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 quasi-Poisson 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.

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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.

1 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 agencies[9,10], academia[11–14] 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 COVID-19 pandemic in Peru during 2020. 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.[28,29]However, 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.

2 Data and methods

2.1 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).

2.2 Excess mortality methods

Our approach to estimate excess mortality decomposes the estimate of total excess 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).

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:

$$log(\text{Deaths}_i) = \beta_0 + \beta_1 \text{COVID-19} + \beta_2 \text{Year} + \beta_3 \epsilon_{t-1} + \sum \beta_k \phi_k(\text{Week}) + \log(\text{Pop}) + \epsilon_t \quad (1)$$

where we fit a natural cubic B-spline function $\phi_k(\text{Week})$ on weeks to address long-term trends and seasonality[30] and Year to deal with registration growth. Additionally, we use lagged residuals ϵ_{t-1} 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 fraction[31] based on the relative risk RR from parameter β_1 in equation (1), as follows:

$$\widehat{\text{Excess}}_{\text{Reg}} = (\text{RR} \breve{} 1)/\text{RR} * \text{n} \quad (2)$$

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

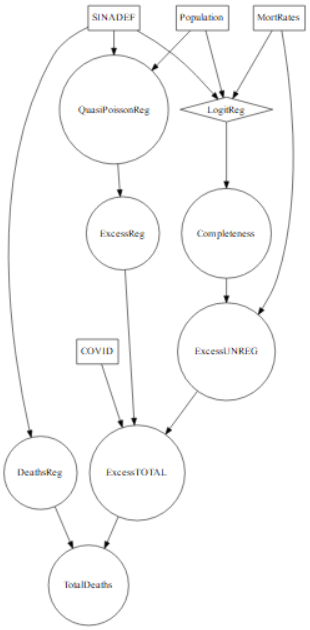

Figure 1: Flowchart: Data, analysis and outputs

To estimate our second term, we predict the logit of death registration completeness for years 2017 and 2019 (years for which data are available).[29] We exploit variability in mortality rates, population over 60 and rurality to address potential differences in terms of registration completeness. We model random-effects regressions by region using the equation:

$$\begin{aligned} \text{logit}(\text{Reg complete}_{jk}) = \beta_0 + \beta_1 * \text{RegCDR} + \beta_2 * \text{RegCDR}^2 + \\ \beta_3 * \text{complete} < 5 + \beta_4 * +60 + \beta_5 * \log(\text{5q0}) + \beta_6 * \text{LPG} + \beta_7 * \text{k} + \epsilon_{jk} + \gamma_j \end{aligned} \tag{3}$$

where RegCDR and RegCDR^2 are the Crude Death Rates based on the Registration System, complete < 5 is the completeness registration rate for infants, $log(\text{5q0})$ is the logarithm under-five mortality rate and +60 represents the fraction of the population over 60. LPG 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, ϵ_{jk} in the error term and γ_j is the region-level random effect.

Then, we compute the completeness of deaths registration, $\widehat{\text{Completeness}}$ using the inverse logit of the predicted values from equation (3) and $\widehat{\text{Excess}}_{\text{Reg}}$ from equation (2), as follows:

$$\widehat{\mu}_{\text{Deaths}_{\text{Not reg}}} = \left(1 - \widehat{\text{Completeness}}\right) * \sum \widehat{\text{Excess}}_{\text{Reg}} \tag{4}$$

The third term, unregistered COVID-19 deaths, is computed to correct for situations where the proportion of cumulative cases of COVID-19 exceeds registered deaths for 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:

$$\widehat{\mu}_{\text{Deaths}_{\text{COVID not reg}}} = \begin{cases} \widehat{\mu}_{\text{Deaths}_{\text{COVID Reg}}} - \widehat{\mu}_{\text{Excess}_{\text{Reg}}} & \text{if } \widehat{\mu}_{\text{Deaths}_{\text{COVID Reg}}} > \widehat{\mu}_{\text{Excess}_{\text{Reg}}}, \\ 0 & \text{if } \widehat{\mu}_{\text{Deaths}_{\text{COVID Reg}}} < \widehat{\mu}_{\text{Excess}_{\text{Reg}}}. \end{cases} \tag{5}$$

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 $\widehat{\mu}_{\text{Deaths}_{\text{Not reg}}}$ 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 $\widehat{\text{Excess}}_{\text{Reg}} \leq 0$ 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 β_1 in equation (1) is not statistically significant and therefore we set $\widehat{\text{Excess}}_{\text{Reg}} = 0$.

Equation (6) summarises the estimation of $\widehat{\text{Excess}}_{\text{T}_{\text{min/mean/max}}}$ as follows:

$$\widehat{\text{Excess}}_{\text{T}_{\text{min/mean/max}}} = \widehat{\text{Excess}}_{\text{Reg}_{\text{min/mean/max}}} + \widehat{\mu}_{\text{Deaths}_{\text{Not reg}}} + \text{Deaths}_{\text{COVID Not Reg}} \tag{6}$$

Finally, we estimate total mortality during 2020 by adding $\widehat{\text{Excess}}_{\text{T}_{\text{min/mean/max}}}$ from equation (6) and the counterfactual difference of SINADEF deaths during 2020 and $\widehat{\text{Excess}}_{\text{Reg}_{\text{min/mean/max}}}$, adjusted by $\widehat{\text{Completeness}}$ as follows:

$$\widehat{\text{Total}}_{Mortality\ 2020} = \widehat{\text{Excess}}_{\text{T}_{\text{min/mean/max}}} + \Big(\big(\sum_{week=1}^{52} \text{SINADEF}_{2020} - \widehat{\text{Excess}}_{\text{Reg}_{\text{min/mean/max}}} \big) * \big(1 + \widehat{\text{Completeness}} \big) \Big) \tag{7}$$

3 Results

Estimates of registration completeness derived from our logistic regression model fit the data according to R^2 and Root Mean Square of Errors parameters. Model fit and goodness-of-fit are presented in Appendix 1. Figure 2 shows important variations in regional completeness rates: Amazonas and Loreto (in Amazonia), Lambayeque (on the coast), and Cajamarca and Pasco (in the Andes) show estimated completion of below 40%, while Ica (coast) and Madre De Dios (Peru's least populated regions in Amazonia) appear to have full registration completeness (see Appendix 1).

Table 1 summarises our estimates of excess mortality. The quasi-Poisson models show a good fit for our first term (weekly excess registered deaths) -across models. Excess registered mortality is estimated to be 110,113 (95% CI 93,248 - 115,769), of which 37,724 are reported as COVID-19 deaths. This represents an increase of 192 % (95% CI 147 % - 207 %) compared to MoH data.

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 estimated deaths in 2020	101556 (95% CI 95900 - 118421)
Total estimated deaths in 2020	289949 (95% CI 257565 - 322334)

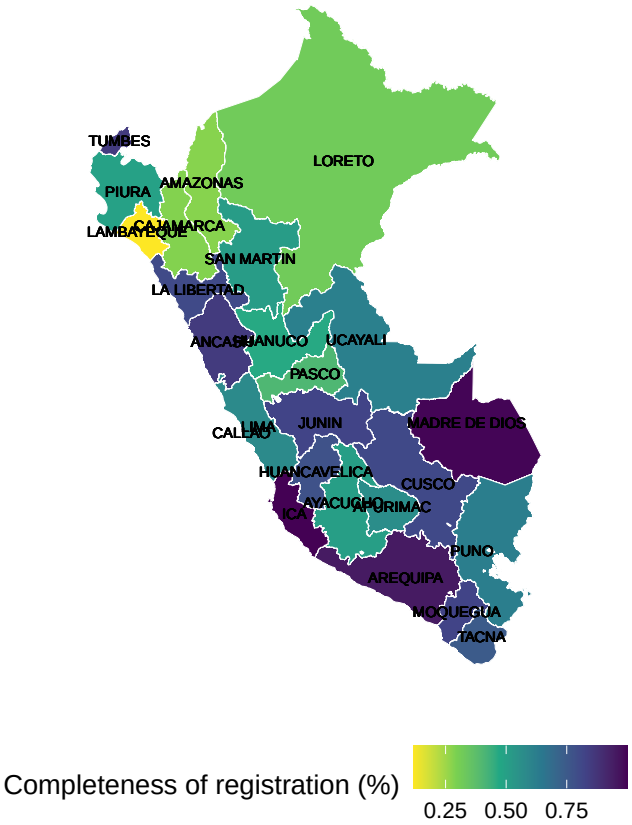

Figure 2: Completeness of registration

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 numbers. 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 the two youngest 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-group

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

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
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 at younger ages. The regions with the highest under reported COVID-19 values are the 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 (95% CI 129,070 - 161,454) and our estimate of total deaths for 2020 is 289,949 (95% CI 257,565 - 322,334). This is 51.5 % (95% CI 29.9 % - 60.4 %) more than deaths projected 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 for Amazonas.

4 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 308 % (95% CI 242 % - 328 %) higher than the level officially attributed to COVID-19. Registered excess mortality was 192 % (95% CI 147 % - 207 %) 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 75.9% 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

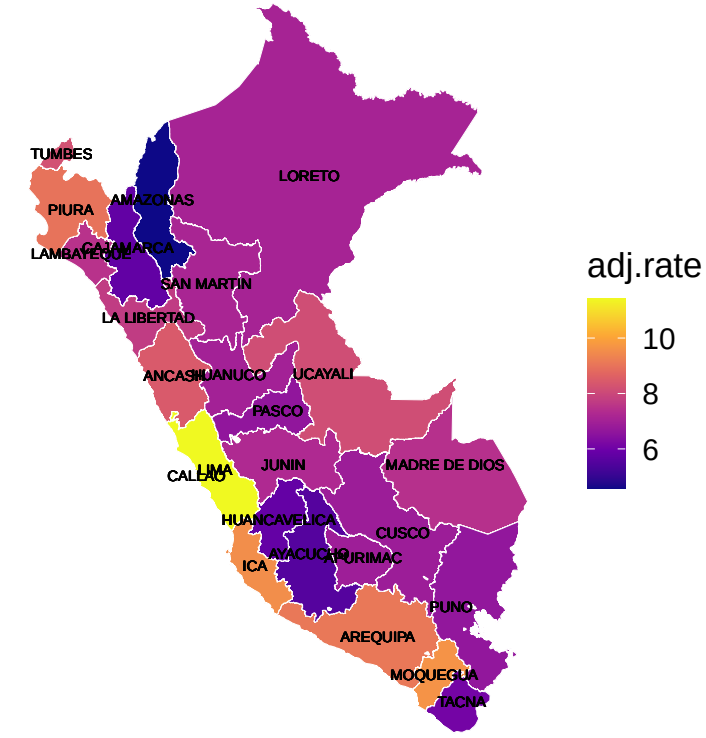

Figure 3: Mortality rates

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.

5 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.

6 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.

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8 Appendices

8.1 Appendix 1: Model fit registration completeness

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

```
## [1] 0.0527
```

```
## [1] 0.239
```

8.1.1 Quasi-Poisson models

Table 4: Model fit Quasi-Poisson (continued below)

Departamento	range	null.deviance	df.null	logLik	AIC	BIC
AMAZONAS	a0.9	70.49	136	NA	NA	NA
AMAZONAS	a10.19	24.47	74	NA	NA	NA
AMAZONAS	a20.29	22.62	106	NA	NA	NA
AMAZONAS	a30.39	41.52	119	NA	NA	NA
AMAZONAS	a40.49	77.28	159	NA	NA	NA
AMAZONAS	a50.59	125.9	172	NA	NA	NA
AMAZONAS	a60.69	263.5	179	NA	NA	NA
AMAZONAS	a70.79	243.1	200	NA	NA	NA
AMAZONAS	a80	279.1	209	NA	NA	NA
ANCASH	a0.9	234.9	209	NA	NA	NA
ANCASH	a10.19	109	183	NA	NA	NA
ANCASH	a20.29	171.9	200	NA	NA	NA
ANCASH	a30.39	196.3	201	NA	NA	NA
ANCASH	a40.49	353.7	207	NA	NA	NA
ANCASH	a50.59	791.8	209	NA	NA	NA
ANCASH	a60.69	1186	211	NA	NA	NA
ANCASH	a70.79	1201	211	NA	NA	NA
ANCASH	a80	934.5	211	NA	NA	NA
APURIMAC	a0.9	105.1	169	NA	NA	NA
APURIMAC	a10.19	21.71	104	NA	NA	NA
APURIMAC	a20.29	41.26	135	NA	NA	NA
APURIMAC	a30.39	68.23	148	NA	NA	NA
APURIMAC	a40.49	120.5	162	NA	NA	NA
APURIMAC	a50.59	182	194	NA	NA	NA
APURIMAC	a60.69	284.2	202	NA	NA	NA
APURIMAC	a70.79	275.9	210	NA	NA	NA
APURIMAC	a80	398	210	NA	NA	NA
AREQUIPA	a0.9	239.6	207	NA	NA	NA
AREQUIPA	a10.19	104.9	172	NA	NA	NA
AREQUIPA	a20.29	188.4	201	NA	NA	NA
AREQUIPA	a30.39	239.2	209	NA	NA	NA
AREQUIPA	a40.49	614.1	207	NA	NA	NA
AREQUIPA	a50.59	1524	210	NA	NA	NA
AREQUIPA	a60.69	2509	211	NA	NA	NA
AREQUIPA	a70.79	2570	211	NA	NA	NA
AREQUIPA	a80	2815	211	NA	NA	NA
AYACUCHO	a0.9	157.4	173	NA	NA	NA
AYACUCHO	a10.19	52.87	122	NA	NA	NA
AYACUCHO	a20.29	104.5	167	NA	NA	NA

Departamento	range	null.deviance	df.null	logLik	AIC	BIC
AYACUCHO	a30.39	96.41	161	NA	NA	NA
AYACUCHO	a40.49	171.5	172	NA	NA	NA
AYACUCHO	a50.59	215.1	191	NA	NA	NA
AYACUCHO	a60.69	346	205	NA	NA	NA
AYACUCHO	a70.79	499.8	208	NA	NA	NA
AYACUCHO	a80	485.4	209	NA	NA	NA
CAJAMARCA	a0.9	261.1	206	NA	NA	NA
CAJAMARCA	a10.19	53.35	143	NA	NA	NA
CAJAMARCA	a20.29	129.5	182	NA	NA	NA
CAJAMARCA	a30.39	183.2	193	NA	NA	NA
CAJAMARCA	a40.49	253.6	201	NA	NA	NA
CAJAMARCA	a50.59	553.2	209	NA	NA	NA
CAJAMARCA	a60.69	873.1	210	NA	NA	NA
CAJAMARCA	a70.79	754.7	211	NA	NA	NA
CAJAMARCA	a80	640.8	211	NA	NA	NA
CALLAO	a0.9	226.1	198	NA	NA	NA
CALLAO	a10.19	54.22	134	NA	NA	NA
CALLAO	a20.29	188.2	201	NA	NA	NA
CALLAO	a30.39	287.1	205	NA	NA	NA
CALLAO	a40.49	740.9	208	NA	NA	NA
CALLAO	a50.59	1510	211	NA	NA	NA
CALLAO	a60.69	2428	210	NA	NA	NA
CALLAO	a70.79	2093	211	NA	NA	NA
CALLAO	a80	1616	211	NA	NA	NA
CUSCO	a0.9	311	211	NA	NA	NA
CUSCO	a10.19	162.5	196	NA	NA	NA
CUSCO	a20.29	237.3	205	NA	NA	NA
CUSCO	a30.39	204.6	206	NA	NA	NA
CUSCO	a40.49	374.3	210	NA	NA	NA
CUSCO	a50.59	496.7	210	NA	NA	NA
CUSCO	a60.69	863.2	211	NA	NA	NA
CUSCO	a70.79	745.5	211	NA	NA	NA
CUSCO	a80	968.5	211	NA	NA	NA
HUANCAVELICA	a0.9	180.1	200	NA	NA	NA
HUANCAVELICA	a10.19	79.24	135	NA	NA	NA
HUANCAVELICA	a20.29	68.08	146	NA	NA	NA
HUANCAVELICA	a30.39	79.13	159	NA	NA	NA
HUANCAVELICA	a40.49	158	176	NA	NA	NA
HUANCAVELICA	a50.59	210.3	199	NA	NA	NA
HUANCAVELICA	a60.69	289.6	206	NA	NA	NA
HUANCAVELICA	a70.79	383.5	210	NA	NA	NA
HUANCAVELICA	a80	283	209	NA	NA	NA
HUANUCO	a0.9	197.9	207	NA	NA	NA
HUANUCO	a10.19	98.72	161	NA	NA	NA
HUANUCO	a20.29	118.3	190	NA	NA	NA
HUANUCO	a30.39	177.5	194	NA	NA	NA
HUANUCO	a40.49	248.7	204	NA	NA	NA
HUANUCO	a50.59	335.8	210	NA	NA	NA
HUANUCO	a60.69	450.2	210	NA	NA	NA
HUANUCO	a70.79	423	211	NA	NA	NA
HUANUCO	a80	399.5	210	NA	NA	NA
ICA	a0.9	176.6	204	NA	NA	NA

Departamento	range	null.deviance	df.null	logLik	AIC	BIC
ICA	a10.19	55.59	133	NA	NA	NA
ICA	a20.29	157.8	191	NA	NA	NA
ICA	a30.39	225.2	199	NA	NA	NA
ICA	a40.49	547.1	206	NA	NA	NA
ICA	a50.59	1065	211	NA	NA	NA
ICA	a60.69	1750	211	NA	NA	NA
ICA	a70.79	1184	209	NA	NA	NA
ICA	a80	1048	210	NA	NA	NA
JUNIN	a0.9	250.7	211	NA	NA	NA
JUNIN	a10.19	136.6	192	NA	NA	NA
JUNIN	a20.29	203.9	208	NA	NA	NA
JUNIN	a30.39	255.6	209	NA	NA	NA
JUNIN	a40.49	446.4	210	NA	NA	NA
JUNIN	a50.59	824.6	211	NA	NA	NA
JUNIN	a60.69	1085	211	NA	NA	NA
JUNIN	a70.79	907.6	211	NA	NA	NA
JUNIN	a80	929	211	NA	NA	NA
LA LIBERTAD	a0.9	250.4	209	NA	NA	NA
LA LIBERTAD	a10.19	181	190	NA	NA	NA
LA LIBERTAD	a20.29	244.2	208	NA	NA	NA
LA LIBERTAD	a30.39	270.6	210	NA	NA	NA
LA LIBERTAD	a40.49	567.4	210	NA	NA	NA
LA LIBERTAD	a50.59	1518	211	NA	NA	NA
LA LIBERTAD	a60.69	2366	211	NA	NA	NA
LA LIBERTAD	a70.79	2050	211	NA	NA	NA
LA LIBERTAD	a80	1492	211	NA	NA	NA
LAMBAYEQUE	a0.9	350.2	182	NA	NA	NA
LAMBAYEQUE	a10.19	60.08	114	NA	NA	NA
LAMBAYEQUE	a20.29	150.1	163	NA	NA	NA
LAMBAYEQUE	a30.39	203	176	NA	NA	NA
LAMBAYEQUE	a40.49	571.5	182	NA	NA	NA
LAMBAYEQUE	a50.59	1090	186	NA	NA	NA
LAMBAYEQUE	a60.69	2064	198	NA	NA	NA
LAMBAYEQUE	a70.79	2191	203	NA	NA	NA
LAMBAYEQUE	a80	3716	205	NA	NA	NA
LIMA	a0.9	463.5	211	NA	NA	NA
LIMA	a10.19	282.5	211	NA	NA	NA
LIMA	a20.29	497.2	211	NA	NA	NA
LIMA	a30.39	1413	211	NA	NA	NA
LIMA	a40.49	5115	211	NA	NA	NA
LIMA	a50.59	12694	211	NA	NA	NA
LIMA	a60.69	20998	211	NA	NA	NA
LIMA	a70.79	18227	211	NA	NA	NA
LIMA	a80	15668	211	NA	NA	NA
LORETO	a0.9	249	209	NA	NA	NA
LORETO	a10.19	79.99	150	NA	NA	NA
LORETO	a20.29	143.8	191	NA	NA	NA
LORETO	a30.39	218.4	199	NA	NA	NA
LORETO	a40.49	447.8	206	NA	NA	NA
LORETO	a50.59	857.3	208	NA	NA	NA
LORETO	a60.69	1598	210	NA	NA	NA
LORETO	a70.79	1387	210	NA	NA	NA

Departamento	range	null.deviance	df.null	logLik	AIC	BIC
LORETO	a80	866.2	210	NA	NA	NA
MADRE DE DIOS	a0.9	74.38	132	NA	NA	NA
MADRE DE DIOS	a10.19	20.02	80	NA	NA	NA
MADRE DE DIOS	a20.29	72.1	153	NA	NA	NA
MADRE DE DIOS	a30.39	69.1	140	NA	NA	NA
MADRE DE DIOS	a40.49	93.59	149	NA	NA	NA
MADRE DE DIOS	a50.59	217.3	165	NA	NA	NA
MADRE DE DIOS	a60.69	262.2	176	NA	NA	NA
MADRE DE DIOS	a70.79	202.9	172	NA	NA	NA
MADRE DE DIOS	a80	174	176	NA	NA	NA
MOQUEGUA	a0.9	19.28	77	NA	NA	NA
MOQUEGUA	a10.19	4.309	39	NA	NA	NA
MOQUEGUA	a20.29	17.29	82	NA	NA	NA
MOQUEGUA	a30.39	16.74	79	NA	NA	NA
MOQUEGUA	a40.49	92.24	123	NA	NA	NA
MOQUEGUA	a50.59	253.6	157	NA	NA	NA
MOQUEGUA	a60.69	556	186	NA	NA	NA
MOQUEGUA	a70.79	718.1	203	NA	NA	NA
MOQUEGUA	a80	530.2	209	NA	NA	NA
PASCO	a0.9	69.04	140	NA	NA	NA
PASCO	a10.19	14.4	60	NA	NA	NA
PASCO	a20.29	31.61	101	NA	NA	NA
PASCO	a30.39	49.05	105	NA	NA	NA
PASCO	a40.49	58.92	131	NA	NA	NA
PASCO	a50.59	138.3	163	NA	NA	NA
PASCO	a60.69	211.9	169	NA	NA	NA
PASCO	a70.79	243.2	192	NA	NA	NA
PASCO	a80	291.5	196	NA	NA	NA
PIURA	a0.9	270.7	209	NA	NA	NA
PIURA	a10.19	111	169	NA	NA	NA
PIURA	a20.29	226.6	200	NA	NA	NA
PIURA	a30.39	359.6	206	NA	NA	NA
PIURA	a40.49	935.7	207	NA	NA	NA
PIURA	a50.59	1661	211	NA	NA	NA
PIURA	a60.69	3278	211	NA	NA	NA
PIURA	a70.79	2489	211	NA	NA	NA
PIURA	a80	1948	211	NA	NA	NA
PUNO	a0.9	265.3	209	NA	NA	NA
PUNO	a10.19	135.9	185	NA	NA	NA
PUNO	a20.29	217.2	206	NA	NA	NA
PUNO	a30.39	278.8	207	NA	NA	NA
PUNO	a40.49	403	210	NA	NA	NA
PUNO	a50.59	752.1	210	NA	NA	NA
PUNO	a60.69	1015	211	NA	NA	NA
PUNO	a70.79	926.8	211	NA	NA	NA
PUNO	a80	857.7	211	NA	NA	NA
SAN MARTIN	a0.9	213.3	206	NA	NA	NA
SAN MARTIN	a10.19	95.47	152	NA	NA	NA
SAN MARTIN	a20.29	120	188	NA	NA	NA
SAN MARTIN	a30.39	204.7	205	NA	NA	NA
SAN MARTIN	a40.49	327.1	208	NA	NA	NA
SAN MARTIN	a50.59	502	207	NA	NA	NA

Departamento	range	null.deviance	df.null	logLik	AIC	BIC
SAN MARTIN	a60.69	815.9	211	NA	NA	NA
SAN MARTIN	a70.79	605.2	210	NA	NA	NA
SAN MARTIN	a80	815.5	211	NA	NA	NA
TACNA	a0.9	54.88	128	NA	NA	NA
TACNA	a10.19	4.114	66	NA	NA	NA
TACNA	a20.29	47.15	125	NA	NA	NA
TACNA	a30.39	91.16	155	NA	NA	NA
TACNA	a40.49	161	174	NA	NA	NA
TACNA	a50.59	347.6	191	NA	NA	NA
TACNA	a60.69	602.6	201	NA	NA	NA
TACNA	a70.79	453.1	209	NA	NA	NA
TACNA	a80	360.2	209	NA	NA	NA
TUMBES	a0.9	57.83	131	NA	NA	NA
TUMBES	a10.19	5.142	58	NA	NA	NA
TUMBES	a20.29	29.23	109	NA	NA	NA
TUMBES	a30.39	53.22	130	NA	NA	NA
TUMBES	a40.49	98.7	152	NA	NA	NA
TUMBES	a50.59	274.3	179	NA	NA	NA
TUMBES	a60.69	472.5	191	NA	NA	NA
TUMBES	a70.79	375.1	197	NA	NA	NA
TUMBES	a80	398.4	210	NA	NA	NA
UCAYALI	a0.9	189.3	193	NA	NA	NA
UCAYALI	a10.19	43.62	126	NA	NA	NA
UCAYALI	a20.29	141	174	NA	NA	NA
UCAYALI	a30.39	170.5	177	NA	NA	NA
UCAYALI	a40.49	255.5	202	NA	NA	NA
UCAYALI	a50.59	518	205	NA	NA	NA
UCAYALI	a60.69	747.7	210	NA	NA	NA
UCAYALI	a70.79	899.3	206	NA	NA	NA
UCAYALI	a80	630	209	NA	NA	NA

deviance	df.residual	nobs	fit	dif.dev	df	p
63.16	128	137	0.1041	7.336	8	0.5008
19.4	66	75	0.2071	5.069	8	0.7502
20.89	98	107	0.07651	1.73	8	0.9882
34.49	111	120	0.1693	7.03	8	0.5334
74.37	151	160	0.0376	2.906	8	0.9401
113.7	164	173	0.09711	12.23	8	0.1414
175.1	171	180	0.3353	88.33	8	1.015e-15
230.5	192	201	0.05163	12.55	8	0.1283
246.4	201	210	0.1173	32.73	8	0.00006879
216.5	201	210	0.07825	18.38	8	0.01853
106.7	175	184	0.02046	2.23	8	0.9732
161.2	192	201	0.06239	10.72	8	0.2178
187.1	193	202	0.04697	9.22	8	0.3241
251.1	199	208	0.29	102.6	8	1.275e-18
328.5	201	210	0.5852	463.3	8	5.146e-95
336.3	203	212	0.7165	849.9	8	3.644e-178
400.4	203	212	0.6666	800.6	8	1.565e-167
454.5	203	212	0.5136	479.9	8	1.439e-98
95.77	161	170	0.08903	9.36	8	0.3129

deviance	df.residual	nobs	fit	dif.dev	df	p
20.37	96	105	0.06181	1.342	8	0.995
36.57	127	136	0.1138	4.696	8	0.7895
65.64	140	149	0.03788	2.585	8	0.9577
101.4	154	163	0.1582	19.06	8	0.01454
146.3	186	195	0.1958	35.63	8	0.00002053
236.7	194	203	0.1671	47.5	8	1.231e-07
206.1	202	211	0.2531	69.84	8	5.289e-12
242.8	202	211	0.3899	155.2	8	1.642e-29
222.2	199	208	0.07273	17.43	8	0.02597
93.53	164	173	0.1079	11.32	8	0.1844
180.8	193	202	0.04036	7.605	8	0.4729
205.3	201	210	0.1419	33.94	8	0.00004166
304.6	199	208	0.504	309.5	8	3.886e-62
339.5	202	211	0.7772	1184	8	2.68e-250
401.3	203	212	0.8401	2108	8	0
441.4	203	212	0.8282	2128	8	0
530.2	203	212	0.8116	2284	8	0
123.3	165	174	0.2162	34.03	8	0.00004016
49.06	114	123	0.07201	3.807	8	0.8741
90.34	159	168	0.1353	14.14	8	0.07819
85.03	153	162	0.118	11.38	8	0.1812
148.4	164	173	0.1348	23.12	8	0.003213
183.8	183	192	0.1455	31.29	8	0.0001246
216.2	197	206	0.3752	129.8	8	3.102e-24
289.3	200	209	0.4211	210.4	8	4.009e-41
257.6	201	210	0.4694	227.9	8	8.331e-45
222.6	198	207	0.1475	38.5	8	6.082e-06
51.37	135	144	0.03702	1.975	8	0.9818
121.5	174	183	0.06211	8.044	8	0.4292
158.6	185	194	0.1344	24.63	8	0.001796
197.2	193	202	0.2223	56.36	8	2.404e-09
272.4	201	210	0.5075	280.7	8	5.211e-56
330.7	202	211	0.6212	542.4	8	5.614e-112
323	203	212	0.572	431.7	8	3.088e-88
361.7	203	212	0.4356	279.1	8	1.132e-55
214.1	190	199	0.05334	12.06	8	0.1485
51.73	126	135	0.04593	2.49	8	0.9622
179.1	193	202	0.04879	9.185	8	0.3269
226.4	197	206	0.2115	60.72	8	3.374e-10
308	200	209	0.5843	432.9	8	1.71e-88
355	203	212	0.7649	1155	8	4.307e-244
433.4	202	211	0.8215	1995	8	0
410	203	212	0.8041	1683	8	0
491	203	212	0.6961	1125	8	1.792e-237
247.6	203	212	0.2039	63.4	8	1e-10
153.7	188	197	0.05443	8.846	8	0.3554
218.6	197	206	0.07858	18.64	8	0.01689
173.8	198	207	0.1507	30.84	8	0.0001497
305.8	202	211	0.1829	68.44	8	1.004e-11
337.3	202	211	0.3208	159.3	8	2.212e-30
403.5	203	212	0.5325	459.7	8	3.067e-94
361.5	203	212	0.5151	384	8	4.894e-78

deviance	df.residual	nobs	fit	dif.dev	df	p
448.6	203	212	0.5368	519.9	8	3.806e-107
168	192	201	0.06735	12.13	8	0.1454
71.26	127	136	0.1006	7.975	8	0.4359
60.85	138	147	0.1063	7.236	8	0.5114
76.66	151	160	0.03121	2.469	8	0.9631
137.4	168	177	0.1304	20.6	8	0.008303
178.4	191	200	0.1516	31.87	8	0.00009811
224.2	198	207	0.2259	65.42	8	3.977e-11
281.8	202	211	0.2652	101.7	8	1.915e-18
239.2	201	210	0.1546	43.76	8	6.321e-07
176.9	199	208	0.1063	21.04	8	0.007054
89.81	153	162	0.09024	8.908	8	0.3501
113.3	182	191	0.04221	4.991	8	0.7585
162.5	186	195	0.08425	14.95	8	0.06005
222.6	196	205	0.1052	26.16	8	0.0009844
276.6	202	211	0.1763	59.2	8	6.684e-10
258.2	202	211	0.4264	191.9	8	3.173e-37
290.1	203	212	0.314	132.8	8	7.306e-25
290.7	202	211	0.2723	108.8	8	6.753e-20
171	196	205	0.03186	5.628	8	0.6888
49.36	125	134	0.1121	6.23	8	0.6214
146.5	183	192	0.07158	11.29	8	0.1857
177.9	191	200	0.2099	47.27	8	1.36e-07
235.2	198	207	0.5701	311.9	8	1.217e-62
298.5	203	212	0.7198	766.7	8	3.103e-160
353.2	203	212	0.7981	1396	8	3.343e-296
399.9	201	210	0.6623	784.1	8	5.619e-164
450.3	202	211	0.5705	598.1	8	5.904e-124
241.7	203	212	0.03601	9.028	8	0.34
129.3	184	193	0.0532	7.267	8	0.5081
190.2	200	209	0.06737	13.74	8	0.08888
241.1	201	210	0.05696	14.56	8	0.06827
299.3	202	211	0.3295	147.1	8	7.976e-28
298.9	203	212	0.6376	525.7	8	2.137e-108
366.7	203	212	0.6621	718.3	8	8.164e-150
366.9	203	212	0.5957	540.7	8	1.305e-111
449.6	203	212	0.516	479.4	8	1.882e-98
231.4	201	210	0.07591	19.01	8	0.01482
170.4	182	191	0.05862	10.61	8	0.2247
231.1	200	209	0.05354	13.07	8	0.1093
235.4	202	211	0.1299	35.15	8	0.00002506
336.1	202	211	0.4076	231.2	8	1.619e-45
432.4	203	212	0.7151	1085	8	5.239e-229
466.8	203	212	0.8027	1900	8	0
455.5	203	212	0.7779	1595	8	0
515	203	212	0.6549	977.4	8	1.108e-205
163.9	174	183	0.5319	186.3	8	5.002e-36
49.37	106	115	0.1784	10.72	8	0.2182
106.7	155	164	0.2894	43.45	8	7.213e-07
135.4	168	177	0.3331	67.61	8	1.464e-11
276	174	183	0.5171	295.5	8	3.688e-59
288	178	187	0.7357	801.7	8	8.861e-168

deviance	df.residual	nobs	fit	dif.dev	df	p
383.1	190	199	0.8144	1681	8	0
412.4	195	204	0.8118	1778	8	0
525.3	197	206	0.8587	3191	8	0
378.2	203	212	0.184	85.27	8	4.235e-15
248.1	203	212	0.1219	34.45	8	0.00003372
394.7	203	212	0.2063	102.6	8	1.263e-18
412.8	203	212	0.7079	1001	8	1.15e-210
485.2	203	212	0.9051	4630	8	0
831.7	203	212	0.9345	11862	8	0
1068	203	212	0.9491	19930	8	0
1182	203	212	0.9351	17044	8	0
1476	203	212	0.9058	14192	8	0
227.6	201	210	0.08598	21.41	8	0.006144
74.43	142	151	0.06951	5.56	8	0.6964
136.3	183	192	0.05269	7.578	8	0.4757
172.2	191	200	0.2114	46.17	8	2.211e-07
242.2	198	207	0.4591	205.6	8	4.283e-40
327.1	200	209	0.6184	530.2	8	2.33e-109
393.3	202	211	0.7539	1205	8	8.391e-255
390.3	202	211	0.7186	996.6	8	8.132e-210
379	202	211	0.5624	487.1	8	4.022e-100
64.85	124	133	0.1281	9.526	8	0.2999
17.98	72	81	0.1018	2.037	8	0.9799
66.87	145	154	0.07247	5.225	8	0.7333
64.3	132	141	0.06952	4.804	8	0.7783
79.85	141	150	0.1468	13.74	8	0.08874
126.2	157	166	0.4192	91.1	8	2.778e-16
138.8	168	177	0.4707	123.4	8	6.534e-23
123.6	164	173	0.3905	79.22	8	7.021e-14
117.6	168	177	0.3243	56.41	8	2.344e-09
17.27	69	78	0.1039	2.004	8	0.9809
3.486	31	40	0.1911	0.8234	8	0.9991
15.12	74	83	0.1251	2.163	8	0.9756
14.04	71	80	0.1611	2.697	8	0.9519
60.24	115	124	0.3468	31.99	8	0.00009352
108.9	149	158	0.5708	144.8	8	2.406e-27
212.4	178	187	0.618	343.6	8	2.092e-69
258.7	195	204	0.6397	459.4	8	3.592e-94
254.3	201	210	0.5204	275.9	8	5.473e-55
58.75	132	141	0.149	10.29	8	0.2453
11.93	52	61	0.1715	2.47	8	0.9631
28.6	93	102	0.09542	3.017	8	0.9333
45.02	97	106	0.08213	4.028	8	0.8546
48.35	123	132	0.1794	10.57	8	0.2274
91.88	155	164	0.3357	46.44	8	1.961e-07
133.3	161	170	0.371	78.62	8	9.269e-14
179.8	184	193	0.2608	63.44	8	9.821e-11
229.4	188	197	0.2129	62.07	8	1.829e-10
239.1	201	210	0.1165	31.53	8	0.0001131
102.7	161	170	0.07488	8.312	8	0.4036
186.3	192	201	0.1777	40.27	8	2.857e-06
222.8	198	207	0.3803	136.7	8	1.128e-25

deviance	df.residual	nobs	fit	dif.dev	df	p
351.5	199	208	0.6243	584.2	8	5.897e-121
356.9	203	212	0.7851	1304	8	3.315e-276
462.9	203	212	0.8588	2815	8	0
438.6	203	212	0.8238	2050	8	0
574.6	203	212	0.705	1373	8	3.799e-291
211	201	210	0.2046	54.27	8	6.114e-09
125.3	177	186	0.07841	10.66	8	0.2219
204.5	198	207	0.05853	12.71	8	0.1222
272.2	199	208	0.0238	6.635	8	0.5765
296.3	202	211	0.2647	106.7	8	1.852e-19
342.8	202	211	0.5443	409.3	8	1.88e-83
337.8	203	212	0.6671	676.9	8	6.763e-141
353.2	203	212	0.6189	573.6	8	1.106e-118
453.4	203	212	0.4714	404.3	8	2.256e-82
187	198	207	0.1234	26.31	8	0.0009299
84.75	144	153	0.1122	10.71	8	0.2184
110.1	180	189	0.08208	9.847	8	0.276
174	197	206	0.1503	30.76	8	0.0001547
238.1	200	209	0.2719	88.93	8	7.666e-16
287.2	199	208	0.4279	214.8	8	4.756e-42
333.7	203	212	0.5909	482.2	8	4.741e-99
301.8	202	211	0.5013	303.4	8	7.942e-61
379.5	203	212	0.5346	436	8	3.736e-89
48.73	120	129	0.1122	6.156	8	0.6298
3.41	58	67	0.171	0.7036	8	0.9995
42.47	117	126	0.0993	4.682	8	0.791
88.65	147	156	0.02755	2.511	8	0.9612
126.7	166	175	0.213	34.29	8	0.00003604
211.7	183	192	0.3909	135.9	8	1.709e-25
290.9	193	202	0.5173	311.7	8	1.304e-62
272.7	201	210	0.3982	180.4	8	8.331e-35
308.6	201	210	0.1433	51.63	8	1.985e-08
55.09	123	132	0.04737	2.739	8	0.9496
3.969	50	59	0.2282	1.173	8	0.9969
27.64	101	110	0.05437	1.589	8	0.9911
47.87	122	131	0.1005	5.349	8	0.7197
75.36	144	153	0.2365	23.34	8	0.00295
146.2	171	180	0.4668	128	8	7.229e-24
209.8	183	192	0.556	262.7	8	3.448e-52
214.6	189	198	0.4279	160.5	8	1.264e-30
248.4	202	211	0.3766	150.1	8	1.909e-28
154.3	185	194	0.1848	34.97	8	0.00002711
40.99	118	127	0.0603	2.63	8	0.9554
127	166	175	0.09946	14.02	8	0.08117
142.8	169	178	0.1622	27.65	8	0.0005449
203.5	194	203	0.2036	52.01	8	1.673e-08
277.6	197	206	0.464	240.3	8	1.927e-47
331.1	202	211	0.5572	416.6	8	5.261e-85
297.1	198	207	0.6696	602.2	8	8.045e-125
334.6	201	210	0.469	295.5	8	3.82e-59

8.1.2 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
```

8.1.3 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
```

8.1.4 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
```

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##    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
```

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##          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
```

8.1.5 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
```

8.1.6 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
```

8.2 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).