London School of Economics and Political Science

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MSc Social Research Methods

Migrant fertility in England and Wales

Measuring fertility convergence

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Contents

Abstract

There is a stated need for more research on the fertility of second and third generation migrants living in Europe, especially those living in England and Wales. In particular, it remains to be shown whether migrant fertility converges with native fertility over different generations. Research on migrant fertility frequently makes use of the own-child method to measure fertility, (an indirect method linking mothers to their resident children), but it remains uncertain whether results are substantially affected by own-child measurement error. This research aims to redress these gaps using data from the Office for National Statistics Longitudinal Study (LS), a one per cent sample of the England and Wales population, including 2001 Census data linked to information on births registered in England and Wales.

For a sample of women aged 16 to 45-years-old, multinomial regression is used to show that fertility will be underestimated using either the own-child method or registered births, although for different reasons. The effect of child mortality on own-child estimates is found to be small, and it is concluded that most children are missed by the own-child method because they do not live with their mother. Since most sources of data on migration only allow fertility to be estimated using the own-child method, estimates of these errors are provided for the benefit of fellow researchers.

Poisson regression models are applied, using the different fertility measures, in order to test whether migrant fertility converges with native fertility over different generations. Compared with registered births, the own-child method is found to be preferable for studying migrant childbearing, largely because it includes foreign-born children. The own-child method does not lead to materially different conclusions compared with a method that takes the maximum number of births (for each woman) using both the own-child and registered measures. Nevertheless, the 'maximum' is recommended for future research on fertility using the LS. When this maximum measure is used, evidence of generational fertility convergence is found. In aggregate, the fertility of second generation migrants tends to be more similar to that of ancestral natives compared with the first generation. However, convergence is more evident for particular migrants, especially those with South Asian origins.

Introduction

For the last seventeen years, there has been a net inflow of international migrants to the United Kingdom (ONS 2010, ONS 2011a). Alongside changing public attitudes to migration (Crawley 2009, Meuleman 2009), this has stimulated debate among politicians, civil society, and the media (e.g. Spencer 2003, BBC 2008 & 2011, House of Commons 2008, House of Lords 2008a & 2008b, Mulley 2010). Given this level of interest, and the fact that migration is a multi-disciplinary topic (Massey et al. 1993, Brettell and Hollifield 2000, Bijak 2006, Calavita 2006), it is clear that high levels of net migration have implications for research across the social sciences. This is augmented by the fact that a similar trend has occurred in the majority of developed countries (Teitelbaum 2004, Marcu 2009, OECD 2010).

For demographers, the principal concern has typically been the increased impact of migration on population estimates and projections (e.g. Coleman 2008). This has presented a particular challenge because there is much more uncertainty associated with migration than the other components of population change (i.e. fertility and mortality) (Shaw 2007). According to the most recent projections, 45% of the projected UK population increase between 2008 and 2033 is directly related to migration (ONS 2009a), and a further 23% is indirectly related to migration, almost entirely through its impact on future births (ONS 2009b). This indicates the substantial influence that immigrant fertility may have on the future UK population, but questions remain about how immigrant fertility rates change over time (ONS 2007, Tromans et al. 2009). Although fertility rates of foreign-born women in the UK are known to differ from those of UK-born women (Sigle-Rushton 2008, Coleman et al. 2002, Tromans et al. 2009), less is known about whether these rates converge for migrant generations. There have been recent calls for further research on this topic at both the UK and European level (ONS 2007, Sobotka 2008).

In addition to informing population projections, research on migrant childbearing is of perennial interest to demographers, and provides a focussed link between theories of fertility and migration (Lee 1966, Kosmin 1982, Blau 1992, Haug 2002). Understanding immigrant childbearing allows a more comprehensive explanation of national fertility change (Sobotka 2008). At the same time, a greater knowledge of the relationship between fertility and migration assists the development of migration theory, which has been seen to be *"fragmented"* and *"segmented by disciplinary boundaries"* (Massey et al. 1993).

To allow the robust identification of small migrant groups, studies of migrant fertility usually require very large sample sizes. However, large samples (e.g. censuses) often exclude direct measures of childbearing, a situation which frequently leads researchers to use the own-child method to estimate fertility (Goldstein and Goldstein 1981, Ng and Nault 1997, Abbasi-Shavazi and McDonald 2000, Coleman and Dubuc 2010, Adsera and Ferrer 2011). This method calculates previous births based on *"all children who can be identified as residing with their mothers"* (Rindfuss 1977). Although researchers often compare own-child fertility estimates with those produced using other sources (typically official vital statistics, e.g. Abbasi-Shavazi 1997), it is rare that own-child estimates have been compared with estimates using the same data source, with the main exception being previous research using the Office for National Statistics Longitudinal Study (LS) (Werner 1984 & Penhale 1989 in Hattersley and Creeser 1995).

It is long established that the own-child method underestimates childbearing levels (Rindfuss 1977), but a further question is whether measurement errors are large enough to influence the interpretation of analysis on migrant fertility. If so, there will be implications for future data collection (e.g. which questions to include), measurement methods (i.e. which methods to use), and data sources (i.e. which sources to use). The last point is important for research on migrant fertility in the UK because there are a variety of data sources, but no one source is comprehensive or without limitations (UK Statistics Authority 2009, Cangiano 2010, UK Statistics Authority 2011).

This research begins with a descriptive comparison of registered births and the own-child method, and then uses these measures to test whether migrant fertility converges with that of ancestral natives. Although the reasons for convergence are taken into account, the focus is to explore evidence for its existence in England and Wales. This requires consideration of the characteristics associated with convergence (or lack of it), and how it varies among migrant groups. Unless otherwise specified, all statistics concern the resident population of England and Wales, (whereas the UK includes England, Wales, Scotland and Northern Ireland). Likewise, results for native-born women refer to women born in England and Wales.

Literature review

Definitions in the literature

Definitions of migrant fertility convergence are derived from theories of immigrant fertility (Lee 1966, Hervitz 1985, Gjerde and McCants 1995, Kulu 2005, Sobotka 2008), and informed by sociological theories of assimilation and acculturation (Park and Burgess 1921, Gordon 1964, Kazal 1995, Menjvar 2010). In the foreword of a recent European Population Committee report, Haug relates convergence to the fact that: *"The behaviour of migrants lies generally somewhere on a continuum between the region of origin and the country of adoption"*, a statement which echoes that of Lee, made over 35 years earlier (Lee 1966, Haug 2002). Although this suggests a restricted focus on first generation immigrants, the synthesis report of the same volume suggests that *"the ability to test such concepts as demographic convergence in the context of immigration may require quite a long generational perspective"* (Compton and Courbage 2002).

A review of the literature suggests that there are three overlapping types of migrant fertility convergence. The first concerns individual migrants, whose life-course behaviour may converge with the norms of their destination country, dependent upon duration of residence (Ford 1990, Blau 1991, Young 1991, Abbasi-Shavazi and McDonald 2000, Alders 2000, Østby 2002, Andersson 2004, Bélanger and Gilbert 2006, Toulemon 2006, Milewski 2007). The second is less frequently studied, and compares migrants (and their ancestors) at a given destination with those 'left behind' in their country of origin (Coleman 1994, Frank and Heuveline 2005). The third concerns different migrant generations, where the behaviour of higher order generations (e.g. the second generation), may be more likely to converge with the 'native' norm (Kahn 1994, Alders 2000, Frank and Heuveline 2005, Bélanger and Gilbert 2006, Fokkema et al. 2008, Parrado and Phillip Morgan 2008).

The distinction is important because each type of convergence requires a different comparison, and implies a different counterfactual. This research is focussed on the third type, a comparison of migrant generations, and is therefore concerned with aggregate change, rather than change over an individual life-course. Generational comparison means that the level of fertility at origin is relatively unimportant, particularly given that migrants are a select group (Feliciano 2005, Bodvarsson and Van den Berg 2009). An absence of generational convergence is therefore a situation where (having accounted for the general fertility trend, changes in migrant streams, migrant origins and population composition), the fertility of migrant generations remains constant, and consistently different from the fertility of ancestral natives.

The definition of an immigrant can vary in a number of ways, but research on migrant fertility has typically identified immigrants according to country of birth, nationality or citizenship, rather than the United Nations definition based on migrant flows (UN 1998, Sobotka 2008). Country of birth (COB) is used for this research, largely due to availability, but also because it allows a more consistent comparison with research for other countries (Sobotka 2008). Using age of migration and/or parental country of birth, many studies also identify migrant generations (Frank and Heuveline 2005, Bélanger and Gilbert 2006, Sobotka 2008). Based upon these established definitions, Table 1 indicates the different migrant generations that are used here.

Table 1: Generational groups

Detailed Generation	Aggregate generation	Place of birth	Age at migration	Parent's place of birth
Ancestral natives	Third	Native-born		Both native-born
Generation 2.5	Second	Native-born		One foreign-born
Second generation	Second	Native-born		Both foreign-born
Child migrants	First	Foreign-born	Child (0-16)	
Adult migrants	First	Foreign-born	Adult (>16)	

Note: Ancestral natives are sometimes called the 'third-or-more' generation. Child migrants are often referred to as generation 1.5 and are defined here as those who first arrived in the UK aged 16 or under.

As inferred in Table 1, migrant generations are typically ranked according to the proximity that they have to their arrival (at destination), or (for native-born generations), the arrival of their first ancestor (Østby 2002, Andersson 2004, Bélanger and Gilbert 2006). In a sense, the order reflects the amount of 'exposure to destination' that each generation has experienced, and it may even represent proximity to a migration decision, although some migrant groups (e.g. forced migrants), will not have made an entirely autonomous decision to migrate (Roseman 1983, Massey et al. 1993, Bodvarsson and Van den Berg 2009).

It is therefore hypothesised that the number of children born to women who are resident in England and Wales can be ordered according to the migrant generations shown in Table 1. Although it is common in England and Wales that adult migrants have a higher fertility than the native-born (Tromans et al. 2009; Sigle-Rushton 2008, Coleman et al. 2002), this is not required for the hypothesis to hold. It may be that convergence occurs where adult migrants have the lowest fertility, and ancestral natives the highest.

Theories and approaches

Over time, and over generations, migrants are typically expected to become more like ancestral natives, a process which occurs through acculturation, adaption, amalgamation, assimilation, and convergence (Park and Burgess 1921, Gordon 1964, Kazal 1995, Menjvar 2010). This process occurs across multiple dimensions such as culture, language, residential segregation, and socio-economic status (Massey 1981, Waters and Jiménez 2005, Bleakley and Chin 2010). Another important dimension is partnership (e.g. intermarriage), which may be considered as individual assimilation (Waters and Jiménez 2005), or considered as a separate process (Park and Burgess 1921). This difference can be partially reconciled by conceding that convergence occurs at both the individual and the generational level (see *Definitions in the literature* above).

In addition to sociological explanations, there are many other theories across the social sciences to suggest mechanisms of convergence. Economists and ecologists emphasise intergenerational trade-offs between the quantity and quality of children (Becker et al. 1960, Becker 1993, Lawson and Mace 2011), a process that is likely to be affected by migration and its impact on (family) resources. Another body of theories, particularly relevant for understanding the effects of age at migration, derive from psychology and anthropology. Evidence suggests that children are more capable of assimilation due to faster language acquisition (Bleakley and Chin 2010), or being more able to adjust their cultural meaning systems (Minoura 1992).

A remote explanation for convergence, taken from demographic transition theory, suggests that fertility change may also be driven by exposure to a different mortality context (Dyson 2010). Nevertheless, demographers typically explain convergence by considering reasons for migration (Kulu 2005, Sobotka 2008, Bodvarsson and Van den Berg 2009). For example, the partnership and fertility behaviour of marriage migrants is expected to differ from that of migrant workers.

Considering the three types of fertility convergence mentioned in this literature review, previous research provides a range of different results. For individual convergence, there is some evidence that the fertility of immigrants is disrupted after arrival in their new destination (Blau 1991, Abbasi-Shavazi and McDonald 2000), but recent research shows that fertility is more likely to be disrupted prior to arrival (Alders 2000, Østby 2002, Toulemon 2006, Bélanger and Gilbert 2006, Milewski 2007). Toulemon suggests three reasons why this might be the case: selection, anticipation, or reverse causality (2006). For example, women who plan to migrate may postpone childbirth (anticipation), and those who do have children may be less likely to migrate (reverse causation).

But what would happen to a migrant's fertility if they did not migrate? This question alludes to the counterfactual for tests of 'origin and destination' convergence. Coleman finds evidence of convergence between origin and destination for European immigrants within Europe (1994), whereas a recent study of Mexico and the US found that: *"A comparison of the fertility rates of Mexican women in Mexico and Mexican-Origin women in the U.S. illustrates that currently, Mexican-Origin women in the U.S. demonstrate higher levels of overall fertility"* (Frank and Heuveline 2005). This study shows the value of comparing origins and destination, but there are a number of issues with this approach. Immigrant fertility can decline at the same time as the fertility of both the origin and destination country (Coleman 1994). Convergence is therefore difficult to identify, particularly when national fertility trends are similar (e.g. falling). Furthermore, migrants are a select group, and unlikely to match the population at origin or destination in terms of age distribution, let alone other socio-demographic characteristics (Feliciano 2005, Bodvarsson and Van den Berg 2009, Tromans et al. 2009). Even the assumption that their fertility is 'in between' origin and destination is often incorrect. For example, Bangladeshis in England and Wales in 1996 had higher fertility than the average for Bangladesh (Coleman et al. 2002).

Existing evidence of generational convergence

At the most simple level, previous research on generational convergence compares foreign-born and native-born women. Total fertility rates in England and Wales are higher (on average) for foreign-born women compared with those born in the UK (Tromans et al. 2009;

Sigle-Rushton 2008, Coleman et al. 2002), and a similar finding exists in many other European countries (Haug 2002, Sobotka 2008). However, alongside problems with using period fertility rates (see *Aims and methods of analysis* below), this comparison does not adequately consider the amount of time that different first generation migrants have been exposed to their destination (Ford 1990). It is *"extremely important to consider the effect of time since the migration event on the fertility outcome"* (Andersson 2004), or to account for age at migration (Toulemon 2006), both of which can be calculated from a migrant's year of arrival. When this is done, there is evidence that first generation migrants who arrive as children (rather than adults) have fertility levels more like the native-born (Abbasi-Shavazi and McDonald 2000, Andersson 2004, Bélanger and Gilbert 2006, Toulemon 2006).

As well as disaggregating the foreign-born into adult and child migrants, the native-born can be separated according to parental country of birth (see Table 1). Recent research on the US population distinguished between first, second and third generations, and found *"a clear pattern of convergence in fertility levels between Hispanic (and Mexican) and white women across immigrant generations"* (Parrado and Phillip Morgan 2008), but other research on the US population suggests that these differences may be otherwise explained, in part due to age and cohort differences in the timing and level of childbearing (Kahn 1994, Frank and Heuveline 2005). Unfortunately, there is not enough research to reconcile these differences.

Research for Canada supports convergence after controlling for age composition, and shows that differences between the first, second and third generation become very small after adding further controls for marital status and living in a low income family (Bélanger and Gilbert 2006). Research for the Netherlands *"indicates that the timing of having children clearly differs between first and second generation migrant women."* (Fokkema et al. 2008), and that unless births have truly been 'postponed' rather than forgone, the cohort fertility of second generation migrants will in general be less than that of the first generation (Alders 2000). Furthermore, it seems that differences between the first and second generation depend upon country of origin, with certain migrant origins more likely to show signs of 'cultural maintenance' rather than convergence (Kahn 1994, Abbasi-Shavazi and McDonald 2000, Alders 2000).

For England and Wales, there is indirect evidence that the fertility of second generation migrants converges with that of native-born women (ONS 2007). However, this remains to be rigorously tested. In part this is due to a lack of data, but there is nevertheless a shortage of research on second and third generation fertility (Sobotka 2008). This research therefore seeks to contribute to the literature by studying five different migrant generations for England and Wales (Table 1).

In a recent review of migrant childbearing in Europe, Sobotka notes that *"a case of a complete convergence has not thus far been recorded"* (2008), but the question remains whether this 'complete case' can be identified, or whether it is confounded by too many other factors, many of which are associated with convergence. One of the largest problems with testing generational convergence is that immigration is an ongoing process. Similar to any long-run fertility analysis, it is difficult to tease apart the age, period and cohort influences on the fertility of each migrant generation (Hobcraft et al. 1982). As with the analysis here, one way to control for this is to compare generational groups belonging to the same cohort, who have therefore been exposed to similar societal conditions (at least while in England and Wales). Nevertheless, possible differences between generations should be considered when interpreting results, even when holding origin constant.

Data, sample and method

Sample design

The data used here are a sub-sample of the Office for National Statistics Longitudinal Study (LS), itself a sample of around one per cent of the population of England and Wales (see Appendix 1, and CeLSIUS 2007a, ONS 2008). Based on a sample of the 1971 Census, enumerated residents have been equivalently sampled for each subsequent census (1981, 1991, and 2001), and linked to existing sample members using the National Health Service Central Register (NHSCR) (Hattersley and Creeser 1995, Blackwell et al. 2003). Census information has also been linked for all people living in the same household as the sample member (Blackwell et al. 2003).

In addition to census information, 'events' data is linked to the sample using a variety of administrative sources (Blackwell et al. 2003). Events related to the childbearing of LS members include: births to sample mothers, stillbirths to sample mothers, and deaths of sample mother's infant children. Also relevant to this study are 'entry' and 'exit' events. In between censuses, a one per cent sample of immigrants enter the LS when they register with the NHS for the first time. Existing members are flagged as leaving the sample through either death or emigration (Hattersley 1999).

The LS has a number of advantages over other sources, not least its large sample size. Before dropping cases, it includes over 500,000 individuals at each census (Blackwell et al. 2003). Another advantage is that, even when not used longitudinally, the LS design allows information from multiple data sources to be accurately linked at an individual level. This research makes use of the link between 2001 Census data and administrative records on registered births, which in turn allows the different measures of fertility to be compared. Additionally, information on co-residents (at each census) allows the own-child method to be applied, and assists with the coding of variables on partnership and parental county of birth.

A further advantage of the LS is the quality of data linkage (ONS 2008), although it is noted that there is high variability in linkage quality (i.e. some failed linkage) for births to foreign-born women (Hattersley and Creeser 1995). Also, some migrants that are sampled at census are not found in the NHSCR (Hattersley 1999), and this is the main cause of missing data on age at migration (see *Explanatory variables and missing cases*). It is worth mentioning that the LS data are also affected by the varying quality of each original data source, including inaccuracies in birth registration or census non-response (Hattersley and Creeser 1995, Estee 2004, ONS 2005). All these issues must be considered when interpreting analytical results.

Although possible, this research does not use a longitudinal design because there are issues with census comparability, and a large number of women present in 2001 were not present in previous censuses (Blackwell et al. 2003). For some women, there are legitimate reasons for their absence, such as immigration, but for others their absence is difficult to explain, thereby making it difficult to apply an analysis that accounts for censoring. An alternative to longitudinal analysis is to treat the LS as a repeated cross-section (for example by randomly allocating those present in both 1991 and 2001 to a given year). Compared with analysing one census only, the main advantage of this design is to increase sample size, but the benefits of this increase are offset by increased problems with census comparability. The county of birth question in 1991 was coded with less detail than the question in 2001 (CeLSIUS 2007c), thereby making consistent aggregation problematic. Also, the education question in the 1991 census was far less detailed than in 2001, which created a differential pattern of non-response for 1991 (CeLSIUS 2007d, and author's own analysis). A further disadvantage of a repeated cross-section, with 10-year intervals between data-points, is that it generates problems with comparing the experience of different cohorts. For these reasons, the LS is analysed here as a single-year cross-section, using the 2001 Census as the main source. The analysis effectively takes place in 2001, and all variables are either measured at 2001 (e.g. fertility, education), or should not change over time (e.g. parental country of birth).

Measuring fertility

Aside from a 1971 Census question on marital birth history (which is not suitable for studying recent childbearing), the LS allows fertility to be measured in two different ways: using 2001 Census data (via the own-child method), or using vital statistics data (registered births). The calculation of registered births is based upon data that has been linked to LS sample members by ONS. The source data are all registered births occurring in England and Wales, so the exclusion of foreign births is likely to be the largest issue for studies of migrant fertility, (although there are other issues relating to linkage and the source data, see *Sample design* above).

The own-child method has its origins in reverse-survival techniques, and was first used in the 1960s (Grabill and Cho 1965, Cho et al. 1970, Rindfuss 1977, UN 1983). Fertility is estimated by linking women with their birth children using household relationship information, and the results give estimates of the level and timing of childbearing. Although the broad approach remains relatively unchanged since its inception, contemporary data sources make it easier to exclude children not born to women (e.g. stepchildren) (Dubuc 2009). The 2001 Census household relationship question includes separate options for 'son or daughter' and 'step-child' (ONS 2001, ONS 2004), and relationships were only inferred for large households of six people or more, (as opposed to previous censuses which inferred all relationships other than *"Relationship to Person No.1"*) (ONS 1991, Haskey et al. 2004, ONS 2004, Grundy et al. 2010). This implies that fewer own-children have been inferred, overestimated or missed, although the variation in quality by household size remains a potential issue (Haskey et al. 2004).

Although it is expected to make little difference in a low mortality context (Abbasi-Shavazi 1997, Dubuc 2009), the own-child method can be adjusted to account for underestimation due to child mortality. The effects of mortality are calculated here (see *Analysis of fertility measures*), but an adjustment is not made to the measure itself, partly to allow better comparison with recent research using unadjusted measures (e.g. Adsera and Ferrer 2011), but also to avoid introducing differential bias for immigrants (because the LS only includes information on child deaths occurring in England and Wales). The other enduring issue with the own-child method is that not all children live with their mothers (Rindfuss 1977, Abbasi-Shavazi 1997, Dubuc 2009). It is for this reason that the sample is restricted to women aged 16-45 in 2001.

Explanatory variables and missing cases

All variables are coded as categorical, and descriptive statistics are shown in the Appendix (Tables A.2, A.3a & A.3b). The majority of explanatory variables are derived and coded using 2001 Census data in accordance with census definitions (ONS 2004), and census data on household members allows foreign partners to be identified. Additionally, an urban/rural indicator is created, based on whether respondents live in a ward with more than 500 people per square kilometre (code provided by ONS).

Sources other than the 2001 Census are used for the remaining explanatory variables: age at migration, parental country of birth (parental COB) and generation. Age at migration is derived from two sources. The first is a 1971 Census question on 'year of first arrival in the UK', which is used for women who were present in 1971 and responded. In the absence of other census questions, year of first registration with the National Health Service (NHS) is used for remaining women as a proxy for year of arrival. This is an established assumption when using the LS (Hattersley 1999). Coding of parental COB also relies on multiple sources, with priority given to sources where parents are most likely to report their own country of birth (COB). The first source is linked information derived from the sample member's own birth registration. For women whose parental COB remains missing, coding is then based on parents living in the same household at any of the censuses (1971-2001), followed by information from a 1971 Census question on parental COB. Having coded the above variables, foreign-born women are identified using country of birth (COB), which is coded into groups and aggregated to create a foreign-born indictor. Generation is then derived using age at migration, COB, and parental COB.

The final stage of sample preparation was to drop cases, largely due to missing data. Unfortunately, although multiple imputation was attempted, it was not completed due to restricted access to the secure data laboratory (see Appendix 1). As such, complete case analysis is deemed to the most rigorous approach for this research (Greenland and Finkle 1995, Acock 2005). Detailed information on dropped cases is given in Appendix Table A.1. Although the sample size remains large (99,210 women aged 16-45), bias may affect the following results because a large number of cases were missing age at migration (if foreign-born) or parental COB (if native-born), both of which are required to derive the generation variable. Prior to dropping any cases due to missing data, just over 4% of all women (or 5% of native-born women) are missing parental COB, and around 2% of all women (or 22% of foreign-born women) are missing age at migration (see Appendix Table A.1). The latter is primarily because they are not found in the NHS Central Register.

Aims and methods of analysis

The analysis that follows is separated into two parts: a descriptive analysis of different fertility measures, and tests of generational fertility convergence using these measures. The first part begins by exploring the accuracy of fertility measures, including a discussion of measurement assumptions, and a comparison with official statistics. Multinomial regression is then used to consider how the undercounting of children (by each method) varies for migration-related variables (Simonoff 2003b, Agresti 2007b). The second part of the analysis then aims to test the hypothesis of fertility convergence, but also to establish whether the results of this test will change depending upon the way that fertility is measured.

A variety of data and methods have been used to test fertility convergence. It is rare that cohort measures of fertility have been analysed (Alders 2000), and the most common methods are a comparison of period total fertility rates (TFRs) (e.g. Coleman 1994, Schoorl 1995, Toulemon 2006), or models of birth risks based on event history and survival analysis (e.g. Andersson 2004, Milewski 2007). It is unlikely that TFR comparisons are satisfactory for testing generational fertility convergence because they do not distinguish between changes in the level of childbearing (quantum) and the timing of births (tempo), and they provide limited control of factors (other than age) that may explain variation between groups (Murphy 1995, Schoorl 1995, Andersson 2004, Ní Bhrolcháin 2009 & 2011). Survival methods do not have the same problems, but they are more difficult to apply (and interpret) where all births are to be considered simultaneously.

Poisson regression models are therefore used to test the convergence hypothesis. These models consider all births (up to 2001), women's exposure to childbearing, and the effect of characteristics other than age. The response variable is the number of children ever born, a count variable with a low expected value (see Appendix Table A.7). When compared with specific generalised linear modelling approaches, it is well established that ordinary least squares is a less reliable method for modelling count data (Simonoff 2003a, Long and Freese 2006). This research therefore uses Poisson regression, an approach that has been applied in a number of recent studies of fertility (Winkelmann and Zimmermann 2000). In particular, through the inclusion of an offset term and the presentation of incidence risk ratios (see below), Poisson models are particularly suited to modelling comparative birth risks (Adsera and Ferrer 2011). The section below titled *Other models and robustness checks* includes further discussion of the Poisson models used here, the suitability of their assumptions, and alternative count models. The Poisson model can be described as follows:

If the response variable for each women,

Y = number of children ever born

And for each woman, her assumed number of childbearing years lived so far is:

t = exposure

Then the rate of occurrence of events is:

Y/t = incidence of fertility (a form of individual fertility rate)

And the expected value of this rate is:

$$E\left(\frac{Y}{t}\right) = \frac{1}{t}E(Y) = \frac{\mu}{t}$$

The Poisson loglinear model for the expected rate of the occurrence of events is:

$$\log\left(\frac{\mu}{t}\right) = \alpha + \beta x$$

Which can also be written as follows, (where the term log(t) is usually referred to as an 'offset'):

$$\begin{aligned} \log(\mu) - \log(t) &= \alpha + \beta x \\ \log(\mu) &= \alpha + \beta x + \log(t) \\ \mu &= \exp(\alpha + \beta x + \log(t)) \\ \mu &= \exp(\alpha) + \exp(\beta x) + \exp(\log(t)) \\ \mu &= te^{\alpha}e^{\beta x} \end{aligned}$$

(Equations adapted from: Simonoff 2003a, Long and Freese 2006, Agresti 2007a)

The expected value of Y therefore depends on both x and t, where x is the set of explanatory variables, all measured here at the individual level. The exposure (t) is calculated as 'age minus 15 years', such that a woman aged 16 is assumed to have been exposed to the risk of childbearing for one year. Although this does not reflect the timing of early teenage births (e.g. ONS 2002), this is a reasonable assumption for modelling purposes.

Given the difficulty of interpreting coefficients of Poisson models, it is common to report results in the form of 'Incidence risk ratios' (IRRs). In the context of this research, each IRR gives the ratio of fertility rates, based on completed fertility in 2001, for one category compared with a reference category. These are similar to odds ratios, except that they represent a ratio of rates, rather than odds. The relevant equation for IRRs is as follows:

$$IRR\left(X_j\right) = \frac{E\left(Y_i \,\middle|\, X_j = 1\right) = \lambda_i = \exp(\hat{\alpha} + \hat{\beta}x + \hat{\beta}_j(1))}{E\left(Y_i \,\middle|\, X_j = 0\right) = \lambda_i = \exp(\hat{\alpha} + \hat{\beta}x + \hat{\beta}_j(0))} = \exp(\hat{\beta}_j)$$

(Adapted from: Long and Freese 2006, Adsera and Ferrer 2011)

The above equation implies that the IRR is the effect of one unit change in the variable of interest (X_j) on the incidence of fertility. For example, if X_j=0 for native-born women, and X_j=1 for those who are foreign-born, the IRR represents the ratio of foreign-born female fertility rates compared with those of the native-born.

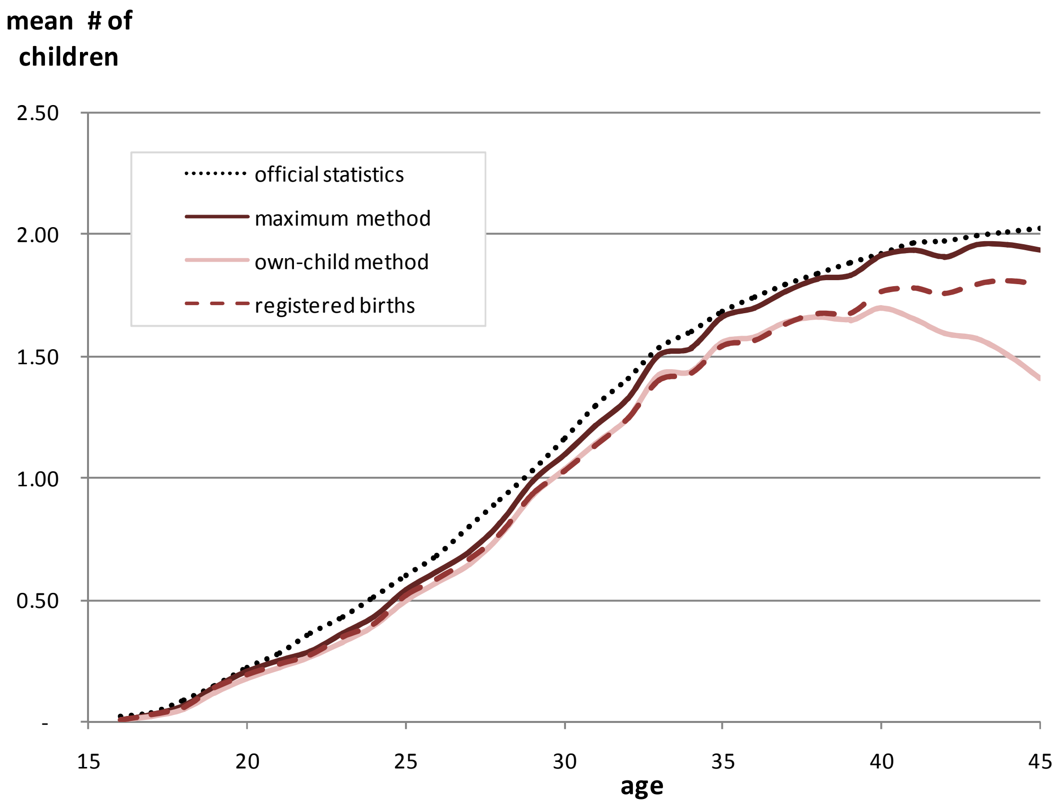
For all regression models that follow, Stata software was used (v.11), and variable selection was initially based on theoretical expectations with reference to previous research (see *Literature review*). All models were tested in a nested form, starting with a null model and then adding each variable one at a time (in perceived order of importance). However, these tests were all significant at well below the 1% level (p<0.001), no doubt due to the large sample size. Hence they are not reported throughout.

Analysis of fertility measures

Initial comparison

Two measures of fertility are initially available from the LS: registered births and own-child births (see *Measuring fertility* above). In order to compare them, and to estimate children that are 'missed', a third measure is created for each woman that uses the maximum of both methods, (i.e. the largest number of children recorded by either the own-child method or registered births). This gives three measures of the number of children born to each sample woman. Figure 2 shows the mean number of children born to women in 2001 for each measure, alongside official statistics on all registered births (i.e. the source of linked birth registration data in the LS) (ONS 2002). Completed fertility appears to be underestimated at older ages when using either registered births or the own-child method, in particular the latter.

Figure 2: Comparison of completed fertility in 2001 (children ever born)



Note: The maximum is the largest value for each woman of the 'own-child' and 'registered births' measures. Official statistics are based on all registered births in England and Wales.

Source: ONS (author's calculations using the LS, and ONS 2002)

The own-child method reports almost 4,600 fewer children than the registered births method (Appendix Table A.5), but both methods report fewer children than the 'maximum'. Compared with the maximum, the registered births method estimates 8,249 fewer children, while there are 12,826 fewer using own-children (Appendix Table A.5). In other words, for women whose number of registered births is larger than their number of own-child births, the difference is 12,826 births. This is assumed to be a reasonable estimate of children 'missed' by the own-child method, (and represents 11% of total births estimated using the maximum method). However, it is worth noting that even this may be an underestimate of missing births. This analysis makes no attempt to compare the ages of registered births and own-children, (which would be an additional way of checking whether missing children are underestimated due to both methods missing a child).

Rindfuss states *"four implicit assumptions"* that need to be met in order for the own-child method to accurately estimate fertility levels *"(1) that ages of children are correctly reported, (2) that all children reside with their mothers, (3) that mortality is negligible for women and children, and (4) that all women and children are covered by the census"* (1977). The first of these can be ignored because there is no restriction here on the age of children to be included. Additionally, the fourth assumption is likely to have minimal impact given extremely high response rates for the 2001 Census (ONS 2005 & 2006). The third assumption can be investigated (for children) using LS data (Appendix Table A.6), but even after accounting for child mortality, the number of missing children remains high (11,751), a result that is expected for low mortality settings (Abbasi-Shavazi 1997, Dubuc 2009). As such, the fact that only 8.4% of missing births (using the own-child method), are due to mortality suggests that children are most likely to be missed by the own-child method because that are not resident with their mother (Appendix Tables A.5 & A.6).

As the maximum method suggests, even when the registered and own-child methods show similar aggregated means, children may still be missing. The maximum is consistently similar to official statistics, even at older ages (Figure 2), which suggests that it is the most accurate measure of fertility that can be derived from the LS. Of course, it is possible that children are overestimated for some women (thereby inflating the maximum, and estimates of 'missing children'). However, it seems highly unlikely that births are over-registered (given the formal legal process and links with NHS information, see ONS 2002), and own-child births should only be overestimated if the census relationship question is not answered correctly (i.e. children are assigned to women who are not their mothers). The inclusion of a detailed relationship question in 2001 (including stepchild options) makes this much less likely, (except perhaps for large households) (Haskey 2004). More importantly, if all children were living with their mother (and no children had died), the own-child method (and maximum method) should in fact be larger than the official statistics (which are themselves calculated using registered births in England and Wales), due to the inclusion of children born abroad. It therefore seems that even the maximum measure may underestimate births to sample members.

Multivariate models of missing children

Bivariate analysis shows that (on average) native-born women have a larger number of registered births (compared with own-child births), whereas the opposite is true for foreign-born women (Appendix Table A.5). Multinomial regression indicates that this result holds after controlling for age, partnership and student status (variables chosen as most likely to relate to children and mothers not living together) (Appendix Table A.8). The model is based on a response variable where each woman either has:

- more registered births than own-child births (missing using the own-child method),
- more own-child births than registered births (missing using registered births), or
- the same number of births using either method (the reference category)

Table 3: Predicted probabilities by foreign indicator (selected age groups)

COB	No missing Children	Some missing using own-child method	Some missing using registered births
Women aged 21-25:			
Native-born	95%	3%	2%
Foreign-born	86%	3%	11%
Women aged 31-35:			
Native-born	89%	6%	2%
Foreign-born	67%	4%	29%
Women aged 41-45:			
Native-born	70%	23%	7%
Foreign-born	49%	16%	35%

Note: The analysis controls for age, partnership and student status (see Appendix Table A.8 for full results). Predicted probabilities are based on women who are married or cohabiting, and not studying full-time.

Source: ONS (author's calculations)

The predicted probabilities in Table 3 illustrate that foreign-born women are much more likely to have missing children when fertility is estimated using registered births, and that this is true even at early childbearing ages. This is largely explained by the fact that registered births do not include foreign-born children (which are more likely to have been born to foreign-born women). However, when models are run that exclude foreign-born children, foreign-born women still have higher odds (relative to native-born women) of missing children using registered births (although the odds are approximately halved). The best explanation for this remaining difference may be that foreign-born mothers in the LS have poorer quality linkage of registered births (Hattersley and Creeser 1995).

In fact, failed linkage in the LS is perhaps the best explanation for all missing native-births using the registered births method. Previous linkage studies found an additional 4,394 missing births to LS sample members between 1971 and 1981 (Werner 1984 and Penhale 1989 in Hattersley and Creeser 1995), and although these were added to the LS data after 1981, an equivalent exercise has not been carried out for subsequent decades. Given that the registered births method is shown here to underestimate miss almost 8,250 children, two further decades of linkage failure may go some way to explaining underestimated fertility using registered births.

For older women (both native- and foreign-born), there are high probabilities of children being missed using the own-child method. Considering the exclusion of other factors (e.g. mortality, see *Initial comparison* above), the best explanation for this is that children do not live with their mothers. Reasons for this could be that children have left home (to study or start a family), or are being cared for by someone other than their mother. For example, 10% of lone parents with dependent children were male in England and Wales in 2001 (McConnell and Wilson 2007). Children may also be living with other relatives, in communal establishments, or have emigrated (perhaps to marry, study, travel, or be cared for abroad).

Migration and missing children

Following on from the previous results (Table 3), Table 4 shows predicted probabilities for a similar model, but for generational status, (and with the addition of covariates used in the convergence models below, see *Testing for fertility convergence*) (Appendix Table A.9 shows full results). Considering generational order, the generations closer to ancestral natives are less likely to have missing children, in particular missing children using registered births.

Interestingly child migrants are clearly distinct from those who arrived as adults, suggesting the importance of age at migration for missing births.

Table 4: Multinomial regression predicted probabilities: generation

Generation	No missing Children	Some missing using own-child method	Some missing using registered births
Ancestral native	70%	23%	7%
Generation 2.5	69%	23%	8%
Second generation	65%	27%	8%
Child migrants	61%	25%	15%
Adult migrants	54%	12%	34%

Note: The analysis controls for age, partnership, foreign partners, student status, education, region, and urban/rural (see Appendix Table A.9 for full results). Predicted probabilities are based on women who are aged 41-45, married or cohabiting with a native-born partner, with qualifications at less than degree level, not studying full-time, and living in urban North England.
Source: ONS (author's calculations)

In addition to generational effects, the multinomial model behind the figures in Table 4 shows the importance of other explanatory variables for missing births (Appendix Table A.9). In general, the pattern is the same for both the own-child method and registered births. Births are more likely to be missing if women are: older, partnered, have a foreign-partner, have no qualifications, are not students, and are living in urban areas or outside London. Notably, the effects of partnership and having a foreign partner are stronger for missing children using registered births. The latter probably relates to a higher likelihood of having foreign-born children.

Additional multinomial models were used to explore variation in missing children by country of birth and age at migration. As might be expected due to the exclusion of foreign-born children, missing children using registered births were more likely for all countries of birth relative to the native-born (Appendix Figure A.10), and also more likely as age at migration increases. The results were less clear for births missed by the own-child method. Odds of missing children were significantly higher (at the 1% level, relative to native-born women) for women born in Southern Asia, and significantly lower (at the 5% level, relative to native-born women) for women born in Europe, North America, Oceania, Asia, the Middle East, and some areas of Africa. For missing children using the own-child method, age at migration effects were volatile and showed no coherent pattern.

Testing for fertility convergence

Generational convergence

As stated previously, the convergence hypothesis is that the number of children born to women who are resident in England and Wales can be ranked according to their migrant generation as follows:

1. Adult migrants (foreign-born women who migrated aged >16)
2. Child migrants (foreign-born women who migrated aged 0-16)
3. Second generation (native-born women with two foreign-born parents)
4. Generation 2.5 (native-born women with one foreign-born parent)
5. Ancestral natives (native-born women with two native-born parents)

The hypothesis is tested here using the previously discussed fertility measures as response variables, and accounting for years exposed to childbearing. The measure of interest is the incidence of fertility, represented by IRRs from a Poisson regression model (referred to in the text as fertility rates relative to the reference category, see *Aims and methods of analysis* above). Basic controls are included for age and geography (region and urban/rural) implying that the comparison of generational fertility rates holds these (endogenous) variables constant.

Considering results using the maximum method, the relative fertility rates (IRRs) for generations are not in the same order as the hypothesis (Table 6). This is not dissimilar to the results of bivariate analysis (shown in Appendix Table A.4). As predicted, there is a distinct difference between foreign-born generations (child and adult migrants) and native-born generations. However, child migrants have slightly higher fertility rates than adult migrants, and generation 2.5 has a significantly lower fertility rate compared with ancestral natives. The results are similar when using the own-child method to calculate fertility, except that adult migrants now have a slightly higher fertility rate compared with child migrants (in line with the hypothesis). However, the results for child and adult migrants using registered births are quite different from those using the other measures. This might be expected given that foreign-born women are more likely to have missing children using this method (Table 3).

Table 6: Poisson regression: generational model with basic controls

	Maximum method		Own-child method		Registered births	
Variable	**IRR**	**p-value**	**IRR**	**p-value**	**IRR**	**p-value**
Generation						
Ancestral native (ref)						
Generation 2.5	0.95	-	0.96	-	0.95	-
Second generation	0.97	0.11	0.97	0.07	0.97	0.03
Child migrants	1.20	-	1.22	-	1.09	-
Adult migrants	1.16	-	1.24	-	0.78	-
Age						
16 to 20	0.44	-	0.46	-	0.44	-
21 to 25	0.68	-	0.78	-	0.70	-
26 to 30	0.94	-	1.11	-	0.97	0.01
31 to 35	1.17	-	1.38	-	1.18	-
36 to 40	1.14	-	1.30	-	1.13	-
41 to 45 (ref)						
Rural	0.94	-	0.97	-	0.94	-
Region						
North (ref)						
Midlands	0.99	0.13	1.00	0.63	0.99	0.49
London	0.77	-	0.79	-	0.76	-
South	0.93	-	0.95	-	0.93	-
Wales	1.05	-	1.04	0.01	1.05	-

Note: P-values are not shown where less than 0.01

Source: ONS (author's calculations)

An important methodological question for models of fertility convergence is which control variables should be included. In particular, the inclusion of variables that are simultaneous with convergence may not be appropriate, (depending upon when they are measured and how they are modelled). For example, assimilation may influence education, resulting in a consequent change in fertility, but fertility may also affect education (and assimilation). This issue is often discussed elsewhere under the heading of migrant selection or reverse causation (e.g. Toulemon 2006). Without repeated measures of control variables, especially variables recorded at migration and childbirth, the addition of a control for education measured at the same time as fertility is not sufficient to disentangle the convergence process.

Taking this into account, Table 7 shows results of a similar model to that shown in Table 6, but with the addition of controls for partnership, foreign partners, and education (the student indicator was excluded due to theoretical overlap with education). The main difference is that the effects for child and adult migrants are reduced. In particular, the fertility of adult migrants is lower relative to ancestral natives when using the maximum method to measure births. Adding each new control separately (to the basic model shown in Table 6), showed that the two partnership variables were the main explanation for the switching direction of the adult migrant effect (between Table 6 and Table 7). In particular, the sole addition of a control for foreign partners reduced the adult migrant IRR in the basic model (Table 6) from 1.16 to 1.00, while the IRR for foreign partners in this model was 1.35, which highlights the importance of considering partner's country of birth when assessing convergence, (what Park and Burgess refer to as amalgamation (1921)).

Also of interest is that current partnership status had a notable (but smaller) 'sole' effect, reducing the adult migrant IRR from 1.16 to 1.09 when added to the basic model shown in Table 6. This suggests that partnership explains some of the differences in fertility rates between adult migrants and ancestral natives.

Table 7: Poisson regression: generational model with additional controls

	Maximum method		Own-child method		Registered births	
Variable	**IRR**	**p-value**	**IRR**	**p-value**	**IRR**	**p-value**
Generation						
Ancestral native (ref)						
Generation 2.5	1.01	0.37	1.02	0.19	1.01	0.56
Second generation	1.05	-	1.04	0.03	1.05	-
Child migrants	1.10	-	1.11	-	1.02	0.25
Adult migrants	0.96	-	1.03	0.02	0.67	-

Note: The analysis controls for age, partnership, foreign partners, education, region, and urban/rural (see Table A.11 for full results). P-values are not shown where less than 0.01

Source: ONS (author's calculations)

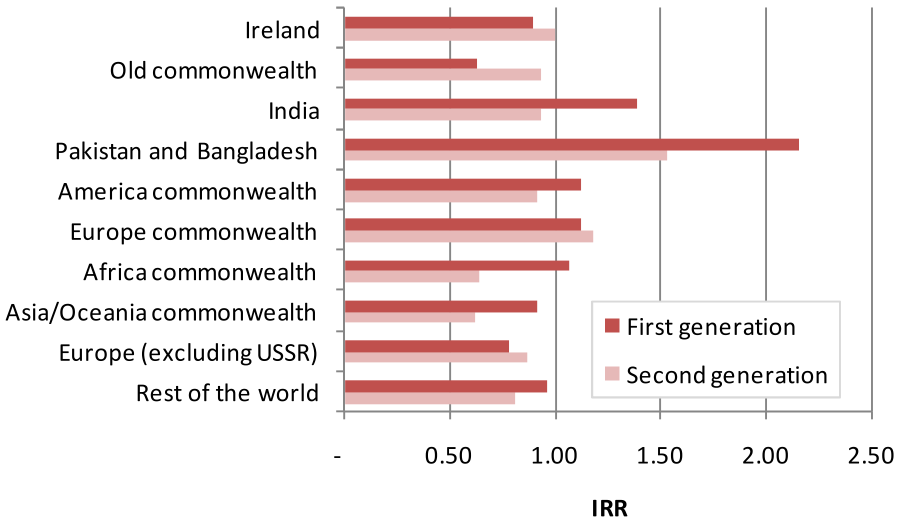
Country of origin

Convergence is expected to vary according to country of origin and country of ancestry (see *Literature Review*). This is tested here using Poisson models that collapse the five generations tested previously into three aggregate generations (shown in Table 1). The dummy variable for foreign-born migrants is then replaced by a variable for country of birth (COB), and the dummy for second generation migrants is replaced by a variable for mother's country of birth (COB). This means that IRRs for each origin (for first or second generation women) are with reference to 'ancestral natives', and can therefore be compared with each other. Unlike previously, the ancestral natives category used here also includes women with a native-born mother and a foreign-born father.

One of the requirements of this comparison is that origin countries are grouped into the same categories for both COB and mother's COB. Categories were chosen based on the least flexible (i.e. most aggregated) variable, which was the 1971 Census question on mother's COB. The categories used for this analysis are therefore historical, and probably not ideal for identifying contemporary groups of interest (e.g. East Europeans). Nevertheless, they represent historical migrant streams that may be more appropriate for grouping second generation migrants.

Figure 8 shows country of origin results using the maximum method to measure births (see Table A.12 for full results). These results are interpreted such that evidence of fertility convergence is where the second generation IRR is much closer to 1.00 than the IRR for the first generation. This is certainly true for women from South Asian origins (India, Pakistan and Bangladesh). Of course, this could be related to the different characteristics of migrant generations other than age and geography, as well as changes in the migrant selection process, (an explanation that might apply to all of the results in Figure 8). Nevertheless, the strongest evidence of convergence is for women with South Asian origins, while the results for other origins are less clear. For the (1971) Commonwealth countries of Africa and Asia, second generation fertility rates are well below those of both the first generation and ancestral natives. Low fertility might be expected for women with Asian origins, but there is no obvious reason why fertility is lower for the second generation. It may be that the results for Asia and Africa relate to delayed births for the second generation (i.e. the exposure offset may not fully account for timing). For some origins, the first generation has lower fertility than the second, but in these cases maternal IRRs are not significant, except for women with European origins.

Figure 8: Poisson regression: country of origin model (maximum method)



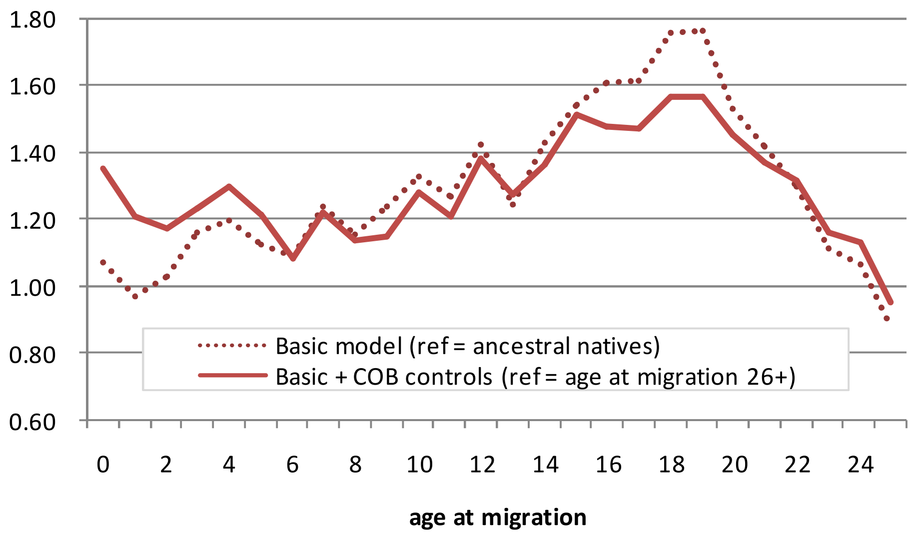
Note: The analysis controls for age, region, and urban/rural (see Table A.12 for full results). Second generation is defined here as all women with a foreign-born mother. The reference category for every origin (and both generations) is ancestral natives, defined here as women with a native-born mother. Source: ONS (author's calculations)

Equivalent results for the own-child and registered births methods are broadly similar to those shown in Figure 8, in terms of both the size of effects and the differences between generations (see Appendix Table A.12). The largest differences between results for different methods are for first generation COB using the registered births method, a result which aligns with evidence that foreign-born women have larger proportions of missing children using this method (see Table 3).

Age at migration

Although there appears to be limited difference between the fertility rates of child and adult migrants (Table 6), this may be due to the age at migration cut-off used to distinguish the two groups. This result is therefore further explored by looking at the results of a Poisson model replacing these two generations with an age at migration variable (Figure 9).

Figure 9: Poisson regression: age at migration models (maximum method)



Note: Both models control for age, region, and urban/rural. The reference category for the basic model is ancestral natives (native-born women with both parents native-born). The reference category for the model with COB controls is foreign-born women who migrated when aged over 25, (see Table A.13 for detailed results).

Source: ONS (author's calculations)

Adult migrants are defined as those arriving aged over 16, but the results in Figure 9 suggest that the adult category is a mixture of relatively high and low fertility rates. Irrespective of whether country of origin is controlled for, the highest rates are for migrants who arrive when aged 18 or 19-years-old. Interestingly, somewhat similar results have been shown for France (Toulemon 2004). For immigrants to England and Wales who arrive when 25 or older, there is no real difference compared with ancestral natives, and the same can be said of those who arrive as infants (before controlling for country of birth). After accounting for country of birth, the differences between migration ages become less, with all young arrivals showing higher fertility relative to those who arrive aged 26 or more.

Other models and robustness checks

One assumption of Poisson regression models is that the conditional mean of the response is equal to the conditional variance (Long and Freese 2006). If the variance is greater than the mean (as descriptive statistics suggest, see Appendix Table A.7), then the Poisson model is said to be overdispersed, and Negative Binomial regression is preferred (largely due to improved estimation of standard errors) (Long and Freese 2006). A number of the previous Poisson models were therefore rerun as Negative Binomial specifications, and a likelihood ratio test was used to assess the hypothesis that the Negative Binomial reduces to the Poisson model (i.e. that the additional parameter in the Negative Binomial, alpha, is equal to zero, see Long and Freese 2006). For the model in Table 7 (Appendix Table A.11), the Poisson model was found to be appropriate (i.e. the hypothesis test was not significant). However, for the model in Table 6, there was some evidence of overdispersion (for the maximum measure of fertility, the hypothesis test was significant at the 5% level, p=0.04). Nevertheless, further analysis found that there was no clear difference between the Poisson model shown in Table 6 and an equivalent Negative Binomial model. Estimates of IRRs and p-values were virtually unchanged, so that (to two significant figures), the only difference between the two models for the generational effects (for all fertility measures) was that the p-value for the second generation using registered births changed from 0.03 to 0.04.

Additional to the above, convergence tests were rerun using zero-inflated Poisson and zero-inflated Negative Binomial models. These produced some interesting results concerning childlessness (predicted zero counts), and are recommended to be applied in further research.

Finally, in order to test the effect of dropping cases with missing values for age at migration and parental COB, the models shown in Table 6 were rerun with these cases reinstated, and included as two additional dummies in the model (as part of the generation variable). Using the maximum measure of fertility, the dummy for missing parental COB was not significantly different from ancestral natives, suggesting that these missing cases might not be crucial to the results. Conversely, the dummy for missing age at migration had an IRR less than that for both child and adult migrants. This suggests that age at migration is not missing at random, and omitting missing cases may affect the results.

Discussion

This research set out to test fertility convergence in England and Wales, but also to inform the literature on fertility measurement by exploiting a unique data source, the ONS Longitudinal Study (LS). The LS allows fertility to be measured by both the own-child method and registered births, the former based on 2001 Census data and the latter based on linked vital events. Descriptive statistics show that fertility is underestimated by both methods, particularly for women who are close to completing their childbearing. Interestingly, the demographic profile of women with missing children is broadly the same for both methods (Appendix Table A.9).

Measuring fertility in the LS using registered births is more likely to distort the results of migrant fertility analysis, with the main issues being the exclusion of foreign-born children and failed linkage in the LS. Unless migrant births are of little importance, the implication for future fertility research using the LS is to either avoid this measure or to adjust it using the own-child method. An unadjusted measure may seem appropriate where only births after migration are to be considered, but the problem with this approach is that it prevents a full understanding of the timing, level and parities of migrant births (e.g. Toulemon 2006). For researchers using the LS, it is therefore recommended that the maximum (of both registered and own-child births) is used to avoid missing children.

For researchers using the own-child method with other datasets, this research indicates likely sources of measurement error, and provides statistics that might be used as correction factors. If missing (registered) births are added to the own-child calculation (referred to here as the 'maximum'), then the estimated number of children increases by 13%. Infant mortality is found to have a small effect on the number of missing children, equating to 8.4% of missing children (and 0.9% of all children when using the maximum method). Children therefore seem most likely to be missed by the own-child method because they do not live with their mother. This is more prevalent for native-born women, possibly because their children are more likely to leave home earlier (to study or enter a partnership) (Rumbaut and Komaie 2010). The implication for future research using the own-child method is that this issue should be accounted for, either by restricting the analysis (to younger women, or those with recent births only), or correcting the number of births (ideally using the same data source).

This report began by stating the need for more robust information on fertility convergence, to inform population projections for England and Wales, and contribute to the development of fertility and migration theory. The findings show that second generation fertility in England and Wales is very similar to that of ancestral natives, suggesting that aggregate generational convergence occurs for all native-born women, regardless of migrant ancestry (Tables 6 & 7). The inclusion of origin effects complicates this stark conclusion, showing that generational convergence is not consistent across origins (Figure 8), although there is strong evidence of convergence for women with South Asian origins. A topic for future research, this may be due to the second generation not retaining the high marriage and low divorce patterns found previously for first generation South Asians (Murphy 1995).

Another result that aligns with previous research is the fact that generation 2.5 migrants have lower fertility compared with ancestral natives (see Table 6) (Kahn 1994, Bélanger and Gilbert 2006). Further work could establish the influence of having a single foreign-born parent more precisely. Related to this, the influence of foreign partners also appears to have a material impact on convergence, but future research should use time-varying covariates to test this (and other simultaneous variables) more appropriately (Table 7 and Appendix Table A.11).

For all of these findings it is difficult to disentangle the effects of selection, timing, and births prior to migration. For example, little difference is found when comparing child and adult migrants (Tables 6 & 7), but this aggregation masks the elevated fertility of immigrants arriving aged 18-19. There are also outstanding questions about whether the results are affected by the use of complete case analysis (Appendix Table A.1), and whether an analysis that compares the ages of children (rather than just their total number) might identify further missing children.

In summary, this research makes a specific contribution to the limited literature on generational fertility convergence, and suggests the way ahead for future work on the topic. The results also make a methodological contribution, providing valuable information for researchers attempting to measure fertility, particularly when using the own-child method, and especially when using the ONS Longitudinal Study.

Appendix 1: Acknowledgements, data access and copyright

I am extremely grateful for the assistance of my supervisors, as well as other staff and fellow students at the LSE. I would also like to acknowledge the lifetime support of my grandmother, who died while I was writing this dissertation.

The permission of the Office for National Statistics to use the Longitudinal Study (LS) is gratefully acknowledged, as is the help provided by staff of the Centre for Longitudinal Study Information & User Support (CeLSIUS). CeLSIUS is supported by the ESRC Census of Population Programme (Award Ref: RES-348-25-0004). The clearance (and project) number for the LS data shown here is 30135.

Access to the LS is governed by ONS, and researchers must be granted approved status before being permitted to analyse the data (ONS 2008). One of the criteria for approval is that a project is deemed to be *"statistical research for the public good"* (See 'Approved researcher form', available at CeLSIUS 2007b). Researchers must also demonstrate an understanding of disclosure and confidentiality issues associated with the LS, as well as the capacity to adequately handle these issues while carrying out their research (CeLSIUS 2007b). All analysis takes place in a secure data laboratory on ONS premises, and all analytical output (e.g. tables, charts, regression results), must be reviewed and cleared by ONS prior to public dissemination (i.e. beyond those with approved researcher status). Support for academic users is provided by Celsius to assist with this process, and the related process of data management (e.g. dataset construction) (CeLSIUS 2007b). Nonetheless, the author alone is responsible for the interpretation of LS data.

Appendix 2: Tables and figures

Table A.1: Cases dropped from the initial sample

	n	%
All women aged 16-45 in 2001	**111,498**	
drop scotland and n.ireland	2,152	1.9
drop communal establishments	1,783	1.6
drop student not in HH at term-time	740	0.7
drop missing parental COB (if native)	4,659	4.2
drop missing age at migration	2,378	2.1
drop missing spouses COB	432	0.4
drop missing COB	52	0.0
drop not specific COB	22	0.0
drop not stated COB	31	0.0
drop missing rural	39	0.0
drop missing region	-	-
drop missing education	-	-
drop missing partnership	-	-
All women in final sample	**99,210**	
total dropped	12,288	11.0
total dropped directly due to missingness	7,613	6.8

Note: Almost 2% of women were dropped because they were born in Scotland or Northern Ireland. Given that the coverage of the LS is England and Wales, these individuals are classified as foreign-born, but they are not necessarily immigrants, at least not to the UK. Also, a number of the other sources of migrant information (chiefly questions from the 1971 Census) do not distinguish between UK constituent countries. Although they were mainly dropped for these reasons, removing these cases also avoids problems with interpretation and confusion over UK geography. It also has the advantage that they had a high proportion of missing values for age at migration. Women living in communal establishments were dropped because they do not live with their children, thereby preventing the use of the own-child method to calculate their fertility. Women were also dropped if they were students who lived away from the household during term-time. As far as the 2001 Census is concerned, these women were enumerated elsewhere (in another household or a communal hall of residence). However, they were dropped because they were only asked the first six questions on the individual part of the household census form, which meant they had missing values for country of birth and education (ONS 2001). The remainder of dropped cases relate directly to missing values.
Source: ONS (author's calculations)

Table A.2: Descriptive statistics (fertility and explanatory variables)

variable	Native-born[1]	Foreign-born	All women
mean number of children			
own-child	1.01	1.26	1.03
registered births	1.09	0.98	1.08
maximum	1.14	1.36	1.16
age group			
16-20	14%	7%	14%
21-25	14%	14%	14%
26-30	17%	20%	17%
31-35	19%	20%	19%
36-40	19%	19%	19%
41-45	17%	20%	17%
education			
no qualifications	14%	25%	15%
less than degree	66%	42%	63%
degree qualifications	20%	34%	21%
partnership			
single	35%	23%	33%
married or cohabiting	57%	69%	58%
separated/widowed/divorced	9%	8%	8%
foreign partner?			
partner is foreign-born?	4%	41%	8%
rural			
residence is rural? (not urban)	20%	8%	19%
region			
North	29%	14%	27%
Midlands	30%	23%	29%
London	11%	42%	14%
South	25%	19%	24%
Wales	6%	2%	5%
student			
is student? (living at home)	11%	10%	11%
observations (n)	**88,487**	**10,723**	**99,210**

1: Native-born women are those born in England and Wales. Women born in Scotland or Northern Ireland are dropped from the sample (see Table A.1).

Source: ONS (author's calculations)

Table A.3a: Descriptive statistics (generation and age at migration)

variable	All women	%
generation		
Ancestral native	77,952	79%
Generation 2.5	5,807	6%
Second generation	4,728	5%
Generation 1.5	3,663	4%
First generation	7,060	7%
age at migration		
Native	88,487	89%
0-5	1,824	2%
6-11	1,023	1%
12-16	816	1%
17-19	1,407	1%
20-25	2,975	3%
26+	2,678	3%
observations (n)	**99,210**	

Note: Percentages may not add up to 100 because of rounding

Source: ONS (author's calculations)

Table A.3b: Descriptive statistics (country of origin)

origin	First generation	%	Second generation	%
Ireland	489	5%	1,815	25%
Old commonwealth	589	5%	149	2%
India	1,296	12%	1,034	14%
Pakistan	1,665	16%	801	11%
America commonwealth	299	3%	871	12%
Europe commonwealth	216	2%	231	3%
Africa commonwealth	1,275	12%	464	6%
Asia/Oceania commonwealth	568	5%	207	3%
Europe (excluding USSR)	1,855	17%	1,107	15%
Rest of the world	2,472	23%	596	8%
observations (n)	**10,724**		**7,275**	

Note: Percentages may not add up to 100 because of rounding

Source: ONS (author's calculations)

Table A.4: Mean number of children

	method		
generation	**own child**	**registered**	**maximum**
Ancestral native	1.03	1.12	1.16
Generation 2.5	0.91	0.98	1.03
Second generation	0.80	0.85	0.89
Generation 1.5	1.18	1.14	1.32
First generation	1.30	0.89	1.39
Total	**1.03**	**1.08**	**1.16**

Note: The maximum method uses the largest value for each woman of the 'own-child' and 'registered births' measures.

Source: ONS (author's calculations)

Table A.5: Number of children estimated using different fertility measures

ALL WOMEN:	# of women			# of children		
	method			method		
# children	**own-child**	**registered**	**maximum**	**own**	**reg**	**max**
0	46,694	46,174	43,868	-	-	-
1	17,838	17,335	16,473	17,838	17,335	16,473
2	23,276	22,837	24,278	46,552	45,674	48,556
3	8,571	9,013	10,105	25,713	27,039	30,315
4	2,103	2,756	3,155	8,412	11,024	12,620
5	477	717	861	2,385	3,585	4,305
6	150	238	284	900	1,428	1,704
7	66	89	115	462	623	805
8 or more	35	51	71	314	445	624
total	**99,210**	**99,210**	**99,210**	**102,576**	**107,153**	**115,402**

NATIVE-BORN:	# of women			# of children		
	method			method		
# children	**own-child**	**registered**	**maximum**	**own**	**reg**	**max**
0	42,073	40,567	39,532	-	-	-
1	16,029	15,392	14,663	16,029	15,392	14,663
2	20,934	20,992	21,871	41,868	41,984	43,742
3	7,291	8,193	8,792	21,873	24,579	26,376
4	1,713	2,447	2,661	6,852	9,788	10,644
5	312	597	650	1,560	2,985	3,250
6	91	192	205	546	1,152	1,230
7	32	68	71	224	476	497
8 or more	12	39	42	104	339	364
total	**88,487**	**88,487**	**88,487**	**89,056**	**96,695**	**100,766**

FOREIGN-BORN:	# of women			# of children		
	method			method		
# children	**own-child**	**registered**	**maximum**	**own**	**reg**	**max**
0	4,621	5,607	4,336	-	-	-
1	1,809	1,943	1,810	1,809	1,943	1,810
2	2,342	1,845	2,407	4,684	3,690	4,814
3	1,280	820	1,313	3,840	2,460	3,939
4	390	309	494	1,560	1,236	1,976
5	165	120	211	825	600	1,055
6	59	46	79	354	276	474
7	34	21	44	238	147	308
8 or more	23	12	29	210	106	260
total	**10,723**	**10,723**	**10,723**	**13,520**	**10,458**	**14,636**

Note: The maximum method uses the largest value for each woman of the 'own-child' and 'registered births' measures.

Source: ONS (author's calculations)

Table A.6: Child mortality statistics

	Native-born[1]	Foreign-born	All women
Number of women with a deceased child	899	104	1,003
% of all women	1.02%	0.97%	1.01%
Number of deceased children	956	119	1,075
% of all children (own-child method)	1.07%	0.88%	1.05%
% of all children (maximum method)	0.95%	0.81%	0.93%
observations (n)	**88,487**	**10,723**	**99,210**

1: Native-born women are those born in England and Wales. Women born in Scotland or Northern Ireland are dropped from the sample (see Table A.1).

Source: ONS (author's calculations)

Table A.7: Comparison of means and variances for fertility measures

	method		
	own child	**registered**	**maximum**
E&W-born			
Mean	1.01	1.09	1.14
Variance	1.32	1.52	1.58
Standard deviation	1.15	1.23	1.26
Foreign-born			
Mean	1.26	0.98	1.36
Variance	2.03	1.69	2.22
Standard deviation	1.42	1.30	1.49

Note: The maximum method uses the largest value for each woman of the 'own-child' and 'registered births' measures.

Source: ONS (author's calculations)

Table A.8: Multinomial regression results: foreign indicator model (odds ratios)

Variable	(Response reference is: own-child = registered) Registered larger than own-child	p-value	Own-child larger than registered	p-value
Foreign-born	0.95	0.21	7.00	-
Age				
16 to 20	0.07	-	0.12	-
21 to 25	0.10	-	0.19	-
26 to 30	0.13	-	0.31	-
31 to 35	0.19	-	0.61	-
36 to 40	0.37	-	0.89	-
41 to 45 (ref)				
Student	0.43	-	0.79	0.02
Partnership status				
Single (ref)				
Partnered	1.43	-	4.64	-
Div/Sep/Wid	3.43	-	5.86	-

Note: P-values are not shown where less than 0.01

The model is based on a response variable such that a woman has: more registered births than own-child births (missing own-child), more own-child births than registered births (missing registered), or the same number of births using either method (the reference category)

Source: ONS (author's calculations)

Table A.9: Multinomial regression results: generation model (odds ratios)

Variable	(Response reference is: own-child = registered)			
	Registered larger than own-child	p-value	Own-child larger than registered	p-value
Generation				
Ancestral native (ref)				
Generation 2.5	1.02	0.71	1.18	0.02
Second generation	1.24	-	1.28	-
Child migrants	1.24	-	2.53	-
Adult migrants	0.69	-	6.40	-
Age				
16 to 20	0.06	-	0.11	-
21 to 25	0.11	-	0.18	-
26 to 30	0.15	-	0.31	-
31 to 35	0.20	-	0.63	-
36 to 40	0.39	-	0.91	0.02
41 to 45 (ref)				
Student	0.48	-	0.82	0.06
Partnership status				
Single (ref)				
Partnered	1.51	-	3.76	-
Div/Sep/Wid	3.27	-	5.36	-
Foreign partner	1.17	-	2.05	-
Education				
No qualifications (ref)				
Less than degree	0.33	-	0.61	-
Degree qualifications	0.15	-	0.48	-
Region				
North (ref)				
Midlands	0.88	-	0.86	-
London	0.74	-	0.90	0.03
South	0.82	-	0.88	-
Wales	1.10	0.07	1.02	0.81
Rural	0.85	-	0.97	0.43

Note: P-values are not shown where less than 0.01

The model is based on a response variable such that a woman has: more registered births than own-child births (missing own-child), more own-child births than registered births (missing registered), or the same number of births using either method (the reference category)

Source: ONS (author's calculations)

Figure A.10: Multinomial regression results: country of birth model (odds ratios)

	odds ratios (reference = no missing children)		p-value	
individual cob	**More reg**	**More own**	**More reg**	**More own**
Republic of Ireland	0.45	2.70	-	-
North Europe	0.08	3.23	0.01	-
West Europe	0.59	3.00	-	-
South Europe	0.57	4.28	0.02	-
East Europe	0.36	11.15	0.01	-
North America	0.42	3.90	-	-
Central America	0.86	5.43	0.89	0.01
Caribbean	1.31	6.20	0.15	-
South America	0.88	5.99	0.68	-
Middle East	0.58	10.68	0.01	-
China (& connected)	0.64	6.76	0.11	-
North East Asia	0.09	8.64	0.02	-
South East Asia	0.47	4.52	-	-
Southern Asia	2.14	10.81	-	-
Northern Africa	1.81	10.52	0.06	-
Central Africa	1.53	12.28	0.27	-
Western Africa	0.57	9.31	0.02	-
Eastern Africa	0.71	6.88	0.01	-
Southern Africa	0.20	5.96	-	-
Oceania	0.18	1.97	-	-

Note: P-values are not shown where less than 0.01

The model is based on a response variable such that a woman has: more registered births than own-child births (missing own-child), more own-child births than registered births (missing registered), or the same number of births using either method (the reference category)

The analysis controls for age, partnership and student status

Source: ONS (author's calculations)

Table A.11: Poisson regression: generational model with additional controls

	Maximum method		Own-child method		Registered births	
Variable	**IRR**	**p-value**	**IRR**	**p-value**	**IRR**	**p-value**
Generation						
Ancestral native (ref)						
Generation 2.5	1.01	0.37	1.02	0.19	1.01	0.56
Second generation	1.05	-	1.04	0.03	1.05	-
Child migrants	1.10	-	1.11	-	1.02	0.25
Adult migrants	0.96	-	1.03	0.02	0.67	-
Age						
16 to 20	0.86	-	0.92	0.02	0.85	-
21 to 25	1.06	-	1.20	-	1.09	-
26 to 30	1.19	-	1.37	-	1.23	-
31 to 35	1.31	-	1.52	-	1.32	-
36 to 40	1.20	-	1.36	-	1.20	-
41 to 45 (ref)						
Partnership status						
Single (ref)						
Partnered	2.43	-	2.61	-	2.40	-
Div/Sep/Wid	2.57	-	2.51	-	2.52	-
Foreign partner	1.19	-	1.21	-	1.10	-
Education						
No qualifications (ref)						
Less than degree	0.70	-	0.77	-	0.69	-
Degree qualifications	0.49	-	0.56	-	0.48	-
Region						
North (ref)						
Midlands	0.98	-	0.98	0.01	0.98	0.02
London	0.88	-	0.88	-	0.86	-
South	0.96	-	0.96	-	0.96	-
Wales	1.04	-	1.03	0.03	1.04	-
Rural	0.97	-	0.98	0.02	0.96	-

Note: P-values are not shown where less than 0.01

Source: ONS (author's calculations)

Table A.12: Poisson regression: country of origin models

	Maximum method		Own-child method		Registered births	
Variable	**IRR**	**p-value**	**IRR**	**p-value**	**IRR**	**p-value**
Country of birth						
Ireland	0.89	0.01	0.93	0.14	0.78	-
Old commonwealth	0.63	-	0.68	-	0.53	-
India	1.39	-	1.46	-	1.12	-
Pakistan	2.15	-	2.20	-	1.66	-
America commonwealth	1.11	0.02	1.12	0.03	0.97	0.56
Europe commonwealth	1.12	0.04	1.16	0.01	0.91	0.13
Africa commonwealth	1.06	0.03	1.14	-	0.80	-
Asia/Oceania commonwealth	0.91	0.01	0.97	0.45	0.70	-
Europe (excluding USSR)	0.78	-	0.82	-	0.58	-
Rest of the world	0.96	0.04	1.03	0.15	0.57	-
Parental country of birth						
Ireland	0.99	0.79	1.01	0.52	1.00	0.95
Old commonwealth	0.93	0.37	0.97	0.73	0.86	0.10
India	0.93	0.04	0.91	0.01	0.91	0.01
Pakistan	1.53	-	1.48	-	1.44	-
America commonwealth	0.91	0.01	0.87	-	0.92	0.02
Europe commonwealth	1.18	0.02	1.24	-	1.18	0.02
Africa commonwealth	0.63	-	0.65	-	0.62	-
Asia/Oceania commonwealth	0.61	-	0.66	-	0.62	-
Europe (excluding USSR)	0.86	-	0.89	-	0.86	-
Rest of the world	0.81	-	0.81	-	0.79	-
Age						
16 to 20	0.43	-	0.46	-	0.44	-
21 to 25	0.68	-	0.78	-	0.70	-
26 to 30	0.95	-	1.12	-	0.98	0.03
31 to 35	1.17	-	1.38	-	1.18	-
36 to 40	1.14	-	1.31	-	1.13	-
41 to 45 (ref)						
Rural	0.96	-	0.99	0.13	0.96	-
Region						
North (ref)						
Midlands	0.99	0.25	1.00	0.87	1.00	0.61
London	0.80	-	0.82	-	0.78	-
South	0.95	-	0.97	-	0.95	-
Wales	1.06	-	1.05	-	1.06	-

Note: P-values are not shown where less than 0.01

The analysis controls for age, region, and urban/rural. Second generation is defined here as all women with a foreign-born mother. The reference category for every origin (and both generations) is ancestral natives, defined here as women with a native-born mother.

Source: ONS (author's calculations)

Table A.13: Poisson regression: age at migration models (maximum method)

	Basic model		Basic + COB	
	Maximum method		Maximum method	
Variable	**IRR**	**p-value**	**IRR**	**p-value**
Age at migration				
0	1.07	0.07	1.35	-
1	0.97	0.57	1.21	-
2	1.03	0.63	1.17	0.01
3	1.16	0.02	1.23	-
4	1.20	-	1.30	-
5	1.12	0.09	1.21	0.01
6	1.09	0.24	1.08	0.28
7	1.24	-	1.22	-
8	1.15	0.04	1.14	0.07
9	1.24	-	1.15	0.04
10	1.33	-	1.28	-
11	1.27	-	1.21	0.01
12	1.42	-	1.38	-
13	1.24	-	1.27	-
14	1.43	-	1.36	-
15	1.54	-	1.51	-
16	1.61	-	1.48	-
17	1.61	-	1.47	-
18	1.75	-	1.57	-
19	1.76	-	1.57	-
20	1.53	-	1.45	-
21	1.41	-	1.37	-
22	1.30	-	1.31	-
23	1.12	0.01	1.16	-
24	1.07	0.16	1.13	0.01
25	0.88	0.01	0.95	0.38
26+	0.88	-	reference	

Note: P-values are not shown where less than 0.01

The analysis controls for age, region, and urban/rural, and for the second model also country of birth. All terms not shown were significant at the 5% level, except for around one quarter of the country of birth estimates, and the midlands region.

Source: ONS (author's calculations)

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