Individual and area level factors influencing colorectal cancer survival in Scotland

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November 27, 2017

Summary

Previous research has demonstrated that Scots cancer survival is poor. This research uses individual level data provided by Scottish Longitudinal Study *(SLS)*, NHS and GIS-based travel-to-treatment center data to explore colorectal cancer survival in the Scottish context using survival analysis techniques. We found that although travel time to cancer hospital is not significant, household access to a vehicle is associated with better cancer survival than no household access to a vehicle. The association between "household access to a vehicle" and survival is robust to other correlates of socio-demographic cancer survival which display the expected associations with survival. The males showed poor cancer survival after adjusting for other covariates.

KEYWORDS: Accessibility, health, colorectal cancer, survival, network analysis

1. Introduction

Colorectal cancer is the second most common cause of cancer death for both gender, which represents a major public health problem in Scotland. In Scotland, about 1 in 16 males, and 1 in 20 females develop colorectal cancer during their lifetime (ISD data file, 2015). In terms of cancer survival, individual factors, social class, stage at diagnosis, healthcare (screening, treatment type) and genetic are the possible drivers as adopted from Foot and Harrison (2011) and Black et al 1998. There is strong evidence which suggest that these factors explain cancer survival differences in combinations of many factors (Gatta et al., 2000). In relation to above factors, previous research shows that geographical accessibility to health services play a major role in terms of cancer survival between urban and rural areas (Campbell et al., 2001, Athas et al., 2000, Müller et al., 1998, Murage et al., 2016). This research will, for the first time, use individual level data provided by Scottish Longitudinal Studies *(SLS)*, NHS and GIS-based travel-to-treatment center data to explore colorectal cancer survival in the Scottish context using survival analysis techniques.

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2. Methods

2.1. Data

2.1.1 NHS data

The three major datasets from NHS used in this research are; Scottish Cancer Registry data (SCR), hospitalisation data and death registry data. These data are managed by NHS National Services Scotland (NSS). The SCR holds and provides all information related to cancer. The NHS death registry records information relating to all deaths and it determines if the principal cause of death was cancer.

2.1.2 SLS

The SLS is a detailed anonymised dataset for approximately 5.3% of the Scottish population (approximately 270,000 people) and is managed by "Longitudinal Studies Centre – Scotland (LSCS)". The longitudinal nature of the data means that analyses can be repeated on multiple cohorts and the results can be compared across cohorts enabling exploration of changes in outcomes over time and how these changes are related to other factors. The SLS facilitates research on various outcomes through its particularly rich data linkage including administrative data from NHS, Vital Events and other administrative sources.

2.1.2 Accessibility index

Travel times and distances from each post code (total postcodes 148310) in Scotland to the nearest hospital providing cancer treatment (total 40) in Scotland were calculated using ArcGIS network analyst. The road network data was accessed through the Ordnance Survey. A map showing travel time by car (and for Island, it includes ferry time) to the nearest cancer hospital in Scotland (Figure 1) demonstrates the spatial variation in travel time to treatment centre across Scotland, and these data were used as a covariate in the subsequent modelling.

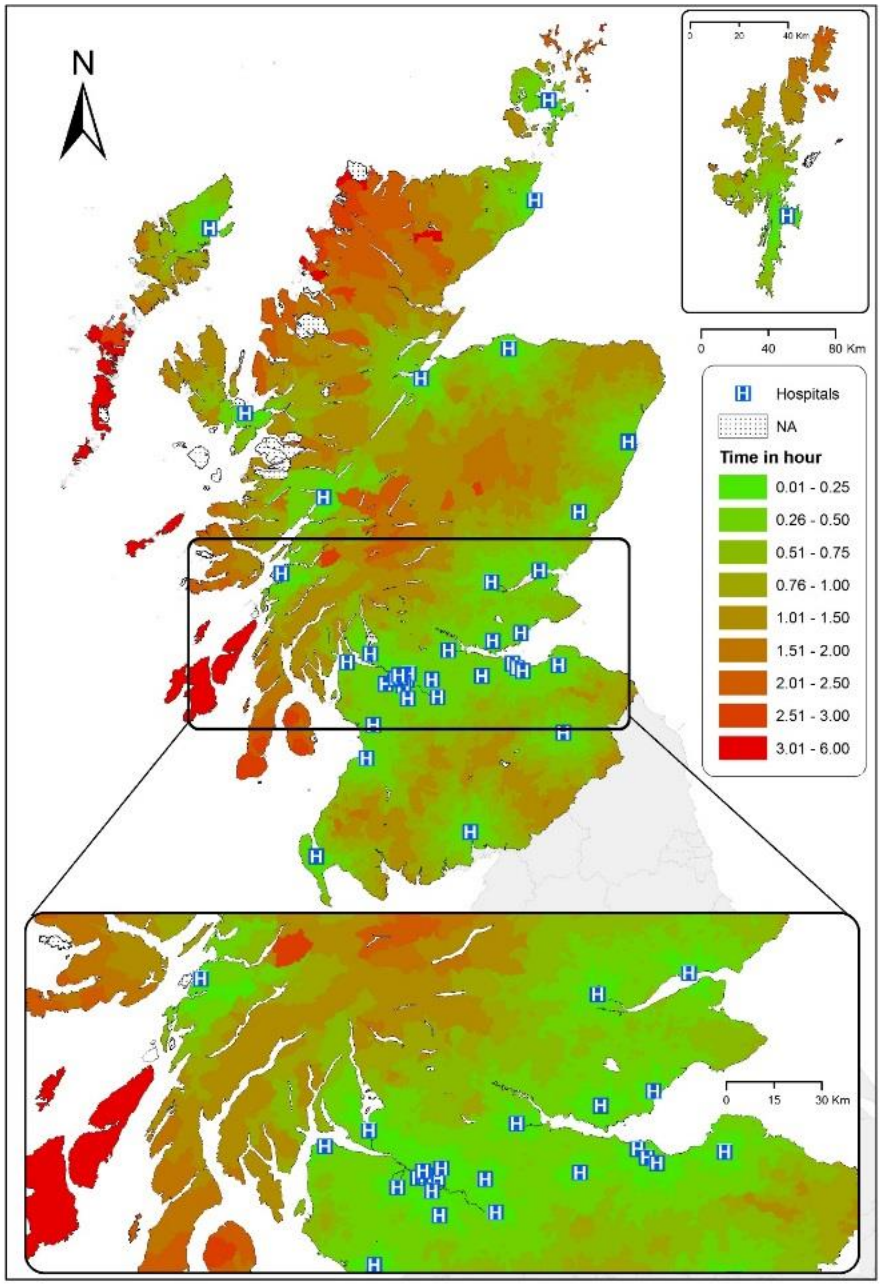


Figure 1: Travel time to nearest hospital providing cancer treatment in Scotland at postcode level.

2.2. Survival analysis

Survival analysis is a statistical technique used to analyse the time (survival) until an event occurs. In this research, the survival time for cancer patients (n=2838) and those who died (n=1626) is calculated in months from diagnosis to death (i.e., from 29th April 2001 until July 2016).

The Kaplan–Meier (KM) curves were plotted for all individual variables of colorectal cancer based on their respective classes that are recoded for each variable. A Cox proportional hazards model (Therneau, 2000) is used for survival analysis in R using package 'survival' (Therneau, 2015). A total of twelve covariates were selected for the survival analysis in this research. Each covariate is recoded and is

modelled individually (un-adjusted) using Cox regression model. For the final model (adjusted), multivariate Cox regression model is used by including all the covariates in the model (Table 1). To assess multicollinearity we used the variance inflation factor (VIF) and for all variables in the multivariate model was VIF < 2.

Table 1: Selected covariates and their data sources for colorectal cancer in Scotland

Variable	Source	Selected Reference
Age at diagnosis	NHS SMR06	Nemet and Bailey (2000).
Treatment (Chemo, Surgery, or Radiotherapy)	NHS SMR06	Lin et al. (2015)
Stage at diagnosis	NHS SMR06	Jones et al. (2008b)
Charlson score (co-morbidity)	NHS SMR01	Charlson et al. (1987)
Practicing religion	SLS	Aquino and Zago (2007)
Long term illness	SLS	Comber et al. (2011)
Ethnicity	SLS	Basta et al. (2014)
No. of Cars in household	SLS	Jack et al. (2006)
Household tenure	SLS	Sharpe et al. (2014),
Gender	SLS	Sharpe et al. (2014),
Area deprivation (SIMD)	Scottish Government	Pozet et al. (2008)
Travel time (at Postcode level)	Ordnance survey	Murage et al. (2016)

For deprivation, the Scottish Index of Multiple Deprivation (SIMD) of 2009 is used (SIMD, 2009). SIMD "identifies small area concentrations of deprivation across all of Scotland". SIMD provides great information which helps to identify areas in Scotland suffering from multiple types/forms of deprivation and helps to improve our understanding about the outcomes, especially for people living in the most deprived areas of Scotland.

3. Results

Figure 2 shows a KM plot for survival time in months for colorectal cancer. The graph shows that as time increases, the proportion of people surviving decreases. At time zero, the survival proportion is 1 (means 100% people are alive). At time 100 months, the proportion of people who survived is less than 40%. Similarly, more than 50% of people have a survival time less than 40 months. The dotted lines in the graph show the 95% confidence interval.

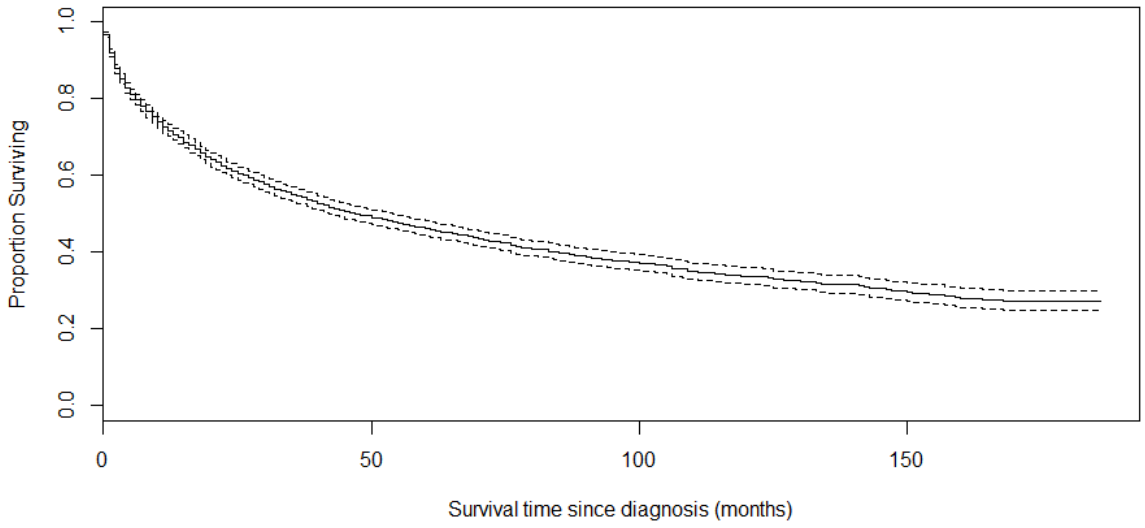


Figure 2: KM plot of survival time (months) for colorectal cancer in Scotland (data source: SLS, NHS)

Survival function (i.e., KM plots) are calculated for all the covariates (table 1). Figure 3, 4 and 5 show the result of survival function for age, SIMD and stage of diagnosis for colorectal cancer.

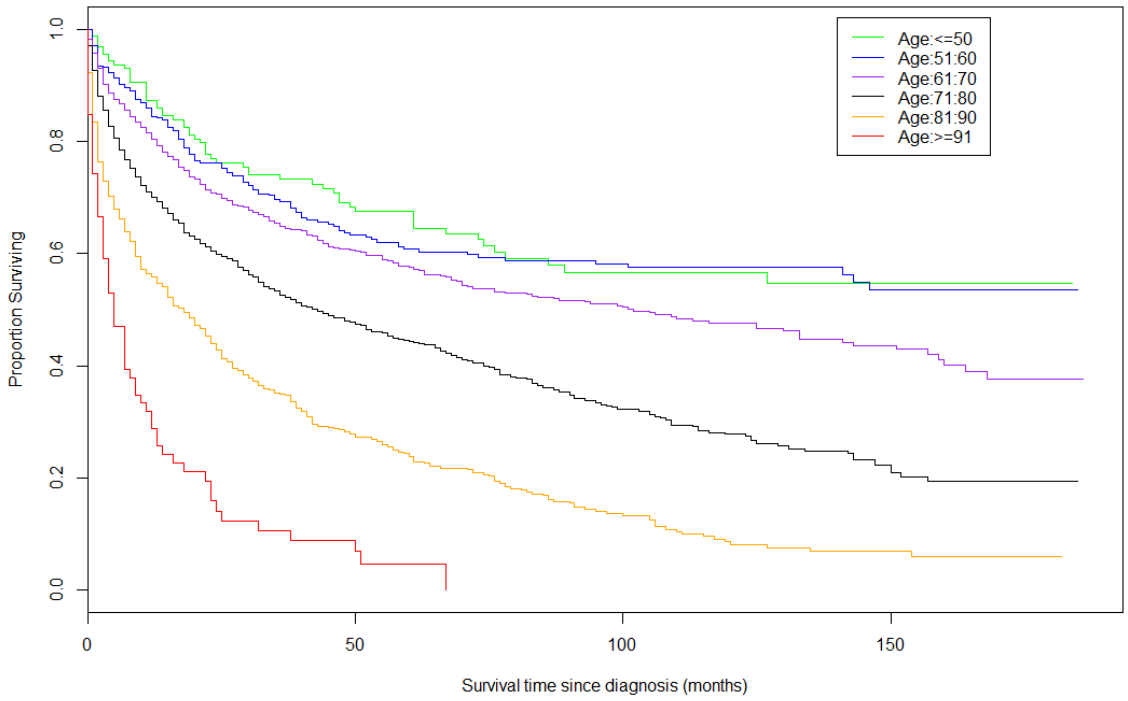


Figure 3: Survival time (months) for age at diagnosis of colorectal cancer in Scotland *(data source: SLS, NHS)*

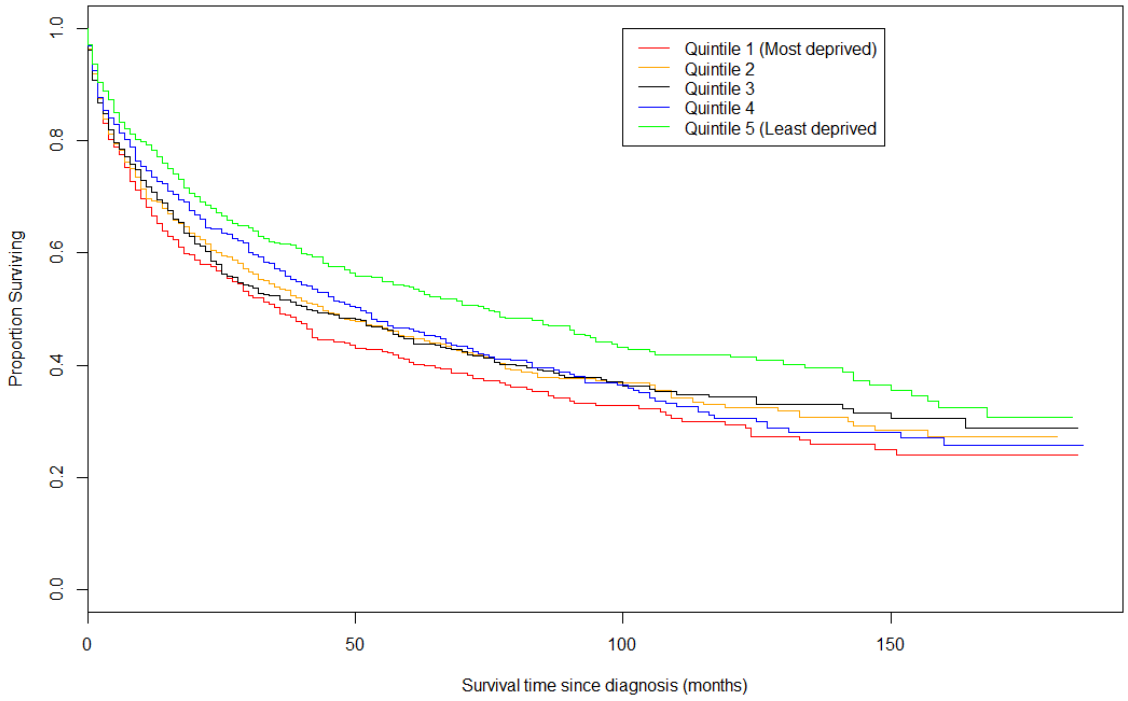


Figure 4: Survival time (months) for deprivation of colorectal cancer in Scotland *(data source: SLS, NHS)*

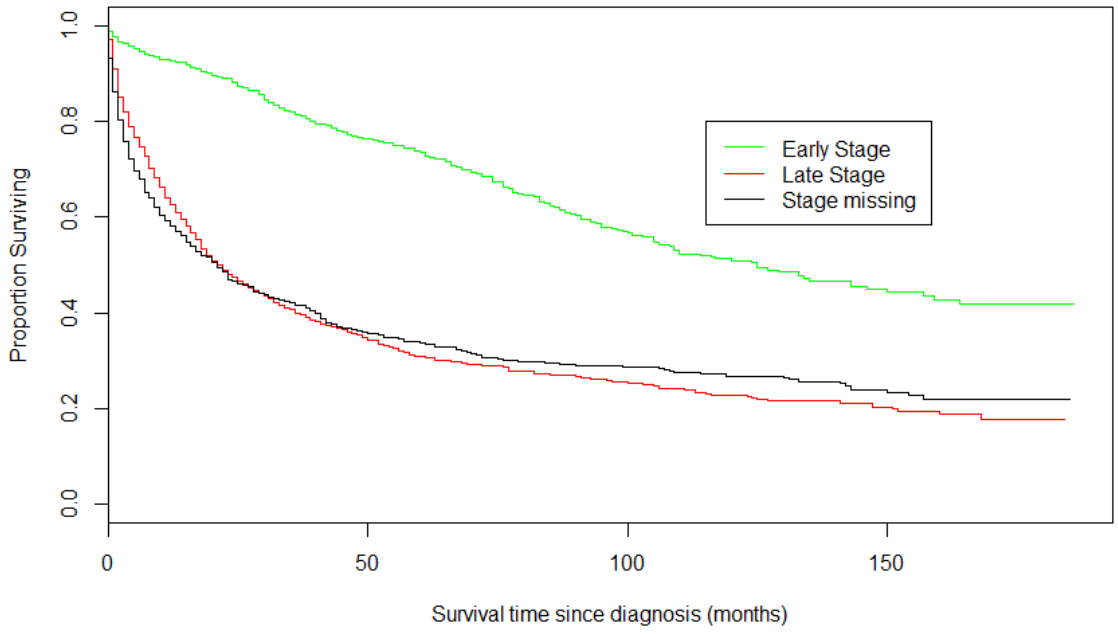


Figure 5: Survival time (months) for stage at diagnosis of colorectal cancer in Scotland *(data source: SLS, NHS)*

The results for univariate analysis in figure 3 for age at diagnosis shows that as age increases, the survival rate decreases. For example, the survival rate for patients aged >=90 is 7.67 time worse compared to aged <=50. The results for deprivation quintile in univariate analysis (figure 4) shows that deprived areas show poor cancer survival compared to less deprived areas. The results for travel time in both univariate and multivariate analysis is not significant. Similarly, the results for univariate analysis for late stage diagnosis shows 3 times worse cancer survival compared to patients who are diagnosed at early stage.

Table 2 shows the Cox regression coefficients for multivariate model (i.e., adding all the covariates in the model). With age at diagnosis, we found that survival rate decreases with age. Travel time to cancer hospitals was not significant, but "household access to a vehicle" was associated with better survival than having "no household access to a vehicle". Having cancer treatment (i.e., surgery, chemotherapy or radiotherapy) shows better cancer survival rate, than having no cancer treatment. Cancer survival rate for late stage diagnosis is worse. Although, Charlson score (co-morbidity) is not significant in the final (adjusted) model, however, patients with long term illness showed poor survival than having no long term illness. People who owned private house showed better cancer survival rate than people who rented (public or private). Females showed better cancer survival rate than males. People in less deprived area (Quintile 4) showed poor survival than most deprived area (Quintile 1). Ethnicity and practicing religion were not significant in multivariate model.

Table 2: Cox regression multivariate model results for the covariates of colorectal cancer in Scotland.

Multivariate analysis *(Rsquare= 0.353),* *= significant at p<0.05					
Covariate		Coefficient	exp(coef)	95% CI	*P*-value
Ethnicity	White Scottish (n=2484)	Reference			
	Rest of the UK (n=222)	-0.021	0.978	(0.82 - 1.18)	0.82
	Rest of the World (n=46)	0.182	1.200	(0.81 - 1.78)	0.37
	Non-response(missing/edited) (n=86)	0.083	1.087	(0.83 - 1.42)	0.54
Gender	Male (n=1568)	Reference			
	Female (n=1270)	-0.171	0.843	(0.76 - 0.94)	0.001*
Household Tenure	Owned (n=1943	Reference			
	Public rented (n=721)	0.150	1.162	(1.02 - 1.32)	0.021 *
	Private rented (n=78)	0.459	1.582	(1.19 - 2.09)	0.001*
	Non-response(missing/edited) (n=79)	0.287	1.332	(1.00 - 1.77)	0.045 *
Long term illness	Having long term illness (n=1004)	Reference			
	No long term illness (n=1698)	-0.197	0.82	(0.74 - 0.91)	0.0003*
	Non-response(missing/edited) (n=136)	0.183		(0.97 - 1.48)	0.089
Age at diagnosis	Age:<=50 (n=157)	Reference			
	Age:51:60 (n=335)	0.069	1.072	(0.78 - 1.46)	0.66
	Age:61:70 (n=752)	0.231	1.26	(0.95 - 1.67)	0.10
	Age:71:80 (n=994)	0.579	1.78	(1.35 - 2.34)	3.36e-05 *
	Age:81:90 (n=534)	0.887	2.43	(1.82 - 3.22)	1.05e-09 *
	Age:>=91 (n=66)	1.15	3.16	(2.17 - 4.61)	2.18e-09 *
Deprivation	Quintile 1 (Most deprived, n=540)	Reference			
	Quintile 2 (n=578)	0.086	1.09	(0.93 - 1.27)	0.27
	Quintile 3 (n=566)	0.152	1.164	(0.97 - 1.37)	0.07
	Quintile 4 (n=548)	0.173	1.189	(1.00 - 1.40)	0.044*
	Quintile 5 (Least deprived, n=606)	0.017	1.017	(0.85 - 1.21)	0.84
Travel time at postcode level	Travel time (minutes)	-0.00055	0.99	(0.99 - 1.00)	0.66
Stage at diagnosis	Early Stage (n=978)	Reference			
	Late Stage (n=1120)	1.073	2.92	(2.57 - 3.33)	< 2e-16 *
	Non-responsive(missing/edited) (n=740)	0.355	1.43	(1.21 - 1.67)	1.39e-05 *
Charlson Score	No co-morbidity (n=2397)	Reference			
	Having co-morbidity (n=126)	0.207	1.23	(0.99 - 1.52)	0.057
	Non-response(missing/edited) (n=315)	-0.319	0.72	(0.60 - 0.87)	0.0006*
Treatment	No treatment used (n=509)	Reference			
	Treatment used (n=2303)	-1.37	0.252	(0.21 - 0.29)	< 2e-16 *
	Non-response(missing/edited) (n=26)	-0.292	0.746	(0.48 - 1.16)	0.192
No. of cars	No household access to a vehicle (n=877)	Reference			
	Having household access to a vehicle (n=1902)	-0.244	0.783	(0.69 - 0.88)	9.84e-05 *
	Non-response(missing/edited) (n=59)	-0.285	0.751	(0.52 - 1.08)	0.125
Practicing religion	No (n=409)	Reference			
	Yes (n=2321)	-0.043	0.957	(0.82 - 1.11)	0.57
	Non-responsive(missing/edited) (n=108)	-0.219	0.802	(0.59 - 1.10)	0.16

4. Discussion and conclusion

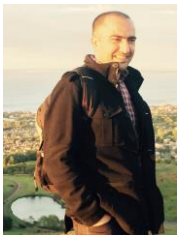
The results from the final multivariate Cox regression model (adjusted) is interesting as deprivation shows an opposite pattern to individual model results. However, no significant deprivation gradient is found in fully adjusted model. Therefore our results show that higher area deprivation is associated with shorter survival in univariate analysis. But once it is control for individual circumstances, then area deprivation has no significant effect. In other words we might argue it is the individual and not the area deprivation that matters. Our results from adjusted model for ethnicity shows no evidence of ethnic inequalities in cancer survival. Although, the travel time to cancer hospital is not significant (both in univariate and in the final model) in Scotland compared to England (Jones et al., 2008a, Jones et al., 2008b). However, having household access to a vehicle showed better cancer survival rate individually and in the final model. After controlling for other factors, our results showed that early stage at diagnosis (Murchie et al., 2015) and having cancer treatment (Campbell et al., 2002) are the most important factors in terms of better cancer survival. The individual factors in un-adjusted models in our study showed worse survival comparing to adjusted model. Our results acknowledged the initiatives by Policy makers within Scottish Government and their focus on early diagnosis process (Scottish Bowel Screening Programme, 2015). In conclusion, linking three major datasets (SLS, NHS and accessibility) in this research enables us to understand the wider multidimensional factors that influence colorectal cancer survival (including the long term effect where vital events data are linked on annual basis for SLS members) after controlling for important individual variables.

5. Acknowledgements

This PhD study is funded by the University of St Andrews (600th Anniversary scholarship) to which we are deeply thankful. The help provided by staff of the Longitudinal Studies Centre - Scotland (LSCS) is acknowledged. The LSCS is supported by the ESRC/JISC, the Scottish Funding Council, the Chief Scientist's Office and the Scottish Government. The authors alone are responsible for the interpretation of the data. Census output is Crown copyright and is reproduced with the permission of the Controller of HMSO and the Queen's Printer for Scotland.We also acknowledge the help provided (for NHS data) by eDRIS co-ordinator Mark McCartney from National Services Scotland and Information Services Division, NHS National Services Scotland for providing us the data on cancer treatment hospitals and GPs location data.

6. Biography

All contributing authors should include a biography of no more than 50 words each outlining their career stage and research interests.



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Alan Marshall is a Social Statistician by training with both substantive and methodological research interests. His substantive research uses longitudinal data from social surveys in the UK and overseas to better understand the social and biological determinants of inequalities observed in health and wellbeing in later life.

Zhiqiang Feng is a senior lecturer in human geography at the School of Geosciences of University of Edinburgh. He obtained a PhD in geography from Lancaster University. He holds a BSc in geography (Peking University, China) and MSc in cartography and remote sensing (Chinese Academy of Sciences).

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