ACTL3141 Assignment

Neel Patel (z5205344)

Neel Patel
Z5205344

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Task 1: Comparing the trends in mortality by deprivation decile in England

In actuarial practice**,** the links between life mortality and the socio-economic factors of a life are commonly related to each other. The general rule of thumb is that individuals in better circumstances tend to have a higher life expectancy. Hence, the study of the UK population based on the IMD decile**,** which measures socio-economic circumstances at a small government area, allows us to investigate this phenomenon.

Directly Age Standardised Death Rate (DASRD)

The DASDR provides us a weighted average of age specific death rate per 100,000's using $sE^{c}_{x,t}$ as the weights.

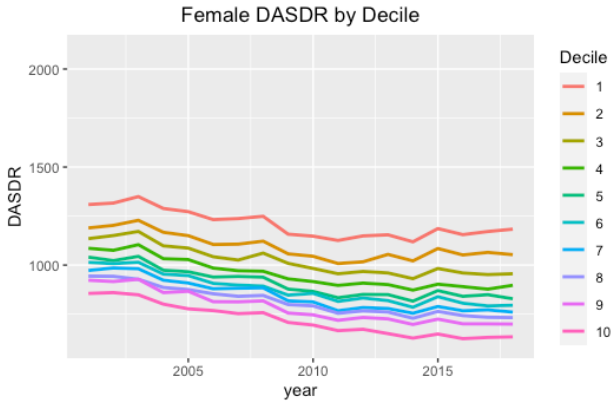


Figure 1

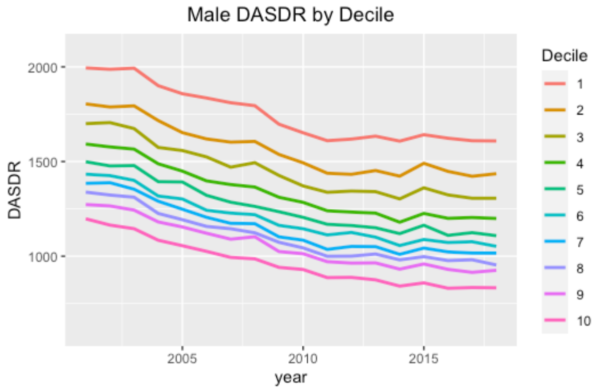


Figure 2

We can see that the assumption holds up when we examine the trends of the DASDR. By grouping the population into IMD decile based on the local socioeconomic factors, we can see that most deprived areas experience a greater death rate per 100,000 in comparison to the least deprived. We can also see another evident trend in the declining DASDR for each decile from 2001 to 2008**,** indicating an improvement in mortality. For males living in the most deprived areas, it has come down from 1994 to 1609, which is a decline of around (-)19.3%, whereas for males living in the least deprived areas its decreased from 1197 to 833, a fall of (-)30%. Similarly, for females living in the most deprived areas, the DASDR has decreased from 1309 to 1183 a (-)9.6% change for females living in least deprived areas, a reduction from 855 to 634 a (-)25.84% change for the least deprived areas. However, we can see that there is a slowdown in mortality improvement for both females and males living in the most and least deprived areas post 2011. Also, there is a much greater variance in DASDR between deciles for males compared to females, proposing that socioeconomic variables have a greater impact on male's mortality compared to females.

Infant Mortality

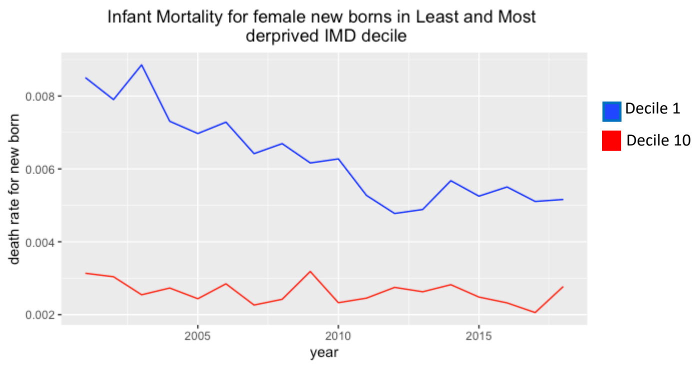


Figure 3

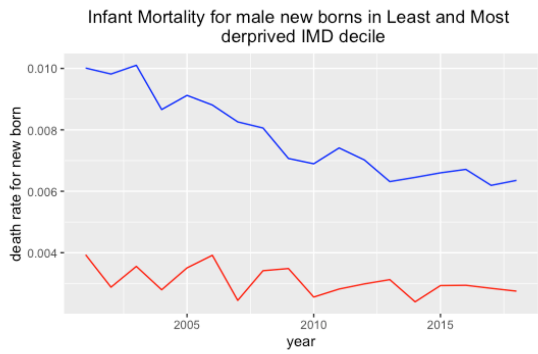


Figure 4

This trend is also present for infant mortality. The death rate for a newborn child in the least deprived area is much lower than a newborn child in the most deprived area. The death rate for the least deprived seems constant with small variability, whereas for the most deprived for both female and male, we can see that the death rate is decreasing, the same trend which is observed in figures 1 and 2 for DASDR. Hence, it is very clear that deprivation has an impact on one's mortality even at an early age. There can be many reasons for which one could be the lack of general access and quality of health care that is achievable at each decile level may vary.

Life Expectancy

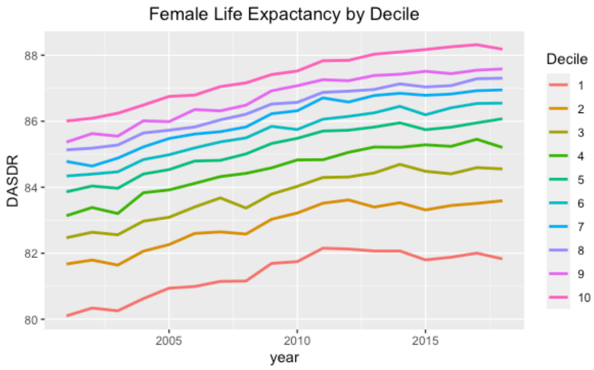


Figure 5

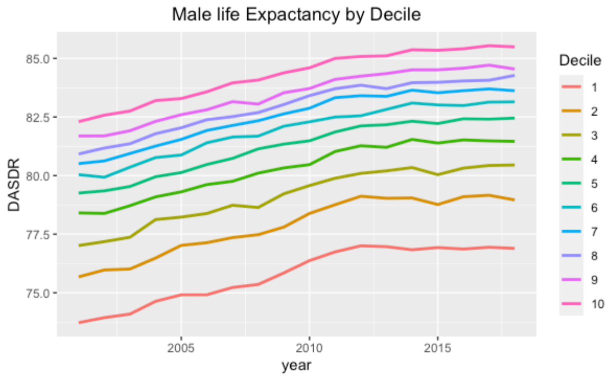


Figure 6

Since that data for deaths and the population size for each individual age was capped at age 89, it is not possible to calculate the full life expectancy. However, we can assume that if an individual has lived up to age 90 and beyond, the mortality rates will be similar regardless of the deprivation decile. The ONS estimates that a life expectancy for a person aged 90 is 4.1 years for males and 4.6 years for females. Thus, assuming these numbers for all deciles, we can study the life expectancies of each deprivation decile. We can see that for the most deprived decile, the life expectancy increased from 2000 and peaked around 2012 and remained constant for the rest of the years. This is the result of slowing down in improvements of the mortality seen in figures 2, as the DASDR curve started to flatten out after 2011. The same trend can be observed for the least deprived decile, however its increase in life expectancy is less than that of the most deprived and it also sees the life expectancy flatten after 2011. However, there seems to be no improvement in the life expectancy gap between the least and most deprived areas. Similar trends are observed for female life expectancy where both the least and most deprived areas see an improvement in life expectancy, however it levels out after 2011 as anticipated by figure 1 with DASDR flattening out after 2011. The rate of improvement for life expectancy is much greater for males as compared to females and this results in the reduction of the gap between gender life expectancies, with it decreasing from 6.22 years to 4.79 for the most deprived and 3.56 years to 2.56 years for least deprived between 2001 to 2018.

This shows that there is a clear link between deprivation deciles and life mortality. Lives in the most deprived deciles experience a greater death rate per 100,000 compared to the least deprived. Even newborn babies in the most deprived deciles experience a higher life mortality compared to the least deprived. However, it could also be put down to other factors such as access to health care. But we can see that overall, every decile has experienced an improvement in mortality since 2001 which has resulted in the increase in life expectancy observed. However, the gap between IMD deciles still remain.

Task 2: Graduation of a Female IMD decile 4 period life table for the year 2018

The graduation of the crude central mortality rate was done using the Gompertz, Makhem, and the two splines, cubic and smoothing. Statistical tests were conducted to test which is the better graduation method, from which it is evident that smoothing splines provide the best graduation to the crude rates calculated, meeting the required qualities of smoothness and goodness of fit.

Statistical tests

Chi-Square Test

The Chi-square tells us which of the graduation methods provides the best goodness of fit to the crude mortality rates. Only the smoothing splines provides the best fit for the graduated data at a significance level of 5% with a p-value of 0.664929, failing to reject the null hypothesis (as stated in Appendix A). Contrastingly**,** others reject the null hypothesis with a p-value less than 0.05. indicating that other graduation methods provide a poor graduated rate that fits the data.

Standardised deviations test

The standardised deviations test is used to check if the standardised deviations follow a standard normal distribution. If the standard deviations are too spread out, it means there are a of values in the tail and indicates overgraduation, whereas if the standard deviations are too bunched up, it means at it is more concentrated centrally, which might indicate undergraduation. From the test, only the smooth spline failed to reject the null hypothesis, giving a p-value of 0.9836, whilst others had a p-value less than 0.05. Having a look at the number of standardised deviations in the interval (-2/3,2/3), only the smoothing splines has roughly half of its standardised deviations in that interval with 22 of the 50 in the interval. Contrastingly, Gompertz has 16 out of the 50 in the interval, Makhem has 19 out of the 50 and cubic splines has 9 out of the 50. This shows that the standardised deviations are too spread out, making a heavier tail and suggesting overgraduation of the mortality rates. This is seen in figures C1 and C2, where the Gompertz and Makhem graduated curves are too smoothed out for ages around 40-55.

Groupings of Signs test (Stevens' Test)

The Grouping of signs test allows us to check for overgraduation by comparing the number of groups of deviation of the same sign with the expected runs of same sign in random order. Therefore, if there are excessively large number of runs positive deviations, this would indicate overgraduation. Only~~,~~ the smoothing spline fails to reject the null hypothesis with a significance level of 5%, reinforcing its optimal choice of graduation method. Contrastingly, the others reject the null hypothesis and as suggested by the standardised deviations test, these graduation methods are overgraduating the crude mortality rates.

Cumulative deviations test

The cumulative deviations test whether the overall number of deaths conforms to the model with the mortality rates assumed in the graduation. This indicates whether the graduated rates are negatively or positively biased. All graduation models fail to reject the null hypothesis at a significance level at 5%, other than the cubic splines. This indicates that the graduated rates are significantly lower than the actual rates, resulting in a greater variance.

Signs test

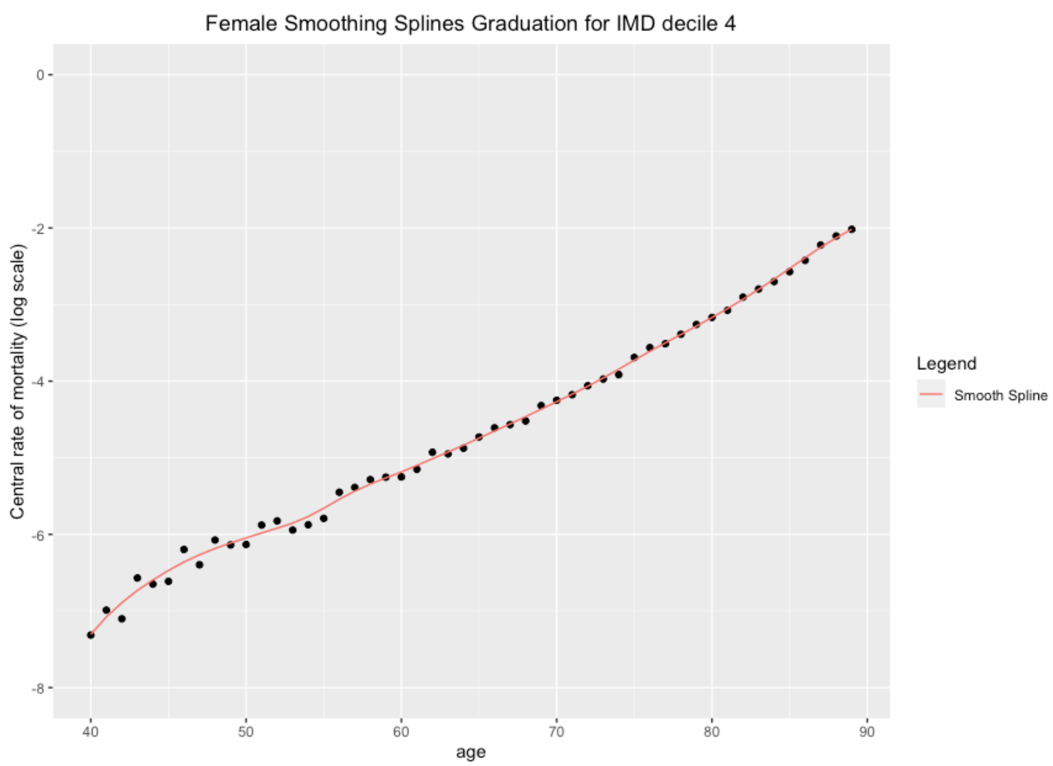
The signs test compares the balance between positive and negative deviations. If the test shows the number of positive values is very high or low, it indicates the mortality rates are on average too low or high. This pattern of signs will indicate at which age range the bias is worst. However, all the tests failed to reject the null hypotheses, indicating a 50% balance between the positive and negative deviations.

Serial Correlations test

The serial correlations test detects excessive accumulation of deviations of the same sign**,** which indicates overgraduation. From the plots of the autocorrelation function (figure D1), we can see that the Gompertz, Makeham and cubic graduation model show significant serial correlation in their standardised residuals as quite a few are outside the confidence interval. Contrastingly, for smoothing splines, it is generally inside the confidence interval, so we cannot reject the null hypothesis of independence of their corresponding standardised deviations.

Smoothing Splines is the optimum method for graduating

Hence, we can clearly see that the best choice of graduating the crude mortality rates is the smoothing splines method. It failed to reject the null hypothesis of every statistical test, resulting in it providing the best fit to the data and the graduated rates residuals are normally distributed and are unbiased. Comparatively, the other models, such as the Gompertz and Makhem model resulted in over-graduating the crude mortality rates as shown by the standardised deviations test and the groupings of signs test and the cubic spline is undergraduating as seen visually from figures C1, C2 and C3.



Task 3: The ethical perspective of the use of deprivation as a rating criterion

In trying to predict the risk factors associated with life mortality to calculate insurance products, it is important to question if it violates any societal ethical constrains. From a deontological view, it is important for insurers to charge an individual based on its associated underlying risk factors. We have seen that deprivation is a clear indicator of a life's mortality rates and from an actuarial standpoint this needs to be addressed as an underlying risk factor. In the aim to address the deprivation as an underlying risk factor, the use of IMD deciles as a measure of deprivation risk poses ethical fairness questions. To answer this, it is important to factor in the key stakeholders that would be impacted if such methods were used to calculate annuities and what the result of the outcome be. This leads to the conclusion that it is from an ethical standpoint important to address all the underlying risk factors associated with deprivation being an indicator of a life's mortality. However, it is ethically unjust to use IMD deciles as a measure of an individual's deprivation and suggests against the use of discriminating lives based on their IMD deciles to calculate their premiums for insurance products such as annuities.

From an actuarial view, it is critical to investigate all the underlying risk factors to provide a fair premium for insurance products. From the analysis conducted already, deprivation deciles are a clear indicator between life mortality. Therefore, from an actuarial standpoint, by using the IMD deciles as a risk factor, actuaries are able to fairly pool the risks together to achieve an actuarially fair outcome. From a deontological point of view, it is ethical as individuals are charged a premium based on their underlying risk factors. However, it would result in the least deprived by IMD decile paying a higher premium which could cause cross-subsidisation resulting in the most deprived being subsidised by the least deprived premiums. Annuities are expensive, and from market research it is shown that people who are well educated, have higher income and are in general healthier would be the more likely individuals to purchase annuity plans. From a utilitarian standpoint, it is ethically unfair to as the majority to pay a higher premium to subsidise for the fewer with a lower risk.

However, by using IMD deprivation deciles as a risk factor, it may result in individual's underlying deprivation risk factors being misrepresented. The IMD deprivation decile provides a good representation as a whole, as it factors in the income, education, health and other lifestyle factors of the local government area. Nonetheless, it can misrepresent an individual's underlying risk factors, which again from a deontological standpoint is unethical since it is morally right to charge a premium to an individual based on their underlying factors. By using IMD deprivation deciles, it might result in other forms of discrimination in the form of race, religion or cultural characteristics as these are other factors that are associated with geographical locations.

Using IMD deciles as a risk factor for calculating risk premiums would result in the assumption that the individuals risk factors mirror those of that in the area. However, if the individual doesn't reflect those underlying risk factors, this could result in an increase of variance of risk in the pool since the individual's underlying risk factors are assumed by the generality of IMD deciles and could possibly be misrepresented. This can result in increased premium prices within the risk pool, making it difficult for the insurers to assess the risks in the pool. Hence, from a utilitarian viewpoint, both the insurers and the customers are economically worse off as the insurers might be taking on greater risk than known, resulting in a greater premium for the customer, thus posing an ethical dilemma.

However, the obvious link between IMD deprivation deciles and life mortality cannot be overlooked. If the annuities premiums are to be calculated without looking at deprivation deciles, the average premium would be much higher. From the insurers perspective it also hinders their ability to evaluate the underlying risks associated with their policies, increasing their operational risk. Especially if an individual with higher risk is not identified, it would result in other premiums cross-subsidising and an increase in the overall premium prices. From a utilitarian standpoint, this is again a worse off outcome for all.

Therefore, other methods are required to measure deprivation and be able to quantify the risk in an actuarially fair manner. Factors such as income, education, occupation and lifestyle habits such as diet, smoking and exercise can be used to measure deprivation. However, in trying to use different methods to price insurance products, such as annuities, it could lead to employment of methods such as risk profiling using selfies and wearable health trackers. The aim to understand the deeper underlying risk factors and provide an ethically fair product, from an actuarial standpoint could result in intrusion of privacy by asking for information, which is personal, other ethical problems, such as data protection.

We can see the moral compass of pricing the insurance products using the underlying risk factors is ethically correct. But using methods such as IMD deciles to measure poses many ethical questions. Is it fair to charge individuals a premium based on the local environment they live in. This causes too many ethical dilemmas with blurred answers. Hence, due to its lack of moral high ground, IMD deciles should not be used as a method of measuring deprivation. Its use has resulted in outcomes which pose ethical flaws and is economically worse for both the insurers and buyers. Hence, there is a bigger need for different methods to study the link between deprivation and life mortality, but they could also cause further ethical questions of its own.

Appendix

A: Statistical hypothesis tests

Chi-Square test:

H_0: The expected number of deaths match the observed number of deaths.
H_1: The expected number of deaths does not match the observed number of deaths.

Standardised Deviations test:

H_0: The observed standardised residuals z_x are normally distributed.
H_1: The observed standardised residuals $z_{x,}$ are not normally distributed.

Signs test:

H_0: The number of deviations is evenly distributed.
H_1: The number of deviations is not evenly distributed.

Cumulative deviations test

H_0: The overall number of deaths conforms to the model with the mortality rates assumed in the graduation.
H_1: The overall number of deaths does not conform to the model with the mortality rates assumed in the graduation.

Grouping of signs test

H_0: The number of positive deviations n_1 and negative deviations n_2 are random.
H_1: The number of positive deviations n_1 and negative deviations n_2 are not random.

B: Statistical tests results

	Gompertz	Makeham	Cubic Splines	Smooth Splines
Chi-Square Test (p-value)	0	5.540181e-08	0	0.664929
Standardised deviations test (p-value)	6.263e-07	0.01691	4.005e-10	0.9836
Signs test	1	0.8877	0.3222	0.8877
Cumulative deviations test (p-value)	0.1391891	0.391358	3.203882e-09	0.9989407
Grouping of signs test (p-value)	7.609967e-07	0.0009887456	0.001130267	0.8023063

C: Graduation Plots

Gompertz Model

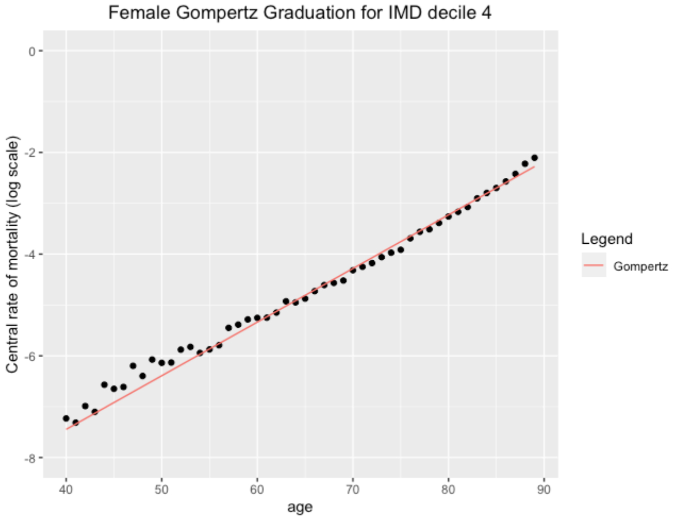


Figure C1

Makeham Model

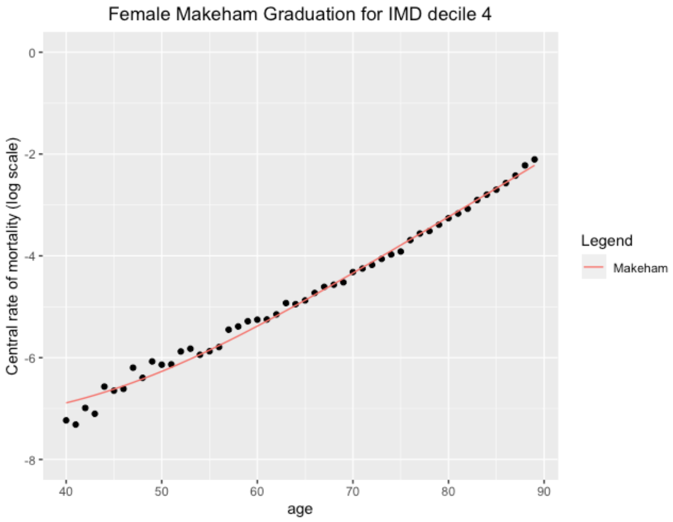


Figure C2

Cubic Splines

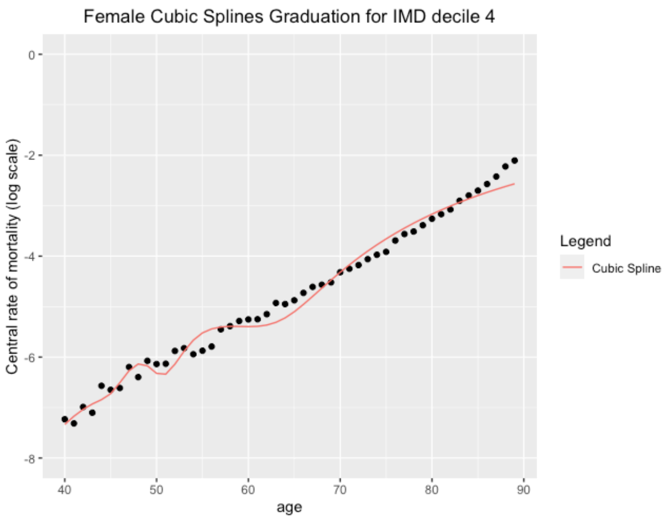


Figure C3

Smoothing Splines

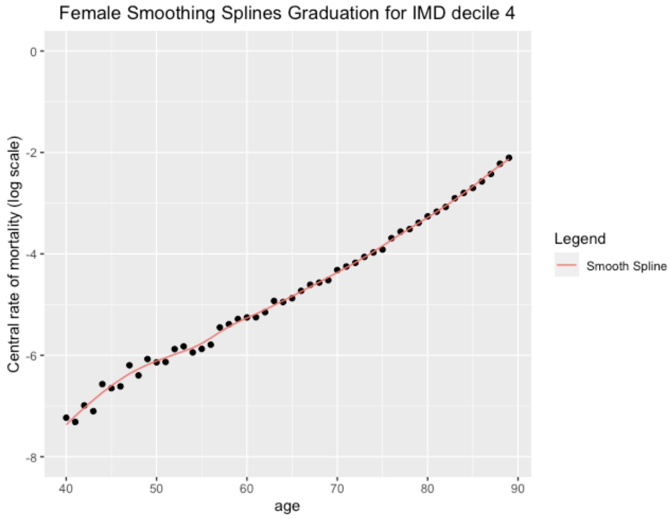


Figure C4

D: Serial Correlations plot

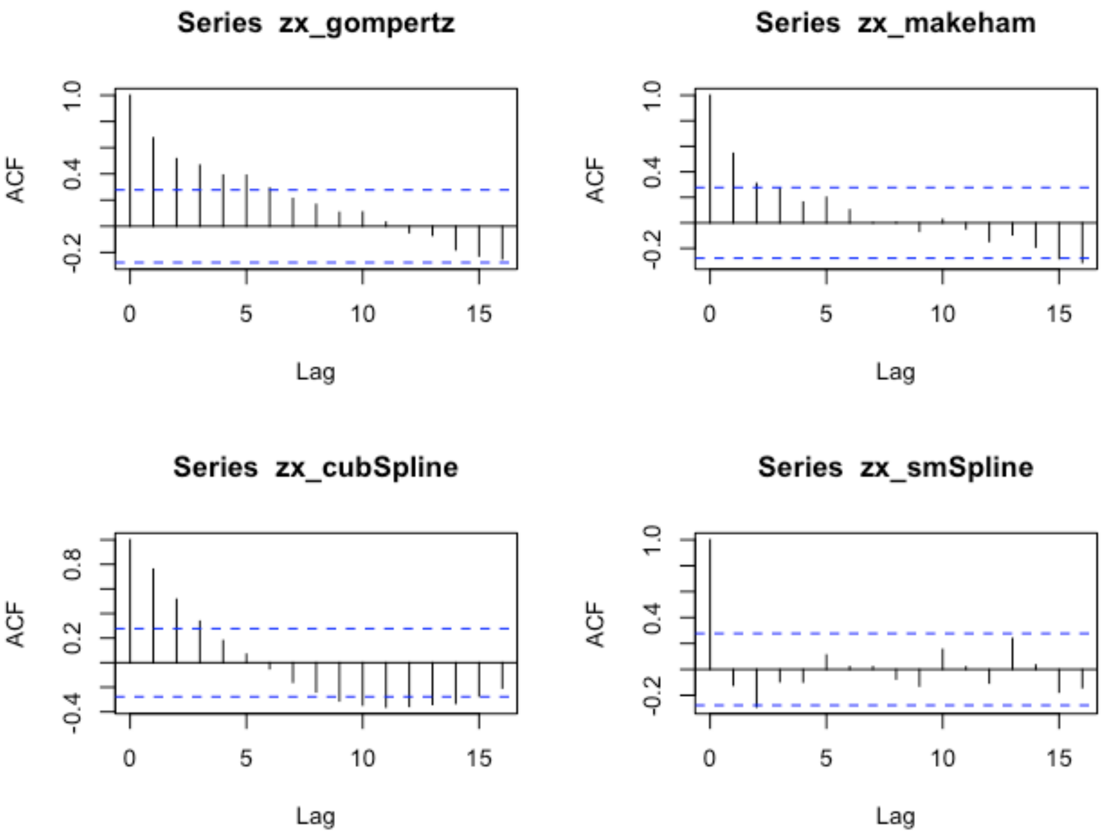


Figure D1

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