Estimation of all-cause excess mortality by age-specific mortality patterns of COVID-19 pandemic in Peru in 2020

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# Summary

## Background

All-cause excess mortality is a comprehensive approach for estimating the direct and indirect effects of COVID-19 on mortality. Estimates are usually derived from Civil Registration and Vital Statistics (CRVS) systems, but these do not include non-registered deaths, which may be affected by changes in mortality registration coverage over time.

## Methods

We use negative binomial regression models to estimate excess registered mortality in Peru during the first wave of the COVID-19 pandemic during 2020. We use logistic mixed-effects models to estimate the completeness of the new online registration system (SINADEF) at this time.

## Findings

We estimate national under-registration of mortality to be 28.4% (95% CI 27.8% - 28.3%). We estimate total all-cause excess were registered during the period of analysis to be 153,832 (95% CI 129,070 - 161,454) of which 110,113 (95% CI 93,248 - 115,769) are excess registered deaths. Mortality in people aged 60 years and over accounts for 75.9% (95% CI 75.2% - 85.9%) of total excess deaths for both models, while there were fewer deaths than expected in younger age groups. Lima region, on the Pacific coast and including the national capital, accounts for 78,366 (95% CI 77,116 - 79,472) excess deaths, while the regions of Apurimac and Pasco, in the Andes, account for less than 400 deaths.

## Interpretation

Estimating excess mortality in low- and middle-income countries (LMICs) like Peru must take under-registration of mortality into account. Combining demographic trends with data from administrative registries reduces uncertainty and measurement errors. In countries like Peru, this is likely to produce significantly higher estimates of excess mortality than studies that do not take these effects into account.

## Funding

None.

# Research in context

## Evidence before this study

We searched PubMed, Google Scholar, medRxiv, and SocArXiv for studies published up to December 08, 2020, using the key words “excess mortality” and “under-registration” or “subregistration,” combined with “coronavirus” or “SARS-CoV-2” or “COVID-19.” We found studies estimating cumulative mortality in high-income countries in Europe and North America solely based on official death counts. We found few studies computing overall COVID-19 mortality in LMICs. Prior research shows a significant percentage of under-registration of deaths in LMICs.

## Added value of this study

To our knowledge, we provide the first estimate of excess mortality associated with COVID-19 in a LMIC accounting for both registered and unregistered deaths. We develop an analytical strategy to address common challenges faced by LMICs, such as low completion rates of death certificates, missing data, inconsistency and variability of data across regions and age groups.

## Implications of all the available evidence

Our approach shows the importance of accounting for unregistered deaths based on demographic trends to generate robust estimates of excess mortality associated with COVID-19. It suggests that previous reports of COVID-19 related mortality in Peru were substantial underestimates.

# Introduction

Monitoring mortality is an essential part of the public health response to the COVID-19 pandemic. In many countries, robust COVID-19 mortality measurement and estimation have been hindered by shortcomings in diagnosis and attribution of cause of death, as well as incomplete registration of general mortality.1 Disentangling the contribution of COVID-19 to overall mortality is especially challenging, as many people who die from COVID-19 have other conditions, such as cardiovascular disease and diabetes.2 A further complication is the decision of some countries to apply an arbitrary maximum cut-off time between a positive COVID-19 test and death when deciding whether to attribute mortality to this cause.3 Also, it is widely documented that the pandemic has led to large numbers of deaths not directly attributable to COVID-19 (either exclusively or in part), due to the wider impacts of responses, including reduced access to treatment for other conditions.4,5 Conversely, there is evidence that the pandemic has, to a limited extent, reduced expected rates of mortality from causes such as road traffic injuries and homicides during lockdowns.6

In the absence of good data on these different mortality effects, robust estimation of all-cause excess mortality offers the most complete and reliable approach for gauging the overall impact of the pandemic on mortality in a defined population over a fixed period of time.7 Excess mortality refers to the number of additional deaths occurring over a time period when specific conditions apply (in this case, the presence of COVID-19), compared to the number of deaths we might reasonably expect over the same period based on historical data. It captures deaths directly and indirectly attributed to COVID-19 and corresponding responses, to provide an estimate of the overall mortality effect of the pandemic as it unfolds.8

Excess mortality estimates have been computed for high-income countries based on registered deaths by surveillance agencies9,10, academia11–14 and news agencies.15–18 However, these types of data are often incomplete or inaccurate, especially in many low and middle-income countries (LMICs). The Global Burden Disease (GBD) project estimates that only 64% of global deaths were registered in 2015.19 In most LMICs, responsibility for mortality data is often divided between different national and subnational agencies.20 This can cause extended delays in national reporting and discrepancies between different sources.12,21 Disaggregation of summary data by different geographical areas or demographic groups is usually very limited.22 These shortcomings in mortality data explain a lack of published studies of excess mortality in LMICs.23,24

We analyse excess mortality associated with the first wave of the COVID-19 pandemic in Peru. This country is well-suited to our analytical approach. Like much of Latin America, Peru has experienced high levels of COVID-19 mortality. Official sources report 37,723 deaths directly caused by COVID-19 between 18 March and December 31 2020. However, these only include cases with positive COVID-19 test results and rates of testing in Peru have been low compared to other Latin American countries.25 Also, many tests have used low sensitivity devices, potentially generating false negatives.26 Anonymised individual level data for mortality and COVID-19 are in the public domain in Peru. Also, the progressive implementation of electronic registration of deaths in recent years enables comparisons of spatial and temporal trends in death registration.27 Other studies show unregistered mortality tends to be more prevalent among older people and in poorer regions.28,29However, as in many LMICs, Peru does not report sub-national data disaggregated by age.

Potentially, our analytical design could be applied to other countries where mortality registration and cause of death data are very incomplete. It may offer a valuable contribution towards assessing the true global impact of the COVID-19 pandemic.

# Data and methods

## Data

We combine several demographic data sources to forecast mortality rates. These sources are (i) population projections from Peru’s National Institute of Statistics and Information (INEI, for its acronym in Spanish) for 2020 disaggregated by region and age group (the most recent census was in 2017); (ii) crude mortality rate estimates disaggregated by region and year from 2015 to 2020 from INEI; (iii) individual-level registered deaths by region and age since 2017 from the Sistema Informático Nacional de Defunciones (SINADEF); and (iv) individual-level registered COVID-19 deaths by region and age in 2020 from the Ministry of Health (MoH).

## Excess mortality methods

Our approach to estimate excess mortality decomposes the estimate of total excess of deaths into three terms, namely 1) excess registered deaths, 2) excess unregistered deaths, 3) unregistered COVID-19 deaths. Figure 1 summarises data sources used (squares), analysis performed (diamonds) and different outputs (circles).

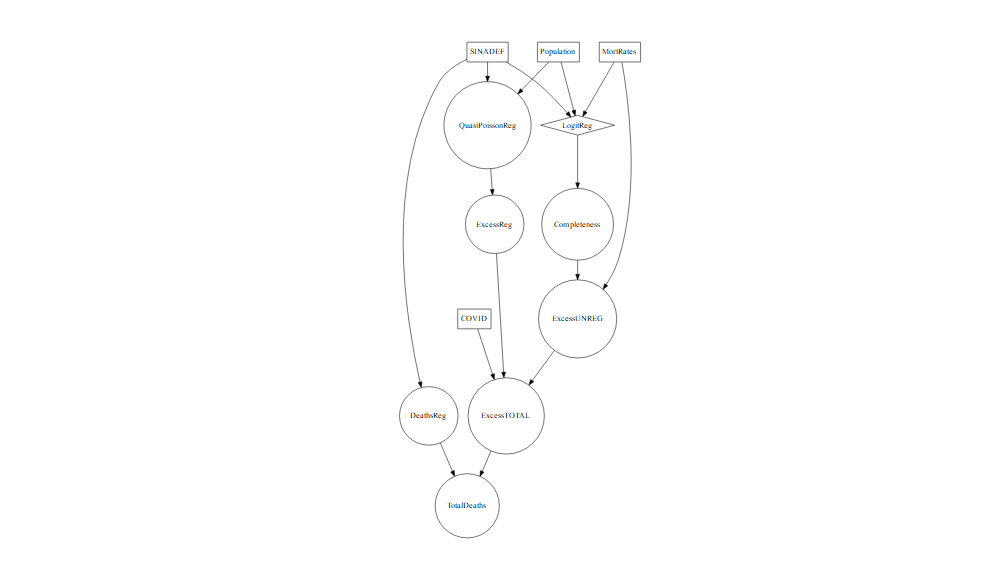


Figure 1: Flowchart: Data, analysis and outputs

To estimate the first term, excess registered deaths, we fit quasi-Poisson regressions to weekly deaths since 2017 by age-groups and region, as follows:

where we fit a natural cubic B-spline function on weeks to address long-term trends and seasonality30 and to deal with registration growth. Additionally, we use lagged residuals and the log of population in 2020 as an offset. Finally, we compute a dichotomous variable starting in the week corresponding to March 16 2020 as the first registered case of COVID-19 in the country.

Secondly, we compute the population attributable fraction31 based on the relative risk from parameter , as follows:

where is the weekly number of deaths,32 computed cumulatively over time.

To estimate our second term, we follow29 to predict the logit of death registration completeness for years 2017 and 2019 (due to data availability). We exploit variability in terms of mortality rates, population over 60 and rurality to address potential differences in terms of registration completeness. We model random-effects regressions by regions using the equation:

where and are the Crude Death Rates based on the Registration System, is the completeness registration rate for infants, is the logarithm under-five mortality rate and represents the fraction of the population over 60. is the share of households that use liquefied petroleum gas (LPG) for cooking, which is an important proxy of rurality in Peru, where 81.8% of rural households primarily use solid fuel compared to 9.8% of urban households, who typically cook with LPG.33 Rurality is an important factor to explain delays and underregistration of deaths as the system requires access to internet and computers. Additionally, in the error term and is the region-level random effect.

Then, we compute the completeness of deaths registration, using the inverse logit of the predicted values, which allows and equation (??), as follows:

The third term, unregistered COVID-19 deaths, is computed to correct for the proportion of cumulative cases of COVID-19 where they exceed registered deaths over that period. It follows a deterministic approach conditional on excess registered deaths being lower than officially registered COVID-19 deaths for each region and specific age-group as follows:

Finally, we estimate total excess deaths for different scenarios. A first scenario is when there is no solid evidence suggesting under-registration of deaths for some regions or age groups and, therefore, no scope to expand registration over time. This usually occurs in areas with very small populations. In those cases is set to 0 as, if not, they would add negative values to the sum. A second scenario is when some groups have fewer deaths than expected, due to effects such as reduced road traffic injuries caused by lockdowns. In these groups is taken account of in our final estimates. A third scenario is related to younger age groups in some regions that have not be significantly affected by COVID-19 mortality. This case corresponds to when in equation (??) is not statistically significant and therefore we set .

Equation (1) summarises the estimation of as follows:

Finally, we estimate total mortality during 2020 by adding from equation (1) and the difference of SINADEF deaths during 2020 and from equation (??), adjusted by as follows:

# Results

The estimations of completeness registration through the logistic regression model fits well the data according to and Root Mean Square of Errors. Model fit and goodness-of-fit is presented in Appendix 1. Figure 2 shows important variations at regional completeness rates: Amazonas and Loreto, in the Amazon, Lambayeque, on the coast, and Cajamarca and Pasco, in the Andes show estimated completion of below 40%, while Ica in the coast and Madre De Dios in the Amazon -the less populated region- achieve values that suggested full registration completeness (see Appendix 1).

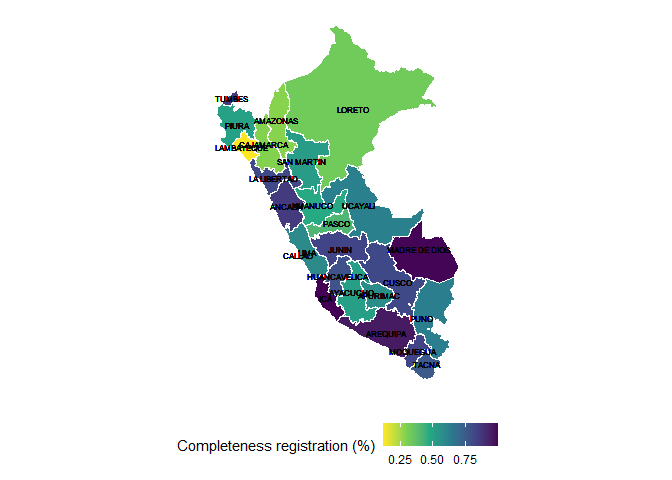


Figure 2: Completeness registration

Table 1 summarises estimations for our computation of excess mortality. Turning to the first term of our excess mortality calculation, excess registered deaths, the negative binomial models generally fitted well the number of daily deaths across models. Excess registered deaths is estimated to be 110,113 deaths ( 95% CI 93,248 - 115,769 ), while 37,724 are reported officially as COVID-19 deaths. This represents an increase of 192 % ( 95% CI 147 % - 207 %).

Table 1: Summary of estimations, Peru, 2020.

|  |  |
| --- | --- |
| **Total Excess REGISTERED mortality based on Poisson models by region and age group** | 110113 ( 95% CI 93248 - 115769 ) |
| **Completeness of CRVS deaths registration** | 71.6 % ( 95% CI 60.6 % - 75.3 % ) |
| **Excess TOTAL mortality** | 153832 ( 95% CI 129070 - 161454 ) |
| **Counterfactual deaths in 2020** | 101556 ( 95% CI 95900 - 118421 ) |
| **Total estimation deaths in 2020** | 289949 ( 95% CI 257565 - 322334 ) |

Table 2 shows estimates by region. Lima, which includes the capital, accounts for 78366 ( 95% CI 77116 - 79472 ) total excess deaths, and Amazonas, Apurimac, and Pasco show the lowest number of deaths. Table 3 shows excess mortality estimates by age group. Deaths among people aged 60 years and over accounts for 75.9% of total excess mortality. There was negative excess registered mortality for age groups under 9 and 10 to 19.

Table 2: Estimated total excess deaths by region

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Region | Total excess (TE) | TE - Lower CI 95% | TE - UpperCI 95% | Excess registered (ER) | ER - Lower CI 95% | ER - Upper CI 95% | Excess Covid-19 |
| AMAZONAS | 374.2 | 242.7 | 455.6 | 196.2 | 119.8 | 243.5 | 36.73 |
| ANCASH | 4594 | 4252 | 4875 | 3938 | 3641 | 4182 | 69.78 |
| APURIMAC | -30.17 | 1653 | 91.54 | -83.75 | 1094 | 1.362 | 89.59 |
| AREQUIPA | 6011 | 3784 | 6500 | 5513 | 3396 | 5977 | 210.7 |
| AYACUCHO | 419.1 | 2201 | 658.2 | 103.6 | 1296 | 263.6 | 264.3 |
| CAJAMARCA | 2683 | -1933 | 3468 | 1429 | -1262 | 1887 | 230.8 |
| CALLAO | 7838 | 7617 | 8011 | 6356 | 6175 | 6497 | 52.95 |
| CUSCO | 1331 | 875.4 | 1662 | 992.9 | 610.7 | 1270 | 147.3 |
| HUANCAVELICA | 715.9 | 550.4 | 823.9 | 565.6 | 430.2 | 653.9 | 24.25 |
| HUANUCO | 1592 | 1078 | 1959 | 1014 | 679.3 | 1254 | 36.34 |
| ICA | 4197 | 3918 | 4419 | 4097 | 3820 | 4320 | 93.33 |
| JUNIN | 3558 | 2975 | 4010 | 2876 | 2381 | 3260 | 171.7 |
| LA LIBERTAD | 7517 | 6982 | 7947 | 6169 | 5722 | 6529 | 139.1 |
| LAMBAYEQUE | 8101 | 8046 | 8149 | 4292 | 4262 | 4317 | 26.55 |
| LIMA | 78366 | 77116 | 79472 | 55172 | 54291 | 55951 | 63.73 |
| LORETO | 4654 | 3107 | 5030 | 2636 | 1714 | 2860 | 228.8 |
| MADRE DE DIOS | 403.9 | 343.8 | 443.2 | 348.9 | 289.3 | 387.9 | 52.1 |
| MOQUEGUA | 976.2 | 841.4 | 1068 | 803.4 | 689 | 881.1 | 29.25 |
| PASCO | 173.2 | -11404 | 288.7 | 12.19 | -7250 | 84.64 | 153.7 |
| PIURA | 11512 | 11263 | 11727 | 7547 | 7382 | 7690 | 151.1 |
| PUNO | 2541 | 710 | 3330 | 1677 | 347.7 | 2250 | 231.1 |
| SAN MARTIN | 2447 | 1502 | 2867 | 1549 | 912.3 | 1832 | 147.2 |
| TACNA | 599.2 | 364.3 | 741.5 | 466.9 | 279.8 | 580.2 | 12.9 |
| TUMBES | 1039 | 940.2 | 1111 | 883.9 | 797.8 | 946.4 | 22.98 |
| UCAYALI | 2219 | 2045 | 2346 | 1557 | 1431 | 1648 | 66.91 |
| Total | 153832 | 129070 | 161454 | 110113 | 93248 | 115769 | 2753 |

Table 3: Estimated total excess deaths by age-groups

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Age range | Total excess (TE) | TE - Lower CI 95% | TE - UpperCI 95% | Excess registered (ER) | ER - Lower CI 95% | ER - Upper CI 95% | Excess Covid-19 |
| < 9 | 323.9 | -3495 | 1578 | -795 | -3087 | 51.87 | 1525 |
| 10-19 | 154.9 | -1123 | 216.3 | -54.61 | -1269 | 3.748 | 212.4 |
| 20-29 | 1024 | 802.2 | 1180 | 290.4 | 134.4 | 400.7 | 611.4 |
| 30-39 | 3129 | 2677 | 3438 | 2083 | 1749 | 2311 | 174.2 |
| 40-49 | 10203 | -1921 | 10712 | 7284 | -403.1 | 7663 | 131.5 |
| 50-59 | 22196 | 21296 | 22844 | 16124 | 15461 | 16605 | 9.589 |
| 60-69 | 37244 | 35975 | 38196 | 27062 | 26110 | 27779 | 65.91 |
| 70-79 | 37972 | 36402 | 39203 | 27612 | 26423 | 28545 | 19.23 |
| > 80 | 41586 | 38456 | 44086 | 30506 | 28129 | 32410 | 3.594 |
| Total | 153832 | 129070 | 161454 | 110113 | 93248 | 115769 | 2753 |

Our second term, excess unregistered deaths, is estimated to be 40,966 deaths ( 95% CI 33,069 - 42,932 ). This represents 28.4 % ( 95% CI 25 % - 39.4 %) additional deaths compared to estimates based only on registered deaths. Coastal regions show the highest values where Lima accounts for 23,194 additional deaths, followed by Piura (3,809) and Lambayeque (3,965). Our third term adds 2,753 deaths corresponding to cases when reported COVID-19 deaths exceed our estimate of adjusted excess registered mortality. This mainly occurs for some smaller groups in younger age groups. The regions with the highest under reported COVID-19 values are in Andean regions of Ayacucho (264), Cajamarca and Puno (both with 231).

Combining all these terms, our estimate of total excess deaths during 2020 is 153,832 deaths ( 95% CI 129,070 - 161,454 ) and our estimate of total deaths for 2020 is 289,949 deaths ( 95% CI 257,565 - 322,334 ). This is 51.5 % ( 95% CI 29.9 % - 60.4 %) more than projected deaths by INEI for 2020.

Figure 3 shows age-standardised rates per 1,000 people by direct standardization methods,34 using INEI estimates as the standard population. We find that Moquegua, Callao, and Lima present the highest rates ranging from 9.65 to 11.4, while regions of Amazonas, Ayacucho, and Cusco show the lowest rates ranging from 4.59 to 6.86. We find that Amazonas` shows -1.59 deaths per 1000 in comparison to INEI’s projections for 2020, which suggests INEI’s overestimations of mortality rates.

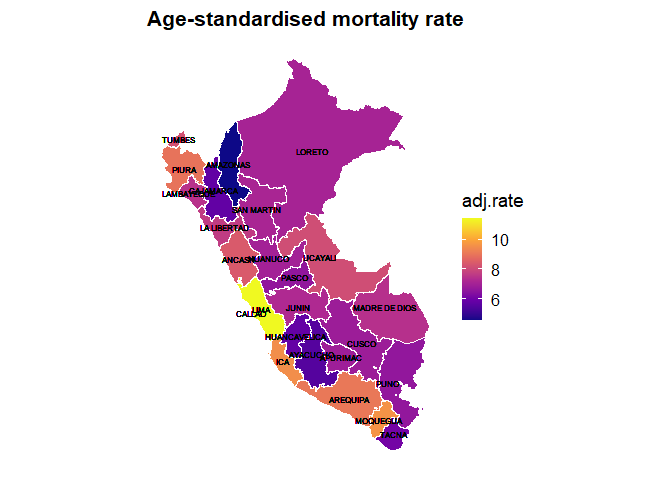


Figure 3: Mortality rates

# Discussion

The COVID-19 pandemic has underscored the need for methodological advances in population health measurement, research, critical data quality assessment and improvement of health information systems to obtain reliable information on the impact of the pandemic from multiple data sources linked to COVID-19. In this regards, our study provides a framework, tools and analytical strategy to estimate the excess mortality caused by the COVID-19 pandemic in Peru and, potentially, other countries where the quality of mortality data is medium to lower.35 The scope for applying a similar approach will vary between countries. In countries such as India, where mortality and cause of death data are of very low quality considerably lower than in Peru, achieving robust estimates by any method will be hugely challenging.@ 36 In other countries, such as Brazil, data quality is similar to Peru’s and a recent reform to its CRVS system is likely to have boosted registration rates where they are relatively complete.37,38

Other published studies of excess COVID-19 mortality fall into two categories. Some studies provide estimates for countries where mortality data are relatively complete and reliable.39–42 As such, they do not apply specific methods to address data gaps. Studies of excess COVID-19 mortality for countries with less complete data do not take unregistered deaths.43–45

We estimate that overall excess mortality in Peru was 278.2% higher than the level officially attributed to COVID-19. Registered excess mortality was 170.7% higher. This is a larger differential than reported by studies for high-income countries. For example, separate studies of the USA show differentials of between 28 and 33%.11,12 Our estimates are higher than those previously published for Peru, which are only based on registered deaths, apply simpler methods.46,47 Our estimates of regional variations for excess mortality are in line with,46 who speculate they may be attributable to the effect of altitude of COVID-19 case fatality.

Despite making up a relatively low share of Peru’s population (12.5% in 2020), people aged 60 or more accounted for 76.4% of excess mortality. No other published study for Peru provides data disaggregated by age groups. A study of registered excess mortality in six Brazilian cities reports that people aged 60 and over accounted for 71.1% of the total.44 An analysis of European countries reports that 91% of excess COVID-19 deaths occurred among people aged 65 or more.41 This reflects a higher proportion of population aged 60 or more in Europe (25.5% in 2020) than in Peru.

# Limitations

Our analysis assumes that comparison between years is not invalidated by specific time-bound mortality events such as additional disease outbreaks or other major external shocks. Our estimates of registration completeness assume no variation across age groups, which may not be the case. We do not take into account changes in registration over time as our estimates are based on provisional data, which are incomplete and there are still fatalities due to COVID-19. Finally, we present a conservative scenario, allowing for the existence of negative as well as positive excess deaths.

# Conclusion

There is an evident need for robust estimates of the direct and indirect mortality effects of the COVID-19 pandemic. To date, much of the data for LMICs in the public domain rely on officially-registered deaths. Inaccurate attribution of cause of death can, to some degree, be resolved by generating excess mortality estimates based on temporal comparisons of all-cause mortality. Also, these approaches do not include deaths that are not officially registered. This paper develops and applies a method to obtain robust estimates of excess mortality for both registered and unregistered deaths.

Our study indicates that official data under-represent the overall mortality impact of the COVID-19 pandemic in Peru. This gap is considerably greater than those reported for high-income countries. It is plausible that under-estimation of excess mortality in other countries with low quality mortality data will be comparable to Peru. In that case, LMICs would account for a much larger share of the global distribution of excess mortality associated with the COVID-19 pandemic than indicated by official data sources.

# References

1. Kung S, Doppen M, Black M, Braithwaite I, Kearns C, Weatherall M, et al. Underestimation of COVID-19 mortality during the pandemic. ERJ Open Research [Internet]. 2020 Dec;00766–2020. Available from: <http://openres.ersjournals.com/lookup/doi/10.1183/23120541.00766-2020>

2. Vincent JL, Taccone FS. Understanding pathways to death in patients with COVID-19 [Internet]. Vol. 8. Lancet Publishing Group; 2020. p. 430–2. Available from: <https://doi.org/10.1016/>

3. Griffin S. Covid-19: England comes into line with rest of UK on recording deaths. BMJ (Clinical research ed) [Internet]. 2020 Aug;370:m3220. Available from: <http://dx.doi.org/10.1136/bmj.m3220>

4. Douglas M, Katikireddi SV, Taulbut M, McKee M, McCartney G. Mitigating the wider health effects of covid-19 pandemic response. The BMJ [Internet]. 2020 Apr;369. Available from: <http://www.heal>

5. Dyer O. Covid-19: Excess deaths point to hidden toll in South Africa as cases surge. BMJ [Internet]. 2020; Available from: <http://dx.doi.org/10.1136/bmj.m3038>

6. Calderon-Anyosa RJC, Kaufman JS. Impact of COVID-19 lockdown policy on homicide, suicide, and motor vehicle deaths in Peru. Preventive Medicine. 2021 Feb;143:106331.

7. Beaney T, Clarke JM, Jain V, Kataria Golestaneh A, Lyons G, Salman D, et al. Excess mortality: the gold standard in measuring the impact of COVID-19 worldwide?

8. Leon DA, Shkolnikov VM, Smeeth L, Magnus P, Pechholdová M, Jarvis CI. COVID-19: a need for real-time monitoring of weekly excess deaths. The Lancet. 2020;395(10234):e81.

9. Vestergaard LS, Nielsen J, Richter L, Schmid D, Bustos N, Braeye T, et al. Excess all-cause mortality during the COVID-19 pandemic in Europe – preliminary pooled estimates from the EuroMOMO network, March to April 2020. Eurosurveillance [Internet]. 2020 Jul;25(26):2001214. Available from: <https://www.eurosurveillance.org/content/10.2807/1560-7917.ES.2020.25.26.2001214>

10. Rossen LM, Branum AM, Ahmad FB, Sutton P, Anderson RN. Excess Deaths Associated with COVID-19, by Age and Race and Ethnicity — United States, January 26–October 3, 2020. MMWR Morbidity and Mortality Weekly Report [Internet]. 2020 Oct;69(42):1522–7. Available from: <http://www.cdc.gov/mmwr/volumes/69/wr/mm6942e2.htm?s_cid=mm6942e2_w>

11. Woolf SH, Chapman DA, Sabo RT, Weinberger DM, Hill L. Excess Deaths from COVID-19 and Other Causes, March-April 2020. JAMA - Journal of the American Medical Association. 2020;324(5):E1–3.

12. Weinberger DM, Chen J, Cohen T, Crawford FW, Mostashari F, Olson D, et al. Estimation of Excess Deaths Associated with the COVID-19 Pandemic in the United States, March to May 2020. JAMA Internal Medicine. 2020;06520(May):E1–9.

13. Vandoros S. Excess mortality during the Covid-19 pandemic: Early evidence from England and Wales. Social Science and Medicine. 2020 Aug;258:113101.

14. Michelozzi P, De’Donato F, Scortichini M, Pezzotti P, Stafoggia M, De Sario M, et al. Temporal dynamics in total excess mortality and COVID-19 deaths in Italian cities. BMC public health. 2020;20(1):1238.

15. Roser M, Ritchie H, Ortiz-Ospina E, Hasell J. Excess mortality during the Coronavirus pandemic (COVID-19) [Internet]. 2020 [cited 2020 Dec 3]. Available from: <https://ourworldindata.org/excess-mortality-covid>

16. Financial Times. Coronavirus tracker: the latest figures as countries fight Covid-19 resurgence [Internet]. 2020 [cited 2020 Dec 3]. Available from: <https://www.ft.com/content/a2901ce8-5eb7-4633-b89c-cbdf5b386938>

17. Wu J, McCann A, Katz J, Peltier E, Deep Singh K. 412,000 Missing Deaths: Tracking the True Toll of the Coronavirus Outbreak - The New York Times [Internet]. 2020 [cited 2020 Dec 3]. Available from: <https://www.nytimes.com/interactive/2020/04/21/world/coronavirus-missing-deaths.html>

18. The Economist. Covid-19 data - Tracking covid-19 excess deaths across countries [Internet]. 2020 [cited 2020 Dec 3]. Available from: <https://www.economist.com/graphic-detail/2020/07/15/tracking-covid-19-excess-deaths-across-countries>

19. Dicker D, Nguyen G, Abate D, Abate KH, Abay SM, Abbafati C, et al. Global, regional, and national age-sex-specific mortality and life expectancy, 1950-2017: A systematic analysis for the Global Burden of Disease Study 2017. The Lancet. 2018;392(10159):1684–735.

20. Cobos Muñoz D, De Savigny D, Sorchik R, Bo KS, Hart J, Kwa V, et al. Better data for better outcomes: The importance of process mapping and management in CRVS systems. BMC Medicine [Internet]. 2020 Mar;18(1):67. Available from: <https://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-020-01522-z>

21. Iburg KM, Mikkelsen L, Adair T, Lopez AD. Are cause of death data fit for purpose? evidence from 20 countries at different levels of socio-economic development. PLoS ONE [Internet]. 2020;15(8 August 2020):1–8. Available from: <http://dx.doi.org/10.1371/journal.pone.0237539>

22. Adair T, Rajasekhar M, Bo KS, Hart J, Kwa V, Mukut MAA, et al. Where there is no hospital: Improving the notification of community deaths. BMC Medicine [Internet]. 2020 Mar;18(1):65. Available from: <https://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-020-01524-x>

23. Jha P. Reliable direct measurement of causes of death in low- and middle-income countries. BMC Medicine [Internet]. 2014 Feb;12(1):19. Available from: <http://bmcmedicine.biomedcentral.com/articles/10.1186/1741-7015-12-19>

24. Setel P, Abouzahr C, Atuheire EB, Bratschi M, Cercone E, Chinganya O, et al. Mortality surveillance during the COVID-19 pandemic [Internet]. Vol. 98. World Health Organization; 2020. p. 374. Available from: <https://pubmed.ncbi.nlm.nih.gov/32514207/ https://pubmed.ncbi.nlm.nih.gov/32514207/?dopt=Abstract>

25. Benítez MA, Velasco C, Sequeira AR, Henríquez J, Menezes FM, Paolucci F. Responses to COVID-19 in five Latin American countries. Health Policy and Technology. 2020 Dec;9(4):525–59.

26. Yañez J, Alvarez-Risco A, Delgado-Zegarra A. Does Peru really have that high number of COVID-19 confirmed cases? The deception of combining RT-PCR and rapid test results | The BMJ. BMJ [Internet]. 2020;369(m2518). Available from: <https://www.bmj.com/content/369/bmj.m2518/rr-4>

27. Peru Implementation Working Group. Peru: An exceptional example of CRVS system advancement. CRVS country reports. Melbourne, Australia: The University of Melbourne; Civil Registration; Vital Statistics Improvement, Bloomberg Philanthropies Data for Health Initiative; 2018. Report No.: March.

28. Lloyd-Sherlock P, Sempe L, McKee M, Guntupalli A. Problems of Data Availability and Quality for COVID-19 and Older People in Low- and Middle-Income Countries. The Gerontologist [Internet]. 2020 Oct;XX:1–4. Available from: <https://academic.oup.com/gerontologist/advance-article/doi/10.1093/geront/gnaa153/5918111>

29. Adair T, Lopez AD. Estimating the completeness of death registration: An empirical method. PLoS ONE. 2018;13(5):e0197047.

30. Currie ID, Durban M, Eilers PH. Smoothing and forecasting mortality rates. Statistical Modelling. 2004;4(4):279–98.

31. Steenland K, Armstrong B. An overview of methods for calculating the burden of disease due to specific risk factors. Epidemiology. 2006;17(5):512–9.

32. Gasparrini A, Leone M. Attributable risk from distributed lag models [Internet]. Vol. 14. 2014 p. 55. Available from: <http://www.biomedcentral.com/1471-2288/14/55>

33. Pollard SL, Williams KN, O’Brien CJ, Winiker A, Puzzolo E, Kephart JL, et al. An evaluation of the Fondo de Inclusión Social Energético program to promote access to liquefied petroleum gas in Peru. Energy for Sustainable Development. 2018 Oct;46:82–93.

34. Curtin LR, Klein RJ. Direct standardization (age-adjusted death rates). US Department of Health; Human Services, Public Health Service, Centers for Disease Control; Prevention, National Center for Health Statistics; 1995. Report No.: 6.

35. Mikkelsen L, Phillips DE, Abouzahr C, Setel PW, De Savigny D, Lozano R, et al. A global assessment of civil registration and vital statistics systems: Monitoring data quality and progress. Vol. 386. Lancet Publishing Group; 2015. p. 1395–406.

36. Gupta M, Rao C, Lakshmi PVM, Prinja S, Kumar R. Estimating mortality using data from civil registration: a cross-sectional study in India. Bulletin of the World Health Organization [Internet]. 2016 Jan;94(1):10–21. Available from: </pmc/articles/PMC4709797/?report=abstract https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4709797/>

37. McLaughlin D, Lopez AD. Strengthening mortality data for health policy and planning: The bloomberg data for health initiative in Latin America [Internet]. Vol. 22. Assocaicao Brasileira de Pos, Gradacao em Saude Coletiva; 2019. Available from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1415-790X2019000400802&lng=en&nrm=iso&tlng=en http://www.scielo.br/scielo.php?script=sci_abstract&pid=S1415-790X2019000400802&lng=en&nrm=iso&tlng=en>

38. Queiroz BL, De Araujo FreireI FHM, Gonzaga MR, De Lima EEC. Estimativas do grau de cobertura e da mortalidade adulta (45q15) para as unidades da federação no Brasil entre 1980 e 2010. Revista Brasileira de Epidemiologia [Internet]. 2017;20(Suppl 01):21–33. Available from: <https://pubmed.ncbi.nlm.nih.gov/28658370/>

39. Banerjee A, Pasea L, Harris S, Gonzalez-Izquierdo A, Torralbo A, Shallcross L, et al. Estimating excess 1-year mortality associated with the COVID-19 pandemic according to underlying conditions and age: a population-based cohort study. The Lancet [Internet]. 2020 May;395(10238):1715–25. Available from: [www.caliberresearch.](https://www.caliberresearch.)

40. Kontis V, Bennett JE, Rashid T, Parks RM, Pearson-Stuttard J, Guillot M, et al. Magnitude, demographics and dynamics of the effect of the first wave of the COVID-19 pandemic on all-cause mortality in 21 industrialized countries. Nature Medicine [Internet]. 2020 Dec;26(12):1919–28. Available from: <https://doi.org/10.1038/s41591-020-1112-0>

41. Vestergaard LS, Nielsen J, Richter L, Schmid D, Bustos N, Braeye T, et al. Excess all-cause mortality during the COVID-19 pandemic in Europe – preliminary pooled estimates from the EuroMOMO network, March to April 2020. Eurosurveillance [Internet]. 2020 Jul;25(26):2001214. Available from: <https://www.eurosurveillance.org/content/10.2807/1560-7917.ES.2020.25.26.2001214>

42. Rivera R, Rosenbaum JE, Quispe W. Excess mortality in the united states during the first three months of the COVID-19 pandemic. Epidemiology and Infection. 2020;

43. Tadbiri H, Moradi-Lakeh M, Naghavi M. All-cause excess mortality and COVID-19-related deaths in Iran. Medical journal of the Islamic Republic of Iran [Internet]. 2020;34. Available from: <https://pubmed.ncbi.nlm.nih.gov/33306040/>

44. Freitas ARR, Medeiros NM de, Frutuoso LCV, Beckedorff OA, Martin LMA de, Coelho MM de M, et al. Tracking excess deaths associated with the COVID-19 epidemic as an epidemiological surveillance strategy-preliminary results of the evaluation of six Brazilian capitals. Revista da Sociedade Brasileira de Medicina Tropical [Internet]. 2020;53:e20200558. Available from: [www.scielo.br/rsbmtIwww.rsbmt.org.br](https://www.scielo.br/rsbmtIwww.rsbmt.org.br)

45. Cevallos-Valdiviezo H, Vergara-Montesdeoca A, Zambrano-Zambrano G. Measuring the impact of the COVID-19 outbreak in Ecuador using preliminary estimates of excess mortality, March 17–October 22, 2020. International Journal of Infectious Diseases [Internet]. 2020 Dec; Available from: <https://linkinghub.elsevier.com/retrieve/pii/S1201971220325674>

46. Quevedo-Ramirez A, Al-kassab-Córdova A, Mendez-Guerra C, Cornejo-Venegas G, Alva-Chavez KP. Altitude and excess mortality during COVID-19 pandemic in Peru. Respiratory Physiology and Neurobiology. 2020 Oct;281.

47. Brown PE, Greenwald ZR, Salinas LE, Martens GA, Newcombe L, Gelband H, et al. Mortality from COVID in Colombia and Peru: Analyses of Mortality Data and Statistical Forecasts. medRxiv [Internet]. 2020 Nov;2020.08.24.20181016. Available from: <https://doi.org/10.1101/2020.08.24.20181016>

48. Hernández-Vásquez A, Gamboa-Unsihuay JE, Vargas-Fernández R, Azañedo D. Exceso de mortalidad en Lima Metropolitana durante la pandemia de COVID-19: comparación a nivel distrital. Medwave [Internet]. 2020 Sep;20(8):e8031. Available from: <https://pubmed.ncbi.nlm.nih.gov/33017383/>

# Appendices

## Appendix 1: Model fit registration completeness

## R2m R2c  
## [1,] 0.743 0.87

## [1] 0.0527

## [1] 0.239

### Quasi-Poisson models

Quitting from lines 455-460 (article.Rmd) Error in pander(nbfit.r, caption = “(\#tab:arima) Model fit Negative Binomial - 2”) : object ‘nbfit.r’ not found Calls: … withCallingHandlers -> withVisible -> eval -> eval -> pander In addition: There were 16 warnings (use warnings() to see them)

### Under-registration rates

## # A tibble: 25 x 2  
## # Groups: Departamento [25]  
## Departamento sub.mean  
## <fct> <dbl>  
## 1 ICA 99.9  
## 2 MADRE DE DIOS 99.2  
## 3 AREQUIPA 94.8  
## 4 ANCASH 85.1  
## 5 TUMBES 85.0  
## 6 JUNIN 82.3  
## 7 MOQUEGUA 82.1  
## 8 CUSCO 80.8  
## 9 LA LIBERTAD 80.4  
## 10 HUANCAVELICA 77.7  
## 11 CALLAO 77.5  
## 12 TACNA 74.4  
## 13 PUNO 62.3  
## 14 UCAYALI 61.8  
## 15 LIMA 58.1  
## 16 APURIMAC 57.0  
## 17 SAN MARTIN 51.5  
## 18 AYACUCHO 50.5  
## 19 PIURA 49.5  
## 20 HUANUCO 46.6  
## 21 PASCO 40.6  
## 22 LORETO 32.1  
## 23 CAJAMARCA 28.5  
## 24 AMAZONAS 28.0  
## 25 LAMBAYEQUE 11.9

### mortality rates

## # A tibble: 25 x 8  
## Departamento adj.rate lci uci crude.rate `2010` `2015` Difference  
## <chr> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>  
## 1 AMAZONAS 4.59 4.39 4.80 4.60 6.05 6.19 -1.59   
## 2 ANCASH 8.43 8.27 8.60 8.41 6.09 6.15 2.26   
## 3 APURIMAC 6.90 6.66 7.14 7.49 6.76 6.61 0.882  
## 4 AREQUIPA 9.09 8.93 9.25 8.24 5.53 5.8 2.44   
## 5 AYACUCHO 5.56 5.39 5.74 6.04 6.15 5.91 0.131  
## 6 CAJAMARCA 5.80 5.68 5.93 6.17 5.39 5.5 0.666  
## 7 CALLAO 11.0 10.8 11.2 10.6 4.91 5.27 5.30   
## 8 CUSCO 6.86 6.72 7.00 6.84 6.88 6.97 -0.133  
## 9 HUANCAVELICA 5.84 5.63 6.05 8.18 5.83 5.54 2.64   
## 10 HUANUCO 7.01 6.84 7.19 8.20 5.94 5.98 2.22   
## # ... with 15 more rows

### Counterfacutual and total deaths 2020

## Departamento range sinadef excess.T excess.l excess.u excess.reg  
## AMAZONAS a0.9 60 0.000 0.000 0.00e+00 0.0  
## AMAZONAS a10.19 22 2.797 2.797 2.80e+00 0.0  
## AMAZONAS a20.29 36 0.000 0.000 0.00e+00 0.0  
## AMAZONAS a30.39 60 6.929 6.929 6.93e+00 0.0  
## AMAZONAS a40.49 83 17.415 17.415 1.74e+01 0.0  
## AMAZONAS a50.59 123 9.589 9.589 9.59e+00 0.0  
## AMAZONAS a60.69 199 165.887 125.102 1.91e+02 96.5  
## AMAZONAS a70.79 199 0.000 0.000 0.00e+00 0.0  
## AMAZONAS a80 337 171.535 80.850 2.28e+02 99.7  
## ANCASH a0.9 243 42.116 42.116 4.21e+01 0.0  
## ANCASH a10.19 101 0.000 0.000 0.00e+00 0.0  
## ANCASH a20.29 163 0.000 0.000 0.00e+00 0.0  
## ANCASH a30.39 224 27.659 27.659 2.77e+01 0.0  
## ANCASH a40.49 471 258.581 217.321 2.88e+02 225.1  
## ANCASH a50.59 892 653.851 624.299 6.78e+02 569.1  
## ANCASH a60.69 1391 1094.688 1068.452 1.12e+03 952.8  
## ANCASH a70.79 1960 1310.347 1254.640 1.36e+03 1140.6  
## ANCASH a80 3133 1206.919 1017.742 1.36e+03 1050.5  
## APURIMAC a0.9 100 -34.010 1649.604 8.77e+01 -83.8  
## APURIMAC a10.19 51 0.974 0.974 9.74e-01 0.0  
## APURIMAC a20.29 64 2.862 2.862 2.86e+00 0.0  
## APURIMAC a30.39 73 0.000 0.000 0.00e+00 0.0  
## APURIMAC a40.49 119 0.000 0.000 0.00e+00 0.0  
## APURIMAC a50.59 200 0.000 0.000 0.00e+00 0.0  
## APURIMAC a60.69 275 0.000 0.000 0.00e+00 0.0  
## APURIMAC a70.79 449 0.000 0.000 0.00e+00 0.0  
## APURIMAC a80 863 0.000 0.000 0.00e+00 0.0  
## AREQUIPA a0.9 216 -0.706 -558.878 1.03e+02 -90.2  
## AREQUIPA a10.19 98 5.150 -1272.499 6.66e+01 -54.6  
## AREQUIPA a20.29 232 53.939 53.939 5.39e+01 0.0  
## AREQUIPA a30.39 329 0.000 0.000 0.00e+00 0.0  
## AREQUIPA a40.49 662 323.316 266.442 3.64e+02 307.3  
## AREQUIPA a50.59 1213 756.726 715.655 7.91e+02 719.2  
## AREQUIPA a60.69 1990 1354.212 1307.535 1.39e+03 1287.0  
## AREQUIPA a70.79 2480 1415.300 1324.757 1.49e+03 1345.1  
## AREQUIPA a80 4307 2103.229 1947.117 2.24e+03 1998.9  
## AYACUCHO a0.9 122 -55.780 1820.458 1.20e+02 -114.8  
## AYACUCHO a10.19 62 1.767 1.767 1.77e+00 0.0  
## AYACUCHO a20.29 95 25.573 25.573 2.56e+01 0.0  
## AYACUCHO a30.39 100 19.597 19.597 1.96e+01 0.0  
## AYACUCHO a40.49 161 35.609 35.609 3.56e+01 0.0  
## AYACUCHO a50.59 214 0.000 0.000 0.00e+00 0.0  
## AYACUCHO a60.69 373 65.908 65.908 6.59e+01 0.0  
## AYACUCHO a70.79 554 326.403 232.379 3.90e+02 218.4  
## AYACUCHO a80 843 0.000 0.000 0.00e+00 0.0  
## CAJAMARCA a0.9 232 -116.622 -3985.197 1.40e+02 -165.8  
## CAJAMARCA a10.19 75 21.831 21.831 2.18e+01 0.0  
## CAJAMARCA a20.29 128 41.127 41.127 4.11e+01 0.0  
## CAJAMARCA a30.39 207 0.000 0.000 0.00e+00 0.0  
## CAJAMARCA a40.49 294 160.024 65.197 2.16e+02 93.3  
## CAJAMARCA a50.59 539 348.689 229.545 4.27e+02 203.3  
## CAJAMARCA a60.69 793 579.875 429.501 6.82e+02 338.0  
## CAJAMARCA a70.79 1071 766.382 639.497 8.63e+02 446.8  
## CAJAMARCA a80 1752 881.212 625.159 1.08e+03 513.7  
## CALLAO a0.9 156 0.000 0.000 0.00e+00 0.0  
## CALLAO a10.19 49 11.571 11.571 1.16e+01 0.0  
## CALLAO a20.29 185 41.380 41.380 4.14e+01 0.0  
## CALLAO a30.39 319 106.690 27.916 1.52e+02 87.1  
## CALLAO a40.49 641 559.143 542.794 5.73e+02 456.5  
## CALLAO a50.59 1192 1146.817 1136.497 1.16e+03 936.2  
## CALLAO a60.69 1958 1782.091 1757.898 1.80e+03 1454.9  
## CALLAO a70.79 2222 1994.467 1969.137 2.02e+03 1628.3  
## CALLAO a80 2982 2196.083 2129.402 2.26e+03 1792.9  
## CUSCO a0.9 354 66.995 66.995 6.70e+01 0.0  
## CUSCO a10.19 178 4.158 4.158 4.16e+00 0.0  
## CUSCO a20.29 246 76.133 76.133 7.61e+01 0.0  
## CUSCO a30.39 319 0.000 0.000 0.00e+00 0.0  
## CUSCO a40.49 519 0.000 0.000 0.00e+00 0.0  
## CUSCO a50.59 789 0.000 0.000 0.00e+00 0.0  
## CUSCO a60.69 1193 421.071 231.231 5.50e+02 353.2  
## CUSCO a70.79 1610 0.000 0.000 0.00e+00 0.0  
## CUSCO a80 2451 762.746 496.928 9.65e+02 639.7  
## HUANCAVELICA a0.9 141 64.947 33.753 8.23e+01 53.1  
## HUANCAVELICA a10.19 60 4.598 4.598 4.60e+00 0.0  
## HUANCAVELICA a20.29 76 0.000 0.000 0.00e+00 0.0  
## HUANCAVELICA a30.39 79 18.865 18.865 1.89e+01 0.0  
## HUANCAVELICA a40.49 152 0.000 0.000 0.00e+00 0.0  
## HUANCAVELICA a50.59 232 100.080 54.233 1.28e+02 81.8  
## HUANCAVELICA a60.69 355 217.753 183.090 2.42e+02 178.1  
## HUANCAVELICA a70.79 548 308.899 255.047 3.48e+02 252.6  
## HUANCAVELICA a80 782 0.786 0.786 7.86e-01 0.0  
## HUANUCO a0.9 187 10.678 10.678 1.07e+01 0.0  
## HUANUCO a10.19 71 1.796 1.796 1.80e+00 0.0  
## HUANUCO a20.29 125 0.000 0.000 0.00e+00 0.0  
## HUANUCO a30.39 166 16.623 16.623 1.66e+01 0.0  
## HUANUCO a40.49 267 7.246 7.246 7.25e+00 0.0  
## HUANUCO a50.59 411 240.295 162.454 2.91e+02 156.6  
## HUANUCO a60.69 670 400.108 300.117 4.71e+02 260.8  
## HUANUCO a70.79 908 425.091 283.569 5.27e+02 277.1  
## HUANUCO a80 1233 490.408 295.907 6.33e+02 319.7  
## ICA a0.9 170 50.749 50.749 5.07e+01 0.0  
## ICA a10.19 52 9.276 9.276 9.28e+00 0.0  
## ICA a20.29 163 33.301 33.301 3.33e+01 0.0  
## ICA a30.39 256 95.823 63.728 1.16e+02 95.7  
## ICA a40.49 527 298.629 274.786 3.17e+02 298.2  
## ICA a50.59 967 633.300 612.556 6.51e+02 632.4  
## ICA a60.69 1468 1109.486 1093.909 1.12e+03 1107.9  
## ICA a70.79 1638 817.414 742.587 8.78e+02 816.2  
## ICA a80 2521 1148.712 1037.511 1.24e+03 1147.0  
## JUNIN a0.9 372 62.256 62.256 6.23e+01 0.0  
## JUNIN a10.19 151 2.607 2.607 2.61e+00 0.0  
## JUNIN a20.29 219 69.883 69.883 6.99e+01 0.0  
## JUNIN a30.39 322 36.910 36.910 3.69e+01 0.0  
## JUNIN a40.49 553 285.279 217.193 3.32e+02 242.3  
## JUNIN a50.59 947 545.545 479.919 5.96e+02 463.4  
## JUNIN a60.69 1394 755.344 658.311 8.31e+02 641.6  
## JUNIN a70.79 1806 876.830 755.274 9.74e+02 744.8  
## JUNIN a80 2746 923.230 692.372 1.11e+03 784.2  
## LA LIBERTAD a0.9 334 47.575 47.575 4.76e+01 0.0  
## LA LIBERTAD a10.19 142 24.410 24.410 2.44e+01 0.0  
## LA LIBERTAD a20.29 297 67.088 67.088 6.71e+01 0.0  
## LA LIBERTAD a30.39 409 154.407 83.940 2.00e+02 129.1  
## LA LIBERTAD a40.49 743 407.672 333.163 4.61e+02 340.9  
## LA LIBERTAD a50.59 1443 1135.426 1097.601 1.17e+03 949.4  
## LA LIBERTAD a60.69 2323 1734.597 1673.595 1.79e+03 1450.4  
## LA LIBERTAD a70.79 2871 2030.325 1951.264 2.10e+03 1697.7  
## LA LIBERTAD a80 4055 1915.679 1703.278 2.09e+03 1601.8  
## LAMBAYEQUE a0.9 81 26.550 26.550 2.66e+01 0.0  
## LAMBAYEQUE a10.19 29 0.000 0.000 0.00e+00 0.0  
## LAMBAYEQUE a20.29 90 0.000 0.000 0.00e+00 0.0  
## LAMBAYEQUE a30.39 175 204.133 190.371 2.14e+02 108.5  
## LAMBAYEQUE a40.49 368 588.050 582.468 5.93e+02 312.6  
## LAMBAYEQUE a50.59 734 1258.995 1256.009 1.26e+03 669.2  
## LAMBAYEQUE a60.69 1231 2067.809 2062.608 2.07e+03 1099.1  
## LAMBAYEQUE a70.79 1194 2004.897 1998.611 2.01e+03 1065.6  
## LAMBAYEQUE a80 1298 1950.664 1929.131 1.97e+03 1036.8  
## LIMA a0.9 1374 63.727 63.727 6.37e+01 0.0  
## LIMA a10.19 483 0.000 0.000 0.00e+00 0.0  
## LIMA a20.29 1297 412.120 190.794 5.69e+02 290.4  
## LIMA a30.39 2631 1869.322 1756.338 1.97e+03 1317.1  
## LIMA a40.49 5419 5542.869 5489.824 5.59e+03 3905.5  
## LIMA a50.59 10548 11383.436 11312.181 1.15e+04 8020.8  
## LIMA a60.69 17129 18620.741 18519.995 1.87e+04 13120.2  
## LIMA a70.79 19325 19153.432 18971.491 1.93e+04 13495.5  
## LIMA a80 27134 21319.870 20811.895 2.18e+04 15022.0  
## LORETO a0.9 275 -98.112 -1473.659 1.53e+02 -153.4  
## LORETO a10.19 85 39.533 39.533 3.95e+01 0.0  
## LORETO a20.29 152 29.907 29.907 2.99e+01 0.0  
## LORETO a30.39 255 119.193 39.243 1.67e+02 71.0  
## LORETO a40.49 389 406.040 381.931 4.25e+02 241.9  
## LORETO a50.59 615 787.209 775.699 7.97e+02 468.9  
## LORETO a60.69 958 1279.430 1267.497 1.29e+03 762.1  
## LORETO a70.79 933 1214.444 1200.033 1.23e+03 723.4  
## LORETO a80 785 876.719 846.403 9.02e+02 522.2  
## MADRE DE DIOS a0.9 92 24.801 24.801 2.48e+01 0.0  
## MADRE DE DIOS a10.19 21 0.000 0.000 0.00e+00 0.0  
## MADRE DE DIOS a20.29 79 27.295 27.295 2.73e+01 0.0  
## MADRE DE DIOS a30.39 92 0.000 0.000 0.00e+00 0.0  
## MADRE DE DIOS a40.49 117 0.000 0.000 0.00e+00 0.0  
## MADRE DE DIOS a50.59 172 91.194 77.583 1.00e+02 90.4  
## MADRE DE DIOS a60.69 191 102.006 87.849 1.12e+02 101.2  
## MADRE DE DIOS a70.79 168 72.214 47.276 8.72e+01 71.6  
## MADRE DE DIOS a80 146 86.401 78.982 9.18e+01 85.7  
## MOQUEGUA a0.9 21 15.708 15.708 1.57e+01 0.0  
## MOQUEGUA a10.19 10 0.000 0.000 0.00e+00 0.0  
## MOQUEGUA a20.29 39 10.259 10.259 1.03e+01 0.0  
## MOQUEGUA a30.39 33 3.288 3.288 3.29e+00 0.0  
## MOQUEGUA a40.49 90 58.702 48.197 6.52e+01 49.8  
## MOQUEGUA a50.59 173 137.157 124.482 1.46e+02 116.4  
## MOQUEGUA a60.69 277 229.320 215.414 2.39e+02 194.6  
## MOQUEGUA a70.79 380 279.254 251.401 2.99e+02 236.9  
## MOQUEGUA a80 506 242.534 172.625 2.89e+02 205.8  
## PASCO a0.9 91 26.258 26.258 2.63e+01 0.0  
## PASCO a10.19 28 0.000 0.000 0.00e+00 0.0  
## PASCO a20.29 45 19.109 19.109 1.91e+01 0.0  
## PASCO a30.39 58 15.138 15.138 1.51e+01 0.0  
## PASCO a40.49 83 -24.767 -11571.736 7.18e+01 -60.2  
## PASCO a50.59 152 115.403 85.517 1.34e+02 72.4  
## PASCO a60.69 219 0.000 0.000 0.00e+00 0.0  
## PASCO a70.79 245 19.225 19.225 1.92e+01 0.0  
## PASCO a80 294 2.808 2.808 2.81e+00 0.0  
## PIURA a0.9 302 126.576 126.576 1.27e+02 0.0  
## PIURA a10.19 91 0.000 0.000 0.00e+00 0.0  
## PIURA a20.29 219 24.479 24.479 2.45e+01 0.0  
## PIURA a30.39 362 308.641 277.136 3.32e+02 205.0  
## PIURA a40.49 743 845.867 828.623 8.61e+02 561.9  
## PIURA a50.59 1387 1676.237 1662.437 1.69e+03 1113.5  
## PIURA a60.69 2446 2962.756 2938.073 2.99e+03 1968.2  
## PIURA a70.79 2514 2740.362 2698.620 2.78e+03 1820.5  
## PIURA a80 3251 2827.183 2706.771 2.93e+03 1878.1  
## PUNO a0.9 291 -60.413 -1075.595 1.51e+02 -170.7  
## PUNO a10.19 129 13.174 13.174 1.32e+01 0.0  
## PUNO a20.29 230 33.647 33.647 3.36e+01 0.0  
## PUNO a30.39 282 9.589 9.589 9.59e+00 0.0  
## PUNO a40.49 486 0.000 0.000 0.00e+00 0.0  
## PUNO a50.59 788 296.233 95.268 4.20e+02 215.1  
## PUNO a60.69 1128 606.650 446.629 7.20e+02 440.4  
## PUNO a70.79 1551 710.265 514.467 8.56e+02 515.7  
## PUNO a80 2134 932.142 672.852 1.13e+03 676.8  
## SAN MARTIN a0.9 191 -23.652 -553.404 9.34e+01 -69.5  
## SAN MARTIN a10.19 69 0.000 0.000 0.00e+00 0.0  
## SAN MARTIN a20.29 153 48.117 48.117 4.81e+01 0.0  
## SAN MARTIN a30.39 208 19.630 19.630 1.96e+01 0.0  
## SAN MARTIN a40.49 322 246.122 205.499 2.74e+02 165.8  
## SAN MARTIN a50.59 522 376.699 314.843 4.21e+02 253.8  
## SAN MARTIN a60.69 744 617.194 560.598 6.60e+02 415.8  
## SAN MARTIN a70.79 796 484.915 380.845 5.60e+02 326.6  
## SAN MARTIN a80 1207 678.233 525.374 7.91e+02 456.9  
## TACNA a0.9 39 7.379 7.379 7.38e+00 0.0  
## TACNA a10.19 18 5.526 5.526 5.53e+00 0.0  
## TACNA a20.29 49 0.000 0.000 0.00e+00 0.0  
## TACNA a30.39 77 0.000 0.000 0.00e+00 0.0  
## TACNA a40.49 131 0.000 0.000 0.00e+00 0.0  
## TACNA a50.59 225 0.000 0.000 0.00e+00 0.0  
## TACNA a60.69 375 226.448 157.509 2.67e+02 180.3  
## TACNA a70.79 396 197.119 127.779 2.40e+02 157.0  
## TACNA a80 444 162.710 66.081 2.21e+02 129.6  
## TUMBES a0.9 58 12.295 12.295 1.23e+01 0.0  
## TUMBES a10.19 20 3.396 3.396 3.40e+00 0.0  
## TUMBES a20.29 47 7.290 7.290 7.29e+00 0.0  
## TUMBES a30.39 80 0.000 0.000 0.00e+00 0.0  
## TUMBES a40.49 116 57.964 40.370 6.88e+01 50.4  
## TUMBES a50.59 232 191.674 185.160 1.97e+02 166.7  
## TUMBES a60.69 366 299.283 291.012 3.06e+02 260.3  
## TUMBES a70.79 354 238.163 218.495 2.53e+02 207.1  
## TUMBES a80 505 229.170 182.225 2.63e+02 199.3  
## UCAYALI a0.9 137 64.582 64.582 6.46e+01 0.0  
## UCAYALI a10.19 57 2.327 2.327 2.33e+00 0.0  
## UCAYALI a20.29 135 0.000 0.000 0.00e+00 0.0  
## UCAYALI a30.39 170 96.321 64.443 1.16e+02 69.7  
## UCAYALI a40.49 213 128.925 96.269 1.50e+02 93.3  
## UCAYALI a50.59 422 311.732 283.988 3.33e+02 225.5  
## UCAYALI a60.69 596 551.689 533.127 5.67e+02 399.1  
## UCAYALI a70.79 655 586.209 565.647 6.03e+02 424.1  
## UCAYALI a80 649 476.759 434.215 5.10e+02 344.9  
## Total - 211669 153832.058 129069.633 1.61e+05 110113.1  
## excess.reg.l excess.reg.u count count.l count.u total total.l total.u  
## 0.0 0.000 60.0 60.0 60.0 103.2 103.2 103.2  
## 0.0 0.000 22.0 22.0 22.0 40.6 40.6 40.6  
## 0.0 0.000 36.0 36.0 36.0 61.9 61.9 61.9  
## 0.0 0.000 60.0 60.0 60.0 110.1 110.1 110.1  
## 0.0 0.000 83.0 83.0 83.0 160.2 160.2 160.2  
## 0.0 0.000 123.0 123.0 123.0 221.1 221.1 221.1  
## 72.7 111.024 102.5 88.0 126.3 342.2 276.4 408.1  
## 0.0 0.000 199.0 199.0 199.0 342.2 342.2 342.2  
## 47.0 132.518 237.3 204.5 290.0 579.6 432.5 726.6  
## 0.0 0.000 243.0 243.0 243.0 321.3 321.3 321.3  
## 0.0 0.000 101.0 101.0 101.0 116.0 116.0 116.0  
## 0.0 0.000 163.0 163.0 163.0 187.3 187.3 187.3  
## 0.0 0.000 224.0 224.0 224.0 285.0 285.0 285.0  
## 189.2 250.982 245.9 220.0 281.8 541.1 470.1 612.1  
## 543.4 590.281 322.9 301.7 348.6 1024.8 970.9 1078.6  
## 930.0 972.795 438.2 418.2 461.0 1598.1 1548.9 1647.2  
## 1092.1 1182.194 819.4 777.8 867.9 2251.8 2148.2 2355.3  
## 885.9 1186.202 2082.5 1946.8 2247.1 3599.4 3254.3 3944.4  
## 1093.6 1.362 183.8 98.6 -993.6 228.7 1790.7 -1333.2  
## 0.0 0.000 51.0 51.0 51.0 73.9 73.9 73.9  
## 0.0 0.000 64.0 64.0 64.0 94.4 94.4 94.4  
## 0.0 0.000 73.0 73.0 73.0 104.4 104.4 104.4  
## 0.0 0.000 119.0 119.0 119.0 170.2 170.2 170.2  
## 0.0 0.000 200.0 200.0 200.0 286.0 286.0 286.0  
## 0.0 0.000 275.0 275.0 275.0 393.2 393.2 393.2  
## 0.0 0.000 449.0 449.0 449.0 642.0 642.0 642.0  
## 0.0 0.000 863.0 863.0 863.0 1234.0 1234.0 1234.0  
## -620.7 8.744 306.2 207.3 836.7 321.4 -340.8 983.7  
## -1268.9 3.748 152.6 94.3 1366.9 165.7 -1173.3 1504.8  
## 0.0 0.000 232.0 232.0 232.0 298.0 298.0 298.0  
## 0.0 0.000 329.0 329.0 329.0 346.2 346.2 346.2  
## 253.2 346.109 354.7 315.9 408.8 696.5 598.8 794.3  
## 680.2 751.346 493.8 461.7 532.8 1276.3 1201.4 1351.2  
## 1242.7 1325.072 703.0 664.9 747.3 2093.9 2007.2 2180.5  
## 1259.0 1416.885 1134.9 1063.1 1221.0 2609.4 2443.4 2775.5  
## 1850.5 2125.511 2308.1 2181.5 2456.5 4531.8 4242.5 4821.1  
## 1140.6 2.645 236.8 119.4 -1018.6 298.1 1998.8 -1402.6  
## 0.0 0.000 62.0 62.0 62.0 94.4 94.4 94.4  
## 0.0 0.000 95.0 95.0 95.0 167.6 167.6 167.6  
## 0.0 0.000 100.0 100.0 100.0 169.1 169.1 169.1  
## 0.0 0.000 161.0 161.0 161.0 276.2 276.2 276.2  
## 0.0 0.000 214.0 214.0 214.0 319.8 319.8 319.8  
## 0.0 0.000 373.0 373.0 373.0 623.4 623.4 623.4  
## 155.5 260.926 335.6 293.1 398.5 828.0 670.4 985.6  
## 0.0 0.000 843.0 843.0 843.0 1259.9 1259.9 1259.9  
## -2420.9 -16.052 397.8 248.1 2652.9 565.8 -3559.7 4691.2  
## 0.0 0.000 75.0 75.0 75.0 150.5 150.5 150.5  
## 0.0 0.000 128.0 128.0 128.0 260.7 260.7 260.7  
## 0.0 0.000 207.0 207.0 207.0 355.1 355.1 355.1  
## 38.0 125.951 200.7 168.0 256.0 504.3 353.5 655.2  
## 133.8 248.876 335.7 290.1 405.2 924.6 727.2 1122.0  
## 250.4 397.661 455.0 395.3 542.6 1360.3 1107.7 1613.0  
## 372.8 503.105 624.2 567.9 698.2 1837.2 1613.7 2060.8  
## 364.4 627.418 1238.3 1124.6 1387.6 3005.5 2554.3 3456.6  
## 0.0 0.000 156.0 156.0 156.0 191.1 191.1 191.1  
## 0.0 0.000 49.0 49.0 49.0 71.6 71.6 71.6  
## 0.0 0.000 185.0 185.0 185.0 268.0 268.0 268.0  
## 22.8 124.336 231.9 194.7 296.2 390.7 266.4 515.1  
## 443.1 467.614 184.5 173.4 197.9 785.2 755.2 815.2  
## 927.8 943.902 255.8 248.1 264.2 1460.1 1440.4 1479.8  
## 1435.1 1472.639 503.1 485.4 522.9 2398.4 2352.4 2444.3  
## 1607.6 1647.044 593.7 575.0 614.4 2721.7 2673.4 2770.1  
## 1738.4 1840.972 1189.1 1141.0 1243.6 3652.7 3527.1 3778.3  
## 0.0 0.000 354.0 354.0 354.0 489.1 489.1 489.1  
## 0.0 0.000 178.0 178.0 178.0 216.4 216.4 216.4  
## 0.0 0.000 246.0 246.0 246.0 369.4 369.4 369.4  
## 0.0 0.000 319.0 319.0 319.0 380.3 380.3 380.3  
## 0.0 0.000 519.0 519.0 519.0 618.8 618.8 618.8  
## 0.0 0.000 789.0 789.0 789.0 940.7 940.7 940.7  
## 193.9 461.140 839.8 731.9 999.1 1422.4 1103.8 1740.9  
## 0.0 0.000 1610.0 1610.0 1610.0 1919.5 1919.5 1919.5  
## 416.8 809.310 1811.3 1641.7 2034.2 2922.2 2454.3 3390.2  
## 27.6 67.294 87.9 73.7 113.4 172.4 123.9 221.0  
## 0.0 0.000 60.0 60.0 60.0 78.0 78.0 78.0  
## 0.0 0.000 76.0 76.0 76.0 92.9 92.9 92.9  
## 0.0 0.000 79.0 79.0 79.0 115.5 115.5 115.5  
## 0.0 0.000 152.0 152.0 152.0 185.9 185.9 185.9  
## 44.3 104.392 150.2 127.6 187.7 283.7 210.3 357.1  
## 149.7 197.986 176.9 157.0 205.3 434.1 375.1 493.1  
## 208.6 284.231 295.4 263.8 339.4 670.1 577.6 762.6  
## 0.0 0.000 782.0 782.0 782.0 957.1 957.1 957.1  
## 0.0 0.000 187.0 187.0 187.0 297.5 297.5 297.5  
## 0.0 0.000 71.0 71.0 71.0 110.7 110.7 110.7  
## 0.0 0.000 125.0 125.0 125.0 191.8 191.8 191.8  
## 0.0 0.000 166.0 166.0 166.0 271.3 271.3 271.3  
## 0.0 0.000 267.0 267.0 267.0 416.8 416.8 416.8  
## 105.9 189.799 254.4 221.2 305.1 630.5 501.8 759.2  
## 195.6 307.139 409.2 362.9 474.4 1027.8 856.8 1198.9  
## 184.9 343.700 630.9 564.3 723.1 1392.9 1149.2 1636.6  
## 192.9 412.907 913.3 820.1 1040.1 1891.5 1554.0 2229.0  
## 0.0 0.000 170.0 170.0 170.0 221.0 221.0 221.0  
## 0.0 0.000 52.0 52.0 52.0 61.4 61.4 61.4  
## 0.0 0.000 163.0 163.0 163.0 196.5 196.5 196.5  
## 63.6 116.218 160.3 139.8 192.4 256.4 203.7 309.0  
## 274.4 316.715 228.8 210.3 252.6 527.8 485.4 570.2  
## 611.7 650.016 334.6 317.0 355.3 968.4 930.0 1006.8  
## 1092.3 1121.751 360.1 346.2 375.7 1470.1 1440.7 1499.6  
## 741.5 876.445 821.8 761.6 896.5 1640.4 1505.3 1775.5  
## 1036.0 1238.615 1374.0 1282.4 1485.0 2524.7 2321.8 2727.6  
## 0.0 0.000 372.0 372.0 372.0 500.2 500.2 500.2  
## 0.0 0.000 151.0 151.0 151.0 180.4 180.4 180.4  
## 0.0 0.000 219.0 219.0 219.0 327.7 327.7 327.7  
## 0.0 0.000 322.0 322.0 322.0 416.0 416.0 416.0  
## 184.5 281.751 310.7 271.2 368.5 651.0 536.5 765.5  
## 407.7 506.288 483.6 440.7 539.3 1114.9 998.7 1231.0  
## 559.2 705.787 752.4 688.2 834.8 1641.1 1468.5 1813.7  
## 641.6 827.036 1061.2 979.0 1164.4 2126.1 1907.8 2344.5  
## 588.1 939.354 1961.8 1806.6 2157.9 3232.7 2819.2 3646.2  
## 0.0 0.000 334.0 334.0 334.0 447.0 447.0 447.0  
## 0.0 0.000 142.0 142.0 142.0 194.2 194.2 194.2  
## 0.0 0.000 297.0 297.0 297.0 422.3 422.3 422.3  
## 70.2 167.099 279.9 241.9 338.8 489.1 373.2 605.0  
## 278.6 385.484 402.1 357.5 464.4 888.6 760.7 1016.4  
## 917.8 976.255 493.6 466.7 525.2 1725.8 1655.8 1795.7  
## 1399.4 1494.374 872.6 828.6 923.6 2778.2 2664.6 2891.8  
## 1631.6 1755.039 1173.3 1116.0 1239.4 3433.6 3285.9 3581.2  
## 1424.2 1750.644 2453.2 2304.4 2630.8 4849.6 4459.2 5240.0  
## 0.0 0.000 81.0 81.0 81.0 178.9 178.9 178.9  
## 0.0 0.000 29.0 29.0 29.0 54.6 54.6 54.6  
## 0.0 0.000 90.0 90.0 90.0 169.3 169.3 169.3  
## 101.2 114.005 66.5 61.0 73.8 329.2 305.1 353.4  
## 309.6 315.128 55.4 52.9 58.4 692.4 681.9 702.8  
## 667.6 670.657 64.8 63.3 66.4 1381.0 1375.2 1386.7  
## 1096.3 1101.673 131.9 129.3 134.7 2316.0 2305.9 2326.1  
## 1062.3 1068.745 128.4 125.3 131.7 2246.4 2234.3 2258.5  
## 1025.4 1046.972 261.2 251.0 272.6 2442.1 2401.4 2482.7  
## 0.0 0.000 1374.0 1374.0 1374.0 2013.8 2013.8 2013.8  
## 0.0 0.000 483.0 483.0 483.0 685.5 685.5 685.5  
## 134.4 400.721 1006.6 896.3 1162.6 1840.8 1462.8 2218.7  
## 1237.5 1385.328 1313.9 1245.7 1393.5 3734.0 3524.2 3943.8  
## 3868.1 3940.394 1513.5 1478.6 1550.9 7690.9 7588.3 7793.4  
## 7970.6 8068.236 2527.2 2479.8 2577.4 14970.2 14831.6 15108.8  
## 13049.2 13187.726 4008.8 3941.3 4079.8 24310.2 24113.6 24506.8  
## 13367.3 13616.197 5829.5 5708.8 5957.7 27426.9 27073.7 27780.1  
## 14664.1 15352.883 12112.0 11781.1 12469.9 38509.7 37532.2 39487.3  
## -972.8 -4.001 428.4 279.0 1247.8 621.0 -1005.3 2247.4  
## 0.0 0.000 85.0 85.0 85.0 182.2 182.2 182.2  
## 0.0 0.000 152.0 152.0 152.0 285.1 285.1 285.1  
## 23.4 99.343 184.0 155.7 231.6 428.1 300.6 555.6  
## 227.5 253.102 147.1 135.9 161.5 653.0 610.1 696.0  
## 462.1 474.899 146.1 140.1 152.9 1032.4 1010.9 1054.0  
## 755.0 768.510 195.9 189.5 203.0 1608.3 1585.6 1630.9  
## 714.8 731.037 209.6 202.0 218.2 1566.3 1539.1 1593.5  
## 504.2 537.266 262.8 247.7 280.8 1317.8 1262.3 1373.4  
## 0.0 0.000 92.0 92.0 92.0 117.6 117.6 117.6  
## 0.0 0.000 21.0 21.0 21.0 21.2 21.2 21.2  
## 0.0 0.000 79.0 79.0 79.0 106.9 106.9 106.9  
## 0.0 0.000 92.0 92.0 92.0 92.8 92.8 92.8  
## 0.0 0.000 117.0 117.0 117.0 118.0 118.0 118.0  
## 76.9 99.585 81.6 72.4 95.1 173.4 150.6 196.2  
## 87.1 110.827 89.8 80.2 103.9 192.6 168.7 216.5  
## 46.9 86.478 96.4 81.5 121.1 169.4 129.5 209.3  
## 78.3 91.049 60.3 55.0 67.7 147.2 134.4 160.0  
## 0.0 0.000 21.0 21.0 21.0 40.5 40.5 40.5  
## 0.0 0.000 10.0 10.0 10.0 11.8 11.8 11.8  
## 0.0 0.000 39.0 39.0 39.0 56.2 56.2 56.2  
## 0.0 0.000 33.0 33.0 33.0 42.2 42.2 42.2  
## 40.9 55.338 40.2 34.7 49.1 106.1 89.1 123.1  
## 105.6 123.726 56.6 49.3 67.4 203.9 182.6 225.3  
## 182.8 203.159 82.4 73.8 94.2 326.5 302.4 350.5  
## 213.3 253.590 143.1 126.4 166.7 447.9 400.4 495.4  
## 146.5 245.311 300.2 260.7 359.5 596.4 479.9 712.9  
## 0.0 0.000 91.0 91.0 91.0 171.3 171.3 171.3  
## 0.0 0.000 28.0 28.0 28.0 44.6 44.6 44.6  
## 0.0 0.000 45.0 45.0 45.0 90.8 90.8 90.8  
## 0.0 0.000 58.0 58.0 58.0 107.6 107.6 107.6  
## -7303.8 0.386 143.2 82.6 7386.8 203.5 -11440.0 11847.1  
## 53.6 84.258 79.6 67.7 98.4 242.3 193.5 291.1  
## 0.0 0.000 219.0 219.0 219.0 349.1 349.1 349.1  
## 0.0 0.000 245.0 245.0 245.0 409.8 409.8 409.8  
## 0.0 0.000 294.0 294.0 294.0 471.5 471.5 471.5  
## 0.0 0.000 302.0 302.0 302.0 581.2 581.2 581.2  
## 0.0 0.000 91.0 91.0 91.0 137.0 137.0 137.0  
## 0.0 0.000 219.0 219.0 219.0 354.1 354.1 354.1  
## 184.1 220.483 157.0 141.5 177.9 544.9 490.2 599.7  
## 550.5 571.684 181.1 171.3 192.5 1118.4 1086.5 1150.4  
## 1104.4 1121.911 273.5 265.1 282.6 2087.9 2061.5 2114.3  
## 1951.8 1983.203 477.8 462.8 494.2 3682.0 3634.7 3729.3  
## 1792.7 1845.455 693.5 668.5 721.3 3784.4 3705.0 3863.7  
## 1798.1 1947.209 1372.9 1303.8 1452.9 4893.8 4669.4 5118.2  
## -907.8 -17.529 461.7 308.5 1198.8 575.5 -650.6 1801.7  
## 0.0 0.000 129.0 129.0 129.0 190.9 190.9 190.9  
## 0.0 0.000 230.0 230.0 230.0 350.4 350.4 350.4  
## 0.0 0.000 282.0 282.0 282.0 398.0 398.0 398.0  
## 0.0 0.000 486.0 486.0 486.0 669.4 669.4 669.4  
## 69.2 304.790 572.9 483.2 718.8 1085.4 760.8 1409.9  
## 324.3 522.581 687.6 605.4 803.7 1553.7 1280.5 1826.8  
## 373.5 621.274 1035.3 929.7 1177.5 2136.3 1795.0 2477.5  
## 488.5 819.103 1457.2 1314.9 1645.5 2939.3 2483.9 3394.6  
## -426.3 9.403 260.5 181.6 617.3 363.0 -283.8 1009.8  
## 0.0 0.000 69.0 69.0 69.0 102.4 102.4 102.4  
## 0.0 0.000 153.0 153.0 153.0 275.2 275.2 275.2  
## 0.0 0.000 208.0 208.0 208.0 328.4 328.4 328.4  
## 138.4 184.546 156.2 137.5 183.6 478.0 409.6 546.5  
## 212.1 283.385 268.2 238.6 309.9 774.9 669.1 880.8  
## 377.6 444.918 328.2 299.1 366.4 1104.5 1004.6 1204.4  
## 256.5 377.192 469.4 418.8 539.5 1181.7 1002.6 1360.8  
## 353.9 532.758 750.1 674.2 853.1 1791.8 1526.3 2057.3  
## 0.0 0.000 39.0 39.0 39.0 56.4 56.4 56.4  
## 0.0 0.000 18.0 18.0 18.0 28.1 28.1 28.1  
## 0.0 0.000 49.0 49.0 49.0 61.5 61.5 61.5  
## 0.0 0.000 77.0 77.0 77.0 96.7 96.7 96.7  
## 0.0 0.000 131.0 131.0 131.0 164.5 164.5 164.5  
## 0.0 0.000 225.0 225.0 225.0 282.5 282.5 282.5  
## 125.4 212.870 194.7 162.1 249.6 470.9 361.1 580.7  
## 101.8 191.492 239.0 204.5 294.2 497.2 384.6 609.9  
## 52.6 175.877 314.4 268.1 391.4 557.5 402.8 712.3  
## 0.0 0.000 58.0 58.0 58.0 79.0 79.0 79.0  
## 0.0 0.000 20.0 20.0 20.0 26.4 26.4 26.4  
## 0.0 0.000 47.0 47.0 47.0 61.3 61.3 61.3  
## 0.0 0.000 80.0 80.0 80.0 92.0 92.0 92.0  
## 35.1 59.877 65.6 56.1 80.9 133.4 104.9 161.8  
## 161.0 171.262 65.3 60.7 71.0 266.7 255.0 278.5  
## 253.1 266.295 105.7 99.7 112.9 420.8 405.6 436.0  
## 190.0 220.073 146.9 133.9 164.0 407.0 372.5 441.5  
## 158.5 228.940 305.7 276.1 346.5 580.6 499.6 661.6  
## 0.0 0.000 137.0 137.0 137.0 254.0 254.0 254.0  
## 0.0 0.000 57.0 57.0 57.0 81.1 81.1 81.1  
## 0.0 0.000 135.0 135.0 135.0 186.6 186.6 186.6  
## 46.6 83.764 100.3 86.2 123.4 235.0 183.6 286.3  
## 69.6 108.437 119.7 104.6 143.4 294.4 240.8 348.0  
## 205.5 240.815 196.5 181.2 216.5 583.3 534.4 632.2  
## 385.7 410.246 196.9 185.8 210.3 823.8 789.9 857.8  
## 409.2 436.504 230.9 218.5 245.8 905.4 867.7 943.1  
## 314.1 368.714 304.1 280.3 334.9 897.1 821.6 972.5  
## 93247.9 115768.635 101555.9 95900.4 118421.1 289949.3 257564.7 322333.9

### Proportion total excess deaths per region

## # A tibble: 25 x 3  
## # Groups: Departamento [25]  
## Departamento suma prop  
## <chr> <dbl> <dbl>  
## 1 AMAZONAS 374. 0.366   
## 2 ANCASH 4594. 4.50   
## 3 APURIMAC -30.2 -0.0296  
## 4 AREQUIPA 6011. 5.89   
## 5 AYACUCHO 419. 0.410   
## 6 CAJAMARCA 2683. 2.63   
## 7 CALLAO 7838. 7.68   
## 8 CUSCO 1331. 1.30   
## 9 HUANCAVELICA 716. 0.701   
## 10 HUANUCO 1592. 1.56   
## 11 ICA 4197. 4.11   
## 12 JUNIN 3558. 3.48   
## 13 LA LIBERTAD 7517. 7.36   
## 14 LAMBAYEQUE 8101. 7.93   
## 15 LIMA 78366. 76.7   
## 16 LORETO 4654. 4.56   
## 17 MADRE DE DIOS 404. 0.396   
## 18 MOQUEGUA 976. 0.956   
## 19 PASCO 173. 0.170   
## 20 PIURA 11512. 11.3   
## 21 PUNO 2541. 2.49   
## 22 SAN MARTIN 2447. 2.40   
## 23 TACNA 599. 0.587   
## 24 TUMBES 1039. 1.02   
## 25 UCAYALI 2219. 2.17

### Population 2020 per region

## # A tibble: 25 x 2  
## Departamento pop.INEI  
## <chr> <dbl>  
## 1 MADRE DE DIOS 153164  
## 2 MOQUEGUA 189701  
## 3 TUMBES 251363  
## 4 PASCO 314677  
## 5 TACNA 362331  
## 6 AMAZONAS 427202  
## 7 APURIMAC 467707  
## 8 HUANCAVELICA 511794  
## 9 UCAYALI 523086  
## 10 AYACUCHO 725649  
## # ... with 15 more rows

## Appendix 2

A simple comparison of registered deaths in Peru for months April to June of 2020 and corresponding periods in 2017-19 estimates 36,322 excess deaths.46 It does not include non-registered deaths or take improvements in data registration into account. Applying our approach to this time period gives an estimate of 35,461 (CI 95% 32,425 – 37,803) registered deaths which climbs to 49,648 (CI 95% 48,037- 51,034). A similar comparison between 1 January to 12 July 2020 and the corresponding periods in 2017-19 shows excess 46,863 deaths, compared to 50,534 (CI 95% 44,448- 55,582), applying our approach to the same period.47 This second study includes 2,000 excess deaths before March 2020, which cannot be attributed to the COVID-19 pandemic. A study of Lima metropolitan region finds an excess of 20,093 non-violent deaths for the first 24 weeks of 2020.48 This is above to our own estimate based on registered deaths in Lima over the same period: 14659 (CI 95% 13579 – 15609). Adding unregistered deaths increases this to 20149 (CI 95% 18839-21323).

1. University of East Anglia [↑](#footnote-ref-20)
2. Pan American Health Organisation [↑](#footnote-ref-21)
3. London School of Hygiene and Tropical Medicine [↑](#footnote-ref-22)
4. London School of Hygiene and Tropical Medicine [↑](#footnote-ref-23)
5. Max Plank Institute for Demographich Research [↑](#footnote-ref-24)
6. University of East Anglia - email:[l.sempe@uea.ac.uk](mailto:l.sempe@uea.ac.uk) [↑](#footnote-ref-25)