend in deaths[14] and not be a flat rate in our prediction. Although we do not offer an assessment on the likelihood of the 'worst-case' occurring, this prediction warns of serious devastation that COVID-19 can inflict on unemployment, given recent record-breaking trends[5] and worrying levels COVID-19 reproduction numbers in many states[50]. This would in turn greatly impact United State's suicide rates. We refer to our less dire prediction under 'unchanged' conditions. Even if percent of deaths due to pneumonia stabilizes at its most recent value, we should not expect insured unemployment to regain its pre-outbreak levels within the next 26 weeks. These forecasts are by no means definitive, as we lack sufficient data to rigorously predict future trends on pneumonia and influenza deaths. However, our model is robust and could generate accurate forecasts provided timely inputs for deaths from pnuemonia and influenza.

Our forecasts warrant concerns from the government about an imminent suicide crisis. Public policy changes are a necessary step to be taken promptly, to prevent convergence of the larger population to the alarming suicide rates of historically at risk populations such as veterans[38]. However, we still need to refine existing policies to tackle the National Suicide Hotline's inefficiency rates[56], as it is an essential part of existing systems to assist individuals in need. We need to account for a large proportion of individuals with a perceived disorder who refuse to receive proper treatment even after making contact with National Suicide Hotline workers and referred to mental health facilities. Studies have found the main reason to be the lack of trust in the practices and systems in place, often due to negative prior experiences[28]. The misconception about mental illnesses as self-recovering without treatment also ranks very high among determining factors hindering the access to health support[28, 37]. Lastly, affordability of treatment expenses is also an inhibiting factor[45]. Bill H.R. 2345 has assigned the investigative commission to report on the viability and necessity of instating a 3-digit dialing code of the National Suicide Hotline service. The proposed dialing code, which has been approved but has yet to come into action, would successfully remove certain accessibility barriers toward needed mental health support services[21].

Most recently, Representative Tim Murphy has championed H.R.2646. The bill was meant to produce a more cohesive approach to dealing with the mental health crisis, by uniting the powers of several governmental agencies with larger funding and by re-examining the current practices in mental health facilities. In specific, it increased the weight of inpatient treatments taking place. The bill was passed by the House of Representatives, but it was voted down at the Senate after receiving ample criticism by civil rights activists. Although the intention of the bill was praised and it was recognized that further similarly focused legislation was most necessary, several sections of the bill were seen as regressive and harmful[35]. During the leading years to 2016, the healthcare system had focused on recovery based treatments for mental disorders. Such an approach had the experiences and wishes of the patients in mind as it was a non intrusive way to increase standard of living. On the contrary, the proposed bill would give the health workers the right to force certain treatments such as the Assisted Outpatient Treatments (AOT)[51]. Such treatments, although they have been shown to reduce the hospitalization rates of the patients[64], they also have a very negative psychological effect on the patients, contributing to their negative perspective of the healthcare system11, which is known to be the main factor pushing patients away from necessary treatment[26].

At this time, suicide rates are especially sensitive to a rise correlated with COVID-19 related unemployment rates and financial distress levels, due to the recent surge in lethal weapon purchasing within the general population[2]. Studies have demonstrated a strong correlation between firearm ownership levels and suicide rates[47], which validates the concerns regarding the suicide susceptibility within the US population in a time of unprecedented firearm ownership and an economic recession like no other over the last three quarters of a century. In order to prevent the projected rise in suicide rates, we can look to our history of successful policy making in tackling that issue. Studies have shown a negative correlation between gun control measures and suicide rates, as the restrict access to the method employed for over half of the suicides committed in the US daily[1]. These restrictions can take diverse forms, with some of them being perceived as more intrusive

than others. Regulations may come in the form of bans, licensing, waiting periods, mandatory training, background checks and many more. At the same time, these regulations may be implemented at the federal level or, as it is the case with most policies in place, at the state level.

Research consistently points to Canadian legislation, and most precisely to bill C 68 the "Firearms Act"[9], as a demonstration of effective gun control regulation[66]. The Canadian example indicates that the most important parts of gun control are gun registration as well as licensing focused on background checks and training[66]. However, the reasons that have been argued to make registration efficient are mainly accountability and feasible gun tracing. These factors are unlikely to have a strong impact on whether or not said firearm is used to commit suicide. Thus, our focus when it comes to reducing suicides by firearm should come in the form of restrictive licensing that thoroughly examines each individual's ability to safely own a firearm without being a threat to themselves or others. On the topic of where the responsibility of said policy ought to lie, we turn to studies that demonstrate that for a gun control policy to have a significant impact on the population, it must be enforced at the federal level[39]. This reduces avenues for individuals to avoid the regulation by travelling across state borders and results in cohesiveness and mutually ensured accountability among different state police departments.

Also, economic measures are crucial in slowing down unemployment rate, which we found to be strongly linked to suicide rates. Even in the scenarios where the economic situation creates a market with excess supply, individuals with a higher accessible wealth level still contribute to the recovery of the economy although often not through direct demand. Tax cuts, debt allowances and relaxed regulation allows businesses, especially smaller ones, to avoid default and the subsequent foreclosure. That itself minimizes the economic shock of the recession, guaranteeing both a shorter recovery period and a minimized number of unemployment filings, which is the factor that we are ultimately trying to mitigate as a result of this study. Government subsidies also allow for businesses to afford abiding by regulation that is necessary for the containment of this pandemic, such as restructuring and social distancing, which can often be very costly[27].

In the face of the Great Recession, larger tax cuts were used as temporary economic stimuli, which were successful in allowing for a faster recovery period. There is uncertain evidence that suggests that such stimuli, which comes as a form of increased income as opposed to lump sums of grants like we have seen the government adopt during this crisis, have a larger stimulative effect on the economy and thus should be prioritized[27].

Our main concern, as demonstrated by the data analysis performed in this study, is job loss and its catastrophic impact in suicide rates. According to the Bureau of Labor Statistics, the unemployment rate rose by 11.2 percent, an increase of over four times, from February to April of 2020[40]. This worrying data is believed to be caused mainly by the economic impact of the necessary lockdown regulations in place to contain COVID-19. That ought to be a great cause for concern as it indicates that the economic shock from the current crisis will likely greatly exceed that of the crippling Great Recession of 2008[46]. The aim of this discussion is, of course, not to recommend relaxing the security measures in place, as we believe that should be an entirely health-based decision and not an economic decision. Our aim is to provide clarity about the most efficient avenues for government policy to minimize the economic shock while respecting the gravity of the health crisis, in an attempt to avoid unnecessary unemployment and its subsequent suicide rate increase.

We encountered certain limitations when developing this project. Some of the data lacked one of the Gender or Race dimension. In order to complete our data entries we assumed the missing values to be constant across the variables, incurring a substantial estimation error. We used US economy-wide data. We could potentially eliminate biases between different states by using state-level data instead. As a matter of fact, we could even use individual level data for maximum precision. Actual rates of infection were proxied by mortality rates and unemployment was proxied by insured unemployment. In order to minimize error by proxy, we should strive to use actual data when available. Future explorations can include more endogenous time series that are co-integrated to boost model accuracy. When data becomes available, modelling and forecasting should be done with suicide rate to

be able to make direct predictions. We deferred analysis into firearms ownership as we found no-cointegrating relations between unemployment and NICS firearms checks with any of our variables.

Conclusions

This research was conducted during one of the harshest economic downturns in decades. With the current health crisis, government efforts are focused on mitigating the impact of COVID-19 and are slowly transitioning into containing its severe financial implications. By investigating the dynamic relationships among economic markers and diseases, and by analyzing time-invariant effects of economic variables on suicide, we produce results that calls attention to the importance of mental health support. From the last major economic crisis we learned that there are a myriad of ways for a government to fight economic adversity, but we have not had a history of responsibility when it comes to facing the health challenges associated with said economic adversity.

We propose that public policy be passed to grant temporary extra funding for the National Suicide Hotline Services while the economic downturn lasts, to honour their vital position and increase their ability to handle the necessary call volume with properly trained individuals. At the same time, we strongly suggest immediately activating the 3-digit dialing code, as it has been unanimously agreed to be a necessary step to increase accessibility to the service. We propose the installment of educational campaigns for mental health, not focussed on destigmatization but rather in debunking common misconceptions, specially regarding its necessity for treatment and recovery in a professional manner. We recommend a thorough investigation into mental health facilities and their patient treatment in order to solve the problem of distrust and negative experiences from the community. We leave open the possibility of creating a full-time commission in charge of maintaining a level of accountability from the facilities that are found to be mistreating their patients. Such commission should be civil rights focused, as opposed to the more economically focused Substance Abuse and Mental Health Services Administration. In order to tackle the another crucial factor that may drive suicide rates to rise, we must also propose gun control regulations. From our research it has become clear that the US population would require the installment of more severe gun licensing restrictions, with special emphasis on background checks. These restrictions, along with the rest of the proposals above, must be implemented at the federal level in order to ensure highest efficacy. These measures we believe to be of utmost importance currently, given the combination of previously rising suicide rates, an all-time high lethal weapon possession rate and the approach of what is likely to be the harshest economic recession in recent history, all strongly indicating an imminent grave suicide rate crisis.

Separately, from an economic perspective, we praise bill H.R.266 in its mission of palliating businesses' economic distress in the coming months. We propose an increase in unemployment subsidy funding, not just for the duration of the pandemic but beyond, until the economy has recovered from the shock. We urge the government to remain diligent in its endeavour to contain the virus, while also remaining vigilant in its monitoring of the economic situation to be able to readily adapt to industry specific collapses. Simultaneously, we propose a shift toward paycheck related economic reliefs, such as tax cuts, as opposed to lump sums of money in order to minimize the economic strain on families, as it has been shown to have a greater influence on the economic recovery.

Moving forward, we suggest a more thorough analysis of historical data, with especially emphasis on the 2008 economic crisis and the US population health before, during and after the crisis. We found median salary and alcohol abuse to be the most significant factors in determining suicide rates. However, studies with different health related response variables may find avenues for public policy and government focus to intervene and palliate the repercussions of an economic downturn, which might help save lives over the coming months all over the world.

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Appendices

A Panel Data

This section lists the dimensions available in each variable of our panel data. For the variables that do not span *both* Gender and Race dimensions, we assume that their values are constant across the missing dimension.

List -
Suicide rate: Gender x Race
Unemployment rate: Gender x Race
Median annual salary: Gender x Race
Drug-induced deaths: Gender x Race
Alcohol-induced deaths: Gender x Race
Deaths from pneumonia and flu: Race
Deaths from liver diseases: Race
Poverty rate: Race
Economic Policy Uncertainty Index: neither

B VAR - Benchmark Model

The benchmark model is generated using a built-in automatic function in R. The function gives an ARIMA(0,0,1) model with drift.

Coefficients Estimates -
MA1: 0.9289 ±1 0.0170
drift: 1.8455 ±1 0.1096