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Is mortality spatial or social?

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ABSTRACT

Mortality modelling for the purposes of demographic forecasting and actuarial pricing is generally done at an aggregate level using national data. Modelling at this level fails to capture the variation in mortality within country and potentially leads to a mis-specification of mortality forecasts for a subset of the population. This can have detrimental effects for pricing and reserving in the actuarial context. In this paper we consider mortality rates at a regional level and analyse the variation in those rates. We consider whether variation in mortality rates within a country can be explained using local economic and social variables. Using Northern Ireland data on mortality and measures of deprivation we identify the variables explaining mortality variation. We create a population polarisation variable and find that this variable is significant in explaining some of the variation in mortality rates. Further, we consider whether spatial and non-spatial models have a part to play in explaining mortality differentials.

1. Introduction

How mortality rates are changing over time, and in particular the increase observed in life expectancy, has been a topic of considerable debate across the world over recent decades. Increases in the cost of providing for pensions, insurance and healthcare at older ages, driven by the rapid improvements in life expectancy, have led to life companies, pension schemes, individuals and governments giving more consideration to how these costs will be met in the future. Key to quantifying these future costs is the need for an accurate picture of how mortality rates vary over time and over populations, and as a result academics and practitioners have focused their efforts on accurately forecasting and quantifying expected future improvements in mortality rates. Aggregate mortality rates, that is, mortality rates at a national level have shown an improving trend over many decades and it is variations in this trend that practitioners have provided advice on and that academics have wrestled with. It is the uncertainty in this trend that has been coined "longevity risk". In a financial context quantifying longevity risk has become a topic of great interest as the capital markets work to create ways to buy longevity risk as a diversification from their traditional financial risks (See Blake et al., 2008, for example).

Within actuarial work, the pricing and reserving for life related products and pensions are based on the latest knowledge of mortality forecasts. Actuaries therefore also have a keen interest in accurately forecasting mortality rates. Implicit in the actuaries advice is the assumption of a homogeneous population, be that within a pension scheme work force or within a region of a country or in a whole country. In the past this has been sufficient and national mortality tables have been used to price products or to advise clients. Driven by the financial and actuarial sector less attention has been given in the actuarial space to considering the possibility that mortality rates within a population are not homogeneous. There is some implicit allowance for differing socioeconomic status within actuarial pricing or pensions since the pension amount is an indicator of socioeconomic status (those with larger pensions will on average have a higher socioeconomic status) however, this proxy is not very robust and indeed Richards (2008) shows that a mortality model using geographic classifications (a postcode mortality model) better fits United Kingdom annuitant mortality than a model using pension amounts. The actuarial profession is thus coming up with some way to recognising mortality variation within populations. The approach used by some with disaggregating mortality experience using purely geographical location (postcode mortality) still does not help in the search for observable, meaningful variables that explain why mortality experience differs within populations. Developing a model that gives consideration to the variation in mortality rates within a population would be important for actuaries as the clients they advise do not usually have a mortality experience that matches that of the aggregated national data. For example, a pension scheme actuary advising the trustees of a scheme of London city workers will expect a very different mortality experience than that of the actuary advising a company of coal miners. In addition many clients are international and therefore within one scheme there may be individuals or groups who have very different mortality experience. For these reasons consideration of mortality variation is valuable to actuaries and ignoring

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variations in mortality rates such as this can lead to mis pricing or mis reserving which ultimately may result in unsustainable or unanticipated liabilities. Combining the use of geographical information as proposed by Richards (2008) with observable variables is one of the aims of this paper.

We consider mortality data gathered from Northern Ireland and divided by geographical location. We use a suite of deprivation data, also divided by geographical location and gathered from the 2010 deprivation study[2] to analyse the variation in mortality rates as a function of various measures of deprivation. We further consider the use of frailty modelling techniques to explain the remaining variation after controlling for deprivation. Considering the deprivation measures separately we are able to identify which aspects of deprivation are more important in explaining the variation we see in mortality rates. We also draw some conclusions regarding the use of frailty modelling in the presence of good socioeconomic data.

The rest of the paper is laid out as follows. In Section 2 we outline the literature in mortality modelling, Section 3 describes the data we have used in this study, and in Section 4 we provide the empirical analysis. Section 5 concludes.

2. Literature review

Within the literature on mortality modelling there has been a large number of models developed over the last two decades. However, little consideration has been given to the issue of linking mortality rates to observable variables such as economic and social factors. This has been a particular issue within the actuarial literature where the main focus has been to forecast and price longevity improvements whatever the cause of those improvements. The proliferation of models that have been developed in the last two decades have been helpfully categorised by Booth and Tickle (2008) into one of three types of model. (i) *Extrapolative models* — taking past data and extrapolating identified trends, (ii) *explanatory models* — modelling mortality as a dependent variable explained by socioeconomic, biological and environmental factors, and (iii) *expectations models* — taking advantage of the expert knowledge of actuaries and demographers and targeting future life expectancy at some expert held belief. Expectations models are the domain of practicing actuaries and rely heavily on their expert judgement to predict long term improvement rates in mortality; we do not consider them further here.

The academic and financial worlds have focused most of their attention on the method of extrapolation as a method to quickly identify and forecast patterns in mortality rates. With the desired outcome being the ability to accurately price future mortality linked financial and insurance products this has been a very successful endeavour. There are many papers in the area to testify to that success. See for example Lee and Carter (1992), Booth et al. (2002), Brouhns et al. (2002), Girosi and King (2005), Renshaw and Haberman (2006), Cairns et al. (2006), Currie et al. (2004), Currie (2006), Hári et al. (2008), Tuljapurkar (2008), Plat (2009), and O'Hare and Li (2012).

The explanatory approach has been primarily left to the medical and social science disciplines and there has been considerable literature linking mortality rates to observable factors. In particular there have been significant efforts to identify the relationship between wealth and mortality rates, see for example Acemoglu and Johnson (2007), Bhargava et al. (2001), Bloom et al. (2004), de la Croix and Licandro (1999), Lindahl (2005), and Preston (1975). The results of this analysis are mixed with strong evidence for a positive wealth effect and strong arguments to the contrary. There have also been many studies linking social and economic factors to mortality rates, see for example O'Hare and French (2013) who link the latent factor structure of mortality rates to observable economic and social variables from OECD data and identify factors such as GDP, fat intake and smoking habits to be significant in explaining mortality rates. Notably in this paper they identify a different number of observable variables for each of the countries they consider. Turrell et al. (2006) consider mortality rates in Tasmania and associate the variance in mortality to measures of socioeconomic disadvantage, social capital and geographic remoteness. They conclude that socioeconomic disadvantage is associated with area variation in mortality rates but that social capital or remoteness does not explain the variation seen in mortality rates. Whilst the results were limited this paper does consider the question of mortality rates at a sub national level, dividing the mortality data into geographical regions along with the measures of socioeconomic disadvantage, social capital and remoteness also divided geographically.

In our paper we extend on this in several ways, firstly we consider a range of measures of socioeconomic disadvantage separately. These include measures of healthcare deprivation, income deprivation, employment deprivation and education deprivation. They also include measures of remoteness such as proximity to services. Secondly, in our paper we give consideration to the ability of spatial and non-spatial frailty modelling to explain mortality variation. Spatial models have been developed and applied to modelling house prices, crime levels and diseases amongst many other applications.[3] Rosen (1974) models house prices using spatial covariates including environmental attributes and geographical characteristics. Waller et al. (2007) models geographic variation in alcohol distribution and violent crime in Houston. Kazembe (2007) examined spatial clustering of malaria risks in northern Malawi. Geodemographic modelling, the spatial modelling of demographic data, is used in a range of applications. Richards (2008) uses geodemographic profiles based on postcodes to analyse life insurance and pension scheme mortality. Tuljapurkar and Boe (1998) outline mortality differentials by sex, education and socioeconomic variables. Richards and Jones (2004) discuss the impact of socioeconomic status on mortality rates in the UK. For Northern Ireland, there is limited formal modelling and analysis of mortality variation by geographical location using spatial models and limited analysis of variation of mortality according to socioeconomic risk factors.

The approach used in this paper can be broken down into three components. Firstly, as the mortality rates in each region will be heavily affected by the age distribution in the region the initial analysis will use a regression approach to age standardise the mortality rates. This will enable the remaining variability not due to age to be analysed. We secondly regress the socioeconomic data on these age standardised mortality rates carrying out a general to specific analysis to identify the significant deprivation measures. Finally, having done this we test the hypothesis that there may remain some unexplained variability or heterogeneity that cannot be explained by the socioeconomic variables that are used in this data set. We fit a non-spatial and spatial model to the residual data to test for this. We then repeat the spatial and non-spatial analysis in the case where we do not have socioeconomic data to assess the use of geographic structures in that case.

3. Data

The analysis in this paper is based on mortality data from 2008 and deprivation data from 2008 provided by the Northern Ireland Statistical Research Agency NISRA and reported in the 2010 deprivation study (NIRSA, 2010). We use deprivation indices created by NISRA from raw government collected data. The data is divided geographically using Super Output Areas (SOA) of which there are 890 in Northern Ireland.

[2] The 2010 deprivation study reports deprivation measures across Northern Ireland compiled based on 2008 data, http://www.nisra.gov.uk/deprivation/archive/Updateof2005Measures/NIMDM_2010_Indicator_Summary.pdf.

[3] For a review of the various applications see Sherris and Tang (2010).