# Explaining population increases in the more developed countries in 1970-2020 despite persistent under-replacement fertility

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## 1. Introduction

What might be the fate of populations after the end of the demographic transition? That is, after fertility has reached replacement level and – from a historical and demographic viewpoint – infant and youth mortality have become negligible? In Europe, the US, Canada, Japan, Australia, and New Zealand, defined as the More Developed Countries (MDCs) by the United Nations Population Division (UNPD)[1], this condition was reached around 1970-74, when TFR=2.16, $e_0$=71.3, ${}_1q_0$=21‰, and ${}_{40}q_1$=45‰ (United Nations Population Division 2019)[2].

Demographic transition theory provides a useful framework for describing population trends in countries around the world as they travel the path of socio-economic modernization (Kirk 1996; Lee 2003). Demographers have thoroughly analysed the demographic transition, and the pre-transitional period, reflecting in particular on the weight of changes in fertility, mortality, migration and age structure on the general trend of population size (see e.g. Chesnais 1990; Lee 2003; Bongaarts 2009). We therefore believe that the time has come to also think about what happens after the transition, a period that in MDC has begun more than 50 years ago.

Yet, understanding (and therefore predicting) post-transition population dynamics has proven more difficult. After the 1970s, demographic processes proceeded in the same directions, though followed different paths. Fertility declined below replacement level, but trends fluctuated over the last decades and countries showed large and often increasing differences (Rindfuss, Choe 2016; Sobotka 2017; Billari 2018; Reher 2021; Castiglioni, Dalla Zuanna, Tanturri 2021). Life expectancy rose yet, for prolonged recent periods, without an expected convergence (Oeppen, Vaupel 2002; Moser, Shkolnikov, Leon 2005). The positive trend in the net migration rate, starting from the end of WWII, continued (Chesnais 1990; Coleman 2006; Billari, Dalla Zuanna 2013; Colombo, Dalla Zuanna 2019) albeit with some stop-and-go. In some MDCs, the influence of immigration and emigration on population turnover progressively grew, becoming more intense than that of birth and deaths (Billari 2022; Eurostat 2023).

We contribute empirically to this puzzle by measuring the weight of the different components of demographic dynamics and of the initial age structure in MDCs after the end of the transition in determining the evolution of total population

SIDeS, «Popolazione e Storia»,
1/2024, pp. 9-26. DOI: 10.4424/ps2024-1

and its age structure between 1970 and 2020. This analysis of the past is driven by a simple observation: despite 50 years of below replacement fertility (TFR=1.75 during 1970-2020), the population of MDCs rose from 1,008 to 1,273 million, with a non-negligible annual growth rate (+0.47%) and population aging (mean age shifted from 37.5 in 1970 to 42.0 in 2020). We measure the role played by the other demographic forces (i.e., mortality, migration, and the initial age structure) in abating the population decline that would otherwise have been induced by the low fertility from 1970 onwards. We first consider the MDCs as a whole, and then look specifically at four countries with different demographic dynamics (the US, Russia, Japan and Italy).

The paper is organized as follows. After presenting the method used to measure the role of the different demographic components in the evolution and structure of the population in 1970-2020, we describe the main demographic transformations in the MDCs over these 50 years. We then show the impact of these changes on the MDCs broadly and the four countries more specifically. Finally, we consider the future of the world population in light of the analyses conducted, also highlighting the weakness, or even the lack, of sufficiently strong and consolidated theories to interpret what can happen after the end of the demographic transition.

## 2. Data and Methods

For the period between 1970 and 2020, we compare the actual population with populations simulated under several assumptions. The aim being to isolate the role of the different demographic components on population trends and characteristics. The data are those produced by the UNPD on the population and demographic dynamics of the MDCs (United Nations Population Division 2019). We adopt the cohort-component method (United Nations 1956), based on the population equation, following that now used by the UNPD when building different projection scenarios[3]. Separately for males and females and considering five-year age groups, population at the beginning of the year t+5 at age x+5 is given by:

(1) $_{t+5}P_{x+5} = {}_tP_x - {}_tD_x + {}_tI_x - {}_tE_x = {}_tP_x - {}_tD_x + {}_tNM_x = {}_tP_x - {}_tP_x\ ({}_tD_x / {}_tP_x) + {}_tP_x\ ({}_tNM_x / {}_tP_x) = {}_tP_x\ (1+s_x+NMR_x)$

where P indicates Population; D, Deaths; I, Immigrations; E, Emigrations; NM, Net Migration; s, survival rate; NMR, net migration rate; and x, the five-year age group x÷x+4. Moreover:

(2) $_{t+5}P_0 = B\ (L_0 / l_0)$, where $B=\Sigma B_x = \Sigma f_x((_{t+5}W_x + {}_tW_x) / 2)$

where B denotes births; $L_0$ and $l_0$ come from the life table; W indicates women; and $f_x$, fertility rates at age x.

The UNPD website provides all these parameters with the exception of $NMR_x$, obtained by difference:

(3) $NMR_x = {}_{t+5}P_{x+5} / {}_tP_x - 1 - s_x$

$NMR_x$ is not calculated starting from direct data on migration, but thanks to the population equation, as a "deviation" from natural demography. The resulting NMR, not distinguished by age, used here and reported in the tables below, is not the same as that in the UNPD reports. However, for both the MDCs as a whole and the four countries examined in our study, the differences are very small if not zero (detailed calculations available upon request).

We thus have the population at the beginning and end of each of five-year-period (1970-75 ... 2015-20) and, for each of these five-year periods, the values of $s_x$ (mortality), $f_x$ (fertility) and $NMR_x$ (net migrations) for all five-year age groups, differentiating between males and females. The sum of the male and female populations is our Observed Population, used as our reference to measure the effects of the three demographic components and of the population structure during 1970-2020.

To isolate the effect of changes in fertility and mortality, we alternately replace the $f_x$ and the $s_x$ actually realized over the course of the 50 years with ${}_{1970\text{-}75}f_x$ and ${}_{1970\text{-}75}s_x$. In this way, we simulate the population that would have been determined if – *ceteris paribus* – fertility had remained that of 1970-75 ($FERT_{1970\text{-}75}$) or if mortality had remained that of 1970-75 ($MORT_{1970\text{-}75}$).

To measure the effect of migration, we use the same logic, but impose zero migration. Namely, we simulate the population that would have been determined if – *ceteris paribus* – for each age the migratory balance had been equal to zero ($MIGR_0$).

These first three simulations follow the same procedure as that utilized for the UNPD forecasts, when defining "constant fertility," "constant mortality," and "zero-migration" scenarios.

Finally, to measure the effect of the age structure, we first calculate the age structure of the "stable equivalent" population associated with ${}_{1970\text{-}75}f_x$ and ${}_{1970\text{-}75}s_x$, applying these mortality and fertility rates to any age structure for a period of 200 years, with zero migration (Preston, Heuveline, Guillot 2001)[4]. The actual demographic dynamics of the 1970-2020 period are applied to this new age structure, thus obtaining the population that would have emerged had the starting age structure not been determined by different demographic shocks prior to 1970 (i.e., linked to the world wars, the baby boom, mortality decline, migration etc.), but had been that associated with the fertility and mortality of 1970-75 and zero migration ($STABLE_{1970\text{-}75}$).

These simulations are not intended to illustrate a real population, as the components of the demographic dynamics are not independent of each other: for example, a persistent decrease in fertility can become a strong immigration pull-factor, because – within a few years – it determines a shortage of working age population. Rather, this method is useful for isolating the strength of each component of the demographic dynamics, just as the aforementioned UNPD projections do with constant fertility and mortality, or with net migration equal to zero.

These procedures are first applied broadly to the MDCs (and to the less developed countries [LDCs] for comparative purposes), and then to four MDCs characterized by different starting age structures and demographic dynamics: the US, Russia, Japan, and Italy. After briefly describing variations in fertility, mortality, migration, and the age structure in 1970-2020, we illustrate the contribution of the four components to the variations in population size and aging in this same period.

### 3. Results: Demographic Dynamics and Age Structure in the MDCs, 1970-2020

Although the demographic evolution of the MDCs is well known, it is still striking to observe the speed and intensity of the changes that occurred in this fifty-year period (tab. 1 and fig. 1).

Tab. 1. *Demographic indicators of the MDCs, 1970-2020*

| | 1970-80 | 1980-90 | 1990-00 | 2000-10 | 2010-20 |
|---|---|---|---|---|---|
| $e_0$ | 71.5 | 73.4 | 74.5 | 76.3 | 78.8 |
| TFR | 2.04 | 1.83 | 1.62 | 1.63 | 1.66 |
| NMR x 1,000 | 1.23 | 1.12 | 2.00 | 2.73 | 2.24 |
| Mean age (a) | 34.0 | 35.6 | 37.3 | 39.3 | 41.2 |
| % age 20-69 (a) | 60.5 | 62.7 | 64.4 | 65.4 | 65.4 |

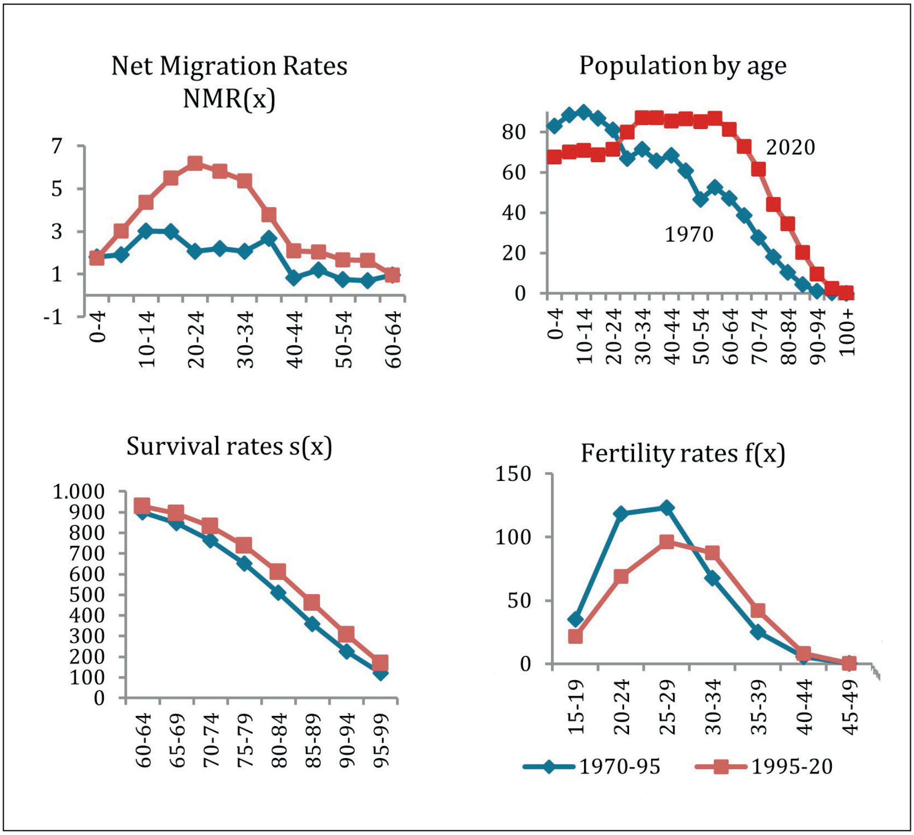
Source: our calculation on UNPD data.
(a) Mean between time t, t+5 and t+10

Compared to 1970, life expectancy at birth rose by more than seven years, and much of this increase – mainly concentrated in the last three decades (1990-2020) – was due to a spectacular upturn in old age survival. Throughout the period of 1980-2020, fertility was consistently below replacement level, attributable to the sharp decrease in births among women under 30. Over 1990-2020, 1.5-1.7 children per woman continued to be born, though the age profile of fertility rates continuously shifted, increasingly concentrated in the second half of fertile life. Finally, the net migration rate, stable around +1.2‰ in the first two decades (1970-1990), more than doubled in the following thirty years (+2.5‰), thanks mostly to people aged 15-34.

All these changes generated a significantly aged age structure due to the decrease in children (aging "from below") and the increase in elderly (aging "from above"). Over the course of 1970-2020, the average age increased by more than seven years, from 34.0 to 41.2. Interesting as well is the modal age class between 1970-75 and 2015-20: the demographic wave of the post-WWII baby boom first generated an increase in children, then in young workers, then in mature workers, which, in the coming decades will translate into a strong rise in people in their third and fourth age.

Demographic changes during 1970-2020 can also be considered from the perspective of an important structural indicator: the proportion of the population potentially active (aged 20-69), supporting those who are either not yet (aged 0-19) or no longer able (aged 70+) to work (see tab. 1, last row). In industrial and post-industrial societies, the increase in this active age group should help economic expansion, as it pushes savings and investment rates upwards (Bloom, Canning,

Fig. 1. *Demographic dynamics by age in the MDCs, 1970-2020. Data x 1,000*



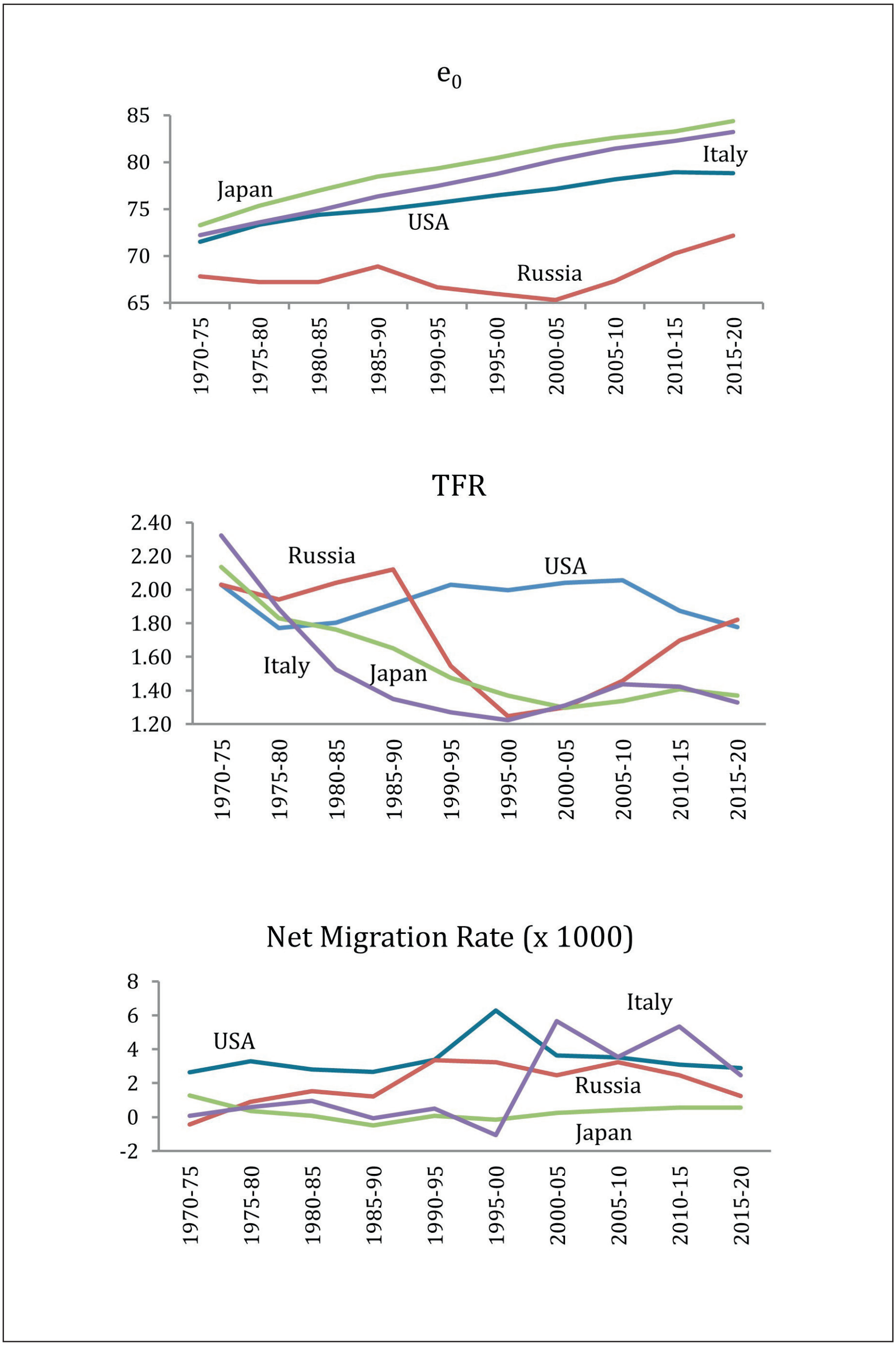

Source: our calculation on UNPD data.

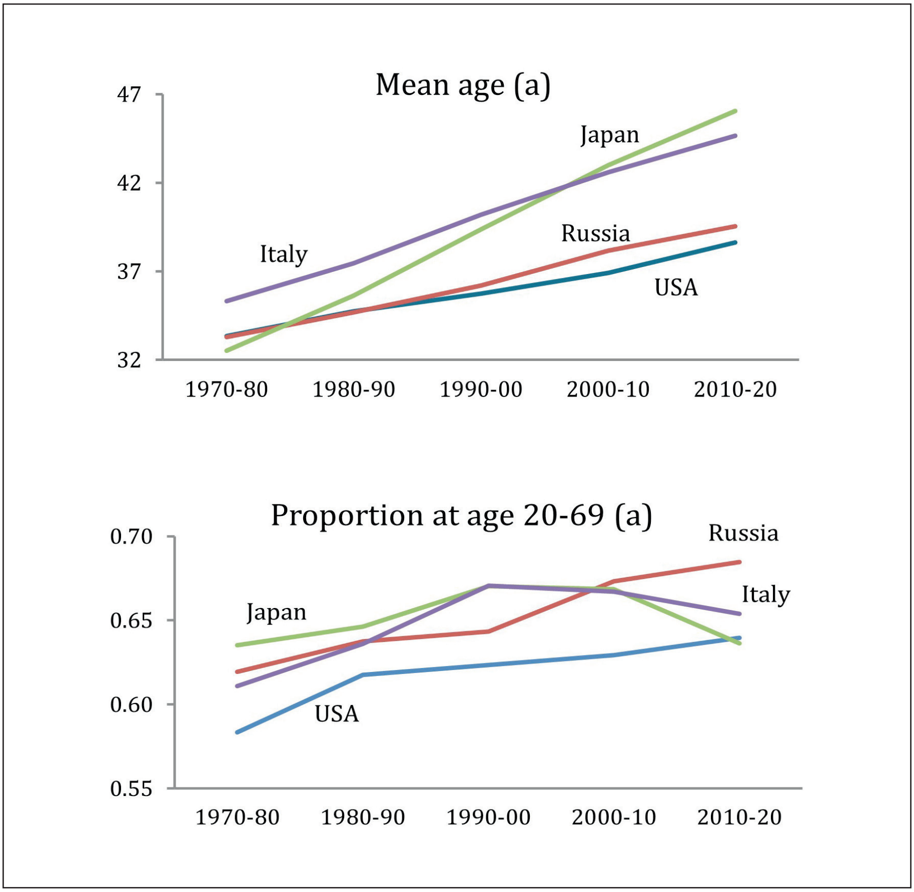
Sevilla 2003). Between 1970 and 2020, the proportion of the population aged 20-69 rose in the MDCs, as the increase in the over-70s was partially offset by the decrease in young people and, especially, because the baby boomers were transiting through the potentially active working ages.

The same indicators in table 1 are displayed for four countries (the US, Russia, Japan, and Italy), showing notable non-homogeneity in post-transitional demographic paths (fig. 2).

Italy and Japan share a similarly strong and linear growth in survival (more than eleven years progressively gained in 1970-2020), while $e_0$ in the US – which in the 1970s was on par with Italy – was respectively five and six years less than that in Italy and Japan in 2015-20. Trends in survival in Russia are more dramatic: a certain recovery can be observed only in the last two decades, though $e_0$ remained twelve years lower in 2015-2020 compared to Japan. In the early 1970s, the four countries considered here all had similar fertility rates, around replacement level.

Fig. 2. *Data x 1,000 Various demographic indicators for the US, Russia, Japan, and Italy between 1970 and 2020*

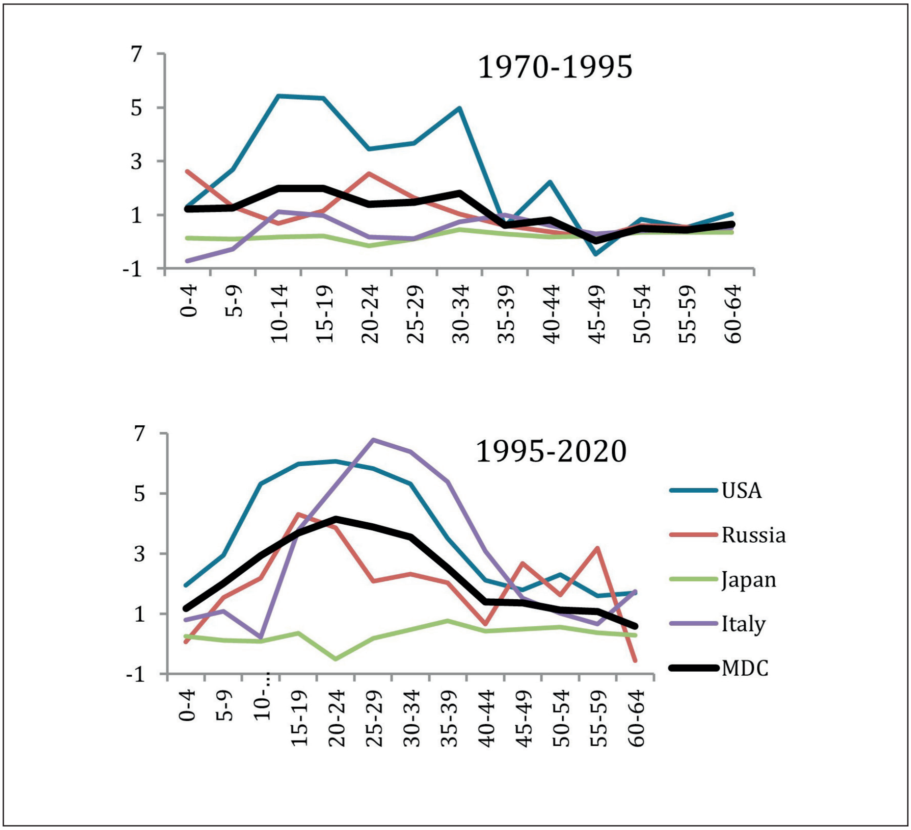





Source: our calculation on UNPD data.
(a) Mean between time t, t+5 and t+10

However, this homogeneity disappears in the decades that follow. In the US, the TFR changed very little, fluctuating around 1.9 children per woman. In Russia, fertility collapsed with the fall of the USSR and then, thanks to pronatalist policies, returned to levels comparable to the US in the early decades of the twenty-first century. Italy and Japan, meanwhile, are the "champions" of lowest-low fertility (Kohler, Billari, Ortega 2002): as early as the 1980s and 1990s, the TFR fell below 1.5 children per woman, and never exceeded this level in the following decades. Migration likewise differed notably in these four countries over this 50-year period. In the US, the NMR never dropped below +2.5‰, peaking at +6‰ at the end of the twentieth century; Italy experienced an immigration boom during the first decades of the new century; in Russia, the NMR rose after the dissolution of the USSR, but without ever reaching the levels observed in Italy and the US; finally, Japan was essentially closed to international migration throughout these years.

Fig. 3. *Net migration rates by age in the MDCs, the US, Russia, Japan, and Italy. 1970-1995 and 1995-2020*



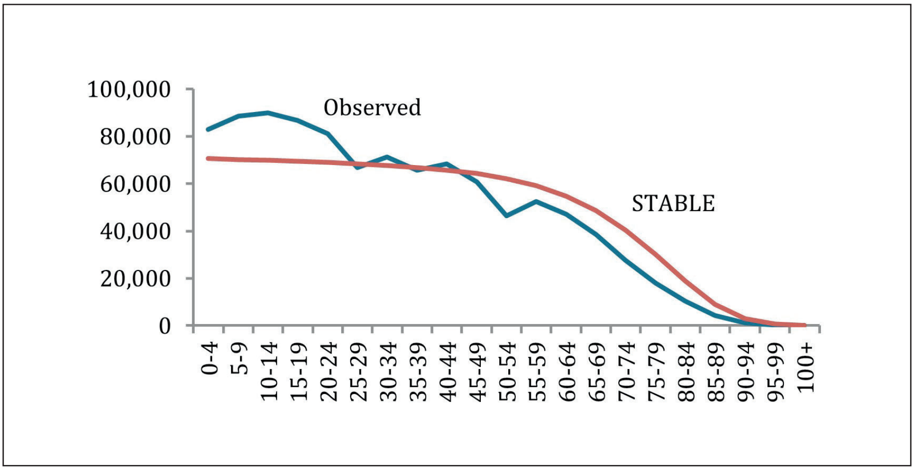

Source: our calculation on UNPD data.

Figure 1 described the age patterns of the net migration rates in the MDCs, considered together. However, in applying the cohort component method, we calculated the $NMR_x$ (Net Migration Rates by age) for each five-year period in each country, measures not published in the UNPD database. We can consequently look at the evolution by age of migratory balances in the four countries, comparing the first and second twenty-five years of 1970-2020 (fig. 3). In the US and Japan, the NMRx curves maintain almost the same age-profile, in spite of the completely diverse pattern. In Russia and especially in Italy, migrations increased, as was also the case in all MDCs, concentrated largely at ages 15-39.

## 4. Results: The contribution of the demographic components to population size and aging in 1970-2020

We first examine the impact of the demographic components on population size.

Fig. 4. *Population by age in the MDCs in 1970-75: observed vs. simulated with STABLE demographic dynamic*




Source: our calculation on UNPD data.
STABLE: stable population with the natural demography of 1970-75 (TFR=2.16, e0=71.1) and zero migration

From 1970 to 2020, the population of the MDCs grew at an annual rate of 0.47%, rising from 1,008 to 1,273 million. Why do we observe population growth during this period, if the mean TFR was well below replacement level (1.75)? Certainly, the 1970-2020 decline in fertility had a strong impact on the 2020 population, as shown in table 2. Had fertility remained constant for this 50-year period, equal to that of the early 1970s (TFR=2.16), the population would have grown to 1,486 million, 213 million more compared to that actually observed in 2020.

Population size did not, however, decrease, as it was sustained by the other three components. Had there been no migration, the population in 2020 would have been 142 million less than that recorded. In addition to a positive migration balance, the young age structure of immigrants also contributed to raising the number of births. A lesser effect (89 million) came from increasing survival, especially as nearly all gains were concentrated among the elderly, without any impact on births. Finally, the effect of the initial age structure on the increase in population size was also strong (183 million), higher than the effect of migration, as the age structure at the beginning of 1970s was much more favorable to population growth than the age structure of the stable population associated with the natural demography of 1970-75 (fig. 4). A relatively young age structure in 1970 also meant that, in the twenty-year period of 1970-1990, the number of births fell more slowly than the TFR. The structure effect then subsided, and in the following years TFR and births decrease in parallel (fig. 5).

Tab. 2. *The effect of fertility, migration, and mortality during 1970-2020 and of population structure in 1970 on population size in 2020 (millions). More and Less Developed Countries, the US, Russia, Japan, and Italy*

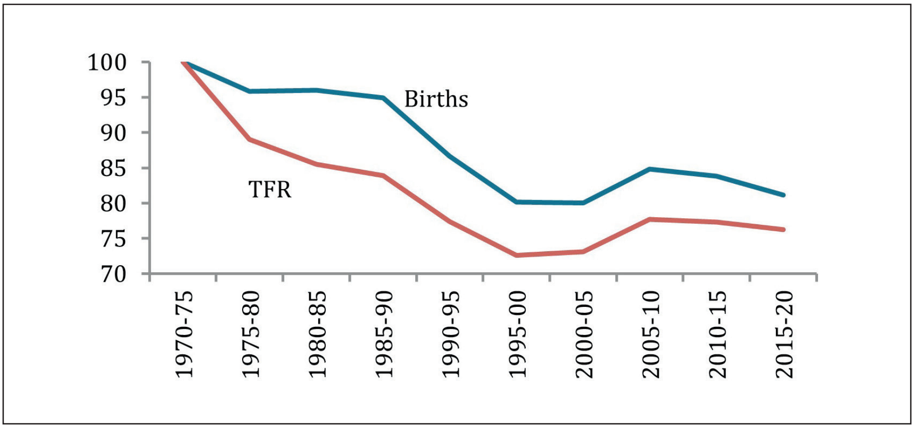
| | MDC | LDC | US | Russia | Japan | Italy |
|---|---|---|---|---|---|---|
| | | | Observed Population | | | |
| 1970 | 1,008 | 2,692 | 210 | 130 | 105 | 54 |
| 2020 | 1,273 | 6,521 | 331 | 146 | 126 | 60 |
| Mean r (year) | 0.47% | 1.77% | 0.91% | 0.23% | 0.36% | 0.21% |
| | | | Simulated Population in 2020 | | | |
| $FERT_{1970-75}$ | 1,486 | 11,119 | 346 | 164 | 155 | 81 |
| $MIGR_0$ | 1,131 | 6,712 | 264 | 130 | 125 | 54 |
| $MORT_{1970-75}$ | 1,184 | 5,575 | 309 | 145 | 111 | 54 |
| $STABLE_{1970}$ | 1,090 | 6,504 | 268 | 121 | 99 | 57 |
| | | | $(\text{Observed – Simulated})_{2020}$ | | | |
| $FERT_{1970-75}$ | -213 | -4,598 | -15 | -18 | -29 | -21 |
| $MIGR_0$ | 142 | -191 | 67 | 16 | 1 | 6 |
| $MORT_{1970-75}$ | 89 | 946 | 22 | 1 | 15 | 6 |
| $STABLE_{1970}$ | 183 | 17 | 63 | 25 | 27 | 3 |
| | | | $((\text{Observed – Simulated})/\text{Observed})_{2020}$ % | | | |
| $FERT_{1970-75}$ | -17 | -71 | -5 | -12 | -23 | -35 |
| $MIGR_0$ | 11 | -3 | 20 | 11 | 1 | 10 |
| $MORT_{1970-75}$ | 7 | 15 | 7 | 1 | 12 | 10 |
| $STABLE_{1970}$ | 14 | 0 | 19 | 17 | 21 | 5 |

Source: our calculation on UNPD data.

For comparative purposes, we applied the same analysis to the Less Developed Countries (LDCs). The results, presented in table 2, show that the decline in fertility during this 50-year period – still above replacement level – had an enormous effect in containing the increase in population, which in 2020 was 6.5 billion, but would have been 11.1 billion if fertility had remained that at the beginning of the period (TFR=6.08 in 1970-75 vs. 2.59 in 2015-20). A negative migratory balance (NMR varying between -2.34‰ in 1970-80 and 1.04‰ in 2010-20) also curbed population size, though less strongly than fertility decline. Mortality meanwhile contributed significantly in the opposite direction. The population of LDCs increased by almost one billion due to a strong decline in mortality ($e_0$=54.8 in 1970-75, 70.7 in 2015-20), particularly intense at young ages (${}_5q_0$=156‰ in 1970-75, 44‰ in 2015-20). Finally, the structure effect in LDCs was almost irrelevant as the actual age structure in 1970 was practically identical to that of the stable population associated with the natural demography at that time.

These same calculations were applied to the US, Russia, Japan, and Italy, which –

Fig. 5. *Index number (1970-75=100) of births and TFR in the MDCs. 1970-2020*

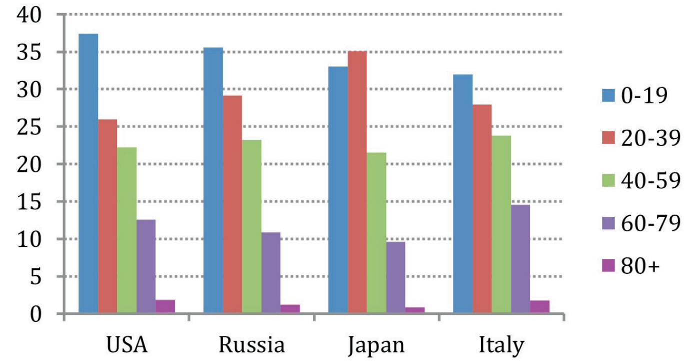



Source: our calculation on UNPD data.

as described above – have experienced very different post-transition demographic dynamics (tab. 2). The population in the US grew at triple the rate compared to the other three countries. As fertility always remained around replacement level, it did not affect population size, though the young age structure in 1970 (fig. 6) and continuously positive migratory balances sustained its increase. $MIGR_0$ and $STABLE_{1970\text{-}75}$ simulations show a similar strength of migration and the initial population age structure in pushing up US population size. Russia meanwhile notably stands out for the almost zero contribution of the drop in mortality to population growth. Furthermore, positive migratory balances and a relatively young starting age structure offset the decline in population that would have been caused by low fertility. In Japan as well the initial age structure, rich in children and people of childbearing age, counterbalanced the population decline induced by the drop in fertility; moreover, the population increased thanks also to mortality decline, even without the contribution of migration. Finally, population grew the least in Italy because the 1970 age structure (the oldest among the four considered countries), the decline in mortality, and the positive migratory balance were barely able to compensate for the reduction in population that would have been induced by the strong decline in fertility.

A comparison of the four countries thus shows that the decline in fertility was indubitably a very important negative component for growth over the 1970-2020 period. Its effect was offset by immigration, strongly where the latter was intense (US), somewhat less so where more moderate (Russia) or fluctuating over time (Italy). Even the decline in mortality, if mainly affecting the ages over 60, was relevant in containing the decrease in population size. While these trends were expected, the analysis also highlights the important role of the young age structure in the 1970s, which offset the fertility decline to differing degrees in the four countries. Notably, Italy, which already had a relatively old age structure, was much more exposed to the

Fig. 6. *Population age structure in 1970 (%). US, Russia, Japan, and Italy*




Source: our calculation on UNPD data.

effects of demographic dynamics, lacking the protection of a young age structure.

We have just seen that the negative impact of the decline in fertility on population size between 1970 and 2020 was offset – to varying degrees – by the other components of demographic dynamics and by the initial age structure. Table 3 displays the effects of these same components on the aging of the MDC population in this period. If there had been no migration, the population would have aged a bit more rapidly, especially from 1995 onwards. The average age in 2020 would have been one year older (43.0 vs. 42.0). In contrast, both the decline in mortality and fertility pushed the average age of the population upwards.

The most interesting result concerns the effect of the age structure in 1970. The average age of the population in 1970 would have been – by construction of the simulation, see the last row in table 3 – around 38 years, i.e., that of the stable population associated with the natural population dynamic of 1970-75, five years older than actually observed in 1970, strongly rejuvenated by the baby boom and the decline in early mortality in previous decades. This means, in other words, that the natural dynamic of 1970-75 is much more typical of a post-transition population than that of the previous period. As the real-world demographic dynamic is applied to this stable age structure in 1970, the age structure itself changes year after year, quickly approaching the actual one because – as is well known – it loses the memory of its initial age structure ("weak ergodicity" – Preston, Heuveline, Guillot 2001). In 2020, the average age of the population of this simulation is similar to the average age actually measured, as the young initial population age structure's pulling down of the mean age has decreased. This result suggests a comparatively weaker impact of the initial age structure in determining the structure 50 years later.

The results are much easier to describe for the LDCs. The aging of the population (from 23.9 years in 1970 to 31.5 in 2020) is entirely due to the decline in fertility.

In the four countries considered here, the effect of the demographic components on average age variations during the period of 1970-2020 differs. The US is the only country in which the young initial structure and substantial immigration contribute somewhat to keeping the population younger. Fertility meanwhile plays a relatively marginal role, and declining mortality represents – albeit weakly – the most important component for the aging of the population. In the other three countries, the initial structure and migrations – which had a significant effect on population growth – had only a marginal effect on the average age in 2020. The situation is different, however, for the components of natural demography. Where the changes between 1970 and 2020 were intense (Japan and Italy), both the decline in fertility and the increase in survival pushed the average age upwards. Where, on the other hand, these changes were less intense (Russia, similar to the US), the evolution of natural demographics only marginally affected variation in the average age.

Tab. 3. *The effect of fertility, migration, mortality during 1970-2020 and of population structure in 1970 on the mean population age in 2020. MDC, LDC, US, Russia, Japan, and Italy*

| | MDC | LDC | US | Russia | Japan | Italy |
|---|---|---|---|---|---|---|
| | | | Observed Population | | | |
| 1970 | 33.2 | 23.9 | 32.6 | 32.2 | 31.4 | 34.6 |
| 2020 | 42.0 | 31.5 | 39.6 | 40.1 | 47.5 | 45.8 |
| 2020-1970 | 8.8 | 7.6 | 7.0 | 7.9 | 16.1 | 11.2 |
| | | | Simulated Population in 2020 | | | |
| $FERT_{1970-75}$ | 38.5 | 23.9 | 38.7 | 37.4 | 42.1 | 38.7 |
| $MIGR_0$ | 43.0 | 31.4 | 41.1 | 40.5 | 47.4 | 46.0 |
| $MORT_{1970-75}$ | 40.1 | 31.4 | 37.9 | 40.0 | 43.7 | 43.0 |
| $STABLE_{1970}$ | 42.5 | 31.6 | 40.4 | 40.3 | 47.6 | 46.0 |
| | | | (Observed – Simulated)$_{2020}$ | | | |
| $FERT_{1970-75}$ | 3.5 | 7.6 | 0.9 | 2.7 | 5.4 | 7.1 |
| $MIGR_0$ | -1.0 | 0.1 | -1.5 | -0.4 | 0.1 | -0.2 |
| $MORT_{1970-75}$ | 1.9 | 0.1 | 1.7 | 0.1 | 3.8 | 2.8 |
| $STABLE_{1970}$ | -0.5 | -0.1 | -0.8 | -0.2 | -0.1 | -0.2 |
| | | | Stable Population in 1970 | | | |
| 1970 | 37.8 | 24.2 | 39.1 | 37.9 | 38.2 | 36.9 |

Source: our calculation on UNPD data.

The demographic forces that increased the average age also increased the percentage of the population of potential active age (tab. 4), due to both aging from below (a result of the decline in births and the aging of baby boomers) and aging from above (owing to the increase in survival among older people). The different role of each component in the various countries is confirmed. The decline in fertility, and the consequent decrease in the number of young people, was very important in the LDCs, as well as in Italy. This was also true, to a slightly lesser extent, in the other rich countries, with the exception of the US. The increase in survival affected all countries, in particular Japan and Italy. Migrations and the initial age structure, in contrast, had little impact, apart from the US where a young starting age still exerted a pull on the working-age population, as we have seen for mean age. Interestingly, in Japan, changes in fertility and especially mortality determined the turning point in the trend in the proportion of potential workers (see also fig. 2).

Tab. 4 *The effect of fertility, migration, mortality during 1970-2020 and of population structure in 1970 on the proportion of population of age 20-69 (%) in 2020. MDC, LDC, US, Russia, Japan, and Italy*

| | MDC | LDC | US | Russia | Japan | Italy |
|---|---|---|---|---|---|---|
| | | | Observed Population | | | |
| 1970 | 59.4 | 45.6 | 56.2 | 59.9 | 62.9 | 61.1 |
| 2020 | 64.7 | 60.1 | 64.0 | 67.1 | 61.3 | 64.8 |
| 2020-1970 | 5.3 | 14.5 | 7.8 | 7.1 | -1.7 | 3.7 |
| | | | Simulated Population in 2020 | | | |
| $FERT_{1970-75}$ | 61.0 | 45.0 | 63.0 | 63.5 | 57.6 | 59.3 |
| $MIGR_0$ | 64.2 | 60.0 | 63.3 | 66.6 | 61.3 | 63.8 |
| $MORT_{1970-75}$ | 67.3 | 62.6 | 65.7 | 68.2 | 66.7 | 69.0 |
| $STABLE_{1970}$ | 63.5 | 59.7 | 61.9 | 66.0 | 62.2 | 64.3 |
| | | | (Observed – Simulated)$_{2020}$ | | | |
| $FERT_{1970-75}$ | 3.7 | 15.1 | 1.0 | 3.6 | 3.7 | 5.5 |
| $MIGR_0$ | 0.4 | 0.0 | 0.6 | 0.4 | 0.0 | 1.0 |
| $MORT_{1970-75}$ | -2.7 | -2.5 | -1.7 | -1.2 | -5.4 | -4.2 |
| $STABLE_{1970}$ | 1.2 | 0.3 | 2.1 | 1.1 | -0.9 | 0.5 |

Source: our calculation on UNPD data.

## 5. Conclusions

This article aims to measure the weight of fertility, mortality, migration, and the initial age structure in determining the evolution of total population and its age structure in the period of 1970 to 2020. Despite below-replacement fertility during this time, the population of the MDCs increased, primarily due to a relatively young starting age structure (largely generated by the post-WWII baby boom). According to our simulations, this initial young age structure nearly neutralized the depressive effect of the subsequent 50 years of low fertility on total population. The contribution of immigration was also significant. The role of augmented survival in the rise in population was, in contrast, less relevant, though it did strongly increase the number of old people and therefore the average age.

We applied the same methodology to four MDCs characterized by different demographic dynamics and 1970 population age structures (the US, Russia, Japan, and Italy), observing the effects of the four components considered. While there are similarities among these countries, they differ in important ways. Their distinct initial age structures differently impacted total population between 1970 and 2020, while everywhere the importance of the starting structures in influencing the evolution of ageing obviously slowly diminished. The "natural" demography, relatively similar in the four countries in 1970, followed diverse paths in the subsequent decades, generating very different populations both in terms of growth/decrease trends and age structure.

These observations naturally raise the question of future population dynamics in the MDCs. Certainly, the next 50 years will be much different, demographically speaking, from the preceding decades. The 2020 age structure is much less favorable to births than that of 1970, and thus will not (or minimally) contribute to pushing up total population, no longer being able to counterbalance below-replacement fertility. Furthermore, the high survival of the elderly together with the entry of baby boomers into the third and fourth ages will lead to a sharp increase in the number of old people.

A dramatic decline in the proportion of the working-age population in the coming decades can therefore only be avoided by strong immigration flows and robust increases in fertility. This will be especially true for countries such as Italy and Japan, where fertility has been very low and survival has considerably increased in recent decades. Where fertility has been more sustained and mortality higher, as in US, the working-age proportion of the population may remain high even with lower migratory balances.

The main objective of this article was empirical: to show how the different components of the demographic dynamic acted, in the MDCs, to model the age structure and to determine the amount of the population after the end of demographic transition. The results obtained, however, also suggest some theoretical considerations, which can help future demographic research. The demographic transition was (and still is in the LDCs) a substantially unitary and homeostatic process: with few exceptions, the decline in the birth rate follows – sooner or later – that of mortality, capping the "population bomb" (Lam 2011). This unity means that, when the transition process has started, demographic forecasts are relatively easy. But – as illustrated in these pages – when the transition ends, unity is lost, each country seems to follow its own path, and no clear homeostatic processes can be glimpsed (Buettner 2020, 13): for example, migratory balances do not necessarily compensate for low fertility: they are strong in USA (where fertility is close to the replacement level) and Italy (where fertility is very low), almost nil in Japan, where fertility is also very low. Consequently, demographic forecasts are also much more difficult, because they should consider the specificities of each country (Castiglioni, Dalla Zuanna, Tanturri 2021).

This does not mean that – even after the transition – demographic processes strongly characterized by homeostasis cannot occur, and that groups of countries cannot follow similar paths (Billari, Dalla Zuanna 2013; Castiglioni, Dalla Zuanna, Tanturri 2021). For example, as hypothesized by Eurostat in its recent demographic projections, it is possible that in the coming years the decline in the working-age population in Europe will act as an irresistible pooling factor, attracting young people from developing countries (Eurostat 2023). Or, since a positive statistical relationship between women's work and fertility (Comolli 2021; Alderotti 2022) is stabilizing in the 21st century in the MDCs, it is possible that in the near future fertility will increase, together with the commitment of women to work outside the home.

In short, demography does not end with the end of the demographic transition, and the space for demographic research is very, very large.

[1] As suggested by UNPD (https://population.un.org/wpp/DefinitionOfRegions/), the designation of "more developed" and "less developed" regions is intended for statistical purposes and does not express a judgment about the stage in the development process reached by a particular country or area.

[2] By the time we completed the calculations for this article, the 2022 revision of the United Nations Population Prospects had not yet been published. However, since we do not use forecasts, but only the values calculated and estimated for the past, the data used here are practically identical to those of the last revision of 2022.

[3] The cohort-component method is used almost exclusively for demographic projections. However, there are interesting examples of a use similar to ours, in which, starting from the population by age in year t, the population is "projected" up to year t+k by varying, age by age, one or more components of the demographic dynamics. The resulting population takes on the function of counterfactual, and is compared with the actual population of the year t+k. For example, Heuveline (1997) projects the world population from 1950 onward with constant fertility and mortality rates at the 1950 levels. By difference with actual population, this simulation illuminates the contributions of fertility and mortality declines to populations of the second part of 20th century.

[4] As is well known (United Nations 1968), by applying two laws of fertility by age $f_x$ and mortality by age $s_x$ to any age structure, and assuming zero migrations, after about a hundred years the age structure of the resulting population no longer depends on the initial age structure, but exclusively by these two laws $f_x$ and $s_x$.

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## Summary

*Explaining Population Increases in the More Developed Countries in 1970-2020 despite Persistent Under-Replacement Fertility*

Between 1970-2020, the population of the More Developed Countries (MDCs) rose from 1.008 to 1.273 billion, despite 50 years of below replacement fertility (TFR=1.75). In this same period, mean age grew from 34.0 to 41.2 years. For the MDCs and the US, Russia, Japan and Italy, we measure the weight of mortality, fertility, and migration in 1970-2020, and of the age structure in 1970 in determining population size and structure in 2020. Using the cohort-component method and data from the UN Population Division, we compare population in 2020 with populations simulated under four assumptions *ceteris paribus*: fertility of 1970, mortality of 1970, zero migration, and population by age of the stable population with fertility and mortality of 1970. The young age structure of 1970 neutralized the depressive effect of 50 years of low fertility on total population. The contribution of immigration was also significant. Less relevant was augmented survival, which pushed up average age. Differences prevail on similarities between the four countries. If fertility does not increase and/or migratory balances do not become strongly positive, in the coming decades the age structure of the MDCs will no longer curb decline in the portion of the population aged 20-69, as occurred in 1970-2020. The demographic window opened by the baby boom has closed.

## Riassunto

*Come spiegare la crescita della popolazione nei paesi sviluppati tra il 1970 e il 2020 nonostante la fecondità ininterrottamente sotto il livello di rimpiazzo?*

Tra il 1970 e il 2020 la popolazione dei paesi sviluppati è cresciuta da 1,008 a 1,273 miliardi, nonostante cinquant'anni di fecondità sotto il livello di rimpiazzo (TFT=1,75). Nello stesso periodo l'età media è cresciuta da 34,0 a 41,2 anni. In questo lavoro valutiamo il ruolo di mortalità, fecondità e migrazioni tra il 1970 e il 2020 e della struttura per età nel 1970 nel determinare l'ammontare e la struttura della popolazione nel 2020 per l'insieme dei paesi sviluppati e per Stati Uniti, Russia, Giappone e Italia. Utilizzando il metodo per coorti e componenti e i dati della *Population Division* delle Nazioni Unite, confrontiamo la popolazione osservata nel 2020 con la popolazione simulata alla stessa data in base a quattro differenti ipotesi *ceteris paribus*: fecondità costante come nel 1970, mortalità costante come nel 1970, zero migrazioni, struttura per età iniziale uguale a quella della popolazione stabile associata a fecondità e mortalità del 1970. Le nostre analisi mostrano come la giovane struttura per età del 1970 ha neutralizzato l'effetto depressivo di cinquant'anni di bassa fecondità sull'ammontare della popolazione. Il contributo delle migrazioni è stato anch'esso significativo, mentre quello della mortalità è stato meno rilevante, anche se ha contribuito a spingere verso l'alto l'età media. Tra i quattro paesi esaminati le differenze prevalgono sulle somiglianze. Se la fecondità non aumenterà e/o il saldo migratorio non diventerà fortemente positivo, nei prossimi decenni la struttura per età dei paesi sviluppati non sarà più sufficiente ad arrestare il declino della popolazione in età lavorativa, come avvenuto tra 1970 e 2020. In conclusione, la finestra demografica aperta dal *baby boom* si è ormai definitivamente chiusa.

*Parole chiave*
Transizione demografica; Previsioni di popolazione; Popolazione stabile; Paesi sviluppati.

*Keywords*
Demographic transition; Population forecasts; Stable population; More developed countries.