Migration and Intergenerational Replacement in Europe

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A population's history of fertility, mortality, and migration is written into its age structure, revealing the extent to which generations are replacing themselves. In this article we propose an easily calculated measure that enables us to track how these three processes determine the extent of intergenerational replacement. Because mortality is low in most European countries until well after the reproductive ages, it plays a very limited role in determining replacement. Population replacement in Europe is principally influenced by the combined effects of fertility and migration.

Concern over persistent low fertility and observed or expected population decline in many parts of Europe has become marked among both scientists and policymakers. National governments, the European Commission, and Pope Benedict XVI have highlighted Europe's low fertility as a challenge to long-term social and economic sustainability, while demographers have devoted considerable attention to explaining why the birth rate is so low and what might be done to raise it (McDonald 2002; Demeny 2003; European Commission 2005; Vatican 2006; Vos 2009). Demeny (2003), elaborating on the 2001 global population projections by the United Nations, suggested that the marginalization of European populations within the global population is a "fait accompli" (p. 14) and that "immigration is unlikely to halt the decline of population in Europe" (p. 28). Of concern to many observers are the official Eurostat population projections, which in the past predicted that the European Union population will start shrinking as early as 2025.[1] At the same time, researchers have documented substantial regional diversity in European fertility, migration, and population trends, which became more pronounced after the collapse of state socialism in Central and Eastern Europe between 1989 and 1991 (Sobotka 2008a; Avdeev et al. 2011).

There has also been considerable debate on the role migration can play in compensating for below-replacement fertility. The United Nations report *Replacement Migration: Is It a Solution to Declining and Ageing Population?* (UN 2000) triggered extensive and diverse media comment on the matter (Tarmann 2000), with many of the official government responses being unusually sharp (Teitelbaum 2004). These views were often in line with earlier studies suggesting that large-scale immigration is not politically viable in Europe (Teitelbaum and Winter 1985). However, in part because of the media attention set off by the UN's report, migration has gradually become recognized as an important structural feature of European societies, especially since many parts of Southern, Western, and Northern Europe experienced considerable population increase in the first decade of the twenty-first century, largely fueled by increasing migration (Avdeev et al. 2011; VID 2012). Coleman (2006) argued that substantial immigration to rich countries will lead to irreversible transformation of their population composition, constituting a "third demographic transition." In this context, an interesting question is whether any European countries have already experienced migration levels that could be seen as constituting "replacement migration" (e.g., Lesthaeghe 2000; Alho 2008; Bijak et al. 2008; Billari and Dalla Zuanna 2011). Although some evidence suggests this has been the case in many countries, no clear definition of replacement migration exists, making the debate on this subject inconsistent. As Beaujot (2003: 1) noted, "the idea of using immigration 'to keep the population the way it was' can be used not only with regard to maintaining a certain growth rate, or avoiding decline, or preventing aging, but also with regard to regional distribution, even ethnic or linguistic composition, or socioeconomic composition" (for discussion of replacement migration, see Ryder 1997; Lesthaeghe 2000; Coleman 2001; Espenshade 2001; Keely 2001; Beaujot 2003; and Saczuk 2003).

One possible conceptualization of replacement migration assesses whether immigrants can boost the observed number of births in a country so that they close the gap between observed births and a hypothetical number of births that would correspond to replacement fertility. This approach can be termed *birth replacement migration*. Another concept of replacement migration, termed *population replacement migration*, asks whether immigration can inflate the population size in a real or synthetic cohort as it ages, so that it eventually compensates for the difference between the observed number of births and the hypothetical number of births that would have occurred if fertility reached replacement level. A long-term combination of sub-replacement fertility and replacement migration could eventually lead to a stationary population, that is, a population with constant size and fixed age structure (under the assumption that mortality rates also remain constant; see Espenshade 1982 and Alho 2008). Examples of such a process taking place over many decades in Northern Italy can be found in Dalla Zuanna (2006). Our contribution to this debate builds on earlier research (see especially Sobotka 2008a; Dalla Zuanna 2008) and makes use of a cohort indicator of population replacement, the *overall replacement ratio* (ORR), which tracks changes in the size of a birth cohort relative to the size of the cohort of its mothers. We concentrate on cohort trends in the ORR of women from the time of birth up to their peak reproductive age (defined here as age 30) and contrast this measure with selected other measures of population replacement. The ORR is a simple measure that performs well compared to these other measures, and it clearly indicates that many European countries are indeed experiencing population replacement migration.

Measurement

As many rich countries experienced high immigration rates, increasingly affecting childbearing (Sobotka 2008b) as well as population trends (Eurostat 2011b; Sobotka 2009; Coleman 2006), the need to rethink the traditional indicators of population replacement has become obvious (Calot and Sardon 2001; Smallwood and Chamberlain 2005). Ryder's (1997) study on Canada posited that, in the context of persistent sub-replacement fertility, combined with significant immigration, the conventional model of a stable population closed to migration no longer corresponded to actual experience. Later, a new strand of research aiming to assess the combined effects of fertility and migration (and, more conventionally, often accounting for mortality) on population prospects has materialized.

Despite the importance of replacement migration, no measure has yet become a *de facto* standard. Two broad factors may explain this. First, as mentioned above, it is not obvious which populations or population characteristics are to be "replaced" or "maintained" with migration. Research has shown that migration cannot strongly alter, let alone stop, the process of population aging in the most developed countries, as measured by old-age dependency ratios and other indicators (UN 2000; Lesthaeghe 2000; Bijak et al. 2007).[2] Even so, migration has repeatedly been shown to have a potentially important role in maintaining the size of the working-age population, adding to the number of births in a country or expanding the size of initially small birth cohorts born during periods of low fertility (Ryder 1997; UN 2000; Lesthaeghe 2000; Daguet 2002; Dalla Zuanna 2006; Preston and Wang 2007; Ediev et al. 2007; Alho 2008; del Rey Poveda and Cebrán-Villar 2010; Billari and Dalla Zuanna 2011). Second, migration is the most unstable and unpredictable component of population change. Given this instability, it is problematic to use migration rates for any particular year to estimate period indicators of long-term population replacement. To avoid this volatility, we use a measure that shows the cumulated impact of migration on birth cohort size.

As with any standard demographic indicator, measures of birth and population replacement can be computed on a period or a cohort basis (Calot and Sardon 2001) or they can combine both approaches, as a growing number of studies on replacement migration show. More attention has been paid to the indicators of *birth replacement*, analyzing actual or hypothetical population reproduction in the presence of migration. Period indicators of birth replacement date back to the work of Hyrenius (1951), who suggested a *social replacement rate* (S), including migration, as a counterpart of the conventional *net reproduction rate* (NRR). More recent period measures of birth replacement include the *net reproduction rate in the presence of migration* (NRR*) (Preston and Wang 2007) and *combined reproduction* (CR) (Ediev et al. 2007, 2012). The latter indicator also aims to account for the higher fertility of immigrant women.[3] Period indexes of birth replacement do not have to be hypothetical synthetic indicators: they can also relate the size of a "children's generation" as captured by the number of female live births in year *t* to the mean size of the mother's generation at birth, as in the case of the *net birth replacement ratio* (NBRR) proposed by Ortega and del Rey Poveda (2007; see also del Rey Poveda and Cebrán-Villar 2010). Cohort measures of birth replacement can also be derived (e.g, Hyrenius 1951; Calot and Sardon 2001).

In contrast to indicators of birth replacement, measures of *population replacement* do not pertain to biological reproduction. Rather, migration is seen as a substitute for low levels of biological reproduction, and the main question is how immigration modifies the size of different birth cohorts either before they reach their prime reproductive (or productive) age or throughout their life span. The key difference between the indicators of birth replacement and population replacement can be illustrated with a hypothetical example of a population with zero fertility and massive immigration. In this population, birth replacement would be zero, but population replacement can be relatively high and can lead to a stationary population: by reaching a certain age, the population would completely replace itself through migration alone.

A purely period-based indicator of population change through migration across the entire life span has been proposed by Ediev et al. (2007, 2012) and termed *completed net migration* (CNM).[4] A cohort-based approach, comparing the size of a "children's cohort" as it ages to the fixed size of their mother's cohort at the time they were born, has been proposed and discussed by Dalla Zuanna (2008; see also Billari and Dalla Zuanna 2011) and Sobotka (2008a). Dalla Zuanna's *index of replacement including migration*, RM, compares the size of two generations (mother's cohort and children's cohort) at the same age, while Sobotka's (2008a) *gross replacement rate* (GRE) combines period estimates of biological reproduction (the gross reproduction rate in the year of the cohort's birth) with data on subsequent changes in the cohort's population size to estimate replacement for each cohort.[5]

In this study we focus on population replacement. We present a simple method to assess the extent to which migration alters the level of replacement for a birth cohort as it ages. To avoid problems associated with the estimation of fertility, mortality, and migration, we ignore the vital processes altogether, and provide a direct comparison of the size of age groups. The measure used here, the overall replacement ratio (ORR), is calculated by taking the size of a female birth cohort[6] residing in the country divided by the estimated average size of the cohort of mothers in the year of birth. We use female cohorts to facilitate comparison with conventional fertility indexes, but male cohorts (or the two sexes combined) could also be studied in this way. In its interpretation, computation, and aim, the ORR closely resembles the RM proposed by Dalla Zuanna and the GRE proposed by Sobotka. Direct comparison of the GRE and ORR shows that we mostly achieve identical results using the more simply defined ORR (Wilson et al. 2010; see also below). We prefer the ORR because it requires information solely on age structure, whereas the GRE uses the total fertility rate, or gross reproduction rate, as well as age structure. Although this measurement simplification is not a large advantage for contemporary European populations, for historical data and some developing countries where age structure is known but age-specific fertility is not, the ORR could have significant advantages. The simplicity of the data required for the ORR also means that it can be calculated for any population for which repeated age-specific estimates of its size are available. This means it can be calculated for small areas or sub-populations defined by socioeconomic, ethnic, or other characteristics. However, when the age structure of women in the reproductive ages is changing rapidly, the GRE may provide more stable estimates.

The ORR is derived in this study as follows:

Let $F(a,c, t = c + a)$ be the size of the female cohort aged a and born in year c (observed in the year $c + a$). This cohort, also termed "daughter's cohort," consists of women residing in the country by age a and includes those immigrating before reaching age a. The mothers of these women ("mothers' cohorts") were born over an interval roughly centered at year $c - g$, where g represents the mean generational interval, which can be approximated by the cohort's mean age at childbearing. We denote the lower and upper bounds of the prime childbearing ages of these mothers' cohorts in year c by $x = (m_1, m_2)$, and denote the age range from m_1 to m_2 as n. Then the average size of the mothers' cohorts (born across the years $c - x$ and observed in year $t = c$) contributing to birth cohort c can be written as:

$$\sum_{x=m_1}^{m_2} F(x,c-x,t=c)/n; \quad n = m_2 - m_1 + 1.$$

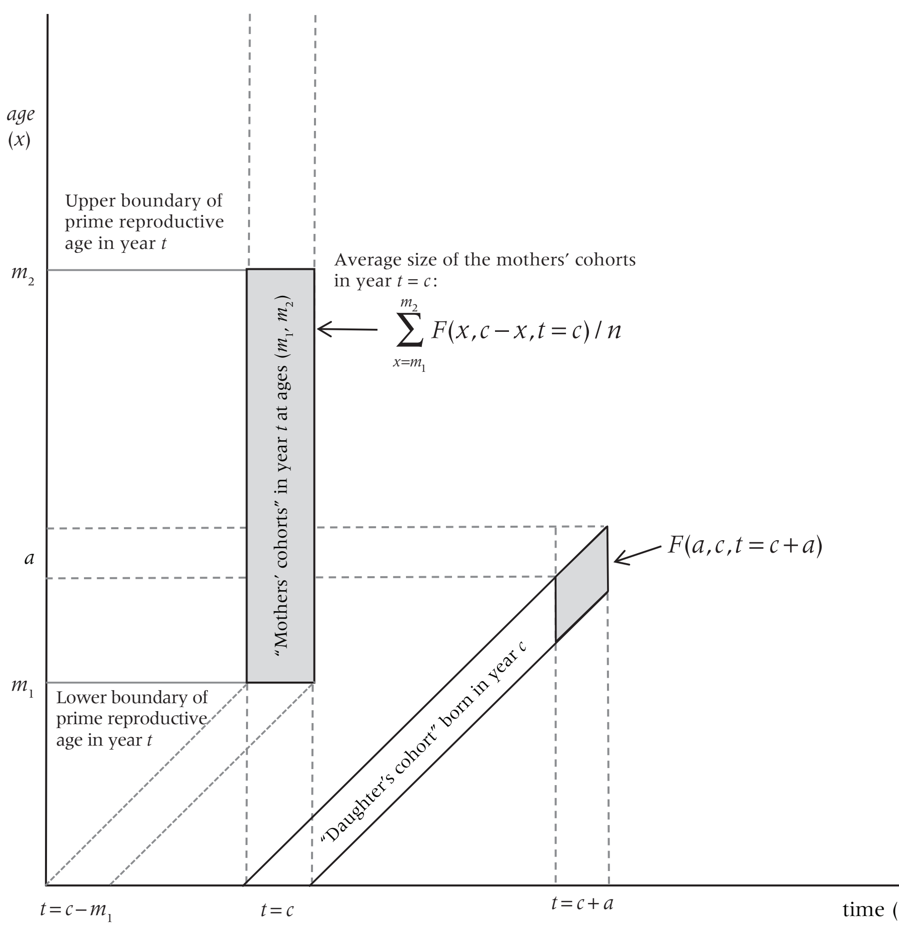
We define the ORR for cohort c at age a by:

$$ORR(a,c) = F(a,c,t=c+a) \Big/ \sum_{x=m_1}^{m_2} F(x,c-x,t=c)/n.$$

The delineation of the mothers' cohorts and of their daughter's cohort used in the ORR computation is illustrated in a Lexis diagram (Figure 1). Note that the size of the mothers' cohorts is "frozen" in year *c*, that is, at the time of their daughters' birth, while the size of the daughter's cohort changes, depending on age *a* for which the ORR is derived. An ORR of 1 would indicate exact cohort replacement, whether through birth or subsequent migration, by the specified age *a*.[7]

In this article we take ages 20 and 35 for m_1 and m_2, indicating roughly the limits of the main childbearing ages in most countries during the 1970s and 1980s.[8] Other age ranges and definitions of the average size of the mothers' cohorts could, of course, be used, but our initial analysis suggests that for the European countries studied here 20–35 is the most suitable choice (see Appendix). With some exceptions, the ORR does not seem to be strongly af-

FIGURE 1 Lexis diagram showing the daughter's cohort and the mothers' cohorts used in the computation of the overall replacement ratio



fected by the definition of the mothers' cohorts, as long as the range selected is large enough to eliminate effects of short-term baby booms and busts.[9] In historical populations and for European populations in more recent years (when fertility has been significantly delayed compared with the 1970s and 1980s), a broader age range (e.g., 20–40 or 20–45) appears more suitable (Appendix). When calculating the ORR for populations exhibiting significant perturbations in the age structure (e.g., countries such as China or Iran, where fertility decline has been especially rapid), more precise definitions of the mothers' cohorts would be advisable. Because our main interest lies in tracking how the generation of mothers with below-replacement fertility is subsequently replaced by a positive migration balance, we focus on tracking the ORR until the ages when their daughters typically become mothers themselves. At these ages, cohort survivorship in contemporary developed countries is practically unaffected by mortality, which makes the changes in ORR over time almost entirely determined by fertility and subsequent migration.

Using the ORR: Data, illustrations, and interpretation

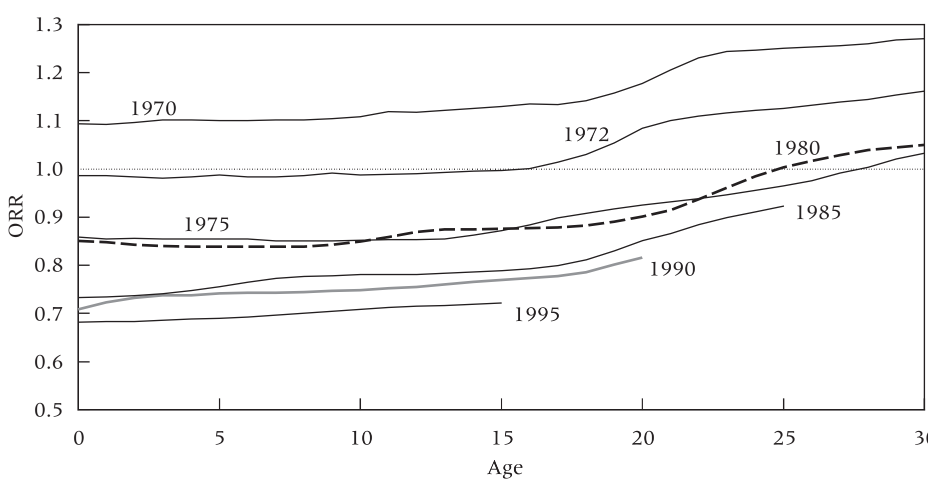
The principal data for calculating the ORR are from Eurostat's online database. For Ireland we complement the Eurostat data with estimates of the female population by age from the Human Mortality Database (HMD 2012b), while historical data for Sweden are derived from both the Human Fertility Database (2012) and the HMD (2012a). The national statistical offices of all member states of the European Union make annual estimates of their populations by single year of age. These are then collated by Eurostat and made available (along with data for selected other European countries) on their website (Eurostat 2012). It is important to realize that these data often constitute estimates that differ from the "true" population size. Countries calculate the population resident in their territory in different ways: some—especially the Nordic countries, but also Austria, Estonia, the Netherlands, and Slovenia—make use of detailed and accurate population registers, while others rely on combinations of vital statistics and decennial censuses, which themselves may be deficient. Thus, the data we use constitute the best guesses of Europe's national statistical offices, which can be affected by different definitions of resident population and different degrees of accuracy in registering immigration and emigration. While some statistical offices point out the approximate nature of their population estimates, it is evident that these best guesses mostly provide highly plausible and consistent information on the evolving population structures of the EU member states. The greatest concern over the robustness of the estimates is for some countries in Eastern Europe that have seen large-scale emigration since 1989 and where the infrastructure of national statistics is weaker than elsewhere in the EU. In such cases, data may be missing for certain years or sharp discontinuities may be evident in the data series. In most cases, however, the Eurostat data capture the main trends in each country.

We now give some empirical illustrations to show the merits and limitations of the ORR. For example, we can compare the size of the 1980 cohort over time to the number of women in the main childbearing ages in 1980. Using annual estimates of the size of the 1980 cohort enables us to track the effect of migration on the implied level of cohort replacement. In the absence of migration, this ratio will remain almost constant for the first decades of life, corresponding roughly to the net reproduction rate in 1980, and then decline as mortality reduces the size of the cohort. Where net immigration is significant, however, the ratio will rise as the cohort ages, with the increases taking place at the ages of immigration. Conversely, with net emigration, the ratio will decline as the cohort ages.

Given that most migrants move at young adult ages, immigration leads to additions to the size of a birth cohort especially between ages 15 and 40. This age profile of migration can strongly modify the size of each cohort before it reaches typical childbearing ages. For example, it is possible for every cohort to reach the replacement level, while some widely used age structure indicators, such as the conventional age pyramid, show a striking shortfall in the relative size of the cohort throughout childhood.

As an illustration, Figure 2 presents estimates of the ORR for selected female birth cohorts in Austria from 1970 to 1995. The ratios are based on annual single-year-of-age population estimates from 1969 to 2011 provided in Eurostat (2012). The uppermost line (1970 birth cohort) starts above 1 (the

FIGURE 2 Overall replacement ratio by age for Austria, selected cohorts 1970–95



SOURCE: Computed from Eurostat (2012) data.

replacement level) and remains there, rising further throughout the next 30 years. The year 1972 was the last in which the period total fertility rate in Austria exceeded the replacement level, and all later cohorts begin below 1. The cohorts show varying, though modest, changes for the first 10–15 years of life, but all rise substantially from the late teens on, when significant net immigration begins to increase the cohort sizes. The experience of each cohort is truncated at its age in 2011, but it is clear that all the cohorts that have reached age 30 exceeded the population replacement level before attaining that age, and the subsequent cohorts are likely to do so eventually.

To illustrate the differences between the overall replacement ratio and other indicators of reproduction and replacement, we compare ORR trends in Sweden in the cohorts of women born in 1950–1980 with the conventional period net reproduction rate (NRR), with the NRR in the presence of migration (NRR*), and with the net birth replacement ratio, NBRR, for 1950–2010.[10] Table 1 and Figure 3 highlight the contrasts in the underlying assumptions as well as in empirical results provided by these measures. The NRR, which measures biological reproduction in a single-year synthetic cohort framework, fell below replacement in 1968 and with a brief exception in 1991–92 stayed below that level, fluctuating in line with the ups and downs of period fertility in Sweden (see Oláh and Bernhardt 2008). The NRR* captures in addition the influence of migration on the hypothetical birth replacement rate in a comparable synthetic cohort framework, based on the observed fertility and net migration rates in a single year. Because migration also fluctuated widely, the migration-adjusted NRR* shows even less stability than the NRR, reaching a minimum of 0.79 in 1983 and recently peaking at 1.35 in 2009.

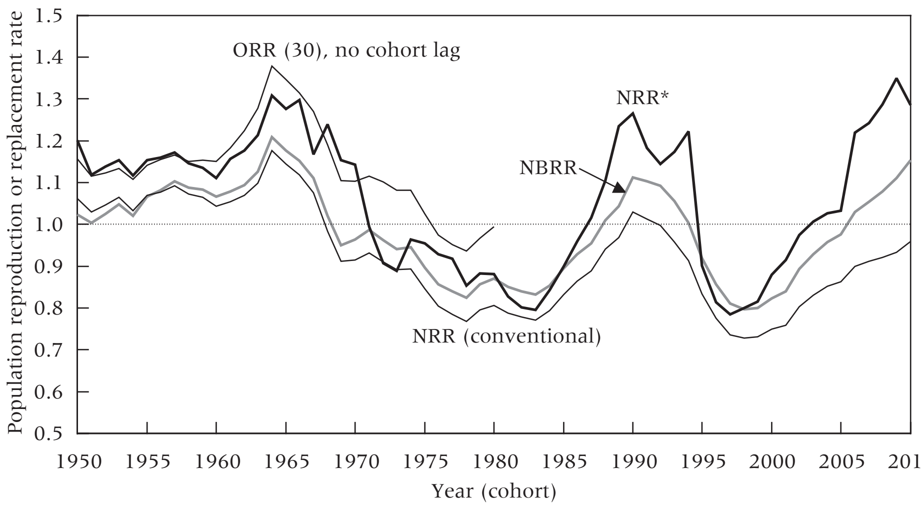
Similar trends, but considerably more stable results, are depicted with the NBRR, which is an indicator of birth replacement relating the observed number of births (“cohort of daughters”) in a year to the size of the “cohort of mothers” at birth. This is a quasi-period indicator, which—similar to the NRR and NRR*—measures period birth replacement in a given year, but which is also affected by the migration history of all cohorts of mothers of reproductive ages prior to that year. During the period analyzed, the NBRR follows relatively closely the NRR trends until 1970, indicating that migration to Sweden had little impact on the observed number of births in 1950–70 (however, a crossover is observed in 1956, with migration shifting from having a negative influence on the observed number of live births to having a net positive effect on total live births). After 1970 immigration became a significant factor contributing to the observed number of births in Sweden through both the “inflated” size of the mothers’ cohorts and the higher fertility rates among migrant women (Sobotka 2008b). The NBRR has consequently risen well above the NRR levels, especially since 2004 when the difference between these two indexes has exceeded 0.1 in abso-

TABLE 1 Selected indicators of population reproduction, birth replacement, and population replacement

			Components included		
Indicator	**Authors**	**Type of indicator**	**Fertility**	**Mortality**	**Migration**
Net reproduction rate (NRR)	Kuczynski (1928)	Synthetic period measuring population reproduction	Yes - period (*t*)	Yes - period (*t*)	No
Net reproduction rate in the presence of migration (NRR*)	Preston and Wang (2007); similar concept by Hyrenius (1951)	Synthetic period measuring birth replacement	Yes - period (*t*)	Yes - period (*t*)	Yes - period (*t*)
Combined reproduction (CR)	Ediev et al. (2007, 2012)	Synthetic period measuring birth replacement	Yes - period (*t*); differentiates between fertility of native and migrant women	Yes - period (*t*)	Yes - period (*t*)
Net birth replacement ratio (NBRR)	Ortega and del Rey Poveda (2007); del Rey Poveda and Cebrán-Villar (2010)	Quasi-period measuring birth replacement (observed period births in *t* vs. cohort size of mothers at birth)	Yes - period (*t*) / "cohort of mothers" at birth combination	Indirectly - cohort (modifying the size of "mothers' cohort" prior to year *t*)	Indirectly - cohort (modifying the size of "mothers' cohort" prior to year *t*)
Overall replacement ratio (ORR)	Wilson et al. (2010, this article); similar concepts by Dalla Zuanna (2008) and Sobotka (2008a)	Quasi-cohort measuring population replacement (cohort born in *t* subsequently modified by migration)	Yes - period (*t*) / "cohort of mothers" in *t* combination	Yes - cohort: affecting cohort size after year *t*	Yes - cohort: affecting cohort size after year *t*

lute terms. In the long term, the NRR suggests that biological reproduction among Swedish women fell short of replacement level by 14 percent in 1968–2010 (average NRR = 0.86), while the two indicators of birth replacement suggest a close-to-replacement number of births in Sweden (average NRR* = 1.01; average NBRR = 0.96). The contrast between these three measures was particularly strong in the most recent period, when the NBRR and even more so the NRR* indicated high birth replacement rates, implying increasing cohort size at birth.

FIGURE 3 Overall replacement ratio (cohorts 1950–80 observed at age 30) compared with the conventional net reproduction rate and two indicators of birth and population replacement: Sweden 1950–2010



NOTE: The authors thank Kryštof Zeman for computing time series of indicators used here (except the NRR*).
SOURCES: Computations based on Human Fertility Database (2012; data on age-specific fertility rates in 1900–2010); Eurostat (2012; data on female population by age, 1960–2011); and Human Mortality Database (2012a; data on live births by sex, 1900–2010; data on female population by age, 1960–2011; and female mortality tables in 1900–2010).

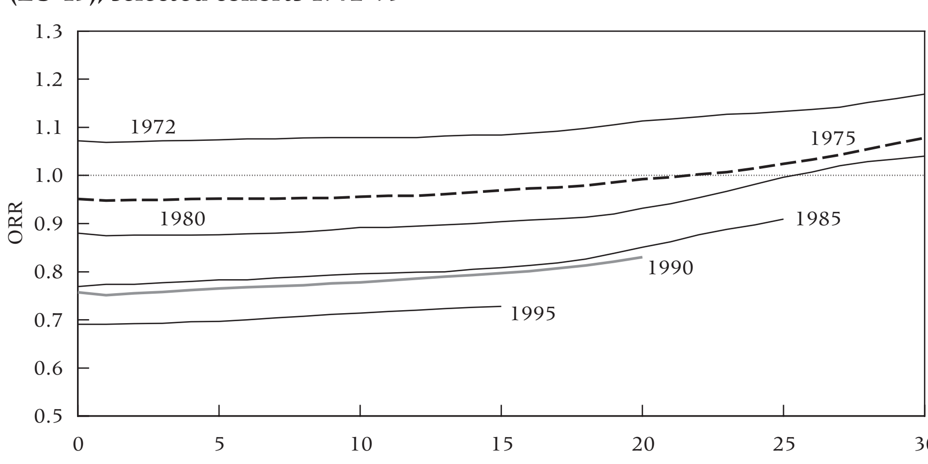
Finally, the ORR is a cohort indicator that combines biological reproduction in a cohort's birth year (comparable to the period for which the NRR, NRR*, and NBRR were computed) with subsequent net migration that inflates or decreases cohort size. Because fertility in the year of the cohort's birth usually affects the ORR more than does subsequent migration, we compare the ORR(30) with the period-based indicators of birth replacement and reproduction in the year of a cohort's birth, rather than shifting it by a time lag corresponding to the age for which the ORR is computed. Among the cohorts born in 1970–79, the ORR at age 30 stood well above the corresponding levels of biological reproduction and birth replacement. In 1978, when the NRR reached a low of 0.77, the two birth replacement indicators also reached relatively low levels of 0.83 (NBRR) and 0.85 (NRR*), while the ORR reached 0.94, indicating that by age 30 migration had increased the size of the 1978 cohort of women almost to the size of their mothers' cohorts in 1978. The observed trends suggest that the ORR at age 30 in Sweden reached its lowest postwar level in that cohort and is likely to remain above population replacement for the cohorts born since 1981. As we illustrate in our analysis, this pattern of migration acting as population replacement is not unique to Sweden.

Results

Figure 4 gives the ORR by age for the EU-15 (i.e., the EU before the enlargements of 2004 and 2007), while Figure 5 presents the same information for 12 European countries. The birth cohorts chosen range from 1972 to 1995, and the cohorts' experience is truncated at ages between 18 and 35, with the most recent data pertaining to 1 January 2011. We selected these cohorts because the conventional indicator of fertility, the total fertility rate (TFR), first fell below replacement for the EU-15 in the 1974 cohort. Because much migration occurs only from the late teens onward, cohorts born after 1990 have generally not yet had sufficient time to experience significant immigration.

The results for the EU-15 in Figure 4 paint a consistent picture. The initial values of the ORR fall steadily over time, as this was a period of rapidly falling fertility, especially in Southern Europe. Subsequently, there is a strong upward trend in the ORR as each cohort ages. The 1980 cohort was born with a size about 12 percent below the average of its "maternal cohort" (ORR of 0.88). However, by the time the cohort reached age 30, its size had expanded so as to surpass by 4 percent the size of its maternal cohort in 1980. Younger cohorts were born with progressively lower relative size and are unlikely to surpass intergenerational replacement until later in life, but are, nevertheless, clearly moving close to that level. Similar patterns are reflected in the graphs in Figure 5 for Belgium, France, Germany, Italy, Sweden, Switzerland, and the United Kingdom. The lines mostly begin well below one, sometimes far below (e.g.,

FIGURE 4 Overall replacement ratio by age for the European Union (EU-15), selected cohorts 1972–95



NOTE: The 15 countries are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden, and United Kingdom.
SOURCES: Computed from Eurostat (2012) data; data for Ireland based on Human Mortality Database (2012b).

Switzerland), indicating that fertility was below the replacement level. As each cohort ages, it usually increases in size, although a few downward movements are also recorded. The ages and cohorts at which the largest rises occur also vary, and the impact of specific migration events can be seen. For example, the large rise in each cohort in Germany in the early 1990s indicates the influx of refugees from the former Yugoslavia and the return of ethnic Germans from the former Soviet Union and Romania. Whatever the specific national features, the broad similarity of graphs for Western European countries is apparent. The panel for Switzerland shows perhaps the most striking and stable pattern of immigration systematically compensating for the shortfall of births, the result of sustained high immigration for several decades. In contrast, very low fertility in Germany, together with less intensive migration, implied an ORR that remained consistently below one in all the cohorts observed.

The results for Spain show a different pattern; they are also shown on a different scale from the other countries because Spanish fertility remained higher longer, with the ORR at age zero not falling below one until the 1982 cohort (1985 cohort shown in the figure). The dramatic upsurge of immigration into Spain over the last two decades (before the onset of the recent recession) is also readily seen in the lines plotted. In Spain immigration seems to have more than filled the gap in cohort sizes created by very low fertility. To some extent the precise track of the Spanish curves may be deemed conjectural, since much of the immigration into Spain was initially undocumented and only later regularized in a series of amnesties. Nevertheless, there is no ambiguity about the scale of replacement migration in Spain. No other country in Europe has seen a similar level of immigration, with 5.2 million people added to Spain's population of 40 million during the first decade of the millennium (Sobotka 2009). With its distinctive combination of very low fertility and massive immigration, Spain is an intriguing example of a country where the ORR ultimately jumps well above replacement and implies rapid population growth.

The next two panels in Figure 5, for the Czech Republic and Hungary, show two distinct patterns. Until the end of Communism in 1989 international migration was negligible and so the lines for each birth cohort run horizontally, with just a few minor discontinuities, possibly corresponding to mismatches between earlier estimates and updates following censuses. But, as in the older member states, immigration is coming to play a significant role more recently. In the Czech Republic, from about the time of accession to the EU in 2004, the lines curve upward. Clear discontinuities are evident in Hungary around the time of the collapse of Communism, and thereafter younger cohorts show a gradual increase in the ORR. The increase is mostly a reflection of migration to Hungary of ethnic Hungarians from neighboring countries, especially Romania.

Finally, the last two panels depict countries in Southeastern and Eastern Europe that have experienced substantial emigration, which is often poorly

FIGURE 5 Overall replacement ratio by age in 12 European countries, selected cohorts 1972–95

Western and Northern Europe

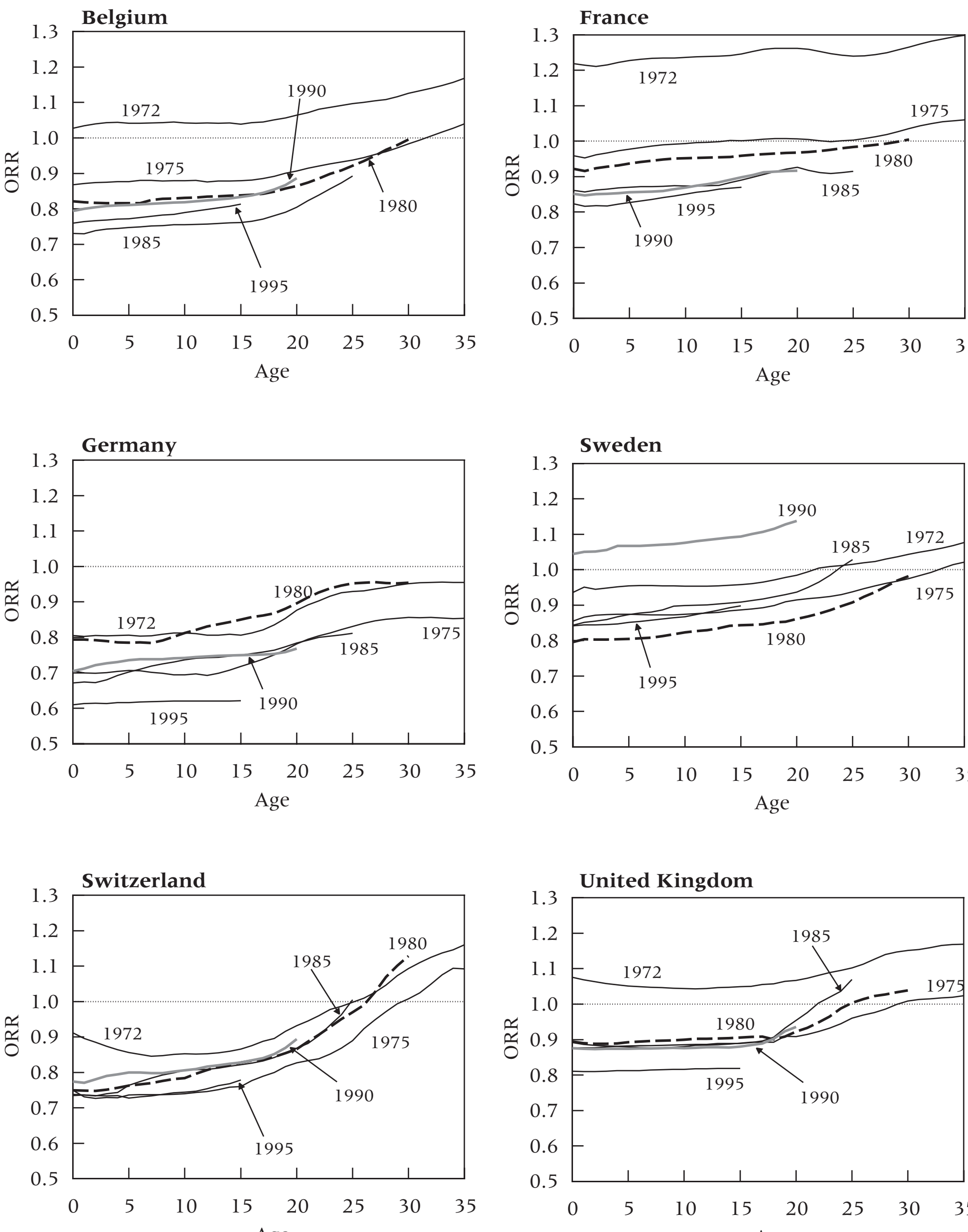
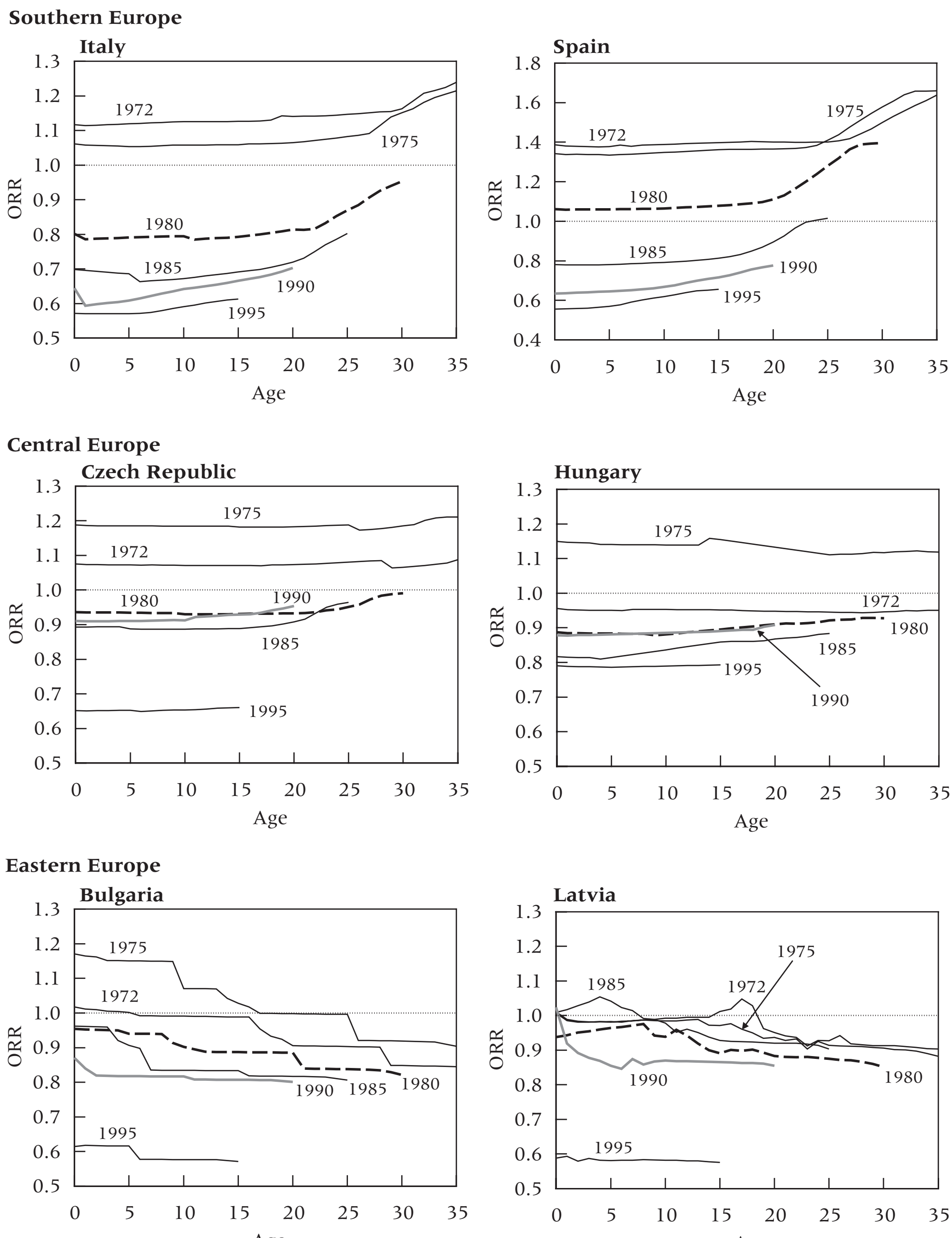


FIGURE 5 (continued)



NOTE: Data for Spain plotted on a different scale from other countries (see text).
SOURCE: Computed from Eurostat (2012) data.

documented. Therefore, the official data frequently display peculiar and unlikely jumps and discontinuities. Nevertheless, the graphs for Bulgaria and Latvia paint a clear picture of populations that are rapidly shrinking, with subsequent cohorts displaying ever lower initial ORRs at birth (especially in Bulgaria) and then shrinking further as emigration depletes the resident population at younger ages. The most spectacular emigration effect is observed for the 1975 cohort in Bulgaria, which had an ORR well above replacement at the time of birth (1.17), but had contracted by almost a quarter, reaching an ORR just above 0.9 by the time it reached age 35.

Regional comparison

To provide a more systematic assessment of population replacement in different parts of Europe, Table 2 gives the overall replacement ratio at ages 0 and 30 for two cohorts of women born during a period of declining fertility, 1975 to 1980. Country data are grouped by broader regions. The declining fertility of the late 1970s is clearly reflected in the fall or stagnation of the ORR between the two cohorts at age 0 (Germany, where fertility fell sharply before 1975, is an exception). However, the trend at age 30 is much less clear-cut, with Austria, Belgium, Germany, Ireland, Sweden, Switzerland, and the United Kingdom all seeing increases in the ORR(30) between the 1975 and 1980 cohorts. High fertility in 1980 combined with subsequent immigration pushed the ORR(30) in Ireland as high as 1.75. Almost everywhere in Europe (the only exceptions being Ireland and some Southern and Eastern European countries), the 1980 cohort was initially at the sub-replacement level. By the time this cohort reached age 30, however, the ORR was close to or above replacement in most cases and above 0.9 almost everywhere (except in Denmark and parts of post-communist Europe). Because a further rise in the ORR is likely to occur after age 30, it seems safe to conclude that in most countries the 1980 cohort will probably surpass the value of one before its members reach age 40. Only in a number of ex-communist countries has the ORR actually declined, although in a few cases, including Bulgaria, Latvia, and Romania, it has plummeted, a trend that is likely to have long-term negative consequences for the population age structure. These countries face the challenging prospect of sizable and lasting population decline, especially if emigration continues among the younger cohorts born in the period of very low fertility in the late 1990s and early 2000s.

Almost all the countries analyzed saw a larger increase in the ORR for the 1980 cohort than for the 1975 cohort. The absolute and relative increases in the ORR between ages 0 and 30 were particularly marked in Ireland, Spain, and Switzerland, with absolute increases between 0.27 and 0.38 in the 1980 cohort. In short, even countries with very low fertility and net reproduction rates around 0.7 (i.e., with a TFR below 1.5) can reach replacement migration

TABLE 2 Overall replacement ratio at ages 0 and 30 in female birth cohorts of 1975 and 1980, selected European countries

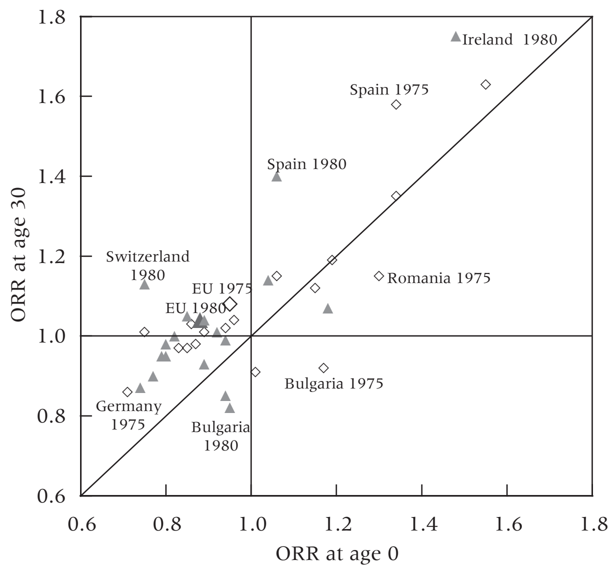
	ORR at age 0		ORR at age 30		Absolute increase in ORR between ages 0 and 30		Relative change (index): ORR at age 30 / ORR at age 0	
	1975	1980	1975	1980	1975	1980	1975	1980
EU-15	**0.95**	**0.88**	**1.08**	**1.04**	**0.13**	**0.16**	**1.13**	**1.18**
Western Europe								
Belgium	0.87	0.82	0.98	1.00	0.11	0.17	1.13	1.21
France	0.96	0.92	1.04	1.01	0.08	0.08	1.08	1.09
Ireland	1.55	1.48	1.63	1.75	0.08	0.27	1.05	1.18
Netherlands	0.83	0.77	0.97	0.90	0.14	0.13	1.17	1.16
United Kingdom	0.89	0.89	1.01	1.04	0.12	0.14	1.13	1.16
Nordic countries								
Denmark	0.94	0.74	1.02	0.87	0.09	0.13	1.09	1.18
Sweden	0.85	0.80	0.97	0.98	0.12	0.19	1.14	1.23
German-speaking								
Austria	0.86	0.85	1.03	1.05	0.17	0.20	1.20	1.23
Germany	0.71	0.79	0.86	0.95	0.15	0.16	1.21	1.20
Switzerland	0.75	0.75	1.01	1.13	0.26	0.38	1.34	1.50
Southern Europe								
Italy	1.06	0.80	1.15	0.95	0.09	0.15	1.08	1.19
Portugal	1.34	1.04	1.35	1.14	0.01	0.10	1.01	1.10
Spain	1.34	1.06	1.58	1.40	0.24	0.33	1.18	1.31
Central and Eastern Europe								
Hungary	1.15	0.89	1.12	0.93	–0.03	0.04	0.97	1.05
Czech Republic	1.19	0.94	1.19	0.99	0.00	0.05	1.00	1.06
Bulgaria	1.17	0.95	0.92	0.82	–0.25	–0.13	0.79	0.86
Latvia	1.01	0.94	0.91	0.85	–0.10	–0.09	0.90	0.91
Romania	1.30	1.18	1.15	1.07	–0.15	–0.10	0.88	0.91

SOURCES: Computed from Eurostat (2012) data; data for Ireland based on Human Mortality Database (2012b).

by as early as age 30. Hungary and the Czech Republic made a transition from a declining ORR with age to an increasing one between the 1975 and 1980 cohorts, possibly following an earlier pattern seen in Southern Europe.

The scatterplot in Figure 6 adds a further dimension to this comparison. Although most of the countries have moved to a below-replacement ORR at age 0 (ORR on the x axis lower than 1), this is not necessarily so by age 30. Figure 6 also shows that the EU-15 reaches an ORR around one by age 30. It further indicates that the ORR rises with age in all non–Eastern European countries (i.e., the points in Figure 6 are clustered above the diagonal). Finally, it reveals that the initially close correlation between the ORR at age

FIGURE 6 Overall replacement ratio at ages 0 and 30, cohorts 1975 (diamonds) and 1980 (triangles) in 18 European countries analyzed in Table 2



NOTE: Data for EU-15 as a whole indicated by enlarged markers.
SOURCES: Computed from Eurostat (2012) data; data for Ireland based on Human Mortality Database (2012b).

0 and age 30, as depicted for the 1975 cohort, does not generally hold for the 1980 cohort, especially if we disregard Ireland and Spain, the prominent outliers to the upper right of the graph.

Conclusions and implications

Six decades ago Hyrenius (1951) made a key distinction between biological reproduction and social replacement. Since then, dozens of studies have debated whether migration can partly or fully compensate for a perceived shortage of births and population imbalances, especially in rich countries and regions. Many of these studies focused on the levels and patterns of migration needed to achieve a stable population, given observed or hypothetical levels of fertility and mortality. With the relatively high immigration seen in the last two decades (especially before 2009) across most of the developed world, the concept of replacement migration has increasingly entered the debate. This interest in the long-term effects of migration has been hindered by imprecise and deficient data on migration flows and by the lack of widely shared standard measures and indicators.

Our study highlights three points. First, we emphasize the distinction between *birth replacement* effects of migration (i.e., migrants contributing to the hypothetical or observed number of births) and *population replacement* impacts of migration (i.e., migrants filling the gap in population size attributable to sub-replacement fertility). Second, we propose a simple indicator of cohort population replacement. Third, our new indicator, which has been developed in parallel with a similar index by Dalla Zuanna (2008), clarifies the nature of population dynamics in many parts of Europe, strongly suggesting that some of the past projections of Europe's imminent demographic demise are unrealistic. In much of Europe it is clear that, while the idea of replacement migration, as proposed by the United Nations in 2000, was widely criticized, in reality this is precisely what is happening.

Demographic processes are inherently unstable, and thus the theory of stable populations remains unmatched by long-term experience. However, given this, it is surprising to observe that in many European countries cohorts of women born in the period of sub-replacement fertility actually achieved the size corresponding to population replacement by the time they reached their prime reproductive years. Using a different method, Alho (2008: 644) showed that low fertility in Europe is "associated with high net migration, and vice versa," implying that migration has reduced differences in intrinsic rates of population growth across Europe. Similarly, Billari and Dalla Zuanna (2011: Figure 2) demonstrated that migration rates in Europe are strongly and inversely correlated with the dynamics of births. However, these observations need to be put into broader context. Frequently, the impact of migration goes well beyond a small "topping up" of population numbers, and a few countries obviously "over-achieve" in this regard and see significant population growth as a result of immigration (e.g., Ireland, Spain, and Switzerland). In contrast, since the 1990s some of the economically struggling countries of Eastern and Southeastern Europe, often ignored in comparative European analyses, have shown the doubly negative effect of low fertility and large-scale emigration, implying a prospect of significant population decline.

Countries like Spain or Switzerland show that even very low levels of fertility can be combined with replacement or above-replacement levels of migration. The richer countries among those that joined the EU in 2004 (e.g., the Czech Republic and Slovenia) are showing clear signs in the same direction. There are, of course, exceptions to this general trend and many region-specific patterns. Some affluent countries, including Germany and the Netherlands, have experienced brief periods of net emigration in the past, and the recent economic recession has resulted in net emigration in yet more countries for some years to come. The less wealthy EU member states, especially the Baltic countries, Bulgaria, and Romania, in common with most of Eastern Europe beyond the EU boundaries, are still experiencing substantial emigration.

Taking a longer time perspective, however, the current waves of emigrants from countries such as Poland or Romania have a historical parallel in mass emigration from Italy, Portugal, and Spain from the 1950s to the 1970s. All three of these Southern European countries have since become large net importers of people. If their experience is a valid guide, the countries that joined the EU in 2004 and 2007 can expect similar reversals in time, along with the establishment of large-scale replacement migration.

By itself, replacement migration is not a remedy for Europe's problems related to an aging population; rather it is a potential opportunity that should be complemented by policies to enhance socioeconomic sustainability, including supporting the integration of migrants, increasing the labor market participation of women, delaying retirement, and increasing attainment of higher education for both native and migrant populations. Some immigration-averse governments may aim to stimulate fertility while reducing migration. But earlier European experience suggests that both pronatalist and anti-immigration policies often fail to achieve the desired goal and have unintended adverse consequences (e.g., Castles 2004; Gauthier 2007).

The measure proposed here, the overall replacement ratio, can readily be compared over time and across countries, even in settings with rudimentary population estimates and vital statistics. By focusing on changes in relative cohort size, the ORR shows much higher stability than the synthetic indicators of birth and population replacement constructed solely from period-based data. When computed for single years, these other indicators—including the indexes proposed by Ediev et al. (2007 and 2012) and by Preston and Wang (2007)—are affected by both year-to-year instability and incomplete statistics on migration. In the long term, however, the errors in the statistics on migration and population data are likely to smooth out, making ORR a suitable indicator of population replacement. Modest data requirements make it ideal for analyzing population replacement in both contemporary and historical populations, and for examining population dynamics at the sub-national level, where internal migration often plays a more important role than international migration (see Wilson and Williamson 2011 for the United Kingdom; del Rey Poveda and Cebrán-Villar 2010 for selected Spanish regions; Billari and Dalla Zuanna 2011 and Dalla Zuanna 2008 for Italian regions), or in poorer countries where data limitations may be more substantial. In addition, the ORR can be assessed at different ages, enabling it to respond flexibly to the particular needs of different analysts. While we have chosen to focus on age 30 as a mid-point of the reproductive span, the ORR can also track changes in relative cohort size across productive ages when migrants contribute to the labor force, or can be used to analyze shifts in relative population size before reaching retirement.

The Appendix, which compares the ORR at ages 0 and 30 with the conventional gross and net reproduction rates for Sweden over 1850–2010, suggests that the ORR may also be a reasonable proxy for these conventional indicators when detailed information on fertility and mortality is lacking. In spite of its simplicity, the ORR usually performs as well as more sophisticated cohort replacement measures and is, under normal circumstances, relatively insensitive to the definition of the mothers' cohort. In the absence of large sudden shifts in the mothers' cohort size, the error resulting from an estimation of the mothers' cohort size is likely to be considerably smaller than the errors and definitional problems contained in the official population data for many countries. In sum, the overall replacement ratio does not aim to substitute for any of the existing and more sophisticated measures of population dynamics, but we think it can play a useful role as a simple measure for indicating the combined effects of fertility and migration on intergenerational replacement.

Appendix

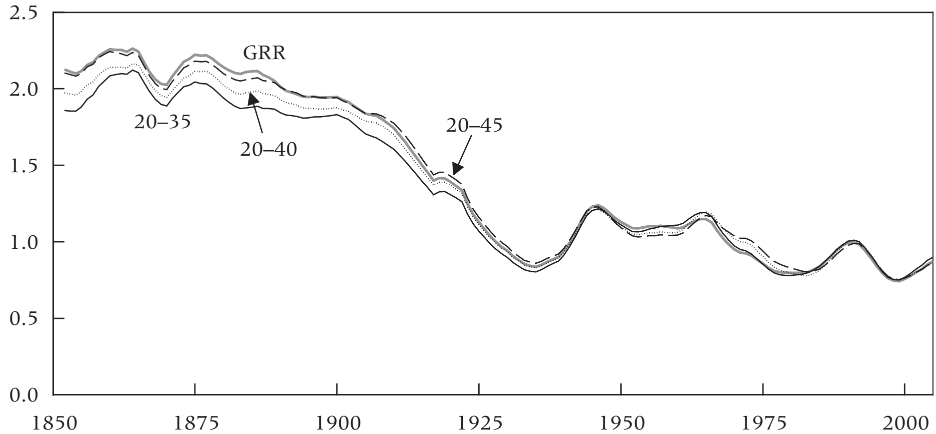
Comparing the overall replacement ratio, the net reproduction rate, and the gross reproduction rate: Sweden 1850–2010

A key assumption underlying the overall replacement ratio is that the age pattern of fertility only needs to be taken into account in a very elementary way, by indicating the upper and lower bounds of the main childbearing ages. The validity of this assumption can be examined by comparing the conventional gross reproduction rate (GRR) with the ORR calculated at birth (i.e., the number of births in a given year divided by the average size of the mothers' birth cohorts in that year).

Figure A1 presents the GRR and the ORR (at birth) defined in three different ways for Sweden from 1852 to 2005. All lines are five-point moving averages of the annual values to avoid unusual fluctuations. It is clear that the suitability of the three definitions of mothers' cohorts (20–35, 20–40, and 20–45) varies over time. However, at every point the best-fitting ORR(birth) comes very close to the GRR. In fact, over the whole 153-year span the best-fitting value is always less than 3 percent above or below the GRR. Table A1 gives the best-fitting age range in each period. From 1852 to 1911 the widest age range for mothers' ages (20–45) gives the best fit, while for the next 30 years (1912–1942) 20–40 is preferred. Since the 1940s the age range of choice has varied, but from 1967 to 1998—that is, throughout the period of main interest in this article—20–35 is the best fitting, and thus is used in all our calculations related to replacement migration.

The pattern of change in the fit makes good sense when reflecting on what is known about the age pattern of fertility. During the late nineteenth and early twentieth centuries, fertility was relatively high throughout the reproductive ages, so 20–45 is a logical best fit. As fertility decline set in, rates dropped most sharply at the oldest ages, so 20–40 became more suitable. As fertility fell to still lower levels and became concentrated in the younger age-groups, 20–35 became the best fit. And finally, with the increasing delay of fertility after the 1960s baby boom, a wider range fits best. The exact dates for which each age range is to be preferred vary from country to country,

FIGURE A1 Gross reproduction rate (GRR) and three versions of the overall replacement ratio (ORR) at birth, with varying definitions of mothers' age range, 20–35, 20–40, and 20–45: Sweden 1852–2005



NOTE: All series are five-point moving averages of annual series.
SOURCES: Human Fertility Database (2012), Festy (1979).

but the overall pattern of change is broadly similar in much of Western Europe, and for the period of most interest here 20–35 is the age range of choice.

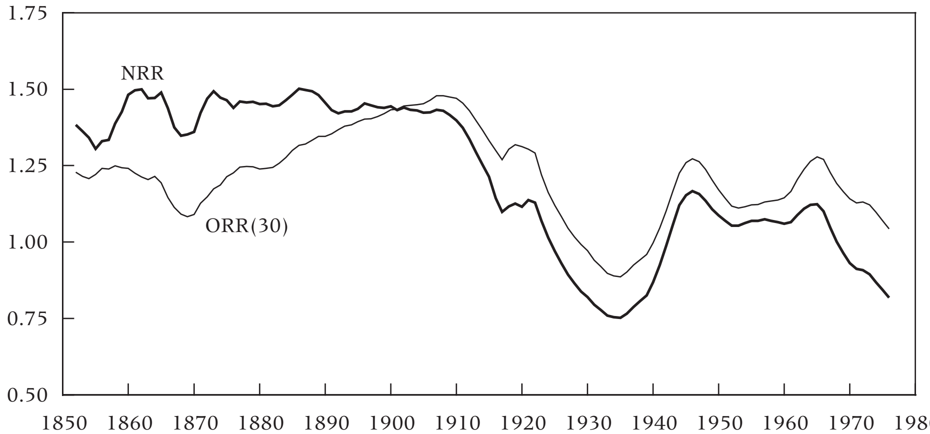
A further comparison that helps illuminate the potential value of the overall replacement ratio is with the net reproduction rate. Figure A2 shows the annual (period) NRR for Sweden from 1852 to 1976, along with the ORR at age 30 for cohorts born 1852–1976. Thirty is chosen for the ORR as an approximate indicator of the mean age at net reproduction. Again, both lines are five-point moving averages. The two measures can be expected to differ somewhat because the cohorts born in each year later experience lower mortality than was prevalent in the year of their birth. Thus, other things being equal, the ORR(30) line could be expected to lie slightly above the NRR because of this mortality difference. The main factor leading to divergence

TABLE A1 Best-fitting definition of mothers' age range for ORR(birth) for fitting to gross reproduction rate and mean percentage error: Sweden 1852–2005

Period	Best-fitting range	Mean difference (percent)
1852–1911	20–45	1.10
1912–1942	20–40	1.42
1943–1947	20–45	0.96
1948–1962	20–35	1.81
1963–1966	20–45	2.80
1967–1998	20–35	1.43
1999–2005	20–40	0.52

NOTE: ORR and GRR values used for fitting are five-year moving averages of annual values.
SOURCES: See Figure A1.

FIGURE A2 Overall replacement ratio at age 30 and net reproduction rate: Sweden 1852–1976



NOTE: Both series are five-point moving averages of annual series. ORR is calculated with mothers' age range set at 20–45.
SOURCES: Festy (1979), Human Fertility Database (2012), and Human Mortality Database (2012a).

between the two lines, however, is migration. Between about 1860 and World War I, roughly one-third of all the natural increase in Sweden was lost through emigration, principally to the United States. This explains why the ORR(30) line lies well below that for the NRR over these decades. However, from the inter-war period on, Sweden became a net importer of people and, as Figure A2 shows, there is a crossover as the ORR(30) exceeds the NRR for cohorts born from the early twentieth century on. The widening gap between the two lines at the right-hand end of the graph is the feature of interest most relevant to this article, as replacement migration becomes an increasingly significant factor. Taken as a whole, the graph suggests that the ORR can make a valuable addition to the demographer's toolkit: the GRR indicates the level of fertility, the NRR reduces this to show the impact of mortality, while the ORR incorporates in addition the impact of migration.

Notes

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1 For instance, the baseline scenario of the Eurostat projection issued in 2005 envisioned that the EU population would start shrinking in

2025 (Eurostat 2005 and 2006); in the absence of migration, the EU population was projected to start shrinking as early as 2008. Two years later, the projected starting year of the EU population decline was put off to 2036 (Eurostat 2008), whereas the latest set of projections, released in 2011, expect the EU population to peak around 2040 (Eurostat 2011a).

2 However, Alho (2008: 649) suggests that in populations that can accommodate increasing net migration, this increase can "markedly slow down the aging of a population." Earlier simulations by Coale (1986) of the effect of immigration on the size and age structure of the US population showed that immigration can alter a population's age composition especially in countries with low or very low fertility. For instance, simulating US population up to 2100 assuming different levels of fertility and two scenarios of migration (no immigration vs. net immigration of 700,000 per year) showed that adding immigrants to the population with a period TFR of 1.4 changed the ultimate proportion aged 65+ in 2100 so that it corresponded to the population with a TFR of 1.6 and no immigration (Coale 1986: 208, Table 2). A recent debate on the subject in *Genus*, informed especially by fertility, mortality, and migration patterns in the low-fertility setting of Italy, differentiated between short-term effects, where migration can alter the trajectory of population aging, and long-term effects, where migration has little influence (de Santis 2011; Gesano and Strozza 2011).

3 Ediev et al. assume in their comparative study that migrants' period total fertility rate exceeds "native" fertility by 25 percent.

4 Alho (2008: Figure 2) computed ratios of net migration to births and showed different combinations of the total fertility rate and net migration needed to maintain a stationary population in four Nordic countries. Different age patterns of fertility and age distribution of net migrants imply that these "tradeoff values" are country-specific.

5 In addition to indicators of population replacement, other measures, including both projections and simulations have been used to estimate the impact of migration on the population. Traditionally, much discussion focused on a stable population model and on identifying a constant stream of immigrants needed to achieve a stable population in the long term, given observed or projected sub-replacement fertility rates (e.g., Coale 1986). Coleman (2009) related period numbers of net migrants to the total number of live births, showing that a number of European countries had net immigration exceeding 50 percent of live births around 2008 (see also Alho 2008). In their projections for the EU-15 countries, Lutz and Scherbov (2003: 11–12) proposed that "the effect of 100,000 additional immigrants per year corresponds to that of an increase in the TFR of 0.1."

6 Note that in our approach, birth cohort is defined solely by the same year of birth and the same country of residence at age x for which the ORR is computed. Thus, our birth cohort is composed of "native" women as well as immigrants, potentially from many different countries, arriving in the country of interest before reaching age x.

7 It is not the extent of immigration as such, but the net balance between immigration and emigration, that determines the ORR computation.

8 We use the female population distribution by age on January 1 of two subsequent years, t and $t + 1$, to estimate mean female population in the mothers' cohorts in the year $t = c$.

9 The ORR can show notable differences from indicators that define the size of the cohort of mothers more precisely in the following cases: 1) when the selected lower and upper bounds of prime reproductive ages do not closely match the actual bounds; 2) when childbearing is strongly concentrated in a narrow age band; and 3) when the size of the analyzed cohorts changes abruptly. For instance, a combination of the second and third factors led to a wide divergence between the ORR and the more precisely defined indicator (the traditional gross reproduction rate, GRR) in the cohorts of the late 1960s and the 1970s in Slovakia (not shown here; data available upon request).

10 For the NBRR computations we used equations 6, 7, and 8 in del Rey Poveda and Cebrán-Villar (2010); for the NRR* we followed life-table computations described in Appendix 1 in Preston and Wang (2007), adapted to a single-year framework (the authors based their computations on five-year periods).

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