Decomposition of Replacement Ratio of Italian Generations at Differing Ages

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1.Introduction. Italian women have continuously decreased over fertility time, so that those born since the early 20th century have not reached sufficient levels to ensure replacements at birth. Table 1 lists some values for the usual indicators: total fertility rate TFR, gross reproduction rate R_t and net reproduction rate $R_{0,t}$ for the generations of Italian women born between 1860 and 1974, constructed with information available in the literature[1]. From 3.2 children per woman in the generations born at the beginning of the 20th century, the average number of children has gradually fallen to 1.4 among the 1970-74 generation – an average reduction of almost 2 children per woman over a period of 70 years. Net reproduction rate $R_{0,t}$ is lower than one for all generations born during the 20th century, falling to 0.68 for the 1970-74 generation. $R_{0,t}$ is known to measure generation replacement at birth, and also takes into account mortality:

$$R_{0,t} = \Sigma_x L_{x,t} f_{x,t} \quad (1)$$

where $L_{x,t}$ and $f_{x,t}$ represent person years lived in a female life table (with a unit radix) and the average daughter-only fertility rate for the cohort born in year t. The sum over age x is within the reproductive life-span, or between the ages of 15 and 49. The temporal decrease in mortality is clearly not sufficient to make up for the drop in fertility among generations and thus ensure replacement. The same indicator, calculated from the 1930s onwards, provides an entirely different picture of replacement of hypothetical generations: from 1930 to 1974, the indicator had a value greater than one – i.e., a sufficient level to ensure replacement – and only in 1975 did the value fall below one[2]. Thus, period indicators give a distorted image of generation replacement.

In a previous article published in this journal (Bonarini 2013), the replacement of Italian generations at various ages *x* was analyzed, also taking natural and migratory movements into account. The 20th-century generations born before the Second World War reached replacement level at later ages, whereas those born after the war remained below the replacement level, even at later ages. It should be noted here that I used a measure, replacement ratio RS, according to a comparison of the dimensions of two generations, daughters and mothers, both considered in their actual size at any given age x, due to mortality and migration patterns. The generation of mothers born in year t was linked with that of their daughters, identified as the generation born at a distance from the former equal to the average interval

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Tab. 1. *Fertility and reproductive measures at birth among cohorts of women born in year t and period measures in the corresponding years t+30*

Measures among the cohorts born in year t								Period measures in year t+30		
Birth years t	Total fertility rate TFR	Gross reproduction rate R	Net reproduction rate R_0	Replacement rate at birth: RS_0 = B t+30 / B t		Ratio (c)/(d)	Ratio (d)/(e)	Reference year t+30	Gross reproduction rate R*	Net reproduction rate R^*_0
				actual births	estimated births					
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(l)
1860-64	5.11[1]	2.48	1.29	1.13		1.14				
1865-69	5.04	2.44	1.21	1.11		1.09				
1870-74	4.92	2.39	1.22	1.07		1.14				
1875-79	4.68	2.27	1.20	1.04		1.15				
1880-84	4.39	2.13	1.18	1.06		1.12				
1885-89	4.00[2]	1.94	1.10	0.73		1.50				
1890-94	3.63[3]	1.76	1.03	1.01		1.01				
1895-99	3.34	1.62	1.00	0.96		1.04				
1900-04	3.20	1.55	0.98	0.92	0.93	1.06	0.99	1930-34	1.54	1.19
1905-09	2.99	1.45	0.97	0.89	0.92	1.08	0.96	1935-39	1.50	1.19
1910-14	2.77	1.34	0.94	0.80	0.83	1.18	0.96	1940-44	1.35	1.06
1915-19	2.60	1.26	0.85	1.14	1.19	0.75	0.96	1945-49	1.42	1.22
1920-24	2.38[4]	1.15	0.88	0.76	0.79	1.16	0.96	1950-54	1.17	1.06
1925-29	2.33	1.13	0.89	0.83	0.86	1.08	0.96	1955-59	1.13	1.05
1930-34	2.32	1.12	0.97	0.95	0.99	1.02	0.95	1960-64	1.19	1.12
1935-39	2.26	1.10	0.99	0.97	1.02	1.02	0.96	1965-69	1.23	1.17
1940-44	2.14	1.04	0.96	0.98	1.03	0.99	0.95	1970-74	1.14	1.10
1945-49	2.01	0.97	0.92	0.79	0.82	1.16	0.96	1975-79	0.96	0.93
1950-54	1.86	0.90	0.86	0.71	0.73	1.21	0.97	1980-84	0.77	0.76
1955-59	1.77	0.86	0.83	0.64	0.65	1.28	0.99	1985-89	0.66	0.65
1960-64	1.60	0.78	0.76	0.58	0.58	1.30	1.01	1990-94	0.64	0.63
1965-69	1.52[5]	0.74	0.72	0.55	0.54	1.33	1.02	1995-99	0.59	0.58
1970-74	1.43	0.69	0.68	0.61	0.57	1.12	1.06	2000-04	0.62	0.61
1975-79				0.74	0.66		1.12			
1980-84				0.89	0.74		1.19			
1985-89				0.93	0.75		1.24			

Note: TFR values were: [1] obtained from the 1931 fertility survey and reported on ever married women. The cohorts were born respectively in the years 1861-65; 1866-70; 1871-75; 1876-80; 1881-85. [2] Estimated as half the sum in the neighbouring years. [3] From Santini (1974). [4] From ISTAT. [5] The age fertility rates from 2009 on are estimated.
The ratios in column e refer to births estimated in the population in the absence of migrations.

between generations, assumed here to be 30 years, or roughly equal to average age at childbirth[3]. The generation of mothers born in year t was thus considered in relation to that of 'daughters' born in year t+30, and the total of the two generations at

age x was compared according to the following ratio:

$$RS_{x,\,t} = (W_{x,\,t+30+x}) \,/\, (W_{x,\,t+x}) \qquad (2)$$

where $RS_{x,t}$ indicates the replacement ratio at age x of the generation born in year t and $W_{x,t+x}$ women at age x in year t+x. This ratio depends on the differing initial size of the two generations compared, and the intensity of mortality and migrations undergone by each generation from birth to the age in question. The overall measure can be decomposed into factors expressing the influence of their various components, in order to highlight their importance at various ages and in subsequent generations.

The above comparison can also be carried out at birth, according to the ratio between the number of annual daughter-only births (B_t) distanced by 30 years:

$$RS_{0,\,t} = B_{t+30} \,/\, B_t \qquad (3)$$

similar to the cohort net reproduction rate, as the two generations compared are understood as those of daughters and mothers. Since this measure is easier to obtain than net reproductive rate $R_{0,t}$, it can be helpful in showing the formal relations which exist between the indicators, in what conditions the two measures take the same value, and still show when $RS_{0,t}$ can be used as an estimate of $R_{0,t}$ with sufficient approximation.

Decomposition of $RS_{x,t}$ and relations between $RS_{0,t}$ and R_0,$_t$ are the aims of this paper.

Specifically, I considered Italian generations born over the course of the 1900s, and first decomposed replacement ratio $RS_{x,t}$ into its natural and migratory components, and then clarified the characteristics of $RS_{0,t}$ and relations existing between $RS_{0,t}$ and cohort net reproduction rate $R_{0,t}$, both related to the generation born in year t.

2. Decomposition of RS_x ratio. As mentioned above, replacement ratio $RS_{x,t}$ compares, at the same age x, the actual size of two generations 30 years apart, allowing us to follow variations in replacements recorded at different ages. The observed values of $RS_{x,t}$ are clearly associated with different numbers of births constituting the initial size of the two generations in question and the different intensity of mortality and migrations (both in and out) experienced by each generation from birth to the age considered. Obviously, the numbers of a generation born in year t at age x, reached in year t + x, ($W_{x,\,t+x}$) can be expressed as the product of the number born in year t (B_t) to the probability of surviving until age x and a factor related to the intensity of migration undergone until that age. In addition, the initial size of the generation can be decomposed into the product of a factor related to the numbers of the female population in year t and to its level of fertility in the same year. Here, it is helpful to use the average generation in year t (Gm_t), i.e., the average number of women of age x ($W_{x,t}$) obtained assuming as weights female fertility rates ($f^*_{x,t}$)

observed in year t (Calot 1984). That is:

$$Gm_t = \Sigma_x W_{x,t} f^*_{x,t} / (\Sigma_x f^*_{x,t}) = B_t / R^*_t. \quad (4)$$

In this ratio, as we have seen, B_t are female births in year t, $R^*_t = \Sigma_x f^*_{x,t}$ is the period gross reproduction rate for year t, and $f^*_{x,t}$ is the age fertility rate in the same year. Ratio (4) directly yields the number of births B_t as the product of average generation Gm_t and the gross reproduction rate in the same year: $B_t = Gm_t R^*_t$.

$RS_{x,t}$ can then be decomposed as follows:

$$RS_{x,t} = (W_{x,\,t+30+x}) / (W_{x\,,t+x}) = (B_{t+30} / B_t)\,(l_{x,\,t+30} / l_{x,\,t})\,(m_{x,\,t+30} / m_{x,\,t}) = (Gm_{\,t+30} / Gm_{\,t})\,(R^*_{t+30} / R^*_t)\,(l_{x,\,t+30} / l_{x,\,t})\,(m_{x,\,t+30} / m_{x,t}). \quad (5)$$

Here $l_{x,t}$ indicates survival up to age x ($l_{x,\,t} / l_{0,\,t}$) and $m_{x,t}$ the net intensity of migration until age x of generation t. Decomposition of the size of a generation at age x into factors linked to total births in year t-x and the intensity of mortality and migrations from birth to age x is certainly not new. For instance, a similar approach was employed by Preston, Himes and Eggers (1989) in the decomposition of age-specific growth rates within a population. Our aim here is to analyse the impact of the above factors on the replacement of compared generations. Decomposition emphasises the importance of conditions which determine the total number of births in years t and t+30 – that is, the various age structures of the population of reproductive age and fertility levels in each of these two years – and the influence of the intensity of mortality and migration from birth until age x on both generations. Note that these factors express effects in comparative terms. A value of the ratio between migration coefficients greater than one can mean either less out-migration among the generation of daughters (generation t+30) with respect to that of the mothers (generation t) or a different quantum of immigration for the two generations. In practice, the first three factors above can easily be calculated directly, whereas the fourth, linked to migrations, can be estimated as a residual by replacement ratio $RS_{x,t}$.

Table 2 lists the results of this decomposition applied to Italian generations born between 1900 and 1969, with reference to $RS_{x,t}$ values for three age classes[4]. Several indicators are estimated, as explained in note[5]. In particular, the replacement ratios for the more recent generations were constructed according to the expected cohorts in the medium scenario for the Italian population of by ISTAT (2007). Similar results for generational replacement can be obtained from expected populations in other scenarios[6]. These ratios, computed according to estimates of future populations or intensity of various phenomena are shown in italics in table 2.

Almost all the generations born before the Second World War are replaced by generations of daughters in every age class after birth, whereas generations born later are not replaced at 20-24 years of age until those born from 1945 onwards, and not until after 1950 when all three age classes are taken into account (fig. 1). Note the particularly high replacement ratios of the generations born during the First

Tab. 2. *Decomposition of the replacement ratio $RS_{x,t}$ for selected age groups*

Cohort (t)	$RS_{x,t}$	Gm_{t+30} / Gm_t	R^*_{t+30} / R^*_t	$l_{x,t+30} / l_{x,t}$	$m_{x,t+30} / m_{x,t}$
	age 20-24 years				
1900-04	1.17	1.39	0.67	1.23	1.03
1905-09	1.07	1.37	0.65	1.27	0.94
1910-14	0.94	1.33	0.61	1.26	0.93
1915-19	1.38	1.30	0.67	1.31	1.21
1920-24	0.91	1.29	0.59	1.21	0.99
1925-29	0.98	1.26	0.67	1.20	0.97
1930-34	1.10	1.19	0.78	1.18	1.01
1935-39	1.15	1.14	0.82	1.11	1.10
1940-44	1.16	1.12	0.85	1.07	1.14
1945-49	0.92	1.09	0.67	1.05	1.19
1950-54	0.83	1.08	0.66	1.04	1.11
1955-59	*0.76*	*1.09*	*0.59*	*1.03*	*1.16*
1960-64	*0.68*	*1.12*	*0.53*	*1.03*	*1.10*
1965-69	*0.63*	*1.14*	*0.48*	*1.02*	*1.13*
	age 30-34 years				
1900-04	1.23	1.39	0.67	1.36	0.98
1905-09	1.11	1.37	0.65	1.36	0.90
1910-14	0.95	1.33	0.61	1.32	0.89
1915-19	1.46	1.30	0.67	1.36	1.23
1920-24	0.94	1.29	0.59	1.26	0.99
1925-29	1.02	1.26	0.67	1.22	1.00
1930-34	1.17	1.19	0.78	1.13	1.11
1935-39	1.20	1.14	0.82	1.08	1.18
1940-44	1.27	1.12	0.85	1.06	1.26
1945-49	*1.06*	*1.09*	*0.67*	*1.05*	*1.38*
1950-54	*0.98*	*1.08*	*0.66*	*1.03*	*1.33*
1955-59	*0.87*	*1.09*	*0.59*	*1.03*	*1.32*
1960-64	*0.75*	*1.12*	*0.53*	*1.02*	*1.23*
1965-69	*0.70*	*1.14*	*0.48*	*1.02*	*1.25*
	age 40-44 years				
1900-04	1.23	1.39	0.67	1.47	0.93
1905-09	1.11	1.37	0.65	1.43	0.90
1910-14	0.95	1.33	0.61	1.37	0.90
1915-19	1.46	1.30	0.67	1.39	1.25
1920-24	0.94	1.29	0.59	1.27	1.02
1925-29	1.02	1.26	0.67	1.24	1.02
1930-34	1.22	1.19	0.78	1.09	1.21
1935-39	*1.30*	*1.14*	*0.82*	*1.07*	*1.30*
1940-44	*1.36*	*1.12*	*0.85*	*1.05*	*1.36*
1945-49	*1.12*	*1.09*	*0.67*	*1.04*	*1.47*
1950-54	*1.02*	*1.08*	*0.66*	*1.03*	*1.39*
1955-59	*0.91*	*1.09*	*0.59*	*1.02*	*1.40*
1960-64	*0.77*	*1.12*	*0.53*	*1.02*	*1.27*
1965-69	*0.69*	*1.14*	*0.48*	*1.01*	*1.24*

Note: For the meaning of coefficients see equation (5) and footnote 4 in the text.

Fig. 1. *Replacement ratios of Italian cohorts in the age groups 20-24, 30-34 and 40-44*

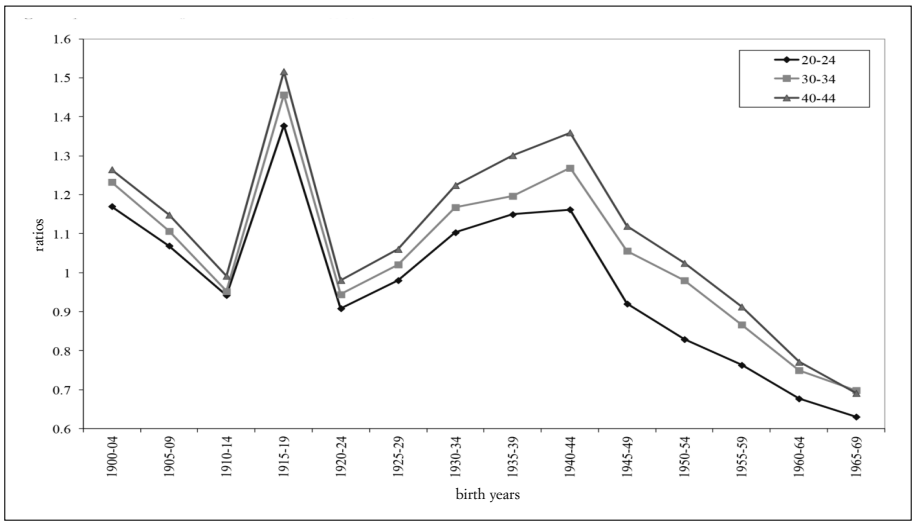
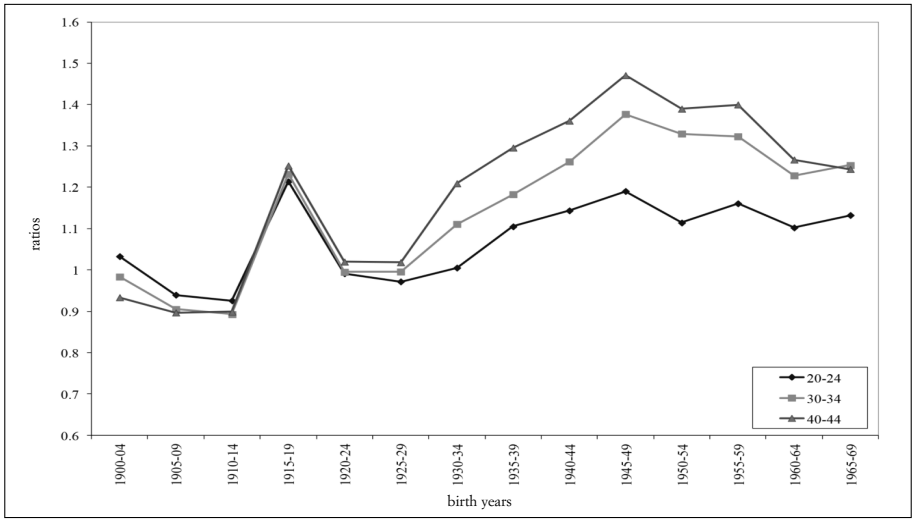


Fig. 2. *Ratio between migration index in the cohorts of daughters and in the cohorts of mothers* ($m_{x,\,t+30}\,/m_{x,\,t}$:) *in the age groups 20-24, 30-34 and 40-44*



World War, the rising ratios for the generations which had higher fertility levels during the *baby boom* and, lastly, the clear-cut decrease in ratio values for successive generations, with lower fertility rates.

The role of fertility change in temporal variations of the replacement ratio is essential, as evidenced by the low values of the respective coefficients and the parallel dynamics of the two indicators: $RS_{x,t}$ and R^*_{t+30} / R^*_t. All the factors of the

Fig. 3. *Ratio between survival index in the cohorts of daughters and in the cohorts of mothers* ($l_{x,\,t+30} / l_{x,\,t}$) *in the age groups 20-24, 30-34 and 40-44*

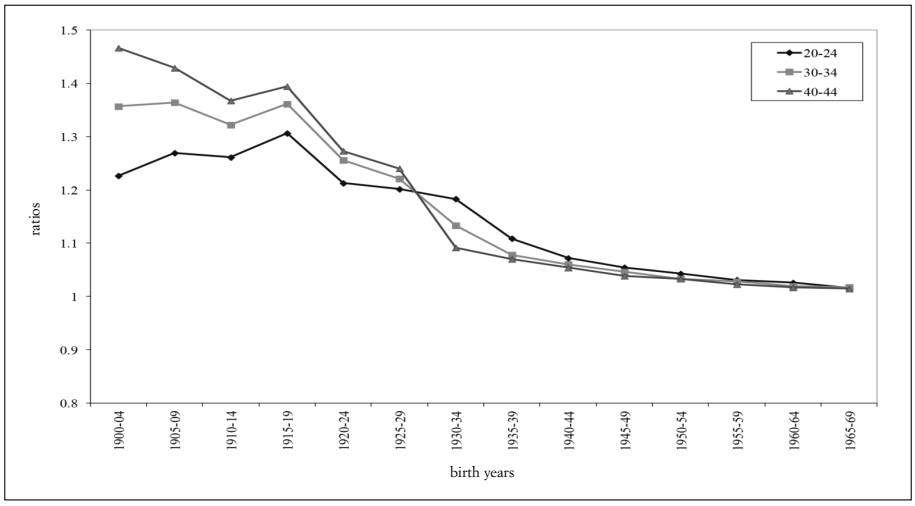
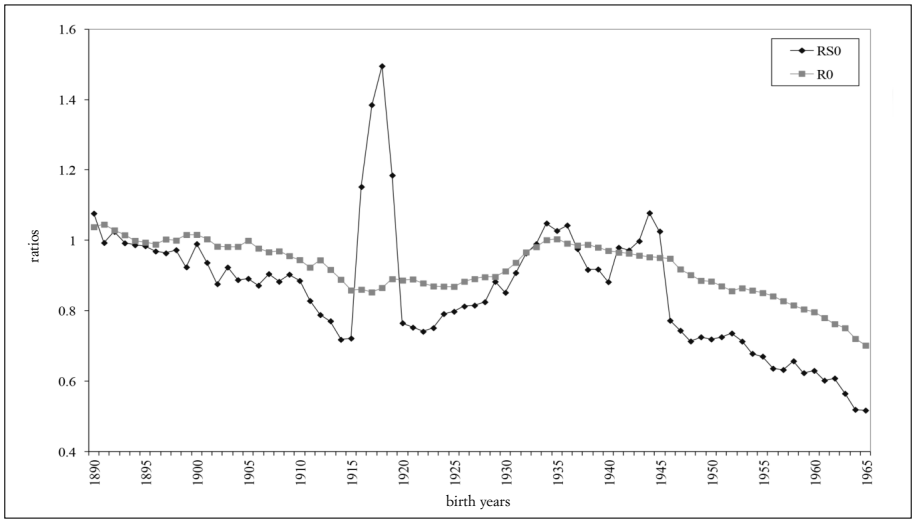


Fig. 4. *Values of* $R_{0,t}$ *(net reproduction rate) and* $RS_{0,t}$ *(replacement ratio at birth) for the cohorts born in the years indicated*



decomposition contribute to the recent decrease in the replacement ratio. The only exception is the factor linked to migrations, which is working in the opposite and positive direction, although it is insufficient to neutralize the negative impact of the other factors.

For the most part, migrations have had a positive effect on the generations examined here, with a coefficient greater than or close to one and, among the more

recent generations, even higher, especially in the older age classes (fig. 2). Instead, the contribution of the decrease in mortality, essential in the replacement of older generations, has constantly declining values until it becomes almost insignificant among the youngest generations, with coefficients near one (fig. 3). Also quite evident is the decrease in the importance of the effect of population structure and the average size of cohorts of reproductive age, which resemble mortality except for the fact that we observe that coefficients increase with respect to the most recent generations, reflecting moderately rising values due to a slight recovery of fertility and foreign immigration. A measure of the weight of each factor on the $RS_{x,t}$ replacement ratio can be seen in the absolute values of the logarithms of the respective coefficients and the relative percent distributions. Focusing on more recent generations, fertility is observed to have a relative weight – on the sum of the coefficients – exceeding 60%, but it may even reach 70% in several cases. Migrations play an increasing role with age, slightly more than 10% in the 20-24 age class of recent cohorts, but as high as 30% in the older age classes, among cohorts born in the period immediately after the Second World War. The structural component has a more modest weight of around 12% and mortality of less than 2%.

3. Generation replacement at birth. As already mentioned, the replacement ratio at birth of generation t is given by comparing the number of births in years t and t + 30, i.e., $RS_{0,t} = B_{t+30}/B_t$. The values for this indicator are listed in table 1, column d, and were obtained from the ratio between the number of births during calendar years t+30 - t+34 and births during years t - t+4. Figure 4 also shows the values of the same indicator, calculated with reference to births in each calendar year, compared with those over a distance of 30 years.

The temporal dynamic of $RS_{0,t}$ mirrors the trend already highlighted by $R_{0,t}$, although several peculiarities reflect conditions linked to WW1 and the baby boom of the 1960s. WW2 had less obvious repercussions on this temporal dynamic. The $RS_{0,t}$ ratio is greater than one – and thus expresses the attainment of replacement at birth – among the generations born between 1862 and 1883. This ratio then falls to values lower than one, and these levels were maintained until very recently, except those relating to the generations born during the years of war. The decrease in births due to WW1 is echoed in the replacement ratio of the generations born around the year 1889. These are more numerous, compared with the relatively smaller groups born around 1919, and do not achieve replacement levels at birth. Instead, the generations born during WW1, due to their scarcity, are abundantly replaced by those born after WW2, i.e., around 1948. As a consequence, we observe a relatively high $RS_{0,t}$ value, near 1.6. Similarly, the value of $RS_{0,t}$, greater than one, is observed for the generations born between 1934 and 1936, which are compared with the more numerous generations born between 1964 and 1966. A similar pattern emerges for the less numerous generations born in 1944-45 compared with those of 1974-75. As mentioned above, the decline in $RS_{0,t}$ persists until the 1965-69 generation, associated with the next generation of births, when fertility fell to an historic low (1995). This dynamic is then reversed, with rising values of

Tab. 3. *Decomposition of the ratio $R_{0,t}$ / $RS_{0,t}$*

Years	Gm_t / Gm_{t+30}	R^*_t	$l_{30,t}$	R_t / R^*_{t+30}	$R_{0,t} / RS_{0,t}$
t	(a)	(b)	(c)	(d)	(e)
1930	0.81	1.70	0.81	0.96	1.07
1935	0.87	1.50	0.89	0.85	0.98
1940	0.88	1.54	0.93	0.89	1.10
1945	0.91	1.19	0.94	0.95	0.93
1950	0.93	1.26	0.95	1.14	1.23
1955	0.93	1.13	0.96	1.26	1.27
1960	0.91	1.17	0.97	1.25	1.26
1965	0.87	1.29	0.98	1.24	1.36

Note: Gm_t indicates the mean generation in year t , R^*_t the gross reproduction rate in year t and R_t the gross reproduction rate for the cohort born in year t.

$RS_{0,t}$ until the most recent generations, due to the recovery of births over the last few years. The ratio for the 1985-89 generation was calculated according to births forecast by ISTAT. In sum, this indicator shows that the generations born during the 20th century did not replace themselves at birth, apart from a few exceptions. The $RS_{0,t}$ values provide roughly the same information as that obtained with $R_{0,t}$ but with a more extensive temporal framework.

Comparison of the two indicators shows that $R_{0,t}$ is usually greater than $RS_{0,t}$ – except among the generations affected by WW1 and those born in the baby boom years – particularly for those born after 1945. We can analyse the difference between the two indicators and generally see in what conditions the two indicators have the same value.

For this purpose it is useful to develop the ratio $R_{0,t}$ / $RS_{0,t}$ as follows, taking into account that equation (4) gives $B_t = Gm_t R^*_t$.

$$R_{0,t} / RS_{0,t} = R_{0,t} (B_t / B_{t+30}) = R_{0,t} ((Gm_t R^*_t) / (Gm_{t+30} R^*_{t+30})) \approx$$
$$R_t l_{30,t} (Gm_t / Gm_{t+30}) (R^*_t / R^*_{t+30}) = (Gm_t / Gm_{t+30}) R^*_t l_{30,t} (R_t / R^*_{t+30}). \quad (6)$$

$R_{0,t}$ and R_t indicate the net and gross reproduction rates of the generation born in year t, $l_{30,t}$ expresses survival of the same generation to age 30, and R^*_t indicates the period gross reproduction rate for year t[7].

The ratio between $R_{0,t}$ and $RS_{0,t}$ for generation t is decomposed as the product of four factors. The first (Gm_t/Gm_{t+30}) is related to the different age structure of the female population of childbearing age in the year of birth of the two cohorts. When this population grows over time, the factor assumes values of less than one. Instead, when such a population is not growing, the factor assumes values equal to or greater than one. Table 3 shows that, for Italian generations, this factor is consistently lower than one and grows in time, so that for the 1980 generation (not shown in table 3) it is 0.99.

The second factor, R^*_t, expresses the level of fertility in year t. It is known that

Italian fertility was higher in the past, with R^*_t greater than one, and that it then decreased to R^*_t equal to 0.65 in 1995.

The third factor expresses the level of survival from birth to average age at childbirth of generation t. Over time, mortality decreases and approaches one for younger generations.

The fourth factor (R_t / R^*_{t+30}) compares the fertility of the generation born in year *t* with that observed in year t + 30. If there were no temporal variations in average age at childbirth among the generations and if a linear dynamic of R_t is assumed, then factor (R_t / R^*_{t+30}) would be one (Ryder 1964). When average cohort age at childbirth decreases, i.e., when the fertility age profile is rejuvenated, this ratio is less than one. Instead, when average age at childbirth increases – or fertility ages – the ratio is greater than one. We can describe this effect as cohort variations in average age at childbirth, or factor d. Table 3 shows that, from the 1950 generation onwards, this factor is greater than one and is almost stable.

The combination of these factors determines the value of the ratio between the indicators. In the generations born after 1945, this ratio is high and therefore the value of $R_{0,t}$ is appreciably higher than $RS_{0,t}$. The difference is attributable to the fertility level in the year of birth of generations of mothers (born in year t) and to an increase in average age at childbirth in generations.

As in the latest generations, the first and third factors are both close to one; as discussed above, in order to reach equality between the indicators for generation t, it is sufficient to assume a value of $R^*_t = 1$ and constancy of average age at childbirth over generations.

The estimate of $R_{0,t}$ for the most recent generations according to the values of $RS_{0,t}$ is easily obtainable, as we know the fertility of recent years (R^*_t) and can set the value on factor d, as the factors related to age structure and survival are almost equal to one. For example, at present, we do not know R_0 for 1975 and 1980 generations, but we do know $RS_{0,t}$. Factor d may be assumed to be constant and equal to the last value listed in table 3. We thus obtain values of $R_{0,1975} = 0.80$ and $R_{0,1980} = 0.87$, starting from $RS_{0,1975} = 0.66$ and $RS_{0,1980} = 0.87$. The value of $R_{0,1980}$ is given by the product of the factor linked to population structure, 0.99, $R^*_t = 0.82$ and d = 1.24.

The replacement ratio at birth, $RS_{0,t}$, can also be used to estimate the effects of migration on the replacement of Italian generations. The decomposition made in the previous section, $RS_{x,t}$ allows us to assess the impact of migration from birth onwards, but migrations also include an indirect effect, due to changes in the population, with repercussions on the number of births in the various years. Births B_t and B_{t+30} in ratio $RS_{0,t}$ are those recorded each year for the resident population and thus drawn from the resulting population net of mortality and migratory movements. We can evaluate the effect of migratory movements on the number of births each year – and thus on the replacement ratio value – by comparing the number of births with those which would have occurred in the population without migrations over a given time period or, in this case, over the whole of the 20th century. For this purpose, the Italian population, distinguished by sex and age at the beginning of each year from 1900 onwards, was reconstructed, beginning with the generations

born during the second half of the 19th century and projected with survivals taken from the respective life tables. This population was used to estimate births according to fertility rates by age for each year.

The actual number of births is lower than that estimated for all the years of the 20th century, with a ratio of 89% at the beginning of the century, decreasing to 82% in the decade 1975-84 and then foreseen to rise to over 102% in 2015-19[8]. Replacement ratios $RS_{0,t}$, calculated with estimated births (column e of table 1) reflect the dynamic described by the ratios calculated with actual births. However, until the generation born in 1960-64, the ratios obtained with estimated births take on values higher than those calculated from actual births and the opposite for cohorts born after 1964 (column g in table 1). Thus, past out-migrations reduced the replacement ratio at birth until the generation of 1960-64. Among successive generations, the effects of two convergent forces combine. On one hand, in the actual population, migratory flows changed direction and in-migration became more prevalent. On the other hand, in the reconstructed population, the temporal reduction in fertility caused a decrease in the number of births. Consequently, the replacement ratios calculated in the two populations have an inverse relationship with that observed among the previous generations.

In any case, replacement ratios calculated for the closed population are also less than one, with the exception of those for generations born during the years of the two World Wars. Thus, the non-replacement of generations at birth in the actual population is only partially attributable to the indirect effects of migrations, and is essentially due to the effects of natural components.

4. Conclusions. Generation replacement is analysed here by linking the generations of mothers with those of their daughters, identified as the generation born at a distance equal to the average interval between the generations. Empirically speaking, we analyse the replacement of generations distanced by 30 years.

The measure used, $RS_{x,t}$ (replacement ratio at age x of the generation born in year t) was constructed with reference to birth ($RS_{0,t}$) with the ratio between the number of births in year t+30 and year t and, in general, with reference to age x, with the ratio between the size of the two generations observed at the same age x in years t+30+x and t+x. This measure was relatively easy to calculate with information normally available and, unlike other similar measures recently proposed, was constructed taking into account both generations compared at the same age, at a distance of 30 years from one another. This procedure allowed an assessment of generational replacement in particular age ranges.

The $RS_{x,t}$ ratio can easily be decomposed into factors linked to various components identified in the population structure and fertility levels in the years of birth (t and t+30) of the compared generations and levels of mortality and migration undergone by the two generations until age x. Decomposition thus allows us to measure the effect of migrations on generational replacement, obtained as a residual effect, even in situations in which reliable direct data are not available. With regard to births, the $RS_{0,t}$ ratio essentially mirrors the temporal dynamic of cohort

net reproduction rate $R_{0,t}$ in the time periods which were not particularly perturbed. Comparison of the two indicators with reference to the Italian generations shows that $R_{0,t}$ is usually greater than $RS_{0,t}$. Examination of the relations between the indicators for the most recent generations shows that the main factors determining the difference between the indicators are the level of fertility in year t, or the period reproduction rate (R^*_t) in the year of birth of cohort t (that of the mothers), and variations in average age at childbirth among generations. If $R^*_t = 1$ and average age at childbirth among the generations is constant, the two indicators are nearly equal.

Italian generations born in the 20th century have an R_0 value lower than one. However, those born before WW2 recovered replacement levels at successive ages, benefiting from improvements in survival and the differential effect of migrations. The generations born after that war did not recover these levels, at least for the young ages considered here. Decomposition of replacement ratios at various ages (RS_x) highlights the essential importance of migrations in the replacement ratios at various ages. These last factors have a particularly significant impact at older ages and reach a weight near and sometimes greater than that relative to fertility. The age classes considered here are essentially exemplary in meaning, although replacement ratios could certainly be calculated with reference to other ages, e.g., that around retirement. The replacement ratios at 60-64 years of age for the 1915-19 generation are 1.65 and for the 1945-49 generation 1.15. This means that, in 2010, women in this age class were 65% more numerous that those recorded in 1980, and in 2040 they will be 15% more numerous than those recorded in 2010. If we consider less unique generations, such as those born in 1920-24 and 1950-54, replacement ratios at the same age are lower, 1.07 and 1.04 respectively, but they move in a similar direction to those above.

[1] For Italy, total fertility rates can be calculated beginning with the generations of the mid-1800s onwards. More specifically, for generations born between 1851-56 and 1881-85, data are available from the 1931 fertility survey (ISTAT 1936), reprocessed and applied to cohorts of women, including those who did not marry, by Festy (1979). For generations born between 1890 and 1941, data from Florentine demographers are available, integrated and reported by Santini (1974) and carried out with data on civil status available from 1930 onwards. Lastly, for generations born after 1920, ISTAT data are available (1997, 1998, 2000).

[2] Period indicators are marked with an asterisk from now on, in order to distinguish them from those concerning generations.

[3] I verified that, considering alternatively generations born at a distance of either 30 years or a smaller number of years up to 27 years, replacement ratios at birth were almost identical. A more accurate choice of this distance, as changes in the mother's average age at birth would be irrelevant (Bonarini 2013).

[4] For easier reading, in table 3 the subscripts reported in the single coefficients refer to the initial calendar year t or the initial year of age *x* in the generations (five-year groupings) born in years t - t+4 and of age x - x+4. $RS_{x,t}$ (as shown in the table) thus refers to the replacement ratio of generations born in the years t-t+4 and of age x-x+4 at the end of years t+4+x, compared with generations born in years t+30 – t+34 and of the same age x –x+4 at the end of year t+34+x. Gm_t and R^*_t are average values referring to years t-t+4. Similarly, $l_{x,t}$ and $m_{x,t}$ are average values of survival and the net effect of migrations until age x for generations born in years t - t+4.

[5] For the years prior to 1930, the total fertility rate (TFR*) and thus the gross reproduction rate (R*) were estimated according to the ratio ($B_t / W_{15\text{-}49}$) x 35. For the years prior to 1930, average genera-

tion Gm_t was estimated according to age-specific fertility rates from 1930. Survival for the years until 2007 was extrapolated. The survival coefficient used – $l_{x,t}$ – refers to the generation born in the median year of each five-year grouping.

[6] I verified that the replacement ratios for the various ages did not change significantly when ISTAT's population projections, particularly the medium and high scenarios, were applied.

[7] It is assumed the equation $R_{0,t} = l_{\mu,t} \Sigma_x f_{x,t} = l_{\mu,t} R_t$. This is valid if there is a linear variation of l_x between ages 15 and 50, where μ is the average age at childbirth. In addition, μ is assumed to be 30 years.

[8] Obviously, comparisons made in the last few years according to number of births estimated by ISTAT also includes migration.

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Riassunto

Una scomposizione del rapporto di sostituzione delle generazioni italiane alle varie età

Questo articolo considera la sostituzione delle generazioni alla nascita ed alle età successive, tenendo conto delle componenti naturali e dei movimenti migratori. La generazione nata in un anno t (generazione delle madri) è confrontata con la generazione nata nell'anno t+30 (generazione delle figlie). Si costruisce un rapporto tra l'ammontare effettivo delle due generazioni a confronto considerate alla nascita (rapporto analogo al tasso netto di riproduzione) ed in generale ad ogni età x. Tale rapporto può essere facilmente scomposto nel prodotto di fattori legati alle diverse componenti che lo determinano: la dimensione iniziale delle generazioni, dovuta alla struttura per età della popolazione ed alla fecondità nell'anno di nascita, il livello di mortalità e le migrazioni sperimentate da ciascuna generazione fino all'età x. I risultati conseguiti riguardano le generazioni italiane nate nel ventesimo secolo.

Summary

Decomposition of replacement ratio of Italian generations at differing ages

This article considers generation replacement at birth and at successive ages, taking into account both natural and migratory movements. The generation born in year t (generation of mothers) is compared with the generation born in year t+30 (generation of daughters). We consider the actual size at any given age x for each of these generations. A measure is constructed with reference to birth, and, in general, with reference to age x. The relation with the net reproduction rate is explored. The measure can easily be decomposed into factors linked to the different components: population structure and fertility level in the years of birth of the compared generations and level of mortality and migration experienced by the two generations. We consider Italian generations born over the course of the 1900s, each of which recorded a net reproduction rate of less than one. The results allow for an evaluation of the impact of migrations and mortality on the replacement of Italian generations at various ages.

Parole chiave
Sostituzione delle generazioni; Scomposizione del rapporto di sostituzione; Impatto delle migrazioni; Impatto della mortalità; Stima del tasso netto di riproduzione.

Keywords
Generation replacement; Decomposition of generations replacement; Effect of migrations on generation replacement; Estimation of net reproduction rate.