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Association of Physician Density and Covid-19 Vaccination Rates in California Counties

Over 104,000 people have died of COVID-19 in California as of today, and of those deaths, 75,000 are believed to have occurred before the availability of widespread vaccines in late 2021 (New York Times, 2023). Given the fact that rural areas throughout the pandemic had a higher mortality rate (Anzalone et al,2022), it is concerning that rural areas continue to have lower COVID-19 vaccination rates than urban areas with rural residents almost twice as likely to be unvaccinated than urban residents according to the CDC as of September 2023 (CDC, 2023). It is because of that discrepancy that my research question is what is the relationship between physician density in California counties and their COVID-19 vaccination Rate? My hypothesis in turn is that counties with a higher density of physicians will have a higher vaccination rate.

At the moment, there does not exist much data that examines a possible relationship between COVID-19 Vaccination rates and physician density per capita relationship, besides a German study from a couple of years ago (Ambros and Frenkel, 2021) and a study of U.S. Counties (Lo et al, 2022) not much research has been done on the topic . This study and examining this hypothesis, as well as other variables for their effect on the p-values from the data, will add to the little research that exists out there currently, which hopefully could make more people aware of the possible correlation. Since a study like this has not been done for

California before there is no knowing what relationship there might be that the data could reveal and what that data could have an impact on.

My motivation for doing the research for this project and writing this paper is ultimately due to one reason, there is no pre-existing research on the matter. If the hypothesis is correct that there is a positive, and potentially meaningful relationship between physician density per capita and COVID-19 vaccination rates, that could be the groundstone for further research. If the research including any strong influence from the other variables prove the hypothesis that could in turn have an impact on policy which could help reduce preventable deaths and increase vaccination rates during the next pandemic.

However, while there is a general trend of rural counties overall having a lower vaccination rate than urban counties according to the CDC, there does appear to be some degree of variation in vaccination rates (CDC,2023). My hypothesis for why this is the case is that there is a direct, positive correlation between the number of physicians in a county per capita, I.E. per thousand compared to the overall population of each respective county, and the rate of COVID-19 vaccination. Overall this study looks at the relationship by analyzing data vaccination data from all 58 California counties, from March 1st, 2021, when the vaccines became widely available, and September 1st, six months afterward as well as analyzing other data determining to what extent physician density has on vaccination rates. Besides going into analyzing the relationship between physician density and COVID-19 vaccination rates, this paper will also analyze several other variables, particularly median household income, the percentage of the 2020 Presidential Vote for Donald Trump, the percentage of the population over 65 years old, and the percentage of the population that has at least a bachelors degree.

Overall, this topic is important, the first being the lack of existing research on this topic, as well as the potential implications that could affect policy in a meaningful way, specifically by improving the ability to get more people vaccinated that this research paper and its results are important. The fact that there is a lack of research papers existing on a possible correlation between physician density and vaccination rates, let alone the potential results of such a study on California, the results of this research and any after it are important in contributing in some way that will hopefully be able to affect policy that could save lives during the next pandemic.

BACKGROUND

Since the COVID-19 Pandemic began, more than 104,000 people have succumbed to the disease and been sickened. The pandemic, excluding its responsibility in hospitalizing and killing many people, has affected people throughout the state and world with stay-at-home orders, to supply chain issues, schools being shuttered, and many other incalculable ways. It was during the pandemic that two trends began to emerge that exemplify the issue this paper attempts to answer on COVID-19 Vaccination and physician density. The first trend that began to emerge during this period, which potentially exemplifies the issue regarding vaccination and the density of physicians, is the trend that began to emerge in late 2020 of rural areas having higher mortality and hospitalization rates than rural areas. After the initial early stage of the pandemic with urban areas being the hardest hit regions, starting in late 2020, rural areas started to see a rise in hospitalization and mortality rates (Dobis & McGranahan, 2021). This first trend of rural areas having higher mortality rates and hospitalization has continued unabated to this day with residents in rural areas more likely to die from COVID-19 than urban areas (Anzalone, et al, 2022) as of 2022.

The other trend that emerged during this period which has influenced my view is the trend of rural vaccination rates. Up until December 14th, 2020, there were no preventative vaccines that existed for COVID-19, it was only after the first vaccines began to be distributed that people were vaccinated for COVID-19. During the initial period vaccination rates between rural and urban areas remained similar, however starting in early 2021 a divergent trend began to emerge of rural areas having lower vaccination rates than urban areas. My hypothesis for this case is that there are fewer physicians per capita in those areas than in urban areas and that those barriers created by living in a rural region whether it be due to geography, a higher percentage of people that are advanced age and lower vaccination rates due to feelings of not having to get vaccinated because there are fewer people is the reason that those areas have lower vaccination rates.

The other reason this variable was included as a control variable is that not only is potentially knowing a relationship between vaccination rates and age important in this context for the COVID-19 pandemic, but it is also important for the future of California. According to Ageing.CA, a state government website that provides information and data regarding advanced-aged Californians, the portion of Californians over 65 is growing and by 2030 it is projected that the portion of Californians over the age of 65 will increase to 10.8 million, or nearly 25% (California Department of Aging, 2021). In the context of the increasing amount of older Californians, knowing the ability of older Californians during the COVID-19 pandemic to receive vaccines may hopefully be something that (includes monitoring the relationship between age and vaccination rates today to inform policymakers going forward)

Regarding existing literature, there is not much that currently exists that has analyzed the relationship between physician density and vaccination rate. Of the data that does exist, two notable papers seem to have been written on this matter. The first paper appears to be one of only a handful of papers to cover this topic and at least the first to cover the entirety of California, except for a paper that studied this relationship with several other U.S. states and 50 of California's 58 counties (Lo et al, 2022), and another paper that studied this relationship in Germany (Ambros and Frenkel, 2021). Both studies in turn also appear to find a positive correlation between physician density and vaccination rates. Overall I hope that this study will add to the small amount of existing literature and hopefully provide more information that covers this topic to educate people.

METHODOLOGY

When it comes to the type of research paper, this research paper is an empirical research study that uses an Ordinary Least Squares regression (OLS) to analyze the data for this project. This project analyzes five variables, with physician density rat, and vaccination rate in September 2021 being the two main variables, and the 2020 vote for Donald Trump, county median household income, county population percent over 65, and the median education level all controls. In the context of this paper, a positive correlation between physician density and vaccination rate implies that areas with a higher density of physicians do have a higher vaccination rate, and a weak relationship would imply that there is only a minor effect of physician density on vaccination rates. On top of that, graphs were created for several of the variables and other relations, such as the relationship between county populations over 65 and

physician density rate or the graph for the direct relationship between the physician density and vaccination rate.

The reason that I chose this paper to be an empirical research project, as opposed to a systematic paper, is because there has not been much research done on this topic, which would make it difficult to do a systematic paper if there is not much data to review. On top of that, the other reason why this paper is an empirical research paper is because there is already a sufficient amount of data available to analyze to see if the hypothesis is correct.

The data for this study, specifically the physician density, vaccination, and control variable data, were collected from quite a few different sources depending on what data for which category was being collected. For instance, for the physician density data, I created the rate data myself by finding the number of physicians, specifically the number of non-primary care and primary care physicians, in each of California's 58 counties and the population of each of the corresponding counties and then dividing the total number of physicians by the population than multiplying it by 1000 to get the rate. To source that information, I was able to find the number of physicians in each California county as of January 2020 in an almanac by The California Health Care Foundation. This almanac, titled California Physicians, 2021: A Portrait of Practice (California Health Care Foundation 2021), is the 2021 version of the annual almanac of the organization, which is a non-profit that is focused on the California healthcare system. For the population aspect, I was able to find population estimates for the period of 2020-2022 for each of the counties and used the 2021 data for that. That population data was sourced from the U.S Census Bureau website, where I went to a subsection for county population total projections for each state, selected California, and found the data for each county(USCB, 2022). The reason

why estimates were used was because there are no exact numbers for how many residents each county had in 2021.

For the data for the vaccination rate, I obtained that data from several sources too, and like the physician density rate I had to create the vaccination rates for each county. The vaccination data used in this study covers two points in time, the vaccination rate for March 1st, 2021, and September 1st, 2021. In both cases, the vaccination rate only includes those who had received a single dose of the COVID-19 vaccines. The reason why both of those dates were chosen was that March 1st was around the time that the vaccines started to be expanded to include not just older Californians, but average people too. The reason why September 1st was included was that it was 6 months after most people were given access to the vaccine, exempting minors, which would mean the accuracy of the vaccination data would be more reflected in the ability of people to access the vaccine. It was also chosen since it was around the time that the first boosters were being announced, which would help ensure that no confounding variable from the vaccination rate of people who received a second dose.

To obtain the vaccination data, for both March 1st 2021, and September 1st 2021, I sourced the data from the California Open Data Portal, a state government website where data from state agencies is located, with this data in particular specifically under the section of COVID-19 Vaccine Progress Dashboard (California Department of Public Health, 2023). This data, in turn, was originally collected by the California Department of Public Health. It was on this website, where I found the data section for the COVID-19 vaccines total for the counties on each exact day and cumulatively.

After I retrieved the data from there for each county for the dates of March 1st and September 1st, 2021, I divided the total cumulative number of vaccines by that day by the population estimates for each county for 2021, then multiplied the results by 100 so that I was able to get the percent vaccinated rate for each county up until then. This process was done to collect the vaccination data for both March 1st and September 1st, 2021, and the data for both was collected from the same source. The reason why the March 1st data was included too, even though there would be no measurable change in physician density over 6 months, was to contrast the September data regression with that of the March vaccine data.

For the controls used in this study, while the main point of this study was to analyze the relationship between vaccination rate and physician density rate for each county, data was also collected. In total, data was collected for five controls for each California county, which in turn was used to run the regression to find the percent of the relationship explained by the physician density rate on the vaccination rate. Those four variables that ended up being analyzed for this study were the percent of each county that voted for Donald Trump in the 2020 election, median household income per county as of 2021, the percentage of each county's population over the age of 65 and the median education level for each county. Overall each of these variables was chosen and analyzed as a control due to the believed importance of each of these on vaccination rates.

To gauge partisanship, which in the context of this paper is important due to the polarized nature of the COVID-19 Pandemic, data was collected of the presidential vote percentage for both Joe Biden and Donald Trump during the 2016 election to gauge partisanship for either the Democratic or Republican parties. When it came to finding the county presidential vote, the Presidential vote data for each county was sourced from the Politico.com 2020 presidential

election site for coverage of California's results (Politico,2020). Data for several counties, particularly Alameda (ACvote,2020) and Alpine counties (Alpine County.CA, 2020) was contrasted first with each of their county's respected election sites to compare accuracy.

Since the Politico Trump, Biden vote percentage for each of those counties was the same as each of those county's election sites, with the exception being the vote for each of the counties on Politico was rounded to the second decimal place, the Politico election site was used for the vote data. Also, since the percentage for each county was already calculated, the data after collection was just put into my chart in once written down. While data for Biden was taken initially, it was not included in the OLS regression since the vote would most likely be only the inverse of the Trump vote, and the Trump vote mattered most due to the partisan nature of COVID-19 vaccines and policies during the pandemic.

For the median income per household, this variable is nothing more than the median household income in each of the 58 Californian counties in 2020. This variable, was included as a control due to the belief that wealthier places are more likely to afford to get vaccinated since they should have fewer barriers preventing them from getting vaccinated, such as being able to afford a ride to a physician's office or vaccination site. This data in turn was simply collected from the U.S. Federal Reserve Economic Department, or F.R.E.D., which has the median household income available for each of the respective counties as of 2021 (FRED,2020). The median income per household was chosen as opposed to the median income per individual since I could not find the median per individual. Once it was collected it was simply put down in my chart for each of the respective Californian counties where it was included in the regression after that.

Regarding the median education level variable, this variable is simply the 5-year estimate of the percentage of people in each county that have obtained a bachelor's degree as of 2020. This data was also sourced from the same place as the previous variable, the U.S. Federal Reserve Economic Data (FRED,2020). This data was included because of the existing relationship between education attainment and vaccination rate.

The last data variable collected and used for the control was the percentage of each county's population over 65 years old, simply the percentage of each county's population over 65. This variable was included because people over 65 on average have higher COVID-19 mortality, hospitalization, and vaccination rates, which might have potentially affected the data. The data for this variable was sourced from the U.S. Census Bureau's website.

RESULTS

In this section of the paper, I will go over the results of the regression run for the paper as well as the implications for the results. Once the vaccination data for September 2021 and the control variables were run in the OLS regression several interesting results were noticed. Arguably the first and most important thing that the data revealed was the coefficient for physician density and vaccination rate relationship. Looking at the initial regression coefficients seen in Figure 1, the coefficient for Phsycian density and vaccination rate is large at 3.73. This coefficient is a strong positive coefficient, which implies that for every 1 percentage point increase in COVID-19 physician density rates, there is a roughly 3.73 percent increase in vaccination rates. This strong coefficient is an important data result since it implies that the hypothesis appears to be true and that physician density is positively related to vaccination rates.

vaccinerateseptember1st2021	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
physcianpercapita2021per1000roun	3.732681	1.55036	2.41	0.020	.6216554	6.843706
medianeducationlevelwithatleastb	-.0251519	.1811048	-0.14	0.890	-.3885652	.3382614
percenttrump	-.5756503	.0906117	-6.35	0.000	-.7574759	-.3938246
estimatedmedianhouseholdincome20	.0001071	.0000782	1.37	0.177	-.0000498	.000264
percentover65	.0512206	.1636223	0.31	0.756	-.2771116	.3795529
_cons	68.76287	6.915191	9.94	0.000	54.88652	82.63921

Figure 1 . September 2021 Vaccination Data Regression

Interestingly, regarding the regression data for March 2021, the data shows just like with the September 2021 regression that there is a strong positive relationship between physician density and vaccination rate with a coefficient of 1.65, as seen in Figure 2. While both regressions have a strong regression, what is interesting is that the regression for March 2021 shows the regression having a weaker regression strength than the later regression. This data revelation is interesting since I would have assumed that the regressions would have been roughly the same. This is something that I can not explain why it might be the case. However, fact that both regression have this strong of a coefficient further provides proof of the hypothesis validity since this is another data source that backs it up.

vaccineratemarch1st2021	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
physcianpercapita2021per1000roun	1.651178	.7753511	2.13	0.038	.0953224	3.207034
medianeducationlevelwithatleastb	.068808	.0905723	0.76	0.451	-.1129387	.2505548
percenttrump	-.1452375	.0453158	-3.21	0.002	-.2361704	-.0543047
estimatedmedianhouseholdincome20	-.0000197	.0000391	-0.50	0.616	-.0000982	.0000587
percentover65	.5065487	.0818292	6.19	0.000	.3423464	.670751
_cons	11.44565	3.458358	3.31	0.002	4.505942	18.38535

Figure 2. March 2021 Regression Data

Another interesting result that the regression data provided was that besides the coefficient for physician density and the vaccination rate, another variable had a strong

coefficient. The variable in particular that had the strong coefficient besides the main coefficient, was the relationship between the 2020 Trump vote and the vaccination rate. Specifically, the regression data showed a coefficient of -0.57, which implies for every one percent increase in the physician density rate there appears to be a 0.57 decline in the vote share for Donald Trump. This relation is considered a moderately strong, weak correlation. While that data revelation does not surprise me, because areas that have higher physician density and vaccination rates on average are wealthier and more liberal than rural areas which are the main source of Republican support, what does surprise me is the strength in the relationship.

Comparing that to Figure 2, which compares the regression data from March 2021, that negative Trump relationship is there, however, it is not nearly as strong with only a -0.14 coefficient. My opinion for why that is the case is since more people were getting vaccinated numerically in cities, it resulted in the relationship not being as strong as later when most of the unvaccinated areas were predominantly rural.

Yet another unexpected result that the data revealed was an unexpected initial relationship between the physician density rate and the percentage of a county's population over 65. Looking at that initial graph, in Figure 3, the graph line of best fit seems to imply there is a minor negative relationship between physician density and vaccination rate.

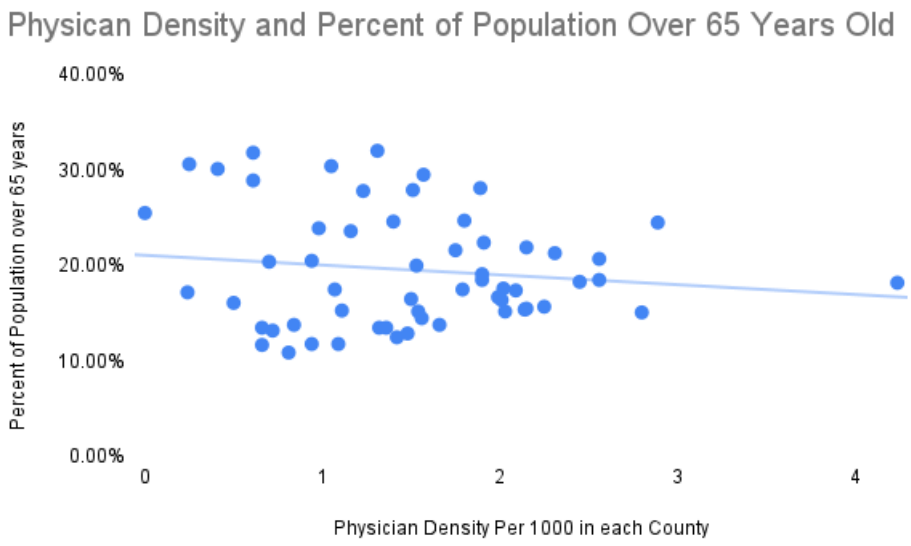

Figure 3. Relationship of Physician Density and Population over 65 Percentage

This result is surprising because people over the age of 65 are significantly more likely to die or get hospitalized from COVID-19 than any other age group, with over 80% of all people hospitalized for COVID-19 in 2021 and them being 23 more times to die from it, according to a paper in the Impact Journal on Aging (Mueller et al, 2020) and yet this relationship existed. Even when so many precautions were taken to ensure as many vulnerable people were vaccinated too. A potential reason for this could be that since most people of advanced age were vaccinated earlier, it could be due to the lack of many of those who have not been vaccinated yet that the relationship is weaker. However, once the data was imputed into the regression, like believed there was a positive relationship, which had a coefficient of 0.05 which is weak and positive.

Comparing these results to the data from the March 2021 regression data, there was a major difference. Unlike the September 2021 regression data, the March 2021 data, shown in Figure 2 does show a strong, moderate relationship between physician density and population

over 65. This very much contrasts with the September regression data which shows a very weak relationship. My hypothesis why this is the case is that even though rural areas have a higher older population percentage, numerically the majority of those who wanted the vaccine that were of that age received it, thus resulting in fewer people of that age receiving it and the relationship weakening.

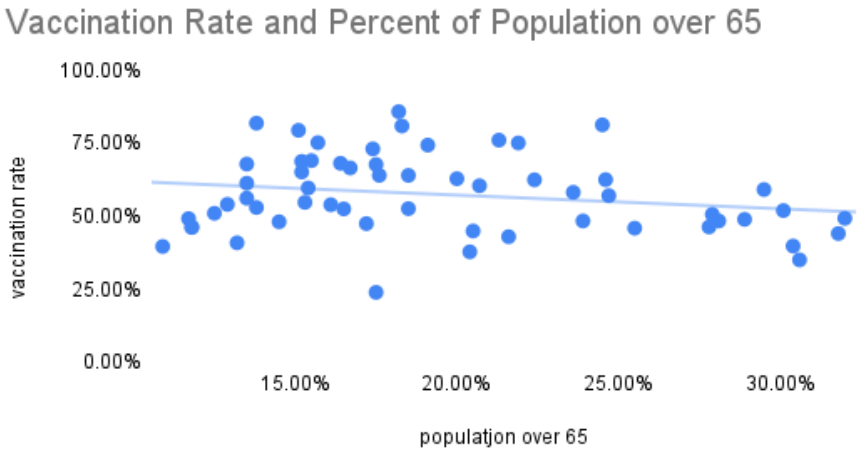

Figure 4. Relationship of County Portion of Population Over 65 and Vaccination Rate

Regarding the relationship between the population over 65 and the vaccination rate, as seen in Figure 4, it is clear that there is a slight negative relationship, which is interesting. Considering what was said earlier, regarding how during the pandemic the federal government and state governments emphasized and tried to encourage more at-risk seniors to get vaccinated it is an interesting discovery that counties that appear to have more people of advanced age appear to have slightly lower vaccination rates. My hypothesis for this relationship is that this is

the case because of aspects of rurality such as higher poverty rates, greater distance to physicians' offices, and higher amount of older residents result in this situation.

Another thing that the September regression data revealed was that the relationship between median household income and its coefficient for its effect on the relationship between physician density and vaccination rate was minor. Specifically, the data revealed that the effect of median household income contribution to explain the change in the vaccination rate is 0.0001. This coefficient while very weak, does imply that the relationship of median household income on physician density and vaccination rate is very weak, positive one, and overall has almost no impact on the vaccination rate. This very minor positive relationship for the September regression contrasts to the March regression relationship of -0.00001, seen in Figure 2, which implies that in early 2021 like late 2021 there was nearly no relationship between counties' vaccination rate and median household income. My belief that this is the case is that during the COVID-19 Pandemic, the U.S. Federal government doing as much as it can to ensure that everyone had access to the vaccine by making them free, according to the Centers for Medicaid and Medicare Services (CMS, 2021).Had the federal government and state governments not made the vaccines free in turn the data would have shown median income having a stronger effect on vaccination rates since the vaccines having a financial cost would have made it difficult for many to receive for financial reasons.

The last thing that the regression data revealed had to do with the education level rate effect on the physician density and vaccination rate. Looking at the September regression data, there appears to be a coefficient of -0.025 for the relationship between the vaccination rate and the education level. This relationship is interesting because I would have assumed there would be

a positive correlation, studies such as a study in the European Journal of Pediatrics, people with a higher level of education are more likely to get themselves and their families vaccinated (Scharff et al, 2021). On top of that the fact that it is a negative relationship, implies that every 1 percent increase in the physician density rate results in the education level declining by 0.025. This -0.25 decline compares to the positive 0.06 relationship between vaccination and education levels when looking at the March regression data, according to Figure 2. My hypothesis for this might be the case is that those with a higher degree of education would have already been the most likely to have received a vaccine, which would result in those who have not had the vaccine yet being more likely to have lower education levels, thus resulting in a negative relationship.

CONCLUSION

With every piece of data used in this study analyzed via an OLS regression line, the results of the study do seem to be promising. The data with its high coefficient seems to support the hypothesis that there is a strong, positive relationship between physician density and COVID-19 vaccination rates in the state of California during this period. On top of that some of the results of the study, such as the weak relationship between older Californians and vaccination rates, as well as the great difference in vaccination rates in rural and urban areas. The results data hopefully provide evidence that could help influence policymakers and researchers about the relationship between physician density and vaccination rates. However, with all of that said since this is one study, on a topic that has not been well-researched I would suggest that the results are taken with a degree of skepticism. Even though it appears to be the case that physician density is

related to vaccination rates and that the hypothesis appears to be true, there are still caveats that could be affecting the data in unknown ways.

One example of a caveat that could be affecting the results is that this study is only limited to 58 counties, which might seem like a fair amount for a study, however, there is a chance that since it was only 58 counties in California, which is only a small amount of the counties in the country, there is a chance that there not have been enough data collected for the results to be accurate. Another potential caveat is that the results of this study might be off due to other unknown reasons or variables that may not have been collected in the study. On top of that, the results of this study may differ from other states because California is not demographically or economically reflective of the U.S. as a whole.

Lastly, with all of the caveats and results mentioned, when it comes to suggestions for future research and for the state to implement I can think of several. In regards to the state of California, I would suggest creating a plan to be able to better educate and inform rural residents of the efficacy of COVID-19 vaccines as well as locations to receive them. I also would suggest that the state government create a plan to be able to better increase accessibility to vaccines and physicians who provide them as well to ensure that rural residents have access to vaccines to begin with. Regarding future research, I suggest any study done to include data from more than 58 counties, to improve the accuracy as well as other variables used in the control that may not have been included in this study. Lastly what I suggest is that all of the data from this study is taken with a grain of salt since this appears to be one of only a few studies to research this trend and topic and not be surprised if the results for some reason are different from this study.

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