ACTL 3141 Assignment

Using IMD Decile in Pricing English Life Annuities

z5194905

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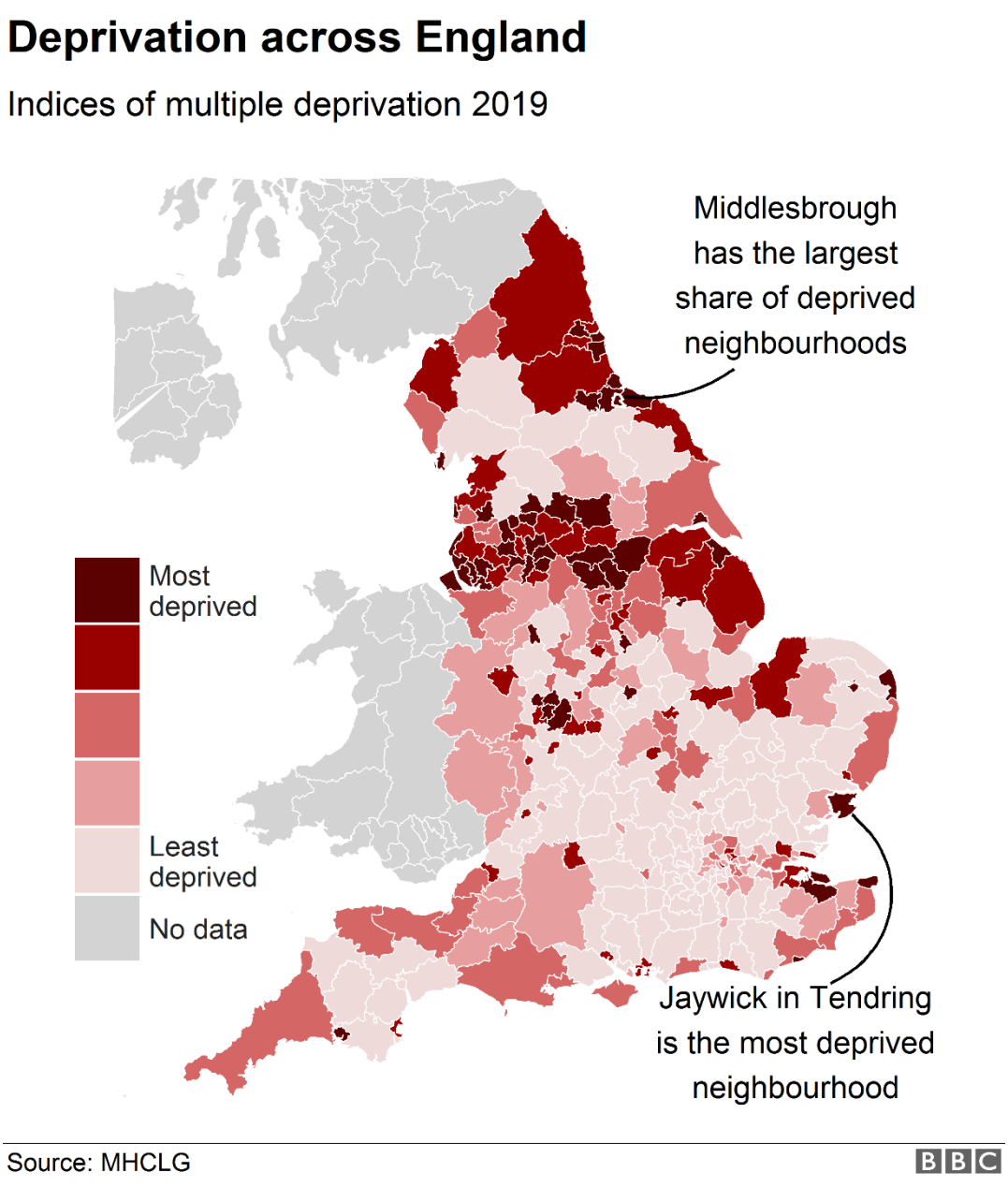


[1] British Broadcasting Company, *England's most deprived areas named as Jaywick and Blackpool* https://www.bbc.com/news/uk-england-49812519

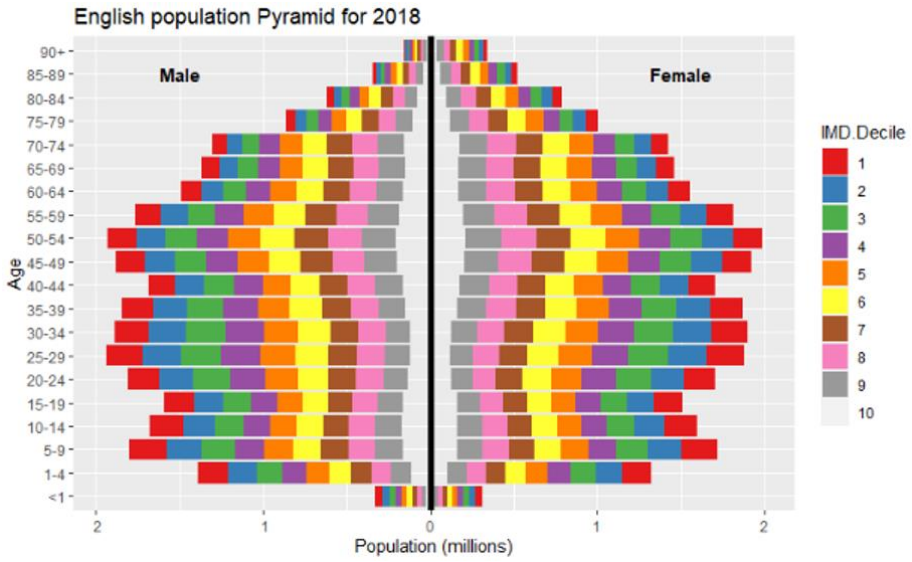
Executive Summary

The Index of Multiple Deprivation (IMD) measures relative deprivation across small areas in England according to a weighted combination of seven indices; income (22.5%), Employment (22.5%), Education (13.5%), Health (13.5%), Crime (9.3%), Barriers to housing and services (9.3%), and Living environment (9.3%)[2]. See title visual for 2019 divisions.

This report is divided into 3 sections. The **first** section analyses the effects of an individual's IMD decile on their mortality rate and concludes that deprivation is a strong indicator of life expectancy. The **second** section graduates a 2018 lifetable for all women in the 5th decile aged between 40 and 89 considering several approaches including the Gompertz, Makeham, Cubic splines and Smoothed Splines. This report found that Smoothed Splines was the overall best method to use, despite being the least smooth of the 4 models. The **third** section develops an ethical framework to discuss the possible implications of using deprivation as a rating criterion when setting prices for up-front, lump-sum annuities. After considering the effects on the company, policyholders and society, this report deemed that to do the most public good, both an individual's deprivation level and income level should be included in pricing.

Section 1: *Descriptive analysis of mortality trends by deprivation decile*

Before the deprivation effects on mortality are considered, it is important to establish the impacts of other factors such as an individual's registration year and sex, to isolate a decile's contribution to these changes. Across the whole data, there are slightly more females over the population (50.8%) and a female majority in each decile. The male and female demographic of each decile were roughly equivalent, with no more than 51% female. Therefore, this section will mostly consider the two sexes separately as their mortality rate varies significantly from one another.



The population pyramid of 2018 has a similar structure to the population across all registration years.

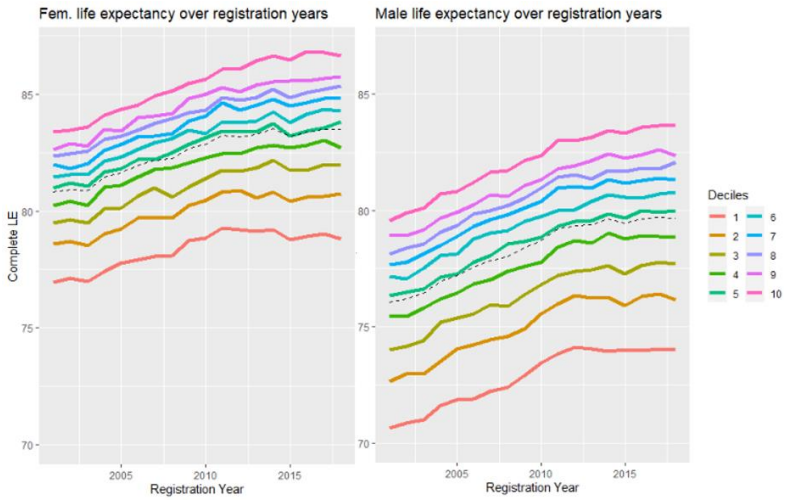
(see "Appendix B")

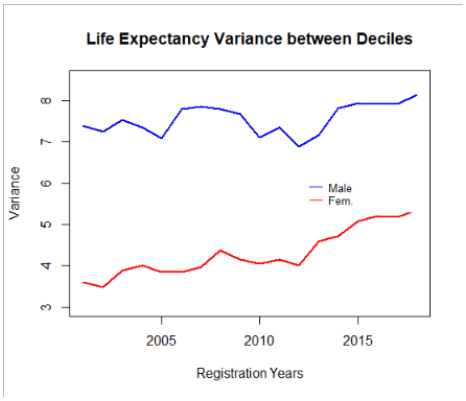
The 2018 pyramid shows that people are quite evenly split among decile groups at all ages and between male and female.

Life Expectancy

As expected, life expectancy generally increases overtime, this growth was mapped below with the average shown as the black dotted line. *Note: This life expectancy includes projected ages for those who lived to 90. See "Appendix B" for further details*

[2] GOV.UK



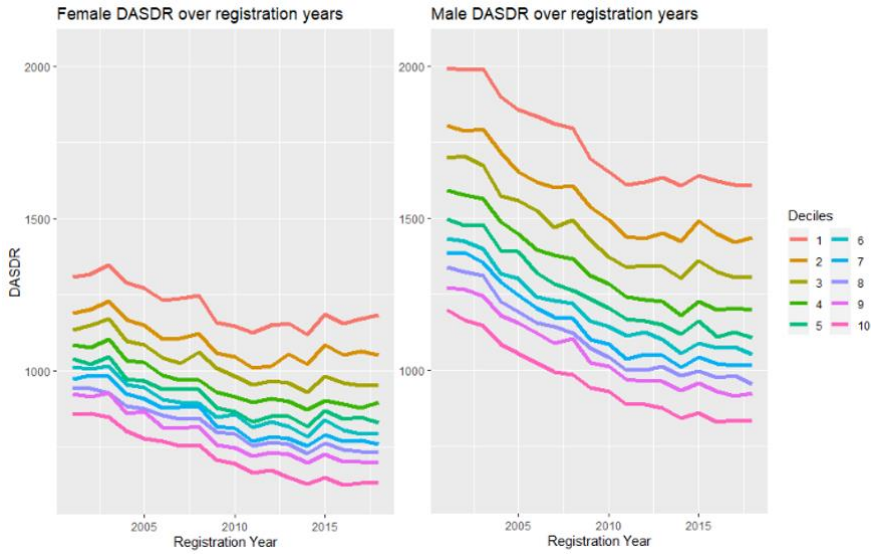


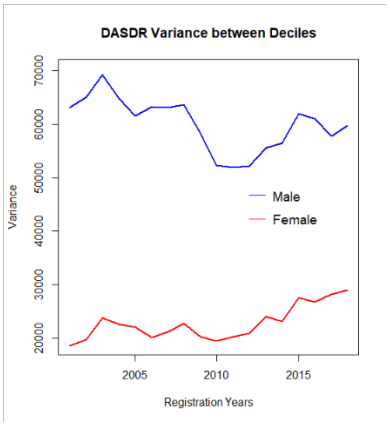
Like most population groups, females had higher life expectancies and the difference remains at a relatively constant 4 years difference to their male counterparts, although the discrepancy lessens in later years. Apart from perhaps a slight increase in variability for women in later years, all variance remains relatively constant with no clear trends. Male life expectancy between deciles is more volatile, as there is almost a 10-year difference in life expectancy between the 10th and 1st decile.

Directly Age-Standardised Death Rate (DASDR)

Unlike life expectancy, The DASDR does not include projected mortality rates for ages over 90 and standardises the age brackets to the European Standard Population allowing for comparisons between data with different characteristics. As expected, DASDR decreases as decile increases.

Again, the male DASDR is much more volatile - in 2018, there would be nearly double the amount of deaths per year in a standard population (833 in decile 10 compared to 1609 in decile 1).



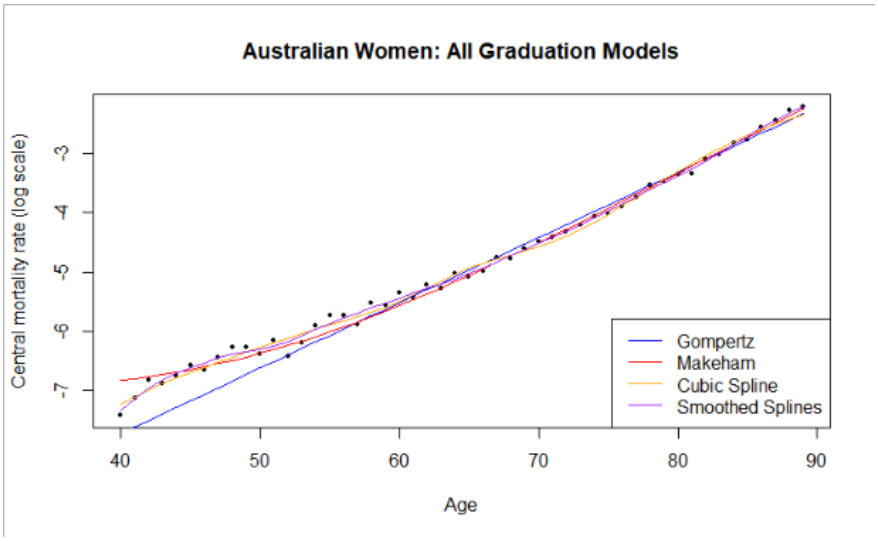


In 2017 the difference in the rate of avoidable death between the most and least deprived deciles in England was 358.3 for males and 205.5 for females per 100 000 people.[3] This could represent an increase in risky behaviors. This mortality difference is also clear from the rectangularization as individuals become less deprived *(see "Appendix B").*

Finally, under a 5% significance level, the null hypothesis that the mortality rate of each decile is equal to the average is rejected *(see "Appendix B").* Therefore, this report concludes that from the period of 2011- 2018, the IMD decile is an indicator of life expectancy and DASDR.

Section 2: *Recommended graduation model of women in the 5th decile in 2018*

A Smoothed Splines (SS) model with a spar of 0.548 was chosen as the graduation model for several reasons *(see "Appendix C").* Of the 4 models considered (Gompertz, Makeham, Cubic Spline (CS) and SS), its fitted values were closest to the data, shown both graphically and by adherence tests assessed at a 5% significance level.



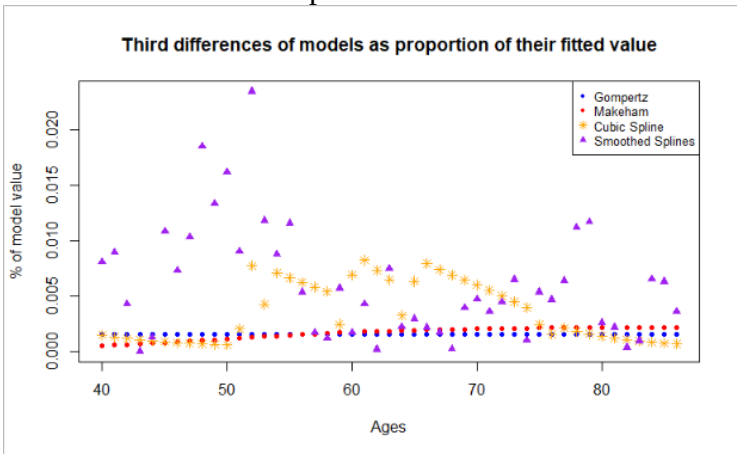
From the plot of graduation models, the Gompertz model is clearly the worst fit with large biases for all ages below 60. The Makeham model is a large improvement, working as an appropriate model for ages greater than 43, and, given that it only contains three parameters, is quite parsimonious. The CS and SS models both fit the data well.

P-value of each model by test	***Chi squared***	***Standard Deviations***	***Cumulative Deviations***	***Signs***	***Grouping of Signs***	***Average third difference***
Gompertz	0.000	0.000	0.044	0.480	0.001	0.002
Makeham	0.000	0.000	0.400	0.672	0.216	0.002
CS	0.000	0.005	0.260	0.322	0.232	0.004
SS	0.262	0.426	0.959	0.888	0.995	0.006
Short Makeham	0.000	0.043	0.523	0.480	0.164	0.002

All models passed the signs test, showing that each method had an appropriate number of positive and negative residuals. The Gompertz was the only model that failed the grouping of signs test, as it had too many consecutive negative or positive residuals to be random, suggesting that it is an overgraduated model. Similarly, the Gompertz was the only one to fail the cumulative deviations test, showing the large difference in residuals. The Makeham model passed the cumulative deviations, signs and grouping of signs test as well as having small third differences, indicating that it is both smooth and partially adheres to the data. The Makeham model was also fit to ages above 43 since it is simple and was relatively close to the data after these ages. This new model did have smaller deviations from the data, but it performed worse on both tests of signs. So, with no significant change to its effectiveness in graduating the data, it was discarded.

Graduating by cubic splines produced a function that appeared to fit reasonably well, however, it requires more parameters than the Makeham model and performs worse on more tests. Finally, the SS model was the only model to pass all tests, and although it has more parameters then the Makeham model, it was chosen for its small deviations.

However, the SS model has the largest third differences (as a proportion of fitted value), which can indicate undergraduation. These higher differences represent a "faster" rate of change and therefore a less smooth graph. These differences are plotted below-



Although the SS model has the highest differences, as a proportion, these values are still marginal and do not suggest gross undergraduation. In "Appendix C", the autocorrelation plots of the residual show the residuals correlation to "lagged" residuals. The Gompertz has positive correlations in its deviations, suggesting it is an overgraduated model. The CS model has slight oscillations, enough to be statistically significant at lags 6, 7 and 8, which could indicate undergraduation. Similarly, the Makeham model seems valid but has slight oscillations that are borderline significant. Comparatively the SS model after lag 3, is approximately 0, making it the better fit.

Therefore, through these careful considerations of the above models, this report recommends a SS model with a spar of 0.548 since it represents the data well and is relatively smooth.

Section 3: *Ethics of including deprivation as a rating criteria in the pricing of an upfront, lump-sum, life annuity*

Firstly, it is important to note that, pricing based on deprivation decile is legal[3]. This report will consider two main ethical theories, Utilitarianism and Deontology, and the framework of discussion will be based on Dobrin[4] (2008) ("Business Ethics – The Right Way to Riches").

Stakeholders, key facts and assumptions

There are three main parties to consider. **The annuity providers** who want to make profit through selling annuities whilst maintaining a reputable business. **Current and potential policyholders** who want a secure, retirement income stream for a low price that will not intrude on their privacy. And lastly, **the public** relies on fair transactions to protect the most vulnerable of society.

Key Facts:

- Although not true for all individuals, deprivation level can provide an indication of a group's mortality rate. Therefore, the most accurate way to price an annuity is to incorporate this data into its price.
- If IMD deciles are used in pricing, more deprived individuals will be offered cheaper annuities as the term of the policy will be expected to be shorter

[3] Equality Act 2010
[4] Dobrin (2008), "Business Ethics – The Right Way to Riches"

Assumptions:

- The insurance market is competitive and other insurers are incorporating deprivation decile into their models. Otherwise a new entrant to the market could discriminate more effectively among risks and price annuities more efficiently.

Core Values

This report will discuss 3 principles in its evaluation of including deprivation in pricing: fairness, privacy, and responsibility. By nature, these values are subjective to an individual, and so, to take an objective stance, this report will establish a series of Deontological maxims, adopted for each value.

Fairness as described by Rawl is citizens holding equal basic rights and cooperating within an economic system[5]. **Maxim one:** Fairness is ensuring that annuitants are priced by factors they can *control* and by *relevant* criteria to accurately assess risky behaviours. Secondly, privacy can be defined as the ability to control the access others have to us[6]. **Maxim two:** annuities should be priced with as *little information* as possible. Thirdly, Utilitarian philosophers like Bentham and Singer define responsibility as the avoidance of suffering[7]. The annuity provider has a dual responsibility to both the policyholder and shareholders. **Maxim three:** these providers have a duty to operate *profitably*. These maxims give us the following framework for a rating criteria. It should:

a) Have controllable factors
b) Only have relevant criteria
c) Require little information
d) Be profitable

Often, these interests can be aligned through the "invisible hand" of the free market. When the insurer reduces costs to increase profits, in a competitive situation, this can lead to more affordable and accessible insurance for the public and so aligns with the main tenets of Utilitarianism. However, as Rawl discusses[8], an unchecked capitalist market is not infallible, and so when introducing a new underwriting measure, it is key to discuss the ethical consequences of doing so.

Four courses of action were proposed-

	Controllable factors	**Relevant criteria**	**Information required**	**Profitable**
Option 1: No deprivation measures	No	No	None	No
Option 2: IMD decile	Somewhat	Somewhat	Small	Somewhat
Option 3: IMD decile and income	Somewhat	Yes	Medium	Somewhat
Option 4: Individual health check, income, education, crime history and living environment	No	Yes	High	Somewhat

[5] John Rawl *"Justice as Fairness"* 2001
[6] Gavison, 1980; Allen, 1988; Moore, 2003
[7] Bandura, Albert (June 2002). "Selective Moral Disengagement in the Exercise of Moral Agency". *Journal of Moral Education*.
[8] John Rawl *"Justice as Fairness"* 2001

Option 1, while private, is unfair to the policyholder and is an inefficient business model so it does not uphold the duty to the shareholders. It can also be argued that if insurers do not properly analyse risk, businesses or individuals may be unaware of their exposure, so insurers share in the accountability for any unforeseen consequences. Insurance products are more expensive for the most deprived and so the most disadvantaged of the community are more exposed to risk. Option 1 is also the least profitable as it can introduce adverse selection. In a competitive environment where other providers can discriminate between risks, annuity buyers can buy their cheapest respective annuity.

Option 2 makes large improvements; however, deprivation decile is a relative measure based on the small area where a policyholder lives and so grouping individuals together into a large collective does not accurately represent the risk of individuals themselves and presents conduct risk concerns[9]. In fact, the UK government has stated that the index "is not a suitable tool for targeting individuals"[10]. Living arrangements of a policyholder are also not particularly controllable as moving has a high financial barrier. However, this option still respects privacy, only requiring an individual's postcode.

Option 3 incorporates an individual element, allowing policyholders to be judged on their unique risks. This is fairer, providing a rating on more relevant criteria, but, out of necessity, it includes more private information.

Option 4 takes the IMD rating criteria and applies them to individuals. This is problematic in several ways. Firstly, high barriers to entry and invasive questions can dissuade potential policyholders from buying an annuity. Therefore, although it may be the best assessment of risk, it may not even prove profitable as it reduces pooling size. Secondly, by applying Thomas Pogge's concept of "Loopholes in Moralities"[11], considering deprivation on an individual level can create a moral hazard by incentivising risky behaviours.

Ethical decision

Considering these consequences, this report recommends option 3 in the pricing of annuities as it allows the company to remain competitive, disincentive risk, protect the disadvantaged of the community by offering cheaper annuities, and upholds free market efficiencies. This decision is also not likely to be perceived negatively by media or stakeholders as it is in fact making annuities more accessible to the lower IMD deciles.

Conclusion:

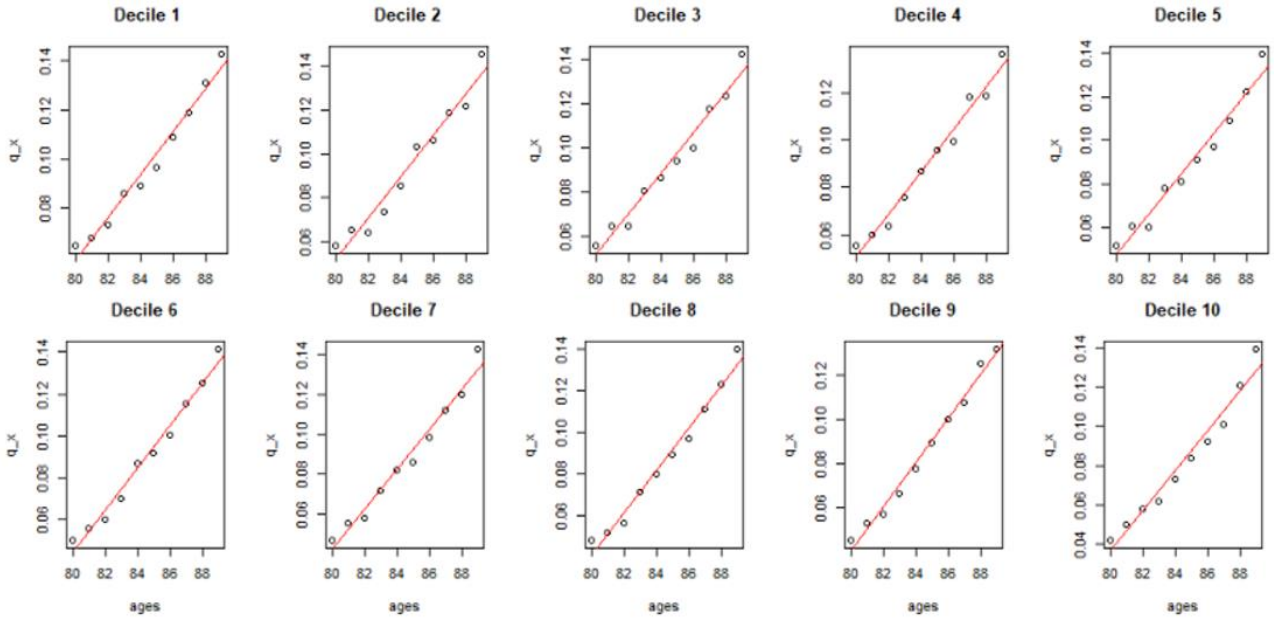
This report has explored the trends between deprivation and mortality in England from the period of 2001-2018. As expected, life expectancy decreases and DASDR increases as individuals become more deprived. A SS graduation model was shown to be the best fit for females in the 5th decile in the 2018 data. After consideration of the ethical implications, this report recommends pricing annuities based on IMD decile and their income level.

[9] Institute and Faculty of Actuaries, September 2017, *"Data science in Insurance"*
[10] Department for communities and Local Government, 2015,
[11] Thomas Pogge, *"Loopholes in Moralities"*

Appendices:

Appendix A - Assumptions:

- Annuities are priced as a lump sum up front
- Constant force of mortality between integer ages was assumed to approximate q_x for each age in the probability table
- A key assumption for calculating life expectancies was that q_x for ages greater than 90 increased linearly. An exponential model was fitted to the q_x values for the ages of 80-89 in the 2018 data, but, under a Kolmogorov-Smirnov test, every decile rejected the model except for the 10th decile which still had a low p-value of 0.05782. So instead linear growth was assumed and, visually, this assumption seems valid as seen from the plots of the 2018 data below. For each decile in each registration year, q_x for ages 90-110 was estimated by least squares of the mortalities between 80 and 89.



- In the life tables, all those projected to live to 110 died that year with a probability of 1
- Data is recorded as age last birthday at the time of death
- For calculating central exposed to risk, population in data was the mid-year estimate

Appendix B - Section 1

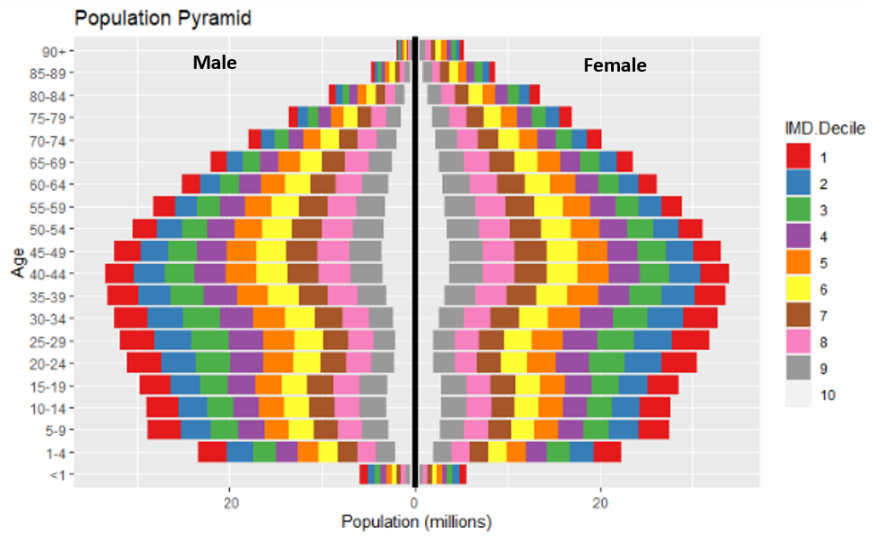
Hypothesis Test-

2018 was the only year used for the test as variances between years was constant enough. Further investigation may need to be conducted. The test was conducted as 10 separate hypothesis tests, comparing each decile to the average deaths per year using the Central Limit Theorem to approximate the binomial distribution to the normal distribution. Of the 10 tests, 5 were rejected on a 5% significance level.

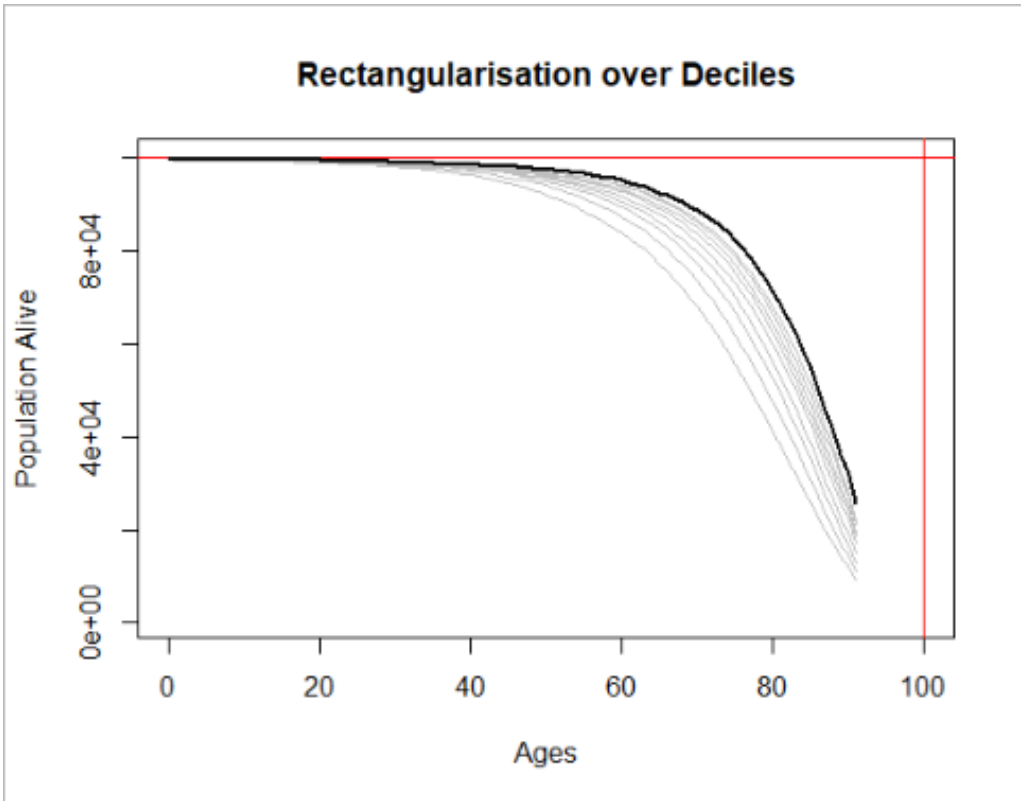
Decile	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
P-Value	0	0.679	0	0.419	0.026	0	0	0.469	0.089	0

Population Pyramid-

The below population pyramid shows the population structure from all registration years and shows that the year of 2018 was typical. This pyramid was not used in the report as a single age would be counted 18 times through the registration years and so would not reveal large outliers. However, it is helpful to note the general structure of the English population



Rectangularisation –



Appendix C - Section 2

The parameters were found using linear regression and the "R" package "demography".

Gompertz –

$$b_0 = -12.1071, \qquad b_1 = 0.1098$$

Makeham –

$$A = 0.0008, \qquad b_0 = -13.14, \qquad b_1 = 12.22$$

Cubic Splines-

$$knots = 7, 12, 16, 18, 20, 32, 53, 54, 61, 66, 77$$

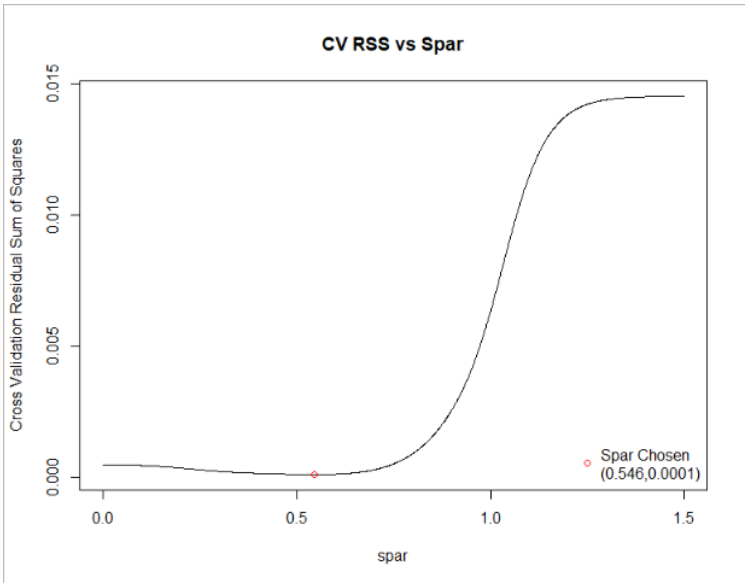
$$intercept = 0.0837, \qquad cb_4 = 0.0054, \qquad cb_5 = -0.253, \qquad cb_7 = -0.0807, \qquad cb_8 = -0.0801$$

$$cb_9 = -0.0740, \qquad cb_{10} = -0.0780, \qquad cb_i = NA, \forall\ other\ i \in [1,10]$$

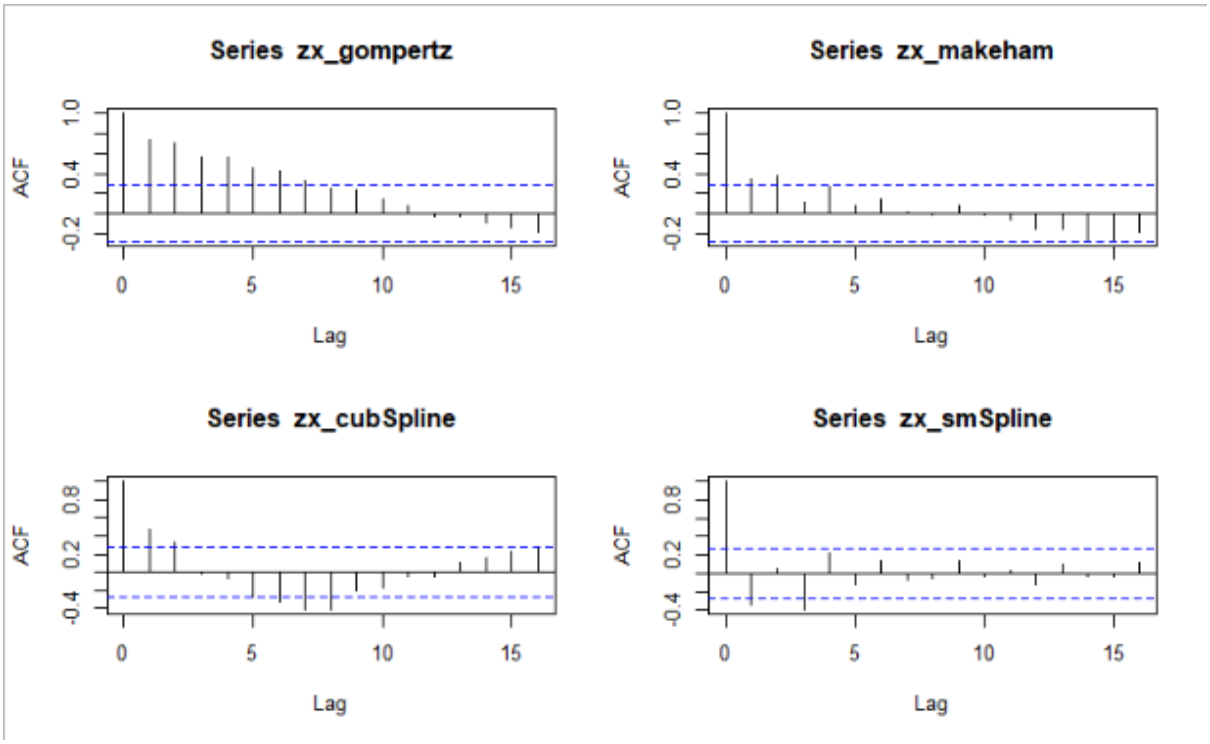
Smoothed Splines -

$$spar = 0.5458, \qquad \lambda = 0.0001$$

The spar value of the smoothed splines model was chosen by minimizing the residual sum of squares of cross validated values. The plot of these residual sums is shown below-



Serials Correlation Test-



References:

1. *Equality Act 2010, c. 15*. London: The Stationery Office
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