Highlights

- Energy Poverty and deprivation are distinct concepts in England
- The relationship between these two measures is heterogeneous across England
- Energy poverty policy & interventions should be designed at a local level.
- English Index of Multiple Deprivation needs redesigning to include energy access
- The methodology proposed may be useful for targeting energy poverty globally

Examining the relationship between energy poverty and measures of deprivation

Abstract

Energy poverty is defined as the inability to afford to heat the home to an adequate temperature at reasonable cost. Such a concept has gained political recognition in an increasing number of countries; however, in the United Kingdom, related policies tend to rely upon measures of general deprivation as a practical proxy. This has often resulted in the design of sub-optimal schemes for eradicating this issue.

After engaging with the debate about the independence of the energy poverty concept, this paper evaluates the relationship between energy poverty and multi-dimensional measures of deprivation through a statistical analysis. Findings demonstrate that energy poverty constitutes an additional and independent form of deprivation, which is not captured by the current English Index of Deprivation. Also, results are utilised to develop a classification matrix that identifies areas by their level of deprivation and energy poverty that can be mapped through a Geographic Information System at a Lower Super Output Area. The resultant maps can be utilised to develop effective local area interventions focused on the factors that are most likely to reduce energy poverty in that geography.

Keywords: Fuel Poverty; Energy Poverty; Index of Multiple Deprivation; Area Based Targeting; Housing; Energy Policy

Introduction

Energy poverty, most simply defined as "the inability to heat the home to a socially and materially necessitated level" (Buzar, 2007a, p. 225) first emerged as a concept in England in the 1970's. At its conception in the UK it was known as fuel poverty and gained recognition within academia and social rights campaigns. Despite sustained academic interest, policy-makers have often failed to recognise fuel poverty as a distinct issue, independent of general deprivation. The issue is now receiving increasing attention internationally (Ambrose and Marchand, 2017), most notably within Northern (Brunner et al., 2012; Legendre and Ricci, 2015; Thomson and Snell, 2013) and Eastern Europe (Buzar, 2007b; Tirado Herrero and Ürge-Vorsatz, 2012) as well as Australasia (Howden-Chapman et al., 2012) and America (Mohr, 2018). As the issue has grown in international interest, increasingly the language of the field has moved from labelling it as fuel poverty to energy poverty. This shift recognises the importance of both the technical and socially defined requirements for a warm home, aligning closely with Townsend's (1987) conception of deprivation, and as such is the term adopted in this paper.

After an exploration of the literature, this study aims at undertaking a statistical examination of energy poverty as an independent concept through exploring the relationship between the Index of Multiple Deprivation (IMD), a composite indicator of poverty within England; and the annually published, official fuel poverty statistics. Both of these data sets are modelled at the Lower Super Output Area (LSOA), allowing a direct comparison of energy poverty and general poverty at the same geographic area. We then present a classification matrix which categorises all LSOA's in England according to the statistical relationship between energy poverty and general poverty. The results are then mapped with the use of a Geographic Information Systems (GIS) programme (QGIS) to present a visual representation of the relationship. The study concludes by discussing the implications of this analysis and subsequent classification framework for the delivery of energy poverty interventions.

In considering the literature on the relationship between energy poverty and deprivation to date, and examining this relationship statistically, the work presented here seeks to answer the primary research question:

RQ1: Is there an obvious (statistical) relationship at the national level between the IMD and sub-regional Energy poverty (FP) datasets?

After exploring this question, we progress to discuss two further research questions:

RQ2: Can geographical areas be identified with differing relationships between Energy poverty and deprivation.

RQ3: Can a classification framework be developed that allows categorisation of the geographies identified from research question 2?

The study adds statistical evidence to support the arguments of many energy poverty researchers about the distinctiveness of energy poverty compared to general deprivation. Furthermore, this work introduces a new methodology that can be used by public authorities and third sector for identifying specific geographies and applying the most appropriate mitigation measures for reducing energy poverty in the area.

Literature Review

2.1 Why does the independence of energy poverty matter?

To understand the distinctiveness of the energy poverty concept from that of a more general measure of deprivation is important for government, Local Authorities (LAs) and the third sector. If energy poverty has been misrepresented as an independent concern, there may no longer be a need for the government to divert resources and policy responses to energy poverty reduction, and instead it will be more pertinent to utilise these funds to tackle the root causes of general deprivation.

The debate over the independence of the energy poverty concept has existed since the inception of the issue in the mid 1970’s. Successive Conservative governments did not recognise energy poverty as an independent issue, noting that we did not recognise food poverty as a distinct form of poverty (HC Hansard, 1985).

In 1983 Bradshaw and Harris observed that energy poverty and poverty were distinct and different concepts. The reasoning utilised by Bradshaw and Harris was echoed by Boardman, who developed this analysis further to argue that the existence of energy poverty was as a result of a lack of capital investment in the housing stock as opposed to a lack of income support (Boardman, 1991). The demarcation of energy poverty from general deprivation along the lines of capital investment level, Boardman argues, relies upon an understanding that households are seeking to purchase an adequate supply of warmth. This requires two forms of capital investment – an efficient heating system and an efficient building system. If either of these systems, realised through capital investment, is inefficient then energy poverty has the ingredients to exist. By 1993

Ron Campbell went as far as to declare “Uniquely among such manifestations, energy poverty can be resolved through capital investment; in this case investment is a cure, not a palliative” (Campbell, 1993, p. 58).

Particularly with reference to low income groups, often living within rented accommodation or social-housing, their ability to influence, alter or improve the efficiency of the heating system or building fabric is beyond their reach (Boardman, 1991). Unsurprisingly, lower income households were found to be more twice more likely to live in non-decent housing than wealthy households (Gilbertson et al., 2006).

Despite the theoretical distinction between energy poverty and poverty, the close practical association of the issues has historically been substantiated through empirical examination of monitoring statistics. This examination has tended to show that fuel poor households are often also poor households (De Haro and Koslowski, 2013). Palmer et al. (2008) demonstrated that this relationship had started to change over the last decade. In 2005, roughly three quarters of fuel poor homes were also income poor, but by 2007 this figure had fallen to roughly two-thirds of fuel poor homes, driven by an increase in domestic gas and electricity prices by 21 – 25%. Palmer et al (2008) argue that as the strength of relationship between the two concepts decreases, tackling poverty will have a reduced benefit for energy poverty reduction.

Burlinson, Giulietti and Battisti (2018) develop this further in creating their identification framework. They note that energy poverty is a distinct from general poverty, but that “poverty is exacerbated by fuel costs (IP and HIP), and for other households, fuel costs may indeed push them in to poverty (FIP)” (p.137)

Palmer et al (2008) also undertook analysis of the relationship of energy poverty with a number of other indicators including unemployment, number of vulnerable households and area deprivation. Yet the degree of overlap between energy poverty and geographies classified as deprived was only slightly greater than the overlap between energy poverty and non-deprived areas. Palmer et al. (2008) suggest that this may be due to the fact that inhabitants in deprived areas tend to live in smaller properties and more efficient homes. This seems a reasonable explanation, substantiated by the impact of the Decent Homes programme (Environment Food and Rural Affairs Committee, 2009). The programme required all social housing to be of decent condition by 2010, and delivered significant improvements in amongst other aspects, the energy efficiency of the homes measured by their Standard Assessment Procedure (SAP) rating.

Against a background of significant national budgetary pressures, the 2010 spending review (HM Treasury, 2010) paved the way for the first thorough governmental examination of energy poverty since the creation of the fuel poverty strategy in 2001 (DEFRA & DTI, 2001). The report by Hills (2012) was specifically mandated to re-examine the independence of the energy poverty concept. Hills reported his analysis of this question of independence in the interim report on fuel poverty (Hills, 2011). As with the analysis of Palmer et al. (2008), Hills concluded that "there is considerable overlap between those in fuel poverty and those in income poverty" (Hills, 2011, p. 90). The report acknowledged, as with the discussion above, that although energy poverty is distinct from poverty, separating the two issues is a complex task. Hills' analysis reaffirmed that income is a predictor of energy poverty, but as with the analysis of Boardman, emphasised that the energy efficiency of the home was also key.

2.2 Paper Contribution

Despite the recognition of the energy poverty concept independence, a historically close relationship with income poverty (Boardman, 2010; c.f. Palmer et al., 2008) has resulted in the use of proxy indicators for practical targeting of energy poverty policy in England. As this relationship has weakened following significant increases in energy prices (Palmer et al., 2008), the suitability of utilising income levels or other social indicators for targeting of schemes can be questioned (Fahmy et al., 2011).

The National Audit Office in 2003 highlighted concerns over the accuracy of targeting of funds to tackle energy poverty. By 2006, less than 25% of energy poverty expenditure was successfully being spent on fuel poor homes (Boardman, 2010).

As such, identifying fuel poor homes is a major barrier to successful energy poverty reduction programmes (Boardman, 2010; Dubois, 2012). In response to these concerns a growing body of work is emerging that seeks to develop area-based approaches to identifying the fuel poor (c.f. Fahmy et al., 2011; Walker et al., 2014, 2012). It is intended that by identifying the fuel poor at smaller geographical regions, the accuracy of programme targeting is improved, maximising expenditure effectiveness (Walker et al., 2012)

This study aims to contribute to this literature on geographically based identification of fuel poor households, driven by analysis of extant government data sets, to support increasingly accurate delivery of effective policy interventions.

Improving the accuracy of policy delivery and therefore also the effectiveness of social expenditure on energy poverty eradication is a clear priority given the legislative requirements to "ensure that as many fuel poor homes as is reasonably practicable achieve a minimum energy efficiency rating of Band C, by 2030" (DECC, 2015, p. 12).

In the next section, a new methodology for identifying and prioritising households in England for energy poverty policy delivery is presented.

Methodology

Reflecting the findings and central recommendation of Hills (2012) that the fuel poor are those that are both low income households and have high fuel costs, the core aspect of this statistical analysis focusses on exploring the relationship between deprivation level and energy poverty severity. This is similar to the work of Palmer et al. (2008), but deviates from their chosen methodology by utilising the Index of Multiple Deprivation (IMD) score from English Indices of Deprivation (EID), a composite indicator of deprivation, instead of the income poverty flag contained within the English Housing Condition Survey (EHCS) as a measure of deprivation for statistical comparison. We have chosen to utilise the IMD measure rather than a purely income deprived poverty score for comparison with energy poverty because energy poverty refers to the consumption of a condition, warmth, rather than consumption of a product, fuel. As such, the poverty score does not reflect the condition being investigated, whereas by utilising a deprivation score we can more accurately represent the technical and social nature of the condition of energy poverty in relation to a comparable, though more encompassing, measure of deprivation.

3.1 Data sources

As an exploration of the current relationship between energy poverty and deprivation utilising existing data sources, the decision was made to utilise the official government fuel poverty statistics. The annual report on fuel poverty statistics, published each year by DECC and subsequently BEIS, details the level of energy poverty in England two years prior to the reports publication, and is a certified national statistic receiving the quality mark of the UK Statistics Authority. In support of the annual report, BEIS also publish sub-regional fuel poverty data sets, though these are not designated as National Statistics. The sub-regional statistics are modelled statistics, utilising a binary variable identifying whether a house is fuel poor or not in the English Housing Survey as the dependent variable and matching against data from the most recent census (amongst other sources) as the independent variable, in a logistic regression (DECC, 2014). This dataset reports on energy poverty levels at English region, county, parliamentary constituency, local authority and LSOA level, aggregating up from the Census Output Area to provide figures at larger geographies. Lower Super Output Areas were created using 2001 census data (Neighbourhood Statistics, 2007). Each LSOA contains roughly 650 households, representing around 1500 inhabitants (Neighbourhood Statistics, 2007). Utilising the 2001 LSOA boundaries gave 32,482 LSOA's in England for the data sets being considered.

Deprivation statistics were sought from the IMD. As a composite indicator the IMD captures multiple forms of deprivation across 7 domains as detailed in Table 1. In measuring deprivation across multiple domains, the IMD allows the examination of any of the domains discretely, or by utilising the aggregated deprivation score a much broader picture of deprivation in England can be captured. This will undoubtedly deliver differing results to the analyses undertaken by Palmer et al. (2008), who used poverty flags contained within the EHCS for their analysis of the relationship with income poverty. Fahmy et al (2011) note that the method utilised for gathering income data in the EHCS differs from that used in other government surveys of income which may result in an inaccurate picture of income levels if utilised in this analysis and further justifies using an alternative measure of deprivation in the study.

INSERT TABLE 1 HERE

By analysing a multi-dimensional measure of deprivation alongside the current energy poverty statistics it is possible to develop a more holistic thorough understanding of how energy poverty is distributed in England and its relationship with deprivation, enabling policy makers and planners to include a more representative picture of energy poverty to be utilised in England.

3.2 Research process

A research process was defined by the three research questions previously outlined, the answers to which drove the direction of subsequent levels of analysis.

Initially, a correlation analysis was completed on the aggregated national level of the datasets. Following the completion of the correlation analysis, the study seeks to answer the primary research question:

RQ1. Is there an obvious (statistical) relationship at the national level between the IMD and sub-regional Energy poverty (EP) datasets?

If there is a strong, significant statistical relationship, the study proceeds to present the results and discussion of this outcome. Should a relationship not be observable at the national level, the analysis is re-run at the Government Operating Region (GOR) level. In completing the analysis at a regional level we hope to explore our second research question, whether there are differing relationships between deprivation and energy poverty across England at a smaller geographical area or whether there is still a lack of identifiable relationship at this area:

RQ2. Can geographical areas be identified with differing relationships between Energy poverty and deprivation.

If at GOR level, relationships between the two concepts still cannot be identified, the analysis is repeated at Local Authority (LA) level, again looking for identifiable geogrpahical areas with distinct energy poverty/deprivation relationships. However, if distinct relationships are identified at GOR level, regions of interest are then identified for further analysis at the LA level. This analysis is then utilised to answer our final research question:

RQ3. Can a classification framework be developed that allows categorisation of the geographies identified from research question 2?

To answer this research question, outputs from RQ1 and 2 will be utilised to develop an understanding of the statistical relationships at these different geographies, from which a system of categorisation can be developed. Finally the results of the research process will be presented and discussed.

3.3 Geographical levels of examination

The nature of the chosen datasets provides the opportunity to explore the relationship between the two phenomena at differing geographic levels, defined by the statistical methodology used to build the two data sources. As previously highlighted, the sub-regional energy poverty dataset provides data at the LSOA, LA, parliamentary constituency, county, and English region level. This enables direct comparison with the English Indices of Deprivation dataset at each of these levels, as well as at an aggregated national comparison. Whilst the datasets can be cut at different geographical levels of output, the decision as to which level of output is used is driven by the outcomes of the statistical analysis. The statistical analyses are initially completed at the aggregated national level; containing all 32482 LSOA's in England.

3.4 Statistical analyses

The study utilises correlation analysis to scrutinise the relationship between the English Indices of Deprivation, 2010 and the sub-regional Energy poverty statistics, 2012. Prior to completing the analyses, the datasets will be subjected to tests of normality, skewness and kurtosis in SPSS. These tests ensure the fundamental assumptions required to complete a valid correlation analysis are met, and will inform whether a Pearson's correlation or Spearman's Rho correlation are used. After identifying which form of correlation analysis to use, the tests will be run with the results measured for statistical significance at both the 0.01 and 0.05 level.

Results & Discussion

4.1 Correlations at the national level

The datasets were subjected to the Kolmogorov-Smirnov test to assess the normality of the data. With such a large dataset it was expected that tests would indicate non-normality of data with the existence of skewness and kurtosis. This was confirmed with the Kolmogorov-Smirnov (K-S) test with all variables returning significance values of 0, indicating non normality of data (Field, 2013), and Q-Q plots and box plots of variables all demonstrating a visual representation of skewness and/or kurtosis existing for each variable in the dataset.

The combined results of these tests indicated significant departures from normality within the dataset and therefore that a non-parametric approach would be appropriate. A Spearman's rank order correlation coefficient (i.e. Spearman's rho) was calculated to assess RQ1 at the national level of the dataset. For clarity, selected correlations are reported in Table 2 focussing on the variables of greatest interest relating to energy poverty and deprivation. In order to assess the validity of the correlation coefficients, 95% and 99% confidence intervals were calculated through use of the bootstrapping procedure in SPSS, 100 bootstrap samples were utilised to calculate these values.

INSERT TABLE 2 HERE

The Spearman's rho coefficients demonstrated that there was a statistically significant relationship between all variables examined, though there was a varying strength of relationship. The 95% and 99% confidence intervals were in all cases very narrowly banded around the correlation coefficients calculated. This suggests that correlation values calculated can be considered with strong confidence as containing the population correlation value. Although the correlation was reported for all components of the IMD and FP dataset, RQ1 is explicitly interested in understanding whether there is a significant statistical relationship between Energy poverty and the IMD score. In order to gauge the strength of the correlation, categories were adopted from those set out by Dancey and Reidy (2014) .

The analysis revealed a moderate, positive, statistically significant relationship between the aggregate IMD score and the percentage of households considered Fuel Poor under the 10% definition of energy poverty ($r_s[32482] = .41, p<.01$). If we consider the relationship between the number of fuel poor households in the LSOA and the aggregate IMD score, the coefficient becomes a weak, positive, significant relationship ($r_s[32482] = .38, p<.01$). When these scores are considered in conjunction with their scatterplots, it is apparent that given the relatively low strength of the correlation coefficients and the significant spread of the plots, there is not an obvious statistical relationship between energy poverty and deprivation at the English national level.

4.2 Correlation at Government Operating Region (English Region) level

The process therefore moved to consider RQ2 “Can geographical areas be identified with differing relationships between Energy poverty and deprivation”, SPSS was used to split the dataset according to Government Operating Region before a Spearman’s rho coefficient was calculated across the same variables as in RQ1. The full results can be found in Table 3

Resultant coefficients varied across England. All were significant at $p<0.01$, except between IMD aggregate score and percentage energy poverty in London . The weakest statistically significant coefficient was found between the number of fuel poor homes and IMD aggregate score in London (r_s [4765] = .094, p<.01) with the strongest coefficient for that relationship found in the North East (r_s [1656] = .562, p<.01). The coefficient for the relationship between percentage energy poverty and IMD aggregate score for the North East was stronger still (r_s [1656] = .695, p<.01). The strongest statistical relationship was found between these two variables in the East Midlands region (r_s [2732] = .696, p<.01). Examination of the coefficients contained within Table 3 demonstrates the possibility to identify differing relationships between deprivation and energy poverty across England at the Government Operating Region level. The results also demonstrate the existence of a broad north-south divide in the relationship between deprivation and extent of energy poverty with a general trend for an increasing strength of correlation from the south to the north of England. Southern regions range from a non-significant negative correlation between percentage of LSOA's considered fuel poor and IMD aggregate score in London of -2.4% (r_s[4765] = -.024) to a moderate positive correlation in the South East of 37.8% (r_s[5319] = .378, p<.01). Northern regions (including the Midlands) ranged from a lower limit of strong positive 51.7% correlation in Yorkshire and the Humber (r_s [3293] = .517, p<.01) to strong positive 69.6% correlation in the East Midlands region (r_s [2732] =.696, p<.01). The correlations in the northern regions did not demonstrate a geographical relationship (i.e. the correlation strength did not increase as more northerly regions were considered), but were all notably stronger correlations than those demonstrated in southern regions.

INSERT TABLE 3 HERE

4.3 Correlation at the Local Authority level

To further explore the geographic variation in the relationship, the analysis was repeated at the next smallest geographic area available in the dataset. The constituent LAs of six of the English GOR's previously analysed were identified to provide a small area picture of the relationship. As with the prior analyses, SPSS was used to split the dataset and extract the relevant GOR's in order to analyse the LAs using the Spearman's rank order correlation analysis. The GOR's chosen were East Midlands, London, North East, North West, South West and Yorkshire & the Humber. These GOR's were identified as they contain all of the English cities that are members of the UK core cities group, as well as the English capital city of London. These cities and their constituent urban areas are the "most economically important English cities outside of London" (DCLG, 2012) and represent around 27% of the English economy and one third of England's population (Core Cities, 2013). By focussing on these core cities as well as London (which is home to 16% of the English population (Office for National Statistics, 2013) and accounts for around 26% of the English economy (Office for National Statistics, 2014)), this analysis captures the major population centres of England.

At the Local Authority (LA) level, the strength of the correlation coefficients within each English region varied to a large extent as did the number of significant coefficients. Although results varied within each region, the broadest range of coefficients was found in London. Excluding non-significant results, coefficients between IMD and both the number of fuel poor households within the constituent LSOA's and the percentage of households considered fuel poor within the constituent LSOA's were found with both negative and positive correlations. Negative correlations were not found in the northern regions, and only one example found in the South West region in Christchurch for the correlation between IMD aggregate score and the percentage of LSOA considered fuel poor (r_s[30] = -.466, p<.01) . The next section examines notable correlations at LA level in the GOR's analysed, demonstrating the variation in coefficients across these areas.

4.3.1 Correlations in the London region

In London the strongest negative correlation was found in Bexley for the correlation between IMD aggregate score and the percentage of LSOA considered fuel poor (r_s [146] = -.543, p<.01). Similar negative correlations were found in Brent, Hackney, Islington, Newham, Sutton and Waltham Forest. Fewer than 33% of correlation coefficients between IMD score and number of households were positive, with only 18.18% of correlation coefficients between IMD score and percentage of LSOA considered fuel poor positive in London. The strongest positive coefficients were found in Haringey with IMD against number of Fuel Poor households a weakly positive correlation (r_s [144] = .351, p<.01) and a weakly positive correlation between IMD aggregate score and percentage of LSOA considered fuel poor (r_s [144] = .330, p<.01)

4.3.2 Correlations in the South West region

As with the London region, non-significance of correlations was common throughout the dataset, with 45.9% of correlation coefficients between IMD and Number of households considered fuel poor being non-significant and 54% of correlation coefficients between IMD and percentage of households considered fuel poor non-significant. Amongst those results that were significant, the South West demonstrated a more consistently positive relationship between energy poverty and deprivation as previously discussed. Cornwall Unitary Authority had two weak positive correlations, with IMD against number of fuel poor households presenting a 20.1% correlation (r_s [327] = .201, p<.01) and IMD against percentage of fuel poor households presenting a 19.2% correlation (r_s [327] = .192, p<.01). Gloucester demonstrated a strong positive relationship in both domains; (r_s [74] = .742, p<.01) for IMD against number of households fuel poor, and (r_s [74] = .692, p<.01).

4.3.3 Correlations in the North East region

The North East was the only region analysed where all correlations were statistically significant with all bar one coefficient greater than 50% . Durham Unitary Authority had the weakest correlation of 48.8% (r_s [320] = .488, p<.01) between the IMD score and the number of households considered fuel poor. Stockton-On-Tees returned the strongest correlation in both categories of interest; (r_s [117] = .735, p<.01) for IMD score against number of households considered fuel poor and (r_s [117] = .858, p<.01) for IMD score against percentage of households considered fuel poor.

4.3.4 Correlations in the North West region

The North West region offered a broad range of strength of correlations across the two focal relationships. Around 11% of results in these two categories were not statistically significant, but in keeping with all northern regions analysed, no negative correlations were observed.

Pendle had a particularly strong correlation between IMD aggregate score and percentage of LSOA considered fuel poor (r_s [57] = .874, $p<.01$), though only a moderate strength correlation between IMD aggregate score and number of households in LSOA considered fuel poor (r_s [57] = .609, $p<.01$). The region's two core cities of Liverpool and Manchester both demonstrated statistically significant but weak correlations across both of the measures of energy poverty being considered, around the .40, $p<.01$ level. Lancaster returned the weakest statistically significant correlations across both factors. When considering IMD aggregate score against Number of households in the LSOA considered fuel poor the result was (r_s [89] = .321, $p<.01$) and IMD against percentage of LSOA considered fuel poor was (r_s [89] = .277, $p<.01$).

4.3.5 Correlations in the Yorkshire and the Humber region

Similar to the North West Region, Yorkshire and the Humber demonstrated a great diversity of results compared to the other regions analysed at LA level. It contained a small number of non-significant results and no negative correlation coefficients. The range of coefficients was broader than those demonstrated in the North East, though not as great as the North West, with the weakest relationship in the City of Kingston Upon Hull (r_s [163] = .230, $p<.01$) between IMD score and the number of households considered fuel poor and (r_s [163] = .329, $p<.01$) between IMD score and the percentage of households considered fuel poor. The LAs of Sheffield and Scarborough also had particularly weak correlation coefficients.

Whilst some particularly weak correlations were evident within Yorkshire and the Humber, some strong relationships were also noted. East Riding of Yorkshire had a correlation coefficient of 67.4% (r_s [209] = .674, p<.01) between IMD score and number of fuel poor households, and 70.1% (r_s [209] = .701, p<.01) between IMD and percentage energy poverty.

4.3.6 Correlations in the East Midlands Region

The correlation figures for the constituent LAs of the region were varied although they were narrower than those returned within Yorkshire and the Humber, and similar to those in the North West of England. Again, there were few non-significant results.

Ashfield returned the strongest correlation coefficient between percentage of homes considered fuel poor and IMD overall score (r_s[74] = .829, p<.01), slightly weaker than that experienced in Pendle in the North West. The weakest correlation between these two factors in the region was experienced in the Derbyshire Dales (r_s [43] = .388, p<.05), although this was only significant at the 5% level.

The correlations between number of homes considered fuel poor and IMD aggregate score were much more closely bounded, generally fitting in the range of 0.4-0.7. There was one exception to this in West Lindsey which demonstrated the weakest statistically significant result in the region (r_s [53] = .288, p<.05).

Unlike many of the LAs in the region that experienced notable differences in the two different correlation coefficients, the region's core city of Nottingham returned a much more balanced set of coefficients, (r_s[176] = .532, p<.01) for IMD against number of homes considered fuel poor and (r_s[176] = .536, p<.01) for IMD against the percentage of homes considered fuel poor.

4.4 Summary of the FP/IMD correlation analysis

Having analysed the relationship between energy poverty and deprivation at Local Authority, Government Operating Region and National levels, the results demonstrate that there is not a consistent relationship between the two concepts across England at any of these geographic levels. Broadly speaking a north-south divide is evident with an increasing strength of correlation coefficients moving north through the country.

As the analysis increased in granularity to consider the relationship within the constituent LAs of six GORs identified as they contain each of England's core cities, the analysis also demonstrated that there is notable variation in the relationship between energy poverty and IMD within each focal GOR. Thus, whilst the strength of the relationship tends to be stronger in the north of England, when considering a finer level of geographic detail it is apparent that there are pockets of LAs with very weak correlations between the concepts (such as City of Kingston Upon Hull ($r_s[163] = .230$, $p<.01$) between IMD score and the number of households considered fuel poor) and others with very strong correlations (for example Stockton-On-Tees ($r_s[117] = .735$, $p<.01$) for IMD score against number of households considered fuel poor).

The lack of consistent relationships at all geographic levels suggests that instead of seeking to treat the issue with a consistent approach across England, it would be more appropriate to understand the relationship between energy poverty and poverty in a more localised manner.

4.5 Developing a classification framework

The breadth of variation in the relationship between IMD and energy poverty demonstrated by the statistical analysis drove the research to RQ3 seeking to develop a classification framework for the different geographies identified.

IMD is utilised as a measure of deprivation for many public policy decisions. Although all LSOAs are ranked within the dataset, it is common for the dataset to be split by quartile, quintile or even decile depending upon the needs of the analyst. In order to provide a classification of the LSOA's in England, it was decided to reflect this approach in the classification development.

SPSS was used to classify each LSOA according to its IMD quintile and percentage of households considered fuel poor quintile. Quintiles were chosen as they allow for comparison of different levels of deprivation and affluence, and are a common level of separation used for setting public health targets and in local authority poverty profiling. The use of quintiles creates 25 different categories of depth of deprivation and depth of energy poverty, providing a detailed level of separation for each of the 32482 LSOA's in England, without being as large and potentially too nuanced as would be achieved with using deciles (i.e. 100 different categories).

Quintiles were not weighted to reflect the distribution of scores, but were instead created by dividing the two datasets into equal sized categories. This gave 25 categories as demonstrated in Table 4.

Matrix classification categories results were then mapped back using SPSS on to each of the LSOA's contained in the dataset. This dataset was then loaded in to QGIS and mapped on to the Office of National Statistics maps for the LSOA boundaries in England for 2010. The resultant map for the whole of England can be seen in Figure 1. In order to demonstrate different degrees of homogeneity, a selection of more detailed local geographic area maps are also provided (Figures 3 – 5). As can be seen, some areas demonstrate a much greater homogeneity of classification than others, with city areas tending to show greater variation than rural zones. This will be considered in more detail in the discussion.

INSERT TABLE 4 HERE.

INSERT FIGURE 1 HERE

Figure 1 Map of IMD, EP classification matrix values in England at LSOA level

INSERT FIGURE 2 HERE

Figure 2 Map of IMD, EP classification matrix values for London LSOA's

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Figure 3 Map of IMD, EP classification matrix values for North Cornwall LSOA's

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Figure 4 Map of IMD, EP classification matrix values for Sheffield LSOA's

Discussion

In order to validate the assertions made in the literature (Boardman, 1991; Bradshaw and Hutton, 1983; Campbell, 1993; Hills, 2012; Palmer et al., 2008), that energy poverty is a distinct issue from that of general deprivation, this study compared deprivation as identified in the IMD, and measures of energy poverty from sub regional Energy poverty statistics. By applying bivariate correlational analysis to variables contained within these datasets, it was possible to explore the relationship between the two concepts at different geographical areas of interest.

At the national level, a moderate, positive correlation between percentage of LSOA considered fuel poor and deprivation score was discovered of 41%. Whilst this demonstrated that there is a relationship between the two concepts, it is also showed that utilising deprivation measures as a proxy for likelihood of energy poverty existence is unlikely to result in accurate identification of fuel poor homes. This is in line with the current (Burlinson et al., 2018; Fahmy et al., 2011) and historic (Boardman, 1991; Campbell, 1993) literature. Exploration of the English House Condition Surveys shows that private rental houses are more likely to fail to meet the minimum housing standards set out in the Decent Homes Standard (Kemp, 2011) than social housing. It was beyond the scope of this study to explore the relationship between the two concepts considered according to occupancy tenure, but understanding the impact of tenure on the correlations considered would be a useful direction for future research. If, as the Energy Act (Energy Act, 2011) legislates, private rental homes with an Energy Performance Certificate rating of F or G, are no longer eligible to be rented out to tenants, the strength of the correlation between poverty and deprivation is likely to weaken further still.

Furthermore, by exploring the relationship at different geographic areas, the analyses have demonstrated the geographic diversity of the relationship between energy poverty and deprivation in England. A north-south divide is evident in the relationship, with northern regions (i.e. above and including the Midlands) presenting a stronger positive correlation than southern regions.

At the regional level, it starts to become apparent that there are distinct geographies of energy poverty and deprivation relationships in England. The broad north-south divide in the strength of the relationship demonstrates that there is not uniformity of relationship between energy poverty and deprivation across the country. This suggests that centralised policy responses are unlikely to support the most efficient intervention schemes for the eradication of energy poverty and provides a potential insight to the reasons that roughly three quarters of the money spent on energy poverty policy interventions fails to reach those that are fuel poor (Boardman, 2010).

The sub-analysis of six regions of England further strengthens this finding. Both London and the South West's LAs had predominantly weak correlation coefficients and a large number of non-significant coefficients when compared to the northern regions of Yorkshire and the Humber, the North East and the North West. Within the LAs themselves there was notable variation in correlation coefficients, demonstrating that beyond the influence of income on energy poverty deprivation, other factors are influencing the existence of the energy poverty phenomenon.

In terms of improving the targeting of policy and interventions to tackle energy poverty as well as driving research in to the field of energy poverty, the development of the Lower Super Output Area classification framework marks a contribution to the academic and policy realm. The analysis of the relationship between deprivation and energy poverty at national, regional and local authority level indicates the need for localised approaches to understanding the existence of energy poverty. This principle applies at both the local authority and regional level.

By categorising geographic areas according to the relationship between energy poverty and deprivation (in quintiles), a simple, yet useful classification of areas for intervention targeting is created. The bivariate examination of these closely related socio-economic issues suggests that in seeking to design the most appropriate intervention for each area, understanding the balance between deprivation and energy poverty more precisely could deliver substantial benefits to policy makers. Classifications which demonstrate high levels of deprivation and energy poverty (such as those areas classified as “25” in the matrix presented in Figure 1) are likely to see a greater reduction in energy poverty levels as a result of policies tackling the general deprivation in the area, improving the householder income which can subsequently contribute towards energy bills. Similarly, areas classified as low energy poverty but high deprivation (e.g. area “21”) would be better suited to deprivation intervention measures. High energy poverty low deprivation areas such as areas classified as “5” will see little benefit in terms of energy poverty reduction from the application of general deprivation interventions, but applying energy efficiency improvements in to this region would have a much greater return.

Through examination of some of the small area GIS mapping of the LSOA classifications and also the full map of England, a clear visible representation of the variability in heterogeneity and homogeneity in different areas of England is also apparent. Areas such as North Cornwall demonstrate significant homogeneity in their constituent LSOA's, providing a more straightforward opportunity for the LAs in these areas to deliver significant improvements in energy poverty or deprivation. However, in more urban areas such Sheffield and London, the heterogeneous nature of their constituent LSOA's makes targeting a much more challenging task. Comparison of these two areas indicates the differences in the homogeneity of the relationship between energy poverty and deprivation in more rural LAs and urban LAs, resulting in differing challenges in the delivery of interventions. Understanding the socio-technical causes of these variations will be important for achieving energy poverty eradication.

At a time when government resources are highly scrutinised with a limited budgetary reach, this classification approach enables appropriate targeting of resources to maximise social and economic return (Boardman, 2010). It also suggests a potential limitation of the current conception of multiple deprivation in England. If, as we and others argue, energy poverty is conceived as a form of deprivation, it is surprising that there is not a closer relationship between IMD and Energy Poverty. Upon closer examination of the components of IMD, it can be seen that there is no measure of energy access within its seven domains, with the closest measure being the lack of central heating in the home. This is a poor proxy for energy poverty, as the presence of a central heating system does not necessarily indicate the ability to afford to utilise it. It is therefore pertinent to question whether the current IMD is fit for purpose given the wide ranging social and societal implications of living in energy poverty.

5.1 Future research directions

Further studies should be undertaken to examine the structural, economic and ecological factors influencing the relationship between energy poverty and deprivation; as well as understanding the causes in their variance in different areas of England.

This study has not sought to explain the multifarious influences that have resulted in the local, regional and national variation in the relationship between energy poverty and deprivation experienced in the UK. There are likely to be a number of technical, environmental and social reasons that will contribute to the north-south divide in the relationship and further academic research is required to confirm whether factors such as geographic variation in temperature, household wealth, property ownership levels, form of household tenancy (owned, private rented, socially rented) and local rurality.

The small area classification approach developed in this paper could be applied to other countries both within and beyond Europe. As a growing field of study outside of the UK, there is a need to examine the relationship between energy poverty and deprivation in other geographic contexts. Thomson and Snell (2013) note the importance of location in determining the likelihood of being fuel poor across the EU and Deller (2018) warns of the policy impacts of focussing on high level measures of energy poverty in terms of tackling the actual thermal reality of a given household. At a country level, the work of Belaid (2018) highlights the role of targeting interventions (in France) utilising specific classifications of households, based on more than energy expenditure; and both Boemi and Papadopoulos (2019) and Ntaintasis et al. (2019) emphasise the importance of recognising the regional variations in the drivers of approaches to tackling energy poverty in Greece. The measure proposed in this research may be of particular relevance to the Southern European context, and the application of this approach may be insightful when considering the impact of austerity economics within Europe (Stuckler et al., 2017) and specifically upon the region. With many studies noting the multiple dimensions of energy poverty and the importance of geographical targeting, adapting the methodology applied in this paper, utilising locally available data, such as the similar study by Besagni and Borgaro (2019), may be beneficial for targeting policy to eradicate energy poverty in many different national and international contexts.

Conclusion and Policy Implications

This study progresses the initial work of Boardman (1991) and subsequent work by Palmer et al. (2008) to understand the difference between energy poverty and deprivation. Despite the now accepted view that energy poverty and deprivation are distinct issues, the over-simplified practice of using proxy-indicators to identify fuel poor homes, often by identifying homes for interventions based on their household income, has resulted in less than 25% of energy poverty reduction expenditure being spent on fuel poor homes (Boardman, 2010) utilising current targeting methodologies. In responding to this criticism, this study has differentiated between poverty and deprivation, to consider (reflecting the work of Townsend (1987)) the multidimensional influences of deprivation rather than the singularly monetary focus of UK poverty definitions within its comparison. In doing so it demonstrates that the two concepts are distinct as found in previous work, but furthermore there is significant heterogeneity in the two concepts relationship across England. This has implication for the development of successful policy interventions in support of the eradication of energy poverty in England.

In developing the energy poverty - deprivation classification matrix, this work establishes a picture of the energy poverty - deprivation relationship across England which shows that the current approaches to tackling energy poverty are unlikely to respond to the criticisms highlighted above. The focus on supplier side Energy Efficiency Commitments (EEC's) and winter warmth payments which are both capital focussed interventions, predominantly targeted at low income households, is unlikely to succeed in reducing energy poverty figures as these interventions will not benefit many households that are not captured through the current measure of energy poverty. The findings of this paper resonate with the similar work of Robinson et al. (2018) that examines the micro level geographic variation of energy poverty in England, validates the views of Boardman (2010) concerning the current approaches to tackling energy poverty and reflects the inherent structural complexities with EEC's highlighted by Powells (2009) that have to date suffered from unintended policy overflows with unplanned or unexpected consequences. There is a need to move to localised design and delivery of energy poverty interventions.

The classification matrix proposed in this paper is a powerful yet simple tool that offers decision makers and support providers with a novel ability to understand the relative importance of energy poverty or general deprivation issues for different geographic regions of interest. It also highlights the presence of significant geographic nuances in the existence of energy poverty which must be understood in order to begin to craft an approach to tackling the issue that can meet the needs of all involved stakeholders. Finally, this research highlights a limitation in the current conception of multiple deprivation in the UK. The IMD only acknowledges warmth through the presence (or lack thereof) of radiators in the home. The failure to acknowledge the importance of affordable energy access, despite its multiple associations with other domains of deprivation (González-Eguino, 2015) demonstrates a failing in current conceptions of deprivation in the UK which must be addressed in order to appropriately conceptualise multiple deprivation for accurate measurement and relevant policy responses.

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Table 1

Table 1 Domains and component indicators of the Index of Multiple Deprivation (Mclennan et al., 2011)

IMD Domain	Component Indicators	Domain Weight
Income Deprivation	Adults and children in Income Support families	22.5%
	Adults and children in Income-Based Jobseeker's Allowance families	
	Adults and children in Pension Credit (Guarantee) families	
	Adults and children in Child Tax Credit families (who are not in receipt of Income Support, Income-Based Jobseeker's Allowance or Pension Credit) whose equivalised income (excluding housing benefits) is below 60 per cent of the median before housing costs	
	Asylum seekers in England in receipt of subsistence support, accommodation support, or both	
Employment Deprivation	Claimants of Jobseeker's Allowance (both Contributory and Income-Based) women aged 18-59 and men aged 18-64, averaged over 4 quarters	22.5%
	Claimants of Incapacity Benefit women aged 18-59 and men aged 18-64, averaged over 4 quarters	
	Claimants of Severe Disablement Allowance women aged 18-59 and men aged 18-64, averaged over 4 quarters	
	Claimants of Employment Support Allowance women aged 18-59 and men aged 18-644	
	Participants in New Deal for the 18-24s who are not in receipt of Jobseeker's Allowance, averaged over 4 quarters	
	Participants in New Deal for 25+ who are not in receipt of Jobseeker's Allowance, averaged over 4 quarters	
	Participants in New Deal for Lone Parents (after initial interview) aged over 18, averaged over 4 quarters.	
Health Deprivation and Disability	Years of Potential Life Lost – an age and sex standardised measure of premature death	13.5%
	Comparative Illness and Disability Ratio – an age and sex standardised measure of morbidity and disabilitu	
	Measures of acute morbidity – an age and sex standardised rate of emergency admissions to hospital	
	Proportion of adults under 60 suffering from mood or anxiety disorders – a modelled indicator for the proportion of adults suffering from mood and anxiety disorders.	
Education, Skills and Training Deprivation	Sub-domain: Children/young people	13.5%
	Average points score of pupils taking English, Maths and Science Key Stage 2 exams	
	Average points score of pupils taking English, Maths and Science Key Stage 3 exams	
	Average capped points score of pupils taking Key Stage 4 (GCSE or equivalent) exams	
	Proportion of young people not staying on in school or non-advanced education above age 16	

	Secondary school absence rate – the proportion of authorised and unauthorised absences from secondary school Proportion of those aged under 21 not entering Higher Education. Sub-domain: Skills Proportion of adults aged 25-54 with no or low qualifications	
Barriers to Housing and Services	Sub-domain: Wider barriers Household overcrowding – the proportion of households within an LSOA which are judged to have insufficient space to meet the household's needs Homelessness – the rate of acceptances for housing assistance under the homelessness provisions of the 1996 Housing Act (at local authority district level) Difficulty of access to owner-occupation (local authority district level) – proportion of households aged under 35 whose income means they are unable to afford to enter owner occupation. Sub-domain: Geographical barriers Road distance to a GP surgery Road distance to a supermarket or convenience store Road distance to a primary school Road distance to a Post Office.	9.3%
Crime	Violence – number of reported violent crimes (19 reported crime types) per 1000 at risk population Burglary – number of reported burglaries (4 reported crime types) per 1000 at risk population Theft – number of reported thefts (5 reported crime types) per 1000 at risk population Criminal damage – number of reported crimes (11 reported crime types) per 1000 at risk population.	9.3%
Living Environment Deprivation Domain	Sub-domain: The indoors living environment Social and private housing in poor condition Houses without central heating. Sub-domain: The outdoors living environment Air quality Road traffic accidents.	9.3%

Table 2

Table 2 Nonparametric correlations between energy poverty and the Index of Multiple Deprivation at the aggregated National level

			IMD overall (aggregated) score	% LSOA considered EP	Number households EP
IMD overall (aggregated) score	Correlation Coefficient		**1.000**	.410**	.380**
	95% Confidence Interval	Lower	**1.000**	.400	.370
		Upper	**1.000**	.420	.390
	99% Confidence Interval	Lower	**1.000**	.397	.367
		Upper	**1.000**	.423	.394
% LSOA considered FP	Correlation Coefficient		.410**	**1.000**	.895**
	95% Confidence Interval	Lower	.400	**1.000**	.892
		Upper	.420	**1.000**	.898
	99% Confidence Interval	Lower	.397	**1.000**	.891
		Upper	.423	**1.000**	.899
Number households FP	Correlation Coefficient		.380**	.895**	**1.000**
	95% Confidence Interval	Lower	.370	.892	**1.000**
		Upper	.390	.898	**1.000**
	99% Confidence Interval	Lower	.367	.891	**1.000**
		Upper	.394	.899	**1.000**

**. Correlation is significant at the 0.01 level (2-tailed).

b. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Table 3

Table 3 Nonparametric correlations between energy poverty and IMD aggregate score split by Government Operating Region

Government Operating Region Name		Number households FP	% LSOA considered FP
East Midlands	IMD aggregate score	.556**	.696**
	% LSOA considered FP	.815**	1.000
	Number households FP	1.000	.815**
East of England	IMD aggregate score	.372**	.376**
	% LSOA considered FP	.833**	1.000
	Number households FP	1.000	.833**
London	IMD aggregate score	.094**	-.024
	% LSOA considered FP	.688**	1.000
	Number households FP	1.000	.688**
North East	IMD aggregate score	.562**	.695**
	% LSOA considered FP	.817**	1.000
	Number households FP	1.000	.817**
North West	IMD aggregate score	.499**	.591**
	% LSOA considered FP	.803**	1.000
	Number households FP	1.000	.803**
South East	IMD aggregate score	.400**	.378**
	% LSOA considered FP	.839**	1.000
	Number households FP	1.000	.839**
South West	IMD aggregate score	.378**	.372**
	% LSOA considered FP	.840**	1.000
	Number households FP	1.000	.840**

West Midlands	IMD aggregate score	.453**	.585**
	% LSOA considered FP	.800**	1.000
	Number households FP	1.000	.800**
Yorkshire and The Humber	IMD aggregate score	.367**	.517**
	% LSOA considered FP	.776**	1.000
	Number households FP	1.000	.776**

Table 4

Table 4 IMD and Energy poverty classification matrix. Cell numbers represent individual classification categories based on Percentage Energy poverty and IMD quintile

IMD Score Range	IMD Quintile					
34.18 +	80.01 – 100%	21	22	23	24	25
21.36 - 34.17	60.01 – 80%	16	17	18	19	20
13.8 - 21.35	40.01 – 60%	11	12	13	14	15
8.5 – 13.79	20.01 – 40%	6	7	8	9	10
0 – 8.49	0.00 – 20 %	1	2	3	4	5
	Energy poverty Quintile	00.00-20%	20.01-40%	40.01-60%	60.01-80%	80.01-100%
	% Energy poverty Range	0 - 10.9%	10.91 - 14.10%	14.11 - 17.60%	17.61 - 21.70 %	21.71% +

Figure 1 Map of IMD, EP classification matrix values in England

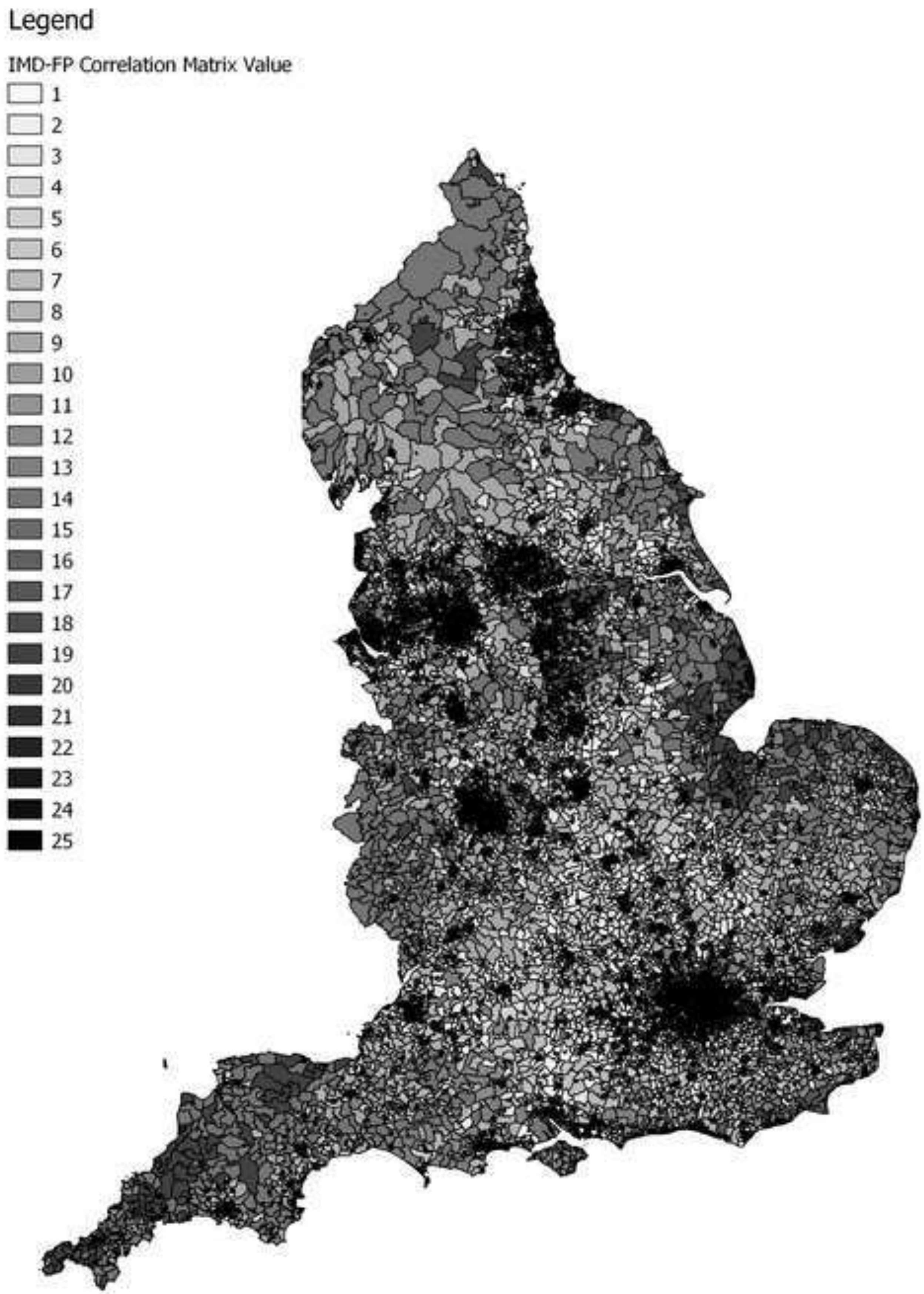

Figure 2 Map of IMD, EP classification matrix values for London

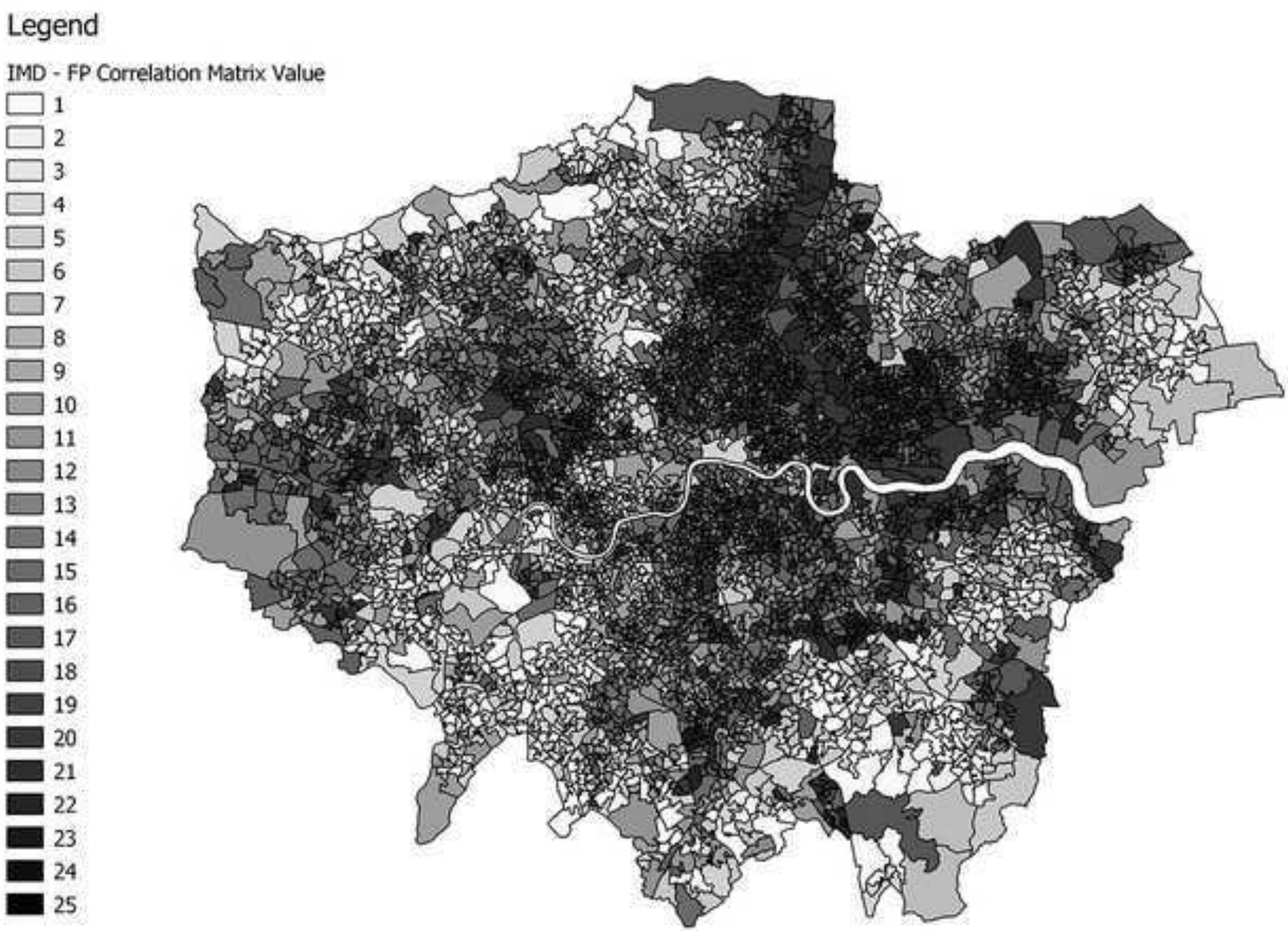

Figure 3 Map of IMD, EP classification matrix values for North C

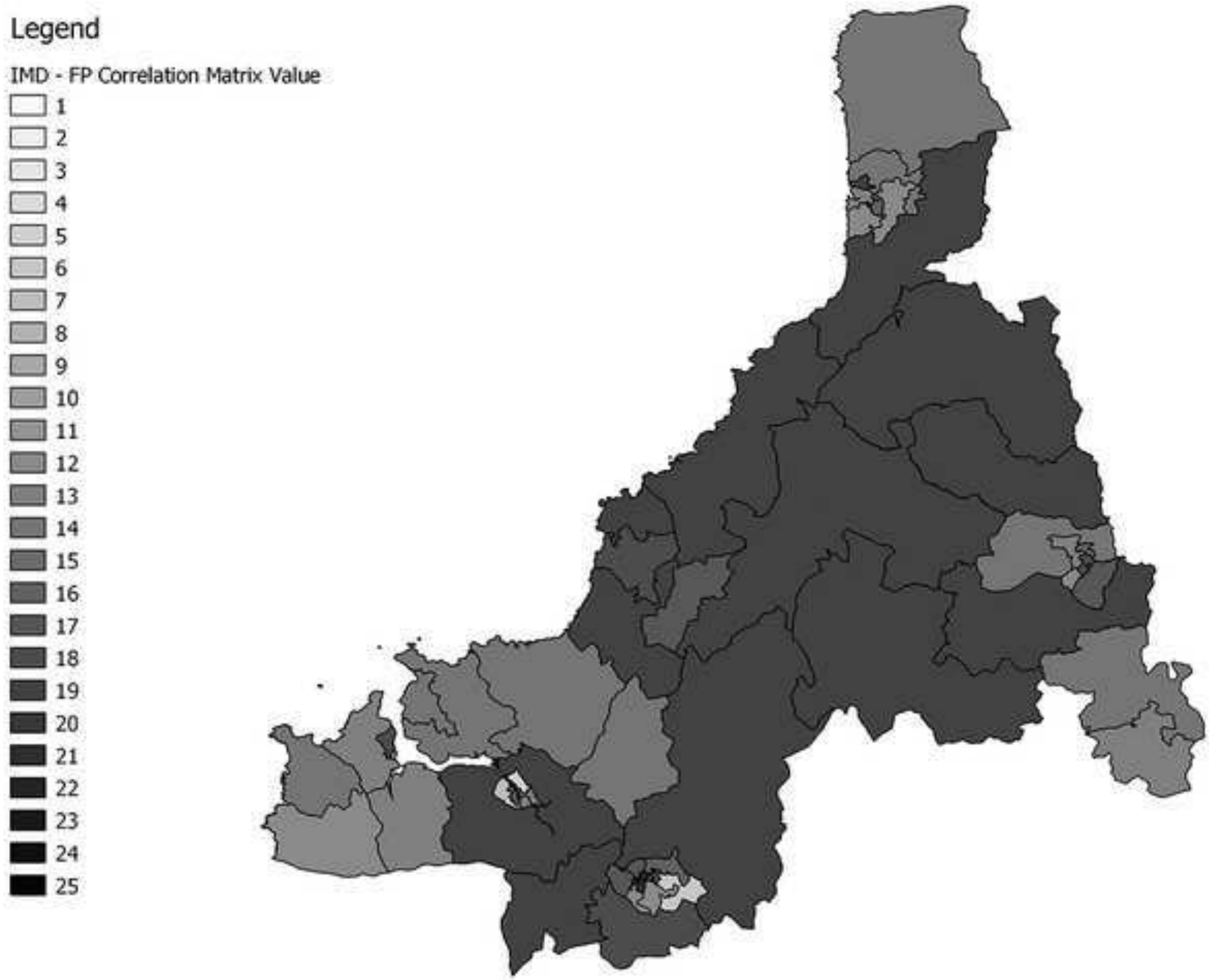

Figure 4 Map of IMD, EP classification matrix values for Sheffie