The demographic drivers of future ethnic group populations for UK local areas 2001-2051

The demographic drivers of future ethnic group populations: English local authorities 2001-2051

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Abstract. Projections of the ethnic composition of the United Kingdom's population presage radical change in the future at both national and local level. The first question that users of such population projections ask is 'what is driving the results?' The answer can be found in the assumptions made for future mortality rates, future fertility rates, future migration rates and flows and the age-sex structure of the starting populations. But it is difficult to disentangle the component effects and demographic momentum. We adapt a methodology proposed and used by Bongaarts and Bulatao in 1999 by extending to national, subnational and ethnic group projections, applying it to projections of the ethnic group populations in English local authorities plus the home countries of Wales, Scotland and Northern Ireland. We assess the roles played by immigration assumptions (the subject of continuous public debate), fertility assumptions, mortality assumptions and internal migration assumptions together with the role of the existing population age structure of each group in each area. Our findings are that positive immigration assumptions contribute to population growth in all local authorities, below replacement fertility lowers the population everywhere, declining mortality compensates for missing babies but substitutes elders and internal migration has very different effects depending on the local authority. Ethnic groups vary enormously in terms of the contribution of the current age structure. The demographic momentum of the White groups produces population declines while it is the most important demographic driver for some but not all of minority ethnic groups. The paper

reports on the methods, assumptions and results associated with a systematic set of 'what if' projections. These enable us to determine the demographic drivers of future ethnic population change for England's local areas over the time horizon 2001 to 2051.

KEY WORDS: Demographic momentum, component assumptions, population projections, local authority populations, ethnic group populations, England

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Introduction

Population projections are one of the most important contributions that demographic analysis makes to societal planning. Analysts feed assumptions about the future levels and distributions of the components of demographic change into a model of the way populations classified by age and sex change over time. Most projection models are based on the cohort-component method, whether implemented with macro or microdata (van Imhoff and Post 1998). The drivers of projection are assumptions about the components of mortality, fertility and migration. The exact specification of the cohort-component model depends on the spatial scale of the populations of interest. At the world scale migration is not relevant. At the scale of country or groups of countries, international migration plays an important role, particularly in developed countries which are the destination of substantial migrant flows. At the sub-national scale (of regions, counties, districts, for example), it is necessary to distinguish between international and internal migration, which may make quite different contributions to population change dependent on the locations of interest. Projections for sub-national areas may be implemented using cohort-component models similar to those for countries which input net migration assumptions for each area or origin to destination migration variables may be explicitly included in a multiregional form of the cohort-component model (Wilson and Rees 2005). When populations of sub-national areas are heterogeneous in their demographic characteristics and behaviour, projections may be separately implemented for each sub-group with the area's population. Ethnic groups are sub-populations which exhibit considerable variety in their demographic structures and behaviours.

It is important to try to understand the future of ethnic group populations for several reasons. Firstly, for many planning purposes such as resource allocation from central government to sub-national areas, populations one to five years in advance of the current year are needed. This is the "nowcast" function of population projections. Secondly, ethnic populations are measured comprehensively for local areas only at a census and afterwards, for more than ten years, we rely on the last census. Projections of ethnic group populations update the base population by age and sex. Official estimates of the mid-year populations of ethnic groups (Large and Ghosh 2006a, 2006b) help

to fill this gap but have some of the characteristics of projections because of the assumptions needed to fill gaps in input data series. Thirdly, businesses find it very useful to have knowledge of the ethnic group populations of their market areas because consumer tastes in food and clothing, for example, are linked to ethnic group. Fourthly, because we have legislation that aims to ensure equality of opportunity for minority groups, we need to monitor into the short term future numbers in local areas in each ethnic group. Fifthly, for longer term planning we need to build potential ethnic heterogeneity into our projections: a changing mix of groups could higher or lower projected populations than if we stuck to population not differentiated by ethnicity. Sixthly, citizens and residents will benefit in the longer term knowing how the ethnic composition of the population will change into their old age (who is likely to be their carer?) and knowing who their children and grandchildren are likely to be going to school with.

For these reasons, we prepared a new set of population projections for local districts in the UK by ethnicity. Descriptions are given in Wohland *et al.* (2010) and Rees *et al.* (2011, 2012). For example, under assumptions aligned to the official National Population Projections, the UK population grows from 59 million in 2001 to 76 million in 2051 and the ethnic minority share of the UK population increases from 17.5% in 2011 to 32.5%. Table 1 summarises the features of these projections which produce outputs for 355 areas and 16 ethnic groups for 50 years at single year of age resolution. The model used is a bi-regional cohort-component model (Wilson and Bell 2004). Revised projections have been produced since the reports cited above. Full details of these revised projections can be accessed via www.ethpop.org.

[Table 1 about here]

A question that we have frequently been asked about these projections is "what was the contribution of the different components/assumptions to the projection results?" We were able to point to the set of assumptions used in each of our main projections and make statements based on judgement about the impact of different drivers. However, those responses were incomplete. A search of the projection literature revealed that John Bongaarts and Rodolfo Bulatao had published a paper

which set out a methodology which made possible quantitative assessments of the different projection drivers (Bongaarts and Bulatao 1999). They suggest that the contribution of each the four demographic factors, migration, fertility, mortality and momentum can be measured by comparing systematically a simple series of hypothetical projections. By demographic momentum is meant the future population changes that would occur if replacement fertility rates were applied retaining current mortality rates and ignoring migration. Momentum reflects the growth or decline implicit in current age structure (Pressat 1985, p.150) In this paper we adapt and expand the Bongaarts and Bulatao method to enable us to determine how component assumptions were affecting the projected ethnic group populations of 355 UK local areas. In particular, we extended the methodology to investigate the contribution of internal migration to future populations and, given some distinct differences in population structures and demographic rates, variations in changes by ethnic group.

The plan for the paper is as follows. In the second section we summarise the methods proposed by Bongaarts and Bulatao (1999). In the third section we extend these methods to include the contribution of internal migration. In the fourth section we present and interpret results for the UK at the country scale. In the fifth section, we show how the demographic drivers vary between ethnic groups. In the sixth section we discuss how the component effects vary across the UK at local area scale for each ethnic group. The final section summarises and discusses our findings.

Review

Bongaarts and Bulatao (1999, p.518) state that "the contribution of each of the four demographic factors to future population growth can be estimated by a simple series of hypothetical projections." These hypothetical projections are set out in Table 2. The *standard* projection is the 1998 Revision by United Nations for the countries of the world by five year age group and sex for every fifth year from 2000 to 2050 (UN 1999). They run the projection omitting net immigration as a *natural* increase projection. In a third projection, the *replacement*, they adjust fertility rates to replacement levels. In their fourth projection they hold the mortality rates constant at benchmark values with replacement level fertility and no international migration. This is the *momentum* projection which reflects the

effect of the 2000 age structure. The rightmost column of Table 2 represents the populations of each projection by the letter P to which is attached an identifying subscript.

[Table 2 about here]

The effects of component assumptions on the projected population can be assessed by comparing the four projections in sequence (Table 3). Two comparisons can be made: differences between successive projections; or multipliers (ratios) relating successive projections. The differences and multipliers can be combined to show how the start populations and standard end population are linked. Bongaarts and Bulatao (1999) showed that, for the world, *Momentum* makes the largest contribution to population growth, *Declining mortality* makes about 50% of momentum's contribution, *Fertility above replacement* makes about 50% of momentum's contribution. *Migration* makes no contribution, by definition.

[Table 3 about here]

Bongaarts and Bulatao also examine the contributions to future population growth for the world divided into "South" (less developed countries) and "North" (more developed countries). The contributions to population growth in the "South" are close to those for the World, as the region makes up 81% of the World population in 2000 and 89% in 2100. Migration makes hardly any difference. The "North" experiences quite different contributions that lead to overall population decline. Migration does make a contribution but it is only small.

We would expect the significance of the contributions of different components to become more diverse as the spatial scale is reduced and to see the importance of migration increase as the spatial scale is reduced. We use the Bongaarts and Bulatao method for the UK local populations of the 16 ethnic groups we used in our projections, which were likely to show very variable impacts of the

different components. We would expect some groups to behave like the "South" and some like the "North". However, we anticipated that the impact of international migration would be much larger.

Methods

In Table 4 are shown the assumptions adopted in a sequence of hypothetical projections for our UK populations. This sequence extends the Bongaarts and Bulatao method to assess the impact of internal migration on future local-ethnic group populations. The first projection, our standard, is the *Trend* projection based on aligning all component assumptions to those in the UK's official National Population Projections generated using a mid-2008 base population (ONS 2009). The second projection, *Natural increase-1*, sets international migration flows to zero. Comparison of P_s and P_n projected populations provides an assessment of the impact of international migration. The third projection, *Natural increase-2*, sets both internal and international migration variables to zero and so provides a no migration scenario. Comparison of P_n and P_i projected populations enables us to assess the impact of internal migration. The fourth projection, *Replacement*, sets the age specific fertility rates for local ethnic group populations so that they sum to a TFR of 2.07 (the replacement rate under UK female mortality conditions, Smallwood and Chamberlain 2005). Comparison of P_i and P_r projected populations yields an estimate of the impact of assumed fertility rates. The fifth projection, *Momentum*, projects the population using demographic rates and flows as estimated for the first mid-year interval, 2001-2, in our projections. Comparison of P_r projected population and the P_0 mid-2001 base population gives an estimate of the impact of the age structure of the population at that time.

[Table 4 about here]

Table 5 sets out the arithmetic that yields estimates of the impacts of component assumptions and momentum. The first panel confirms the definitions. The second panel of the table lists the differences between successive projected populations that we call effects. The third panel lists the ratios between successive projected populations that we call multipliers. The last but one entry in the

second panel shows the combination of effects that add to total population change between base year and projection year. The last entry in this panel gives the additive equation for population change. The last but one entry in the third panel shows the combination of multipliers the product of which yields population change between base year and projection year. The last entry in this panel gives the multiplicative equation for population change.

[Table 5 about here]

Component drivers for the UK total population

We first consider the impacts of component drivers on the future populations of the whole UK. The populations are the sum of 5,680 local-ethnic sub-populations (355 local areas × 16 ethnic groups). Figure 1 graphs the five projected populations. Under the *Trend* (Standard) projection the UK's population grows to 75.8 million people in 2051. This figure is a little lower than the 77.1 million in the 2008-based projections (ONS 2009) and the 78.7 million in the principal projection of the 2010-based UK projections (ONS 2011). The variations are due to small differences in component assumptions.

[Figure 1 about here]

The *Natural increase-1* projection without international migration inputs sees the population grow to 61.0 million. The difference between the two projections is 14.8 million, which represents the impact of international migration over 50 years. This is 87% of the total projected change and includes not just the cumulated net immigration flows over the 2001-2051 but also the further contribution to the population from children and some grandchildren of immigrants born in the UK in the period.

The *Natural increase-2* projection with no migration inputs almost coincides with the Natural increase-1 projection, so that the difference between the projections is only -0.1 million, measuring

the effect of internal migration on UK population change, 2001-2051. Why should internal migration have any effect at all because if the UK population was projected as one unit internal migration would not figure? The reason that there is a small effect is that we project 5,680 sub-populations: over the 50 years internal migration re-distributes the population between local areas which vary in their growth potential. The negative effect suggests that people move internally on average to local areas with lower population growth.

The *Replacement* projection results in populations much higher than the Natural increase-2 projection because rather few of the 5,680 sub-populations experience above replacement fertility (only Pakistani and Bangladeshi groups in the largest cities). The Trend projection assumes that TFR will be 1.84 in the long run. The population in 2051 would be 6.1 million more if fertility rates rose to replacement level.

When we compare the Replacement projection with the *Momentum* projection, we obtain an estimate of the effect of declining mortality on the UK's future population. This is at 5.9 million; almost as large as the fertility below replacement effect. However, these two sets of component assumptions will impact different age groups: the fertility below replacement effect will mean fewer children, while the declining mortality effect means more older people. A comparison of the Momentum projection 2051 population with the mid-2001 base population provides an estimate of the momentum effect, which is 2.2 million or 13% of total change.

Component Drivers for UK ethnic populations

We examine next the impact of component assumptions on the ethnic sub-populations for the UK as a whole. The effects for each ethnic group are assembled in Table 6 and the multipliers are presented in Table 7. UK official statistics have used the concept of ethnicity since inclusion in the Labour Force Survey in the late 1970s with an ethnic question included in the 1991, 2001 and 2011 Censuses. "Ethnic" derives from the Greek work "ethnos" for nation. Ethnicity can be defined using survey or census questions on country of birth, nationality, country of family origin, racial group, language, religion or through self-reporting. Ethnic classifications in the United Kingdom are based on self-

reporting (ONS 2003). The question is formulated after extensive consultation. The resulting categories are a compromise between the demands of pressure groups interested in promoting their own group and the need for a question which everyone can understand. Ethnic classifications change over time because the groups that immigrate change and because people from different groups marry or become partners and have children of mixed ethnicity. Tables 6 and 7 report on population effects for the 16 ethnic groups used in the 2001 Census. The groups are sorted by broad ethnic group, based on racial group: White, Mixed, Asian, Black and Other.

[Table 6 about here]

International migration makes a positive contribution to all groups though some are quite small. By far the largest effect is for the Other White group (whose regions of origin include Western Europe, North America, Africa, Oceania, etc.) and reflects the experience of large migration inflows to the UK in the 2000-2009 decade from other European Union countries, particularly from the 8 east European countries that joined the EU in 2004. There is freedom of migration between EU states and growing harmonization of labour regulations and qualifications makes intra-EU migration easier over time. We forecast continuing strong immigration to 2051 of this group, though its composition may change, with more recent evidence of increasing immigration from recession hit Iberia. The immigration multiplier is the largest (marked in bold) for 8 of the 16 groups (Table 7) and is high (above 2) for the White Other, Indian, Black African, Chinese and Other Ethnic groups Multipliers are low (below 2) for the Mixed Groups including the Black Other as these are groups formed within the country. Immigration multipliers are also low for the Pakistani and Bangladeshi groups where immigration control is strict. For the White British group the multiplier is just above 1 indicating a tiny gain only through international migration.

[Table 7 about here]

The internal migration multiplier is quite close to 1 for all groups with 9 groups below 1 and 7 groups at 1 or above. The Asian and Black groups all have multipliers below 1. As shown in Wohland *et al.* (2010) and Rees *et al.* (2011), these groups experience redistribution out of high population density and high ethnic concentration local authorities in the largest metropolitan areas towards lower density local authorities around the big cities. This means a shift also to join lower population growth regimes, although for all groups the effect on their size is very small.

The fertility and mortality multipliers work uniformly across ethnic groups in opposite directions. In 2001 the total fertility rates of all groups apart from the Bangladeshi were below replacement. Our projections incorporate a rise in TFRs to 2010 reflecting catch up from earlier postponement but thereafter we forecast below replacement fertility with continued convergence for the traditionally high fertility South Asian groups. The fertility multipliers are therefore all below 1 which reduce future population growth. The mortality multipliers are all above 1 reflecting the added population because of improving survival rates and life expectancies increasing at a rate of 0.2 of a year per year. Ethnic differences in life expectancy are moderate (Rees *et al.* 2009), as a result of health services free at the point of delivery (the National Health Service of the UK). Mortality multipliers are highest for groups with older age structures such as the White British, White Irish, White Other, Black Caribbean, Chinese and Other Ethnic groups, where improving survival chances have more impact. For the White British group the mortality multiplier makes the largest contribution to population change.

The momentum multipliers reveal the demographic potentials of the different groups. The White groups and Other Ethnic group have multipliers below 1; the Chinese and Black Caribbean have multipliers just above 1. The Mixed groups have momentum multipliers above 3, while Pakistani and Bangladeshi groups have multipliers above 2. The Indian, Other Asian and Black African groups have multiplier between 1 and 2. These multipliers are directly linked to the 2001 age structures of each group, which are described in detail in Wohland *et al.* (2010, section 11). Overall, the positive momentums of the traditional and mixed minority ethnic groups just compensate for the negative momentum of the largest group, the White British.

Component drivers for ethnic groups and local areas

We generated multipliers for 16 ethnic groups and 355 areas (352 English local authorities – LAs – and the countries of Wales, Scotland and Northern Ireland). In this section of the paper we describe the variation in each multiplier by ethnic group and local areas. The results are summarised in five sets of histograms shown in Figures 2 through 6, one for each multiplier. Each figure contains 16 histograms, one for each ethnic group. The bars record the number of local authorities that fall in class intervals for each multiplier. Each histograms has a vertical line to highlight the location of the neutral one multiplier on each ethnic group graph. Bars on the left hand side of the vertical line indicate multipliers below one and indicate that the component decreases population counts of the ethnic group and *vice versa*. The scales needed to be reset for each group and some scales are stretched by outliers.

Figure 2 depicts international migration multipliers for ethnic groups and local areas. The main contrast is between, on the one hand, the White British histogram which shows significant numbers of local authorities with multipliers below one, indicating a net emigration loss, as well as above one and, on the other hand, all other groups in which, with the exception of one LA, have multipliers above 1, indicating net immigration gain. The LAs are distributed symmetrically around the national multiplier (Table 7) for the groups with higher multipliers. For groups with lower multipliers the distributions tend to have long right tails.

[Figure 2 about here]

Figure 3 shows the internal migration multipliers for ethnic groups and local areas. All histograms show LAs both above and below one, as should be the case with internal migration, in which subnational out-migration and in-migration flows must sum to the same total, with a difference of zero. This leads to fairly symmetric distributions (similar numbers of gainers and losers through internal migration) for the White British, White Other, the Mixed Groups and Chinese groups. The other groups have highly asymmetric distributions with long right tails. Only a few LAs are affected

negatively by internal migration while large numbers of LAs are affected positively. This is a product of the structure of internal migration which leads to a de-concentration of group members for most ethnic minority groups.

[Figure 3 about here]

Figure 4 draws histograms for the fertility multiplier. For the majority of LAs the multipliers fall below 1 and for most groups there are reasonably normal distributions around the national average multiplier. The range of multipliers is fairly narrow in contrast to the quite extreme international and internal migration histograms. A moderate below replacement fertility effect characterises most ethnic group/local authority populations.

[Figure 4 about here]

Figure 5's histograms of the mortality multipliers also tend to have narrow ranges and symmetric distributions but values are generally above 1 except for the Mixed groups where for many LAs the mortality multiplier is below 1. These groups have very young age structures and will experience fast ageing over the projection interval which will inevitably increase the number of deaths in those groups more than declining mortality rates can compensate.

[Figure 5 about here]

The final set of graphs in Figure 6 show the distribution of LAs by the momentum multiplier. For the White British group most of the momentum multipliers fall below 1 but there is a significant minority of LAs in which the current age structure makes a positive contribution to future population. For the White Irish with an old age structure and the White Other group with a mainly working adult age structure, the momentum multiplier impacts on population are mainly negative. For the Mixed

groups with their very young age structures the momentum multipliers all have positive and large effects. They are mostly positive and moderate for the Asian groups but with many LAs where the age structure does not contribute to future growth. The Black Caribbean group has an age structure which is older than all of the minority ethnic groups apart from the White Irish and a majority of LAs have a momentum multiplier below 1. The other Black groups have mainly momentum multipliers above 1, reflecting their youthful age structures. The Chinese group and the Other Ethnic group both have large numbers of LAs with momentum multipliers below 1, reflecting the concentration of their populations in the working ages.

[Figure 6 about here]

To conclude this discussion of local area multipliers, it is useful to look at profiles by ethnic group for two contrasting local authorities. Table 8 shows the multipliers for the London Borough of Newham, the most ethnically diverse local authority in the United Kingdom (and location, appropriately, of the 2012 Olympic Games). International migration is projected to make a significant contribution to population growth 2001-2051 with an average multiplier of 2.14, which is counterbalanced by the significant contribution of internal migration to population decline 2001-2051 with an average multiplier of 0.53 for the borough. The product of these multipliers, measuring the overall effect of migration, is therefore only 1.13. Newham is characterised for all ethnic groups by substantial out-migration through suburbanisation and counterurbanisation to other areas in the UK, balanced by gains from immigration from outside the UK. Below replacement fertility multipliers fall in a narrow range of 0.87 to 0.95 across the groups. Most mortality multipliers are close to the borough average of 1.07 with the exception of the White Irish group, which has an old age structure and therefore benefits more from declining mortality. Momentum multipliers vary substantially between groups with the Mixed, Black Other and Bangladeshi groups having very high growth potential linked to their young age structures, while the White British, White Other, Chinese and Other Ethnic groups have low positive potentials. Only the White Irish group has a momentum multiplier below one.

North Norfolk is a Shire District in the county of Norfolk with a population living in hamlets, villages and small towns, many of whom have migrated to the area around retirement. Even such a rural district is projected to receive boosts to its population from international migration, with high immigration multipliers characteristic of the White Other, Other Ethnic and Chinese groups. The internal migration multipliers contribute most to the populations of 11 out of 16 groups and some of the numbers are very high indeed. This is the result of very small populations in 2001 being augmented by small numbers of internal migrants (e.g. from London) in the 2001-2051 projection interval, under the assumption that the internal ethnic migration pattern measured by the 2001 Census persists. The fertility multipliers for all ethnic groups fall below one, reducing the growth potential of North Norfolk's population. The effect of declining mortality is to boost growth a little for most groups but not for the Mixed. However, growth of the Mixed group populations is assured by their high momentum multipliers. The momentum multipliers for the White groups all fall well below one, the product of their old age structures. The combined multipliers show a very large range with Asian and Black groups having very high values and the White British and White Irish groups having low multipliers.

Discussion and conclusions

In this paper we have extended a method for decomposing the impact of component assumptions in population projections in two ways. First, we have added an internal migration impact/multiplier to those developed by Bongaarts and Bulatao. This is essential when analyzing the projected populations of sub-national populations. Second, we have applied the method, developed for very large populations and have shown it can be applied to small populations.

For UK sub-national areas we have found that for virtually all LAs and ethnic groups immigration has a positive impact on population numbers, below replacement fertility will reduce the populations and the assumption of declining mortality will increase the population, though not by a lot. Variations between LAs and between ethnic groups derive from two components: internal migration and momentum. Internal migration multipliers will by definition be distributed above and below one. A set of gaining local area populations (e.g. Newham) must be balanced by a set of losing

local area populations (e.g. North Norfolk). The White groups mainly exhibit "negative" momentum and the Black, Asian and Minority Ethnic groups mainly have "positive" momentum reflecting the differences in their age structures.

At the moment the methods discussed here are not used by the UK's National Statistical agencies to analyse and make sense of their variant projections. The Office for National Statistics (ONS 2011) carry out some 24 variant national projections. Four of these, the Principal, the Zero net migration, the Replacement and the Constant, correspond to the Standard, Natural, Replacement and Momentum projections of the Bongaarts and Bulatao method and so could be used to compute impacts/multipliers for the National Population Projections. At present the Office for National Statistics do not produce variant projections for sub-national populations in England. National Records Scotland (NRS 2011) has produced variant projections for Scottish Areas but they are not suitable, as yet, for use in our extended method. We therefore recommend the adoption of the impacts/multipliers methods by National Statistical Offices when preparing their national and sub-national projections because of the increased understanding of the results that it provides. Our demographic drivers approach represents a way of organizing scenario projections that show clearly the direct and indirect impact of component assumptions at both national and subnational scales.

Can central or local governments implement policies that will influence the projection outcomes? In general, the answer is only to a small extent. The effect of demographic momentum alone will ensure the sustained growth of minority ethnic groups throughout the 2001 to 2051 period. The continuation of below replacement will limit that momentum growth for most ethnic groups. Can the government nudge up fertility rates to long term replacement? Probably not, as even where pro-natalist policies have been adopted in countries such as France the effect has been small. The last decade has seen UK fertility rates rise by nearly 0.4 children per woman, through the catch up from previous postponement for native women and the increasing share of higher fertility ethnic groups among women in the fertile age range (Tromans *et al.* 2009), neither much influenced by policy.

The impact of our mortality assumptions that rates will continue to decline moderately in future will be to increase the older population. Although health care faces funding challenges, society

will still give a high priority to improving, if possible, provision and advances in dealing with the main cardiovascular diseases and cancers will continue.

We have seen that internal migration has very important redistributive effects that vary according to local authority. Internal migration may be indirectly influenced by national policies but the Coalition Government created in May 2010 has largely handed responsibility to local authorities and businesses for developing healthy local economies, with virtually no help from central government. The Coalition Governments is trying to influence the final component of population change, international migration, through a points system that selects skilled migrants. However, their actions apply only to a minority of international migration flows, not affecting migration from other EU states, family reunification or the UK's obligation to accept genuine refugees and asylum seekers. So we do not anticipate that our international migration assumptions and impact measures will be drastically lowered by current government measures. The UK in 2051 will have a larger and more ethnically diverse population.

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Table 1 Features of the projections for UK local ethnic populations

Feature	Description
Projection model	Bi-regional cohort component separately for each ethnic group
Fertility model	Includes an ethnic mixing process
Ages	Single years from 0 to 100+
Sexes	Male, female
Ethnic groups	16 ethnic groups in the 2001 Census
Areas	352 local authorities in England plus Wales, Scotland and Northern Ireland
Components	Fertility, Mortality, Internal Migration, International Migration
Time interval	Mid-year to mid-year annual intervals
Time horizon	2001 to 2007 = estimates; 2007-2051 = projections
Variants	Trend, Natural increase with internal migration, Natural increase only, Replacement, Momentum
Selected	Trend (uses assumptions of 2008-based National Population Projections)

Source: adapted from Wohland *et al.* (2010)

Table 2 The hypothetical projections used by Bongaarts and Bulatao 1999

Projection variant	Factors affecting future growth	Projected population
Standard	Young age structure, rising life expectancy, fertility above replacement, net immigration	P_s
Natural	Young age structure, rising life expectancy, fertility above replacement	P_n
Replacement	Young age structure, rising life expectancy	P_r
Momentum	Young age structure	P_m

Source: adapted from Bongaarts and Bulatao (1999)

Table 3 Effects of component assumptions on the projected populations

Effect	Projections compared	Differences	Multipliers
Immigration	Standard versus Natural	$D_i = P_s - P_n$	$M_i = P_s/P_n$
Fertility above or below replacement	Natural versus Replacement	$D_f = P_n - P_r$	$M_f = P_n/P_r$
Declining mortality	Replacement versus Momentum	$D_d = P_r - P_m$	$M_d = P_r/P_m$
Momentum	Momentum versus Start Population	$D_m = P_m - P_0$	$M_m = P_m/P_0$
Total change	Standard versus Start Population	$D_t = P_s - P_0$	$M_t = P_s/P_0$

Source: adapted from Bongaarts and Bulatao 1999

Table 4 Assumptions used in a sequence of ethnic population projections for the UK

Driver/Component	Estimates 2001-7	Assumptions 2008-51
	P_s Trend (standard)	
Age structure (base population 2001)	Roll forward	Roll forward
Fertility (above & below replacement)	Our estimates	TFR 1.84 as NPP 2008
Mortality (rising life expectancy)	Our estimates	Decline rates as NPP 2008
Internal Migration	Our estimates	Constant from 2007-8
International Migration	Our estimates	Aligned to NPP 2008
	P_n Natural increase-1(no international migration)	
Age structure (base population 2001)	Roll forward	Roll forward
Fertility (above & below replacement)	Our estimates	TFR 1.84 as NPP 2008
Mortality (rising life expectancy)	Our estimates	Decline rates as NPP 2008
Internal Migration	Our estimates	Constant from 2007-8 on
International Migration	No international migration	Zero international migration
	P_i Natural increase-2 (no migration)	
Age structure (base population 2001)	Roll forward	Roll forward
Fertility (above & below replacement)	Our estimates	TFR 1.84 as NPP 2008
Mortality (rising life expectancy)	Our estimates	Decline rates as NPP 2008
Internal Migration	No internal migration	Zero internal migration
International Migration	No international migration	Zero international migration
	P_r Replacement	
Age structure (base population 2001)	Roll forward	Roll forward
Fertility (replacement)	TFR = 2.07	TFR 2.07 from 2007-8 on
Mortality (rising life expectancy)	Our estimates	Decline rates as NPP 2008
Internal Migration	No internal migration	Zero internal migration
International Migration	No international migration	Zero international migration
	P_m Momentum	
Age structure (base population 2001)	Roll forward	Roll forward
Fertility (replacement)	TFR = 2.07	TFR 2.07 from 2007-8 on
Mortality	Constant at 2001-2	Constant at 2001-2
Internal Migration	No internal migration	Zero internal migration
International Migration	No international migration	Zero international migration

Source: Authors' projections
TFR = Total Fertility Rate, NPP = National Population Projections (NPP), Decline rates = annual percentage decline in age-specific mortality rates

Table 5 Effects and multipliers due to drivers/components

Projected populations
P_s = Trend (Standard based on NPP assumptions)
P_n = Natural increase-1 (No International Migration)
P_i = Natural increase-2 (No Migration)
P_r = Replacement (Fertility rates set to TFR of 2.07)
P_m = Momentum (base population with constant rates/flows)
P_0 = Population at time 0 (2001)
Population effects
$P_s - P_n$ = effect of international migration
$P_n - P_i$ = effect of internal migration
$P_i - P_r$ = effect of fertility above & below replacement
$P_r - P_m$ = effect of declining mortality
$P_m - P_0$ = effect of momentum
$P_s - P_0$ = total change
$P_s - P_0 = (P_s - P_n)+(P_n - P_i)+(P_i - P_r)+(P_r - P_m)+(P_m - P_0)$ = total change
$P_s = (P_s - P_0) + P_0$ = population change equation
Population multipliers
$M_n = P_s/P_n$ = international migration multiplier
$M_i = P_n/P_i$ = internal migration multiplier
$M_r = P_i/P_r$ = fertility multiplier
$M_m = P_r/P_m$ = mortality multiplier
$M_0 = P_m/P_0$ = momentum multiplier
$M_t = P_s/P_0$ = total multiplier
$M_t = M_n \times M_i \times M_r \times M_m \times M_0$ = total multiplier
$P_s = M_t P_0$ = population change equation

Source: Extended by the authors from Bongaarts and Bulatao (1999)
TFR = Total Fertility Rate, NPP = National Population Projections (NPP)

Table 6 Population effects for 16 ethnic groups, UK, 2001-2051

Ethnic group	Effects					
	International migration	Internal migration	Below replacement fertility	Declining mortality	Momentum	Total Change
White British	429.2	96.8	-4,767.9	5,002.4	-1,215.3	-454.9
White Irish	335.2	23.8	-165.2	152.8	-255.8	90.6
White Other	6305.9	-12.2	-74.8	198.7	-355.3	6,062.6
Mixed White & Black Caribbean	94.0	0.2	-103.4	19.6	605.7	616.1
Mixed White & Black African	203.5	4.5	-30.7	8.7	176.7	362.8
Mixed White and Asian	391.5	3.4	-84.1	17.3	435.7	763.8
Mixed Other	431.8	-6.5	-66.0	15.6	342.9	717.8
Indian	1,385.3	-32.5	-151.4	128.4	425.0	1,754.7
Pakistani	834.5	-28.6	-272.8	89.6	932.6	1,555.3
Bangladeshi	153.9	-28.7	-162.3	38.3	467.3	468.6
Other Asian	567.7	-2.4	-31.9	34.3	102.0	669.7
Black Caribbean	224.5	-35.8	-61.3	78.9	40.4	246.8
Black African	1,228.2	-48.7	-92.6	73.4	344.4	1,504.7
Black Other	81.0	-12.6	-27.8	13.1	122.0	175.7
Chinese	793.3	-1.1	-18.9	33.9	8.8	816.0
Other Ethnic Group	1,325.9	0.0	-14.8	35.9	-25.4	1,312.7
All groups	*14,785.3*	*-80.4*	*-6,125.6*	*5,940.7*	*2,151.6*	*16,671.6*
Formula	$P_s - P_n$	$P_n - P_i$	$P_i - P_r$	$P_r - P_m$	$P_m - P_0$	$P_s - P_0$

Source: Authors' computations.
The population effects are in 1,000s.

Table 7 Population multipliers for 16 ethnic groups, UK, 2001-2051

Ethnic group	Multipliers					
	International migration	Internal migration	Below replacement fertility	Declining mortality	Momentum	Combined
White British	1.01	1.00	*0.91*	**1.10**	0.98	0.99
White Irish	**1.28**	1.02	0.88	1.13	*0.82*	1.06
White Other	**6.17**	0.99	0.94	1.18	*0.76*	5.14
Mixed White & Black Caribbean	1.12	1.00	*0.88*	1.02	**3.47**	3.51
Mixed White & Black African	1.84	1.02	*0.89*	1.03	**3.14**	5.38
Mixed White and Asian	1.69	1.01	*0.87*	1.03	**3.22**	4.88
Mixed Other	1.96	0.99	*0.87*	1.03	**3.11**	5.42
Indian	**1.96**	0.98	*0.91*	1.09	1.40	2.64
Pakistani	1.56	0.98	*0.85*	1.05	**2.23**	3.05
Bangladeshi	1.26	0.96	*0.80*	1.05	**2.62**	2.62
Other Asian	**2.60**	0.99	*0.92*	1.10	1.40	3.64
Black Caribbean	**1.38**	0.94	*0.91*	1.13	1.07	1.43
Black African	**2.58**	0.94	*0.90*	1.09	1.69	4.01
Black Other	1.42	0.94	*0.88*	1.06	**2.23**	2.77
Chinese	**3.87**	1.00	*0.94*	1.13	1.04	4.22
Other Ethnic Group	**6.67**	1.00	*0.94*	1.17	0.89	6.55
All groups	**1.24**	1.00	*0.91*	1.10	1.04	1.28
Formula	P_s/P_n	P_n/P_i	P_i/P_r	P_r/P_m	P_m/P_0	P_s/P_0

Notes:
Numbers above one indicate the component assumptions increase the projected population.
Numbers below one indicate the component assumptions decrease the projected population.
The bolded numbers in cells indicate the highest multiplier for an ethnic group.
The italicised numbers in cells indicate the lowest multiplier for an ethnic group.
Source: Authors' computations.

Table 8 Population multipliers for the London Borough of Newham, 2001-2051

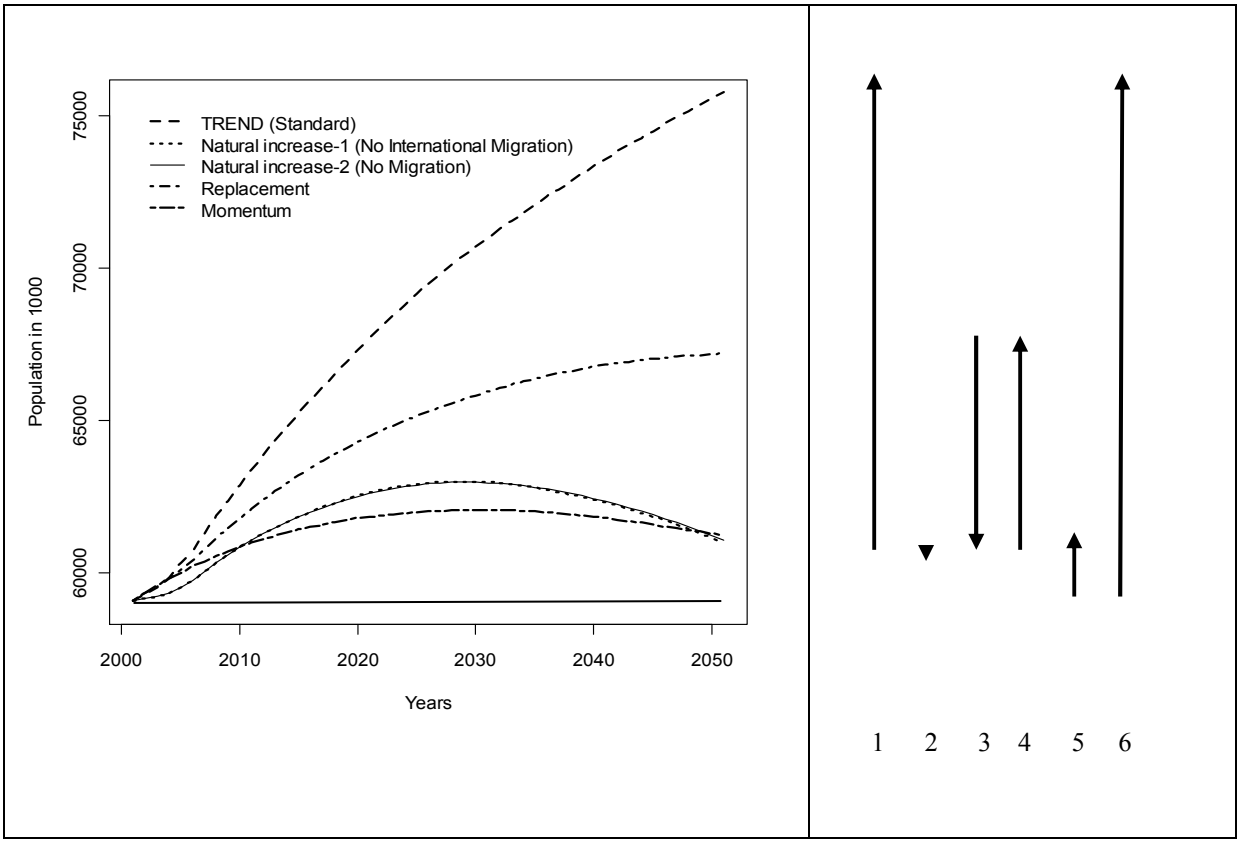
Ethnic group	Multipliers					
	International migration	Internal migration	Below replacement fertility	Declining mortality	Momentum	Combined
White British	1.05	*0.54*	0.93	1.10	**1.17**	0.68
White Irish	**2.00**	0.91	0.95	1.28	*0.48*	1.07
White Other	**6.65**	*0.62*	0.94	1.16	1.11	5.00
Mixed White & Black Caribbean	1.17	*0.63*	0.91	1.02	**3.13**	2.15
Mixed White & Black African	2.04	*0.47*	0.91	1.02	**3.44**	3.08
Mixed White and Asian	1.89	*0.45*	0.87	1.00	**6.28**	4.71
Mixed Other	2.19	*0.45*	0.89	1.01	**4.82**	4.28
Indian	**2.53**	*0.38*	0.92	1.07	1.89	1.80
Pakistani	**2.06**	*0.54*	0.90	1.06	2.00	2.13
Bangladeshi	1.35	*0.60*	0.88	1.03	**2.91**	2.15
Other Asian	**3.13**	*0.39*	0.94	1.09	1.87	2.31
Black Caribbean	**1.56**	*0.53*	0.92	1.11	1.28	1.08
Black African	**2.79**	*0.55*	0.90	1.05	2.16	3.14
Black Other	1.66	*0.37*	0.88	1.02	**3.80**	2.06
Chinese	**4.02**	*0.90*	0.95	1.10	1.30	4.91
Other Ethnic Group	**6.84**	*0.84*	0.94	1.13	1.03	6.32
All groups	**2.14**	*0.53*	0.91	1.07	1.76	1.94
Formula	P_s/P_n	P_n/P_i	P_i/P_r	P_r/P_m	P_m/P_0	P_s/P_0

Source: Authors' computations.
Numbers above one indicate the component assumptions increase the projected population.
Numbers below one indicate the component assumptions decrease the projected population.
The bolded numbers in cells indicate the highest multiplier for an ethnic group.
The italicised numbers in cells indicate the lowest multiplier for an ethnic group.

Table 9 Population multipliers for the Shire District of North Norfolk, 2001-2051

Ethnic group	Multipliers					
	International migration	Internal migration	Below replacement fertility	Declining mortality	Momentum	Combined
White British	1.01	1.54	0.94	**1.08**	*0.69*	1.08
White Irish	1.29	**1.78**	0.95	1.27	*0.25*	0.69
White Other	**4.69**	1.21	0.94	1.12	*0.62*	3.71
Mixed White & Black Caribbean	1.10	2.42	*0.89*	0.97	**5.25**	12.06
Mixed White & Black African	1.63	2.00	*0.89*	0.98	**4.27**	12.15
Mixed White and Asian	1.56	**2.57**	*0.90*	0.99	2.50	9.00
Mixed Other	1.76	2.50	*0.89*	0.98	**2.93**	11.21
Indian	1.77	**46.16**	*0.91*	1.10	1.00	81.97
Pakistani	1.44	**45.33**	*0.86*	0.97	3.38	183.38
Bangladeshi	1.20	**9.80**	*0.90*	1.02	2.37	25.64
Other Asian	2.22	**10.94**	*0.91*	1.05	1.23	28.38
Black Caribbean	1.29	**15.93**	*0.90*	1.07	1.34	26.62
Black African	2.23	**24.67**	*0.93*	1.12	0.75	43.17
Black Other	1.33	**9.90**	*0.92*	1.10	1.19	15.92
Chinese	3.15	**3.69**	*0.94*	1.04	1.09	12.51
Other Ethnic Group	5.02	**5.01**	0.97	1.17	*0.75*	21.29
All groups	1.11	**1.65**	0.94	1.08	*0.70*	1.29
Formula	P_s/P_n	P_n/P_i	P_i/P_r	P_r/P_m	P_m/P_0	P_s/P_0

Source: Authors' computations.
Numbers above one indicate the component assumptions increase the projected population.
Numbers below one indicate the component assumptions decrease the projected population.
The bolded numbers in cells indicate the highest multiplier for an ethnic group.
The italicised numbers in cells indicate the lowest multiplier for an ethnic group.



Key

Projection		Effect		Formula	Population differences (millions)	Population multipliers
P_s	TREND (Standard)	1	International migration	$P_s^{2051} - P_n^{2051}$	75.8 – 61.0 = 14.8	75.8/61.0 = 1.24
P_n	Natural increase-1 (no international migration)	2	Internal migration	$P_n^{2051} - P_i^{2051}$	61.0 – 61.1 = –0.1	61.0/61.1 = 0.99
P_i	Natural increase-2 (no migration)	3	Fertility below replacement	$P_i^{2051} - P_r^{2051}$	61.1 – 67.2 = –6.1	61.1/67.2 = 0.91
P_r	Replacement	4	Declining mortality	$P_r^{2051} - P_m^{2051}$	67.2 – 61.3 = 5.9	67.2/61.3 = 1.10
P_m	Momentum	5	Momentum	$P_m^{2051} - P_0^{2001}$	61.3 – 59.1 = 2.2	61.3/59.1 = 1.04
P_0	Base (2001)	6	Total change	$P_s^{2051} - P_0^{2001}$	75.8 – 59.1 = 16.7	75.8/59.1 = 1.28

Figure 1 Projection results for the UK, 2001-2051, for all ethnic groups combined
Source: Authors' computations

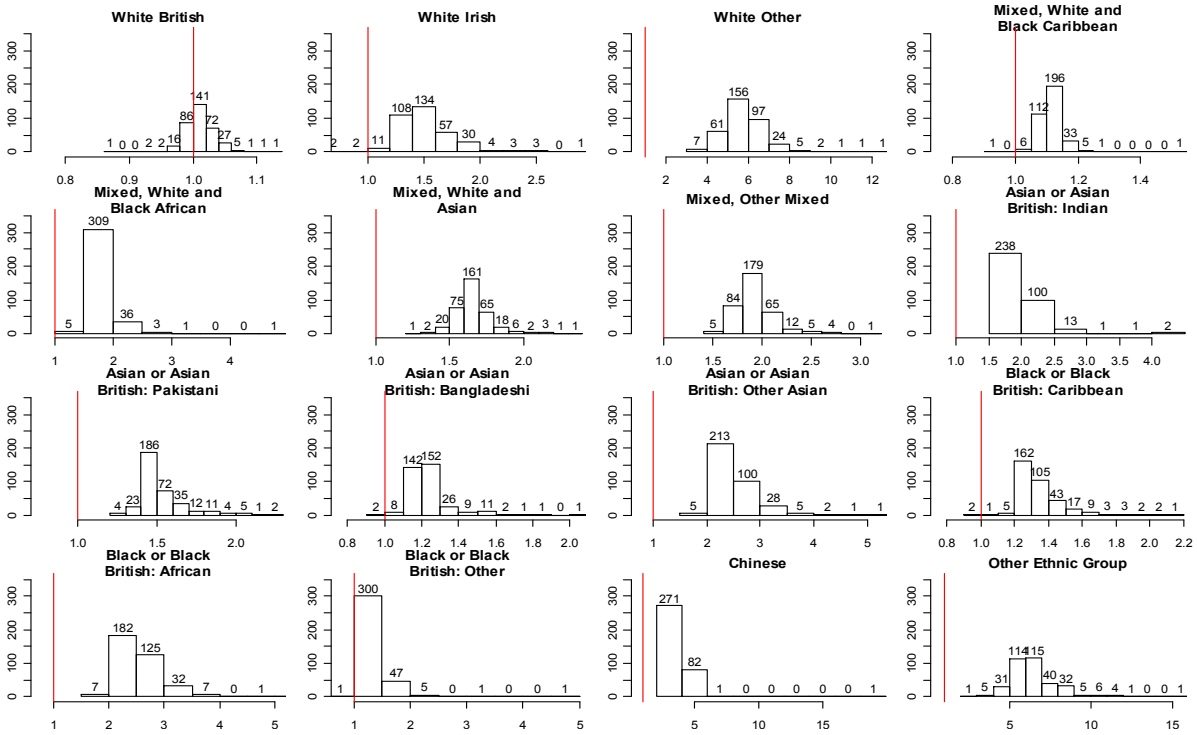


Figure 2 International migration multipliers for ethnic groups and local areas, 2001-2051
Source: Authors' computations.
The graphs plot the ratio P_s/P_n (2051 population in *standard* projection/2051 population in *natural increase only-no international migration* projection). The vertical line indicates an international migration multiplier of 1, i.e. no impact. Values below 1 indicate international migration leads to population loss. Values above 1 mean international migration leads to population gain.

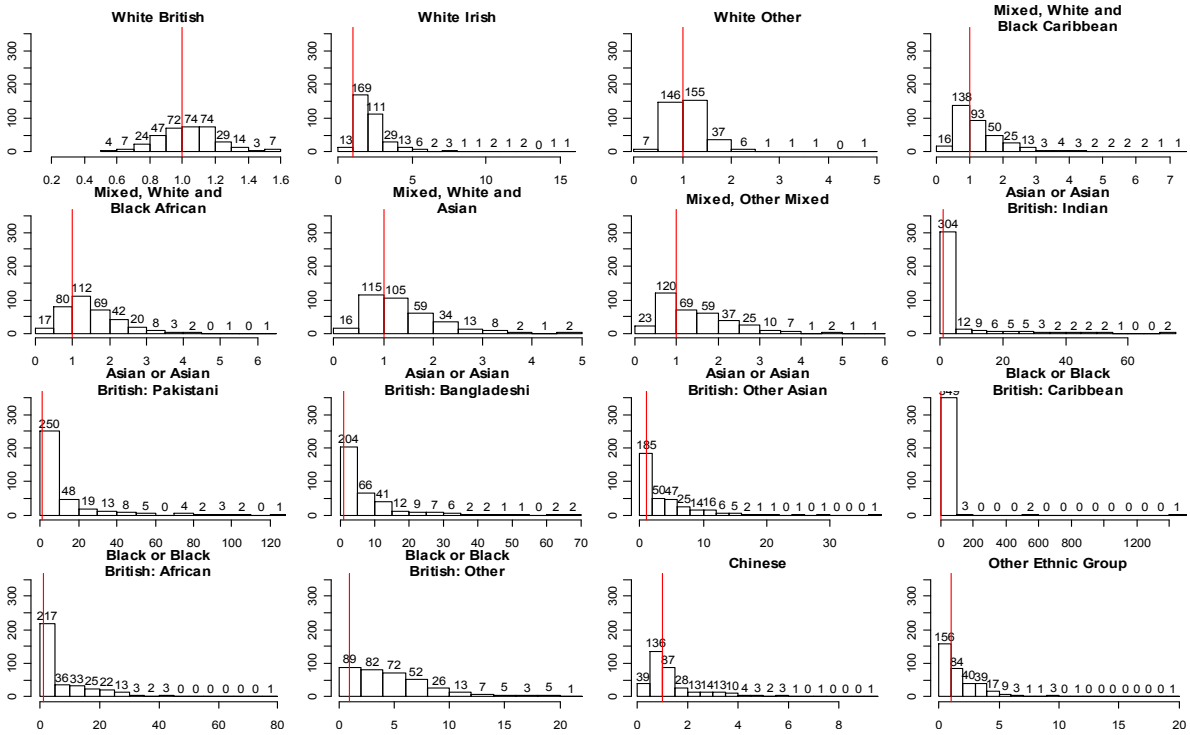


Figure 3 Internal migration multipliers for ethnic groups and local areas, 2001-2051
Source: Authors' computations.
The graphs plot the ratio P_n/P_i (2051 population in *natural increase with internal migration-no international migration* projection /2051 population in *natural increase only-no migration* projection). The vertical line indicates an internal migration multiplier of 1, i.e. no impact. Values below 1 indicate internal migration leads to population loss. Values above 1 mean internal migration leads to population gain.

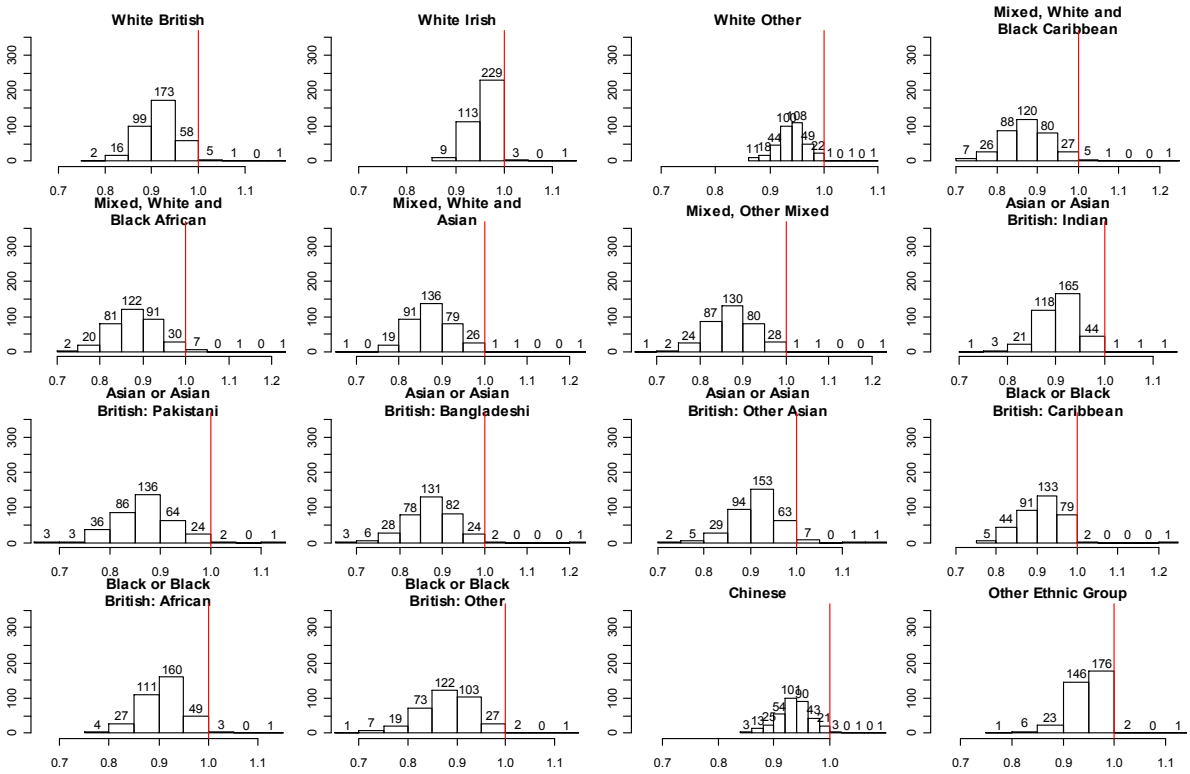


Figure 4 Fertility multipliers for ethnic groups and local areas, 2001-2051
Source: Authors' computations.
The graphs plot the ratio P_i/P_r (2051 population in the *natural increase only-no migration* projection/2051 population in the *replacement fertility* projection). The vertical line indicates an internal migration multiplier of 1, i.e. no impact. Values below 1 indicate internal migration leads to population loss. Values above 1 mean internal migration leads to population gain.

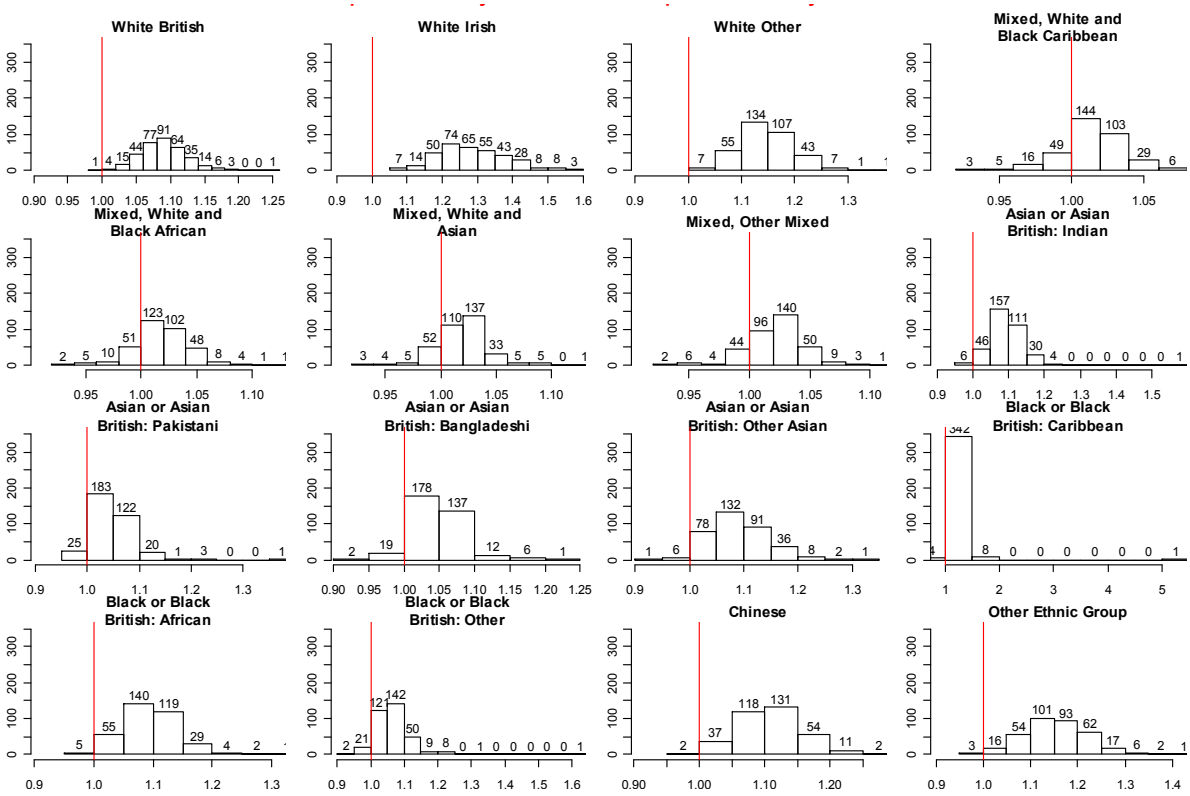


Figure 5 Mortality multipliers for ethnic groups and local areas, 2001-2051
Source: Authors' computations.
The graphs plot the ratio P_r/P_m (2051 population in the *replacement fertility* projection/2051 population in the *momentum* projection). The vertical line indicates an internal migration multiplier of 1, i.e. no impact. Values below 1 indicate internal migration leads to population loss. Values above 1 mean internal migration leads to population gain.

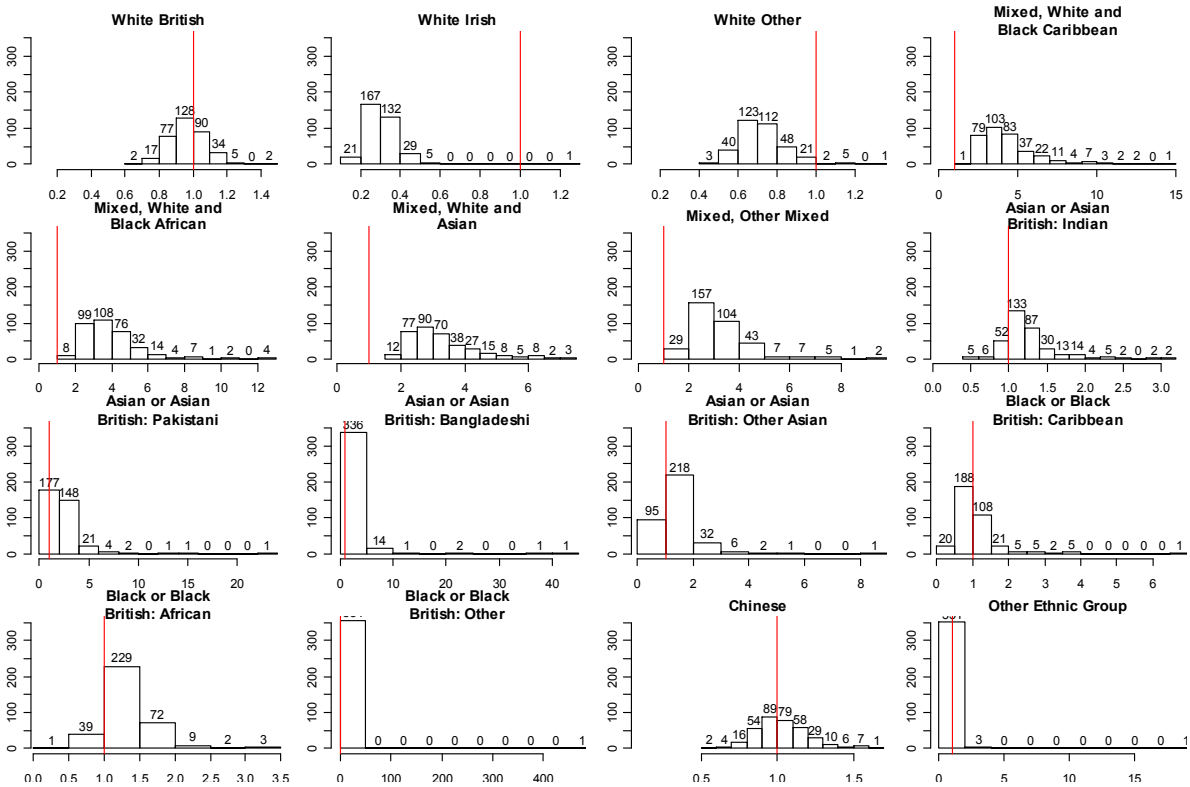


Figure 6 Momentum multipliers for ethnic groups and local areas, 2001-2051
Source: Authors' computations.
The graphs plot the ratio P_m/P_0 (2051 population in the *momentum* projection/2001 population). The vertical line indicates an internal migration multiplier of 1, i.e. no impact. Values below 1 indicate internal migration leads to population loss. Values above 1 mean internal migration leads to population gain.