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Measuring multiple deprivation at the small-area level

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Abstract. Indices to measure deprivation at a small-area level have been used in the United Kingdom to target regeneration policy for over thirty years. The development of the Indices of Deprivation 2000 for England and comparable indices for Northern Ireland, Wales, and Scotland, involved a fundamental reappraisal and reconceptualisation of small-area level multiple deprivation and its measurement. Multiple deprivation is articulated as an accumulation of discrete dimensions or 'domains' of deprivation. This paper presents the key principles that were taken into consideration when constructing these four indices and the more recent English Indices of Deprivation 2004, and provides an account of the statistical techniques that were used to operationalise them.

Introduction

In this paper we draw together the key principles which underpin the indices of multiple deprivation that have been created for the different countries within the United Kingdom over the last five years. The paper relates to the English Indices of Deprivation 2000 (ID 2000) (Noble et al, 2000a; 2000b, 2000c, 2000d), its successor the English Indices of Deprivation 2004 (ID 2004) (Noble et al, 2004), the Welsh Index of Multiple Deprivation 2000 (Noble et al, 2000d), the Northern Ireland Measures of Multiple Deprivation 2001 (Noble et al, 2001), and the Scottish Indices of Deprivation 2003 (SID 2003) (Noble et al, 2003a; 2003b). Though at the time of production each of the indices was accompanied by a government report, this paper considers all five indices, and documents the key principles that informed them. A detailed account of the components of the various indices falls beyond the scope of this paper. Also, rather than reporting on the research findings, which are available for all to explore as the indices themselves have been publicly released, this paper focuses on the innovations to the model of multiple deprivation, and the statistical techniques that were employed in the development of these particular indices.

Small-area indices of deprivation are not peculiar to the United Kingdom and this paper will therefore also be of relevance beyond these particular boundaries (see, for example, Hirschowitz et al, 2000; McIntyre et al, 2000; Madhya Pradesh Human Development Report Project Office, 1995; Salmond et al, 1998; Social Research and Western Cape Population Unit, 1999).

All developments of this type are evolutionary in their origins. The indices that we describe are no exception; yet, in some respects, they do represent a break from the past and offer a fresh view of measuring multiple deprivation. As a background to this paper, we begin with an overview of the rationale for measuring multiple deprivation at an area level, and present a brief history of the UK predecessors of the indices. The new model of multiple deprivation is then described and the statistical techniques that

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were developed to operationalise the model are discussed. The concluding remarks include suggestions for areas of research that would further enhance the theoretical rigour of future indices.

Background: area-level multiple deprivation

Some commentators ascribe three different meanings to area deprivation: a compositional meaning, a collective meaning, and an environmental meaning (Cemlyn et al, 2002, page 13). A compositional meaning of area deprivation is where an area is considered to be deprived if it contains a large number or proportion of deprived people. A collective meaning refers to the possible presence of 'area effects', that is, the additional deprivation in an area which is above and beyond those attributable to the concentration of deprived people in the area. The environmental meaning refers to the deprivation in an area flowing from the lack of facilities in that area or some other area feature. In a summary area measure, it is difficult to imagine that the collective meaning could exist independently of the compositional meaning. The five indices referred to in this paper are 'compositional', in the sense outlined above. No assumption has been made about the possibility of area effects in the indices, as it is an empirical question as to whether such effects exist (Kleinman, 1999; McCulloch, 2001).

The conceptual framework presented in this paper is based on the premise that deprivation is ultimately suffered or experienced by individuals and, hence, that it is theoretically possible to account for the entirety of deprivation by measuring deprivation at the individual level. However, this does not entail a commitment to the view that individual-level explanations of deprivation can account for the entirety of the causes of deprivation. Even if the concentration of deprived people in an area does have a compounding effect on the overall level of deprivation in that area, we would argue that this deprivation must still be experienced by individuals.

Whereas area measures derived from individual data might be criticised for failing to allow for the possibility of area effects, the converse argument has also been made. That is, that area measures in themselves imply that the causes of deprivation lie at the area level. The new indices referred to in this paper entail no conclusions on the *causes* of deprivation. Area-level aggregates are one way of obtaining a further understanding of these processes, but they do not assume in advance which level is most important.

An area measured as relatively deprived by an index may contain large numbers of people who are not deprived and, conversely, areas which are relatively less deprived might contain deprived people (Smith, 1999). Area-based policies have often been criticised on two grounds: first, because the majority of deprived people do not live in deprived areas, so policies which focus exclusively on such areas will not be effective in solving wider deprivation (Kleinman, 1999); second, such policies are less cost-effective than general antideprivation policies that target deprived individuals wherever they live (PIU, 2000). These are pertinent points; however, they do not undermine the approach in the new indices to measuring multiple deprivation at the small-area level. The presentation of data at different geographical levels should not be taken to imply assumptions about the fundamental causes of deprivation, nor should it be taken to imply assumptions about the appropriate solutions. The identification of deprived areas may be necessary if area-based solutions to deprivation are to be pursued, but identifying deprived areas in no way assumes that such solutions are the only ones.

At least since the mid-1960s the aim of creating an index (or indices) to measure deprivation at the local level, to identify priority areas and target programmes more effectively, has been a consistent feature of government policy in the United Kingdom. At times, these indices have been concerned with specific areas of policy, such as education

or health, but since the 1980s the idea of a national index of 'multiple deprivation' at the local level has become a central concern. The publication of the decennial Census of Population in electronic form with data available for small geographical areas undoubtedly contributed to this development.

As early as 1974, Holterman (1975) undertook an analysis of multiple deprivation using data from the 1971 Census. In England, following the 1981 Census of Population, the Inner Cities Directorate of the then Department of the Environment undertook an analysis "to assess the relative levels of deprivation in individual local authorities in England" (DoE, 1983). The reasons for the work related specifically to aspects of urban policy, including guiding expenditure under the Urban Programme, and to inform decisions on the designation of authorities under the 1978 Inner Urban Areas Act. This index was based on eight indicators, seven of which were derived from the census. The approach was largely to focus on what were termed 'surrogates for deprivation'—that is, predominantly, what might be described as groups 'at risk', for example, lone parents, lone pensioners, and those born in the New Commonwealth. This wide-ranging set of indicators was selected to pin down 'area deprivation' in its major forms. Its proponents may have been reluctant to claim that they had measured 'multiple deprivation' as such, but, as they observed, "it is reasonable to assume that areas which do not appear deprived on the eight indicators examined in this analysis are unlikely to have high overall levels of deprivation" (DoE, 1983).

In the 1991 English Index of Local Conditions (ILC) (DoE, 1994), this multidimensional view of area deprivation was continued and the idea of different dimensions or 'domains' of deprivation was developed. However, in several important respects, it differed from its 1981 predecessor. First, following the recommendations of a review undertaken by the Centre for Urban and Regional Development Studies at the University of Newcastle upon Tyne (Coombes et al, 1995), its emphasis moved away from groups 'at risk' of deprivation to more direct measures, referred to as 'incidence' indicators. Second, the index was built up from the small area to the larger area, with larger-area values being aggregates of smaller-area values (with additions of other 'deprivation' variables where these were not available at the smaller-area level). Third, the basic method for standardisation prior to summation moved from z-scores to the signed χ^2 technique (Robson et al, 1995). The 1997 review (DETR, 1998) of the ILC was primarily an exercise in updating. It was not a fundamental review in the sense that no new subdistrict indicators were introduced (though some were removed).

Other parts of the United Kingdom have also used Census of Population information to generate measures of small-area deprivation. Thus, each of the three Censuses of Population in 1971, 1981, and 1991 were used to produce information on deprivation in Northern Ireland. The result of the 1991 analysis was the construction of a series of deprivation measures (Robson, 1994), which followed closely the methodology adopted in England (DoE, 1994; Robson et al, 1995). These measures have been used by a wide variety of programmes and projects to direct resources to areas with high levels of social and economic deprivation.

Moving away from a census-based approach

Though the Census of Population offers indicators which are comprehensive in small-area coverage, they can be problematic as components of a deprivation index or source of deprivation scores. In the first place, the census contains few direct measures of deprivation. For example, the census contains no measures of income. Previous indices have used 'no access to a car' as a problematic proxy for income deprivation. Second, the census is decennial. The data rapidly become out of date and, for example, the release of data for the 1991 Census was two years after the census date. Data release for the 2001 Census was even

slower, with some output-area-level data delayed until 2004. Updating of indicators that are derived from the census is therefore only possible on a ten-year cycle.

However, advances in the collection and use of other data sources, such as administrative data, have allowed analysis of deprivation at the small-area level in the intercensal period. Such advances have also released the analysis from using proxy indicators from the census in favour of using more direct measures of deprivation, such as low income.

Creating measures of multiple deprivation at the small-area level by harnessing new data sources is not, however, simply a case of trawling for indicators of deprivation from administrative sources and combining them in a hotchpotch manner. In the first place, there should be a clear theoretical or conceptual framework which underpins a model of small area deprivation. Second, the methodology for the index or summary measure must be an operationalisation of that model. Third, however good a measure or set of measures might be, it must also, if commissioned to serve a specific purpose, be fit for that purpose.

An index should be neither driven by available data nor by statistical techniques. Once a clear model has been developed, data to provide indicators for the dimensions of deprivation should be sought, and statistical techniques utilised which are consistent with the model.

Establishing a clear theoretical framework for the measurement of small-area deprivation

> "We must first know what poverty is before we can identify where and when it is occurring or attempt to measure it; and before we can begin to do anything to alleviate it."
>
> Alcock (1997, page 57)

In his 1979 account of *Poverty in the United Kingdom* Townsend sets out the case for defining poverty in terms of relative deprivation. Thus his definition of poverty is:

> "Individuals, families and groups can be said to be in poverty if they lack the resources to obtain the types of diet, participate in the activities and have the living conditions and amenities which are customary, or at least widely encouraged or approved in the societies to which they belong" (Townsend, 1979, page 31).

Though 'poverty' and 'deprivation' have often been used interchangeably, many have argued that a clear distinction should be made between them (see, for example, the discussion in Nolan and Whelan, 1996). It could be argued that the condition of poverty means not having enough financial resources to meet needs. Deprivation, on the other hand, refers to unmet need, which is caused by a lack of resources of all kinds, not just financial. In a similar vein, Atkinson (1998) notes that, in recent debates on 'social Europe', the terms 'poverty' and 'social exclusion' have been, on occasions, used interchangeably, but he defines poverty as a "lack of money or material possessions". Townsend himself concurs. In his article "Deprivation", Townsend argues that

> "people can be said to be *deprived* if they lack the types of diet, clothing, housing, household facilities and fuel and environmental, educational, working and social conditions, activities and facilities which are customary.... People are in poverty if they lack the resources to escape deprivation" (Townsend, 1987, pages 131 and 140; our italics).

In his 1987 article, Townsend elaborates distinctions between social and material deprivation. The former—which he acknowledges is more difficult to measure—he describes as "providing a useful means of generalising the condition of those who do not or cannot enter into ordinary forms of family or other relationships". The more easily measured material deprivation relates to diet, health, clothing, housing, household facilities, environment, and work (Townsend, 1987, page 136). By identifying both social and material deprivation, he is anticipating some aspects of what one might now

call 'social exclusion'. Townsend also lays down the foundation for articulating multiple deprivation as an accumulation of single deprivations.

Townsend's formulation of multiple deprivation is the starting point for our model of small-area deprivation which is presented here in respect of the design of new measures of deprivation for the United Kingdom. Though Townsend's work mainly (though not entirely) referred to individuals experiencing deprivation—single or multiple—the arguments can, in modified form, extend to area-based measures. However, limitations of data availability inevitably cause some of the sophistication of his original concept to be lost in practice. It is currently difficult to measure the percentage of the population experiencing more than one type of deprivation in such a way as to reflect the many different domains of deprivation, though this can be accomplished within the parameters of the variables available in the census by commissioning special census tables (and see Atkins et al, 1996). There may also be scope for more comprehensive individual-level analyses of multiple deprivation in future if the United Kingdom develops its administrative data systems in, for example, the Swedish style (for more on this see Smith et al, 2004). It is possible to look at single deprivations at an area level and state that a certain proportion of the population experiences that deprivation or a proportion experiences some other form of deprivation, and at an area-level describe the combination of single deprivations as area-level multiple deprivation. This approach thus conceptualises multiple deprivation as a composite of different dimensions or domains of deprivation. It, however, says little about the *individual* experience of *multiple* deprivation.

The use of the word 'domains' in respect of indices of deprivation is not our invention. Robson used the term to describe the areas of socioeconomic life from which indicators were selected. He specifically mentions 'environment', 'education', 'income', and 'jobs' (Robson et al, 1995). In another part of the report he groups these further into 'environment', 'skills/socialisation', and 'resource base'. They are not, we would argue, intended to convey discrete dimensions of deprivation as a starting point for constructing an index but rather the 'sphere' from which the indicators of deprivation are drawn (further implications of this approach are given in the section on domain weights below). We use the term 'domain' quite differently. Domains, for us, are area-level dimensions of deprivation which need to be measured as accurately as possible and which aggregate to a measure of multiple deprivation. Thus, each dimension is measured independently with the best indicators available to generate a score or domain measure for each aspect of deprivation. These domain scores are then combined with explicit weighting to generate a multiple-deprivation measure. As will be discussed, the availability of new data has allowed these domains to be described with more precision, and in a more robust and consistent way than has been possible before.

The approach allows the separate measurement of different dimensions of deprivation, such as housing deprivation, education deprivation, and health deprivation. There is a question whether there should be an additional domain for low income, or one that measures the lack of socially perceived necessities (Gordon et al, 2000) (for example, adequate diet, consumer durables, and ability to afford social activities). To follow Townsend, within a multiple-deprivation measure, only the deprivations resulting from a low income would be included, so low income itself would not be a component, but lack of socially perceived necessities would. However, there are no readily available small-area data on the lack of socially perceived necessities, and, therefore, low income is an important indicator for these aspects of material deprivation. Moreover, there are arguments that measures of consumption are themselves problematic as lack of certain items may be by choice rather than inability to pay for them. Therefore, it is appropriate to measure low income itself, rather than the possession of certain items.

We therefore recognise income deprivation in its own right but would not argue that it should be the only measure of area deprivation. Other dimensions of deprivation contribute crucial further information about an area. However, low income remains a central component of the definition of multiple deprivation for our work in the United Kingdom. As Townsend writes, "while people experiencing some forms of deprivation may not all have low income, people experiencing multiple or single but very severe forms of deprivation are in almost every instance likely to have very little income and little or no other resources" (1987, page 131).

'Multiple deprivation' is thus not some separate form of deprivation. It is simply a combination of more specific forms of deprivation, which themselves can be more or less directly measurable. It is an empirical question whether combinations of these different forms of deprivation are more than the sum of their parts, that is, whether they are not simply additive but interact, and may have *greater* impact, if found in certain combinations.

This perspective accommodates the reality of varying combinations of deprivation and disadvantage in different types of areas, which has been a persistent finding on the geographical distribution of different forms of deprivation and disadvantage since the pioneering work of Webber (1975) in Liverpool in the 1970s. But it does raise questions about the addition of items to form a measure of 'multiple deprivation'. And if multiple deprivation cannot be *directly* quantified, then there are problems in technically validating any overall multiple-deprivation measure as this would require something against which the multiple-deprivation measure can itself be compared. If this is correct, then the question of how components in the overall multiple-deprivation measure might be weighted becomes a central question.

Measuring different aspects of deprivation and combining these into an overall multiple-deprivation measure raises a number of questions. Perhaps the most important is the extent to which area deprivation in one dimension can cancel out deprivation in another. Thus, if an area is found to have high levels of income deprivation but relatively low levels of education deprivation, should the latter cancel out the former and, if so, to what extent? Our model is essentially a weighted cumulative one and we argue for limited cancellation effects.

Another question concerns the extent to which the same people or households are represented in more than one of the dimensions of deprivation. In previous indices which used census data, no explicit information is available on this aspect of the conceptual framework. The 'households with no access to a car' may well have been the same households who 'live in overcrowded accommodation'. The combination in earlier indices takes no account of possible double counting nor do the published accounts address the potential problem. Our position is that if a family or area experiences more than one form of deprivation this is 'worse' than experiencing only one deprivation. We are therefore not concerned with eliminating double counting *between* domains—we want this if it is appropriate. To summarise, the model which emerges from this theoretical framework is of a series of unidimensional domains of deprivation which may be combined, with appropriate weighting, into a single measure of multiple deprivation.

Having agreed upon this model, the methodology and statistical techniques should be selected to facilitate its operation. There are a number of steps to this process:

(1) The dimensions of deprivation which can reasonably be combined into a measure of multiple deprivation must be identified.

(2) These dimensions or domains must be measured as accurately as possible with indicators which pass certain tests of fitness.

(3) Problems of unacceptable standard error must be dealt with in a way which does not introduce unintended consequences.
(4) The indicators must be combined in such a way as to best measure the construct in question.
(5) The scores of each domain must be capable of being ranked to generate a relative picture for that aspect of deprivation.
(6) The domain scores or ranks must be standardised and transformed in a way which allows for their weighted combination into an overall index. This transformation must avoid generating implicit weights. All weighting should be explicit. Finally, the transformation should take into account rules from the model about the cancellation properties desired when combining the domains.
(7) Appropriate weights for the domains should be selected.

This approach implies rather more items in total than in earlier overall measures of deprivation. It also requires 'domain specific' items (and not what often happens when, for example, 'educational deprivation' is measured by a mix of education, social, and economic factors in combination). It also requires procedures for combining items *within* any domain index according to clear rules.

The spatial scale

A measure of area deprivation should be able to quantify deprivation at a spatial level lower than local authority, so that policymakers can target resources effectively. In an ideal world, these would approximate to 'neighbourhoods', or at least be small areas with similar characteristics and a standard population size. It is also important that, wherever possible, the indicators and their denominators are available or can be constructed at that spatial level. The availability of data for small areas in the intercensal period has improved with the increasing availability of welfare benefits and other data at the individual anonymised level which can then be aggregated to sub-local-authority-level areas.

At the time of the construction of the ID 2000 there were two possible sub-local-authority geographies available. The first consisted of 1991 Census wards and the enumeration districts which comprise them. The second were the then current (1998) wards. Because there had been considerable local-authority-boundary and ward-boundary changes in England in the mid-1990s, and following consultation, the 1998 ward boundaries were selected. In Wales and Scotland, where boundary changes had also occurred, the then current wards (known as 'electoral divisions' in Wales) were used. In Northern Ireland, where boundary changes were much less frequent, the 1984 boundaries on which the 1991 Census was based, were used. Wards are, however, problematic. They vary greatly in population size (from less than 1000 to over 30 000) and do not always meet the criteria of homogeneity.

Since the construction of these indices, there have been major developments in the construction of statistical geographies. Following the introduction in the 2001 Census of an output statistical geography, where homogeneity and even population size were important characteristics (Martin, 2001), the Office for National Statistics (2003) has developed a statistical geography known as 'Super Output Areas' (SOAs). The lower level SOAs are combinations of adjacent output areas, nest within 2003 ward boundaries, have a relatively tight population specification (mean population of 1519 and standard deviation of 200), and are relatively homogenous. They were constructed with a modified version of the algorithm used to generate output areas. These more closely resemble our 'ideal' geographical unit and were used in the English ID 2004 (Noble et al, 2004, page 16).

Domains and indicators

As we have indicated, it follows from the conceptualisation of multiple deprivation we have articulated that indicators of a particular aspect of deprivation should be combined initially to form domains of deprivation. This process produces a score for each of the domains—a domain deprivation measure or 'domain index'—which can be ranked across the country in question to give a relative picture of each dimension of deprivation. The domain deprivation measures can then be combined into an overall multiple-deprivation measure.

The domains comprising the multiple-deprivation measures have varied in the different indices we have constructed. This variation has been driven partly by the availability and robustness of data, and partly by developments in the conceptualisation of each domain (for a list of the domains in each index, please see table 2). The domains were each presented as a separate deprivation measure or score, as each domain reflects a particular aspect of deprivation. For example, the employment domain captures exclusion from the world of paid work—*not* the low income that may flow from it. Similarly, the education domain does not include markers of income deprivation, such as 'children in receipt of free school meals', as children living in low-income families are measured within the income domain. This approach avoids the need to make any judgments about the complex links between different types of deprivation (for example, the links between poor health and unemployment).

The domains each represent a type of deprivation that is measured as directly as possible, rather than comprising a set of 'vulnerable groups' (that is, groups of people at risk of deprivation). Each domain contains a number of indicators. The criteria for these indicators were that they should be:

(1) 'domain specific' and appropriate for the purpose (as direct as possible measures for that form of deprivation),

(2) measuring major features of that deprivation (not conditions just experienced by a very small number of people or areas),

(3) up-to-date,

(4) capable of being updated on a regular basis,

(5) statistically robust, and

(6) available for the whole of the country in question at a small-area level in a consistent form.

The indicators that were included in the measures of deprivation have been constructed using a range of techniques. Some of the data were obtained at the individual level (with due regard to issues of confidentiality) and aggregated to ward or SOA level; some were obtained at other levels (for example, the Labour Force Survey at local-authority-area level) and then 'modelled down' to ward or SOA level. Postcoded data were assigned to relevant wards or SOAs by using appropriate postcode look-up tables. As far as possible, all the data included relate to one time point (1998/99 for England and Wales, 1999 for Northern Ireland, and 2001 for Scotland, and the later English ID 2004, which relates to 2001).

One problem which had to be addressed at the outset of the construction of the multiple-deprivation measure was the question of how the indicators should be scored or scaled (if at all) to allow fair comparisons between areas and appropriate combination with other indicators. The data were not all in the same units of measurement and if the raw data had been used the results would have been driven largely by the size of the population. For these reasons it was not possible to count the numbers of people experiencing each deprivation and add them together. Instead, where possible, rates or some other standard form of measurement were used, which allows areas of different sizes to be compared.

The small-numbers problem and the shrinkage technique

In some areas, particularly where populations at risk are small, data may be 'unreliable', that is, more likely to be affected by measurement error or sampling error, with particular wards getting unrepresentatively low or high scores on certain indicators. The extent of the 'unreliability' of a score can be measured by calculating its standard error.

This problem emerged in the construction of other indices or measures of multiple deprivation in the past and this prompted the use of the signed χ^2 statistic (see, for example, Robson, 1994). However, this technique has been much criticised for its use in this context because it conflates population *size* with *levels* of deprivation (see, for example, Connolly and Chisholm, 1999). Given the problems with the signed χ^2 approach, another technique—'shrinkage estimation', that is, empirical Bayesian estimation—has been used subsequently to deal with the problem (for England see Noble et al, 2000a, page 16; for Wales see Noble et al, 2000e, page 8; for Northern Ireland see Noble et al, 2001, page 11; for Scotland see Noble et al, 2003a, page 15).

Shrinkage involves moving 'unreliable' ward scores (that is, those with a high standard error) towards another more robust score. This may be towards more deprivation or less deprivation. There are many possible candidates for the 'more robust' score to which an unreliable score could move. We have selected the district mean but others could in theory include the national mean, the means of areas of similar characteristics, or the mean of adjacent wards.

It is our view that moving unreliable scores towards the mean score for the whole country in question would be inappropriate because of the large variation across the country and because we wanted to take into account local circumstances. 'Borrowing strength' from adjacent wards is technically straightforward but is problematic, especially near the edges of towns or other heterogeneous areas where the adjacent wards may have different characteristics (Clayton and Kaldor, 1987). Though shrinking to the mean of wards with similar characteristics is superficially attractive, there are also problems. First, at the time of construction of each of the indices there were no classification systems based on the boundaries which were used. Second, any new classification of 'similarity' would have been contentious and would have warranted a project and consultation process in its own right. Shrinkage to the district mean (which is in essence the same as shrinking to the population-weighted ward mean for a district) has advantages. Like shrinking to adjacent wards, shrinking to the district mean takes into account local socioeconomic features, but by effectively pooling the district wards this overcomes some of the disadvantages of shrinking to adjacent wards in that the impact of heterogeneity is reduced.

It could be argued that 'shrinkage estimation' is inappropriate for administrative data which are, in effect, a census. This is not correct. The problem exists not only where data are derived from samples, but also where scans of administrative data effectively mean that we have an entire census of a particular group. This is because such censuses can be regarded as samples from 'super populations'—one could consider these to be samples in time. For example, in an area there may have only been three babies born in a year, one of which had a low birth weight. If we took another year there may have been four babies born, one of which had a low birth weight. The proportions thus fluctuate between a third and a quarter, probably by chance, even though the underlying at-risk population (that is, health-deprived women) is the same. By contrast, another area might have 200 live births a year with twenty children whose birth weight is low. The 10% this represents is less likely to be the result of random fluctuation. We measure the extent of the 'unreliability' of a score by calculating its standard error.

The actual mechanism of the procedure is to estimate deprivation in a particular ward with a weighted combination of (a) data from that ward and (b) data from another more robust source [for example the local authority (LA) mean]. The weight attempts to increase the efficiency of the estimation, while not increasing its bias. If the ward has a high standard error and a district appears to be an unbiased estimation of the ward score, then the ward score moves towards the district score.

Although most scores move a small amount, only 'unreliable' scores, that is those with a large standard error, move significantly. The amount of movement depends on both the size of the standard error and the amount of heterogeneity amongst the wards in an LA.

The 'shrunken' estimate of a ward-level proportion (or ratio) is a weighted average of the two 'raw' proportions for the ward and for the corresponding LA.[1] The weights used are determined by the relative magnitudes of within-ward and between-ward variability. The 'shrunken' ward-level estimate is the weighted average,

$$z_j^* = w_j z_j + (1 - w_j) z ,$$

where z_j is the ward-level proportion, z is the LA-level proportion, w_j is the weight given to the 'raw' ward-j data, and $(1 - w_j)$ the weight given to the overall proportion for the LA. The formula used to determine w_j is

$$w_j = \frac{1}{s_j^2} \Big/ \left(\frac{1}{s_j^2} + \frac{1}{t^2} \right) ,$$

where s_j is the standard error of the ward-level proportion, and t^2 is the interward variance for the k wards in the LA, calculated as

$$t^2 = \frac{1}{k-1} \sum_{j=1}^{k} (z_j - z)^2 .$$

Combining the indicators into domain deprivation measures or domain indices

For each domain of deprivation (for example, income and employment) the aim is to obtain a single summary measure whose interpretation is straightforward in that it is, if possible, expressed in meaningful units (for example, proportions of people or of households experiencing that form of deprivation). In some domains (for example, income and employment), where the underlying metric is the same and where the indicators are nonoverlapping, the indicators can be simply summed and divided by the population at risk to create an area rate. In other domains, deprivations tend to exist in different spatial and temporal forms so, for example, an area will be education deprived if the young people have poor educational performance or poor school attendance. These two situations coexist in an area but relate to different individuals at any given point in time. In these cases it is hypothesised that an underlying factor exists at an ecological level that makes these different states likely to exist together in a local area. This underlying factor cannot be measured directly but can be identified through its effect on individuals. These variables need to be combined at an ecological level to create an area score.

There are a number of ways in which a set of indicators might be used to identify a single dimension of deprivation. The indicators could be combined, after appropriate standardisation, with weights determined by researcher judgment. This judgment might

[1] Where appropriate, the weighted average is calculated on the logit scale, for technical reasons, principally because the logit of a proportion is more nearly normally distributed than the proportion itself.

be based on some theoretical premise of the relationship between the various indicators and the latent component, or it might be possible to assign weights based on the scrutiny of the intercorrelations of the indicators. This method has been used in such a way as to identify the indicator that had the highest correlation within the set of indicators and then to use this as a 'headline' indicator (Robson et al, 2001).

Alternatively, if we assume the existence of a latent construct of the domain of deprivation in question, factor analysis can be used to generate weights for the indicators. There are a number of problems associated with the accurate identification of such an underlying factor. The variables: (1) are measured on different scales, (2) have different levels of statistical accuracy, (3) have different distributions, and (4) measure, to different degrees, the underlying factor imperfectly. Maximum-likelihood (ML) factor analysis was used with a view to overcoming these problems. Other methods, such as applying a linear-scaling model (that is, adding a large number of items that purport to measure the same construct together to increase the reliability of a scale—assuming error elements to be nonadditive and random), deal with only some. Alternative statistical methods, such as principal components analysis (PCA), do not address all these problems. PCA, for example, ignores measurement error (error variance) or the variables' imperfect measuring of the underlying construct (specific variance). This is because it does not attempt to separate common variance (that is, variance shared between three or more variables) from specific variance and error variance. The appropriate technique, where specific and error variance are suspected [that is, problems (2) and (4)], is a form of common-factor analysis of which ML factor analysis is a type.

The premise behind a simple one-common-factor model is that the underlying factor is imperfectly measured by each of the variables in the dataset but that the variables that are most highly correlated with the underlying factor will also be highly correlated with the other variables. By analysing the correlation between variables it is therefore possible to make inferences about the common factor and indeed to estimate a factor score for each case (that is, ward). This, of course, assumes that the variables themselves are all related to the underlying factor to some extent and are in most cases fairly strongly related to it.

It is not the aim of this analysis to reduce a large number of variables into a number of theoretically significant factors as is usual in much social science use of factor analysis (that is, exploratory factor analysis). The variables are chosen because they are believed to measure a single-area deprivation factor. The analysis therefore involves testing a one-common-factor model against the possibility of there being more than one factor. If a meaningful second common factor is found it would suggest the need for a new domain or the removal of variables. Decisions over whether a meaningful second common factor exists are aided by standard tests and criteria, such as examination of eigenvalues. Before factor analysis was applied the indicators were subjected to the shrinkage technique as described above and transformed to a normal distribution.

Once a satisfactory solution has been achieved, a factor score can be estimated for each ward or SOA. That is, the combined indicators, with weights generated by the factor analysis process, are then used as the domain score.

Standardising and transforming the domain deprivation measures or domain indices

Having obtained a set of domain deprivation measures or domain indices, we needed to combine them into an overall 'index of multiple deprivation'. As domain deprivation measures are each based on very different units of measurement, there needed to be some way to standardise the scores before any combination could take place. A form of standardisation and transformation was required that met the following criteria.

First, it must ensure that each domain has a common distribution; second, it must not be scale dependent (that is, conflate size with level of deprivation); third, it must have an appropriate degree of cancellation built into it (discussed below); and fourth, it must facilitate the identification of the most deprived wards. Transformation of the ranks to an exponential distribution met these criteria.

Other procedures were considered, such as z-scores or untransformed ranks. Use of the ranks for each domain would solve some problems but would introduce others. Ranks would certainly put domains onto the same metric. The symmetrical nature of ranks, and 'z-scores' of normally distributed data, means that a 'good' score on one domain could fully cancel out a 'bad' score on another. This means that a relative lack of deprivation in one domain would have had a major impact on a more severe deprivation in another domain when combined into an overall deprivation result.

The exponential distribution selected meets the criteria set out above in the following ways. First, the technique involves the transformation of each domain so that they each have a common distribution, the same range, and identical maximum and minimum values, so that when the domains are weighted and combined into a single multiple-deprivation measure, the impact of the weights is much clearer. Second, the results are not affected by the size of the population of the ward. Third, the part of distribution in which there is most interest—that is, the 'tail', which contains the most deprived wards in each domain—is spread out. Fourth, it enables one to determine the desired cancellation properties.

The transformation to an exponential distribution was carried out by first ranking the scores in each domain. The ranking standardised the domain scores. These ranks were then transformed to a truncated exponential distribution. For any ward, denote its rank on the domain, scaled to the range [0, 1], by R (with $R = 1/N$ for the least deprived, and $R = N/N$, that is $R = 1$, for the most deprived, where N is the number of wards in the country in question).

The transformed domain, X say, is given by

$$X = -\delta \ln\left\{1 - R\left[1 - \exp - \left(\frac{100}{23}\right)\right]\right\},$$

where δ is a constant and represents a 'family' of transformations with different cancellation properties, and in this case equals 23.

Each transformed domain has a range of 0 to 100, with a score of 100 for the most deprived ward. The chosen exponential distribution is one of an infinite number of possible distributions. The constant (23) determines that approximately 10% of wards have a score higher than 50. When transformed scores from different domains are combined by averaging them, the skewness of the distribution reduces the extent to which deprivation on one domain can be cancelled by lack of deprivation on another. For example, if the transformed scores on two domains are simply averaged, with equal weights, a (hypothetical) ward that scored 100 on one domain and 0 on the other would have a combined score of 50 and would thus be ranked at the 90th percentile. (Averaging the untransformed ranks, or after transformation to a normal distribution, would result in such a ward being ranked instead at the 50th percentile: the high deprivation in one domain would have been fully cancelled by the low deprivation in the other.) Thus, the extent to which deprivation in some domains can be cancelled by lack of deprivation in others is, by design, reduced. The exponential distribution stretches out the distribution so that greater levels of deprivation score more highly.

The issue of cancellation is clearly important for understanding the nature of multiple deprivation. If, for example, there were data on an individual who was

known to be at the top of the income distribution, but who had no educational qualifications, an argument *might* be made that the *lack* of income deprivation should cancel out fully the education deprivation, and that this individual should be judged to be not deprived. (However, even here there would be arguments against such a direct and full cancellation.) Our approach in the measures of deprivation has been to conceptualise the various deprivations as measured by each domain as separate and distinct, though they may have cumulative effects in an area (or for any individual). Thus to be poor *and* in ill health is clearly a worse state than experiencing just one of these deprivations on their own. It would be conceptually inappropriate for someone who is poor but healthy to have their income deprivation discounted because they are fortunate enough to be in good health (though this is in effect what many previous indices of multiple deprivation have sometimes done).

The significant advantage of the family of transformations used is that it gives *control* over the extent to which lack of deprivation in one domain cancels or compensates for deprivation in another domain. In particular, it allows precise regulation (though not the elimination) of these cancellation effects. The transformation technique has been used in a way that reflects a level of cancellation appropriate for this approach to multiple deprivation.

Weighting the domains

One of the most difficult and contentious issues faced by all who seek to construct an overall index of multiple deprivation is the question of what 'explicit weight' should be attached to the various components (Coombes et al, 1995; Noble et al, 2004). The weight is the measure of importance that is attached to each component in the overall composite measure.

In the English Index of Local Conditions (ILC) 1991 (DoE, 1994) and the English Index of Local Deprivation (ILD) 1998 (DETR, 1998), indicators were simply summed, that is to say, given equal weight. Because these previous indices contained more variables relating to some aspects of deprivation than others, they in fact weighted those aspects of deprivation more than others. To take the ILC 1991 as an example, this had seven indicators at ward level which were given equal weight. In fact, three of the indicators related to what might be termed 'housing deprivation'—(overcrowding, lacking amenities, and children in unsuitable accommodation); two to 'income deprivation'—(no car, children in low-earner households); one relating to 'employment deprivation' (unemployment); and one relating to 'education deprivation' (low education participation). In the 1998 update, one of the housing indicators was dropped (children in unsuitable accommodation). The resulting weights for the ILC 1991 and ILD 1998 at ward level are shown in table 1.

In fact, even that is not the whole story—as has been discussed above, the actual process by which indicators or domain scores are standardised and transformed before

Table 1. Domain weights for the Index of Local Conditions (ILC) 1991 and the Index of Local Deprivation (ILD) 1998 for England.

	Domain weight (%)	
	ILC 1991	ILD 1998
Income deprivation	28.50	33.33
Employment deprivation	14.25	16.67
Education deprivation	14.25	16.67
Housing deprivation	42.75	33.33

combination is important, as some standardisation techniques, such as *z*-scores, can result in the introduction of unintended 'implicit' weights.

How can one attach weights to the various aspects of deprivation? That is, how can one determine which aspects are more important than others? As has been shown, simply summing indicators can itself lead to weighting, which may be driven more by the availability of indicators rather than by any conceptual model of multiple deprivation.

There are at least five possible approaches to weighting:
(1) driven by considerations emerging from the literature on multiple deprivation and social exclusion,
(2) empirically driven,
(3) determined by policy relevance,
(4) determined by consensus, or
(5) entirely arbitrary.

In the first approach, account is taken of the available research evidence which informs the conceptual model of multiple deprivation, and weights are selected which reflect this research (Coombes et al, 1995). There are two sorts of empirical approaches that might be applicable. First, a commissioned survey or reanalysis of an existing survey might generate weights. Here, one might generate a proxy for multiple deprivation or exclusion—perhaps in terms of 'socially perceived necessities'—and use multivariate predictive modelling to derive weights. A possible recent data set for reanalysis in this way is the Millennium Poverty and Social Exclusion Survey (Gordon et al, 2000). Second, one might apply a technique such as factor analysis to extract some latent 'factor' called 'multiple deprivation' assuming, that is, that the analysis permitted a single-factor solution (see Coombes et al, 1995; Senior, 2002).

Alternatively, the individual domain scores could be released and weighted for combination in accordance and (proportion) to the focus of particular policy initiatives, or weighted in accordance with public expenditure on particular areas of policy. Another approach would be for policymakers and other 'customers' or experts to be consulted for their views and the results examined for consensus (Coombes et al, 1995).

Finally, simply choosing weights without reference to the above or even selecting equal weights in the absence of empirical evidence would come into the category of 'entirely arbitrary'. Weighting *always* takes place when elements are combined together. Thus, if the domains are summed together to create a multiple deprivation measure this means they are given *equal weight*. It would be incorrect to assume that items can be combined without weighting.

For the English ID 2000 and ID 2004, and the Welsh, Northern Ireland, and Scottish indices, we attempted to take into account relevant research literature (Townsend, 1987; and discussed at length in Bradshaw et al, 2004), as well as views emerging from the consultation process. Both the literature and the consultation processes supported the assignment of the greatest weights to the income and employment domains. Based on these criteria, the weights shown in table 2 were used. For each index, extensive sensitivity tests using various weight combinations were undertaken. Because of the high correlation between many of the domains, the differently constructed indices of multiple deprivation themselves correlated highly (see for example, Noble et al, 2000b).

Conclusion

The aim of this paper was to provide an account of the key principles that were taken into consideration when constructing five recent indices of multiple deprivation within the United Kingdom, and of the statistical techniques that were used to operationalise them. It has been argued that, in order to measure multiple deprivation

Table 2. Domain weights for recent UK indices.

	Domain weights (%)				
	English Indices of Deprivation 2000	Welsh Index of Multiple Deprivation 2000	Northern Ireland Measures of Multiple Deprivation 2001	Scottish Indices of Deprivation 2003	English Indices of Deprivation 2004
Income deprivation	25	25	25	30	22.5
Employment deprivation	25	25	25	30	22.5
Health deprivation and disability	15	15	15	15	13.5
Education, skills, and training deprivation	15	15	15	15	13.5
Geographical access to services	10	10	10	10	na
Social environment	na	na	5	na	na
Housing stress	10	10	5	na	na
Barriers to housing and services	na	na	na	na	9.3
Living environment	na	na	na	na	9.3
Crime	na	na	na	na	9.3

Note: na—not applicable.

at a small-area level, it is essential to have a clear conceptual model and translate this into a series of measures with the best data available. The measures should be driven by the conceptual framework not by the data. The statistical techniques selected to standardise and combine the data should also be chosen to support the conceptual framework. Inevitably, these techniques aim to balance statistical integrity with a reasonable level of transparency.

Setting aside issues relating to specific domains and indicators, which fall beyond the scope of this paper, there are a number of issues relating to the methodology which would benefit from further research. These include possible refinements to the shrinkage estimation technique and, in particular, investigation as to the most appropriate areas from which to 'borrow strength' to increase the robustness of small-area-level indicators. There is also a need for further work on the selection of domain weights—a promising empirical direction for such research relates weighting to subjective wellbeing (Kingdon and Knight, 2003).

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References

Alcock P, 1997 *Understanding Poverty* (Macmillan, Basingstoke, Hants)

Atkins D, Champion T, Coombes M G, Dorling D, Woodward R, 1996 *Urban Trends in England: Latest Evidence from the 1991 Census* (The Stationery Office, London)

Atkinson A B, 1998, "Social exclusion, poverty and unemployment", in *Exclusion, Employment and Opportunity* Eds A B Atkinson, J Hills, Centre for Analysis of Social Exclusion, London School of Economics, London, pp 1 – 20

Bradshaw J, Kemp P, Baldwin S, Rowe A, 2004 *The Drivers of Social Exclusion: A Review of the Literature* Office of the Deputy Prime Minister, London

Cemlyn S, Fahmy E, Gordon D, Bennett S, 2002 *Poverty and Neighbourhood Renewal in West Cornwall: Final Report* University of Bristol, Bristol and Cornwall Health Research Unit, Cornwall College, Camborne, Cornwall

Clayton D, Kaldor J, 1987, "Empirical Bayes estimates of age standardized relative risks for use in disease mapping" *Biometrics* **43** 671 – 682

Connolly C, Chisholm M, 1999, "The use of indicators for targeting public expenditure: the Index of Local Deprivation" *Environment and Planning C: Government and Policy* **17** 463 – 482

Coombes M, Raybould S, Wong C, Openshaw S, 1995, "Towards an index of deprivation: a review of alternative approaches", part 1 of *1991 Deprivation Index: A Review of Approaches and a Matrix of Results* Department of the Environment (The Stationery Office, London)

DETR, 1998 *Updating and Revising the Index of Local Deprivation* Department of the Environment, Transport and the Regions, London

DoE, 1983, "Urban deprivation", information note 2, Inner Cities Directorate, Department of the Environment, London

DoE, 1994 *Index of Local Conditions: An Analysis Based on 1991 Census Data* Department of the Environment, London

Gordon D, Adelman L, Ashworth K, Bradshaw J, Levitas R, Middleton S, Pantazis C, Patsios D, Payne S, Townsend P, Williams J, 2000 *Poverty and Social Exclusion in Britain* Joseph Rowntree Foundation, The Homestead, 40 Water End, York YO30 6WP

Hirschowitz R, Orkin M, Alberts P, 2000, "Key baseline statistics for poverty measurement", in *Measuring Poverty in South Africa* Ed. R Hirschovitz, Statistics South Africa, Pretoria

Holterman S, 1975, "Areas of urban deprivation in Great Britain: an analysis of the 1971 census data" *Social Trends* **6** Office for National Statistics, London, 33 – 47

Inner Urban Areas Act, 1978 *Public General Acts—Elizabeth II* chapter 50 (HMSO, London)

Kingdon G G, Knight J, 2003, "Well-being poverty versus income poverty and capabilities poverty?", CSAE WPS/2003-16, Global Poverty Reduction Group Centre for the Study of African Economies, University of Oxford, Oxford

Kleinman M, 1999, "There goes the neighbourhood: area policies and social exclusion" *New Economy* **6** 188 – 192

McCulloch A, 2001, "Ward-level deprivation and individual social and economic outcomes in the British Household Panel Study" *Environment and Planning A* **33** 667 – 684

McIntyre D, Muirhead D, Gilson L, Govender V, Mbatsha S, Goudge J, Wadee H, Ntutela P, 2000, "Geographic patterns of deprivation and health inequities in South Africa: informing public resource allocation strategies", Health Economics Unit, University of Cape Town, Cape Town

Madhya Pradesh Human Development Report Project Office, 1995 *Madhya Pradesh Human Development Report* Directorate of Institutional Finance, Vindhyachal

Martin D, 2001, "Geography for the 2001 census in England and Wales", paper prepared for Census Geography Roadshow, Office for National Statistics, London

Noble M, Penhale B, Smith G A N, Wright G, Dibben C, Lloyd M, 2000a, "Indices of deprivation 2000", Regeneration research summary 31, Department of the Environment, Transport and the Regions, London

Noble M, Penhale B, Smith G A N, Wright G, Dibben C, Lloyd M, 2000b, "Response to the formal consultations on the indices of deprivation 2000", Department of the Environment, Transport and the Regions, London

Noble M, Smith G A N, Penhale B, Wright G, Dibben C, Owen T, Lloyd M, 2000c, "Measuring multiple deprivation at the local level: the indices of deprivation 2000", Department of the Environment, Transport and the Regions, London

Noble M, Smith G A N, Penhale B, Wright G, Dibben C, Owen T, Lloyd M, 2000d, "Measuring multiple deprivation at the small area level: the indices of deprivation 2000", Regeneration research summary 37, Department of the Environment, Transport and the Regions, London

Noble M, Smith G A N, Wright G, Dibben C, Lloyd M, Penhale B, 2000e, "Welsh index of multiple deprivation 2000", National Assembly for Wales, Cardiff

Noble M, Smith G A N, Wright G, Dibben C, Lloyd M, 2001, "The Northern Ireland multiple deprivation measure, 2001", OP18, Northern Ireland Statistics and Research Agency, Belfast

Noble M, Wright G, Lloyd M, Dibben C, Smith G A N, Ratcliffe A, McLennan D, Sigala M, Anttila C, 2003a *Scottish Index of Deprivation 2003: Summary Report* Scottish Executive, Edinburgh

Noble M, Wright G, Lloyd M, Dibben C, Smith G A N, Ratcliffe A, McLennan D, Sigala M, Anttila C, 2003b *Scottish Index of Deprivation 2003: Full Report* Scottish Executive web document available from http://www.scotland.gov.uk/library5/social/siod-00.asp

Noble M, Wright G, Dibben C, Smith G A N, McLennan D, Anttila C, Barnes H, Mokhtar C, Noble S, Avenell D, Gardner J, Covizzi I, Lloyd M, 2004 *The English Indices of Deprivation, 2004* Office of the Deputy Prime Minister, Neighbourhood Renewal Unit, London

Nolan B, Whelan C, 1996 *Resources, Deprivation and Poverty* (Clarendon Press, Oxford)

Office for National Statistics, 2003 *A Guide to the Neighbourhood Statistics: Geography Policy* Office for National Statistics, London

PIU, 2000 *Reaching Out: The Role of Central Government at the Regional and Local Level* Performance and Innovation Unit, London

Robson B, 1994 *Relative Deprivation in Northern Ireland* Northern Ireland Statistics and Research Agency, Belfast

Robson B, Bradford M, Tye R, 1995, "A matrix of deprivation in English authorities, 1991", part 2 of *1991 Deprivation Index: A Review of Approaches and a Matrix of Results* Department of the Environment (The Stationery office, London)

Robson B, Deas I, Bradford M, Wong C, Andersen M, June 2001 *Deprivation in London: An Alternative to IMD 2000* Centre for Urban Policy Studies, University of Manchester, Manchester

Salmond C, Crampton P, Sutton F, 1998 *NZDep96 Index of Deprivation* Health Services Research Centre, Victoria University of Wellington, Wellington

Senior M, 2002, "Deprivation indicators", in *The Census Data System* Eds P Rees, D Martin, P Williamson (John Wiley, Chichester, Sussex) pp 123 – 139

Smith G, 1999, "Area based initiatives: the rationale and options for area targetting", CASE paper 25, London School of Economics, London

Smith G A N, Noble M, Anttila C, Gill L, Zaidi A, Wright G, Dibben C, Barnes H, 2004, "The value of linked administrative records for longitudinal analysis", report to the ESRC National Longitudinal Strategy Committee; available from Department of Social Policy and Social Work, University of Oxford, Oxford, www.ccsr.ac.uk/methods/events/LS/documents/noble2_000.pdf

Social Research and Western Cape Population Unit, 1999 *Poverty in the Western Cape: An Analysis of Poverty in the Western Cape as Enumerated in the 1996 Census* Department of Health and Social Services, Western Cape Provincial Government, Private Bag X9043, Cape Town 8000

Townsend P, 1979 *Poverty in the United Kingdom* (Penguin Books, Harmondsworth, Middx)

Townsend P, 1987, "Deprivation" *Journal of Social Policy* **16** 125 – 146

Webber R, 1975 *Liverpool Social Area Study 1971 Data, Final Report* Centre for Environmental Studies, London