

COVID-19 Case Study Midterm

your name
11:30AM-12:45PM (ET), 11/04/2025

Instruction

This is an in-class exam with a 75-minute time limit. The instructor and teaching assistant will be available during the exam period.

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Instruction: This midterm requires you to use Python. It is completely open book/notes/internet. **NO AI tools (such as ChatGPT, Claude, Copilot, etc.) may be used.** Write your answers using a Python notebook or .py format. Show your codes, plots or Python output when needed. If you have trouble formatting the plots, don't worry about it. We are not looking for pretty solutions, rather to see if you are able to make sense out of the data using Python. Make sure the compiled PDF or HTML shows your answers completely and that they are not cut-off. You may use whatever Python environment you prefer (Jupyter, VS Code, PyCharm, etc.). Throughout the exam, you do not need to use any LaTeX or mathematical equations. **Whenever we ask for test at some level, assume all the model assumptions are satisfied.**

All the answers should be clearly supported by relevant Python code or based on the Python output.

There are 4 questions with various parts:

- Question 1: 3 parts
- Question 2: 1 part
- Question 3: 5 parts
- Question 4: 5 parts

Data needed for the Midterm: covid_county_midterm.csv (available on Canvas)

Electronic Submission: Two files needed: your .py file (or .ipynb if using Jupyter) and a compiled file (either a PDF or HTML). Label them with your full name. In the Assignments section, go to the Midterm assignment and upload your completed files. Each submission should have the Python file (.py or .ipynb) AND the PDF or HTML.

The submission folder will be closed sharp at 12:45PM.

Background

The outbreak of the novel Corona virus disease 2019 (COVID-19) was declared a public health emergency of international concern by the World Health Organization (WHO) on January 30, 2020. Upwards of 112 million cases have been confirmed worldwide, with nearly 2.5 million associated deaths. Within the US alone, there have been over 500,000 deaths and upwards of 28 million cases reported. Governments around the world have implemented and suggested a number of policies to lessen the spread of the pandemic, including mask-wearing requirements, travel restrictions, business and school closures, and even stay-at-home orders. The global pandemic has impacted the lives of individuals in countless ways, and though many countries have begun vaccinating individuals, the long-term impact of the virus remains unclear.

The impact of COVID-19 on a given segment of the population appears to vary drastically based on the socioeconomic characteristics of the segment. In particular, differing rates of infection and

fatalities have been reported among different racial groups, age groups, and socioeconomic groups. One of the most important metrics for determining the impact of the pandemic is the death rate, which is the proportion of people within the total population that die due to the disease.

There are two main goals for this case study.

1. Number of deaths vary drastically across State. We want to find out how State relate to the death rate.
2. Covid seems to target elder people's lives. Is there evidence in our data to show that proportion of elder people indeed relates to the death at county level.

1 Data preparation

To make our case study here simple and manageable in a time fashion, we have assembled a subset of data called: **covid_county_midterm.csv**. It collects county level death rate, labeled as **log_death_rate**, as well as a subset of demographic information based on the two cleaned data:

- **covid_county.csv**: County-level socioeconomic information that combines the above-mentioned 4 datasets: Income (Poverty level and household income), Jobs (Employment type, rate, and change), People (Population size, density, education level, race, age, household size, and migration rates), County Classifications
- **covid_rates.csv**: Daily cumulative numbers on infection and fatality for each county

Death rate

What is a good way to measure Covid death rate? There are quite a number of counties with a very low or none number of deaths. We have created a new measurement of death rate as follows:

- The total number of death for each county is gathered by November 1st, 2020
- The death rate is calculated as the total number of deaths plus 1 in the county divided by the total population of the county plus 2. We then apply the function log to get the **log_death_rate**.

Read data

We are ready to read the data **covid_county_midterm.csv** into Python.

To simplify the analyses further, we created a subset here called **covid_county_sub** for us to use in the entire case study.

```
import pandas as pd
import numpy as np

covid_county = pd.read_csv("covid_county_midterm.csv")

covid_county_sub = covid_county[[
    'log_death_rate', 'State', 'Deep_Pov_All', 'PovertyAllAgesPct',
    'PerCapitaInc', 'UnempRate2019', 'PctEmpFIRE', 'PctEmpConstruction',
    'PctEmpTrans', 'PctEmpMining', 'PctEmpTrade', 'PctEmpInformation',
```

```

'PctEmpAgriculture', 'PctEmpManufacturing', 'PctEmpServices',
'PopDensity2010', 'OwnHomePct', 'Age65AndOlderPct2010',
'TotalPop25Plus', 'Under18Pct2010', 'Ed2HSDiplomaOnlyPct',
'Ed3SomeCollegePct', 'Ed4AssocDegreePct', 'Ed5CollegePlusPct',
'ForeignBornPct', 'Net_International_Migration_Rate_2010_2019',
'NetMigrationRate1019', 'NaturalChangeRate1019', 'TotalPopEst2019',
'WhiteNonHispanicPct2010', 'NativeAmericanNonHispanicPct2010',
'BlackNonHispanicPct2010', 'AsianNonHispanicPct2010',
'HispanicPct2010', 'Type_2015_Update', 'RuralUrbanContinuumCode2013',
'UrbanInfluenceCode2013', 'Perpov_1980_0711', 'HiCreativeClass2000',
'HiAmenity', 'Retirement_Destination_2015_Update'
]]
```

2 EDA

During the course of pandemic, we have witnessed that many policies are carried out at state level. For example when to reopen after the March lock-down. To see the variability of death rates among states we suggest you to go through the following EDA process.

Question 1: (3 parts)

1. Create the average `log_death_rate` by State. Show the histogram of the average `log_death_rate` by State. Use no more than three sentences to summarize the variability of the average `log_death_rate` by State.
2. To see within State county level variability, make box-plots `log_death_rate` by State. Use no more than two lines to describe the variability of `log_death_rate` by State.
3. What is the state with the highest average `log_death_rate`, and what is this rate?

3 Analyses

In the following analyses, we try to find out factors related to `log_death_rate`.

3.1 fit1: Age and `log_death_rate`

There are a number of studies indicating covid claimed most of elder lives. Let us start with a simple regression of `log_death_rate` vs. `Age65AndOlderPct2010`.

Question 2: (1 part)

1. Is `Age65AndOlderPct2010` a significant variable at .01 level in this analysis? Show the p-value.

3.2 fit2: Age and `log_death_rate` controlling for State

Question 3: (5 parts)

How do `Age65AndOlderPct2010` and State collectively affect `log_death_rate`. In fit2, run a linear model of `log_death_rate` vs State and `Age65AndOlderPct2010` (without interactions).

1. Is `Age65AndOlderPct2010` significant at .01 level in this model?
2. How to interpret the coefficient of `Age65AndOlderPct2010` over the `log_death_rate` in fit2? How would you explain the difference in effects of `Age65AndOlderPct2010` in fit1 vs fit2. (No more than 3 sentences).
3. Perform a test to see if State is significant in this model at .01 level?
4. Based on fit2, what is the estimated `log_death_rate` for a county in NJ and AL given `Age65AndOlderPct2010 = 20` respectively. Note that the base level of State is AL. Show your formula and evaluate the final values. Do not use `predict()` in this question.
 - a) For NJ: `log_death_rate = _____`.
 - b) For AL: `log_death_rate = _____`.
5. Are the linear model assumptions reasonably met in fit2? Provide residual and normal plots for fit2. Use no more than three sentences summarizing your model diagnoses.

3.3 fit.final

In this section, using all possible variables available in `covid_county_sub`, we will build a final parsimonious model and to identify a set of important variables that are related to the `log_death_rate`. We will not fine-tune the final model.

As you have seen State effect explains a large portion of variability in `log_death_rate`, we will lock State in all the analyses.

Question 4: (5 parts)

Important Remark: You are going to run LASSO to pick up a few variables in addition to the State. In case you can't get LASSO to work go to 2) directly and use the following set of variables to get your fit.final: State, PetEmpServices, PopDensity2010, Age65AndOlderPct2010, WhiteNon-HispanicPct2010, HiCreativeClass2000. (Note: this is not necessarily the LASSO output.)

1. Use LASSO to pick up a few variables in addition to State. List variables output from the above LASSO. To be specific let us control the following settings to get the same results.
 - Use `random_state=1` to control the cross-validation errors.
 - Use 10-fold cross validations.
 - Force State in all the LASSO models.
 - Pick up the final set of variables using lambda corresponding to 1 standard error rule (`alpha_1se`)
2. Run a final model `fit.final` of `log_death_rate` vs State and the set of variables obtained from your LASSO output. Also include `Age65AndOlderPct2010` regardless whether it is in your LASSO output or not. (You can easily specify the model variables without any algorithm.) Report the summary of `fit.final`.
3. Is State significant at .01 level in this model? Is `Age65AndOlderPct2010` significant at .01 level in this model?

4. Controlling for all other variables in `fit.final`, which state has the highest `log_death_rate` and what is the value?
5. Assume all linear model assumptions are met. Write a brief summary of your findings based on `fit.final`. (No more than 4 lines after compiled)

End of the case study!!!!