Total Fertility Rates with Immediate and Very Long Run Zero Population Growth Implications for European Countries

Abstract

This paper proposes a new version of the long-run population replacement Total Fertility Rate (TFR) for population with non-zero migration. The method adjusts the ‘typically just below 2.1’ replacement level (applicable to populations which are closed to migration) for effects of constant immigration counts and emigration rates. A major advantage of this version of ‘Migration-Adjusted Replacement TFR’ compared to Parr’s (2021) version is its applicability to contexts with negative current net migration. The results for 22 European show the Migration-Adjusted Replacement TFR for 2019 ranges between 0.86 for Spain and 2.44 for Croatia. Its value is below 2.1 in 18 countries. In nine of the countries the TFR is above Migration-Adjusted Replacement level. The long-run perspective on zero growth the ‘Migration-Adjusted Replacement TFR’ provides is supplemented with near-term perspective by also presenting the TFR that would produce immediate zero population growth. The ‘Immediate Zero Growth TFRs” for 2019 range from 0.26 for Sweden to 2.83 for Bulgaria, and are mostly below the long-run Migration-Adjusted Replacement TFR. The paper argues the paired Immediate Zero Growth TFR and (long run) Migration-Adjusted Replacement TFR offer better guidance on birth rates that can prevent depopulation than the familiar ‘typically just below 2.1’ replacement TFR.

Introduction

In 2021 roughly two-thirds of the world's population lived in a country with a Total Fertility Rate (*TFR*) below 2.1 (UNPD 2022a). Every country in Europe had a TFR below this level. It is well known that, for populations with low mortality rates and normal values for the sex ratio at birth, if fertility were to remain at such a level then with zero migration eventually there will be ongoing population size decrease (Gietel-Basten and Scherbov 2021, Shen et al. 2023). However, for national (and subnational) populations observed migration is seldom zero (UNPD 2022a).

Many of the countries in which the *TFR* is below 2.1 continue to grow due to immigration and the effects of the population age-sex structure on natural increase. The latter is a consequence of the historical patterns of births, deaths and migration which have determined age-sex structures (UNPD 2022a, Canudas-Romo et al. 2022). Whether or not a sustained *TFR* below 2.1 would lead to national depopulation over the long run will depend on a country's volume of migration (Parr 2021, 2023a, b).

Recently Parr (2021, 2023a) developed a new method for deriving a 'replacement' value for the *TFR* which is coherent with long run zero population growth, assuming hypothetical stability of a positive volume of net migration and mortality rates[1]. However, whether migration is more appropriately considered in terms of a volume of net migration or in terms of an immigration count and an emigration rate is a matter of debate in the literature (UNPD 2022a, Eurostat 2020, Rogers 1990). Parr's (2021) measure of migration-adjusted replacement is not applicable to the many countries for which cumulative net migration to the female reproductive ages is negative (Parr 2023a). This paper presents a migration-adjusted replacement level for the *TFR* when migration is formulated as age-sex specific counts for

[1] Parr refers to this measure as the 'With Current Migration Replacement TFR' in Parr (2021) and as the 'Migration-Adjusted Replacement TFR' in Parr (2023a). Since the scope for application of such a measure is not restricted to the current migration level this Paper adopts the terminology in Parr (2023a).

immigration and age-sex specific rates for emigration. This measure has the major advantage over the measure of Parr (2021, 2023a) of being applicable when net migration is negative, as well when net migration is positive.

This paper's substantive focus is on European countries for 2019. In this year, despite the *TFR* being below 2.1, for approximately 60 per cent of the countries in Europe the population growth rate for 2019 was positive (Eurostat 2022). Net migration was positive in 73 per cent of Europe's countries[1]. A geographical divide in net migration is apparent, with generally higher net migration in Northern, Western and Central European countries than in Eastern European countries[2]. Of the countries with populations of over 1 million, Spain, Slovenia, Sweden, Ireland and the Netherlands had the highest rates of net migration inflow and Moldova, Kosovo and Albania the highest rates of net migration outflow (UNPD 2022a).

The literature documents a range of methods which extend the concept of population (or cohort) fertility replacement level to consider the effects of migration. Hyrenius (1951) and Preston and Wang (2007) consider the concept of a cohort 'replacement level' corresponding to constant fertility, mortality and net migration rates (as distinct from volumes). However, the underlying assumption that the volume of immigration, as well as emigration, for a specified age-sex group should be related to the corresponding number in the population in that age-sex group is questionable, because it neither reflects the population which is exposed to the risk of moving nor the effects of immigrant policy selection criteria on this number (Kupiszewski and Kupiszewski 2008). Coale (1972) and Keely and Kraly (1978). calculate Total Fertility Rates for the native born that would generate a stationary

[2] In this paper 'Northern Europe' refers to Denmark, Finland, Iceland, Norway and Sweden. ,'Western Europe' refers to Belgium, France, Ireland, Luxembourg, the Netherlands and the United Kingdom. 'Central Europe' refers to Austria, Germany, Liechtenstein, and Switzerland. Southern Europe refers to Greece, Italy, Portugal, Spain, Andorra, Cyprus and Malta. 'Eastern Europe' refers to Bulgaria, Czechia, Hungary, Poland, Romania, Slovakia, Estonia, Latvia, Lithuania, Belarus, Moldova, Russian Federation, Ukraine, Albania, Bosnia and Herzegovina, Croatia, Serbia, Montenegro, North Macedonia, and Slovenia.

population with the an number of births equal to the current number of births, under constant migration volumes and mortality rates and specified constant fertility rates for the immigrant population. Alho (2008) considers cohort replacement considering net migration volumes which are proportional to births. However, the proportionality of net migration to births lacks a convincing rationale or empirical justification. Billari and Dalla- Zuanna (2011) and Wilson et al (2013) empirically observe whether immigration has maintained annual births or the size of birth cohorts reaching prime reproductive age across a range of European countries. Espenshade (1982) formulated an extension of the net reproduction rate to consider the effect on the depletion of female cohort numbers of emigration, as well as mortality. However, what Espenshade (1982) termed the '(Net) Net Reproduction Rate' ignores immigration.

The aforementioned studies focus on female birth cohort replacement (that is on whether numbers of daughters born or the size of cohorts of women will increase) under specified patterns for fertility, migration and mortality. This paper considers a different perspective, namely that of total population size replacement. Total population size replacement is based on stationary population theory for populations with non-zero migration (Pollard 1973, Espenshade et al. 1982, Schmertmann 1992). As Espenshade et al. (1982) put it; "as long as fertility is below replacement, a constant number and age distribution of immigrants (with fixed fertility and mortality schedules) leads to a stationary population". Total population size replacement considers transformations to fertility or migration which would equate the stationary population (referred to here as the Terminal Stationary Population, following Parr and Guest (2014)) to a specified number, assuming all other data inputs into the calculation of the Terminal Stationary Population are unchanged. Espenshade et al. (1982) calculated the constant net migration that would equate the size of Terminal Stationary Population to the then actual US population size, assuming unchanged fertility and mortality. Parr (2023b) presented the values for a range of European countries, using data from 2009-18.

Parr (2021) proposed a formula for calculating a total population size replacement level for fertility. Parr's (2021) formula calculates the value of the *TFR* that in combination with constant migration by age and sex, formulated as the difference between immigration count and emigration count, and constant age-sex mortality rates would generate a Terminal Stationary Population equal in size to a specified population size. When the specified population size is the current population size (as considered in Espenshade et al. (1982) and Parr (2021, 2023a)) the value of such a total population size replacement measure has a long-run zero population growth implication. The comparison of prevailing values of fertility and net migration to the values of the corresponding measures of total population size replacement has considerable potential for enhancing the understanding of the dynamics of and prospects for long run population growth (Parr 2021, 2023a).

The formulation of migration (i.e. net migration) which is used in the calculation of Parr's (2021) 'With Current Migration Replacement TFR' is used in population projections by a range of official national government statistical agencies and by the United Nations (Cappelen et al. 2015, UNPD 2022a). Such a formulation of net migration is appropriate for populations for which immigration and emigration counts move in tandem, as might be expected when immigration policy is formulated with an eye to maintaining a particular net migration number or (with time lags) when international moves involve temporary stays inside or outside the country (and hence departures numbers which are linked to previous arrivals numbers). In some contexts, data availability constraints may make net migration the only feasible operational formulation of migration: in some contexts, indirect estimation of net migration may be feasible even when credible, separate estimates of immigration and emigration are unavailable (Yusuf et al. 2014). However, Parr's (2021) measure of migration-adjusted replacement fertility is inapplicable to certain patterns of net migration. In particular, it cannot be estimated for populations for which (cumulative) net migration to the female reproductive ages is negative (Parr 2023a). For this reason, calculation of values of this measure for the many Eastern European countries for which net migration for females in and below the reproductive ages is negative is not possible. Calculation of Parr's (2021) migration-adjusted measure of replacement also is infeasible for a few countries in which net migration exceeds a particular threshold level[3].

Rogers (1990) argues that, in combination with immigration formulated in terms of counts, it is more appropriate to consider emigration formulated in terms of rates than in terms of counts. Such a formulation relates emigration to the size of the population which is exposed-to-risk of emigration, and is used in population projections by Eurostat (2020) and some official national government statistical agencies (Cappelen et al. 2015).

This paper modifies the method of Parr (2021, 2023a) to consider migration as the combination of age-sex specific immigration counts and emigration rates (per person) by age and sex for 22 European countries for 2019. It examines; (1) the variation in the values of this measure of migration-adjusted replacement level between countries; (2) the differences between the observed TFR and this measure; 3) the differences between these levels of fertility which are coherent with long run zero population growth under hypothetical stability of fertility rates, mortality rates, immigration counts and emigration rates and the levels of fertility which would produce zero population growth immediately; and 4) the differences between this measure and the version of migration-adjusted replacement level proposed by Parr (2021).

[S] When net migration is greater than population/ Mean Life Expectancy After Net Migration. the number of net migration survivors will exceed the actual population size.

Method and Data Source

Parr (2021, 2023a) shows the Migration-Adjusted Replacement TFR (abbreviated here as *MAR_TFR*), which in combination with specified volumes of net migration by age and sex, mortality rates by age and sex and proportionate contributions to *TFR* from the age-specific fertility for the female reproductive age groups generates a Terminal Stationary Population size (*P*) equal in size to the real population for the time period considered (*POP)*, can be calculated by:

$$MAR\_TFR = \frac{TFR}{NRR} \times \frac{POP-P_1}{POP-P_1+\frac{P_2}{NRR}} \tag{1}$$

Where P_1 denotes the size of the 'first generation migrant' component (i.e. surviving (net) migrants) (P_1) of the Terminal Stationary Population and is calculated by:

$$P_1 = M \sum_{j=1}^{2} \sum_{x=0}^{\omega} m_{x,j} e_{x,j} \tag{2}$$

Where *M* denotes the total volume of net migration, $m_{x,j}$ denotes the proportion of total net migration contributed by persons of age *x* (last birthday) and sex *j* (1 for female and 2 for male), $e_{x,j}$ is the (remaining) life expectancy for *x* and *j*, and ω is the maximum age of people in the population. Following Ryder (1997), $\sum_{x=0}^{\omega} m_{x,j} e_{x,j}$ is termed Mean Life Expectancy After Net Migration.

P_2 denotes the size of the 'second generation migrant' component **(**survivors from the births to 'first generation migrants') of the Terminal Stationary Population and is calculated by:

$$P_2 = M\, TFR \sum_{j=1}^{2} s_j e_{0,j} \sum_{x=0}^{k} m_{x,1} \sum_{t=0}^{k-x} f_{x+t}\, {}_{t}p_{x,1} \tag{3}$$

Where *TFR* denotes the Total Fertility Rate, f_{x+t} is the proportionate contribution to *TFR* from the Age-Specific Fertility Rate for age $x+t$, ${}_{t}p_{x,1}$ is the probability of a female surviving from *x* to $x+t$, *k* the upper limit of the female reproductive age range, s_j is the proportion of births of sex *j*, and $e_{0,j}$ is life expectancy at birth for sex *j*.

For all i ≥2

$P_{i+1} = NRR\ P_i$ (4)

where P_i denotes the size of the 'ith generation migrant' component and *NRR* denotes the conventional (zero migration) net reproduction rate.

Thus, for *NRR* < 1, using the expression for the sum of a geometric progression, the total size of the Terminal Stationary Population *(P)* can be calculated by:

$$P = P_1 + \frac{P_2}{(1-NRR)} \quad (5)$$

When immigration is specified in terms of age-sex specific counts and emigration in terms of age-sex specific rates, the formula for the Migration-Adjusted Replacement TFR (abbreviated here as *MAR_TFR**) which, together with the specifications for mortality and the proportionate age distribution of fertility described above, equates the value of *P* with *POP* has a parallel formulation to the formulation presented in Equation (1). *MAR_TFR** can be calculated by[4]:

$$MAR\_TFR^* = \frac{TFR}{NRR} \times \frac{POP-P_1^*}{POP-P_1^*+\frac{P_2^*}{NRR^*}} \quad (6)$$

Where

P_1*, the 'first generation immigrant' (i.e. foreign-born) component, is calculated by:

$$P_1{*} = IM \sum_{j=1}^{2} \sum_{x=0}^{\omega} im_{x,j} e_{x,j}^* \quad (7)$$

Where *IM* denotes the total immigration, $im_{x,j}$ denotes the proportion of total immigration contributed by persons of age *x* (last birthday) and sex *j* (1 for female and 2 for male), $e_{x,j}^*$ is the (remaining) life expectancy for *x* and *j* for the life table with both mortality and emigration as decrements (Yusuf et al. 2014), and ω is the maximum age of people in the population. In this paper $\sum_{x=0}^{\omega} im_{x,j} e_{x,j}^*$ is referred to as Mean Life Expectancy after Immigration.

[4] A spreadsheet for calculating values of MAR_TFR* is available online.

P_2*, the 'second generation immigrant' component (i.e. native-born children of foreign-born mothers), is calculated by:

$$P_2* = \text{IM}\ TFR \sum_{j=1}^{2} s_j e_{0,j}^* \ \sum_{x=0}^{k} im_{x,1} \sum_{t=0}^{k-x} f_{x+t}\ {}_t p_{x,1}^* \quad (8)$$

Where TFR denotes the Total Fertility Rate, f_{x+t} is the proportionate contribution to TFR from the age-specific fertility for age $x+t$, ${}_t p_{x,1}^*$, is the probability of a female surviving and not emigrating between age x and age $x+t$, k is the upper limit of the female reproductive age range, s_j is the proportion of births of sex j, and $e_{0,j}^*$ is life expectancy at birth for sex j for a life table with both mortality and emigration as decrements.

For all i ≥2

$$P_{i+1}* = NRR^* P_i* \quad (9)$$

Where P_i* denotes the size of the 'ith generation immigrant' component and $NRR*$ denotes what Espenshade (1982) termed the (Net) Net Reproduction Rate (i.e. the rate of reproduction for a cohort of females which is depleted by both mortality and emigration). Hence:

$$P = P_1* + \frac{P_2^*}{(1-NRR^{\wedge})} \quad (10)$$

Constant fertility at MAR_TFR* combined with constant immigration counts by age and sex ($IM \times im_{x,j}$) and constant age-sex specific emigration rates and mortality rates will generate a Terminal Stationary Population (P^*) equal in size to the current population. However, the age-sex distribution of the Terminal Stationary Population generally will differ from the current age distribution of the 'real' population. Due to this difference in age-sex structure, the volume of emigration generated by applying the observed age-sex specific emigration rates to the age-sex distribution of the Terminal Stationary Population will differ from the current observed volume of emigration.

This paper aims to supplement the long-run perspective on the relationship between the TFR and zero population growth that is provided by MAR_TFR* with the perspective provided by on the *TFR* which generate zero growth in the short-term. More specifically, it compares observed values of the *TFR* and *MAR_TFR** for 2019 to the value which would have produced zero population growth in that year under the assumption that all Age-Specific Fertility Rates are scaled by the same amount. The scaling of Age-Specific Fertility Rates which would produce zero population growth is multiplication by (population growth minus births) divided by the observed total births for that year. When population growth is zero:

$$B = D - IM + EM - SA \quad (11)$$

Where *B* denotes the annual total number of births, *D* denotes the annual total number of deaths, *IM* is the total volume of immigration, *EM* is the total volume of emigration, *SA* the statistical adjustment to achieve demographic balance[5].

In the apparent absence of a widely-used term in the literature, this measure is referred to in this paper as the Immediate Population Replacement TFR (*IPR_TFR*). Thus *IPR_TFR* is calculated as follows:

$$IPR\_TFR = TFR \times (D - IM + EM - SA)/ B \quad (12)$$

To assist the reader, Table 1 provides a glossary of the new notation and terms.

The data are for 22 European countries for 2019. All data inputs were sourced from the Eurostat (2022) website. The choice of countries was restricted to countries for which all the requisite data inputs for calculating *MAR-TFR** were available for 2019 from this website. There are differences between countries in the completeness of immigration and emigration data, and the definitions used for statistical purposes also differ between countries, as does comparability between countries[6] (Mooyaart et al. 2021, Yar and Bircan 2023),

[5] Following Eurostat (2022), the term Statistical Adjustment is used in this paper to refer to the estimated difference between the estimated change in population stocks during a calendar year and the sum of effects of estimated population flows (components of population growth) in that year. Thus SA = Population Growth – (B – *D* + *IM* – *EM*). Other authors refer to this as "error of closure" is also used for this quantity by some authors (e.g. Zardetto et al. 2022).

[6] Hence the accuracy and comparability of population sizes and rates which use population as a denominator will differ to some extent between countries.

Data Inputs

Migration Rates and Ages

The immigration rates for 2019 for the countries considered range widely (Table 2). The highest immigration rates are for two countries with relatively small total populations, Luxembourg and Iceland, followed those for by Switzerland and Spain (Table 2). The lowest immigration rates are for North Macedonia and Slovakia[7]. Generally, the Eastern European countries have lower immigration rates than the countries in other European regions. Two of the Baltic States, Estonia and Lithuania, were notable exceptions to this pattern.

The countries with higher immigration rates tend also to have higher emigration rates Table 2). As well as having the highest immigration rate, Luxembourg also has the highest emigration rate. Switzerland and Iceland also have very high emigration rates. Except for Denmark, emigration rates for the other Northern European countries are relatively low. The lowest recorded rates are for North Macedonia and Slovakia[8].

Generally, the rates of net migration are lower for Eastern European countries than for countries elsewhere in Europe (Table 2). The highest rates of net migration are for Luxembourg, Iceland, Spain, Sweden and Netherlands. Only four (Latvia, Denmark, Croatia[9] and Bulgaria) of the 22 countries considered recorded a net outflow due to international migration.

The mean ages at immigration (Table 2) are influenced by the numbers of immigrants tending to be greatest in the 20-39 age range. Mean age at immigration tends to be slightly lower where a country has a higher rate of immigration. The highest mean ages at

[7] The rates of emigration for these countries may be significantly understated by the recorded data (Bleha and Sprocha 2020)
[8] The recorded emigration for Slovakia may have been understated due to many people leaving Slovakia but retaining an official address in Slovakia (Bleha and Sprocha 2020).
[9] According to Bencze (2020) rates of emigration from Croatia may be considerably higher than official statistics suggest.

immigration are for Eastern European countries. These high ages may be linked to return migration by former immigrants (OECD 2019). The exceptionally low mean age at immigration for Slovakia is influenced considerably by the large number of immigrants who are aged 0-4.

The mean age of emigrants is greater than the mean age of immigrants for 16 of the 22 countries considered. The exceptions are mostly Eastern European countries from which there has been substantial net outmigration in the past, and may be related to substantial return migration by previous emigrants (OECD 2019).

Life Expectancy at Birth

Of the countries considered, for both sexes Switzerland has the highest life expectancy at birth (Table 3). Life expectancies at birth are generally lower for the Eastern European countries than for countries in the other European regions. The gap between female life expectancy at birth and male life expectancy at birth is widest for the Baltic states, generally wider for Eastern European countries, and narrowest for Sweden and Norway.

The values of *MAR_TFR** are affected by life expectancies and survival probabilities for life tables with both mortality and emigration as decrements (Equations (6)-(8)). The differences between life expectancies at birth for life tables with both these decrements ($e^*_{0,j}$ in Equation (8)) and life expectancies at birth from the more familiar life tables with mortality as the sole decrement ($e_{0,j}$ in Equation (3)) tends to be greater for the countries with higher emigration rates (Tables 2 and 3). For Luxembourg for both sexes the addition of emigration as a life table decrement more than halves life expectancy at birth (Table 3). The differences between $e^*_{0,j}$ and $e_{0,j}$ are also relatively large for Switzerland, Iceland and Denmark. The smallest differences are for North Macedonia and Slovakia, both countries with very low recorded rates of emigration.

The variation in life expectancy at birth when both mortality and emigration are decrements ($e^*_{0,j}$) owes more to the variation in emigration rates than to the variation in mortality rates (Table 3). That North Macedonia and Slovakia have the highest values of $e^*_{0,j}$ is primarily due to their very low levels of emigration, and occurs despite both these countries having relatively high mortality rates. Italy, Finland, Norway and Sweden also have relatively high values of $e^*_{0,j}$, due to a combination of low mortality rates and low emigration rates. The values of $e^*_{0,j}$, are lowest for Luxembourg and Switzerland (for both sexes) and for Lithuania for males. These countries have high rates of emigration (Table 2). For Lithuania relatively high male mortality rates also contribute to the value of $e^*_{0,j}$ being relatively low (Table 3).

Results

Variation in Migration-Adjusted Replacement Level

Figure 1 shows that the trade-off between *MAR_TFR** and net migration expressed per head of population: countries with lower values for *MAR_TFR** generally have higher rates of net migration in 2019 (Alho 2008). This is because when the inflow due to migration is greater a smaller number of births is needed to equate the Terminal Stationary Population size (*P*) with the specified real population size (*POP*). Lithuania is a noticeable outlier to the general trend in Figure 1, because of the unusual sex and age distributions of its migration flows. Whilst in 2019 Lithuania experienced a net gain of males from net migration, it also had a small net loss of females. Numbers of females are far more influential than males on the value of *MAR_TFR**, because, unlike males, they affect the calculation of births. For Lithuania emigrants are significantly younger than immigrants (Table 2). Thus the loss of remaining years of life expectancy per emigrant is greater than the loss of remaining years of life expectancy per immigrant. Moreover, the loss of remaining years of female reproductive life per emigrant is considerably greater the loss of remaining years of female reproductive life per immigrant.

The value of *MAR_TFR** is highest for Croatia (2.44[10]) (Table 4). It also exceeds 2.1 for Latvia (2.43), Bulgaria (2.26) and Lithuania (2.18). The former three countries recorded net outmigration in 2019 (Table 2). For these countries, higher values of *MAR_TFR** are needed to compensate for the effects of higher emigration outflows on Terminal Stationary Population size (*P*). In all four of these countries, life expectancies at birth ($e^*_{0,j}$ and $e_{0,j}$) are relatively low (Table 3). Another reason for the values of *MAR_TFR** for these countries being so high is that a larger inflow of births is needed to compensate for the effect of shorter life expectancy on Terminal Stationary Population size (*P*). The distinctive age-sex distributions of immigration and emigration for Lithuania also contribute to the explanation of its *MAR_TFR** having such a high value.

Of the countries for which its calculation is feasible, the lowest values for *MAR_TFR** are for Spain, Netherlands and Sweden (Table 4). The very low values of *MAR_TFR** for these countries are due to their high rates immigration and (less importantly) relatively high life expectancies at birth (Tables 2 and 3). Especially for Spain and Netherlands, the age-sex distributions of emigration are also conducive to producing a low value for *MAR_TFR**. In 2019 the emigrants from these countries are mostly male and relatively old. Thus the subsequent, indirectly resultant effects of emigration on births and survivorship are relatively small. Consequently, the *TFR* which would generate a specific Terminal Stationary Population size (*P*) is lower than it would be if emigrants were younger and more feminine.

The value of *MAR_TFR** tends to be relatively low for countries in Northern, Western and Central Europe and relatively high for Eastern European countries. This pattern is related

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[10] According to Bencze (2020) emigration from Croatia is undercounted considerably in the official data. If so, the value of MAR_TFR* corresponding to the true level of emigration would be greater..

to the generally higher net migration into Northern, Western and Central European countries, whilst net migration for eastern European countries is generally lower and even, in some cases, negative (Table 2). The values of *MAR_TFR** for Denmark and Finland are considerably higher than those for the other Northern and Western European countries, due to net migration into these countries being lower and more male-dominated.

Of the Eastern European countries, Estonia, Hungary[11] and Czechia have the lowest values of *MAR_TFR** (Table 4). Unlike almost all the other Eastern European countries, all three countries recorded positive net migration in 2019 (Table 2). *MAR_TFR** differs widely between the two Southern European countries considered, having a relatively high value for Italy and a very low value for Spain. This difference is mostly due to Spain having a much higher rate of net migration than Italy.

Comparison of Total Fertility Rate to Migration-Adjusted Replacement Level

For nine of the countries constant immigration volume and fertility, mortality and emigration rates at 2019 levels has a long run population growth implication. For seven of these countries, all of which are in Northern, Western or Central Europe, this is shown by the *TFR* exceeding *MAR_TFR** (Table 4). The difference between the *TFR* and *MAR_TFR** is greatest for Sweden (*TFR* exceeds *MAR_TFR** by 0.55), followed by the Netherlands (0.42), Spain (0.37) and Belgium (0.29). For these countries it would take large reductions to the *TFR* would to produce a fertility-mortality migration combination with a zero or negative long run population growth implication, if migration and mortality were to remain constant. However, for Germany (0.03), Norway (0.11) and Switzerland (0.19) the reductions to the TFR which would produce such an effect are small. In the former two countries, constant fertility,

[11] The recorded emigration for Hungary may understate the underlying level (Godri 2018). If so, the values of *MAR_TFR** will be understated.

mortality and migration propel the population to a size which is only slightly larger[12] than the 2019 size.

For Luxembourg[13] and Iceland[14] it is impossible to calculate a feasible value for *MAR_TFR**. This is because for both these countries the rate of immigration is very high. More formally, immigration exceeds the population divided by Mean Life Expectancy after Immigration (surviving both death and emigration) threshold for which the value of *MAR_TFR** is positive. For these countries, with a constant volume of immigration and constant emigration and mortality rates, the population would grow larger, even if a TFR of zero were to be sustained. For such countries, an alternative way of indicating the coherence of constant fertility, mortality and emigration rates and volume of immigration is to consider the ratio of the size of the Terminal Stationary Population (*P)* towards which the population would converge under constant fertility, mortality and migration to the 2019 population size (*POP*). This ratio indicates that over the long run the population of Iceland would grow towards 2.29 times its 2019 size and the population of Luxembourg towards 1.84 times its 2019 size.

For the remaining 13 countries considered the *TFR* is below *MAR_TFR**. This indicates that if age-sex specific fertility, mortality and emigration rates and volumes of immigration are constant the populations of these countries would ultimately converge towards smaller than current population sizes. The extent to which the *TFR* is below *MAR_TFR** is greatest for Croatia (*TFR* minus *MAR_TFR** equals -0.97), followed by Latvia (-0.82) and North Macedonia (-0.71). For these countries, large increases to the *TFR* would

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[12] 3 per cent larger for Germany and 11 per cent larger for Norway.
[13] For Luxembourg the rate of immigration is 4.2% of population and remaining life expectancy after immigration ($\sum_{x=0}^{\omega} im_{x,j} e^{*}_{x,j}$) is 27.1 years. From Equation (7), the first-generation immigrant population (P_1*) = 1.15 ×population size (*POP*).
[14] For Iceland the rate of immigration is 2.71% of population and remaining life expectancy after immigration is 37.3 years. P_1* =1.01 × (*POP*).

would be needed to prevent long run population decrease if mortality and emigration rates and volumes of immigration were to remain constant.

In 2019 the populations of Finland, Estonia, Czechia and Slovakia all increased (Eurostat 2022). However, the fact of increase may be seen as an artefact of the population age structure. In all these countries, the below Migration-Adjusted Replacement level *TFR* indicates that constant fertility, mortality and would eventually result in a smaller-than-current population (Table 4). In Finland in recent years the *TFR* has fallen markedly, whilst in Czechia and Estonia it has risen considerably (Hellstrand et al. 2020, Eurostat 2022). For the latter two countries the differences between the *TFR* and Migration-Adjusted Replacement levels are small: constant fertility, mortality and migration would, after some initial growth, ultimately lead towards a population size which is marginally lower[15] than the 2019 size.

The populations of Italy, North Macedonia, Poland and Hungary all decreased in 2019 and would decrease further with constant fertility, mortality and migration (Eurostat 2022). The first three countries have very low *TFR*s (Vitali and Billari 2017). The levels of fertility which would prevent long-run depopulation are significantly above the 2019 *TFR*s but below 2.1, due to positive (albeit low) net migration (Tables 2 and 4).

Comparison of (Long-Run) Migration-Adjusted Replacement Level to Immediate Population Replacement Level

The value of the *TFR* which would have produced zero population growth in 2019 (the Immediate Population Replacement TFR (*IPR_TFR*)) is highest for Bulgaria (2.83), followed by Latvia (2.66) and Croatia (2.21) (Table 4). *IPR_TFR* is below 2.1 for every other country for which it could be calculated. For Iceland, Luxembourg and Spain in 2019 net migration

[15] 9 per cent lower for Czechia and 6 per cent lower for Estonia.

(plus statistical adjustment) exceeded deaths. Thus, no feasible (i.e. positive) value for *IPR_TFR* could be calculated. The lowest calculated values of *IPR_TFR* are for Sweden (0.26), Netherlands (0.41), Norway and Switzerland (0.42), and indicate very low fertility rates would suffice to sustain population growth in the near term, if total net migration and deaths are unchanged.

Generally, the values of *IPR_TFR* are lower for Northern, Western and Central European countries and higher for Eastern European countries. Czechia and Estonia are notable exceptions: *IPR_TFR* for both these Eastern European countries shows very low TFR which would have produced zero growth in 2019.

The value of *IPR_TFR* is below the 2019 *TFR* for the eight, mostly Eastern European, countries in which population growth was negative in 2019[16]. The *TFR* below is furthest below *IPR_TFR* for Bulgaria (*TFR* minus *IPR_TFR* equals -1.25), Latvia (-1.05), Croatia (-0.74) and Italy (-0.54)[17]: substantial increases to fertility would be required to prevent immediate population decrease, if other components of population change were to remain unchanged. Of the countries for which values of *IPR* could be calculated, the *TFR* was furthest above *IPR_TFR* for Sweden (*TFR* minus *IPR_TFR* equals 1.46), Netherlands (1.17) and Norway (1.12). The difference between *IPR_TFR* and *TFR* is generally greater for the Northern, Western and Central European countries than for the Eastern European countries.

The value of *IPR_TFR* is below *MAR_TFR** for every country considered (for which both measures could be calculated), except Bulgaria and Latvia (Table 4). In other words, the *TFR* which would produce zero population growth immediately is generally lower than the *TFR* which would generate zero population growth over the longer run. This occurs because in most of the countries considered the 2019 age structure is younger, and more conducive to

[16] Bulgaria, Croatia, Hungary, Italy, Latvia, Lithuania, North Macedonia and Poland.
[17] For Italy a large negative statistical adjustment raises the value from 1.45 to 1.80.

population growth, than the age structure that would be generated over time by constant, immigration numbers and mortality, emigration and Migration-Adjusted Replacement level fertility rates.

The exceptions (Bulgaria and Latvia) for which *MAR_TFR** is below *IPR_TFR* are countries in which net migration is negative and mortality rates (by European standards) are relatively high. The population age structures of these countries are conducive to negative natural increase. Very low fertility rates and net outmigration following political reforms in the 1990s has contributed to sizes of the cohorts at ages 15 to 29 in 2019 being relatively small (Billingsley and Duntava 2017). The small sizes of these age groups are conducive to fewer births.

The extent to which *MAR_TFR** exceeds *IPR_TFR* is greatest for Norway (*MAR_TFR* - IPR_TFR* equals 1.01), Sweden (0.91) and Switzerland (0.88) (Table 4). The reflects the legacy of substantial inflows of young adult immigrants into these (by European standards) rapidly growing populations. The age-sex distributions which have been created by these past trends are conducive to higher births and lower deaths, and hence to very low values for of *IPR_TFR.*

Differences between Migration-Adjusted Replacement Levels for Alternative Formulations of Migration

A major advantage of *MAR_TFR** over the *MAR_TFR* of Parr (2021, 2023a) is that *MAR_TFR** can be calculated for a wider range of populations. The calculation of Parr's (2021, 2023a) *MAR_TFR* is infeasible for six of the 22 populations considered in this paper. For five of these countries this is due to negative net migration, whilst for Luxembourg it is due to an extremely high net migration rate (Table 4). In contrast, the only populations for which calculation of *MAR_TFR** is infeasible are Luxembourg and Iceland, both countries with extremely high immigration rates.

The value of *MAR_TFR** is lower than the value of *MAR_TFR*, defined in Parr (2021, 2023a) for every population for which both values could be calculated, except Slovakia (Table 2). The difference between the two measures is widest for Switzerland (*MAR_TFR** - *MAR_TFR* equals -0.32), followed by Netherlands and Estonia (both -0.16), Sweden, Spain and Belgium (all -0.15). For Slovakia, North Macedonia, Italy and Poland the differences between the values of the two measures of migration-adjusted replacement TFR are negligible. The gap between the two measures is generally greater for countries with lower values of *MAR_TFR** than for countries with higher values of *MAR_TFR**.

The differences in the values of *MAR_TFR** and *MAR_TFR* can be explained by the differences between the age-sex distributions of the Terminal Stationary Populations and the 2019 populations, and the effect this has on the volume of emigration generated by applying the age-sex specific emigration rates to these populations. In all the countries considered, emigration rates tend to be highest in the young adult ages (20-34) and low in the older ages. Since the age distribution of the Terminal Stationary Population tends to be older than the 2019 age distribution for the same country, in the calculation of *MAR_TFR** the volume of emigration tends to be lower for the Terminal Stationary Population than the observed volume for 2019, and the volume of net migration tends to be higher. In contrast, the volume of net migration used to calculate *MAR_TFR* is the same as for 2019. The wider gaps between *MAR_TFR* and *MAR_TFR** when the value of the latter is low occur because the age distributions of the Terminal Stationary Populations generated by lower levels of fertility tend to be older than those generated by higher levels of fertility. Thus the volume of emigration generated by applying specified emigration rates to the Terminal Stationary Population tends to be lower and net migration higher when the fertility rate is lower.

Conclusion

This paper presents a new method which can calibrate the fertility levels which are coherent with long-run zero population growth for populations with non-zero immigration and emigration. This paper's results serve to disprove a seemingly widespread misconception that equates whether a country's population will increase or decrease over the long run with whether it sustains a TFR above or below 2.1 (for example BBC 2020a, b, UNPD 2022b). The results show that, in 18 out of the 22 European countries considered a TFR of 2.1 would be unnecessary for preventing long run depopulation, if net migration and life expectancy were to continue at 2019 levels, whilst in the remaining four countries, all of which are in Eastern Europe, a TFR of 2.1 would be insufficient to prevent long run depopulation.

The values of the Migration-Adjusted Replacement TFR, proposed in this paper, also disprove claims in the scholarly literature that equate very low (below 1.5) *TFR*s with depopulation (for example Demeny 2016). The populations of Belgium, Netherlands, Sweden, Spain, Norway and Switzerland would all increase over the long run with a TFR of 1.5, if migration and life expectancies were to be sustained at the levels for 2019. That the populations of Luxembourg and Iceland would increase even with TFR of zero indicates that there is no universally-applicable minimum level for the birth rate which would sustain a country's population size.

The comparison of observed *TFR* to the Migration-Adjusted Replacement TFR shows that the 2019 immigration volume and fertility, mortality and emigration rates have a long run population growth implication for nine of the countries considered. The values of the Migration-Adjusted Replacement TFR for any given country will vary between years, as may its ordered relationship to the observed TFR (Parr 2023a).

Whilst this paper only calculates Migration-Adjusted Replacement TFR and compares it to the observed TFR based on actually observed values of immigration counts and mortality and emigration rates, such a process of comparison could be applied to understand the population size-related implications of any fertility level (whether observed or hypothetical) in combination with any specified immigration volume, and emigration and mortality rates (whether observed or hypothetical). The constant fertility, mortality and migration scenarios at the prevailing level which underpins the interpretation the Migration-Adjusted Replacement Fertility measures in this paper is, of course, a purely hypothetical,scenario. However, the understanding the relationships between fertility levels and the prospects for long run population growth (or decrease) for national (and subnational) populations could potentially be enhanced by supplementing the values for observed data inputs with simulations of the Migration-Adjusted Replacement TFR for a wide range of other potentially useful points of reference. In particular, the calculations of Migration-Adjusted Replacement TFRs for fertility-mortality-immigration and emigration assumptions for future years used in population projections offers considerable potential to enhance the understanding of the projection results and the country's prospects for population growth. Analysis of long run population dynamics could also be enhanced by examining the sensitivity of the value of the Migration-Adjusted Replacement TFR to specified changes to data inputs[18].

The immediate prospects for national population growth are substantially affected by population age structure and the net migration level. This paper demonstrates how the Total Fertility Rate which would sustain a country's current population size in the immediate future ("Immediate Population Replacement TFR") often differs considerably from the Migration-Adjusted Replacement TFRs which would generate zero growth in the long run under

[18] For example, sensitivity of MAR_TFR* to UNPD (2022) projected change in mortality to 2100 could be examined by comparing the values which use observed mortality rates to values of MAR_TFR* with the projected mortality rates for 2100 used as a data input.

specified hypothetical stability of fertility, mortality, immigration and emigration.For almost all the countries considered the “Immediate Population Replacement TFR” which would sustain the current population size in the near term is below 2.1 and is also lower than the Migration-Adjusted Replacement TFR which would do so over the longer run. The presentation of the Immediate Population Replacement TFR in tandem with the Migration-Adjusted Replacement TFR may offer complementary near-term and longer term on the relationships between fertility levels which and population growth. For most of the European countries considered in this paper not only would sustaining a TFR of 2.1 be unnecessary for achieving long-run population growth and the TFR needed to achieve immediate growth is below that needed to achieve long-run growth.

The issue of whether the formulation of emigration should be in terms of volumes or as rates is debated in the literature, and the answer may vary between different national international migration contexts (Cappelen et al. 2015, Rogers 1990). However, compared to the parallel measure proposed for migration formulated in terms of volume by Parr (2021, 2023a), this paper’s formulation of Migration-Adjusted Replacement TFR in terms of emigration as a rate has the considerable practical advantage of being applicable to populations, such as many of those in Eastern Europe, for which net migration is negative.

The new method in this paper has the potential to help to transform understanding of national population dynamics and prospects for European and other countries with non-zero immigration and emigration.

Table 1: Glossary of Key Notation and Terms

Notation	**Term**	**Description**
P	Terminal Stationary Population size	Size of population towards which a population projection with specified constant fertility, mortality and migration levels would converge.
MAR_TFR	Migration-Adjusted Replacement level for Total Fertility Rate (TFR), as specified by Parr (2021, 2023)	Value of TFR which equates P to observed population size (Pop) when mortality and net migration remain constant at observed levels.
MAR_TFR^*	Migration-Adjusted Replacement level for Total Fertility Rate (TFR)	Value of TFR which equates P to observed population size (Pop) when mortality, immigration volumes and emigration rates remain constant at observed levels.
IPR_TFR	Immediate Population Replacement TFR	Value of TFR which equates population growth in year of observation to zero, if volumes of deahts, immigration, emigration and Statistical Adjustement to population size as as observed for that year.
$e_{0,j}$	Life expectancy at birth for sex j	Period life expectancy at birth for sex j in life table with mortality as the sole decrement.
$e^*_{0,j}$	Life expectancy at birth for sex j	Period life expectancy at birth for sex j in life table with mortality as the sole decrement.
$e^*_{0,j}$	Life expectancy at birth for sex j	Period life expectancy at birth for sex j in a multi-decrement life table with mortality and emigration as the decrements.

Table 2: Population Size, Immigration, Emigration and Net Migration Volume and Rate: Selected European Countries 2019

Country	Population	Immigration		Emigration		Net Migration		Mean Age (Years)	
		no.	rate (per 1000)	no.	rate (per 1000)	No.	rate (per 1000)	immigration	emigration
Belgium	11,537,782	150,006	13.0	102,936	8.9	47,070	4.1	29.4	34.5
Bulgaria	6,951,482	37,929	5.5	39,941	5.7	-2,012	-0.3	42.3	35.5
Croatia	4,058,165	37,726	9.3	40,148	9.9	-2,422	-0.6	38.0	36.5
Czechia	10,693,939	105,888	9.9	77,798	7.3	28,090	2.6	32.0	39.2
Denmark	5,822,763	61,384	10.5	66,520	11.4	-5,136	-0.9	28.6	28.6
Estonia	1,328,976	18,259	13.7	12,801	9.6	5,458	4.1	35.8	34.5
Finland	5,525,292	32,758	5.9	17,263	3.1	15,495	2.8	29.8	32.2
Germany	83,166,711	886,341	10.7	576,319	6.9	310,022	3.7	30.4	35.3
Hungary	9,769,526	88,581	9.1	49,795	5.1	38,786	4.0	30.7	34.6
Iceland	364,134	9,872	27.1	4,590	12.6	5,282	14.5	30.4	31.3
Italy	59,641,488	332,778	5.6	179,505	3.0	153,273	2.6	33.2	34.6
Latvia	1,907,675	11,223	5.9	14,583	7.6	-3,360	-1.8	34.3	32.9
Lithuania	2,794,090	40,067	14.3	29,273	10.5	10,794	3.9	34.6	30.6
Luxembourg	626,108	26,668	42.6	15,593	24.9	11,075	17.7	30.7	34.6
Netherlands	17,407,585	215,756	12.4	107,906	6.2	107,850	6.2	29.4	32.5
N. Macedonia	2,076,087	2,118	1.0	798	0.4	1,320	0.6	35.0	35.1
Norway	5,367,580	48,680	9.1	23,207	4.3	25,473	4.7	29.1	30.5
Poland	37,958,138	226,649	6.0	180,594	4.8	46,055	1.2	30.6	35.7
Slovakia	5,457,873	7,016	1.3	3,384	0.6	3,632	0.7	21.3	33.2
Spain	47,332,614	750,480	15.9	296,248	6.3	454,232	9.6	32.8	38.2
Sweden	10,327,589	115,805	11.2	47,718	4.6	68,087	6.6	27.8	32.3
Switzerland	8,606,033	145,129	16.9	126,221	14.7	18,908	2.2	29.1	30.5

Source: Eurostat (2022)

Table 3: Life Expectancy at Birth for Life Tables with Mortality as a Single Decrement and with Mortality and Emigration as Dual Decrements: Selected European Countries for Males and Females 2019

Country	Life Expectancy at Birth			
	Mortality Only ($e_{0,j}$)		Mortality and Emigration ($e^*_{0,j}$)	
	Male	Female	Male	Female
Belgium	79.8	84.3	51.9	60.0
Bulgaria	71.6	78.8	55.7	60.2
Croatia	75.5	81.6	48.7	55.9
Czechia	76.4	82.2	56.4	63.5
Denmark	79.5	83.5	47.1	49.4
Estonia	74.5	83.0	49.8	55.5
Finland	79.3	84.8	68.6	71.8
Germany	79.0	83.7	54.7	64.7
Hungary	73.1	79.7	59.5	67.0
Iceland	81.7	84.7	48.6	52.4
Italy	81.4	85.7	69.2	73.3
Latvia	70.9	80.1	49.2	57.6
Lithuania	71.6	81.2	44.3	49.8
Luxembourg	80.2	85.2	33.1	34.7
Netherlands	80.6	83.7	59.3	63.7
North Macedonia	74.7	78.7	73.6	77.6
Norway	81.3	84.7	66.3	68.3
Poland	74.1	81.9	59.6	68.5
Slovakia	74.3	81.2	72.9	78.6
Spain	81.1	86.7	61.3	66.2
Sweden	81.5	84.8	65.7	68.2
Switzerland	82.1	85.8	44.0	47.5

Source: Author’s calculations based on Eurostat (2022).

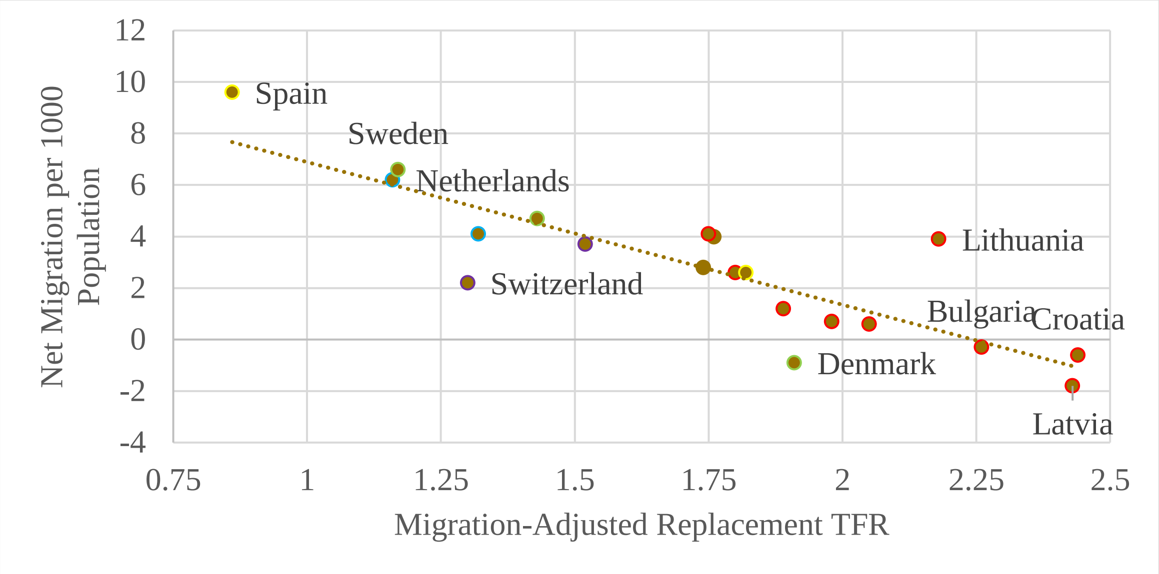
Table 4: Total Fertility Rate (*TFR*), Migration-Adjusted Replacement Levels for Emigration as a Rate (*MAR_TFR) and Emigration as a Count (*MAR_TFR*) and Immediate Population Replacement Total Fertility Rate (*IPR_TFR)*: Selected European Countries 2019**

Country	*TFR*	*MAR_TFR**	*MAR_TFR*	*IPR_TFR*
Belgium	1.61	1.32	1.47	0.69
Bulgaria	1.58	2.26	NA	2.83
Croatia	1.47	2.44	NA	2.21
Czechia	1.71	1.80	1.83	1.04
Denmark	1.70	1.91	NA	1.24
Estonia	1.67	1.75	1.91	1.17
Finland	1.35	1.74	1.78	1.13
Germany	1.55	1.52	1.57	1.25
Hungary	1.55	1.76	1.79	1.60
Iceland	1.75	NA	0.56	NA
Italy	1.26	1.82	1.82	1.80
Latvia	1.61	2.43	NA	2.66
Lithuania	1.61	2.18	NA	1.62
Luxembourg	1.34	NA	NA	NA
Netherlands	1.58	1.16	1.32	0.41
North Macedonia	1.34	2.05	2.05	1.40
Norway	1.54	1.43	1.56	0.42
Poland	1.44	1.89	1.89	1.50
Slovakia	1.57	1.98	1.98	1.36
Spain	1.23	0.86	1.01	NA
Sweden	1.72	1.17	1.32	0.26
Switzerland	1.49	1.30	1.62	0.42

Note: NA Not Applicable.

Source: Author's calculations based on Eurostat (2022).

Figure 1: Scatterplot of Migration-Adjusted Replacement TFR (MAR_TFR*) Against Net Migration Rate: 22 European Countries 2019



Key for markers: green = Northern Europe, blue = Western Europe, purple = Western Europe, yellow = Southern Europe, red = Eastern Europe.

Source: Author's calculations based on Eurostat (2022).

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