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Enhancing the Population Census: A Time Series for Sub-National Areas with Age, Sex, and Ethnic Group Dimensions in England and Wales, 1991–2001

Albert Sabater and Ludi Simpson

Ethnicity data from successive censuses are used to compare population change. This paper shows that such comparisons are often impossible, wrong or misleading. Distortions become more severe as the scale of areal units becomes smaller. The paper outlines the four main sources of confusion and applies solutions for England and Wales for 1991–2001: (1) classifications, including ethnic group and age, changed between censuses; (2) non-response varies between ethnic groups, areas and ages and its treatment differs in each census; (3) the census population base changed, counting students at their home address in 1991 and at their educational address in 2001, and being taken on a different date in each year; (4) geographical boundaries used for standard census outputs changed. Each of these factors operates differentially on the outcome.

Keywords: Sub-National Areas; Ethnic Groups; Non-Response; Population Change; England and Wales

Introduction

The 1991 and 2001 Censuses of Population in England and Wales have provided comprehensive data on ethnic groups from national to local areas, thus stimulating new analytical research about the characteristics and distribution of the population

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(Dorling and Rees 2003; Lupton and Power 2004; Parkinson *et al.* 2006; Simpson 2007a). However, some comparisons between censuses are misleading if inconsistencies between censuses are not allowed for.

In order to judge social polarisation over time, Dorling and Rees use '1991 Census data which have both been re-aggregated to 2001 local authority boundaries and meticulously adjusted for over a million people who were not recorded by that census' in order to make the two censuses 'broadly comparable' (2003: 1289). Lupton and Power introduce their briefing on minority ethnic groups in Britain from the Censuses of 1991 and 2001 with warnings of several problems that beset an attempt to make use of the opportunity that a census time series appears to offer:

One is the problem of the use of different ethnic categories in 1991 and 2001, principally the introduction of 'mixed race' options in 2001. . . . Other problems arise . . . because comparisons of 1991 and 2001 Census data probably show greater increases in population than actually occurred, especially in urban areas where undercounting was worst. They also show artificially high increases in urban areas because the 2001 Census counted students at their term addresses, while the 1991 Census counted them at their vacation addresses. . . . For example, Liverpool's population declined by 3% according to the Census figures, and 7% according to the MYEs [mid-year estimates] (Lupton and Power 2004: 2–3).

The contributions of this paper are to specify the problems of census tabulations as indicators of population change, and to overcome them. By providing complete and consistent sub-national mid-1991 and mid-2001 population estimates for very small areas and single years of age, with sex and ethnic group disaggregation, we allow social researchers to undertake more analyses and to avoid misleading analyses.

Background

Other countries face similar problems in constructing accurate time series of full population estimates with an ethnic group dimension. Here we review the experience and the different approaches of the USA, Canada, New Zealand and Australia.

In the United States, the mid-2000 population estimates are derived from the usually resident population recorded by the census of the same year using a cohort component method, thus accounting for demographic change (births, deaths and net migration) between Census day and mid-year in sub-national areas for each age, sex, race and Hispanic-origin group. The approach also takes into consideration the net movement of US Armed Forces overseas. One of the main challenges appears to be the recoding of each of the persons who identified themselves in the 'Some other race' category in the 2000 Census categories to one or more of the five Office of Management and Budget (OMB) race categories, which are used for the presentation of population estimates. Under-enumeration and duplication of persons were thought to balance each other, so no adjustment was made (Siegel 2002; United States Census Bureau 2006).

In Canada, quarterly population estimates are produced without detail of ethnic group (Statistics Canada 2007). However, population projections for visible minority populations for provinces and regions by age and sex are generated by microsimulation. The base population consists of a 20 per cent census sample of permanent residents, which is adjusted for under-enumeration (Bélanger and Caron Malenfant 2005).

In New Zealand, population estimates are produced from the census of the usually resident population. The method is based on a cohort component method which takes into account demographic change between Census night and mid-year by ethnicity, age and sex for sub-national areas. Adjustments for residents temporarily overseas and for non-response are also made to the population estimates following a post-enumeration survey, taking into account national differentials by age, sex and ethnic group, but without area differentials (Statistics New Zealand 2007).

In Australia, population estimates of the resident population by age, sex and indigenous status are similarly derived from the census and from a census post-enumeration survey for sub-national areas. The latter is used to include an adjustment of census non-response to the population estimates by area, sex, age, country of birth and indigenous status, before an additional allowance for change between census day and mid-year is included (Australian Bureau of Statistics 2006).

In the UK, mid-year population estimates with an ethnic group dimension have rarely been produced. This was attributable to the lack of data classified by ethnic group prior to the 1991 Census (Haskey 1988). In the 1970s and early 1980s, however, OPCS (Office of Population Censuses and Surveys) estimated numbers of residents by age, sex and ethnic group (Indian, Pakistani, Chinese, Other and White) using country of birth information (including parents' countries of birth) (Dummer *et al.* 2000). The availability of 1991 Census data by ethnic groups led a number of researchers to devise methods of estimating the ethnic composition of sub-national areas in 1981 (Owen 1996; Peloe and Rees 1999; Rees and Phillips 1996). The 1991 Census output for ethnic groups itself needed adjustment for census under-enumeration. The census offices produced national factors for this adjustment (OPCS and GRO(S) 1994), but since these were based only on national age–sex response rates undifferentiated between ethnic groups, others estimated sub-national minority populations in various ways (Simpson 2002; Simpson *et al.* 1997).

The release of 2001 Census data with an ethnic group dimension represents the second time for which data for local areas by ethnic group are available. After the 2001 Census, ONS has also published estimates of the mid-2001 population for ethnic groups for each local authority area of England (Large and Ghosh 2006), and has revised its estimates of the overall 1991 Census undercount (ONS 2002), thus making previous time series with an ethnic origin dimension less useful.

The next section of this paper specifies four challenges in creating consistent population estimates for 1991 and 2001, and describes our methods to overcome them. The resulting dataset is not only consistent with ONS population estimates for 1991 and 2001, but contains much more age and geographical detail. We then quality-assure

the results through their internal consistency and the external plausibility of the adjustments that have been made.

Method: The Four Challenges for Comparing 1991 and 2001 Census Output

Although the 1991 and 2001 Censuses in Great Britain have measured the principal variables to compare populations over time and space, four standard but difficult problems of data harmonisation over time remain. These four problems are general to any country when comparing population estimates over time. Their impact for England and Wales for the period 1991–2001 is highlighted in Table 1, and described below with an indication of the solutions adopted to overcome them.

(1) Population Definition

Who is included in the definition of population affects the population estimate published (United Nations 1998). In England and Wales, two differences between practice in the Censuses of 1991 and 2001 are significant: the enumeration of students and population date. Whilst the 2001 Census enumerated the whole population at the address of 'usual residence' including students at their term-time address, the 1991 Census enumerated students at their vacation address. The transfer of students from their vacation address to their term-time address has a significant impact on assessment of population change, by increasing the 1991 population in areas with student campuses (often but not always within urban areas), and decreasing other areas from which students leave to study elsewhere. Because population estimates are usually made for mid-year (30 June) rather than Census day (different days of April in 1991 and 2001), an additional allowance for timing is necessary to bring them both to the same population date. Although the net effect of timing is small nationally, its impact locally can be significant.

(2) Treatment of Non-Response

Since it is widely accepted that no census will count the whole population, adjustments are usually made for undercount and in some countries for compensating overcount. In England and Wales in 1991 and 2001 the treatment of non-response was substantially different. In 1991 extra records for people in missed households were included in the census database and published output. However a further 2 per cent were estimated as missed from the census output (OPCS 1993). In 2001 the One Number Census (ONC) integrated a more complete estimate of non-response in the published census counts for all areas (ONS 2003), with further non-response limited to about 0.5 per cent (Simpson 2007b). In both years, the non-response missed from census output was skewed towards young men, urban areas and minority ethnic groups. Plausible estimates based on evidence from post-enumeration surveys can be used to make allowances for this non-response.

Table 1. Enhancements to comparisons between successive censuses

Enhancement, 1991 and 2001 censuses	Global impact, England and Wales	Examples of extreme impact
<i>1. Population definition</i>	53,975 net addition	
a. Students, transferred from vacation address to term-time address (1991 only)	213,628 net gain for 103 districts 159,653 net loss for 273 districts	14,500 net gain to Oxford, 2,600 net loss from Wirrall
b. Population date, change from census day to mid-year		
1991: 21 April to 30 June	43,094 net addition	974 net gain to Lambeth, 442 net loss to Brent
2001: 29 April to 30 June	41,006 net addition	1,081 net gain to East Riding of Yorkshire, 1,746 net loss to Birmingham
<i>2. Non-response not estimated within census output</i>	In 1991, 1.6% addition In 2001, 0.5% addition	Pakistani addition of 6.7% in 1991, 2.1% in 2001 Manchester addition of 4.0% in 1991, 7.4% in 2001
<i>3. Demographic classifications</i>		
a. Age, distribute broad age groups to individual ages	No net impact on population	Largest approximations in smallest areas where 5 age groups published for each ethnic group in 1991, 7 in 2001
b. Ethnic groups 10 in 1991; 6 extra in 2001	Of those in both censuses, 3.2% changed categories	77% of those recorded as Black Caribbean in 1991 were recorded as Black Caribbean in 2001, while a similar number moved from other groups to Black Caribbean
<i>4. Harmonisation of geographical units</i>	139 of 403 local authority boundaries and 4,398 of 9,527 electoral ward boundaries changed, involving more than 1% of their population	The 2001 boundary of the district of York was expanded from the 1991 district to include parts of Harrogate, Ryedale and Selby in 1991
Smallest 1991 areas converted to 2001 Census units		

(3) Demographic Classifications

While not resulting in any change to the total count of population, changes in recording and coding practices can render censuses incompatible, as happened in England and Wales with ethnic identification and age categories. Whilst the 2001 Census recorded 16 ethnic categories, including four mixed categories, the 1991 Census output included 10 ethnic group categories, with no mixed categories. Analyses of ethnic group stability over time using the ONS Longitudinal Study (LS) data have shown that reliable comparisons over time can be made for five groups: White, Indian, Pakistani, Bangladeshi and Chinese, and less reliable comparisons for the Black Caribbean and Black African groups (Bosveld *et al.* 2006; Simpson and Akinwale 2007). The residual ('Other') ethnic groups of both 1991 and 2001 exhibit very low stability and, therefore, are not appropriate for comparisons. Classifications in which groups are combined (such as 'Black') offer greater stability but less meaningful interpretation as they combine groups with very different demographic trajectories. Although date of birth is captured during census fieldwork, published output uses age bands which are not compatible between censuses. For example the upper age in outputs is age 85 and over in 1991 and 90 and over in 2001, while there are further discrepancies for small areas.

(4) Harmonisation of Geographical Units

The geographical boundaries of most countries' administrative units change over time, in ways that prevent calculation of population change directly from the output of successive censuses. In England and Wales, most census geographical units have been affected by boundary changes between 1991 and 2001.

Solutions to Create a Consistent Time Series

We now proceed to describe a framework to solve these problems when comparing ethnic group populations across time and space, using as target geographies the 2001 census boundaries of districts, Standard Table (ST) wards and Output Areas (OAs) in England and Wales.¹

When making population estimates consistent, there are choices regarding the target for consistency. The population estimates created have been designed to be consistent with mid-year official population estimates and to be disaggregated to fine classifications of age and geography to allow re-aggregation for a variety of general uses. These decisions have resulted in the following constraints:

- The population base of the estimates are consistent with (i.e. they add up to) the mid-year population estimates published by ONS without an ethnic group dimension, in 1991 for local authority districts and in 2001 for districts and electoral wards (ONS 2002).

- The population estimates are also consistent with the 2001 population estimates published by ONS with an ethnic group dimension for districts in England (Large and Ghosh 2006). These assume the same non-response rate for each ethnic group to distribute the extra 0.5 per cent or 276,000 population estimated by ONS after the 2001 Census results were released.
- 1991 population estimates are converted to the boundaries used in the 2001 Census output, including the smallest geographical unit, the OA. These include all electoral boundary reviews agreed by the end of 2003, although they are referred to here as '2001 areas'.
- Single year of age to 89 and '90 and over' are estimated for both 1991 and 2001, to allow subsequent aggregation to suitable age bands.
- Ethnic group categories for 1991 and 2001 are maintained in their respective full detail for each set of estimates. The matching of categories to compare 1991 and 2001 is made subsequently by users of the data.

Meeting these constraints involves a set of technical solutions which are detailed in Sabater (2008). The methods adopted to create mid-1991 and mid-2001 population estimates involve two basic principles: (a) incorporating relevant evidence, and (b) scaling incomplete evidence to more reliable information, usually for larger areas. Prime relevant evidence is the census output itself, which is not rejected but is the rock whose imperfections are filled.

Tabulations from the census and its post-enumeration surveys also provide information about the ethnic composition of students, the transfer of students from vacation address to term-time address, migration rates to estimate population change between census day and mid-year and differential levels of non-response by age, sex and ethnic group. Extensive work during the 1990s by the Estimating with Confidence (EwC) research programme, which created an accepted set of small area population estimates for mid-1991 (Simpson 2002; Simpson *et al.* 1997) has also been incorporated, improving on its internal consistency, extending its age detail and using revised estimates for larger areas of the level of non-response in the 1991 census (Norman *et al.* 2008).

Quality Assurance

In this part of the paper we examine the importance of plausible construction of the estimates, to ensure that the results are internally consistent, and thus have a degree of *internal validity*. Also, we present results to allow users to judge whether the datasets and adjustments made to the census 'make sense' of what they expect. This provides a degree of face validity or *external validity*. These approaches to quality assurance are taken from notions of statistical responsibility (expressed well in Radical Statistics Education Group 1982, which in turn draws on Cook and Campbell 1979; see also Bross 1960).

Internal Validity

Each element of the methods explained earlier on was subject to constraints to ensure internal consistency. In addition to full consistency with ONS estimates as discussed earlier, there are no negative populations although adjustments to census output may be negative, for example the net adjustments for transferring students from vacation to term-time address in 1991, and the impact of population change between each Census day and mid-year.

In addition, wherever possible individual adjustments are estimated separately and in small areas, retaining their own coherence and maintaining known patterns of age, locality, sex and ethnic group. The treatment of non-response in 1991 described above is one example. Another is the conversion from 1991 to 2001 Census geographical boundaries, which has used the lowest geographical source unit possible (the 1991 Census Enumeration District) so that spatial differences in age–sex–ethnic-group patterns are respected when constructing the 1991 population for 2001 boundaries. Therefore, internal validity is shown by using assumptions that are equally or more plausible than other possible assumptions.

External Validity

There is no external truth by which to judge the time series, but its analysis may provide some ‘face validity’ of the results if it agrees with expectations. In this section we provide three analyses of the results, one highlighting the impact on national population growth with and without enhancing 1991 and 2001 census totals for four minority ethnic populations, one focusing on national totals for each ethnic group and with detail of age and sex structure, and the other illustrating the impact of adjustments to ethnic groups locally, in Birmingham.

Figure 1 uses estimates reproduced from Peach (1996) and 2001 Census data as published to represent population growth between 1951 and 2001 for four separate ethnic minority populations. The figure highlights the differences using corrected data for 1991 and 2001. The Black Caribbean population shows stability after correction, as a result of the adjustment for non-response not included in the 1991 Census output. This adjustment also contributes to the growth of the Indian group in 1981–91 which is, after correction, seen to be decelerating rather than accelerating.

The following series of graphs illustrates how the 2001 population estimates were derived from Census output, after aggregating the results for all districts to country totals. Figures 2 and 3 show for England the adjustments due to migration with the rest of the United Kingdom (UK) and international migration (beyond the UK) respectively during the nine weeks between census day in April and mid-year. These reveal the importance of emigration from England of the Irish group, which together deduct between 1 and 5 per cent of the Irish population aged in their mid-20s, and will include the return of graduates after study in England.

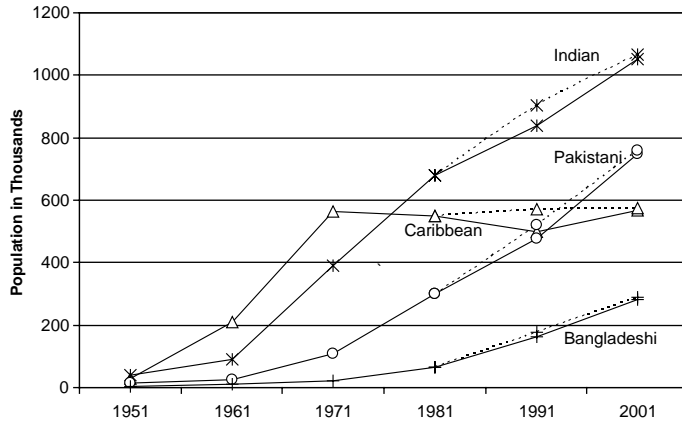


Figure 1. Growth of minority ethnic populations in Britain, 1951–2001

Source: Adapted from Lupton and Power (2004) using 1951–1991 data reproduced from Peach (1996: 9). 2001 data (without correction) from 2001 Census Key Statistics, Table 6.

The rises of population during this nine-week period are principally due to net international immigration of Chinese men and women, Bangladeshi women and Black African men, also focused on young adult ages. Figures 2 and 3 illustrate the assumptions used by ONS for estimates of mid-2001 population for districts of England, which we have replicated.

Figure 4 shows the adjustment of extra non-response identified by ONS after release of census results. The differences between ethnic groups are due to the concentration of each group in particular types of district with different levels of extra non-response. As expected, this extra non-response is mainly concentrated among young male adults. The largest adjustment is for extra non-response among the Black African group, with an increase over the published census population of more than 10 per cent for those in their 20s and early 30s, solely due to their location mainly in London districts with high allocation of extra non-response.

Figure 5 displays the percentage adjustment to the 1991 Census due to the student transfer from vacation to term-time address. This net impact of students otherwise resident outside England and Wales presumably comprises mainly overseas students. The Chinese group experiences the largest addition of students with home address outside England and Wales, with an addition to the initial census population aged 20–24 of about 40 per cent for both males and females.

Figure 6 is a Universal Data Map (UDM: Dorling and Durham 2006) which is used to show the total impact of adjusting each census for a consistent treatment of students, non-response and the move from census date to mid-year. The map showing census output is adjusted only so that 1991 figures refer to 2001 district boundaries. Both the census and the full population estimates displayed in Figure 6 depict a widespread population growth of the non-White groups in districts in

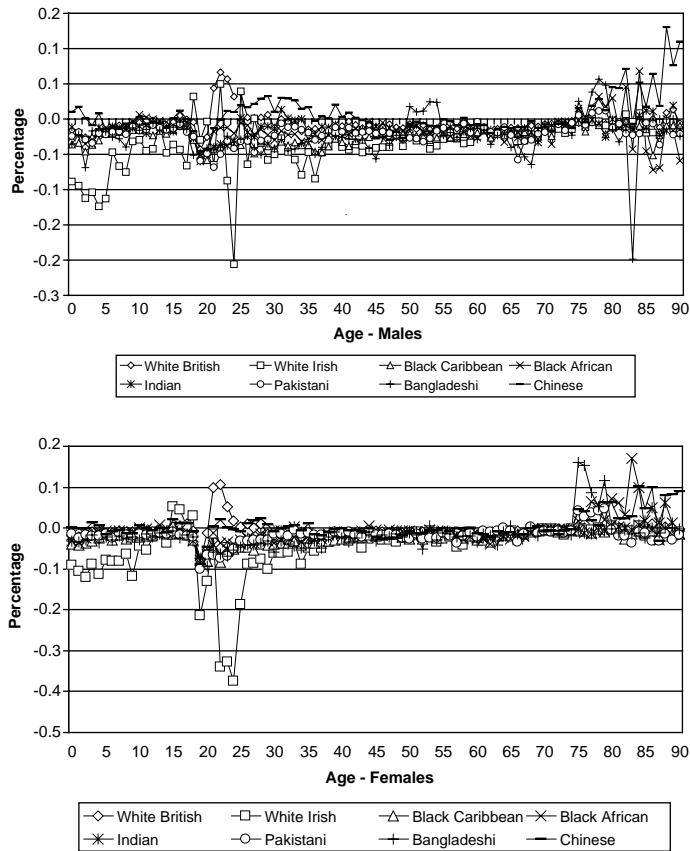


Figure 2. 2001 percentage adjustment due to migration between England and the rest of the UK from Census day to mid-year by age, sex and ethnic group

England and Wales. The only areas showing a decrease are three districts where the USA armed forces have withdrawn in significant numbers during the 1990s (Suffolk Coastal, Cherwell, and Forest Heath). Although both maps show two clear trends of minority population growth and spreading diversity, a comparison of the two maps shows that the census output would be misleading on both trends. First, the unadjusted census over-estimates increase in the non-White population. Second, the over-estimation of non-White population growth is mainly in the urban areas where census undercount is greatest. Thus the spreading of diversity is under-stated by the census. The full population estimates show more clearly that minority population growth is faster outside the urban areas.

The use of full estimates makes some districts not only reduce their population growth but suggests a population decrease rather than an increase. Table 2 shows the adjustments to the 1991 and 2001 Censuses by ethnic group in Birmingham. For this comparison ethnic groups are aggregated to eight categories as advised by ONS (Bosveld *et al.* 2006); Simpson and Akinwale (2007).²

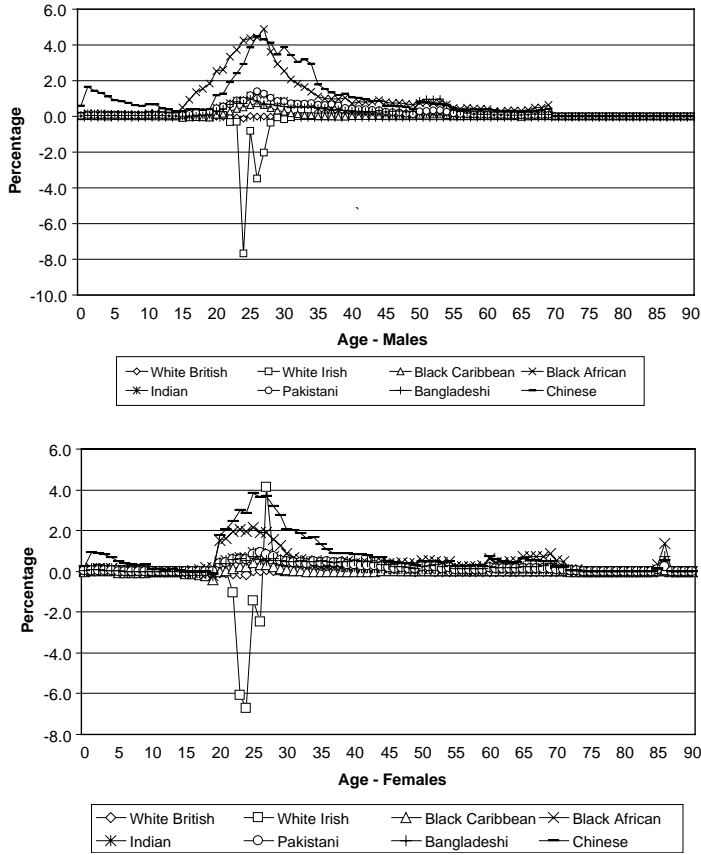


Figure 3. 2001 percentage adjustment due to international migration between Census day and mid-year by age, sex and ethnic group in England

In 1991, the overall impact of adjustments adds 44,000 residents to the census as published, pushing the total population over 1 million. A significant enlargement to the area of Birmingham added almost 9,000 residents from neighbourhoods that were almost entirely White. The largest contributor to the adjustments is non-response, particularly among ethnic groups other than White, which adds 28,000 residents missed by the census in 1991. This represents 65 per cent of the total addition to the 1991 Census as published, and is presented in the table together with the much smaller timing adjustment.³ The impact of transferring students from vacation to term-time address represents a gain, too, for all ethnic groups in Birmingham, adding 6,000 residents. The differences between ethnic groups partly reflect their different age structures, and partly the procedure used to add students which recognises that students moving to Birmingham will not reflect the local ethnic composition. In 2001, the impact of adjustments adds only 7,000 residents to the census as published. This is mainly the result of extra non-response not included in the census output (which adds 9,000 residents to the initial census output, and adds

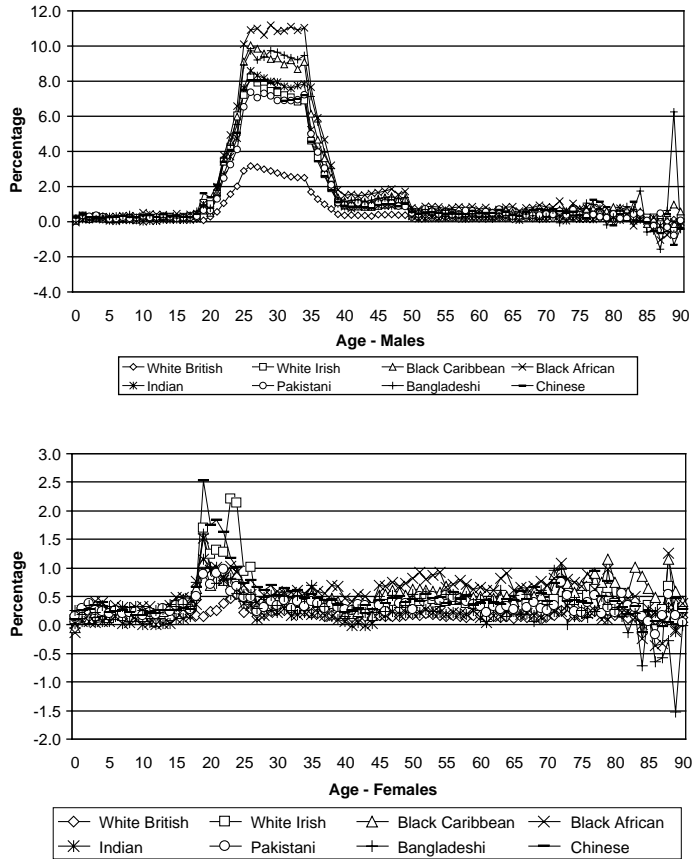


Figure 4. 2001 percentage adjustment due to extra non-response as published by ONS experimental statistics by age, sex and ethnic group in England

slightly greater proportions to the minority ethnic groups than to the White population) and the impact of timing (which reduces the overall population by 2,000 residents).

The Estimates as Building Bricks

The dataset provided as full population estimates contains far too much detail than can be reasonably expected to be valid in every respect. The detail of single years of age and of very fine geographical detail is provided instead to allow aggregation to larger populations. Larger populations, because they incorporate more of the evidence directly available for broader age groups and larger areas, are more likely to be accurately estimated. Similarly, the impact of any conversion errors between the 1991 Census Enumeration District and the 2001 Census Output Area will be small when analyses are carried out using larger geographies. Therefore, the OA estimates are intended as building bricks for aggregation to larger areas to give robust estimates and

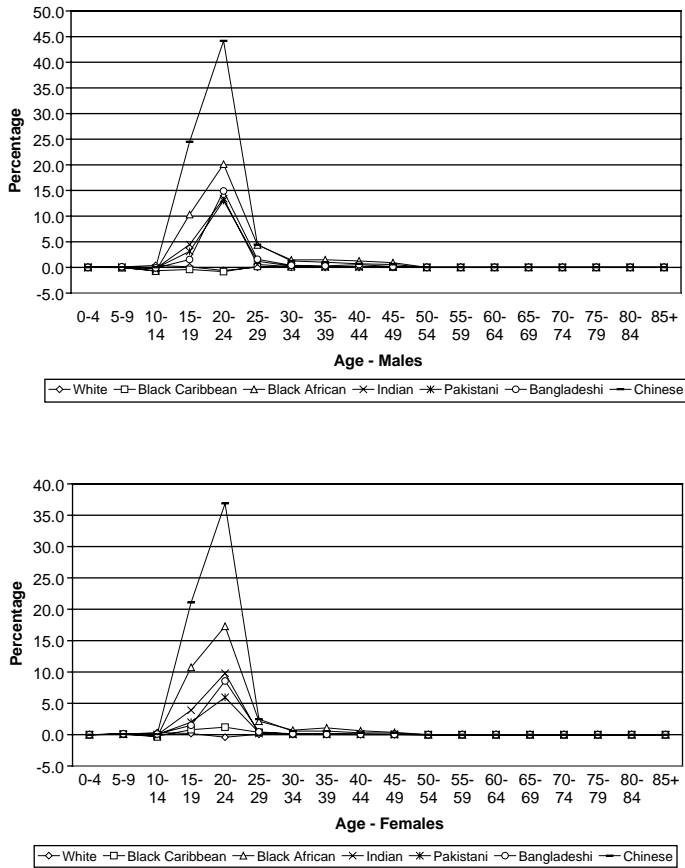


Figure 5. 1991 percentage adjustment due to net student transfer by age, sex and ethnic group in England and Wales

to application-relevant age bands. In this way, the time series of population estimates for ethnic groups is available for *any* area and *any* requirement of age groups.

Discussion

We have presented methodological issues and solutions to enable robust comparisons of population composition between the 1991 and 2001 Censuses. Here we discuss the nature of the advances represented by this paper, the potential that its outputs imply for other studies, and implications for future censuses and demographic studies.

The demonstration that the dataset makes a difference to sub-national comparison of population change of ethnic groups over time represents a wake-up call to those who have used raw census publications uncritically; but also a positive outcome because a solution is provided by these new datasets. The census is by no means rejected. Its local detail is an irreplaceable ingredient of good social science. The message is rather one of caution, and of advice to construct improved analyses wherever possible.

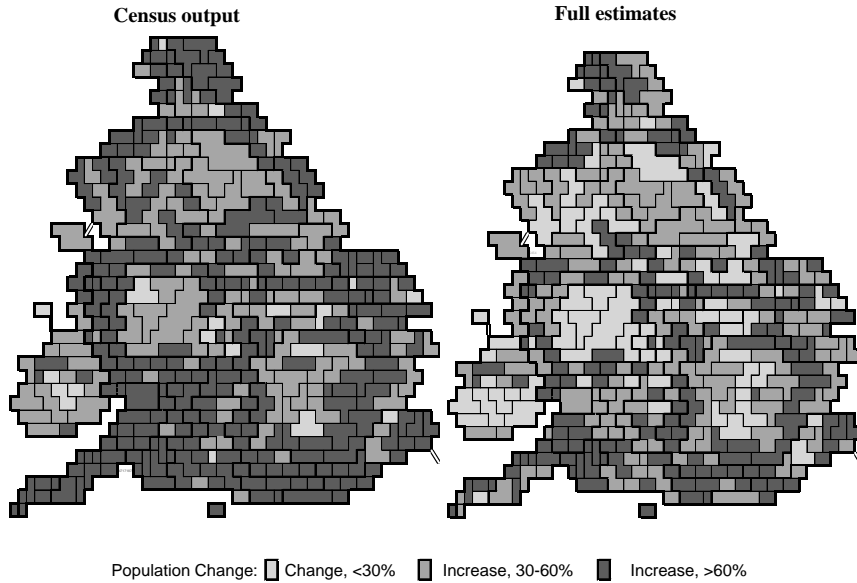


Figure 6. Percentage population change between 1991 and 2001 for non-White groups for 2001 districts in England and Wales

Population studies and a broad range of social, employment and health studies gain from the improved data resource provided by consistent mid-year population estimates, providing denominators for epidemiology, service assessment and monitoring equality. Many analyses of change over time require consistent age and area classifications which are simply not available from census output. Demographic studies of fertility, migration and mortality are improved at a sub-national scale by estimates of change over the decade, of which Finney and Simpson (2009) is one example. Consistent estimates also serve as the base for population projections and forecasts.

Table 2. Adjustments to the 1991 and 2001 censuses by ethnic group, Birmingham district

	Census 1991 as published	Full mid-1991 with 2001 boundaries	Census 2001 as published	Full mid-2001 with 2001 boundaries
Total	960,686	1,004,502	977,105	984,642
White	753,937	772,094	687,406	691,952
Black Caribbean	44,769	53,717	47,832	48,075
Black African	2,797	3,627	6,205	6,430
Indian	51,057	55,512	55,749	56,245
Pakistani	66,081	71,055	104,018	105,137
Bangladeshi	12,733	13,693	20,836	21,062
Chinese	3,318	3,961	5,110	5,230
Other	25,994	30,843	49,949	50,511

The methods used in this paper have focused on estimation of the greatest detail possible, for the smallest census areas of around 100 households, for single years of age, and for the fullest ethnic group classification available in each census year. The advantage of this approach to detail is evident when considering comparison to the next census. Its output cannot be predicted in advance, so the flexibility given by detailed estimates is the only means of coping with this uncertainty. A similar approach has begun to be taken by the ONS itself, whose small area population estimates since 2001 have extended to sub-district levels and are now held as a database of estimates attached to each unit postcode and single year of age, ready for aggregation to the unpredictable boundaries set by government neighbourhood social programmes (ONS 2007). At present these do not extend to an ethnic group dimension between census years, although government reports have suggested that there is demand for such detail (Community Cohesion Panel 2004; Social Exclusion Unit 2000).

For many, this paper will not have gone as far as they would wish—hoping for a consistent sub-national time series of other census variables cross-classified by ethnicity. Within this context, an approach was undertaken when providing a geographically consistent time series for 1971–91 with allowance for non-response in 1991 by Martin *et al.* (2002): the *Linking Censuses through Time* project). Sadly, that time series has not yet been updated to 2001, nor revised following the new population estimates for 1991.

The production of very detailed population estimates does however beg the question of their accuracy for differently sized populations. There is a need to develop statistical approaches which add a measure of reliability to each estimate. Only then will the relationship between population size, characteristics and accuracy of population estimates be available to guide users of population statistics towards robust results.

Acknowledgements

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Notes

- [1] The full population estimates described in this paper are available for small areas at <http://www.ccsr.ac.uk/research/PopulationEstimates.htm>, together with similar estimates for Council areas of Scotland.
- [2] The tables use the following allocation of 1991 and 2001 categories: (a) White: 1991 White, 2001 White British, White Irish and White Other; (b) Caribbean, African, Indian, Pakistani, Bangladeshi, Chinese: in both 1991 and 2001 the single categories with these labels; (c) Other: in both 1991 and 2001 the remaining categories which are residuals or Mixed.

- [3] Non-response and the adjustment from census day to mid-year were not distinguished in the method as applied to ethnic groups in 1991. For the total population, timing accounted for 384 residents and non-response for 28,212 in Birmingham.

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