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Developing strategies for deriving small population fertility rates

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Abstract

Many agencies require population estimates and projections by ethnic group. These projections need ethnic-specific, age-specific fertility rates (ASFRs) but their inclusion is challenging since ethnicity is not recorded at birth registration. Here maternity data are used in a case study of electoral wards in Bradford, West Yorkshire, to develop fertility rates for small populations for a 1991 based projection. The challenge is to capture local variations in fertility by ethnic group when data are sparse.

Here, small areas are grouped together using cluster analysis to define combinations with similar sociodemographic and fertility experiences so that the sparse data can be aggregated for reliable ethnic fertility rates to be estimated. For comparison, the data were aggregated into the 1991 Office for National Statistics classification. The fertility rates by single year of age for all area types were smoothed using the Hadwiger function.

The accuracy of the ASFRs to predict births was assessed using mean absolute percentage error. The results showed that for some minority groups, district-level, ethnic-specific fertility rates produced the most accurate birth estimates even though based on a larger area. This implies that rates created may be informative about the local area for ethnic group White but not in the same way for smaller ethnic groups.

In terms of grouping strategies we recommend that existing classifications are assessed to determine how well variations in rates are stratified before embarking on a custom scheme. Where population sub-groups are small in some areas, it may be more reliable to use rates derived for larger areas and apply these to local populations. Inevitably, the rates used in a projection are a compromise but hopefully will still capture important dimensions of population change.

Keywords: Age-Specific Fertility Rates; Ethnic fertility; Hadwiger function; Area Classification; Small number problems

Developing strategies for deriving small population fertility rates

Introduction

In the UK, population statistics are needed at the small area level to enable the allocation of adequate resources and services in relation to health, employment and housing needs (ONS 1999; Simpson 1997, 1998; Rees et al. 2004). The collection of population statistics by ethnic group relates to the need to monitor discrimination but extends beyond this so that agencies can make informed decisions where there is a requirement for ethnic-specific services (Ní Bhrolcháin 1990; ONS 2003; Simpson 1997, 2002).

Local government and similar agencies therefore require population estimates and projections for planning and resource allocation for varying subdistrict geographies, and often by subgroups, such as ethnic groups (Haskey 2002; Simpson 1998, 2002; Williamson 2007). A projection by ethnic group requires relevant demographic component inputs (Norman et al. 2010) including ethnic, age-specific fertility rates (ASFRs). The inclusion of these rates is challenging since ethnicity is not recorded at birth registration in the UK. It is particularly challenging when attempting to capture local variations in fertility levels by ethnic group when the data are sparse.

This paper explores various strategies to group small area populations together to alleviate small number problems. We use maternity data for thirty electoral wards in Bradford, West Yorkshire, to formulate fertility rates for a 1991-based population projection. We use six ethnic groups: White, Indian, Pakistani, Bangladeshi, Black and 'other' (Chinese and any other combinations) which are a simplification of the groups used for the UK's 1991 Census.

The lack of data to create small area, age-specific fertility rates by ethnic group

There are Office for National Statistics (ONS) estimates of local authority populations by ethnic group from 2001 (Large and Ghosh 2006) but ONS projections of future populations do not have an ethnic breakdown so there is no official view of how these populations will change. Recently, academic research has produced projections by ethnic group at both national (Coleman 2010) and local authority district levels (Norman et al. 2010; Wohland et al. 2010). Whilst the ONS estimates and academic projections include calculations of age-specific fertility by ethnic group, none of these address the challenge of estimating fertility for subdistrict, small area geographies.

Birth registrations in the UK have recorded the mother's country of birth (CoB) since 1969 but no information is collected on the ethnic group of mother or child (Sporton and White 2002; Storkey 2002a). CoB has been used as a proxy for ethnicity, but is less applicable now than a few decades ago since many immigrant groups are in their second and third generations in the UK.

Census data can be used to estimate age-specific ethnic fertility. The 1991 Census asked two questions relating to ethnic origin: indirectly through the question on CoB; and, for the first time in the UK, directly through a question on ethnic group (Coleman and Salt 1996; Ahmad 1999), though not without criticism (Aspinall 2001; Haskey 2000). Williamson (2003) estimated national-level ethnic-specific ASFRs from 1991 Census special table 4PV based on a 10% sample of resident females aged 15-59 by ethnic group, age, country of birth, and number of children. Small area fertility cannot be calculated from this source unfortunately. In the 2001 Census, a revised question on ethnicity was asked. Using a commissioned table from the 2001 Census for England and London, Large and Ghosh (2006:5) estimated ASFRs by ethnic group using a 'mothering ratio' for each childbearing age by ethnic group for women with children aged 0.

A promising data source, the Hospital Episode Statistics (HES), can be used to estimate ASFRs subnationally, since ethnic group has been recorded at hospital admission since 1995 (Aspinall 1995). Here we need indicators of ethnic fertility for 1991 and use a similar source, the Bradford Birth Statistics System database.

Data and methods

Data to calculate age-specific fertility rates

Birth statistics for the calculation of 1991 ASFRs originate from the Bradford Birth Statistics System (BBSS) database. These data were provided by Bradford Health Authority and are based on birth extracts compiled by Bradford Community Health Trust and the Airedale NHS Trust from the Family Health Service Patient Register (Simpson 2000). The BBSS is similar to HES data used by the Greater London Authority (GLA) for London (Klodawski 2003; Bains and Klodawski 2004). Both sources record ethnic groups. The ASFR denominators were derived from population estimates for females produced by West Yorkshire Council and GMAP (Rees 1994) and were made consistent with the ONS mid-1991 mid-year estimates. Numerators and denominators were linked to the 1991 ward geography, harmonised to the same ethnic group categories and available by single year of age. Age-specific fertility rates by single years of age enable annual population projections to be made.

Similar to other estimates of fertility rates (e.g. Congdon 1993; Smith et al. 2001; Storkey 2002b), 1991 ASFRs used a five year average number of births, from 1989 to 1993, in the numerator. There were 37,557 births recorded in the BBSS to women aged 15 to 49 in Bradford district during 1989-1993, with 36,173 containing full age and ethnic group information. The ASFRs by ethnic group were calculated as:

$$f_x = \frac{\text{Births for 1991 (average 1989 - 93) to women aged } x \text{ last birthday at the time of birth}}{\text{1991 Mid - year population of women aged } x \text{ last birthday}}$$

(after Hinde 1998: 97)

Modelling Fertility Age Profiles

> While one would expect fertility to be a smooth function of age […] a set of observed age-specific fertility rates tend to show a rather rugged curve, particularly in small populations. […] When it is reasonable to ascribe such "irregularities" to accidental circumstances, one may get a better picture of the underlying fertility by fitting some nice mathematical function to the observed values. (Gilje 1969: 118).

Despite aggregation of ethnic groups from the 1991 Census categories and the use of births averaged over 1989-1993, single year of age rates are still based on sparse data and require smoothing so that 'ragged' (Congdon 1993) fertility rates can be used reliably in population projections. Smoothing methods mainly fall into two types: parametric and non-parametric. Parametric methods include curves or model schedules and polynomials (Brass 1960; Hoem et al. 1981). Non-parametric methods include splines and kernel methods (Congdon 1993; Schmertmann 2003).

The method applied here is the Hadwiger function as it is widely used for fertility modelling (Chandola et al. 1999, 2002; Congdon 1993; Yntema 1969). The Hadwiger function was used here because it has been applied successfully to estimate ASFRs by single years of age for subnational areas (see below), is based on a small number of parameters and is straightforward to program. The Hadwiger function is preferable to polynomials and splines since these can result in oscillation at end points and return negative values (Gilje 1969; McNeil et al. 1977; Williamson 2007), though splines can prove useful for the interpolation of five year rates to single year of age ASFRs (McNeil et al. 1977; Nanjo 1986). A breakthrough in the use of the Hadwiger function for modelling fertility was the version independently derived by both Yntema (1969) and Gilje (1969) (cited by Hoem et al. 1981: 236), but there has been debate over both the number of parameters and their interpretation (for example, Chandola et al. 1999).

As noted above, the Hadwiger function has been applied to subnational data. Gilje (1969) fitted versions of the Hadwiger function to Norwegian municipalities. Hoem and Holmbeck (1975) fitted the Hadwiger function to various Swedish and Norwegian communes and Hoem and Berge (1975) applied it to Norwegian fertility data for 77 'fertility regions'. It has been used in the London Demographic Projections by the Greater London Council (now the GLA) (Congdon 1990; Hay and Hollis 2005). In terms of population subgroups, Chandola et al. (2002) fitted a Hadwiger 'mixture' model to the non-White population in the US and the Maori population in New Zealand.

Bradford as a Case Study

Fertility varies by ethnic group (Dubuc 2009; Coleman and Dubuc 2010) and these variations need to be incorporated into population projections (Norman et al. 2010). The cosmopolitan university city of Bradford provides a useful case study. Its non-White ethnic groups comprised 15.5% of the total population in 1991 and there was available a data source on small area fertility by ethnic group. The data sources used here

show that in 1991 Bradford had total fertility rate (TFR) of 1.98 for all women, higher than the TFR for England of 1.83 and a younger profile of fertility (Figure 1). The thirty wards of Bradford vary in population size, ethnic composition and TFR with the ward level TFRs ranging from 1.56 to 2.87 (Table 1). Ethnic group TFRs in Bradford range from 1.52 to 4.12 (Table 2).

[Table 1 about here] [Figure 1 about here] [Table 2 about here]

In deriving ward level fertility rates for use in population projections we are faced with the problem that small numbers preclude the calculation of ethnic-specific, ward-level ASFRs. Since there are thirty wards and six ethnic groups, this means that fertility rates for 180 subpopulations are needed. However, because there are zero counts of females of childbearing years in some non-White groups in several of Bradford's wards there are only 150 of these subpopulations present in 1991. Since data are needed to enable the calculation of ASFRs by single years of age, the numbers (populations and births) are too small to estimate reliable ethnic-specific, ward-specific ASFRs for all these subpopulations.

Since fertility varies widely by both ward and ethnic group, ASFRs for use in a population projection need to capture both the ethnic and geographical dimensions of variations in fertility. Some of the geographical variation may be explained by the distribution of ethnic groups and some by other sociodemographic variations. Reducing the set of ASFRs is a compromise between estimating robust rates and losing ethnic-specific, ward-level fertility detail through aggregation of areas. Grouping amalgamates wards to boost numbers whilst retaining the characteristics of their underlying populations (Hoem and Berge 1975).

Grouping Strategies

Demographic behaviour displays distinctive patterns across area types (see, for example, Norman and Bambra 2007 on mortality; Stillwell et al. 2008 and Dennett and Stillwell 2010 on migration; Norman 2010 on fertility and infant mortality). To alleviate the problems of sparse data, areas with similar characteristics, even if not geographically contiguous, can be grouped together and the fertility rate inputs aggregated. Grouping may be based on demographic rates, urbanization, degree of deprivation or a 'geodemographic' classification. The groupings investigated here are based on the 1991 Census data; the year for which the fertility rates are required. The fertility measures used to assess the area groupings are ward level TFRs. ASFRs are calculated once areas have been grouped into what are termed 'Bradford Fertility Areas'.

Figure 2 maps the ward TFRs listed in Table 1 demonstrating that fertility is generally higher in and around Bradford city centre (in the south-east). Fertility is also high for wards in the Keighley area (in the north-west). The simplest strategy would be to group the thirty wards into TFR quintiles or, to use the degree of urban-ness (ONS/GROS 1997). However, neither approach is workable in Bradford because of small population sizes for the non-White groups in many of the aggregations.

[Figure 2 about here]

Initial explorations show strong inter-relationships between the ward level TFRs, the distribution of different ethnic groups and deprivation indices measured by both Carstairs and Townsend schemes (see Senior 2002).

We know that different ethnic groups have different fertility levels (Dubuc 2009), that these levels vary subnationally (Norman et al. 2010) and that the sociodemographic variables which relate to fertility can also have distinct geographies (Boyle 2003). A scheme which captures the multivariate nature of the inter-relationships is therefore needed.

Grouping wards using geodemographic classifications

Wards can be grouped using an existing general purpose classification or by developing a classification which incorporates fertility levels and variables related to fertility. Both options are considered here. Initially, the emphasis is on creating an application-specific classification then an 'off the shelf' measure is used and found to give comparable results.

Cluster analysis is an appropriate method to classify a set of areas with distinctive fertility rates as it utilises spatial differences or similarities across the range of variables specified (Sharma 1996). For a classification of fertility, a set of input variables is needed. Smith et al. (2001) and Bongaarts (1978) identify factors which can influence fertility with the latter grouping factors and their relationships with fertility into indirect and direct determinants. Indirect determinants include socioeconomic variables many of which are available at ward level from 1991 Census data, though there is no information on income.

Here, in addition to the TFR and percentage of non-White ethnic group in each ward, several other variables are included in the classification to capture different socioeconomic influences on fertility and to function as a proxy for deprivation: the percentage of economically inactive people; households renting from local authorities; households with no car; households with no facilities; households with a density of more than 1 person per room; population aged under 16; and those reporting limiting long-term illness. The variables were standardised since the TFRs range from 1.56 to 2.87, whereas the Census variables are percentages and vary in their means and ranges. The results of a five cluster solution using the k-means method are listed in Table 3. Star-plots in Figure 3 display the average percentages across wards for most of the variables used in the clustering process. Not all variables are shown because their scales are not comparable.

[Table 3 about here] [Figure 3 about here]

The clustering of wards in Bradford reported above was conducted using only a small number of 1991 Census variables. An alternative classification was considered that clustered wards using more variables; the 1991 ONS Area Classification (Wallace and Denham 1996). To assess this approach, TFRs were calculated for wards which fell into different clusters in the ONS Area Classification. Whilst there are minor differences in the groupings of wards (in the lower status and deprived areas, for example), the fertility rates using the k-means method are of a similar level (Table 3). The TFRs for this classification clearly stratify fertility between wards of different types.

Although much time was put into developing a classification of Bradford's wards (see Williamson 2007), it is useful for others to know that a general purpose classification may well have utility for the stratification of

demographic rates. Since the custom classification did not distinguish fertility between area types more clearly than the ONS Area Classification, the decision was made to progress this work using the 'off the shelf' source, with slight modifications based on knowledge of the underlying population characteristics. Other researchers may find it more efficient to use a pre-existing classification with no compelling need for a custom classification found here. However, accounting for distinctive population subgroups (students, etc.) in estimates of rates is advised.

Bradford fertility areas: age-specific fertility rates in five groups of wards

Two further steps were taken to avoid small numbers of wards and of births by ethnic group. First, since the ONS Classification membership had few wards of some types, the one 'Prosperous' ward was combined with 'Established owner-occupiers' and the two 'Industrial areas' were combined with 'Lower status owner-occupiers'. The resulting five groups were termed 'Bradford fertility areas' with their names derived from the ONS Classification (given in table 3). Variations in TFRs for these area types are illustrated in Figure 4.

[Figure 4 about here]

Second, preliminary investigations into creating a complete set of ASFRs by ethnic group for the Bradford fertility areas indicated that numbers would be too small to derive reliable rates. Thus, further amalgamations of area types was carried out to ensure sufficient births to create robust ASFRs. The final set of Bradford fertility areas were restricted to those which recorded over 100 births in the period 1989-1993, representing at least 20 births per annum. An exception is University ward which is treated separately. This location is unusual since there are two subpopulations present with distinctively different fertility behaviour: high percentages of persons of South Asian ethnicity who tend to exhibit high fertility (Dubuc 2009); and students who tend to have low fertility (Rindfuss 1991; Hoem 2000). The combinations of the final area type and ethnic groups are listed in Table 4.

The ASFRs for these combinations of ethnic group and area type have been smoothed using the Hadwiger function. The fit of the curve between the raw and predicted rates can be assessed using the R^2 value which can range between 0 and 1, with higher values indicating a better fit. Table 4 shows the R^2 values are all above 0.5 with the lowest based on small numbers of births. ASFRs for White, Indian and Pakistani groups, being based on more births, generally have a better fit. The TFRs of the smoothed and raw rates are also very similar, indicating that the Hadwiger function retains the overall fertility level. When fitted to fertility rates, the Hadwiger function can result in a heavy upper tail (Gilje 1969; Hoem and Holmbeck 1975; Hoem et al. 1981). Checks of residuals indicate that the fit was not as good for fertility at age 40 and over for some ethnic groups.

[Table 4 about here] [Figure 5 about here] [Figure 6 about here]

Figures 5 and 6 illustrate the fit for the Bradford fertility areas (ethnic group 'other' has been omitted). The scale of each plot has been allowed to vary to emphasize early or late peaks. Compare, for example, the ASFRs for White deprived industrial areas with White established owner-occupier / prosperous areas. In general the smoothed fits are reasonable and the ASFRs are not ragged. The exception is the White ethnic

group in University ward where there is very low fertility for women in their late teens and early twenties who are most likely to be students.

Assessing the reliability of the estimated fertility rates

Here we consider aspects which affect the utility of the estimated fertility rates. First we use the rates within a projection and validate by comparing the sum of the births which result with the births from BBSS database. Second, we briefly critique the comprehensiveness of the projections themselves. Then, we consider aspects relating to the data source used.

The validation involved comparing actual births from 1991 onwards with projected estimates of births by using the smoothed ASFRs in the POPGROUP forecasting software (provided by Bradford Metropolitan District Council) (POPGROUP 2010). Comparisons of the projected births were carried out at using each combination of ethnic group by ward using the BBSS database. Moreover, while the aim of this project was to develop strategies for deriving ethnic-specific ASFRs based small population sizes, it is useful to compare the results with a range of differently derived ASFRs. To achieve this, a variety of ASFRs were utilised within POPGROUP:

I GAD England rates for all women;
II Bradford district rates for all women;
III Ethnic group specific rates at district-level but applied in each ward;
IV Ward rates for all women but applied to each ethnic group;
V Bradford fertility area rates relevant to each ethnic group.

All sets of ASFRs were created using the BBSS and were smoothed by the Hadwiger function except the Government Actuary Department (GAD) England and the Bradford district rates for all women.

For the assessment of the observed and estimated births, a regularly-used measure is the Mean Absolute Percentage Error (MAPE) (Simpson et al. 1997; Smith and Tayman 2003). A problem arises, however, when no birth is registered in a year but a birth is projected to occur. This assessment is therefore restricted to ethnic groups within wards that had at least one birth per year. Thus 98 out of the 180 possible combinations of ethnic group by wards were assessed.

Assessing the different age-specific fertility rates by ethnic group in wards

The volume of results prevents presentation in a single table, so attention is confined to the MAPEs calculated for each set of ASFRs by ethnic group. Table 5 shows that using ethnic-specific, local-level fertility behaviour (option V above, the Bradford fertility areas) performs well compared with the ASFRs based on large area or on all women (options I to IV above). However, for Indian, Pakistani and Bangladeshi the Bradford district-level, ethnic-specific ASFRs (option III) produce the smallest MAPE. This could be due to the small numbers on which the Bradford fertility areas ASFRs are based for these ethnic groups.

[Table 5 about here]

Limitations of the assessment

The births were estimated from population projections by entering the ASFRs in the forecasting package POPGROUP, applying national GAD mortality rates for England to all women and assuming no migration. These assumptions about mortality and migration have been held constant since it is problematic to estimate small area mortality and migration rates for the general population and by ethnic group (Williamson 2006a; 2006b). It is acknowledged that better information for assumptions to be made about mortality and migration would give a more meaningful assessment, especially as migration plays a crucial role subnationally (Hinde 1998; Rowland 2003; Smith et al. 2001). However, it is only since 2001 that district level estimates of ethnic mortality have been made (Rees et al. 2009), and that methods to estimate the ethnicity of a child from mixed ethnicity parentage have been developed (Norman et al. 2010). Mixed ethnicity was not recorded in the 1991 Census so was not possible to incorporate this in a projection based on that year.

There were limitations in testing the estimated births using the Bradford Birth Statistics System as a source. There is evidence that the BBSS is incomplete by about 2% and suffers from some mis-classifications of ethnic group (Simpson 2000; Williamson 2007). The ASFRs and estimated births may both be under-estimates. These problems are not unique to the BBSS since the GLA experienced under-recording due to missing data using the HES (Bains and Klodawski 2004). Interestingly, the census also undercounts infants (Norman et al. 2008).

Conclusion

This paper has explored various methods to derive local area age-specific fertility rates by ethnicity for use in population projections using wards in the English city of Bradford. Grouping was needed to generate sufficiently large populations of women and births to facilitate the creation of reliable ASFRs. The grouping resulted in a classification of Bradford fertility areas and was based on knowledge gained carrying out cluster analysis and ultimately on the 1991 ONS classification of wards. These fertility areas are a compromise since the exercise requires a loss of ethnic-specific, ward-level information due to small number problems. The Hadwiger function was then used to smooth the ASFRs by each combination of ethnic group and area type. Validation was carried out comparing different sets of ASFRs which contained a variety of geographical and ethnic information. The results showed that, for some minority ethnic groups, district-level ethnic-specific fertility rates produced the most accurate birth estimates, even though the rates were derived from a larger area. This implies that rates created from local data may be informative for larger ethnic groups but are less reliable where ethnic groups are very much the minority. This is consistent with Rogers and Raymer (1999:182) who note in reference to the migration of the foreign born population in the US by regions:

> High levels of disaggregation permit a greater flexibility in the use of the projections by a wide variety of users; they also lead to a detection of greater consistency in patterns of behaviour among more homogeneous population subgroups. But greater disaggregation requires the estimation of even greater numbers of data points, both those describing population stocks and those defining the future

rates of events and flows that are expected to occur. The practical difficulties of obtaining and interpreting such data soon outstrip the benefits of disaggregation.

When estimating demographic rates for small areas and for sub-populations there is a need to capture differences and inter-relationships between geographic variation and distinctive sub-groups. Where data are sparse, grouping areas together is a useful strategy to avoid small number problems especially when population sub-groups of interest have uneven distributions. In terms of grouping strategies we would recommend that existing classifications are assessed to determine how well variations in rates are stratified before embarking on a custom scheme. Where population sub-groups are small in some areas, it may be more reliable to use rates derived for larger areas and apply these to local populations. Inevitably, the rates used in a projection are a compromise but hopefully, as in the work we present here, will still capture important dimensions of population change.

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Table 1 Bradford ward population size, total fertility rate and percentage of non-White population in 1991

Ward	% non-White	TFR	Total population (rounded)	Ward	% non-White	TFR	Total population (rounded)
Baildon	0.96	1.56	15,400	Eccleshill	2.72	1.86	14,900
Bingley Rural	0.93	1.57	15,300	Thornton	2.5	1.88	13,800
Ilkley	0.99	1.57	13,500	Shipley East	2.46	1.94	14,400
Bingley	1.15	1.58	12,900	Great Horton	22.96	1.96	15,200
Craven	0.69	1.58	14,300	Undercliffe	23.73	2.1	15,500
Worth Valley	0.66	1.58	13,800	Keighley West	9.98	2.15	16,400
Bolton	10.45	1.61	13,200	Little Horton	36.38	2.16	16,800
Rombalds	0.69	1.63	15,300	Tong	3.01	2.2	14,100
Idle	1.91	1.72	14,000	Heaton	28.6	2.26	16,900
Queensbury	2.19	1.72	16,200	Keighley South	9.09	2.26	13,300
Shipley West	13.22	1.74	15,400	Bowling	25.88	2.31	17,800
Clayton	6.69	1.77	13,100	University	73.92	2.43	18,900
Wyke	2.33	1.80	16,900	Keighley North	21.48	2.46	15,500
Wibsey	3.18	1.82	13,800	Bradford Moor	52.74	2.87	16,400
Odsal	14.1	1.84	16,800	Toller	53.06	2.87	17,600

Sources: 1991 Census and authors' calculations

Table 2 Bradford total fertility rate by ethnic group in 1991 and births centred on 1991 (average 1989-1993) and female population aged 15-49 by ethnic group in 1991

Births/ Population	Bradford	White	Pakistani	Indian	Other	Black	Bangladeshi
Births	7,235	5,126	1,605	214	114	89	86
Women 15-49	114,610	95,804	11,472	3,595	1,334	1,518	888
TFR	1.98	1.72	4.12	1.75	2.39	1.52	3.39

Source: Authors' calculations

Table 3 Total fertility rates for wards and the ONS classification

Ward	Ward TFR	k-means membership and cluster TFRs		ONS Group TFR	ONS 1991 Group label	'Bradford fertility areas'
Ilkley	1.57	1	1.61	1.57	Prosperous areas	Established owner-occupiers / Prosperous areas
Baildon	1.56	1	1.61	1.59	Established owner occupiers	Established owner-occupiers / Prosperous areas
Rombalds	1.63	1	1.61			Established owner-occupiers / Prosperous areas
Bingley	1.58	1	1.61	1.62	Suburbia	Suburbia
Bingley Rural	1.57	1	1.61			Suburbia
Bolton	1.61	1	1.61			Suburbia
Craven	1.58	1	1.61			Suburbia
Queensbury	1.72	1	1.61			Suburbia
Shipley West	1.74	1	1.61			Suburbia
Worth Valley	1.58	1	1.61			Suburbia
Clayton	1.77	2	1.87	1.79	Middling Britain	Middling Britain
Idle	1.72	2	1.87			Middling Britain
Thornton	1.88	2	1.87			Middling Britain
Wyke	1.80	2	1.87			Middling Britain
Eccleshill	1.86	2	1.87	1.89	Industrial areas	Lower status owner-occupiers / Industrial areas
Shipley East	1.94	2	1.87			Lower status owner-occupiers / Industrial areas
Odsal	1.84	2	1.87	2.19	Lower status owner occupiers	Lower status owner-occupiers / Industrial areas
Great Horton	1.96	2	1.87			Lower status owner-occupiers / Industrial areas
Heaton	2.26	4	2.52			Lower status owner-occupiers / Industrial areas
Keighley North	2.46	4	2.52			Lower status owner-occupiers / Industrial areas
Toller	2.87	4	2.52			Deprived Industrial areas
Undercliffe	2.10	4	2.52			Lower status owner-occupiers / Industrial areas
Keighley South	2.26	3	2.20			Lower status owner-occupiers / Industrial areas
Keighley West	2.15	2	1.87			Lower status owner-occupiers / Industrial areas
Wibsey	1.82	2	1.87			Lower status owner-occupiers / Industrial areas
Tong	2.20	3	2.20	2.28	Deprived industrial areas	Deprived industrial areas
Bowling	2.31	3	2.20			Deprived industrial areas
Bradford Moor	2.87	4	2.52			Deprived industrial areas
Little Horton	2.16	3	2.20			Deprived industrial areas
University	2.43	5	2.43			Deprived industrial areas

Source: Bradford fertility data and ONS 1991 classifications

Table 4 Area and ethnic groupings: births and total fertility rates

'Bradford fertility area' and ethnic groupings to ensure at least 20 births	Births	TFR from smoothed ASFRs	R^2
White: Suburbia	1,126	1.60	0.98
White: Middling Britain	793	1.81	0.97
White: Established owner-occupiers / Prosperous areas	400	1.55	0.95
White: Lower status owner-occupiers / Industrial areas	1,827	1.81	0.97
White: Deprived industrial areas	929	2.01	0.92
White: University ward	51	1.05	0.57
Black: Suburban more established areas + Low status owner-occupiers / Industrial areas	44	1.71	0.73
Black: Urban deprived industrial areas	45	1.40	0.66
Indian: Suburban more established areas	33	1.56	0.77
Indian: Lower status owner-occupiers / Industrial areas	60	1.64	0.90
Indian: Deprived industrial areas	122	1.85	0.96
Pakistani: Suburban more established areas	59	3.65	0.84
Pakistani: Lower status own-occupiers / Industrial areas	507	4.80	0.89
Pakistani: Deprived industrial areas	1,040	3.87	0.96
Bangladeshi: Suburban more established areas + Low status owner-occupiers / Industrial areas	36	3.12	0.63
Bangladeshi: Urban deprived industrial areas	49	3.89	0.64
Other: Suburban more established areas	29	3.12	0.74
Other: Lower status owner-occupiers / Industrial areas	34	3.05	0.79
Other: Deprived industrial areas	51	1.96	0.81

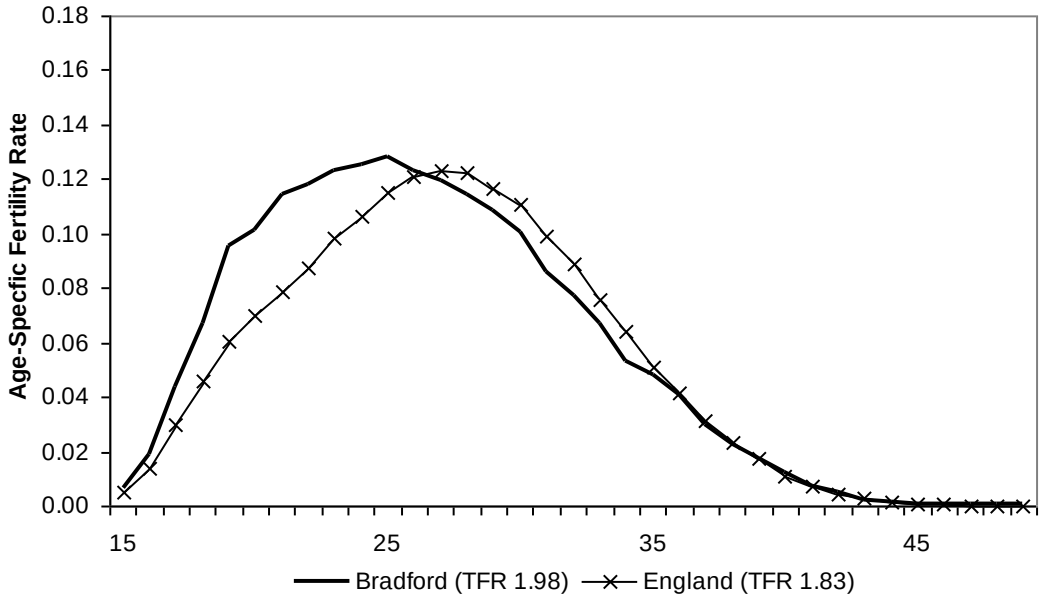
Sources: Bradford fertility data, ONS 1991 classification and smoothed TFR and R^2 value from the non-linear regression in SAS (PROC NLIN)

Table 5 Mean absolute percentage errors (MAPEs) for each ethnic group (number of wards it is based on in brackets) for the time period 1991-1999

Ethnic group	'Bradford fertility areas'	Ward only rates	Ethnic group only rates at district level	Bradford district rates	GAD England rates
White (30 wards)	14.3	35.3	21.9	33.3	26.1
Black (7 wards)	97.1	194.2	106.3	154.2	144.9
Indian (14 wards)	43.2	62.5	42.8	51.6	45.0
Pakistani (19 wards)	26.0	48.4	25.1	52.2	56.6
Bangladeshi (6 wards)	38.5	48.6	37.9	53.0	56.6
Other (22 wards)	56.9	64.0	59.8	57.9	58.0

Source: MAPE based on estimated births from a population projection created in POPGROUP using GAD England mortality rates and no migration. All ASFRs are based on the BBSS except the GAD England rates

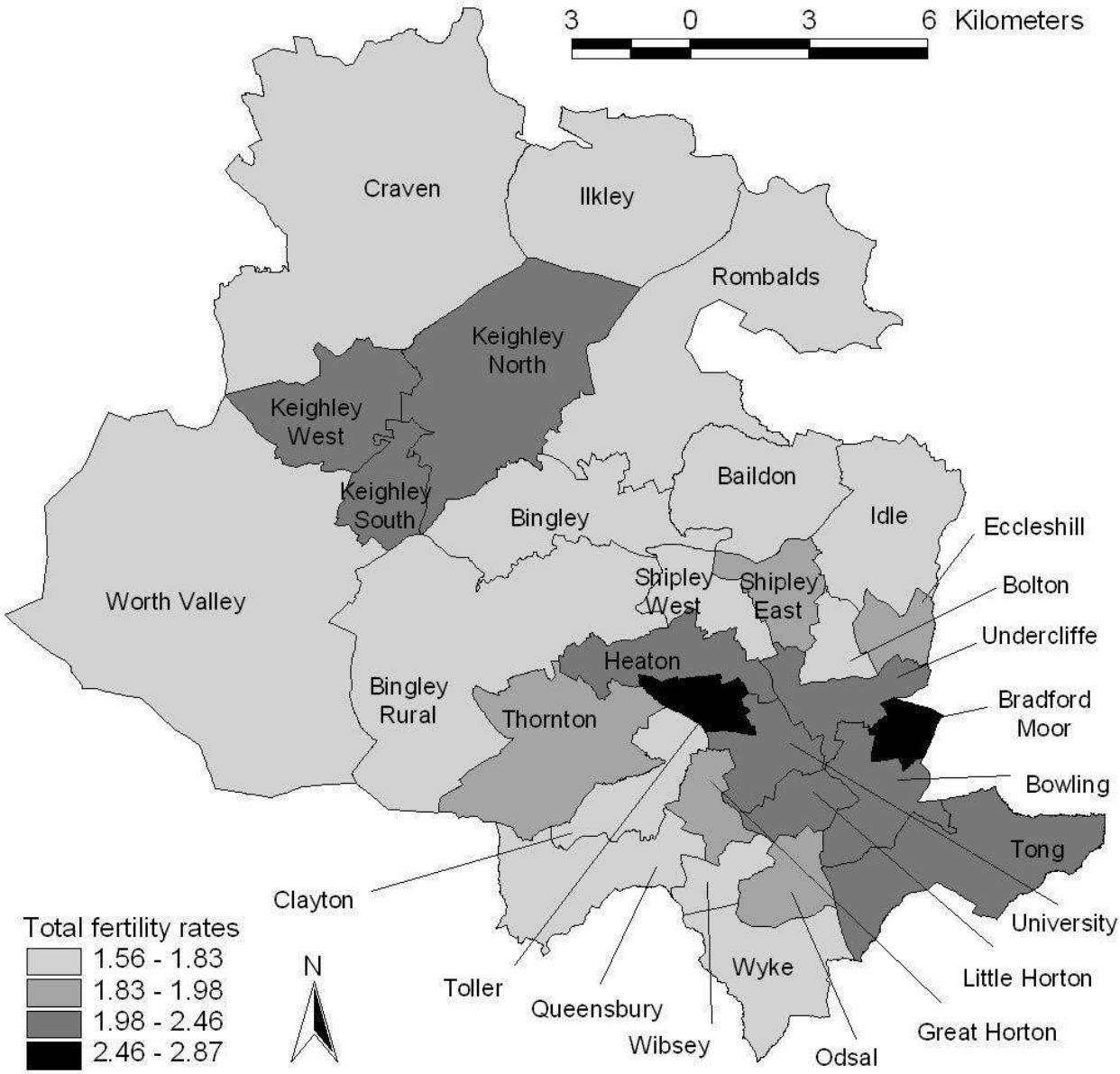
Figure 1 Age-specific fertility rates for Bradford and England in 1991



Note: x axis is the age of mother

Source: ASFRs for Bradford from the authors' calculations and for England from Government Actuary Department (GAD) made available with the forecasting package POPGROUP.

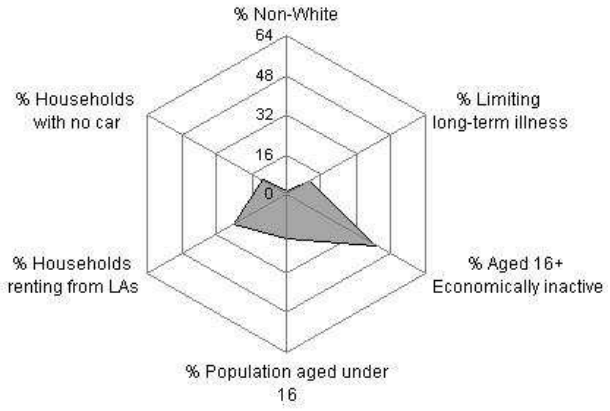
Figure 2 Total fertility rate for Bradford's wards in 1991



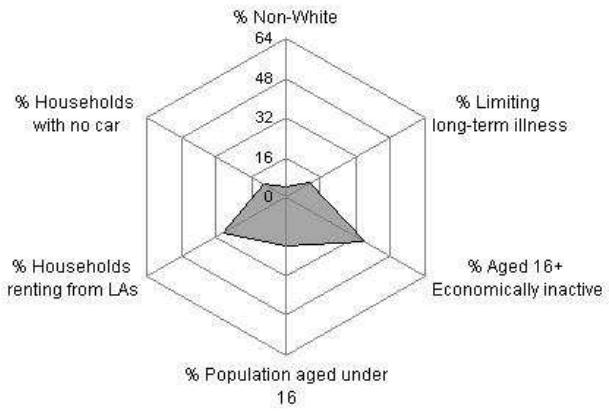
Note: The map class intervals differentiate relevant fertility levels. Wards with TFRs below 1.83 display fertility behaviour below the 1991 TFR of England. The next group, from 1.83 to a TFR of 1.98 represents fertility behaviour below average in comparison to 1.98, the TFR for Bradford district as a whole (but above average for England). Other wards are all above the Bradford average fertility level with one group of wards up to a TFR of 2.46 and two high TFRs of 2.87 in the wards Toller and Bradford Moor.

Figure 3 Classification star-plots: average percentages over the wards for variables used in the Bradford ward clustering

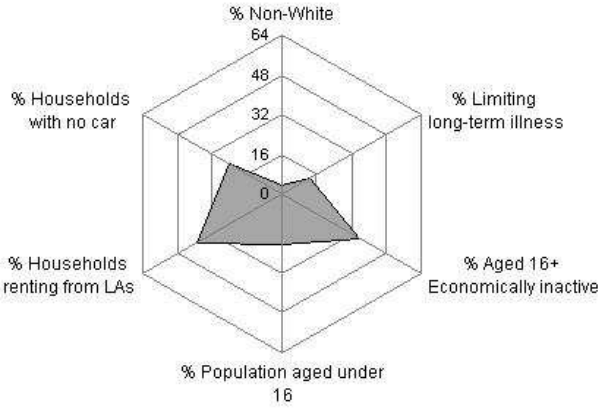
a. Established owner-occupiers / Prosperous areas



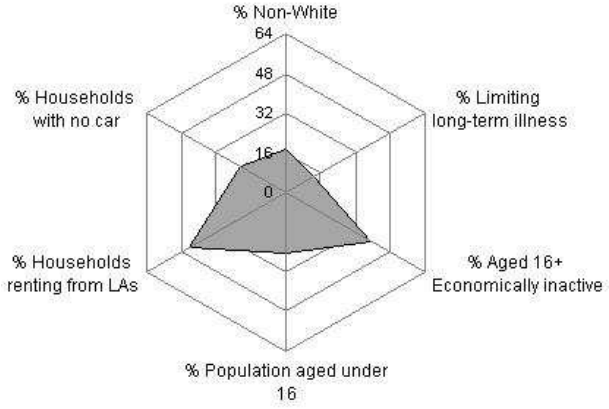
b. Suburbia



c. Middling Britain



d. Lower status owner-occupiers / Industrial areas



e. Deprived Industrial areas

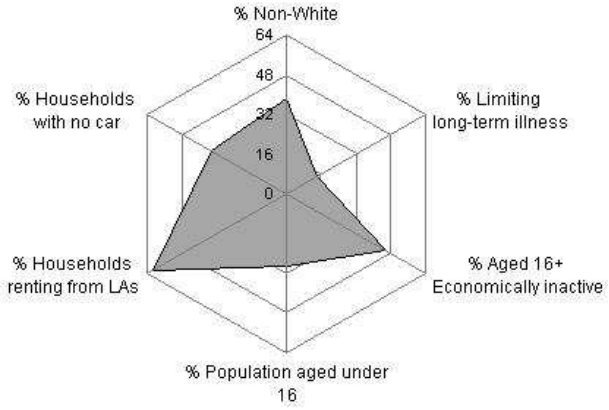
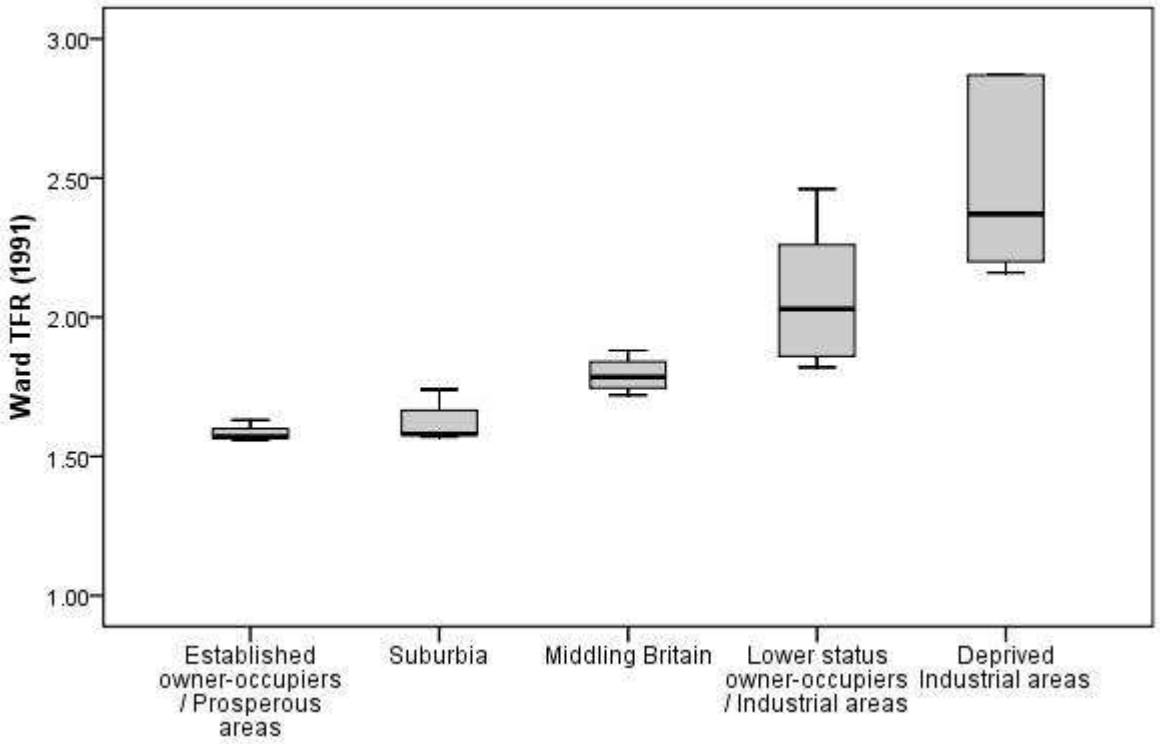


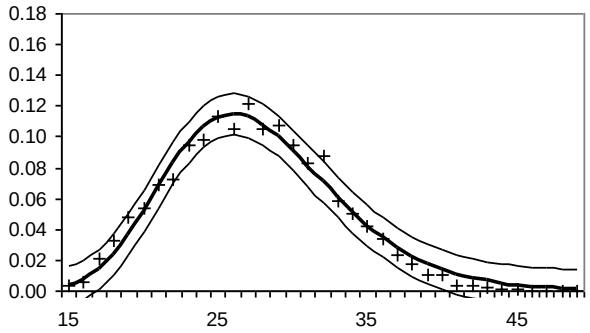
Figure 4 Total fertility rate for wards within the five 'Bradford fertility areas'



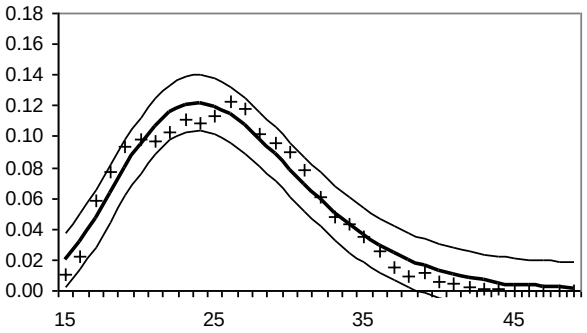
Source: Authors' calculations

Figure 5 Age-specific fertility rates raw and smoothed for 'Bradford fertility areas'

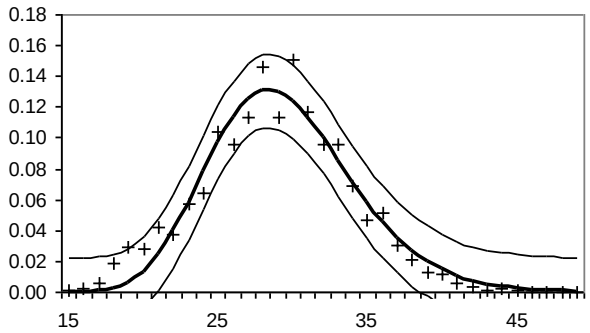
White: Suburbia



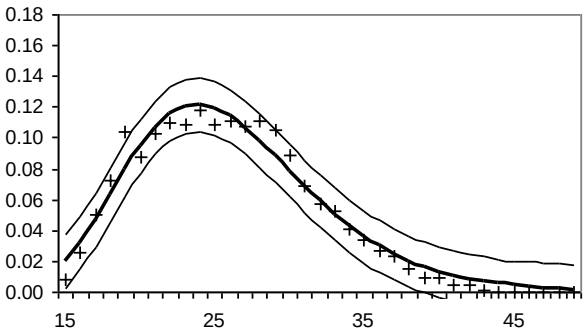
White: Middling Britain



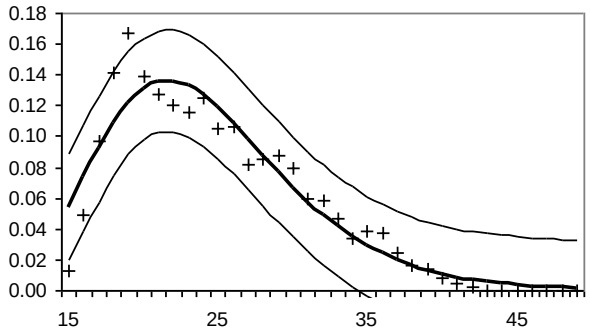
White: Established owner-occupiers / Prosperous areas



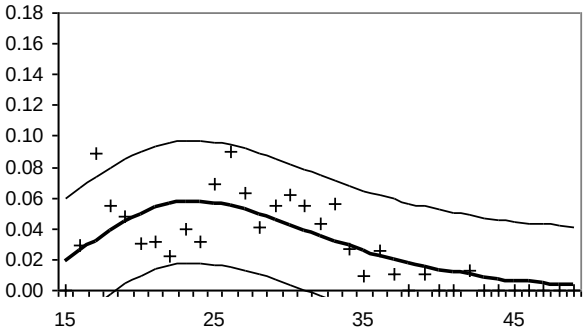
White: Lower status owner-occupiers / Industrial areas



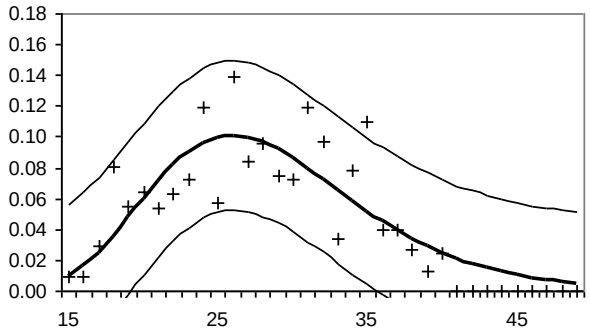
White: Deprived industrial areas



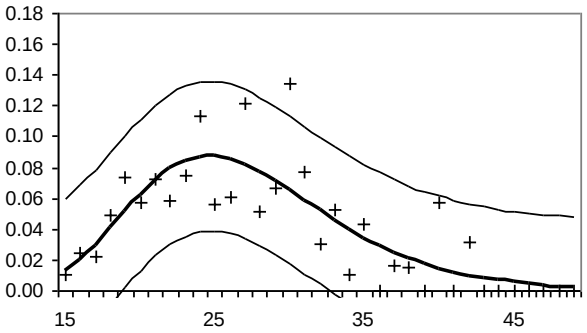
White: University ward

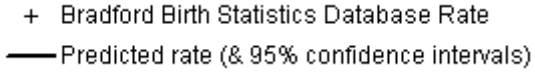


Black: Suburban more established areas + Low status owner-occupiers / Industrial areas



Black: Urban deprived industrial area

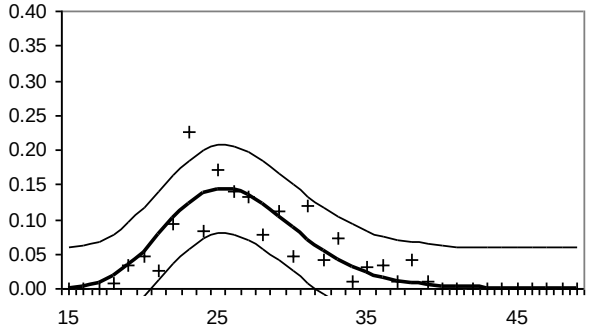




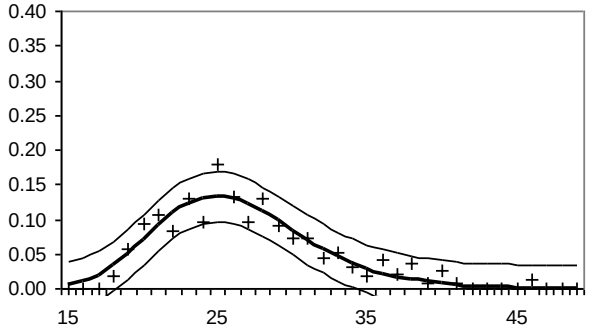
Note: x axis is the age of mother. The y axes are different to figure 6 to better represent each subgroup's fertility

Figure 6 Age-specific fertility rates raw and smoothed for 'Bradford fertility areas'

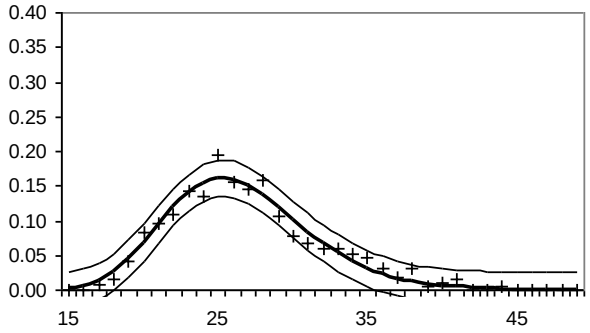
Indian: Suburban more established areas



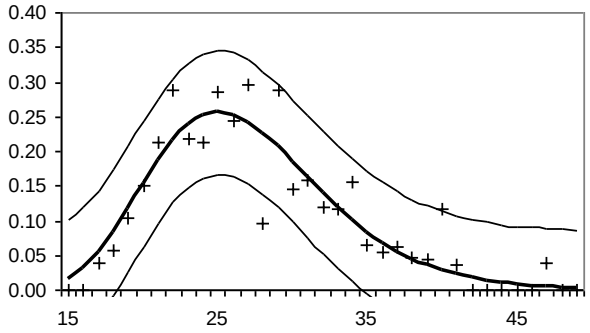
Indian: Lower status owner-occupiers / Industrial areas



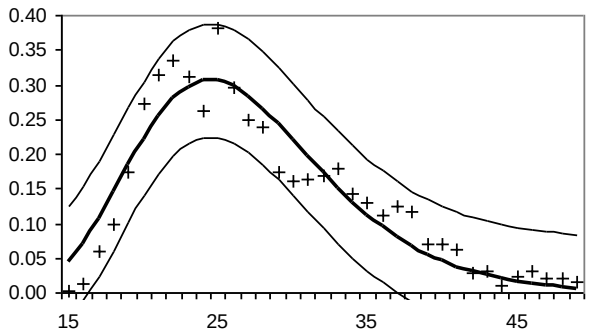
Indian: Deprived industrial areas



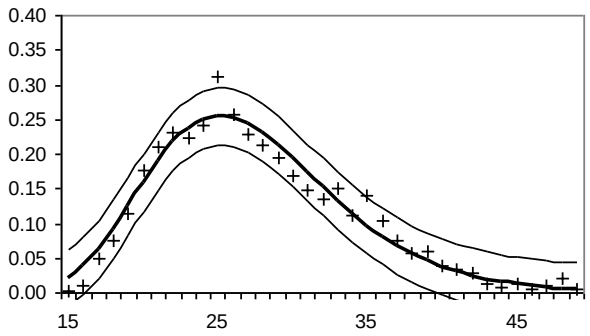
Pakistani: Suburban more established areas



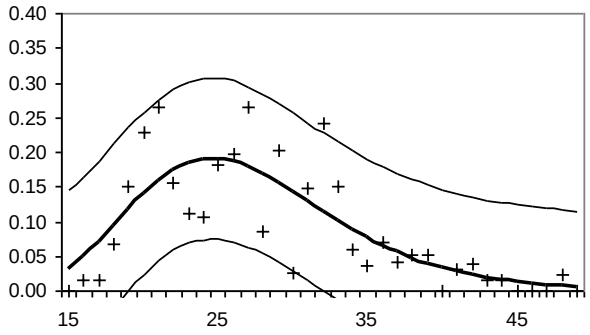
Pakistani: Lower status owner-occupiers / Industrial area



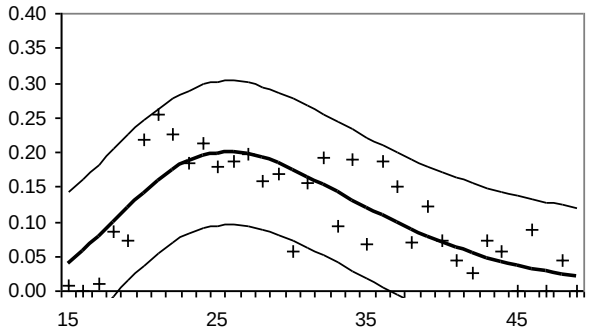
Pakistani: Deprived industrial areas

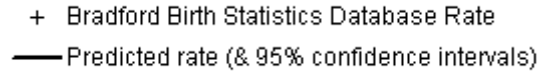


Bangladeshi: Suburban more established areas + Low status owner-occupiers / Industrial areas



Bangladeshi: Urban deprived industrial areas





Note: x axis is the age of mother. The y axes are different to figure 5 to better represent each subgroup's fertility