An English Atlas of Inequality

Technical Report

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CHAPTER 1: INTRODUCTION

1.1. Introduction

The analysis of local socio-economic disparities in England is often based on indicators from the Indices of Deprivation – e.g. relating to health, education, income, employment, and access to services, among others. Whereas such indices focus on area-level data, and they are appropriate for assessing relative socio-economic disparities, they do not necessarily provide adequate information on variations *within* local areas. For instance, the English Indices of Deprivation classifies an area as 'deprived' within the Income domain if, relative to other areas of the country, the incomes of people within the area are considered low. What it does not examine is differences in income levels within the area – i.e. the proportion of rich or poor households within areas who are considered to be deprived or affluent.

Therefore this project, funded by the Nuffield Foundation as part of its focus on geographic inequality and welfare, sought to address three main issues:

i. How are local inequalities best measured?
ii. Which areas of England are most or least unequal? and
iii. Whether areas considered to be more equal have better overall outcomes.

In this study, we focus on local economic inequality by examining the extent to which local variations in income are related to outcomes in health, education, and economic disadvantage on a small number of indicators. The main findings of the study are presented in the project report (An English Atlas of Inequality) which can be accessed online[1]. In addition to the main report, further research outputs in the form of maps and key indicators for Travel to Work Areas, Westminster Parliamentary Constituencies and Local Authority Districts in England were produced and are also available online.

This report outlines the conceptual framework and the methods used in undertaking the research.

1.2. Overview of the Atlas of Inequality

The English Atlas of Inequality research project involved a detailed examination of patterns and relationships between the unequal distribution of economic resources among people living in the same local areas in England, and socio-economic outcomes which are considered essential for the well-being of individuals and households.

The aim is to shed more light on the scale of the inequality problem in England through easy-to-understand maps, charts and indicators.

The project outputs consist of a main report - 'An English Atlas of Inequality' – and three sets of online maps for different administrative, electoral and functional economic areas in England.

[1] http://ajrae.staff.shef.ac.uk/atlasofinequality

The study considers three measures of Income inequality (the Gini coefficient, 20:20 Index, and Moran's I statistic[2]) and outcomes in health, education and skills, and economic disadvantage.

1.3. About the Technical Report

This report presents the conceptual framework for the research and describes datasets used in the project, and their sources. It also outlines the methodological approach and specific methods used in producing the various measures of inequality, and the indicators of outcomes used in the project. In the spirit of open research, a list of datasets and their sources, illustrations of the necessary procedural steps, as well as calculations and code used in producing the research outputs are presented in the appendices for anyone who wishes to produce similar outputs.

The rest of this report is structured as follows:

- We present the conceptual framework for the research in Chapter 2 where we provide a brief overview of what we set out to investigate and why, and how we decided on the various indictors and the spatial unit(s) of analysis used in the research.

- The specific methods and how these methods were deployed in the study to produce the relevant research outputs are outlined in Chapter 3.

Illustrations of calculations (where relevant), which can be followed to reproduce some of the key outputs of the research, are presented in the appendices.

[2] The Moran's I statistic was used to measure the spatial clustering or dispersal of deprivation.

CHAPTER 2: PRODUCING AN ATLAS OF INEQUALITY

2.1 Why an English Atlas of Inequality?

Globally, socio-economic inequality has been identified as a serious social problem, and this has been recognised as one the greatest threats to modern society (Dorling, 2014). But of course this is not new, and there is a long history of concern with socio-economic inequality and its impacts on the outcomes of individuals and households (Wesley and Peterson, 2017), and their spatial configuration. However, interest in the topic has increased significantly since the Global Financial Crisis and the recession that followed, and many people acknowledge that inequality is social problem that now requires urgent policy attention (Boushey et al., 2017; Stiglitz, 2012).

In 2011, major cities in several countries in Africa, the Middle East, Europe and the United States experienced different levels of societal unrest ranging from small sectoral protests to major uprisings that led to the demise of long-established governments. Underlying most of these disturbances was the notion that political and economic systems that are supposed to ensure equitable distribution of opportunities and to protect the most vulnerable in society had failed to live up to expectations (Stiglitz, 2013).

Debates about whether we should be concerned about inequality or not continue, without any agreement on acceptable levels of inequality in a modern society (if any) (Deaton, 2013; Wilkinson and Pickett, 2010). Does it pay to have a few wealthy people in a society where most are poor (Dorling, 2014)? Is it fair to take money from the rich (who have worked for their wealth) and give it to the poor? Should inequalities in some sectors, like health, be more unacceptable than inequalities in income (Haidt, 2012)? These are some of the pertinent questions that have been debated among politicians and commentators for decades. In spite of such debates, there is growing consensus that wide gaps between the richest and the poorest in society are not good. We concur with this assessment and this rationale underpins the contribution we attempt to make with our research.

Income inequality in the UK is among the highest of any of the Organisation for Economic Cooperation and Development (OECD) nations. The Office for National Statistics (ONS) estimates the United Kingdom’s current Gini coefficient to be 0.34 for income before housing costs and 0.39 for income after housing costs. At the same time, the share of income going to the top 1% continues to rise. A significant number of households in the UK have disposable incomes that are less than the median household income, estimated to be £29,400 for the financial year ending 2019 (ONS, 2019).

Despite doubts about its long-term sustainability, economic growth in the UK has surpassed the peaks reached before the Global Financial Crisis (GFC). However, the nature of the income distribution relating to these economic gains remains questionable (Rhodes, 2018). For example, some argue that London and the South East continue to benefit more economically than the rest of the country (Martin, et al., 2016; Kitson and Michie, 2014). Even if these assertions are true, can we say that all or even most households in London and the South benefit from such economic gains?

Conversely, are all households in the other English regions being 'left behind'? What are the potential impacts of inequality within neighbourhoods on crime, health, education, skills, poverty, economic growth, happiness and the general well-being of people? These are the kinds of questions we seek to answer with our English Atlas of Inequality project.

In most of these instances, we simply do not have adequate information to give a definitive answer. Whilst much has been written about rising income and wealth inequality globally, the local characteristics and manifestation of inequalities within districts, cities, and urban areas have not received the same level of attention. In most cases, very little is known or they are poorly understood. This study, An English Atlas of Inequality, is our attempt to address some of these issues and to challenge general perceptions about which places in England might be considered 'rich' or 'poor'.

Before we proceed any further, it is important to pause and clarify what we mean by inequality and how this differs from deprivation, or specific measures of poverty. We discuss these interrelated but conceptually different terms in the next section.

2.2 Inequality, Deprivation or Poverty?

Inequality, poverty and deprivation are distinct but interrelated concepts. Most often, people tend to equate inequality with poverty and deprivation. In fact, it is very common to hear that inequality and poverty are two sides of the same coin. To be poor means a person or household's resources are not sufficient to meet their minimum needs (Goulden and D'Arcy, 2014). Deprivation, on the other hand, relates to a the lack of something, relating to "…types of diet, clothing, housing, household facilities and fuel and environmental, educational, working and social conditions, activities and facilities which are customary, or at least widely encouraged and approved in the societies which they belong." (Townsend, 1987, p. 125). Inequality as perceived in this research is concerned with the way in which desirable things, specifically income, are distributed across a given population.

We acknowledge here the overlaps between poverty, deprivation and inequality and that where inequality is widespread, there is the likelihood of a significant incidence of deprivation and poverty. However, there are conceptual and analytical differences between these concepts. There are different conceptualisations of poverty and deprivation and there are different kinds of inequality. Similar to poverty, inequality can be multidimensional and encompass issues relating to health, educational opportunities, participation, influence, economic or financial security among others (McKnight et al. 2019). Even within conventional definitions of economic inequality, there can be inequality within a group of people considered poor or rich.

This study is not about deprivation or poverty directly; instead, it is about income inequality and its relationship to outcomes, from a spatial perspective. In effect, it is more concerned with *variations* in the distribution of economic resources within geographic boundaries than whether a place is generally above or below some measure of poverty or lacking some economic resource.

2.3 Spatial Unit of Analysis

Arguably, one of the most important variables in studies about inequality is the geographic boundary used for the analysis. Inequality is more likely to be higher if analyses are undertaken across larger study areas than it would be if the area of interest is relatively small. We also recognise the relevance of the modifiable area unit problem (MAUP) and the potential impacts of over-boundedness and under-boundedness of predefined geographic boundaries in exacerbating local inequalities in certain parts of the country. Put simply, these issues relate to the fact that using different boundaries can lead to different results, and we were very mindful of this in our research.

Another important consideration in deciding on the spatial unit of analysis is the role of migration. Unlike national inequality whereby people cannot easily relocate to other countries, more locally people can in theory move from one area to another relatively easily. For example, between July 2014 and June 2015, an estimated 2.85 million residents moved from one local authority district to another (ONS, 2016). Such household moves can have significant impacts on the deprived/less deprived balance within places (Glaser et al., 2015). Where the spatial units of analysis are smaller geographic boundaries, the potential impacts of household moves on the significance of the results can be very high, as in the case of neighbourhood gentrification.

After careful consideration of a wide range of administrative and electoral boundaries in England such as Lower-layer Super Output Areas (LSOAs), WARDS, parliamentary constituencies and local authority districts, among others, we settled on Travel to Work Areas (TTWAs) as the main spatial unit of analysis. This is primarily because TTWA boundaries are the closest match to functional economic zones for different areas in England. Towns, cities, villages and other settlements that are within the same TTWA are more likely to compete for the same opportunities and resources that are necessary for the socio-economic development and well-being of individuals and households.

Furthermore, TTWAs are relatively large, compared to other administrative boundaries like wards, constituencies or even local authority districts. The number of potential relocations between TTWAs are more likely to be considerably less compared to other administrative boundaries. Analysis of inequalities within these zones has the potential to produce meaningful insights into the characteristics of local inequality and the potential impacts on outcomes.

We also acknowledge that the responsibility for addressing some of the problems associated with inequality, from a policy perspective, lies with individual local authorities. There is therefore an additional need to examine the problem at the Local Authority District (LAD) level to identify potential trends and differences between such areas. In this regard, summaries of findings for each Local Authority Area and Parliamentary Constituency in England have been produced and published separately. These can be accessed online[3].

[3] http://ajrae.staff.shef.ac.uk/atlasofinequality

CHAPTER 3: METHODS

3.1 Local Measures of Inequality

There appears to be a growing consensus that inequality in the UK is high. However, there are different views about whether inequality is increasing or decreasing. Most often, opposing views about the trajectory of inequality are due to methodological variations and differences in the underlying data used in its measurement.
Our basic approach to the measurement of income inequality is to adopt the **Gini coefficient**, based on new income research data produced by the Office for National Statistics (ONS) as our main measures of inequality. We supplement the Gini coefficient with two other measures of inequality: (i) the **20:20 Index** based on the IMD2019 Income domain and (ii) **Moran's I** – a spatial statistical measure of economic segregation or clustering also based on the IMD2019 Income domain.

3.1.1 Gini Coefficient

The Gini coefficient, also known as the Gini index, primarily measures the distribution of a specific resource – usually income – within a specified geographic unit and returns a value on a scale of zero to one or zero percent to one hundred percent. A zero coefficient represents perfect equality (a situation where everyone has the same amount of resources) and a score of one represents perfect inequality (only one person has all the resources and the rest have none). A higher Gini coefficient (closer to 1 or 100%) indicates high inequality and a lower Gini coefficient (closer to 0 or 0%) indicates lower inequality.

Even though the Gini coefficient is usually calculated for countries, the same principles can be applied to any geographic unit. In fact, as part of the yearly *Cities Outlook* series, the Centre for Cities produced Gini coefficient estimates for Primary Urban Areas in the UK. A similar approach is adopted in this study.

The Gini coefficient is often represented graphically through the Lorenz curve, which shows income distribution by plotting the population percentile by income on the horizontal axis and the cumulative income on the vertical axis (see Appendix III). The Gini coefficient is equal to the area below the line of perfect equality minus the area below the Lorenz curve, divided by the area below the line of perfect equality.

To calculate the Gini Index for this study we:

- Used nine different income bands based on the midpoint estimate of the ONS equivalised household Income from PAYE and Benefits data bands (see Appendix I for links to the full description of dataset and Appendix II for the equivalisation method used by ONS to estimate household income). We used midpoint estimates of £0, £2,500, £7,500, £12,500, £17,500, £25,000, £35,000, £50,000 and £70,000 to represents income bands £0, £0.1 - £5,000.00, £5,000.01 - £10,000, £10,000.01 - £15,000.00 £15,0000.01 - £20,000.00, £20,0000.01 - £30,000.00 £30,000.01 to £40000.00, £40,000.01 - £60,000.00 and above £60,000.01 respectively.

- Estimated the number of households that fall within each band based on the percentage of households within the boundary estimated for the relevant income band according to the ONS PAYE and Benefit income data.
- Calculated the share of cumulative income for each band of households and used the data to create the Lorenz Curve. See Appendix III for an illustration of how we calculated the Gini coefficient from the Lorenz Curve.

We calculated the Gini coefficient for every Travel to Work Area in England and ranked them from the most unequal to the least unequal. A rank of one is assigned to the most unequal Travel to Work Area in England. Similar calculations were undertaken for all Local Authority Districts and Westminster Parliamentary Constituencies.

3.1.2 20:20 Index

Another common way of understanding inequality is by using ratio measures, like the 20:20 Index. The conventional 20:20 Index measures inequality by comparing the average share of resources of the top 20% richest people or households in a given population to the poorest 20% of the same population. For instance, an income-related 20:20 Index value of eight would indicate the average income of the top 20% is eight times greater than the average income of the bottom 20%. Unlike the Gini coefficient, which measures the distribution of resources among the total population within an area, the 20:20 Index focuses on variations between the extremes.

The 20:20 Index used in this study is conceptually similar, but technically different to the conventional 20:20 Index approach. In deriving the 20:20 Index here, we:

- Calculated the absolute difference in the number of LSOA within the top 20% and the bottom 20% of the Income domain of the English Indices of Deprivation 2019.
- These results were then expressed as a percentage of the total number of LSOA within each TTWA (See Appendix IV for an illustration).

A 20:20 Index value of zero indicates that the number of small areas (LSOAs) within the relevant boundary that falls within the most deprived 20% and least deprived 20% are the same. A measure of 0.5 indicates that the gap between the number of areas within the area of interest that are in the most deprived 20% and least deprived 20% of the IMD income domain decile is equal to approximately 50% of the total number of LSOAs within the administrative boundary. The results of this analysis are reported in full in the main report.

3.1.3 Moran's I

Whereas the potential impacts of inequality on the outcomes of individuals and households is well established, the spatial structure of inequality can produce additional effects beyond what can be attributed to the general level of inequality in the area.

Where people with low income are concentrated in one part of a city or region, and separate from people with high income, the potential impacts of inequality on outcomes of individuals and households is likely to be different to the situation where both people with high income and low income are spatial evenly distributed.

To examine the potential impacts of the clustering of income deprivation within areas and their potential impacts on outcomes were used a spatial statistical measure known as global Moran's I.

The measurement of spatial autocorrelation through the global Moran's I technique involves the calculation of the Moran's I statistic or index value as well as a z-score and a p-value to test for the significance of the Moran's I statistic based on the pairs of feature values and location attributes (the target feature and at least one other feature).

It is simply the correlation between the value of target feature x and the average of all the values of neighbouring[4] features (the spatial lag). Mathematically, the formulae for global Moran's I is:

$$I = \frac{N \sum_i \sum_j W_{i,j}(X_i - \bar{X})(X_j - \bar{X})}{(\sum_i \sum_j W_{ij}) \sum_i (X_i - \bar{X})^2}$$

Where:

N is the number of cases;
X_i is the variable value at location i;
X_j is the variable value at location j;
$\bar{X}$ is the mean of the variables and;
W_{ij} is the weight applied to the comparison between location i and location j.

The null hypothesis of no spatial autocorrelation is given as:

$$E(I) = \frac{-1}{N-1}$$

Moran's I values usually fall between 1 (perfect clustering) and -1 (perfect dispersion, like a chess board) and the null hypothesis cannot be rejected if the p-value is not statistically significant. If the p-value is statistically significant, a positive index value indicates the presence of spatial clustering beyond what would normally be regarded as random. If the Moran's I value is negative and the p-value is statistically significant, it suggests a dispersed spatial pattern than what would normally be deemed to be a random process[5].

Both scenarios suggest that a value observed at location X is dependent on values observed at other locations (which are included in the spatial weights) and that the null hypothesis of randomness may be rejected. A Moran's I statistic of zero indicates no

[4] Features or polygons to be used as neighbours are pre-determined through the spatial weights matrix.
[5] Although negative spatial auto correlation is possible, it is rare (Levine, 1999).

identifiable spatial patterns can be discerned from the study area and therefore suggest randomness (De Smith et al., 2007).

For this study, Moran's I for all TTWAs (and other geographies) were calculated in R (see Appendix V for R code) using the IMD2019 Income domain deprivation scores and first order contiguity as the spatial weights.

Calculating Moran's I for Travel to work Areas, Local Authority Districts and Parliamentary Constituencies required:

a) LSOA shapefile with fields for Local Authority Districts, Parliamentary Constituencies, Travel to Work Areas and IMD2019 Income domain score.

b) A CSV file from the attribute table of the shapefile.

Users can load these into R and use the code in Appendix V to calculate the Moran's I statistics and P-values for TTWAs, LADs and Constituencies separately.

3.2 Indicators of Outcomes

One of the objectives of this study was to examine the relationships and potential impacts of economic inequality on individual outcomes. In this regard, we considered outcomes in health, socio-economic disadvantage, education and skills and selected indicators reflects the relevant outcome and are also available for all areas in England.

3.2.1 Education and Skills

We used outcomes in education and skills to examine the relationships between economic inequality and the potential for social mobility. Studies have shown that on average people with higher education qualifications earn significantly more than others who do not have higher education qualifications. For women, the income gap can be as much as 50% (Belfield, 2019; Strauss, 2011).

The evaluation of educational outcomes was based on the average score of all LSOAs within each spatial unit for the entry to higher education indicator produced by the creators of the English Indices of Deprivation 2019. The entry to higher education indicator score is the inverse of the proportion of young people under the age of 21 who successfully applied to a higher education institution in the UK. For a full description of how the indicator was created see *The English Indices of Deprivation 2019 Technical Report* published by the Ministry of Housing, Communities & Local Government[6].

3.2.2 Health

We used Age Standardized Mortality Rates (ASMR) calculated from the number of deaths registered in 2016 as an indicator of health outcomes. To calculate ASMR for each area, we:

[6] The IMD2019 Technical Report can be accessed from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/833951/IoD2019_Technical_Report.pdf

- Grouped the number of deaths into different age-groups;
- Grouped the population into to the same age-groups as the number of deaths;
- Established the percentage of total population of each TTWA in each group (population weight);
- Calculated the crude mortality rate (per 10,000 people) for each age-group as:

$$\frac{total\ number\ of\ deaths\ per\ each\ age\ group}{total\ number\ of\ population\ in\ the\ same\ group}\ X\ 10{,}000$$

- The Age Standardized Mortality Rate is the sum of the crude mortality rates for each age group multiplied by the population weight of the same age-group (see Appendix VI for an illustration of the calculation of the Age Standardized Mortality Rate).

Areas with high ASMRs are considered to have worse outcomes in health and have lower ranks[7].

3.2.3 Economic Disadvantage

We used the Unadjusted Means-Tested Benefit Rate (UMBR) produced by The Centre for Analysis of Social Exclusion at the London School of Economics as a measure of household economic outcomes. UMBR is a proxy indicator of income poverty for Lower-layer Super Output Areas (LSOAs) in England and Wales and Data Zones in Scotland. It measures the proportion of households within small areas that are considered poor. It is computed from public data sources such as Job Seekers Allowance, Income Support, Employment and Support Allowance and Pension Credits. For a link to the full description of the data set and its source, see Appendix I.

UMBR indicators are available from 2011 to 2013. We estimated the average UMBR for Travel to Work Areas (TTWA) from the LSOA rates. The resulting average rates were ranked from the highest to the lowest. The TTWA with worst outcomes in income poverty has the highest average UMBR and is ranked 1. Areas with best outcomes in income poverty have higher ranks.

[7] A rank of 1 is assigned to the TTWA with the highest number of deaths per 10,000 people.

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APPENDICES

APPENDIX I – INDICATORS AND DATA SOURCES

Data	Sources
Unadjusted Means Tested Benefit Rate (UMBR)	LSE Research Online http://eprints.lse.ac.uk/46449/
IMD overall Index	IMD2019, MHCLG https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019
Entry to High Education	IMD2019, MHCLG https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019
Registered Deaths - 2016	ONS https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/008925deathsbylowersuperoutputarealsoaengland2012to2017registrations
Estimated Income from PAYE and Benefits	ONS https://www.ons.gov.uk/census/censustransformationprogramme/administrativedatacensusproject/administrativedatacensusresearchoutputs/populationcharacteristics/researchoutputsincomefrompayasyouearnpayeandbenefitsfortaxyearending2016
IMD2019 Income Domain Scores	IMD2019, MHCLG https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019

APPENDIX II – ONS INCOME EQUIVALISATION METHODOLOGY

Income equivalisation is used to adjust household income by considering variations in household sizes and composition in order to account for the impact of economies of scale related to certain household expenditure such as water, electricity, gas, broadband and so on.

The equivalence scale used by the Office of National Statistics (ONS) to estimate the equivalised household income from PAYE and benefits income is shown below:

Type of Household Member	Equivalence value
First Adult	1.0
Additional Adult	0.5
Child aged: 14 and over	0.5
Child aged: Under 14	0.3

The sum of equivalence values for each member of the household is the household equivalence value. Using the hypothetical household composition shown in the table above, the household's equivalence value is **2.3**. The household equivalence value is used in estimating the equivalised household income.

Assuming the total household income for the hypothetical household shown in the table above is £40,000.00, the equivalised household income can be calculated as follows:

$$\frac{£40{,}000}{(1 + 0.5 + 0.5 + 0.3)} = £17{,}391.30$$

For further information about ONS Equivalised income, see https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/compendium/familyspending/2015/chapter3equivalisedincome

APPENDIX III - CALCULATING THE GINI COEFFICIENT

Income Band	Population	Mid Income Estimate	% Population	Mid income x Population	%Income	Cumulative _pop_%	Cumulative %I ncome	Area under Lorenz curve
	0	0	0	0	0	0	0	0
Band1	2995	0	0.004884788	0	0	0.004884788	0	0
Band2	84732	2500	0.138196266	211830000	0.020729541	0.143081053	0.020729541	0.001432373
Band3	120055	7500	0.195807401	900412500	0.088113761	0.338888454	0.108843303	0.012685661
Band4	129083	12500	0.210531895	1613537500	0.157899694	0.549420349	0.266742997	0.039536448
Band5	100716	17500	0.164265863	1762530000	0.17248	0.713686212	0.439222997	0.057983057
Band6	103959	25000	0.169555134	2598975000	0.254333945	0.883241346	0.693556942	0.096034327
Band7	40885	35000	0.06668265	1430975000	0.140034251	0.949923996	0.833591193	0.050917142
Band8	22436	50000	0.036592685	1121800000	0.109778593	0.986516682	0.943369786	0.032511887
Band9	8267	70000	0.013483318	578690000	0.056630214	1	1	0.013101537
Totals	**613128**		**1**	**10218750000**	**1**		**Area B**	**0.304202431**

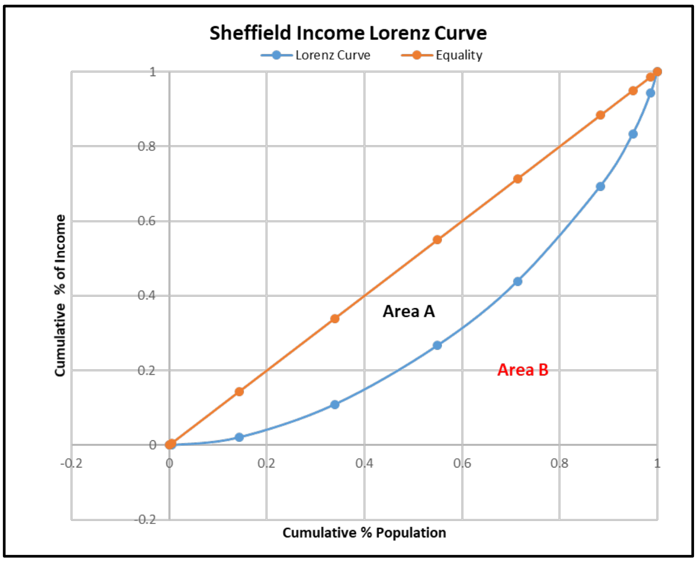
Area A = 0.5- sum of area under Lorenz curve

= 0.5 – 0.3042

= **0.1958**

$$Gini = \frac{Area\ A}{Area\ A + Area\ B}$$

$$Gini = \frac{0.1958}{0.1958 + 0.3042} = 0.392$$



APPENDIX IV – CALCULATING THE 20:20 Index

IMD National Deciles											
Deciles	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**Total**
Number of LSOAs	81	39	31	21	27	29	26	30	26	35	345

20:20 index for the area with the above IMD decile classifications can be calculated as:

$$20{:}20\ Index\ = \frac{ABS(MDQ -\ LDQ)}{Total\ Number\ of\ LSOAs}$$

Where MDQ is the number of LSOA in the TTWA that are within the most deprived 20% of the overall IMD nationally and LDQ are the number of LSOA in the least deprived 20% nationally.

$$20{:}20\ Index\ = \frac{ABS(61 - 120)}{345}$$

$$20{:}20\ Ratio\ = 0.17$$

APPENDIX V - CALCULATING MORAN'S I

R code used to calculate Moran's I

```
library (dplyr)
library (spdep)
library (rgdal)

Eng<-readOGR(".", "Eng_AOI") #read the shapefile

LAD_List<-unique (AOI$LAD19CD) # Creates a list of all Unique LAD Codes

n_LAD<- length (LAD_List) # provides the total number of unique LAD codes for looping

datalist=list()
 for(i in 1:n_LAD)
  {
   LAD_i<-Eng[Eng$LAD19CD %in% LAD_List[i],]
   queen.nb<-poly2nb(LAD_i, row.names = LAD_i$Q1) #this creates queen contiguity in R where
        Q1 is the contiguity field
    moran_i<-moran(LAD_i$Income_19S,nb2listw(queen.nb),length(LAD_i$Income_19S),
        Szero(nb2listw(queen.nb)))# calculates Moran's I statistics
        Morans_sig<-moran.test(LAD_i$Income_19S,nb2listw(queen.nb)) # test for the statistical
        significance of the Moran's I
         datalist[[i]]<-c(LAD_List[i], moran_i$I, Morans_sig$p.value) # creates a data set of
        Morans'I statistics, Morans i P-value for each i (area)
  }
LAD_all=do.call(rbind,datalist) #joins LAD codes to the Moran's I results into one dataset

write.csv(LAD_all,"LAD_Morans_I_Income19.csv", row.names=FALSE) # writes output to CSV file)
```

APPENDIX VI – CALCULATING THE AGE STANDARDIZED MORTALITY RATE (ASMR)

Age Group	*Population*	*Percentages*	*Deaths*	*Crude Mortality Rate (10,000)*	*Age Specific Mortality Rate (10,000)*
P<1	6,593	1.15%	32	48.5	0.56
P01-04	26,843	4.68%	4	1.5	0.07
P05-09	34,061	5.93%	2	0.6	0.03
P10-14	30,655	5.34%	3	1.0	0.05
P15-19	38,089	6.64%	10	2.6	0.17
P20-24	62,926	10.96%	14	2.2	0.24
P25-29	45,851	7.99%	16	3.5	0.28
P30-34	36,823	6.41%	16	4.3	0.28
P35-39	34,559	6.02%	26	7.5	0.45
P40-44	33,491	5.83%	41	12.2	0.71
P45-49	38,420	6.69%	93	24.2	1.62
P50-54	35,602	6.20%	116	32.6	2.02
P55-59	31,191	5.43%	142	45.5	2.47
P60-64	26,288	4.58%	209	79.5	3.64
P65-69	26,713	4.65%	339	126.9	5.91
P70-74	22,258	3.88%	466	209.4	8.12
P75-79	17,639	3.07%	602	341.3	10.49
P80-84	13,312	2.32%	811	609.2	14.13
P85+	12,736	2.22%	1,969	1546.0	34.30
Total	**574,050**	**100%**	**4,911**		85.55

$$Crude\ mortality\ Rate = \frac{Number\ of\ deaths\ in\ each\ age\ group}{Population\ within\ age\ group}\ x\ 10{,}000$$

$$Age\ Specific\ mortality\ Rate = Crude\ Mortality\ Rate\ X\ Percentages$$

$$ASMR\ \ = The\ Sum\ of\ Age\ group\ Specific\ Mortality\ Rate$$

$$Sheffield\ ASMR\ per\ 10{,}0000 = \mathbf{85.55}$$