Identifying change over time in small area socio-economic deprivation

Paul Norman

School of Geography, University of Leeds, Leeds, LS2 9JT, UK

* Correspondence to:

Paul Norman

School of Geography

University of Leeds

Leeds, LS2 9JT

Tel: +44 (0)113 34 38199

Fax: +44 (0)113 34 33308

p.d.norman@leeds.ac.uk

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Identifying change over time in small area socio-demographic deprivation

Abstract

The measurement of area level deprivation is the subject of a wide and ongoing debate regarding the appropriateness of the geographical scale of analysis, the input indicator variables and the method used to combine them into a single figure index. Whilst differences exist, there are strong correlations between schemes.

Many policy-related and academic studies use deprivation scores calculated cross-sectionally to identify areas in need of regeneration and to explain variations in health outcomes. It would be useful then to identify whether small areas have changed their level of deprivation over time and thereby be able to: monitor the effect of industry closure; assess the impact of area-based planning initiatives; or determine whether a change in the level of deprivation leads to a change in health. However, the changing relationship with an outcome cannot be judged if the 'before' and 'after' situations are based on deprivation measures which use different, often time-point specific variables, methods and geographies.

Here, for the whole of the UK, inputs to the Townsend index obtained from the 1991 and 2001 Censuses have been harmonised in terms of variable detail and with the 1991 data converted to the 2001 Census ward geography. Deprivation has been calculated so that the 1991 scores are directly comparable with those for 2001. Change over time can be then identified. Measured in this way, deprivation is generally shown to have eased due to downward trends in levels of lack of access to a car, non-home ownership, household overcrowding but most particularly, to reductions in levels of unemployment. Despite these trends, not all locations became less deprived with gradients of deprivation largely persisting within the UK's constituent countries and in different area types.

For England, Wales and Scotland, the calculation of Townsend scores can readily be backdated to incorporate data from the 1971 and 1981 Censuses to create a 1971-2001 set of comparable deprivation scores. The approach can also be applied to the Carstairs index. Due to differences in data availability prior to 1991, incorporating small areas in Northern Ireland would be challenging.

Key words: Townsend & Carstairs deprivation index; Census; Change over time; Small geographical areas & wards; UK

Identifying change over time in small area socio-economic deprivation

1. Introduction

Many schemes have been devised which aim to reduce a range of socio-demographic information about geographical areas to a measure which summarises the characteristics of areas in a meaningful way. These schemes can be traced back to ideas developed in the 1920s by human ecologists in Chicago (e.g. Park *et al.,* 1925); work which was later developed through community analysis by Shevky and Williams (1949) and social area analysis by Shevky and Bell (1955). Robinson (1998) details various approaches including factor analysis which began to be used by geographers in the 1960s and led to methods that cluster geographically distant places together on the basis of various socio-economic commonalities (Burrows and Rhodes, 1998). This became the basis of geodemographics, the "classification of small areas according to their inhabitants" (Rothman, 1989: 1). Whilst geodemographics is mainly used in business applications, in the UK the Office for National Statistics (ONS) and it's predecessor have produced a series of general purpose classifications in Great Britain, including the Craig-Webber classification (Webber and Craig, 1978), the 1991 and 1999 classifications of local government and health authorities (Wallace and Denham, 1996; Bailey *et al.,* 1999) and more recently, in a collaboration with academia, a classification of Output Areas (the smallest UK census geography) and larger administrative geographies (ONS, 2004; Vickers and Rees, 2006).

Paralleling these schemes and prompted by concerns over increasing social and economic inequalities in the context of public expenditure constraints, Senior (2002: 124) finds a "remarkable, and somewhat bewildering, growth in the use of deprivation measures." Drawing on a wide debate about the concepts and measures of poverty and deprivation (Townsend, 1970; Townsend, 1979), in this context, deprivation can be defined as a state of disadvantage relative to the local community, wider society or the nation to which an individual, family or group belongs (Townsend, 1987). People can be deprived of adequate education, housing of good quality, rewarding employment, sufficient income, good health and opportunities for enjoyment (Dorling, 1996). To identify relatively deprived areas in the UK, various indexes have been devised such as: the Jarman Underprivileged Area index (UPA) (1983); the Townsend index (1987); the Carstairs index (Carstairs and Morris, 1989); Breadline Britain (Gordon, 1995); the Index of Local Conditions (DoE, 1983 and 1994); the Index of Local Deprivation (Noble *et al.,* 2000); and the Index of Multiple Deprivation (IMD, 2004; Noble *et al.,* 2006). The UK indexes have mainly been at the electoral ward scale (a relatively local, small area geography) and are predominantly based on a composite of census-derived variables as indicators of relative conditions between areas although in the recent IMD alternative geographies and input variables are used. Deprivation indexes have also been developed in the US, Canada, New Zealand, France and elsewhere (Bell *et al.,* 2007; Havard, 2008).

These deprivation measures are highly influential for the allocation of public resources (Simpson, 1996; Brennan *et al.,* 1999; Chatterton and Bradley, 2000; Blackman, 2006) and are regularly used as explanatory variables in models of various outcomes including health in both the UK (Law and Morris, 1998; Senior *et al.,* 2000; Boyle *et al.,* 2002; Dibben *et al.,* 2006; Diez Roux, 2005; Norman *et al.,* 2005;) and in other countries (Lorant *et al.,* 2001; Tello *et al.,* 2005; Karpati *et al.,* 2006; Pearce *et al.,* 2006). Choice of which index to use is subject to debate (Mackenzie *et al.,* 1998; Davey Smith *et al.,* 2001) but a high degree of correlation between schemes is found (Morris and Carstairs, 1991; Hoare, 2003).

Despite repeated calls from academics and others, unlike many other countries the UK Census has not included an income question (Marsh, 1993; Dorling, 1999; Boyle and Dorling, 2004). Thus, one of the regular criticisms of the construction of deprivation indexes is the use of 'proxy' indicators. Further criticisms include subjectivity in the choice of input variables, which geographical scale to use, over-complex (and thereby opaque to the general public) or inappropriate methodologies, different relevance in urban and rural locations and the arbitrary choice of threshold scores for fund allocation. Senior (1991), Bradford *et al.* (1995), Simpson (1996) and especially Senior (2002) provide very useful and detailed reviews of indexes and their construction; various aspects of which are discussed further below. Given that these deprivation indexes are area measures, note that the 'ecological fallacy' warns against assuming that all persons and households in deprived areas are necessarily deprived (Fieldhouse and Tye, 1996; Sloggett and Joshi, 1998) and that the results obtained and disseminated at one geographical scale will not necessarily hold at another; the 'modifiable areal unit problem' (MAUP) (Openshaw and Taylor, 1981). Despite much input from highly regarded researchers, Congdon (2004: 742) believes that "much work remains to be done in both index construction and technique."

A deprivation score, along with all other data derived from the decennial census, offers an insight into local socio-demographic conditions pertaining at the time of the census. However, a deprivation score calculated for an electoral ward for one census is not directly comparable with a score calculated for another census. As with other work which constructs a time-series of socio-demographic data (Martin *et al.,* 2002; Norman, 2006), this is for several reasons. The questions on the census forms as well as the categories by which information on people or households is disseminated may vary through time (Marsh, 1993) and as society changes, the meaning or relative importance of particular variables may change. The geography of local government is under periodic review (Norman *et al.,* 2007) so the wards for which deprivation scores are calculated may vary in their population size due to boundary revisions and/or may cease to exist. Even if both the attribute information used as index input variables and the geography remain constant between censuses, the score recorded at one census is relative to the national situation in that year. Thus, a ward may have the same score at successive censuses but may have become relatively more or less deprived over time in comparison with other wards.

For small geographical locations, it may be very useful to identify whether areas have changed their level of deprivation over time. This can relate to:

- Monitoring the level of deprivation itself in relation to the impact of industry closure, the success of area-based regeneration initiatives (Smith *et al.,* 2001) or the extent to which deprivation concentrates over time and space, thereby leading to further negative outcomes (Sloggett and Joshi, 1998);
- Understanding demographic change and the impact of net migration since different types of migrants may be attracted to different types of places (Lee, 1966; Walters, 2000); or
- Determining whether a change in the level of deprivation leads to a change in health (Boyle *et al.,* 2004; Curtis *et al.,* 2002; Norman *et al.,* 2008a).

The Index of Multiple Deprivation (Noble *et al.,* 2006) is the government's current preferred indicator of deprivation in England. Similar, but not directly comparable, IMDs have been developed for the other countries in the UK. The inconsistencies between the IMDs for the UK's constituent countries and a lack of equivalent data over time indicates that constructing a UK-wide IMD time-series is not feasible (Dorling *et al.,* 2007; Whynes, 2008). Morelli and Seaman (2007) acknowledge these difficulties mean that deprivation scores at different time points cannot usually be compared and that as a result, assessments of trends are difficult.

This paper reports on the development of Townsend deprivation scores (Townsend, 1987) for wards across the UK (England, Wales, Scotland and Northern Ireland) for the census years 1991 and 2001. This is not to claim that the Townsend index is necessarily the 'right' measure of deprivation, but the index is well-known and has been widely-adopted in academic studies and public health reports over many years (Higgs *et al.,* 1998). The scheme has the advantage of being reasonably simple (as recommended by Dorling, 1996) and is based only on census data (some indexes use additional information which may not be available over time) so has the potential to be consistently constructed at successive time points. Various aspects are discussed below. First, the input variables are discussed in terms of their availability, compatibility and applicability over time. Next, since boundaries are liable to change from one census to the next, the adjustment of the index input variables to the same geography is described using the City of Plymouth as an example. Then, the calculation of area deprivation in relation to time points is considered. Finally, the changing geography of deprivation in the UK between 1991 and 2001 is appraised including a case study of Plymouth. Since the paper aims to give a balance between explanation of method and presentation of results, the case study is intended to demonstrate the utility of a deprivation measure which is comparable over time rather than being an in-depth study of the location. Note that in the UK, the national statistics offices responsible for the collection and dissemination of census data are: the Office for National Statistics (ONS) for England and Wales, the General Register Office for Scotland (GROS) and the Northern Ireland Statistics Research Agency (NISRA).

2. Constructing a time-series of deprivation scores

The Townsend index is a composite score comprising four census ward-level input variables: percentages of unemployment, no access to a car, non-home ownership, and of household overcrowding (more than 1 person per room). The unemployment and overcrowding variables are log transformed to produce less skewed distributions and all four variables are standardised in relation to national levels using z scores. Full explanations of transformations and standardisations are given by Gilthorpe (1995), Martin *et al.* (1994), Simpson (1996) and Senior (2002). To calculate the Townsend deprivation scores the z scores of all four variables are summed, with each variable given an equal weight. Other indexes such as the Jarman UPA apply a weight to each variable according to perceived importance but in the Townsend Index each variable has equal importance. Negative Townsend scores relate to relatively less deprived wards and positive scores to relatively more deprived wards. To calculate comparable scores for all wards in England, Wales, Scotland and Northern Ireland for both 1991 and 2001 (the last two UK Censuses) will require the raw data to be obtained and harmonised in terms of both variable detail and geography in the face of inter-censal changes. These and other aspects are detailed below.

2.1 Input variables

The Townsend input variable definitions used here relate to the 1991 index (MIMAS, 1999). The definitions of the variables and 1991 and 2001 Census table and cell references are given in Table 1. Whilst there are small difference in the disseminated categorisations, there is little difficulty in devising variables from each census which are closely equivalent. There is most change in the dissemination of information on tenure. The need in this application is to differentiate those households which are owner occupied, and those which are not. This is achieved (for England) as follows:

- In 1991, from table LBS20, home ownership is taken to comprise households which are categorised as ‘owned outright’ or ‘buying’. Non-home ownership comprises households rented privately, either ‘furnished’ or ‘unfurnished’, ‘rented with a job or business’, ‘rented from a housing association’, ‘rented from a local authority or new town’ or ‘non-permanent accommodation’.
- In 2001, from table KS018, home ownership is taken to comprise households categorised as ‘owns outright’, ‘owns with a mortgage or loan’ or ‘shared ownership’. Non-home ownership comprises the categories rented from ‘council (local authority)’, ‘housing association / registered social landlord’, ‘private landlord or letting agency’ or ‘other’.

The data on unemployment, overcrowding, non-car access and non-home ownership have been downloaded via the Census Dissemination Unit’s Casweb interface (http://casweb.mimas.ac.uk/) for both census years and manipulated into appropriate numerators and denominators.

<Table 1 about here>

Given the debate which exists on the merits of deprivation indicator variables included in different schemes (Bradford *et al.,* 1995; Senior, 2002; Eroğlu, 2007), in this context, the applicability of the input variables over time should be considered. Essentially there is no difference in meaning over the ten year

period of what is meant by unemployment, no access to a car, non-ownership of home and household overcrowding so different levels of these variables should provide an indication of change in aggregate population characteristics. Less justifiable over time might be variables used as deprivation indicators in other schemes such as: lacking household amenities or central heating; born in the New Commonwealth; and socio-economic group.

It is worth noting here that the census variable on unemployment is based on the respondent's economic activity during the week before the census. The census count of unemployed tends to be higher than official benefit claimant counts because some persons who would regard themselves as unemployed are not entitled to claim benefits. Thus the census counts of unemployed exceed the official count of the unemployed. Various authors discuss the 'hidden unemployment' missed in the official counts (see Beatty and Fothergill, 2002; Webster, 2002) with the census unemployment counts used as an indicator of the size of the shortfall in the claimant counts as a more realistic count of the unemployed (Green, 1999). The census unemployment variable is a ubiquitous indicator of deprivation for individuals (Fieldhouse and Tye, 1996) and for areas (Haynes *et al.,* 1996).

2.2 Geography

In the UK, the geography used for the census is largely aligned with administrative geography so that data are published for the hierarchy of nation, regions and local government districts, often referred to as local authorities (LAs). 'Small areas' are generally taken in the UK to be sub-local government geographies (Rees *et al.,* 2004). In terms of administrative areas, each LA comprises a set of electoral wards and these are used for the dissemination of census data along with even smaller census-specific geographies (Norman *et al.,* 2008b). In this work, the small area units of analysis being used are the electoral wards utilised for the dissemination of the UK's 2001 Census; the Census Area Statistics (CAS) wards. In Scotland the CAS 'sectors' are the equivalent census geography and these will be referred to here as wards. Wards are used because the census data needed for the Townsend index are readily available for this level of geography in both 1991 and 2001 and because this is the commonest small area geography used for the calculation of deprivation scores since the 1970s. It is acknowledged though that wards may not delineate recognisable neighbourhoods (Burrows and Bradshaw, 2001) and that areas of disadvantage might ideally be identified in ways which are not constrained by administrative or otherwise arbitrarily drawn boundaries (Dorling, 1996; Chatterton and Bradley, 2000). To this end, various authors demonstrate the utility of devising customised geographies of deprivation (Haining *et al.,* 1994; Cockings and Martin, 2005; Haynes *et al.,* 2007; Bell *et al.,* 2007). These sophisticated approaches provide very valuable results but are time-point specific and are unlikely to produce comparable results over time as the geography of deprivation changes. Without taking a consistent geographical approach with time-series data it cannot be known whether socio-demographic changes indicated by variables disseminated for areas are real or due to a change in the boundary system (Norman *et al.,* 2003). Dorling *et al*. (2007) ably present a time-series of poverty and wealth measures, 'Breadline Britain', but whilst these are for a

consistently defined sub-district geography, in comparison to wards, the units are coarse and no not cover Northern Ireland.

Although wards are a regularly-used small area geography in census analysis, they are a sub-district geography devised for the election of local councillors. Within LAs, electoral ward boundaries are regularly adjusted in response to population change to ensure each local authority has similar elector to councillor ratios (Norman *et al.,* 2007). Over time there is substantial revision to the ward geography (Norman *et al.,* 2008a & b) such that relatively few wards remained the same boundary definition between 1991 and 2001. Thus, to investigate change, there is a need to ensure that the 1991 and 2001 Census ward data are aligned to the same geography.

Various techniques have been developed to convert data between geographies, including areal interpolation (Gregory, 2002; Schroeder, 2007). To convert socio-demographic data between different geographical systems and thereby establish time-series data on a consistent geographical basis in the face of ward boundary changes over time, Simpson (2002) and Norman *et al.* (2003) use postcode locations to link the 'source' geography for which the data pre-exist, to the 'target' geography, the zonal system for which the data are needed. Within a 'geographic conversion table' (GCT), as a proxy for population distribution, address count-weighted postcode distributions are used to calculate intersection weights between the source (1991 ward) and target (2001 ward) geographies. This process is described and assessed below using Plymouth as an example.

In common with many other locations, the City of Plymouth in the South-West of England experienced widespread changes to its constituent wards between 1991 and 2001. Figure 1a shows the 1991 wards in Plymouth and Figure 1b illustrates the wards which were used for the dissemination of the 2001 Census. This reveals a large number of boundary changes including differences in the way that water courses were digitised, due to changes in legal definitions.

< Figure 1 about here >

The first step in the construction of a GCT is to establish a link between the source and target geographies. This is achieved using the National Statistics Postcode Directory (NSPD) with a subset of postcodes extracted which are valid in 1991 (the year of the data needing converting) and which are assumed to be residential postcodes (excluding Royal Mail defined 'large users' which are businesses). The national grid reference of the postcode centroid and the count of addresses at each postcode are retained. The postcodes are linked to the 1991 and 2001 wards using the GIS point-in-polygon technique (as the mix of clerical and GIS procedures used to assign postcodes to areas in the NSPD can give biased results). A check at this stage then is whether boundary changes are identified.

Figures 2a and 2b show example wards in the south-west of Plymouth where boundary changes occurred. The 1991 wards illustrated here, Keyham, St Peter, Stoke and Sutton cover a very similar overall area to the 2001 wards Devonport, St Peter & Waterfront, Stoke and Sutton & Mount Gould but the individual wards are very different. Figures 2c and 2d focus on the boundary between three of the 1991 wards with the postcodes associated with each represented by circles in Keyham ward, stars in Stoke and crosses in St Peter. Due to the boundary changes which occurred by 2001, some of the postcodes which were associated with St Peter now fall within Devonport ward, some fall in the extended Stoke ward and some in St Peter & the Waterfront. Just one of the postcodes which was in Keyham ward is now associated with Stoke due to change in the boundary at that place. In this way, associating postcode with wards at different time points identifies that boundary changes have occurred.

< Figure 2 about here >

The next step in the GCT construction is to calculate the conversion weight which will be used to allocate the data from the source to the target geography. The areal extent of the source-target overlap is inappropriate because people are not evenly distributed across space. Since postcode distribution emulates population distribution (Norman *et al.,* 2003), counting the postcodes which fall in the intersection of the 1991 and 2001 boundaries gives a good indication of the proportion of the 1991 data which should be allocated to the overlap with the 2001 ward. However, since the indicator used to derive the conversion weight should correlate as closely as possible to the data to be adjusted between boundary systems (Simpson, 2002) and because more people live at each postcode in urban areas compared with more rural areas (Norman *et al.,* 2003) the count of postcodes can be refined using the number of addresses at each. For the 1991 wards in England and Wales, there is a strong correlation ($r = 0.74$) between the count of postcodes and population but a stronger correlation ($r = 0.83$) between address counts per ward and the population. Figures 2e and 2f illustrate the varying density of address counts at residential postcodes within the example wards in Plymouth.

The conversion weights between geographies are calculated as the sum of the addresses in the intersection between the source and target units divided by the total number of addresses in the whole of each source unit. Table 2 shows how the conversion weights are derived for the 1991 ward, St Peter. This ward overlaps with three 2001 wards. In 1991, there was a total of 6,091 addresses in St Peter ward. Of these, 1,764 addresses have been linked with the 2001 ward Devonport, 4,245 with St Peter & the Waterfront and just 82 addresses with Stoke ward (the small number of crosses identified in figure 2d). The conversion weights are shown in Table 2. These weights sum to one and thereby indicate that all the data existing in the source geography will get allocated to a target unit. This can be regarded as a disaggregation phase of the geographical data conversion with St Peter's 1991 population of 11,153 accordingly apportioned 3,229.99 (= 11,153 * 0.2896) to Devonport, 7,772.86 (= 11,153 * 0.6969) to 150.15 (= 11,153 * 0.0135) to Stoke.

< Table 2 about here >

The data need to be reaggregated into the target geography. Stoke ward in 2001 comprises all of the 1991 definition (so has a conversion weight of 1.00) and has increased in areal extent to overlap with small portions of the 1991 wards Drake, Keyham and St Peters with the conversion weights given in Table 2b. The estimated 1991 population of Stoke ward by its 2001 boundary definition is calculated as 13,066.48. This comprises part of Drake (population 11,703 * 0.0566 = 662.94), plus part of Keyham (population 11,615 * 0.0126 = 146.40), plus part of St Peter (population 11,153 * 0.0135 = 150.15) plus all of Stoke (population 12,701 * 1.00 = 12,701).

As detailed above then, any socio-demographic data disseminated for the 1991 Census ward geography can be converted to be consistent with the 2001 ward boundary definitions. Here this process has been carried out for all wards in England, Wales and Northern Ireland and for the postal sectors in Scotland. The robustness of the conversions is reliant on the linkage of the postcodes to source and target geographies and the ability of this approach to correctly identify that a boundary changes has occurred. Occasionally a 'false positive' indication of a boundary change can arise, invariably when GIS digitising standards vary so that polygon boundaries do not align when they should. During the construction of the geographic conversion tables, the locations with very small weights were checked to ensure the boundary change was real, not due to incorrect linkage of invariably just one postcode. This is not to say, as illustrated above in Figure 2d, that a conversion based on one postcode will be incorrect. The quality of the conversions is also reliant on the strength of relationship between the variable used to calculate the conversion weight and the data needing to be converted. The distribution of address counts has a very strong relationship with population counts and other socio-demographic and household data as available in the census. Whilst the conversions cannot be perfect (and may not be truly assessed without having original microdata assigned independently to each geography to test against) the method is considered reliable enough that a similar approach is now adopted by the ONS Small Area Population Estimates team to provide mid-year estimates for non-standard areas (Bates, 2008).

As Norman (2006) notes, if socio-demographic data are to be converted from one geography to another, it is the raw counts which must be converted not rates, percentages or other derived data such as deprivation index scores. To explain this, Table 3 illustrates a hypothetical geography. If the unemployment rate for ward 'A' in 1991 was 20% and in contiguous ward 'B' was 15% and their shared boundary moved by 2001 such that a proportion (0.25) of ward A was transferred to B. 5% unemployment (i.e. 20% x 0.25) (Table 3a) cannot be subtracted from A and then added to B. The procedure to adopt is to convert the raw data and then recalculate the rates. Thus, in Table 3b, 25% of the numerator and denominator are separately transferred from ward A to ward B, which does not, in percentage terms result in any change in the unemployment rate in A. The assumption in this approach is that employed and unemployed persons are similarly distributed at sub-ward level.

< Table 3 about here>

The numerators and denominators for the input variables needed for the 1991 Townsend index have been converted to the 2001 CAS ward Census geography according to the methods devised by Simpson (2002) and Norman *et al.* (2003) and detailed above. Across England, Wales, Scotland and Northern Ireland there are 10,442 CAS wards in 2001 but since the City of London and the Isles of Scilly have very small populations, the wards in these local government districts have been combined to provide district level data. In this work then there are 10,431 zones in 1991 and 2001 for which to calculate Townsend scores.

Note that in both the 1991 and 2001 UK Censuses, data are available for sub-ward geographies. In 1991 these were known as Enumeration Districts in England, Wales and Northern Ireland and Output Areas in Scotland. In 2001, across the UK all of these most local level census geographies were known as Output Areas. Whilst it is possible to calculate Townsend scores for these very small areas on a cross-sectional basis, two aspects indicate that using the 2001 Output Area geography to compare areas over time may be inadvisable. The first aspect relates to variable information. Due to the need to preserve respondent confidentiality, where there is socio-demographic census data available for a very detailed geography, methods of data blurring and suppression are applied to small cell counts which may otherwise disclose an individual's attributes. Not only are these methods very different in 1991 and 2001 (Rees e*t al.,* 2005) but the methods are applied differently across the UK's countries in 2001 (Stillwell and Duke-Williams, 2006). Differences in counts of indicators between time points may be due to the confidentiality measures rather than being real differences in variables. The disclosure control methods will have less impact at ward level. The second issue involved in creating comparable, very small area deprivation scores is the conversion between the 1991 and 2001 geographies, which were very different. Whilst this has been operationalised (Norman *et al.,* 2008b), the advice these authors give is that 1991 Enumeration District data converted to the 2001 Output Areas should then be aggregated to a higher geography because the conversions may not be accurate enough for reliable, very small area analyses.

2.3 Calculating Townsend scores comparable in 1991 and 2001

Conventionally, Townsend scores (and other area measures) are time-point specific. Observations for wards for each input variable are expressed relative to that variable's national rate (using z scores), e.g. a ward's unemployment rate is relative to UK unemployment rate. This work aims to identify change between time-points. To achieve this, numerators and denominators of the four input variables for the 10,431 wards in both 1991 and 2001 were stacked in one file. Thus, when calculating deprivation, for each ward, rates in both 1991 and 2001 of each variable are expressed relative to the UK 1991-2001 average of that variable. The resulting Townsend scores are then comparable so that if an area changed from a (relatively deprived) score of +6.0 in 1991 to +4.0 in 2001 then, according to the composite of the input variables, the area became less deprived over time by 2.0 Townsend scores. Note that in the Townsend index, higher positive scores indicate greater levels of area deprivation whilst the more negative scores indicate lower levels of deprivation.

Using lack of access to a car, Table 4 shows example calculations for a hypothetical ward which had 26% of households with no access to a car in 1991. In 2001, this figure had reduced to 24%. The z-scores are calculated as the observation minus the national mean, divided by the national standard deviation (SD). If the z-scores are calculated in the conventional way, relative to the 1991 national level of no access to a car, this ward has a z-score of –0.16. The z-score is negative because the ward's figure of 26% is lower (in this application, 'better') than the national mean of 28.39% (SD 14.89). In 2001, the national mean had reduced to 22.97% whilst the ward figure was 24% (SD 13.65). The z-score is now +0.08 since the figure for the ward is now higher ('worse') relative to the national average. Lack of access to a car has improved, but according to this indicator, deprivation has illogically become worse.

< Table 4 about here >

However, the level of car ownership at national level for 1991 and 2001 combined can be used as the comparator. Thus, the ward's lack of access to a car of 26% and 24% in 1991 and 2001 respectively are related to a national level of 25.69 (SD 14.53). This results in z-scores of +0.02 in 1991 and –0.12 in 2001 as the relative position of the ward moves from above, to below the national average. Any z-score which reduces between the time points indicates that deprivation was easing (and *vice versa*). For completeness, the national mean and standard deviation of each indicator variable are listed in Table 5. Note that in the calculation of the Townsend scores for the unemployment and overcrowding variables the log is used, not these percentages. Note also that the means and standard deviations calculated for the years 1991 and 2001 separately are based on 10,431 zones in each year. The means and standard deviations calculated for 1991 and 2001 combined are based on 20,862 zones.

< Table 5 about here >

Many studies stratify results by deprivation quintiles. Quintiles may be equal numbers of areas in each fifth of the total number of areas or equal numbers of population in each fifth of the total population. These are referred to here as ward quintiles and population weighted quintiles, the latter more often used recently. Expressing results by differently defined quintiles can produce different results, although perhaps only subtly. The Townsend scores have been divided into quintiles across the 1991-2001 distribution of both wards (c. 4,170 wards in each equal number of areas quintile) and population (c. 23 million people in each population weighted quintile). Here, the population weighted quintiles will be used because quintiles with equal numbers of areas tend to over-focus population in the more deprived wards. Deprivation then tends to be somewhat exaggerated in urban areas in comparison with rural areas (Martin *et al.,* 2000). The population weighted quintiles have 20% of the population in each. Using equal numbers of wards the proportion of people rises with increasing deprivation with 15% of the 1991/2001 population in quintile 1 (the least deprived wards), 17% in quintile 2, 18% in quintile 3, 22% in quintile 4 and 28% in quintile 5 (the most deprived wards).

In the section which follows, the national distributions of deprivation and indicator variables in both 1991 and 2001 are reported. This is followed by a case study of changes in ward level deprivation in the City of Plymouth in the South West of England.

3. Deprivation in 1991 and 2001: UK coverage

In 1991, the average Townsend score across the UK was 0.36 which reduced by 2.23 scores to –1.87 in 2001. Since smaller Townsend scores mean lower levels of deprivation, measured in this way, deprivation eased overall between the 1991 and 2001 Censuses. Figure 3 shows differences in deprivation across the UK's constituent countries. In 1991, England was on average the least deprived country with Wales, Scotland and Northern Ireland progressively more deprived. By 2001, all countries had shown a reduction in the average level of deprivation with the gradient similar, except that Northern Ireland experienced the largest improvements (over 3.9 Townsend scores) and in 2001 was less deprived than Scotland. The 'error bars' of the standard deviations show a substantial amount of subnational variation within each country.

< Figure 3 about here >

Figure 4 shows clusters of areas experiencing different levels of change in deprivation between 1991 and 2001. Figure 4a illustrates those locations which improved more than the national average of a reduction of 2.39 Townsend scores. These clusters are located largely in the most urban areas, including the Central Belt in Scotland, Belfast in Northern Ireland, South Wales and in England, the North-East, North West, South Yorkshire and West Midland. Whilst the centre of London includes clusters of above national average improvement, Figure 4b reveals that London has more telling clusters whereby deprivation has not improved as much as the national average. Elsewhere, in the more urban areas, the clusters of lack of improvement are largely surpassed by clusters of greater than average improvement. A similar picture exists in less urban areas. Overall there do not appear to be any subnational areas being left behind as other places improve.

< Figure 4 about here >

Figure 5 shows the average deprivation scores across the population weighted quintiles. In both 1991 and 2001, there is the expected gradient from quintile 1 (least deprived) to quintile 5 (most deprived) with no overlap of standard deviations between the quintiles. The least and most deprived quintiles, on average, became less deprived by 0.62 Townsend scores but the middle deprived areas only improved marginally. The gradient of deprivation exists in all of the UK's constituent countries (Figure 6) and the improvements in both the least and most deprived areas are evident in all four countries with the largest improvements in quintile 5 in Scotland. Overall across the UK the disparities between the least and most deprived wards persist between 1991 and 2001, however.

< Figures 5 & 6 about here >

To add detail to the changes occurring in each country, Table 6 has the percentages of wards in a transition matrix of 1991 and 2001 quintiles. The percentages are expressed relative to the total number of

wards in each country. The leading diagonal of the matrix represents wards which stayed in the same quintile. Above the diagonal are those wards which became more deprived and below the diagonal the wards which became less deprived. The row and column marginals are the percentages of wards in each quintile in 1991 and 2001 respectively. Consistent with the results reported above, the majority of wards were in a less deprived quintile in 2001 than in 1991. In Northern Ireland, over 85% of the wards moved into a less deprived quintile with no ward moving into a more deprived quintile. England had the least improvement, but still over 72% of wards were in a less deprived quintile in 2001. In addition to the largest proportion of its wards being in the least deprived quintiles in 2001, England has the largest persistence of advantage with 12% of wards in quintile 1 in both 1991 and 2001. Despite the improvements noted above (Figure 6), Scotland has the largest proportion of its constituent small areas remaining in the most deprived quintile 5 at both censuses.

< Table 6 about here >

Deprivation has previously been shown to vary across area types (Bradford *et al.,* 1995; Martin *et al.,* 2000; Sloggett and Joshi, 1998; Congdon, 1994) so here, the average Townsend scores have been calculated for a slightly simplified version of the National Statistics Area Classification of Local Authorities 'Supergroups' (ONS, 2004; Vickers and Rees, 2006). Deprivation levels for five Supergroups are presented in Figure 7. This reveals a gradient of deprivation across these area types with the lowest levels of deprivation in local authorities classified as Prospering UK. Levels of deprivation progressively increase for wards within Coastal & Countryside (including Northern Ireland's equivalent), Mining & Manufacturing and Cities & Services. On average, London (combining Suburbs, Centre and Cosmopolitan) has the highest levels of deprivation. The standard deviations indicated by error bars in Figure 4 indicate substantial variation within each area type though. Deprivation improved between 1991 and 2001, but most in the Mining & Manufacturing areas (by 2.66 Townsend scores) and least in London (by 1.41 Townsend scores).

< Figure 7 about here >

Figure 8 shows the average deprivation in each quintile within each area type. This demonstrates that there are a range of differently deprived areas within each Supergroup area type. Despite the label, the LAs classified as Prospering UK contain wards which are relatively deprived. Figure 8 reveals that the average deprivation in quintiles 1 to 4 is very similar in each Supergroup but that there are larger differences in deprivation in quintile 5, the most deprived wards. As with the deprivation change within each of the UK's constituent countries, improvements in deprivation between 1991 and 2001 were largest in the least and most deprived wards with the disparities in deprivation persisting. Overall across the UK, 44% of wards improved their level of deprivation by more than the national average improvement of 2.32 Townsend scores. 63% of wards in Mining & Manufacturing areas improved by more than the UK average but only 13% of wards in London experienced this reduction in deprivation.

< Figure 8 about here >

As noted above, Table 5 reports the UK levels of each indicator variable in both 1991 and 2001. Since the changes in the levels of indicators may vary over the decade by Supergroup type and deprivation quintile, Figure 9 illustrates the rates of unemployment, no access to car, non-home ownership and household overcrowding in both 1991 and 2001. In quintiles 1 to 3, there is little variation in unemployment rates across the Supergroups (Figure 9a) but differences start to emerge in quintiles 4 and 5 with rates in quintile 5 in Prospering UK only just higher than in quintile 4 in other areas. In 1991 in Coastal & Countryside, Mining & Manufacturing and Cities & Services, unemployment levels were very high in the most deprived areas (quintile 5). The changes to 2001 are large and relate to the differences in the economy at the two time-points. Despite these changes, the relative differences between area types persist in relation to unemployment.

< Figure 9 about here >

A similar picture is seen for lack of access to a car, although the changes over the 1990s are much less marked and are fairly even across area types (Figure 9b). The lowest rates are in wards in Prospering UK and the highest rates in Cities & Services. In London, there are large differences between quintile 4 and the most deprived wards in quintile 5. Note that low levels of car ownership are assumed to proxy a lack of income (Mackenzie *et al.,* 1998; Wardle *et al.,* 2002) although there may be less necessity for a car in urban than rural areas (Watt *et al.,* 1994) especially in London where there is a widespread public transport system.

Rates of non-home ownership are lowest in non-deprived wards in Mining & Manufacturing, Cities & Services and in London (Figure 9c). Between 1991 and 2001, in Prospering UK and in Cities & Services, rates of non-home ownership change very little, but in Mining & Manufacturing, the differences are more marked. In London, though there are a large differences in rates between quintiles 4 and 5 and over the decade, rates of non-home ownership increase in the middle deprived quintiles 2 to 4. Any of these changes will be highly influenced by local geographies of land ownership and tenure arrangements, differentials in take up of the 'right to buy' opportunities for those previously in publicly rented housing and of the 'buy to let' market which may have been more buoyant in London than elsewhere (Wilson, 1999; Howden-Chapman, 2004).

During the intercensal period, rates of household overcrowding changed rather differently across the Supergroups (Figure 9d). In Prospering UK, there was a small decline in all deprivation quintiles but larger reductions in Mining & Manufacturing and Cities & Services areas and even bigger reductions in Coastal and Countryside, with the size of the reductions increasing with deprivation. A different situation exists in London. Whilst levels of overcrowding reduced in the least deprived areas, in quintiles 2 to 5, overcrowding increased.

4. Deprivation in 1991 and 2001: case study for wards in the City of Plymouth

Here the City of Plymouth is used as a case study area to show how ward level deprivation has changed between 1991 and 2001. The choice of this location is for various reasons. Mackenzie and colleagues (1998) published a very informative paper which compared levels of deprivation Plymouth as measured by different schemes using 1991 Census data. These authors note that deprivation measures have become important tools in examining variations in health and for the planning and delivery of health care and report on the input variables used and on the different organisations which might favour the different schemes. A strong correlation is found between the Townsend index, Jarman index, Index of Local Conditions and Breadline Britain scores but Mackenzie *et al.* (1998) highlight that if wards are ranked by deprivation score then different decisions might have been made on resource allocation if a different scheme were chosen. These authors report that Plymouth had successfully bid for Single Regeneration Budget (SRB) funding in which addressing deprivation was a part. Now discontinued, the Single Regeneration Budget was launched in 1994 as the SRB Challenge Fund. SRB had the holistic aim of improving the quality of life for those living and working in the most disadvantaged areas; and of reducing the gap between disadvantaged and other areas, and between different groups (Nevin *et al.,* 2007; Tilson *et al.,* 1997). The first schemes went live in 1995. Between 1994 and 2000, Plymouth successfully bid in all six rounds of SRB funding. The SRB schemes in Plymouth focused on the areas of greatest deprivation in the city, including the inner city wards of Sutton, St Peter and Keyham; locations specifically named in the funding bids (SWRDA, 2008). Of particular relevance here is that none of these three 1991 wards existed in 2001. Their combined areas are similar to the 2001 wards Devonport, St Peter & Waterfront and Sutton & Mount Gould but, as can be seen in figure 2, the individual wards are very different. Stoke ward nearby, retains the same name but is a different areal extent.

The purpose here is not to provide a critical evaluation of the choice of index (as in Mackenzie *et al.,* 1998) or to assess the success of Plymouth's SRB projects but to use these situations to provide a context. Readers interested in the detail of Plymouth's SRB schemes and their subsequent evaluation should see information made available by the South West of England Regional Development Agency (SWRDA, 2008). Here the comparable 1991 and 2001 Townsend deprivation scores in Plymouth's wards are to be explored.

Thus, using the 2001 ward geography, Figure 10a maps the 1991 distribution of Townsend scores. This shows that the wards in the west and north-west parts of Plymouth are the more deprived and that the east and south-eastern wards are less deprived. Six of Plymouth's twenty wards were classified as quintile 5 in 1991, the most deprived wards in the UK. By 2001, Plymouth as a whole had improved by 2.49 Townsend scores; slightly better the national average improvement of 2.32. Figure 10b shows the 2001 distribution of Townsend scores. Whilst the western wards are still deprived in comparison with the

eastern and south eastern parts of the city the level of deprivation eased, relative to the UK with only one ward, St Peter & the Waterside remaining in quintile 5.

< Figure 10 about here >

Figure 11 graphs Plymouth's wards ranked according to their 1991 level of deprivation with increasing deprivation from left to right. In every ward, the Townsend score was lower in 2001 than in 1991 but with differing levels of improvement. Peverell ward experienced the greatest reduction in the level of deprivation. All the 2001 wards overlapping the 1991 wards which were targeted in regeneration schemes experienced above average improvement. Drake ward had the least improvement, just 0.79 Townsend scores.

< Figure 11 about here >

Figure 12 illustrates each indicator variable for Plymouth's wards in 1991 and 2001, ranked by increasing overall deprivation from left to right. Rates of unemployment reduced substantially in all wards (Figure 12a) including St Peter & the Waterfront where this census-derived unemployment rate fell from 21% to 6%. The changes in levels of the lack of access to car are less dramatic with the rate increasing in 1991 compared with 2001 in three wards, Plympton Erle, Moor View and Drake (Figure 12b). Figure 12c shows a more mixed picture of change in non-home ownership. Nine of the wards had levels of non-home ownership very similar at both censuses with three wards having decreased levels, especially in Peverell where rates fell from 29% to 16% thereby contributing to this ward's advantageous position in 2001 compared with 1991. Six out Plymouth's twenty wards saw increases in non-home ownership. The highest rise was in Drake ward and this will be associated with halls of residence built during the inter-censal period (Robbins built 1994; Radnor built 1999; and Pilgrim built 2000) for students at the University of Plymouth. Changes in wards in which students reside may also relate to differences in the population base definition used for the 1991 and 2001 Censuses which had students recorded respectively at home (presumed their parental domicile address) and term-time address (Norman *et al.,* 2008b). Other wards where non-home ownership increased are in the post-1991 regeneration locations. To ascertain whether these changes are associated with an increased provision of social housing would need local knowledge. Several of the non-deprived wards experienced marginal increases in levels of household overcrowding (figure 12d). Elsewhere, wards generally showed a decrease in overcrowding, especially the most deprived wards, perhaps due to increased housing availability.

< Figure 12 about here >

5. Discussion

The measurement of area level deprivation is the subject of a wide and ongoing debate regarding the appropriateness of indicator variables and the method used to combine them into a single figure index. Part of this debate is the definition of the geography of analysis which is likely to be dominated by the geography of data availability rather than reflecting the distribution of the phenomenon of interest. In the UK, the main data source underpinning the calculation of deprivation indexes has been the decennial

census with the majority of schemes calculated at electoral ward scale. Various issues exist. The census does not include an income question, is only taken every ten years with delays before data are released and is largely based on administrative geographies which are liable to change from one census to the next and the commonly used wards may not represent either neighbourhoods or the geography of deprivation. Moreover, as Dale (1993: 16) notes, "There is an unyielding tension in the collection of census data between change and continuity." The census should be used to collect data of contemporary relevance as society changes, but should provide information which is comparable over time so that change in society can be measured. Many policy-related and academic studies use deprivation scores calculated cross-sectionally to inform planning and regeneration or health outcomes. However, the success of schemes cannot be judged if the 'before' and 'after' situations are potentially based on different combinations of variables, methods and geographies.

Here then, taking the four census variables used as inputs to the Townsend index and believed to be as time-robust as possible, deprivation scores have been calculated in a manner which makes them comparable in 1991 and 2001. Measured in this way, deprivation is generally shown to have eased due to downward trends in levels of lack of access to a car, non-home ownership, household overcrowding but most particularly, to reductions in levels of unemployment (which itself relates to the national economy being in recession in 1991 but in 2001 there was economic growth). Despite these trends, not all locations became less deprived with gradients of deprivation largely persisting within the UK's constituent countries and in different area types.

There may be some drawbacks in the approach used here. In addition to the overall debate on the applicability of different indicator variables and on the various schemes which aim to measure relative deprivation for areas, it may be that different indicators relate in different ways to deprivation at different time-points thus making the scores less comparable over time than assumed here. Whilst the method of data conversion between different geographical boundary systems has been shown to have a good level of accuracy (Simpson, 2002; Norman *et al.,* 2003), the process is not perfect and this could affect the deprivation score calculated in some areas. Despite the efforts of the UK's national statistics offices, the census is not a complete count of the population with under-enumeration tending to be more likely in certain population sub-groups and types of areas (Heady, *et al.* 1994). Following the 1991 Census, it was thought that under-enumeration was particularly high. However, after the 2001 Census was released, with the benefit of hindsight, the levels of upward adjustments to the 1991 and subsequent annual mid-year estimates were revised downwards by the national statistics offices (Norman *et al.,* 2008b). Although the 1991 under-enumeration may not have been quite as poor as previously thought, it must be recognised that it is likely that deprivation is somewhat under-recorded in the most deprived areas. This may also be true in 2001 since hard-to-enumerate areas tend to remain as such. As a result, the deprivation gradient may be somewhat shallower than the true counts in both 1991 and 2001.

Having deprivation scores comparable, but ten years apart misses changes during the inter-censal years, of course. Haynes *et al.* (1996) note the strong relationship between health and unemployment, that unemployment rate is included in all major deprivation indexes and that unemployment data are available on a regular basis. There is then a compelling argument for the use of unemployment rate as an updatable health needs indicator for small areas (wards, in their study). Haynes *et al.* (1996) note the need to overcome differences in census unemployment and official claimant counts and acknowledge their research was restricted to wards where no boundary change had occurred. Norman *et al.* (2003) though demonstrate how to construct an annual time-series of ward statistics in the face of boundary change. When reporting on the development of the Indexes of Multiple Deprivation (IMD), Noble *et al.* (2006) point out the tendency for datedness of census outputs and the deficiency of direct measures of deprivation including that the lack of access to a car may be a problematic proxy for income deprivation. Given advances in the collection and use of alternative administrative sources, the current IMDs include more timely and direct measures of deprivation. Drawbacks with the IMDs include that the geographies of release, 'Lower Super Output Areas' (LSOAs), are unfamiliar to users and, in the context being explored here, that the variables and methods are unlikely to be applicable at successive time-points. Moreover, the schemes are different in each of the UK's constituent countries, so that the IMDs are relevant to each, making a UK wide study impractical. However, unlike the ward boundaries which are liable to change during the inter-censal period, the LSOAs are a 'frozen' geography (at least to 2011) for which more data are becoming available.

The approach reported here has been extended in time to cover England and Wales wards for 1971, 1981, 1991 and 2001 to investigate changes in infant mortality rate in relation to Townsend deprivation (Norman *et al.,* 2008a) and similarly for the same time period for Carstairs scores (see Boyle *et al.,* 2004; Norman *et al.,* 2005; Boyle *et al.,* 2009). For wards in England and Wales there are strong positive correlations between the Townsend and Carstairs indexes (1971 r = 0.93; 1981, r = 0.95; 1991, r = 0.95; 2001, r = 0.93). It is questionable whether other schemes, such as the Jarman UPA index, should be calculated over time since the input variables are more likely to vary in meaning over time (particularly the original use of country of birth of head of household as a proxy for ethnicity) and the applicability of the differential weights applied to each variable. In any case, despite a strong relationship in 1991 with the Townsend index (Mackenzie *et al.,* 1998), the applicability of the Jarman index as a deprivation measure has been questioned (Senior, 1991).

To create a 1971-2001 British index, the work here can also readily be extended to include Scotland for the same time period since both harmonised variables and consistent geographies can be created. A similar approach has been taken in Scotland by Exeter and Boyle (2009) to investigate mortality change between 1981 and 2001 in relation to Carstairs deprivation. The situation in Northern Ireland is somewhat

different as census data for wards in 1971 and 1981 are unavailable in electronic format. The best potential for time-series analysis would be to build on previous work (Power and Shuttleworth, 1997) and utilise the grid/raster data for 1971-2001 (Shuttleworth and Lloyd, 2007). Indeed, there can be distinct advantages in analysing a time-series of socio-demographic data using a raster format (Bracken and Martin, 1989; Martin, 1996) since modelling change is more straightforward and linkages with environmental data can be made, for example in an environmental justice setting (Mitchell and Dorling, 2003) to determine whether people in more deprived places also experience higher levels of pollution and noise and less access to green space compared with people in less deprived locations. A disadvantage of grid approaches, especially for planning and health practitioners, is that the locations are no longer familiar places and do not match administrative areas.

Looking forward, it is most likely that equivalent variables to the deprivation indicators used in the Townsend index will be included in the UK's 2011 Census. Whilst there is an appreciation by the national statistics offices that frozen geographies are needed to analyse change over time, it is reasonable to expect that elements of administrative geographies existing in 2011 will not match the 2001 geographies. Whether or not conversions between geographical boundary systems are required, the debate on which is the right geography and deprivation scheme will, of course, be ongoing.

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Table 1: Census variables used in the Townsend index

Variable	Census	Description (with Census table cell references)
Unemployment	1991	Unemployed residents over 16 (L090109 + L090301) as a percentage of all economically active residents aged over 16 (L090025 + L090217)
	2001	Unemployed persons aged 16-74 (CS0210046) as a percentage of all economically active persons 16-74 (CS0210010)
No car access	1991	Residents in households with no car (L200420) as a percentage of all residents in households (L200411 + L200419)
	2001	No Cars or vans in household (KS0170002) as a percentage of all households (KS0170001)
Non-home ownership	1991	Households not owning their own home ((L200001 + L200009) - (L200002 + L200003)) as a percentage of all households (L200001 + L200009)
	2001	Renting home (KS0180005 + KS0180006 + KS0180007 + KS0180008) as a percentage of all households (KS0180001)
Household overcrowding	1991	Persons in households with 1 and more persons per room (L230054 + L230055) as a percentage of all residents in households (L230051)
	2001	Households with 1 and more persons per room (CS0520013 + CS0520017) as a percentage of all households (CS0520001)

Note: the tables and cell references above relate to wards in England. The detail may vary in Wales, Scotland and Northern Ireland

Table 2: Geographic Conversion Table between example 1991 and 2001 Census wards

a.) Disaggregation phase

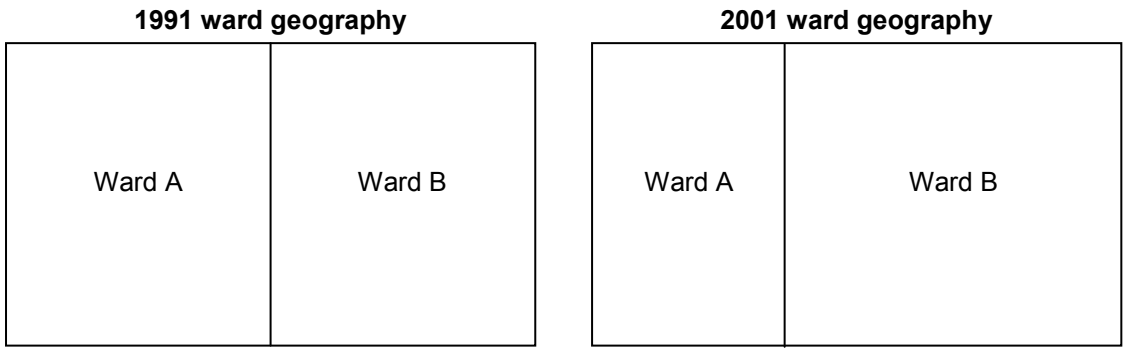
1991 ward name (source geography)	Address count in source-target intersection	Addresses in source ward	Conversion weight	2001 ward name (target geography)
St Peter	1,764	6,091	0.2896	Devonport
St Peter	4,245	6,091	0.6969	St Peter & the Waterfront
St Peter	82	6,091	0.0135	Stoke

b.) Reaggregation phase

1991 ward name (source geography)	Address count in source-target intersection	Addresses in source ward	Conversion weight	2001 ward name (target geography)
Drake	323	5,702	0.0566	Stoke
Keyham	62	4,919	0.0126	Stoke
St Peter	82	6,091	0.0135	Stoke
Stoke	5,148	5,148	1.0000	Stoke

Table 3: Converting rates between geographies

	Source 1991 geography		Conversion weight	Target 2001 geography	
a. Incorrect approach	**Ward A**	**Ward B**	**0.25 (A to B)**	**Ward A**	**Ward B**
Unemployment rate	20.00%	15.00%	5.00% (A to B)	15.00%	20.00%
b. Correct approach	**Ward A**	**Ward B**	**0.25 (A to B)**	**Ward A**	**Ward B**
Unemployed	40	15	10 (A to B)	30	25
Economically active	200	100	50 (A to B)	150	150
Unemployment rate	20.00%	15.00%		20.00%	16.67%



Source: Norman (2006)

Table 3: Calculating z-scores for no car access in 1991 and 2001 for a hypothetical ward

National data on no car access	Mean	Standard deviation
1991	28.39	14.89
2001	22.94	13.65
1991-2001 combined	25.67	14.54
Cross-sectional measures	**Percentage no car access**	**z-score**
1991	26.00	–0.16
2001	24.00	+0.08
Comparable measures	**Percentage no car access**	**z-score**
1991	26.00	+0.02
2001	24.00	–0.12

Table 5: National levels of indicator variables in 1991 and 2001

Variable	Mean	Standard deviation
Unemployment		
1991	8.73	5.53
2001	3.13	1.63
1991-2001 combined	5.93	4.95
No car access		
1991	28.39	14.89
2001	22.94	13.65
1991-2001 combined	25.67	14.54
Non-home ownership		
1991	31.27	16.34
2001	28.91	14.68
1991-2001 combined	30.09	15.58
Household overcrowding		
1991	2.04	1.92
2001	1.53	1.74
1991-2001 combined	1.78	1.85

Table 6: Transitions of wards between 1991 and 2001 deprivation quintiles

	Country	2001 deprivation quintiles					
1991 deprivation quintiles	**England**	Q1	Q2	Q3	Q4	Q5	Total
	Q1	12.06	0.09	0.01	0.00	0.00	12.16
	Q2	26.16	3.08	0.06	0.00	0.00	29.30
	Q3	8.52	13.42	2.65	0.09	0.01	24.69
	Q4	0.58	3.90	10.47	3.10	0.05	18.09
	Q5	0.05	0.04	1.31	7.80	6.55	15.75
	Total	47.37	20.52	14.50	11.00	6.61	100.00
	% Less deprived by 2001	72.24					
1991 deprivation quintiles	**Wales**	Q1	Q2	Q3	Q4	Q5	Total
	Q1	7.04	0.23	0.00	0.00	0.00	7.26
	Q2	16.91	3.29	0.00	0.00	0.00	20.20
	Q3	7.95	18.96	2.61	0.00	0.00	29.51
	Q4	0.34	7.95	19.64	2.84	0.00	30.76
	Q5	0.00	0.23	2.72	7.26	2.04	12.26
	Total	32.24	30.65	24.97	10.10	2.04	100.00
	% Less deprived by 2001	81.95					
1991 deprivation quintiles	**Scotland**	Q1	Q2	Q3	Q4	Q5	Total
	Q1	2.95	0.20	0.10	0.00	0.00	3.25
	Q2	6.91	1.12	0.41	0.00	0.00	8.43
	Q3	4.07	10.87	1.93	0.20	0.00	17.07
	Q4	1.12	8.13	17.48	1.63	0.00	28.35
	Q5	0.41	0.91	5.79	20.12	15.65	42.89
	Total	15.45	21.24	25.71	21.95	15.65	100.00
	% Less deprived by 2001	75.81					
1991 deprivation quintiles	**Northern Ireland**	Q1	Q2	Q3	Q4	Q5	Total
	Q1	2.58	0.00	0.00	0.00	0.00	2.58
	Q2	6.01	0.00	0.00	0.00	0.00	6.01
	Q3	9.11	2.41	0.34	0.00	0.00	11.86
	Q4	2.75	14.60	5.84	0.52	0.00	23.71
	Q5	0.17	4.30	17.70	22.34	11.34	55.84
	Total	20.62	21.31	23.88	22.85	11.34	100.00
	% Less deprived by 2001	85.22					

Note: Figures are percentages of wards in each country. A figure here of 0.00% means a zero count of wards.

Figure 1: Boundary changes in Plymouth's wards, 1991 – 2001

a.) 1991 ward boundaries

b.) 2001 ward boundaries

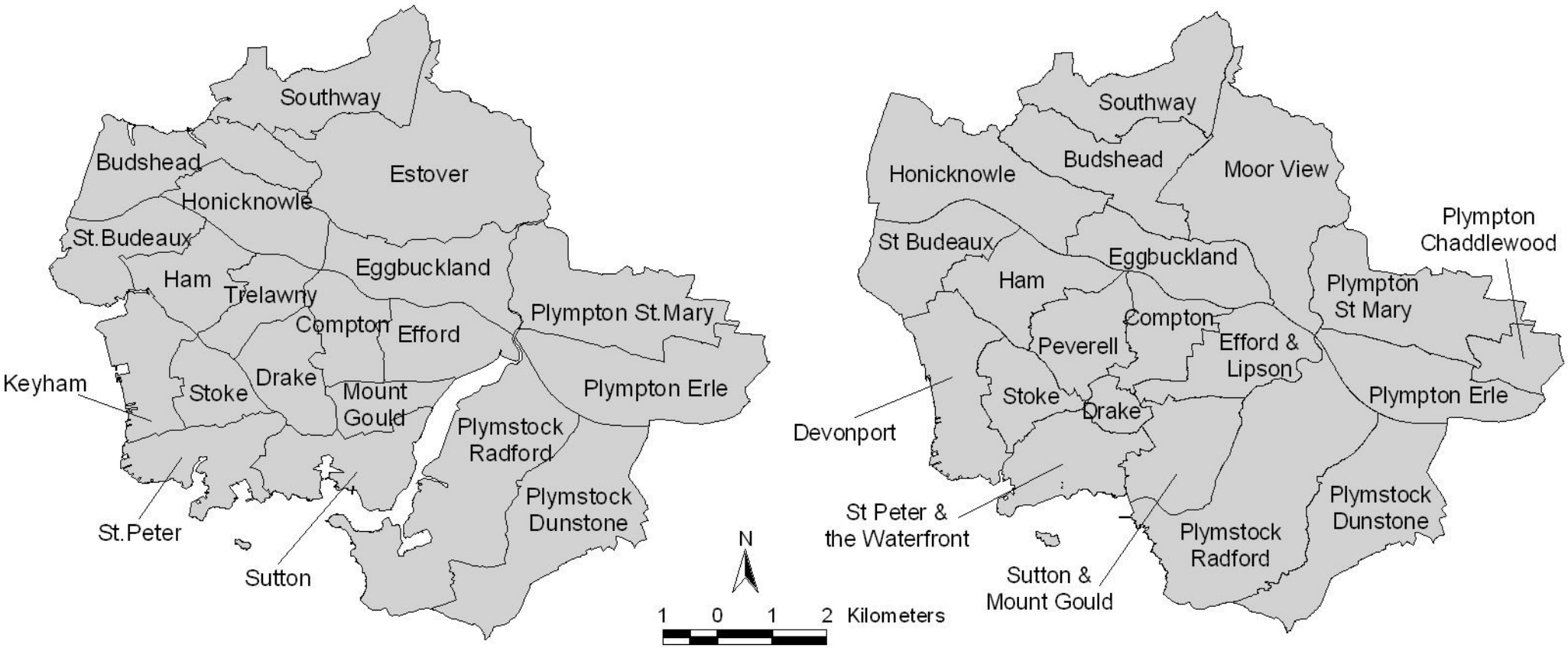
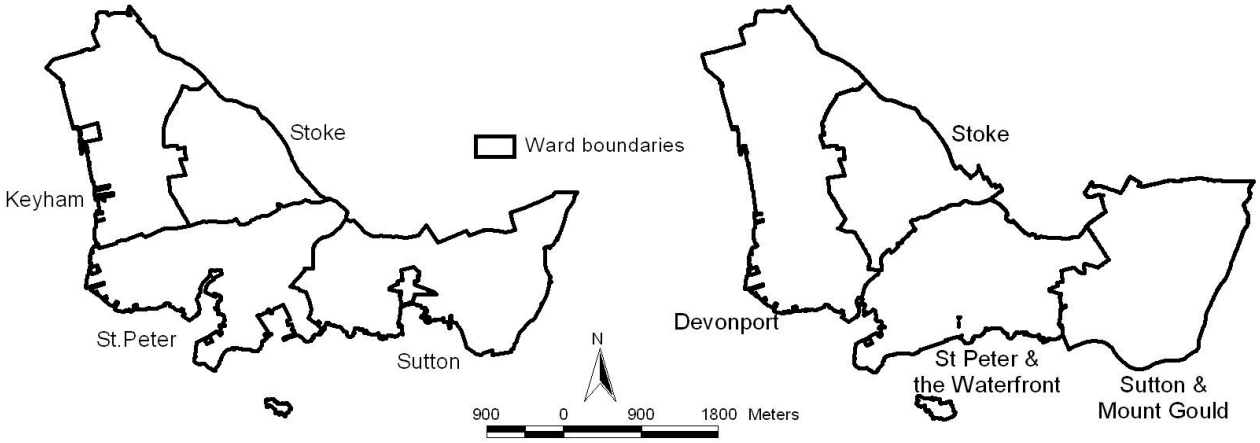


Figure 2: Converting data between different boundary systems

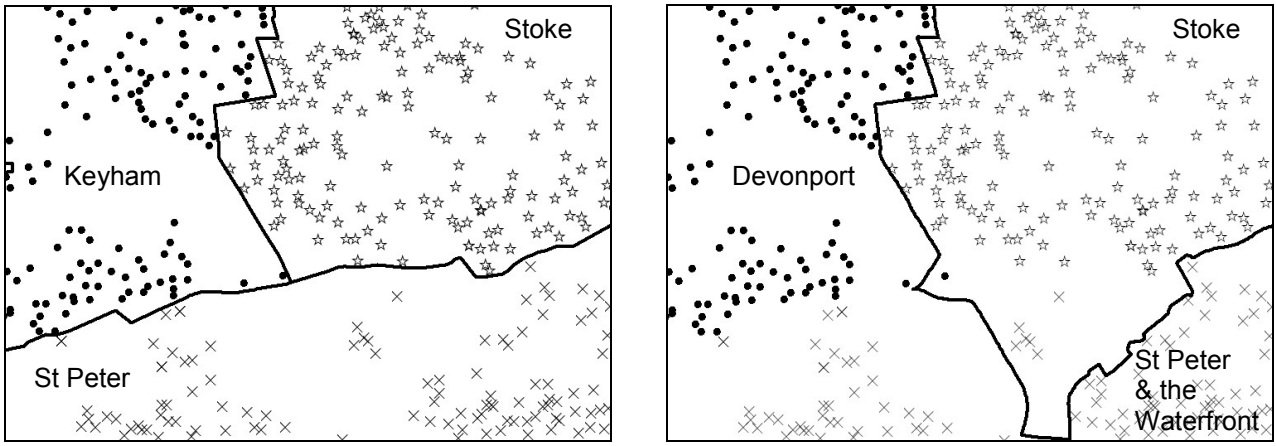
a.) Example 1991 wards

b.) Example 2001 wards



c.) Postcode links to 1991 wards

d.) Postcode links to 2001 wards



e.) Addresses per postcode linked to 1991 wards

f.) Addresses per postcode linked to 2001 wards

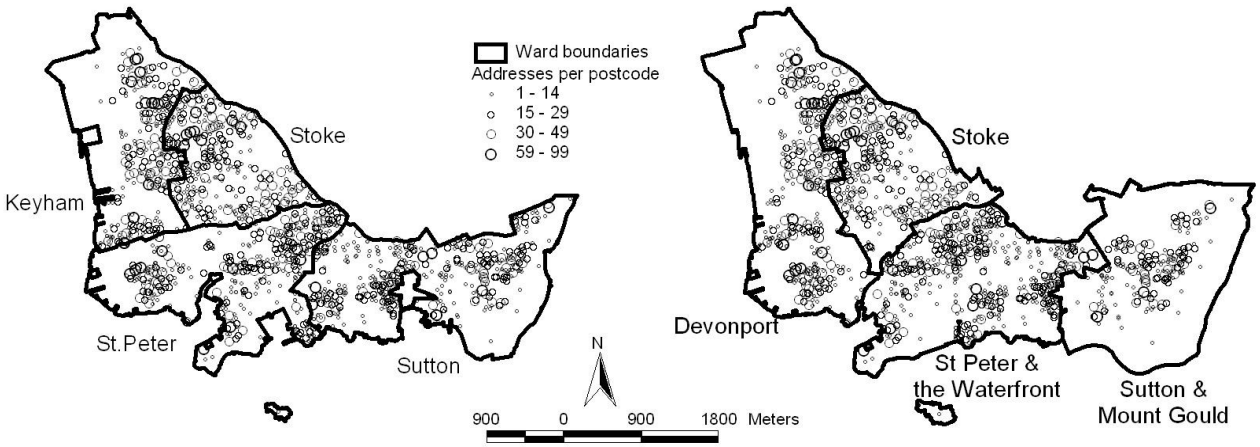
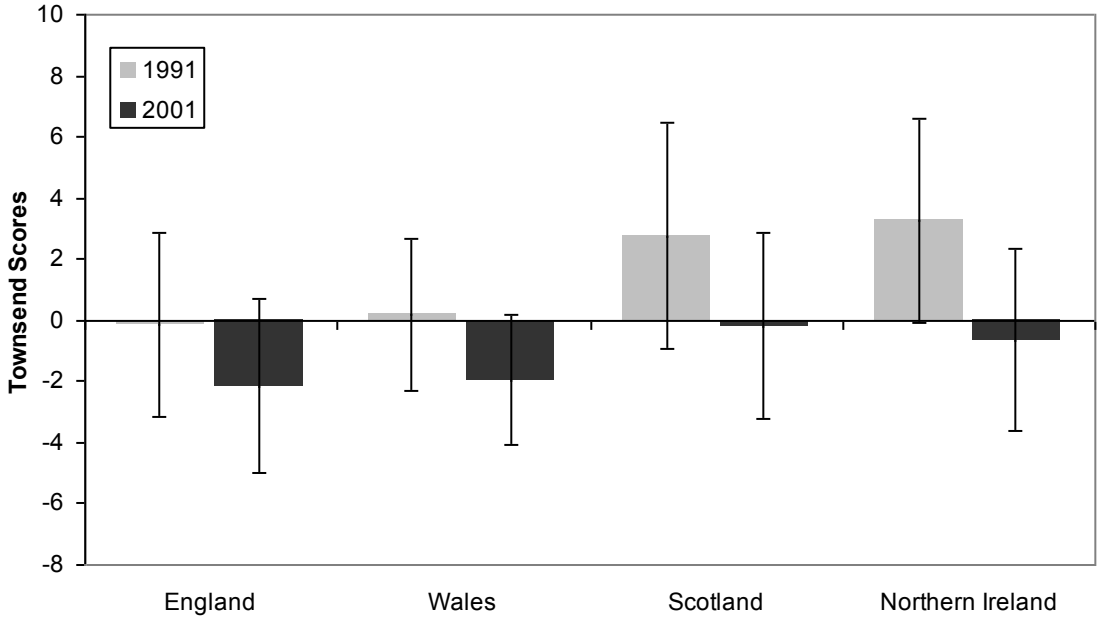


Figure 3: Average Townsend scores for wards in the UK's consistent countries

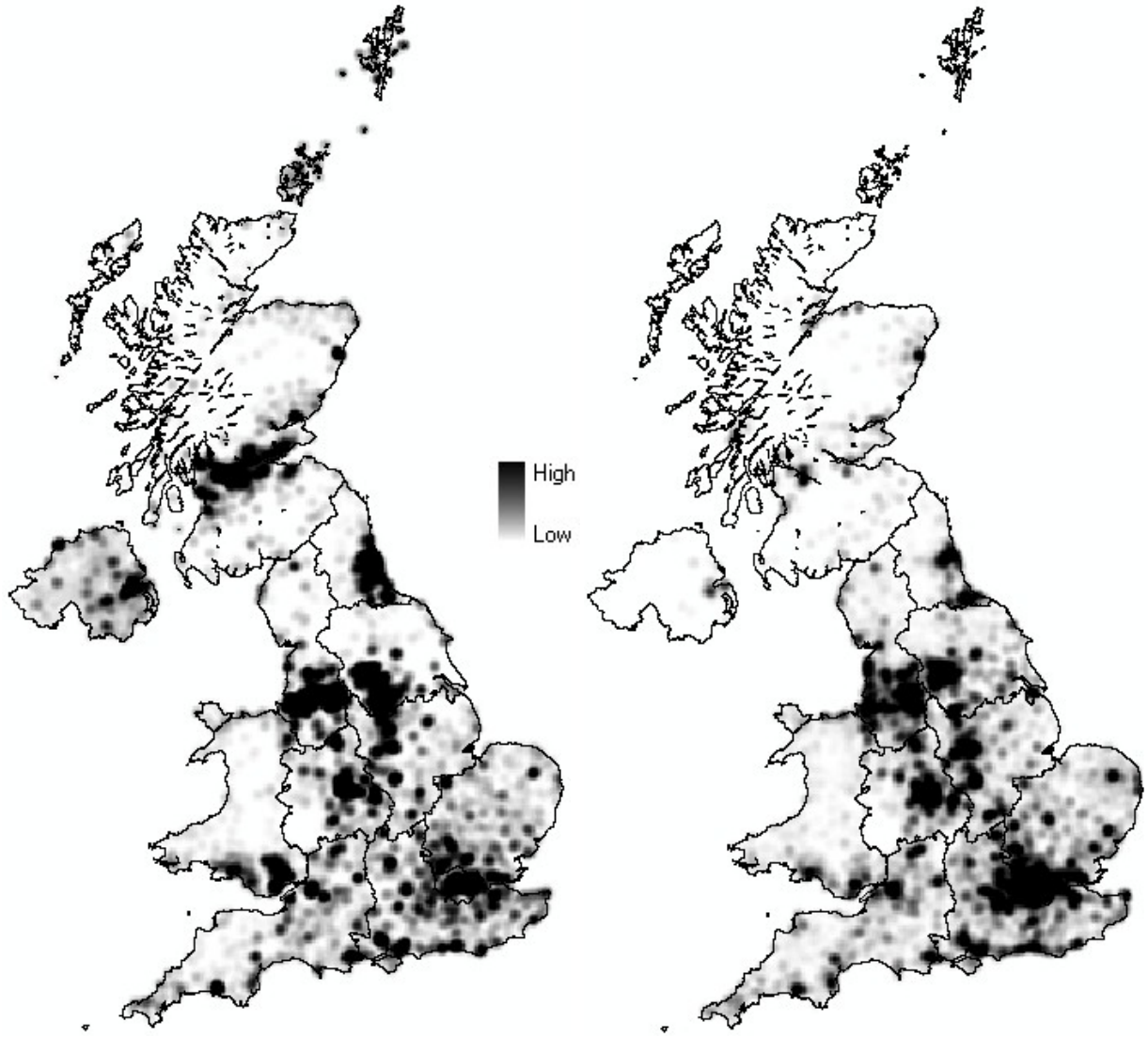


Note: error bars are standard deviations of deprivation

Figure 4: Change in deprivation 1991-2001

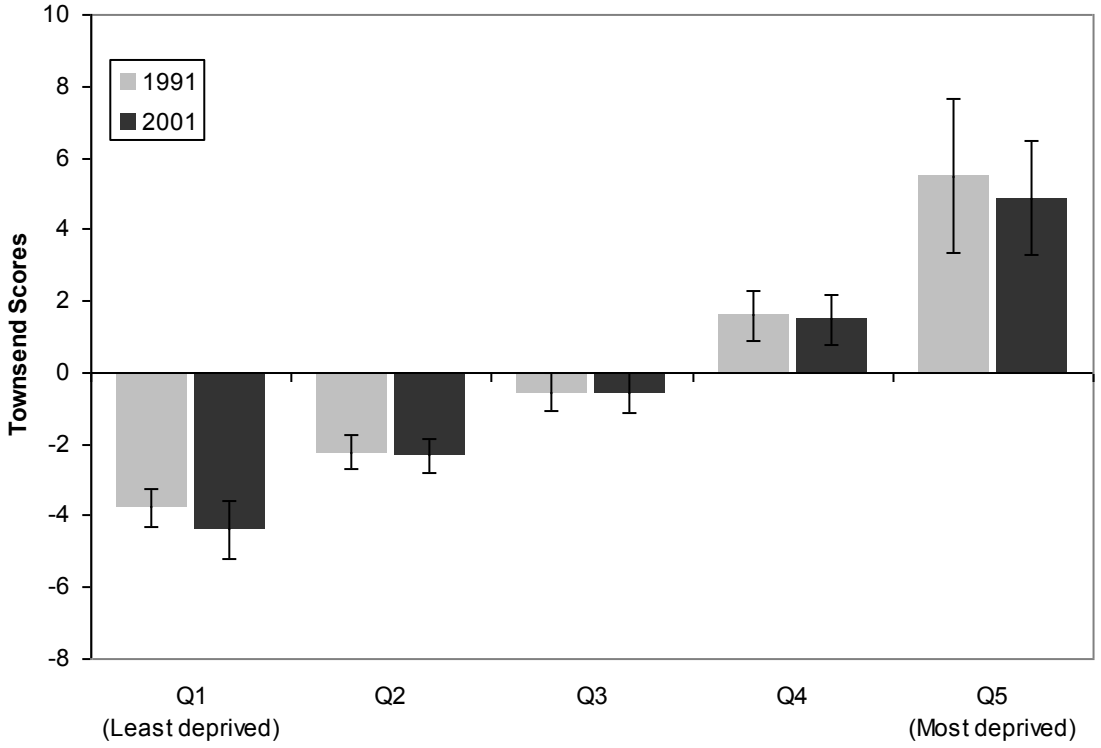
a.) Clusters of change greater than the national average improvement

b.) Clusters of change not greater than the national average improvement



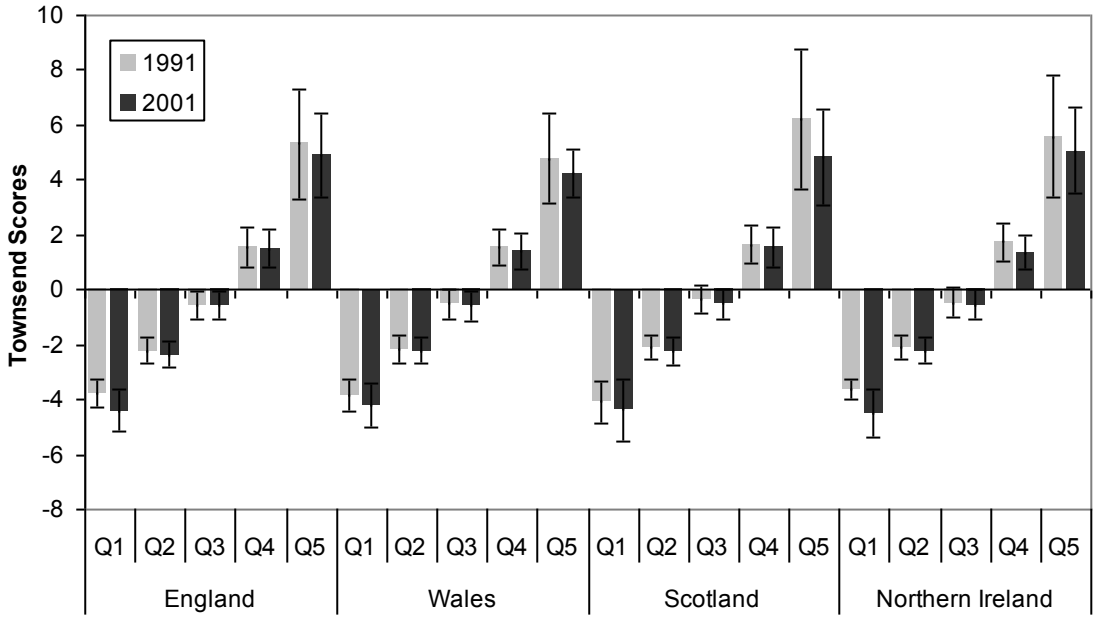
Note: Maps are the kernel densities of locations which, between 1991 and 2001: a.) have improved their level of deprivation greater than the national average reduction of 2.39 Townsend scores; and b.) did not improve their level of deprivation by the national average including those locations which became more deprived.

Figure 5: Average Townsend scores for wards in each deprivation quintile



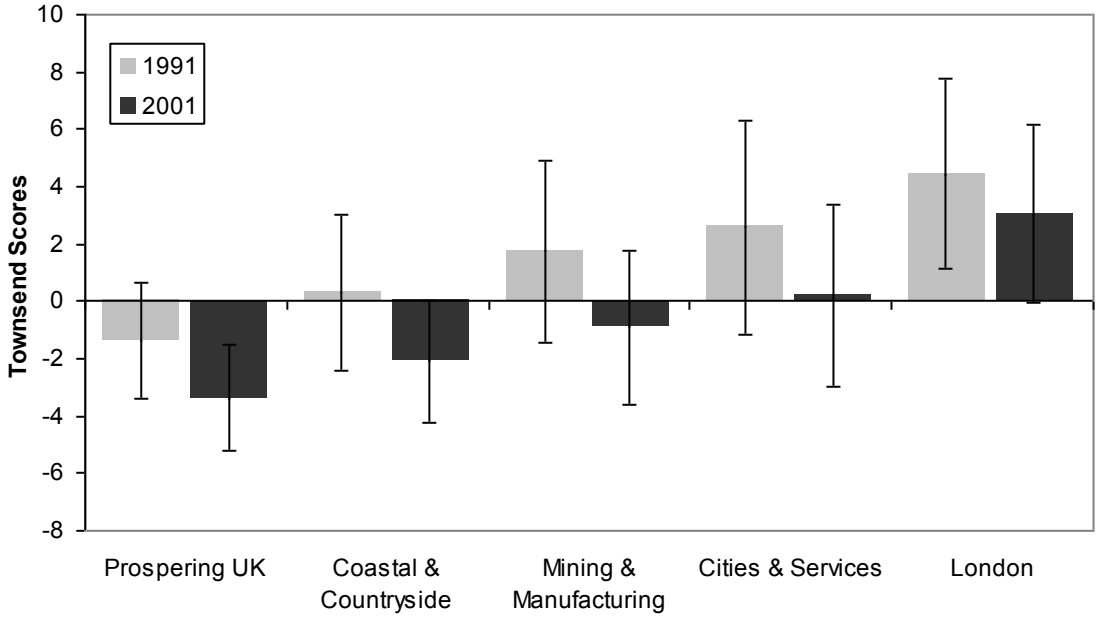
Note: error bars are standard deviations of deprivation

Figure 6: Average Townsend scores for wards in each deprivation quintile within the UK's consistent countries



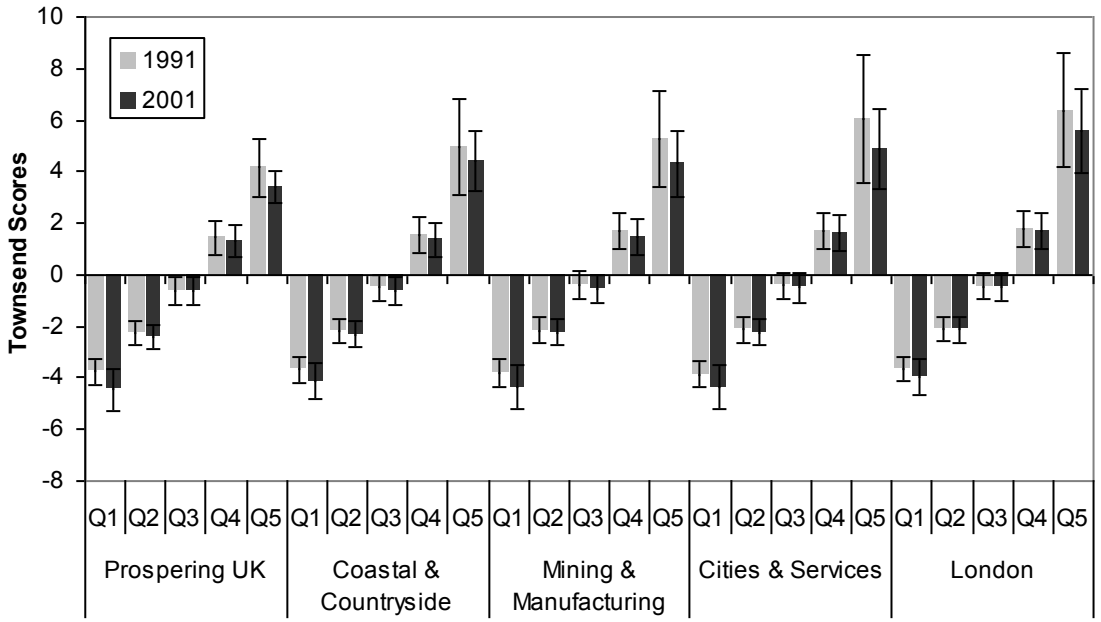
Note: error bars are standard deviations of deprivation

Figure 7: Average Townsend scores for wards in each Supergroup



Note: error bars are standard deviations of deprivation

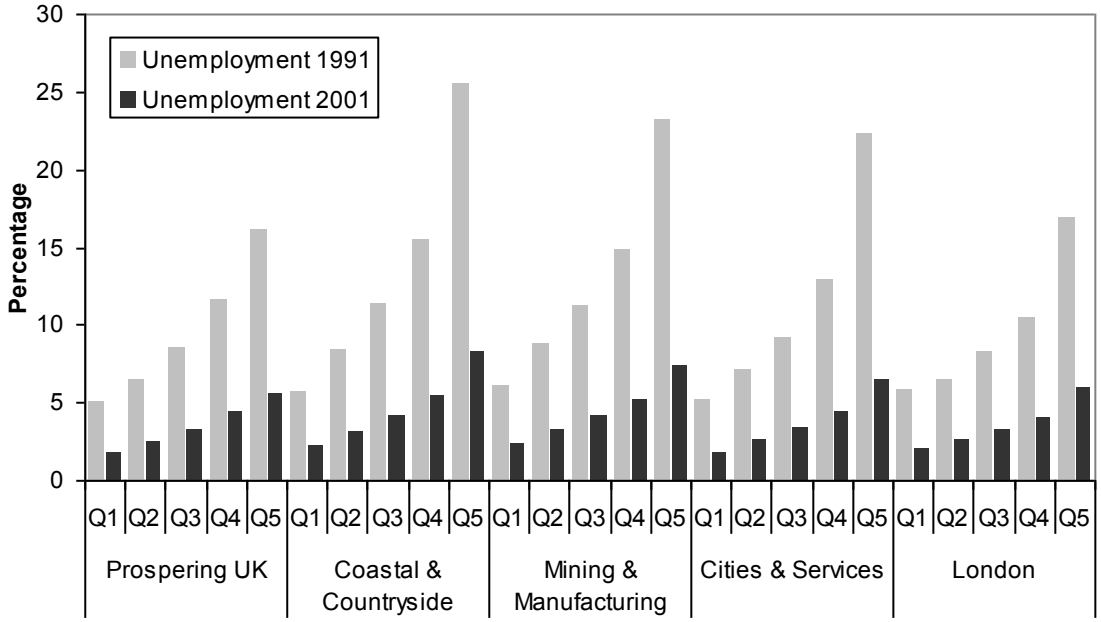
Figure 8: Average Townsend scores for wards in each deprivation quintile within each Supergroup



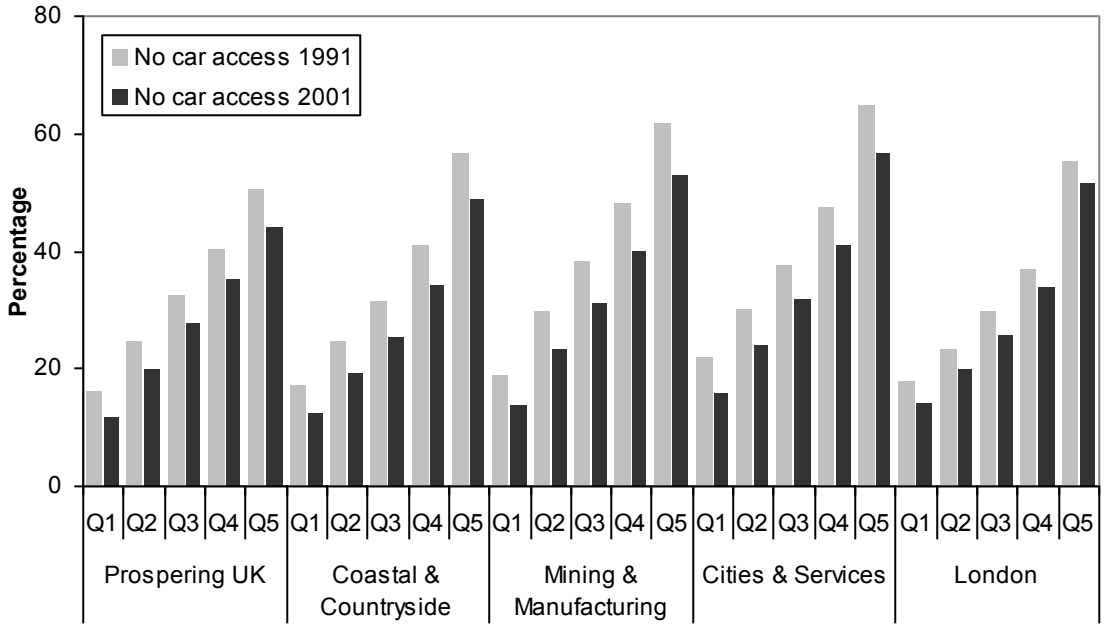
Note: error bars are standard deviations of deprivation

Figure 9: Average rates of indicator variables for wards in each deprivation quintile within each Supergroup

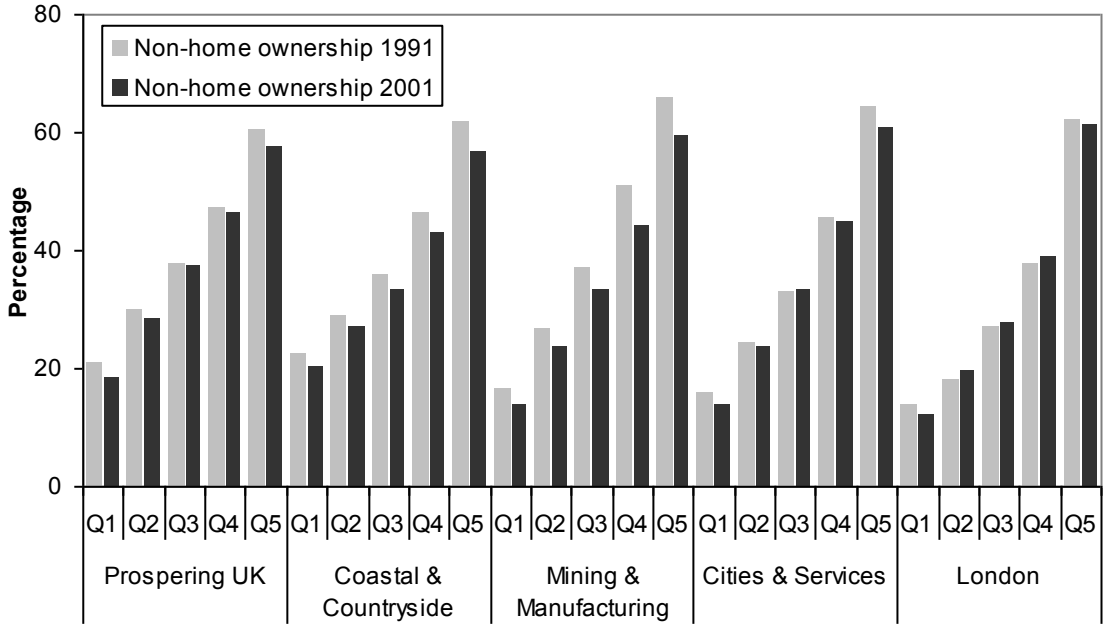
a.) Unemployment rates in 1991 and 2001



b.) No car access rates in 1991 and 2001



c.) Non-home ownership rates in 1991 and 2001



d.) Household overcrowding rates in 1991 and 2001

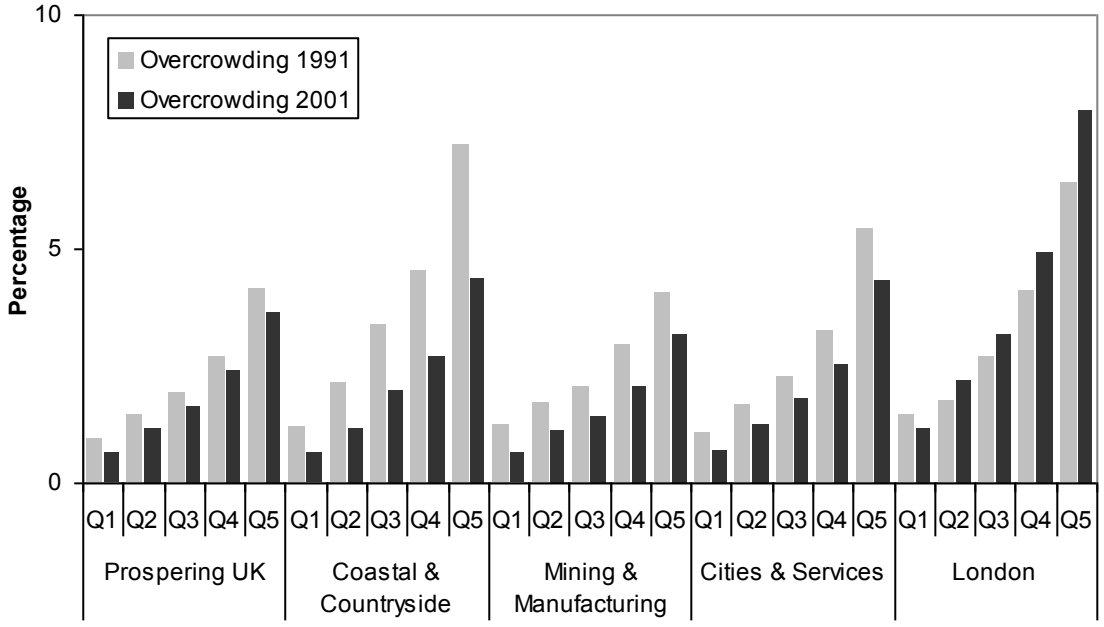


Figure 10: Deprivation change 1991 – 2001 in Plymouth's wards by 2001 geography

a.) 1991 deprivation

b.) 2001 deprivation

c.) 1991-2001 improvement in deprivation relative to national reduction of 2.32

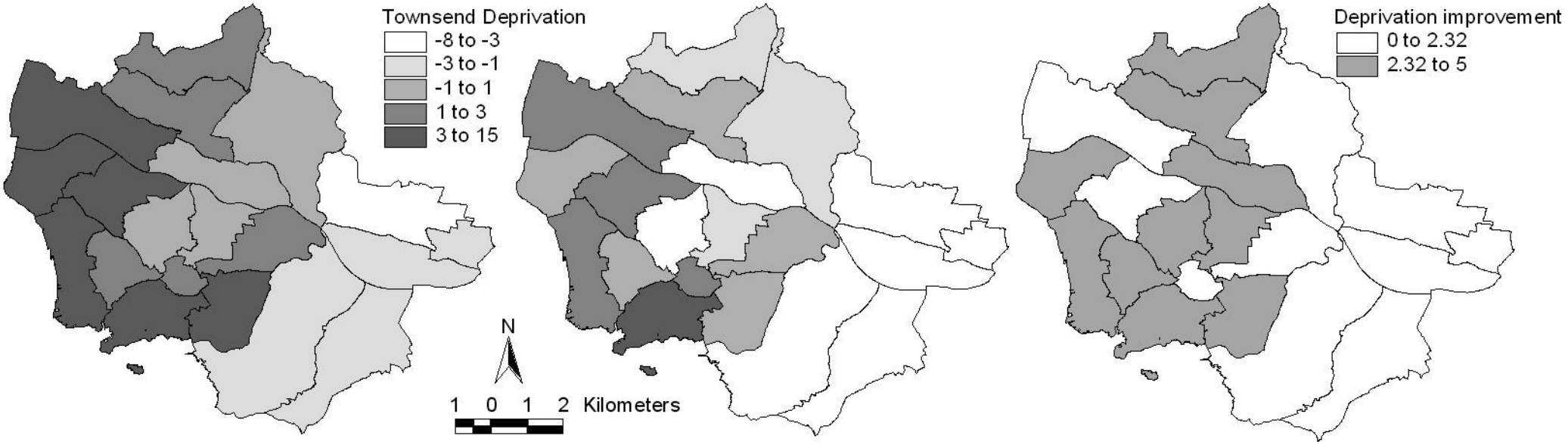


Figure 11: Changing deprivation in Plymouth's wards, 1991 – 2001

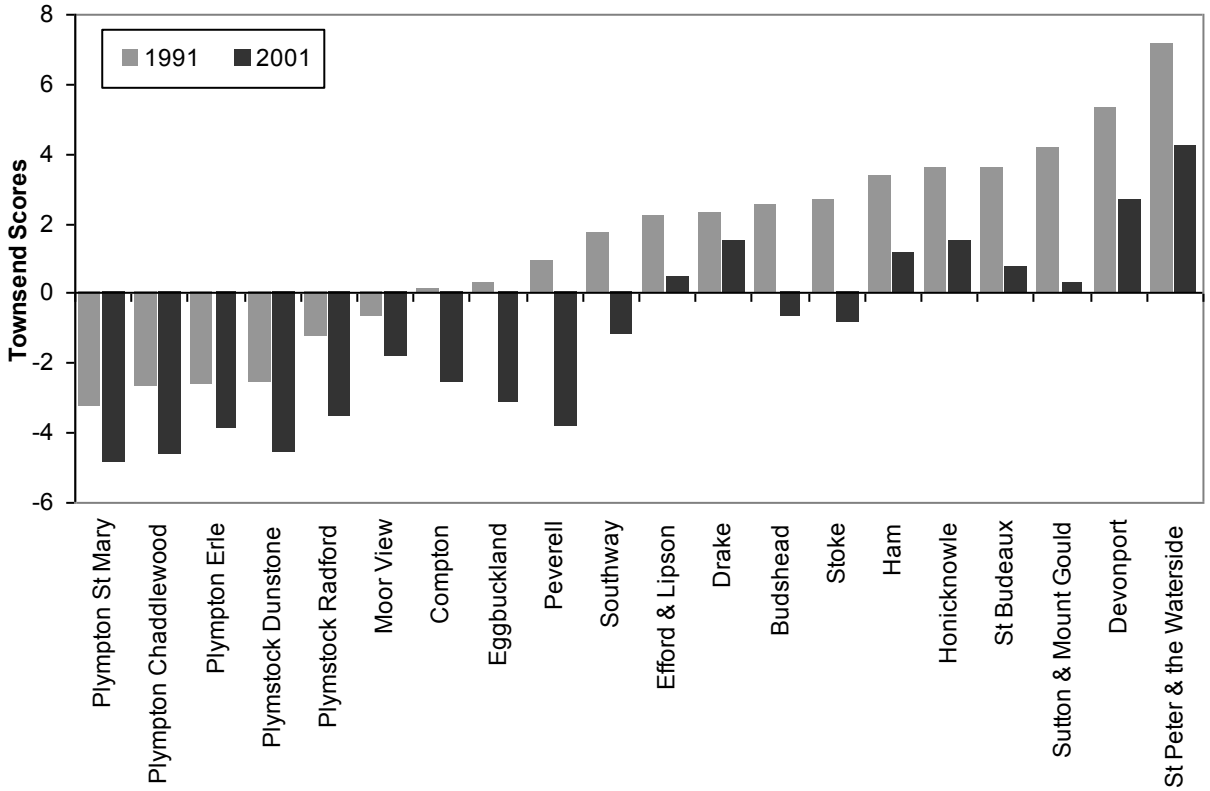
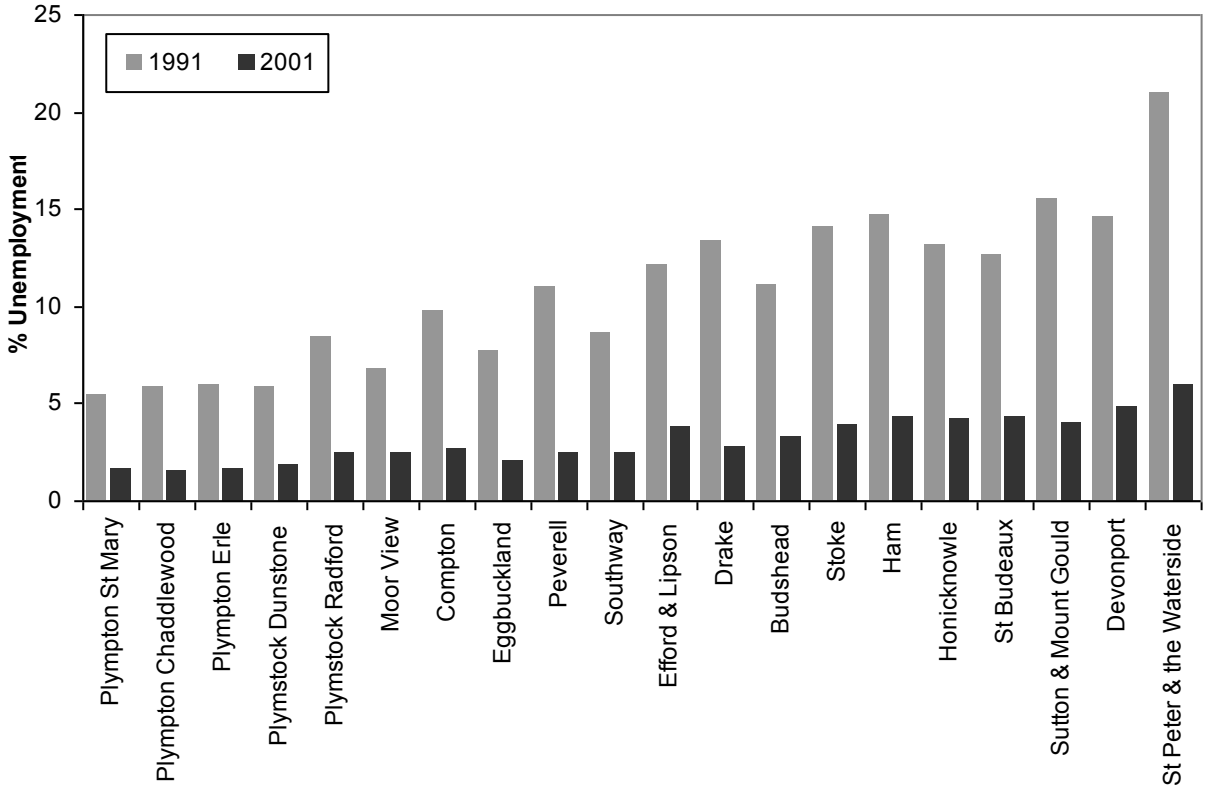
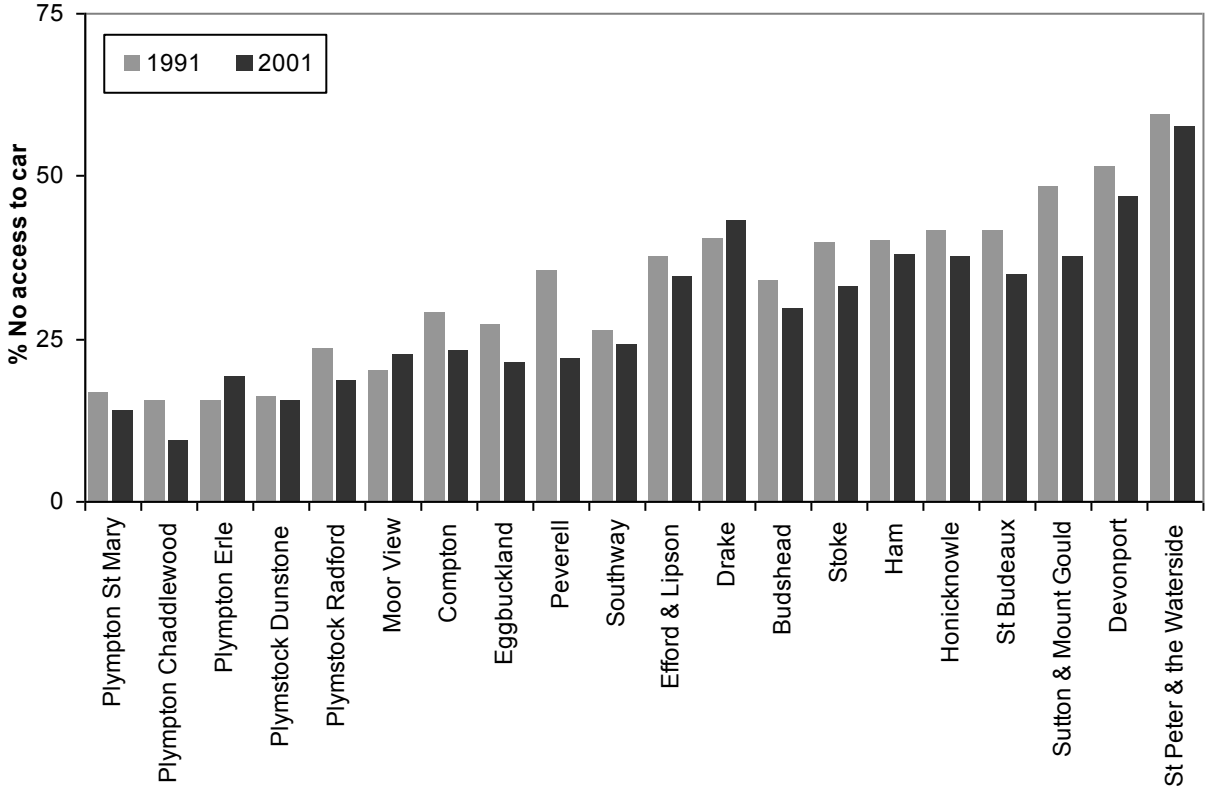


Figure 12: Rates of indicator variables for wards in Plymouth

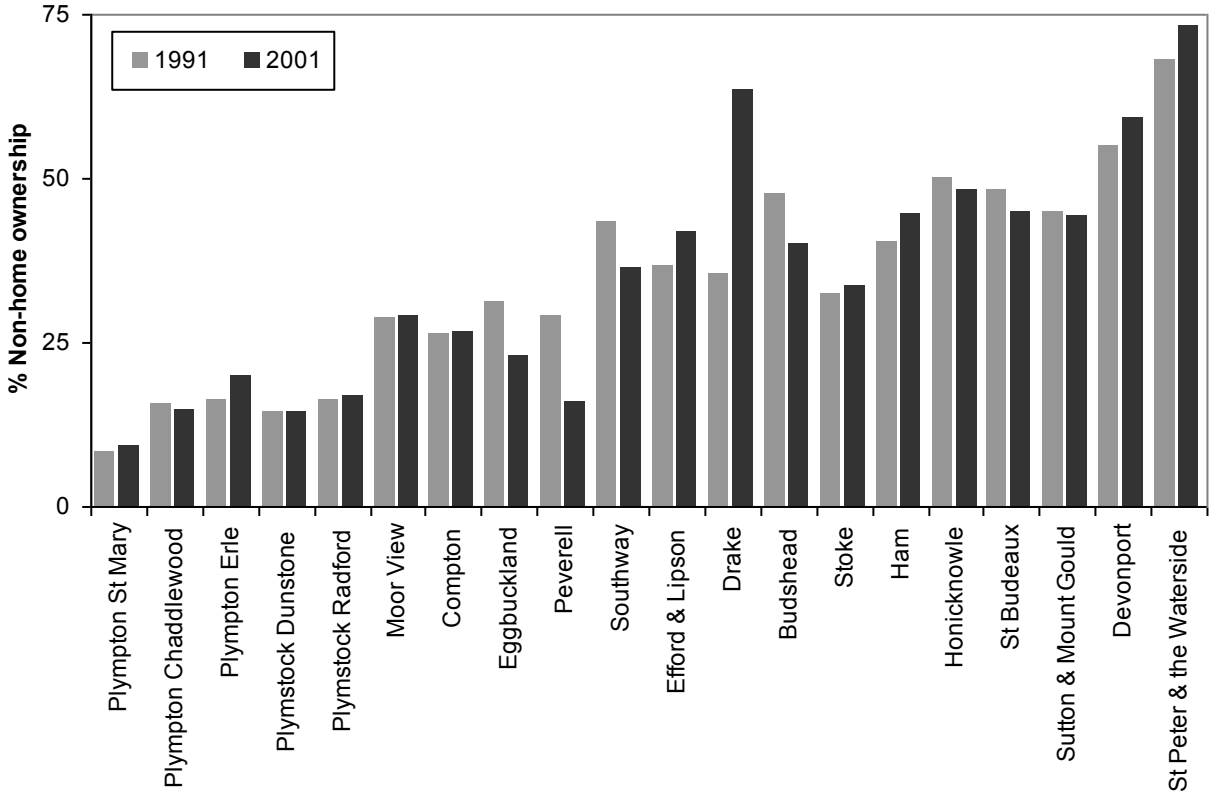
a.) Unemployment rates in 1991 and 2001



b.) No car access rates in 1991 and 2001



c.) Non-home ownership rates in 1991 and 2001



d.) Household overcrowding rates in 1991 and 2001