# Aim

The aim of this paper is to present and describe the processes involved in producing a lattice plot which shows both age-specific fertility rates (ASFRs) available by year, and implied cumulative cohort fertility rates (CCFRs) for dozens of countries whose data is available either within the HFD or HFC. The end result is a lattice of Lexis surface visualisations, arranged by cohort on the horizontal axis and age on the vertical axis. Within this visualisation the ASFRs are represented graphically by cell shade, CCFRs by a series of easily distinguishable contour lines, and the strips which label each of the small multiples within the visualisation are coloured according to geographic region.

We suggest that the full visualisation produced is best viewed by being printed out in colour as an A3 or A2 poster, which we have found to greatly facilitate at-a-glance comparison between countries; to this end we make a high resolution version of the final visualisation available online, along with the R code used to produce this final visualisation and additional figures for individual countries. Within this paper we present this final visualisation, as well as smaller visualisations comprising a small subset of countries to illustrate the value of this approach for both within-country and cross-country comparison of fertility trends.

# Methods

## Data

To provide broad geographic and temporal coverage, data from the Human Fertility Database (HFD) and Human Fertility Collection (HFC) were combined.1,2 The Human Fertility Database (HFD) includes age-specific fertility rates (ASFRs) for 28 countries over a range of periods, and is entirely based on official vital statistics from each country; data from each country are rigorously checked and standardised according to a detailed methods protocol. In addition to overall ASFRs birth-order specific fertility rates are also included in the HFD, alongside summary statistics such as crude birth rates, mean age at birth, and total fertility rates;2 however for the present visualisations only overall ASFRs are used. The HFC is a complementary database to the HFD, created by the same institutions, which aims to supplement the high-quality, official vital statistics contained in the HFD with data from additional sources whose data quality may not be of the same standard.3 Data disaggregated by age in single year was used from both the HFD and HFC, and Lexis squares (one year by one year) rather Lexis triangles or Lexis parallelograms were used. In addition to the 28 countries from the HFD, data from 48 countries were used, but not all were included in the final lattice visualisation because of limited periods of observation.

Data from the HFD and HFC are overlapping for some years and countries. Where more than one country- and year-specific ASFR was available, the value from the HFD was used in first preference; otherwise, records from the HFC were used in the following order of preference according to the ‘collection’ field of the HFC dataset: 1) STAT (Official Statistical Data); 2) ODE (Data from the European Demographic Observatory, L’Observatoire Démographique Européen); 3) RE (Research estimates). For almost all countries, this approach produced a dataset comprising ASFRs for many contiguous years. The only exceptions to this contiguity were Bosnia and Hertzegovina (BIH), where records were missing for the years 1991 to 1995 inclusive, and Belarus (BLR), where records for 2013 were missing. In both of these cases ASFRs for the missing year were imputed through simple interpolation of ASFRs from the last and next observed years (1990 and 1996 for BIH; 2012 and 2014 for BLR).

## Lexis surface mappings

For each country, ASFRs were arranged onto a Lexis surface with birth cohort year on the horizontal axis and age in years on the vertical axis; as mentioned previously Lexis squares rather than triangles or parallelograms were used throughout, so these are not true cohort estimates, but are sufficient to illustrate the principles of the visualisation, and the R code is freely available for researchers to iterate the approach further. ASFRs for each country and year were mapped to colours and shades using the Spectral colour palate from the RColorBrewer R package. [REF] The R packages Lattice and LatticeExtra were used to produce the visualisations.

For birth cohorts where ASFRs were available from age 15 years, CCFRs were produced for each age and cohort year. If refers to the ASFR for country , in year , and at age , then the CCFR for age can be defined as , where is the simple index of birth cohort (. Within the Lexis surfaces, contour lines were added at positions across the cohort-age surface where reached specific values. More specifically, a thin dashed contour indicates of 1.30 babies per woman, a thin solid contour indicates of 1.50, a thick dashed contour indicates of 1.80, and a thick solid contour indicates a replacement fertility level of 2.05. Because is a cumulative quantity, the contour lines will always have the same monotonic ordering - thin dashed, thin solid, thick dashed then thick solid - from bottom to top. The position, presence or absence, and trajectories of these contour lines across different birth cohorts, and between countries, are all useful indicators of how fertility trends have changed over time and place, and how far short of replacement fertility levels most affluent world nations fall. All countries are arranged in order of CCFR for the final year of observation.

# Results

This section will first provide the visualisation for two or more countries at a time, in order to both introduce the visualisation and illustrate its utility for both cross-cohort and cross-country comparisons. The complete visualisation will then be presented as the final figure, though as discussed previously we recommend this last visualisation be downloaded and printed in colour as a large landscape poster.

## Low Fertility European Countries: East Germany, West Germany, and Italy