

ABSTRACT

Concern over unprecedentedly low levels of childbearing in Europe has become increasingly marked among both scientists and policy-makers. In conjunction with these concerns over fertility, there has also been considerable debate on the role migration can play in compensating for fertility below the replacement level.

The issue of how to measure inter-generational replacement has been addressed by several scholars in recent years. In this paper we make use of a very simple method to assess how far migration alters the extent of replacement for a birth cohort as it ages.

We term the measure used here the *overall replacement ratio* (ORR). It is calculated by taking the size of a female birth cohort divided by the average size of the cohorts of mothers in the year of birth. For example, we can compare the size of the 1975 cohort over time to the number of women in the main childbearing ages in 1975. Using annual estimates of the size of the 1975 cohort enables us to track the impact of migration on its implied level of replacement. Where immigration is significant, the ratio climbs over time, often reaching the replacement level by the age of 30 in many countries where fertility is well below the replacement level. The paper presents estimates of the ORR for a range of European countries representing different replacement regimes. In contrast with a frequently expressed notion of a limited impact of migration on population trends in Europe, we demonstrate that for many countries net migration has become a key factor in their population trends during the last decades.

KEY WORDS

Population trends; Europe; replacement level fertility; migration; Overall replacement ratio.

EDITORIAL NOTE

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Authors Chris Wilson and Paul Boyle are members of the ESRC Centre for Population Change. Chris Wilson, Lee Williamson and Paul Boyle are based in the School of Geography and Geosciences at the University of St Andrews. Tomáš Sobotka is based at the Vienna Institute of Demography at the Austrian Academy of Sciences.

Contact author: Chris Wilson: ccbw@st-andrews.ac.uk

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A SIMPLE METHOD FOR ESTIMATING INTER-GENERATIONAL REPLACEMENT BASED ON FERTILITY AND MIGRATION – EUROPEAN EXAMPLES

TABLE OF CONTENTS

1. INTRODUCTION.....	1
2. MEASUREMENT.....	2
3. DATA	5
4. RESULTS	6
5. REGIONAL COMPARISON	11
6. CONCLUSIONS AND IMPLICATIONS.....	14
REFERENCES.....	16
APPENDIX 1.....	18

1. INTRODUCTION

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 paper we propose an easily calculated measure that enables us to track how these three processes determine the extent of inter-generational replacement. Since mortality is low in most European countries until well after the reproductive ages, it plays a very limited role in determining replacement. Therefore, for European populations, population replacement is principally influenced by the combined effects of fertility and migration.

Concern over unprecedentedly low levels of childbearing and potential population decline in Europe has become increasingly marked among both scientists and policy-makers. National governments, the European Commission and even Pope Benedict XVI have highlighted Europe's low level of fertility as a challenge to long-term social and economic sustainability, while demographers have devoted considerable scholarly 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).

In conjunction with the concerns over fertility, there has also been considerable debate on the role migration can play in compensating for fertility below the replacement level. In 2000, the United Nations report *Replacement migration: Is it a solution to declining and ageing population?* triggered extensive (and very diverse) media comment on the matter, with many of the official responses of governments being unusually sharp (Teitelbaum 2004). In most cases, there appeared to be great reluctance to accept that large-scale immigration could be a structural feature of European societies. These views were broadly in line with some earlier studies suggesting that large-scale immigration is not politically viable in Europe (Teitelbaum and Winter 1985)

However, during the media frenzy set off by the United Nation's, few people paused to ask if any European countries already experience migration levels that can be seen as constituting 'replacement migration.' Although some evidence suggests this may be the case, no clear definition of replacement migration exists, which often makes 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 ageing, but also with regard to regional distribution, even ethnic or linguistic distribution, or socioeconomic composition” (see Lesthaeghe 2001, Coleman 2001, Beaujot 2003, and Saczuk 2003 for a critical assessment of the concept). One possible conceptualisation of replacement migration assesses whether immigration makes up for the difference between the observed number of births and the hypothetical number of births that would have been achieved if fertility reached replacement level. A long-term combination of sub-replacement fertility and replacement migration could eventually lead to a stationary population, i.e., a population with constant size and fixed age structure (under the assumption that mortality also remains constant). Examples of just such a process taking place over many decades in Northern Italy can be found in Dalla Zuanna (2006).

However, such a concept of replacement migration is not easily analysed because migration fluctuates widely over time: hence it is problematic to use migration rates for any particular year to estimate long-term population replacement. In order to avoid this volatility, in this paper we use a measure that shows the cumulated impact of migration on birth cohort size rather than conventional period rates. The measure we propose and the data used to estimate it are discussed in the next sections.

2. MEASUREMENT

Many demographers now accept that the importance of immigration for childbearing trends and population change in most developed countries implies the need to rethink the traditional concepts of replacement level fertility (Smallwood and Chamberlain 2005). However, in spite of the recognition that this is an important issue, no measure has yet become a *de facto* standard. Calot and Sardon (2001) suggest that the ‘net replacement rates’ which reflect both mortality and migration are preferable to the widely used ‘net reproduction rates’ and that their inclusion may change the evaluation of future population prospects. This is well illustrated by Daguët (2002) who computed different measures of generational replacement for France. Ortega and del Rey (2007) have taken a different approach, computing *birth replacement ratios* (BRE), relating period numbers of births to the mean size of the mothers’ generation at birth. Preston and Wang (2007) have proposed an alternative method calculating the intrinsic growth rate and net reproduction rate in the presence of migration based on age-specific growth rates. Two further papers that have investigated the links between migration, fertility and population dynamics are Ediev et al (2007) and Philipov and Schuster (2010).

Dalla Zuanna (2008) has proposed an index of replacement including migration, RM, that is very similar to the measure used in this paper. And, finally, Sobotka (2008) has proposed the *gross replacement rate* (GRE) that combines period estimates of fertility (the gross reproduction rate in the year of cohort's birth) with data on subsequent changes in cohort's population size to estimate replacement for each cohort.¹

In this paper we make use of a very simple method to assess how far migration alters the extent of replacement for a birth cohort as it ages. In order to avoid all problems associated with the estimation of fertility, mortality, and migration, we ignore the vital processes altogether, and just present a direct comparison of the size of age groups. We term the measure used here the *overall replacement ratio* (ORR). It is calculated by taking the size of a female birth cohort divided by the average size of the cohorts of mothers in the year of birth. We use female cohorts to facilitate comparison with conventional fertility indices, but male cohorts (or the two sexes combined) could be equally well studied in this way.

Specifically, the *overall replacement ratio* (ORR) is defined in this paper as follows:

$$ORR(a, c) = F(a, t=c+a) / (F(a(20, 35), t=c) / 16)$$

where a is age, c is the year of birth, F size of the female population, and t calendar year. We take 20 and 35 as indicating the limits of the main childbearing ages during the 1970s and 1980s, the birth cohorts which we are mostly studying here. We use the population distribution by age on January 1 of the subsequent year ($b+a+1$) to estimate female population reaching age a during the year $t=b+a$. Other age ranges and more complex definitions of the average size of the mothers' cohorts could, of course, be taken, but our initial sensitivity analysis suggests that the ORR is not significantly affected by the definition of the mothers' cohorts, as long as the range selected is long enough to wash out effects of short-term baby booms and busts. For present purposes we have chosen to keep the definition as simple as possible. 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

¹ In addition to indicators of population replacement, other measures have been used to estimate the impact of migration on the population. Coleman (2009) related period numbers of net migrants to the total number of live births, showing that a number of European countries had net migration exceeding 50% of live births around 2008. In their projection scenarios for the EU-15 countries (EU members as of 2003), 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."

mothers themselves. At these ages, cohort survivorship in contemporary developed countries is practically unaffected by mortality, which makes the ORR changes over time almost entirely determined by fertility and migration.

For example, we 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 impact of migration on its implied level of replacement. In the absence of migration, this ratio will remain almost constant for the first decades of life, and then decline as mortality reduces the size of the cohort. However, where there is significant immigration, 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.

As is well known, most migrants are usually young adults, thus immigration is a process that leads to additions to the size of a birth cohort between roughly the ages of 15 and 40. This age pattern of immigration 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.

In its interpretation and aim, the ORR is very close to the *gross replacement rate* (GRE) proposed by Sobotka (2008). As Appendix 1 shows, we achieve almost identical results using the more simply defined ORR as the GRE.

As an illustration, Figure 1 presents estimates of the ORR for female birth cohorts in England and Wales from 1972 to 1986. The ratios are based on annual single-year of age population estimates from 1972 to 2006 made by the United Kingdom's Office for National Statistics (ONS 2010). The uppermost line (1972 birth cohort) starts above 1 (the replacement-level) and remains there throughout the next 34 years. 1972 was the last year in which period fertility exceeded the replacement level, so all later cohorts begin below 1. No cohorts show any marked changes for the first 10-15 years of life, but all rise substantially from the late teens on, when significant immigration begins to increase the cohort sizes. The experience of each cohort is truncated at its age in 2006, but it is clear that most, if not all, cohorts will pass the replacement level. Although not shown in this paper, useful insights can also be obtained by organizing these data in a different way—either by tracking trends in

ORR for all cohorts at a few selected ages or by looking at the ORR of different cohorts by calendar years.

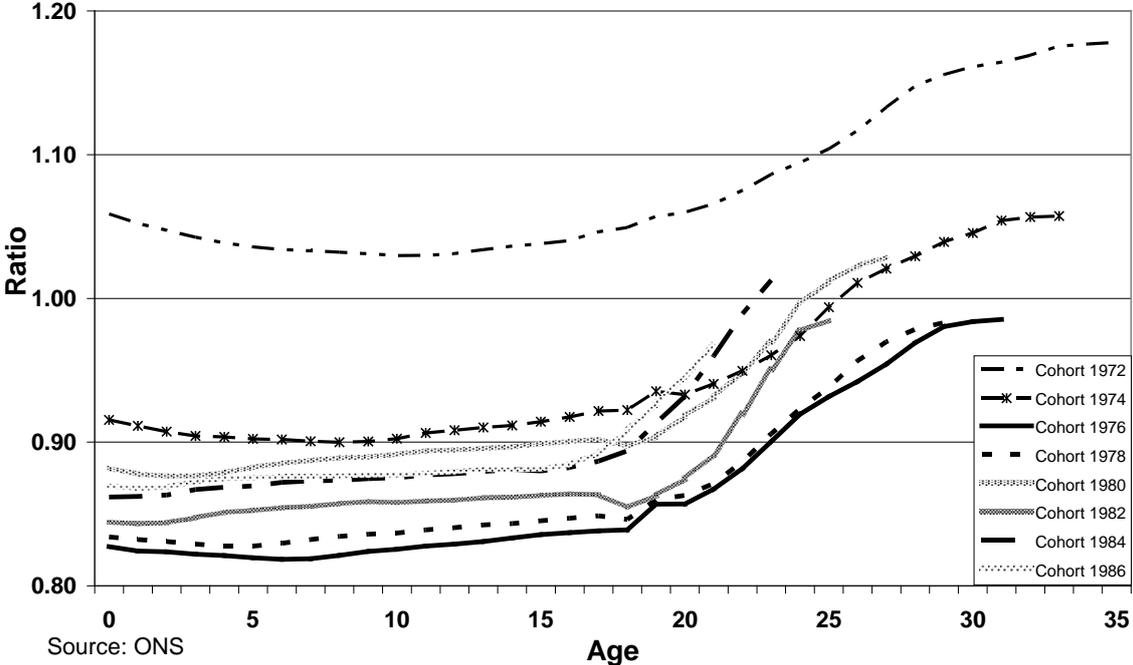


Figure 1: Overall Replacement Ratio for England and Wales, cohorts 1972 to 1986

3. DATA

The data we use in the rest of this paper are all taken from Eurostat’s online database. The national statistical offices of all the 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 2010). 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—can make use of detailed and accurate population registers, others have to rely on combinations of vital statistics and decennial censuses, which themselves may be deficient in various ways. Thus, the data we are using constitute the “best guesses” of Europe’s national statistical offices, which can be affected by different definitions of resident population and by different degrees of accuracy in registering immigration and emigration. Some statistical offices are at pains to point out the approximate nature of their population

estimates.² Nevertheless, it is evident that these “best guesses” mostly provide highly plausible and consistent information on the evolving population structures of the EU’s 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 in any event weaker than elsewhere in the EU. In such cases, sharp discontinuities are sometimes evident in the series or data only given for certain years. Another problematic country for our analysis is Ireland, as the Eurostat site does not give a continuous series of annual population estimates by single years of age up until 1985. For this reason, we exclude Ireland from our calculations. Overall, however, in most cases the data clearly capture the main trends in each country.

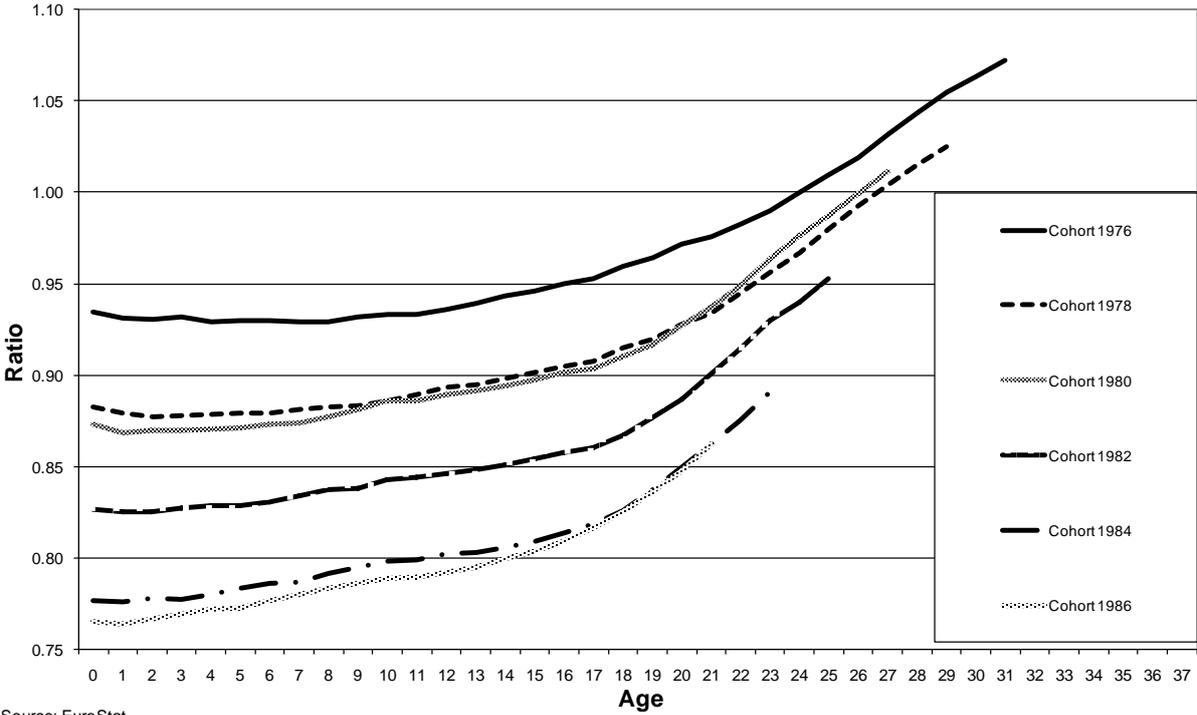
4. RESULTS

Figure 2 gives the ORR for the EU-14 (i.e. the old EU before the enlargements of 2004 and 2007 except for Ireland – see above), while Figure 3 presents the same information for eight European countries. The birth cohorts chosen run from 1976 to 1986, so that the cohorts’ experience is truncated at ages between 23 and 33 in 2009. We selected these cohorts because the conventional indicator of fertility, the *total fertility rate* (TFR) fell below the replacement level for the EU-15 in the mid-1970s. Earlier cohorts thus had no ‘need’ of replacement migration. Since much migration only happens from the late teens onwards, later cohorts have generally not yet had sufficient time to see significant immigration.

The results for the EU-14 in Figure 2 give a clear picture. The initial values of the ORR fall steadily over time, as this was a period of rapidly falling fertility, especially in Southern Europe. However, there is clear upward trend in the ORR as each cohort ages. This pattern reflected, with some variations, in the graphs in Figure 3 for the UK, Germany, France, Austria and Switzerland. The lines all begin well below one, sometimes far below (e.g., 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 to some degree, and the impact of specific migration events can be seen. For example, the large rise in each cohort in Germany

² For example, on their website the UK’s Office for National Statistics pointedly comments in the notes accompanying their estimates that “These estimates are NOT National Statistics. They do not meet the stringent requirements made of National Statistics data and are fit only for certain purposes. These include certain uses within population modelling and enabling understanding of population estimates” (emphasis in original).

in the early 1990s indicates the influx of refugees from the former Yugoslavia. Whatever the specific national features, the broad similarity of all five national graphs 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.



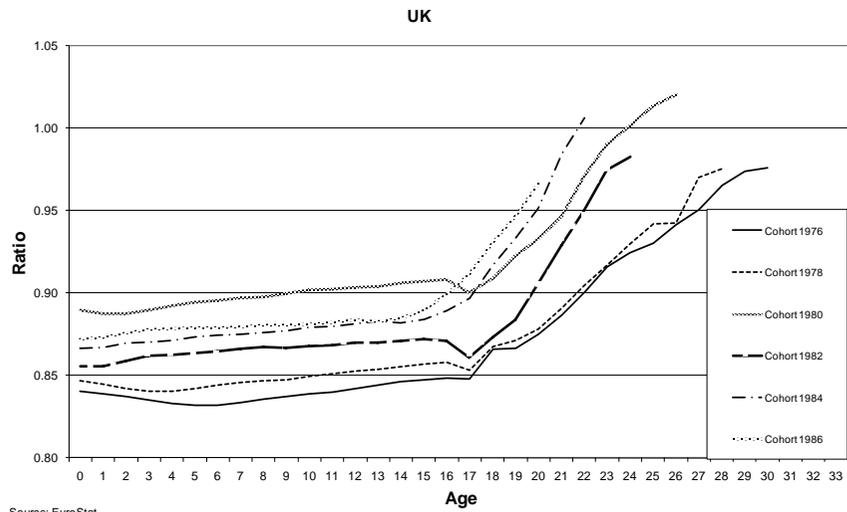
Source: EuroStat

Figure 2: Overall Replacement Ratio by age for the EU-15 (minus Ireland), cohorts 1976-1986

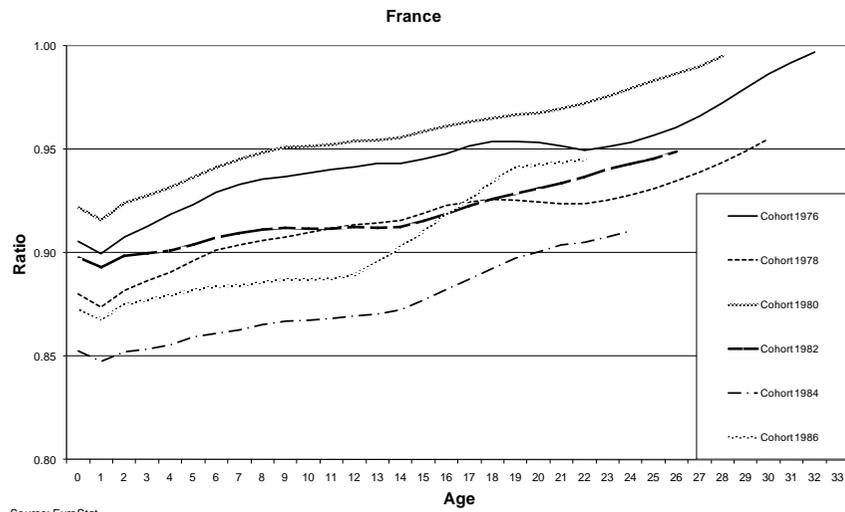
The results for Spain show a somewhat different pattern. Fertility remained higher longer, with the ORR not falling below one until the 1982 cohort. The dramatic upsurge of immigration into Spain, over the last two decades is also readily seen in the lines plotted. In Spain immigration seems to be more than filling the gap in cohort sizes created by very low fertility. To some extent the precise track of the Spanish curves may be deemed especially conjectural. After all, much of the immigration into Spain has been 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 of Europe has seen a similar extent of immigration, adding 5.2 million people to the Spanish 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 with fertility far below replacement increasingly combined with huge immigration. The joint effect

of the two processes is *overall replacement ratios* that are well-above replacement and concomitant rapid population growth.

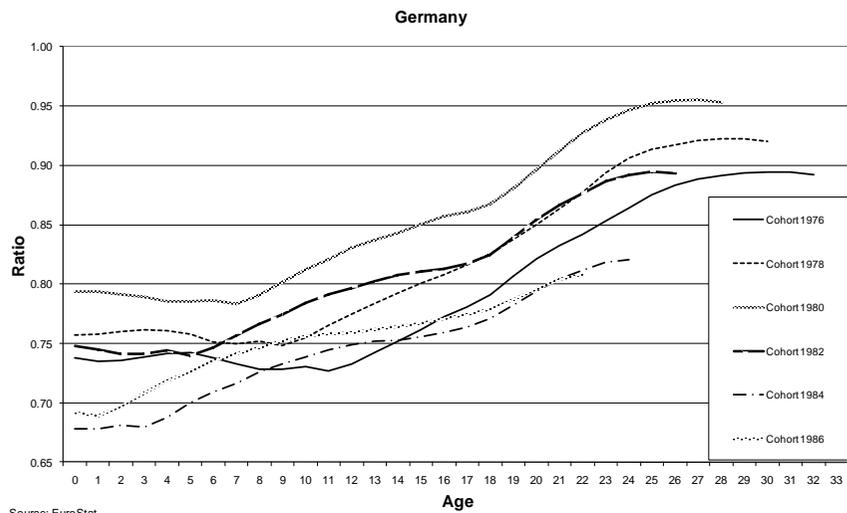
The final two panels in Figure 3 are for the Czech Republic and Hungary. Here we see a very different pattern. Until the end of Communism international migration was all but non-existent and so the lines for each birth cohort run horizontally, with just a few minor discontinuities possibly corresponding to mismatches between earlier estimates and updates following censuses. But as in the older member states, immigration is also coming to play a significant role. In the Czech Republic, from about the time of accession to the EU in 2004, the lines curve upwards. The Hungarian results show yet another pattern. Clear discontinuities are evident around the time of the collapse of Communism, and thereafter most cohorts show a steady increase in the ORR. The increase, which affects all ages, is probably a reflection of migration to Hungary of ethnic Hungarians from neighbouring countries, especially Romania.



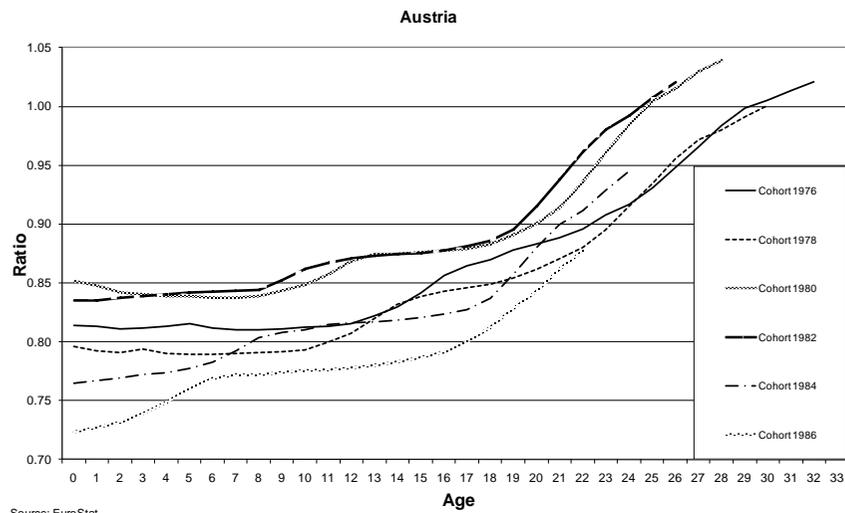
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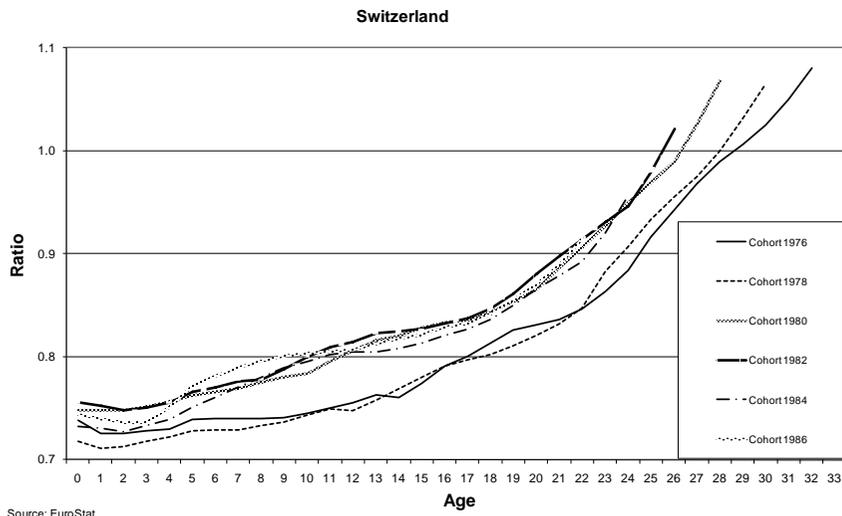


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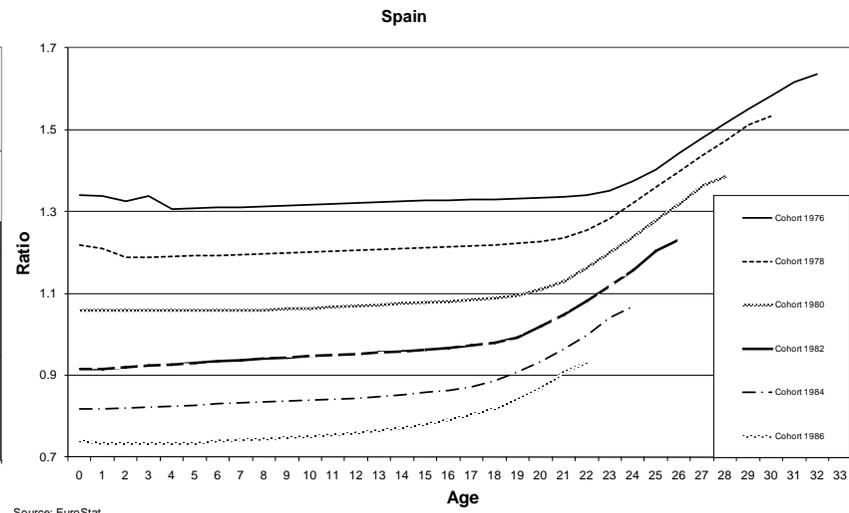


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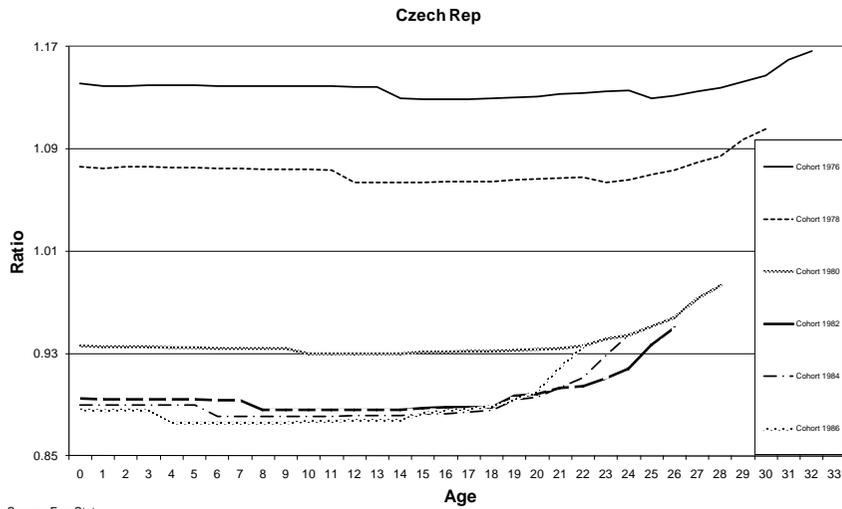
Figure 3: Overall Replacement Ratio for eight European countries, cohorts 1976-1986
Note: For definition of ORR, see text. Vertical scales differ.



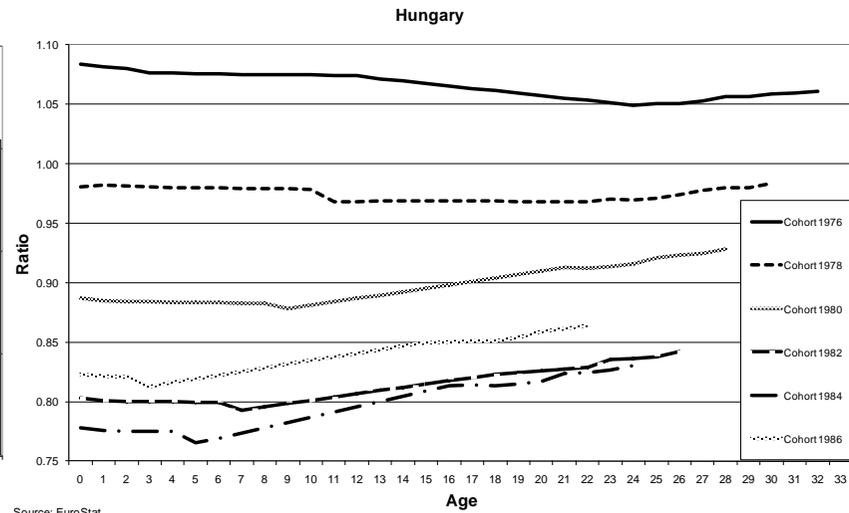
Source: EuroStat



Source: EuroStat



Source: EuroStat



Source: EuroStat

Figure 3: continued

5. REGIONAL COMPARISON

- To provide a more systematic assessment of population replacement in different parts of Europe, Table 1 summarises *overall replacement ratio* at ages 0 and 28 for two cohorts of women born during a period of declining fertility, 1975 and 1980. Country data are grouped by broader regions. The declining fertility of the late 1970s is clearly reflected in the fall or a stagnation of the *ORR* at age 0 between the two cohorts (Germany, where fertility fell strongly before 1975, is an exception). However, the trend at age 28 is much less clear-cut, with Austria, Germany, Switzerland and the United Kingdom all seeing increases in the *ORR* between the 1975 and 1980 cohorts. In all parts of Europe except Ireland and some Southern and Eastern European countries, the 1980 cohort was initially ‘endowed’ with sub-replacement level. By the time this cohort reached age 28, however, the *ORR* was close to or above the replacement level in most cases and above 0.9 almost everywhere (except in Denmark and parts of post-communist Europe). As a further rise in the *ORR* is likely to occur after age 28, it seems safe to conclude that in a most countries the 1980 cohort will probably surpass the value of 1 before its members reach age 40. Only in a number of ex-communist countries, has the *ORR* actually declined, though in a few cases, including Bulgaria and Latvia, it has plummeted, a trend that is likely to have long-term negative consequences for the population structure and long-term prospect of population decline.

Almost all the countries analysed saw a larger increase in the *ORR* for the 1980 cohort than for the 1975 cohort (Figure 4). The absolute and relative increases in the *ORR* between ages 0 and 28 were particularly marked in Spain and Switzerland, with absolute increases of 0.32-0.33 in the 1980 cohort (Figure 4). Obviously, even countries with very low fertility and net reproduction rates around 0.7 (i.e., with the TFR below 1.5) can reach replacement migration as early as at age 28. 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 of Southern Europe (see Fig. 4 below).

	ORR at age 0		ORR at age 28		Abs. increase in ORR		Relative change (index): ORR at age 28 / ORR at age 0	
	C 1975	C 1980	C 1975	C 1980	C 1975	C 1980	C 1975	C 1980
EU-14	0.95	0.87	1.06	1.01	0.11	0.14	1.11	1.16
Western Europe								
Belgium	0.87	0.82	0.96	0.95 ¹	0.09	0.13	1.11	1.16
France	0.96	0.92	1.02	1.00	0.06	0.07	1.06	1.08
UK	0.89	0.89	0.98	1.02 ¹	0.09	0.13	1.10	1.14
Nordic countries								
Denmark	0.94	0.74	1.02	0.86	0.09	0.12	1.09	1.17
Sweden	0.85	0.80	0.96	0.95	0.11	0.16	1.12	1.20
German-speaking								
Austria	0.86	0.85	1.00	1.04	0.15	0.19	1.17	1.22
Germany	0.71	0.79	0.85	0.95	0.15	0.16	1.21	1.20
Switzerland	0.75	0.75	0.97	1.07	0.22	0.32	1.30	1.43
Southern Europe								
Italy	1.06	0.80	1.11	0.93	0.05	0.13	1.05	1.16
Portugal	1.34	1.04	1.33	1.13	-0.01	0.10	1.00	1.09
Spain	1.34	1.06	1.51	1.39	0.17	0.33	1.13	1.31
Central & Eastern Europe								
Hungary	1.15	0.89	1.11	0.93	-0.04	0.04	0.97	1.05
Czech Republic	1.19	0.94	1.18	0.98	-0.01	0.05	0.99	1.05
Bulgaria	1.17	0.95	0.92	0.83	-0.25	-0.12	0.79	0.88
Latvia	1.01	0.94	0.91	0.87	-0.10	-0.07	0.90	0.92

TABLE 1: Overall replacement ratio at ages 0 and 28 in female birth cohorts 1975 and 1980, 15 European countries and EU-14 combined (15 EU member states as of 2003 without Ireland)
Note: 1 ORR for the 1980 cohort measured at age 27 instead of 28

The scatterplot in Figure 5 adds another dimension to this comparison. Though almost all 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 28. It also shows that for the EU-14 (2003 EU member states excluding Ireland) reaches an *ORR* around 1 by age 28. It further indicates that the *ORR* rises with age in all non-Eastern European countries (i.e., the points in Figure 5 are clustered above the diagonal). And, finally, it reveals that the initially rather close correlation between the *ORR* at age 0 and at age 28, as depicted for the 1975 cohort, does not hold much for the 1980 cohort, especially if the prominent outlier, Spain, is disregarded.

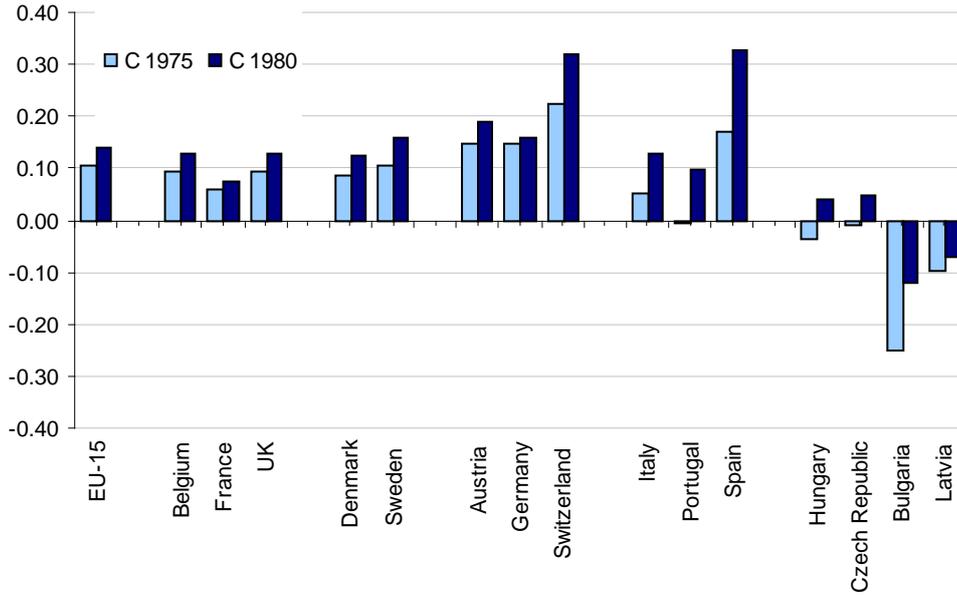


Figure 4: An absolute increase in the *ORR* between ages 0 and 28, cohorts 1975 and 1980

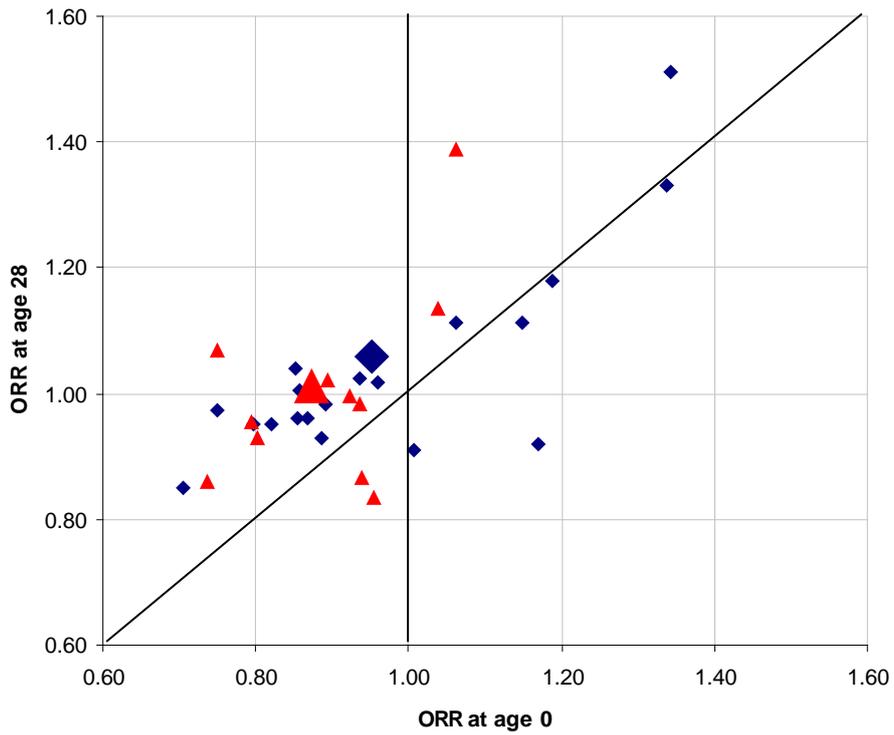


Figure 5: Overall Replacement Ratio at age 0 and at age 28, cohorts 1975 (blue diamonds) and 1980 (red triangles) in 15 European countries. Total for the EU-14 shown by large symbols.

6. CONCLUSIONS AND IMPLICATIONS

The results presented here are based on simple (perhaps even simplistic) comparisons. Yet they throw a clear light on the nature of population dynamics in many parts of Europe, especially in the European Union, suggesting strongly that projections of Europe's imminent demographic demise are far from realistic. In much of Europe it is manifestly 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. Perhaps some of the polemic surrounding the UN's publication was an indication that the idea was too close to the truth for comfort?

The pattern of replacement migration was first established in Western Europe and has since spread to include the richer parts of Southern Europe. Frequently, the impact of migration goes well beyond a small 'topping up' of population numbers; countries such as Spain or Switzerland show that even very low levels of fertility rates can be combined with replacement levels of migration. The richer countries among those that joined the EU in 2004 (e.g. the Czech Republic and Slovenia) are showing the clear signs in the same direction. There are, of course, exceptions from this general trend and many region-specific patterns. Some rich countries, including Germany and the Netherlands, have experienced short periods of net emigration and the recent economic recession may bring net emigration to yet more countries for some years to come. Moreover, some of the poorer EU member states, especially the Baltic countries, Bulgaria, and Romania are still seeing substantial emigration. However, taking a longer time perspective, the waves of emigrants from countries such as Poland or Romania today have a parallel in mass emigration from Portugal, Spain and Italy from the 1950s to the 1970s. All three of these Southern European countries have since switched to becoming 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 due course, and the establishment of large-scale replacement migration.

By itself, replacement migration is not a remedy to Europe's problems with an ageing population, but rather it can be seen as a potential opportunity that should be complemented with policies that aim to enhance socio-economic sustainability, including supporting the integration of migrants, increased labour participation of women, delayed retirement, and further increase in higher education attainment for both native and migrant populations.

The measure proposed here, the *overall replacement ratio*, is a simple, even crude, index. When thinking in terms of the two most common notions of replacement migration—one viewing migrants as contributing to more births in the country, and the other perceiving migrants as ‘filling the gap’ in population size attributable to sub-replacement fertility—the ORR focuses on the second perspective. It is easy to compute, can be compared over time and across countries, and is intuitively understandable. In spite of its simplicity, it performs as well as some more sophisticated cohort replacement measures and is, under normal circumstances, insensitive to the definition of mother’s cohort. In the absence of huge sudden shifts in mothers’ cohort size, the error resulting from an estimation of mother’s cohort size, rather than its’ precise measurement, is likely to be of a considerably smaller magnitude than the errors and definition problems contained in the official population data for many countries. 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 inter-generational replacement.

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APPENDIX 1

A COMPARISON OF THE GROSS REPLACEMENT RATE WITH THE OVERALL REPLACEMENT RATIO

The *Overall Replacement Ratio (ORR)* is based on the same underlying idea as the *Gross Replacement Rate (GRE)* proposed by Sobotka (2008). Both indicators aim to measure the extent to which migration modifies the population size of birth cohorts as they age and to assess whether migration partly or fully compensates for the effects of subreplacement fertility as initially small cohorts of women approach their prime reproductive period. Therefore, both indicators are particularly useful for analysing population dynamics at relatively young ages (through 30-35), especially among women. The *GRE* for the female cohort c at age a is computed by multiplying the gross reproduction rate (*GRR*) of the year $b=c$ when the cohort was born with the ratio of the cohorts' size F at age a to the initial cohort size (i.e., by the number of female live births in the year $b=c$):

$$GRE(a,c) = F(a,t=c+a) / B_F(b) \cdot GRR(b) = F(a,t=b+a) / B_F(b) \cdot TFR(b) \cdot B_F(b) / B(b)$$

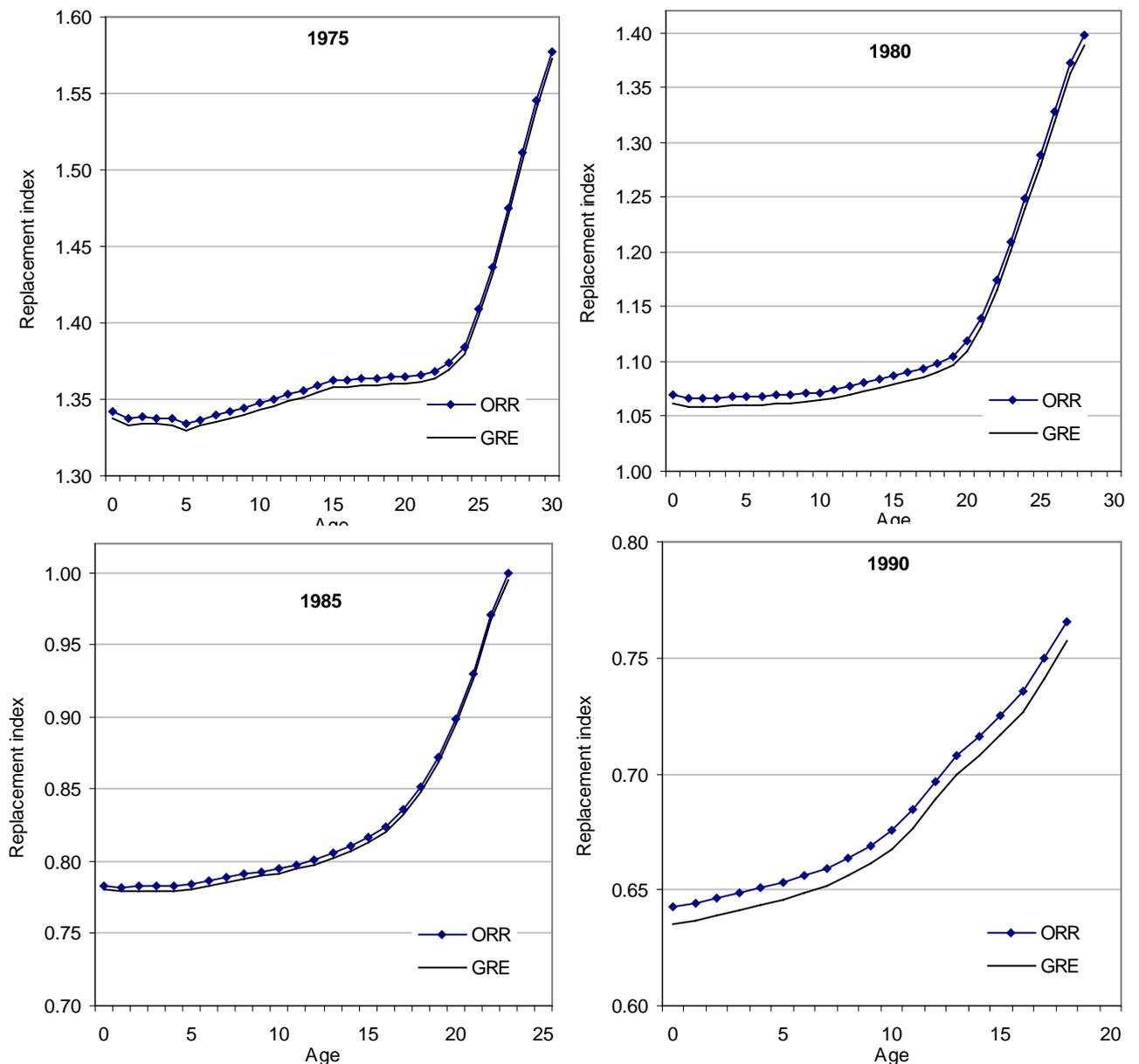
where $B_F(b)$ is the number of female live births in the year $b=c$.

As in the case of the *overall replacement ratio*, the *gross replacement rate* in fact measures population replacement for the mothers of a given birth cohort of 'children'. For instance, the *GRE* for the 1976 cohort measures population replacement among women who were giving birth in 1976. With some simplification, their replacement consisted of two waves: first, in 1976 when they were giving birth and later, especially in the 1990s and 2000s, when the size of their children's cohort expanded through immigration.

Theoretically, the *ORR* may diverge from the *GRE* for two reasons: First, the *ORR* does not account for the effects of mortality before and during the childbearing years among the generation of mothers of a given cohort. This effect is likely to lead to a minor upward bias in the *ORR*. Second, an approximation of the mothers' cohort size by a simple fixed age group in the *ORR* may cause deviations from the *GRE*, which properly controls for the size of mothers' cohort.

Because of the simplifications contained in the computation of the ORR, we might expect it to be less stable and slightly higher than the GRE. To study this difference we have carried out a comparison of these two indices. Here we present as an illustration the results for four female birth cohorts (1975, 1980, 1985, and 1990) in Spain. Surprisingly, both indicators show an almost perfect overlap and become distinguishable only when inspected on a detailed scale (Figure A1). As expected, the *ORR* reaches slightly higher values, but this minor difference, almost always below 1%, is remarkably consistent across cohorts and over age groups. Contrary to our expectations, under normal circumstances the *ORR* shows no more instability than the *GRE*, nor any significant deviations from that measure. Overall, this similarity leads us to a positive assessment of the *ORR*, whose performance matches the more sophisticated measure of cohort replacement.

Figure A1: A comparison of the ORR and GRE for Spain, female birth cohorts 1975, 1980, 1985 and 1990



ESRC Centre for Population Change
Building 58, Room 2001
Faculty of Social and Human Sciences
University of Southampton
SO17 1BJ

T: +44 (0)2380 592579
E: cpc@soton.ac.uk
www.cpc.ac.uk

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