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Social Factors Involved in the Morbidity and Mortality of COVID-19

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COVID-19 in Piura, Peru

The northern region of Peru has been significantly impacted by the global COVID-19 pandemic, causing significant harm to those residing in this region. Disease burden, as indicated by factors including morbidity and mortality, has been substantially higher in northern Peru than in other regions within the country, with mortality rates in some districts reaching as high as 25%. Our organization, EcoSwell, has set out to determine the cause of heightened disease burden in Northern Peru in order to establish a foundation for creating informed prevention strategies for COVID-19. EcoSwell is a non-governmental organization located in the northern coastal region of Piura, Peru, with the purpose of aiding in sustainable development in vulnerable populations. COVID-19 has proven to be particularly harmful in vulnerable populations such as those with which we work. Because of the high presence of vulnerable populations and heightened disease impact in Piura, this region provides a strong case study for understanding the social factors involved in the transmission of COVID-19.

In this study, we utilized a combination of quantitative and qualitative research methods to understand the role of social factors in the disease burden of COVID-19, specifically focusing on government expenditure, population density, and poverty level in Piura, Peru. Using these methods, we discovered significant correlations between COVID-19 disease burden and government expenditure per capita, as well as between COVID-19 disease burden and population density. Furthermore, we identified how state institutions have acted in response to COVID-19 in Piura, and concluded that state-implemented methods of mitigating the disease burden do not address the needs of the region's most vulnerable populations.

It is our intention that the correlations found in this study, as well as the qualitative information gathered, can be used to inform institutional responses to COVID-19. It may be necessary to modify current responses in order to reduce global disease burden. Implementing suggestions derived from our data may create a more effective preventative system for COVID-19, and aid in the recovery of harshly affected regions around the globe.

Role of health expenditure and population density in disease transmission

Spending on public health plays a large role in the global persistence of a disease. One of the biggest causes of disease outbreaks can be attributed to a lack of public health infrastructure (Bogich, 2012), which is often caused by a lack of spending. Generally, disease spread is driven by underlying socioeconomic factors (Jones, 2008), including monetary investments in public health infrastructure. When more money is invested proactively into public health infrastructure rather than reactive spending on a disease during an outbreak, preventative methods typically prove to be more effective. In fact, creating stronger public health infrastructure through increased spending limits pathogens from becoming pandemic (Bogich, 2012). This is especially relevant in regards to the COVID-19 pandemic. If additional investment in public health infrastructure had occurred prior to the beginning of the pandemic, the likelihood of the novel virus becoming a pandemic would have decreased.

In addition to government expenditure, population density also has a large role in the disease impact of COVID-19. Mathematical disease modeling for other air-borne diseases has

shown that during times of general activity, disease transmission follows a density dependent pattern (Hu, 2013). As the population density of a location increases, the likelihood of disease transmission increases as well. Eventually, disease transmission reaches a saturation point and becomes frequency dependent rather than density dependent. This, however, is only the case for events with extremely dense populations such as a concert and does not apply to typical daily activities. In the case of COVID-19 in particular, we likely are not seeing the spread of the disease reaching the frequency-dependent stage due to the various globally enacted social distancing mandates, which limit social interaction to general activity with few high-density events. In fact, for COVID-19, this factor of population density holds true; densely populated locations are more apt for spreading disease, as contact with infected individuals is proportional to population density (Rocklöv, 2020). The spread of COVID follows the formula

$$\beta = \tau c$$

where β , the daily reproductive number of the virus, is equal to transmissibility (τ) multiplied by the contact rate (c) (Rocklöv, 2020). The growth of the virus in a population increases linearly with contact rate, and thus is proportional to population density.

Additionally, the World Health Organization (WHO) has stated that individuals should remain at least one meter apart from each other in order to prevent the spread of COVID-19 through aerosol droplets. In urban areas with higher population density, it is much more difficult to maintain one meter of distance than in areas with low population density. Furthermore, recent research has indicated that one meter is not enough physical distance to effectively prevent the disease. The need for additional distance to prevent the spread of COVID-19 makes maintaining space in an area with high population density even more difficult.

Research methodology: understanding disease spread through official government statistics and empirical data

Historically, the northern region of Peru has been significantly impacted by various disease outbreaks. During the El Niño weather event of 2017, northern Peru experienced uncharacteristically high numbers of Dengue cases as compared to other regions. Once again, the northern region of Peru is showing a tendency of higher fatality rates due to COVID-19 than other regions within the country. Because of this region's tendency for severe disease outbreaks, we decided to use databases from Peru's Ministry of Economics and Finance, the National Institute of Statistics and Informations, and the Ministry of Health to collect data on these two outbreaks. We used the quantitative data from these databases to look for statistically significant correlations between social factors and disease impact of both diseases using Pearson's Correlation Coefficient with a P value of 0.05 to test for significance. We utilized this information to establish patterns in social factors that may lead to overall worsened disease burden, however we found that these two diseases display disparate patterns.

COVID-19 is transmissible between humans via respiratory droplets, whereas dengue is a vector-borne disease and thus is not transmitted between humans. Due to these distinct

patterns of transmission, the diseases appear to have different social and political factors involved in their transmission. During our preliminary variable selection, there appeared to be strong negative correlations between COVID-19 mortality and government expenditure per capita on COVID-19, as well as between COVID-19 mortality and poverty level. There also appeared to be a positive correlation between COVID-19 mortality rates and population density. These correlations were not present in the data from the 2017 Dengue outbreak. Due to the gravity of the COVID-19 pandemic, we decided to narrow the scope of our research to focus solely on the social factors acting on COVID-19.

As our organization is located in Piura, Peru, we decided to focus our research efforts on this region. EcoSwell has a pre-established medical electives program with two local medical centers, so tailoring our research to the area in which these medical centers reside allows us to quickly apply the information we gathered in conjunction with the medical centers. We chose to look at the region on a district level because our research has a strong focus on the efficacy and distribution of public expenditures. Using this scale mitigates the potential confounding factors that may occur while analyzing data from different regional governments. Looking at a region under the same governance eliminates differences in policies put in place by different administrations. Looking at the region on a district level also allowed us to obtain a statistically significant sample size ($n > 30$), as there are 65 districts within the region of Piura.

Additionally, we gathered qualitative data by interviewing two physicians located in the region of Piura. Both physicians interviewed are the medical chiefs of staff in their respective medical centers and therefore are representatives for the Ministry of Health. One physician, Hugo Albán, works in the hospital of the semi-urban city of Talara. The other physician, Luisa Cosio, is the head of the rurally located Lobitos medical post. We conducted 40-minute phone interviews with both physicians, using a predetermined discussion guide. The discussion guide was created using our quantitative data analysis, in order to confirm the statistical results with the first-hand experience of the physicians. It contained questions designed to address the physicians' experience with transmission of the disease throughout Piura, as well as their experience receiving public aid and funding.

Results: social factors involved in the spread of COVID-19

During our statistical analysis, we looked for correlations between social factors and COVID-19, using both morbidity and mortality as indicators for the disease burden. We focused on the parameters of government expenditure per capita, population density, and poverty rate as our social factors. The government expenditure per capita was found using government data on COVID-19 spending by district. As an index for the poverty rate, we used the percent of a given district's population under the poverty line, percent of population with access to running water seven days a week, and percent of population with a refrigerator as indicators of poverty. Using these parameters, we found there to be a moderate positive correlation between population density and morbidity ($R = 0.481$) that was statistically significant, however there did not appear to be a statistically significant correlation between population density and mortality in the region. This means in locations with higher population density, there is a greater likelihood

of finding individuals infected with COVID-19. Even so, an increased population density does not appear to have any effect on the mortality rate of the disease.

We also discovered there is a moderate negative correlation between government expenditure per capita and COVID-19 morbidity and mortality ($R = -0.499$ and -0.432 , respectively). These correlations signify that government expenditure and disease burden have an inverse relationship, where increased spending on the disease causes a decrease in disease burden. These correlation coefficients proved to be statistically significant with P values far less than 0.05. However, when the database was extended to include districts from two other surrounding regions, Lambayeque and La Libertad, these correlations did not hold true. This may be indicative of the role of regional governance in the prevention of the disease.

Interestingly, we found there to be a moderate negative correlation between poverty level and COVID-19 morbidity ($R = -0.676$), although there was no correlation between poverty level and mortality rate. This correlation can likely be attributed to the location in which impoverished populations are located in Piura. There is a negative correlation between population density and poverty level, meaning those in poverty most frequently live in rural areas where individuals would have less contact with others. Additionally, our qualitative data suggests this correlation may be related to a lack of access to COVID-19 testing in rural regions. Although our correlations dispute the impact of poverty on disease burden, the information we gathered from local physicians says otherwise. Limited access to testing likely has had a large effect on the official statistics gathered. Doctor Luisa Cosio from the Lobitos medical post claims she has seen more COVID-19 patients from impoverished communities than more affluent areas nearby, stating that:

“The majority of patients treated here... come from a place of extreme poverty”¹

This disparity between the government statistics and experiences of medical professionals in the region is likely due to the limited testing available. In the province of Talara, access to testing has been extremely limited and inefficient in rural and urban areas alike. The urban hospital for the city of Talara has only received approximately 300 test kits from the government for a population of approximately 91,000 people. The medical post for the district of Lobitos, a rural area located within the province of Talara, did not receive any test kits until June of 2020. This was three months after the first cases of COVID-19 reached Peru, and two and a half months after Peru went into a country-wide shelter-in-place order.

A barrier that prevented the Lobitos medical post from receiving tests was providing proof that tests were necessary. In order to receive test kits from the government, the medical post needed to obtain proof there had been positive cases of COVID-19 in the area, however the post was unable to provide proof of positive cases without receiving test kits from the government to test individuals with COVID-19 symptoms. When the medical post finally received aid, it was not managed in an effective way by the government. The Lobitos medical post became part of testing campaigns where large scale testing was done in short periods of

¹ Original quote: “La mayoría de los pacientes que tratamos acá... vienen de lugares de pobreza extrema”

time. All individuals within the area had access to testing during the campaigns, however the campaigns were short lived and testing would become limited once again after the campaign had finished. This method of testing has been ineffective, as it has not allowed individuals who are displaying symptoms to get tested after the campaign ends. Having short lived campaigns and limited access to testing during a large portion of the pandemic has potentially caused rural areas to report significantly lower numbers of cases than what is actually occurring.

Lack of access to consistent and effective testing also has continued to harm the wellbeing of those infected with COVID-19, even after they have recovered. People who have had COVID-19 in the past are being marginalized and ostracized from their communities due to their health status. In Lobitos, the majority of the population works for the municipality in temporary, manual labor positions. In order to be employed by the municipality, individuals who have had COVID-19 are required to obtain a medical report that shows they no longer are infected before being allowed to return to work. As tests are already limited, it is difficult for individuals to access additional testing. Furthermore, the rapid diagnostic tests that are the least expensive and most readily available show a positive result even once the infected individual has recovered. Because the test displays a positive result even after recovery, individuals who have had COVID-19 in the past are having trouble accessing the job market. The methods of mitigating the impact of COVID-19 that have been implemented in Piura have not provided aid to the most vulnerable of populations.

Individuals living without support systems, such as those living without family members, are among those most vulnerable to COVID-19. With no outside support, these individuals risk more exposure to COVID-19 as they are required to continue working in order to financially sustain themselves. In order to mitigate the pandemic's financial strain on the population, the Peruvian national government created an aid package that gave stimulus checks to citizens. Although beneficial in theory, this form of aid actually may have contributed to worsening the impact of COVID-19. Doctor Hugo Albán of the Talara medical center postulates,

“If we consider that the majority of people do not have bank accounts, then the government gives them a bonus, in order for them to [receive] this bonus, they have to appear at the banks in person.”²

Due to the fact that most individuals living in Piura do not have bank accounts, they must physically go to the bank to receive a stimulus check. This undermines the shelter-in-place order given by the government and forces individuals to increase their potential exposure to the disease. With a lack of strong financial infrastructure in the rural regions of Peru, the process of receiving stimulus checks could have exposed more individuals to the disease, and thus worsened the disease impact.

Physicians at the Lobitos medical post and Talara hospital both gave similar critiques to the government aid response during the pandemic; the aid given was supposed to benefit the people, however, the government overlooked the issues faced by the most vulnerable of

² Original quote: “Si consideramos que la mayoría de personas no tienen cuentas bancarias, entonces el gobierno les da un bono, pero para que puedan [obtener] este bono, tienen que apersonarse a los bancos”

populations. In addition to potential exposure while receiving a stimulus check and lack of access to testing during the peak of the pandemic, the government aid package also overlooked other common issues faced by vulnerable populations. Among this is access to a refrigerator for food storage. In Piura, well under 70% of the population has access to a refrigerator, with some districts being as few as 10%. Individuals without access to a form of long-term food storage are required to leave their homes frequently to purchase food, thus increasing their potential exposure to COVID-19 infected individuals. A potential solution for this, as suggested by one of the physicians, is to provide food delivery for the most vulnerable of populations, however this is only possible if the focus of government is shifted to this vulnerable group.

As government aid has fallen short of being effective, private organizations have begun to fill in where national aid is lacking. Medical professionals from both the medical post in Lobitos and the hospital in Talara have reported receiving more aid from private organizations than their governmental counterparts. The Talara hospital received more COVID-19 test kits from the private companies of INEL and Petroperú than from the national government. In Lobitos, the medical post received aid donations from non-governmental organizations such as the civil association Unámonos Lobitos as well as the local churches. Without these outside forms of aid, the level of preparation for handling COVID-19 in Piura would have been even less sufficient than it is today. In many ways, the Peruvian government is overlooking its most vulnerable populations when finding solutions to the COVID-19 pandemic, and frankly may not even know how to give aid to these groups.

Discussion: the potential roles of poverty and local governance

When looking at the relationship between social factors and COVID-19, there were statistically significant correlations in the region of Piura, however when the scope of the data was widened to include the coastal regions of Lambayeque and La Libertad, these correlations no longer held true. The research suggests this may be due to differences in local governance, rather than an issue with the correlations. It is likely that if the regions of Lambayeque and La Libertad were studied discretely, each would show similar correlations between COVID-19 cases and population density or government expenditure as seen in the region of Piura, simply on a different scale. Differences in local legislation in response to the disease likely cause a shift in the number of cases in each region, and the number of cases would need to be normalized in order to compare across regions. The necessity for normalization could be mitigated by looking at each region discretely, and then comparing the correlations found in each location. A source of future analysis could be to analyze the role of local governance in the transmission of diseases. It appears highly likely that local government plays a significant role in the mitigation of disease burden in the case of COVID-19.

Further studies should also be conducted on how disease burden is impacted by poverty. One of our initial hypotheses was that higher rates of poverty would be correlated with higher rates of COVID-19, however the data did not suggest this to be true. All indicators of poverty, including access to running water every day of the week, having a refrigerator within the home, and the percent of the population below the poverty line, actually showed a negative correlation or no correlation with COVID-19 morbidity and mortality. This indicates that places

with more poverty actually have less cases of the disease. This result comes as a surprise, as poverty is typically positively correlated with worsened disease burden and medical staff in the region anecdotally have seen a positive correlation between poverty and the occurrence of COVID-19. One factor that may influence these results is the scale at which the data was analyzed. This study looked at poverty by district, but a district scale may be too large to fully understand trends. Within a district, there likely is a large range of poverty levels between households that become averaged when using a district-level scale. In order to effectively see the role of poverty in the disease burden of COVID-19, future studies should use a smaller geographical scale. It would be beneficial to look at poverty by blocks, or even on the basis of household rather than by district.

It is also highly possible that the correlation between COVID-19 disease burden and poverty is in part due to the relationship between poverty and population density in Peru. Impoverished communities tend to be located in rural areas, resulting in a lower population density in these communities. It appears that population density is a larger factor in the disease burden of COVID-19 than poverty, however this is a claim that needs to be studied more extensively in further research studies. Additionally, limited access to testing in rural areas likely has a role in the correlations suggested by the data. Without prompt and reliable access to testing in rural areas, the official COVID-19 numbers may not be reflective of the severity of the disease.

Key findings and final recommendations: strengthening preventative measures for COVID-19

As limited access to testing indicates, the governmental response to COVID-19 in Piura has not addressed the needs of its vulnerable populations. In order to provide effective mitigation to COVID-19 disease burden, the national government must address all the factors at play in the transmission of the disease. This includes understanding how to provide aid in a population without access to refrigeration or bank accounts. Our study has found that government expenditure is negatively correlated with disease burden, which may provide a starting point for addressing the needs of vulnerable populations. We also found a positive correlation between population density and COVID-19 morbidity, which should be addressed while implementing remediation measures.

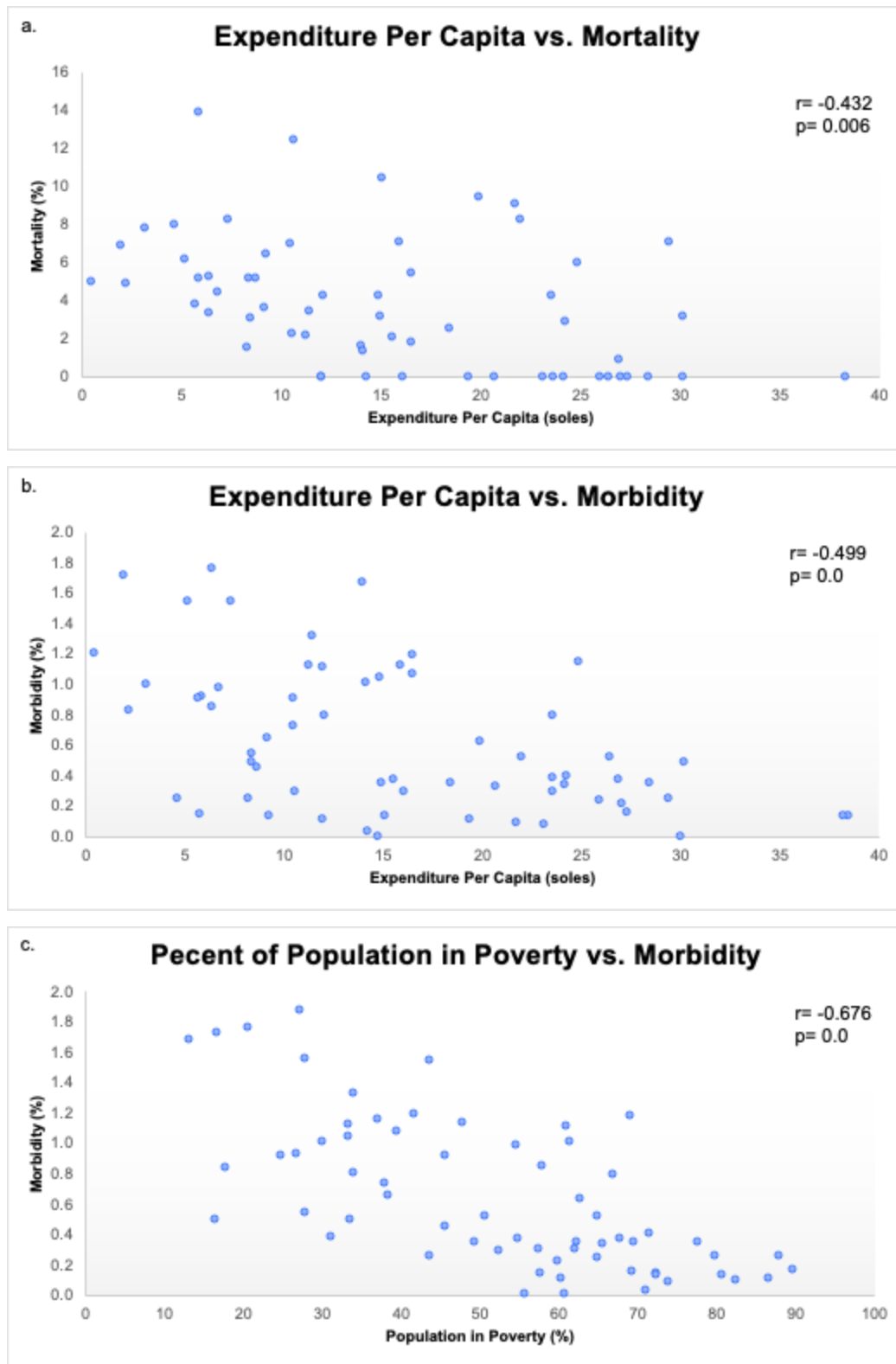
It is our intention that the correlations found in this study, as well as the qualitative information gathered, can be used to inform institutional responses to COVID-19 in order to protect vulnerable populations. Additional spending in particularly vulnerable areas may be a solution to help mitigate the impact of COVID-19. Understanding the needs of these populations and the areas in which they reside is crucial when creating preventative policies. Although the data collected in this study provides a basis for understanding the impact of COVID-19 in Piura, further studies need to be conducted to strengthen this foundation. This is particularly true surrounding the role of regional governance and poverty levels on disease burden. Further studies should be conducted to see if these correlations hold true in different regions while normalizing for variance created by different administrations. Furthermore, this study can be replicated and applied globally to aid in the prevention of COVID-19. Additional research also

should be conducted to understand the role of poverty in disease burden, using blocks or individual households as a geographical scale. Understanding these factors will strengthen the foundation for addressing COVID-19 in order to optimize aid distribution and the implementation of preventative measures globally.

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Appendix I



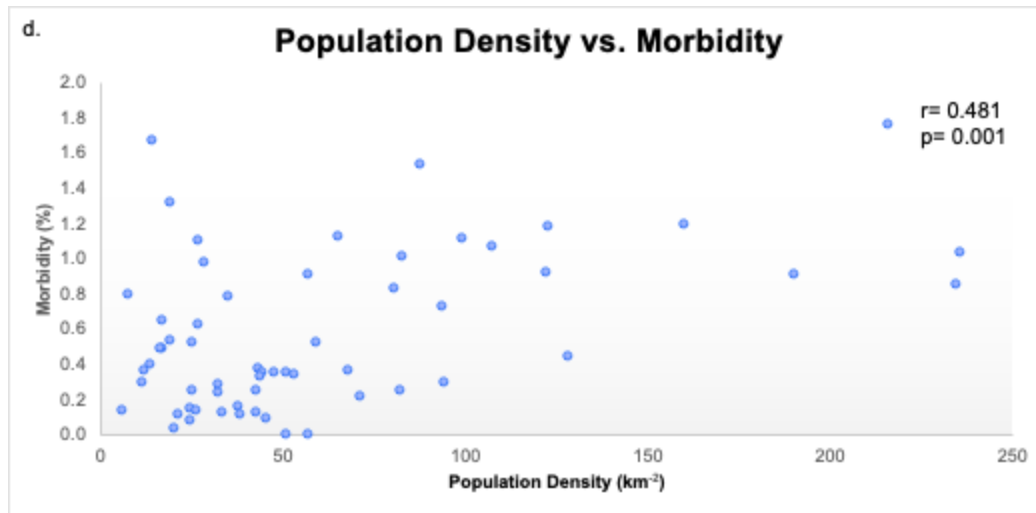


Figure 1: Graphs showing various social factors versus indicators of disease burden by district in Piura, Peru as of June 17th, 2020 with Pearson's correlation coefficient r and p values shown in the top right corner. a.) Expenditure per capita in soles versus COVID-19 mortality. b.) Expenditure per capita in soles versus COVID-19 morbidity. c.) Percent of population under the poverty line versus COVID-19 morbidity. d.) Population density versus COVID-19 morbidity.

Indices tested	Pearsons's Correlation Coefficient (r)	P-value
Government expenditure versus COVID-19 mortality	-0.432	0.006
Government expenditure versus COVID-19 morbidity	-0.499	0.000
Population density versus COVID-19 morbidity	0.481	0.001
Percent of population in poverty versus COVID-19 morbidity	-0.676	0.000

Figure 2: Correlations between indices of COVID-19 disease burden and poverty level, population density, and government expenditure.

Appendix II

Discussion guide: Spread of COVID-19 in Talara, Piura

Objective: Test our hypothesis that urban environments have a greater propensity for spreading COVID-19 and greater levels of spending reduces the spread of COVID-19.

Warm up questions

How long have you been a doctor? Do you have a speciality?

Have you always worked in this medical post/hospital or have you worked in others too? Why did you choose to work in this hospital specifically? Do you have ties to this area or did you choose to work here for other reasons?

How many patients do you see on a normal day? Have you had an increase in the number of patients you see recently? Is it because of COVID-19?

How many of the patients that you see have COVID-19 related concerns?

PUBLIC EXPENDITURE AND AID

Objective: Evaluate the effect of public expenditure and aid in the transmission of COVID-19

- **AMOUNTS:** How much aid has your hospital/medical post gotten from the regional government? And from other institutions?
- **PROCESS:** When did you get the aid? Has the process of getting aid been efficient and effective? Why or why not?
- **SUPPLIES:** What forms of aid have you received so far? Which specific supplies did you receive or purchase? Why?
- **PREPAREDNESS:** Have you received enough aid to obtain all the supplies necessary to protect and treat both hospital employees and patients?—What aid do you still need in order to effectively prevent and treat the virus? Are the medical posts sufficiently staffed to treat the number of cases they are receiving? Why?
- **POLICIES:** Do you feel the way that the central government has managed COVID-19 related policies, such as, access to stimulus checks, has been beneficial or detrimental to the spread of the virus? What other policies could have affected the spread of the virus? How so?
- **DISTRIBUTION:** Has the funding for district medical posts been evenly distributed? Or are some districts getting more aid than others? Does the distribution vary between regions? What is this dependent on?

SPREAD OF THE VIRUS

Objective: Identify causes for faster spread of COVID-19 virus and the role that population density plays in the region.

- **ENVIRONMENT:** What type of environment do most of your COVID patients come from? Is it a rural or an urban environment? Do you think this matters when talking about COVID-19 spread? Why?
- **SOCIAL PROFILE:** Do most COVID patients have a certain home structure, occupation, income level or medical history or not? Do you believe social profile matters when talking about COVID-19 spread? Why?
- **QUARANTINE:** For individuals living in Piura, is quarantining feasible or not? How likely is it that patients with symptoms are actually able to self isolate? What about patients without symptoms? Why? What needs to be implemented in order for patients to effectively self-isolate?
- **TRANSPORT:** How are people getting to the hospital? Is there public transportation to the clinic where patients would potentially expose other community members?
- **TESTING:** How accessible is testing for COVID in Piura?
- **INSTITUTIONAL RESPONSE:** How quickly and effectively are the government officials and public servants in Piura responding to the virus? Does this vary by district?