PLEASE DO NOT QUOTE WITHOUT PERMISSION OF THE AUTHORS

SELECTION EFFECTS ON REGIONAL SURVIVAL DIFFERENCES IN ITALY

Elisabetta Barbi and Graziella Caselli

Department of Demography – University of Rome "La Sapienza"

May, 2002

1. Introduction

The transition from the XVIII to the XIX century was a period of great upheaval and change in Italy and the impact on mortality was equally tumultuous. One aspect of the shifting panorama was the role played by geographical differences, alongside the drop in mortality and the ever-widening gap between the North, penalised by high mortality at adult ages, and the South with high infant and adolescent mortality. While immediately following the Unification of Italy (1870) and, indeed throughout the 1800's, pockets of high infant mortality were found throughout the country (Caselli, 1987), and infectious diseases caused a growing number of deaths, with the dawning of the new century mortality for these ages and causes became increasingly a prerogative of the South. This pattern was to continue during subsequent phases of mortality. Meanwhile, in the North, cancers and ischaemic heart diseases – that appear to be particularly influenced by specific risk factors (linked to occupation and life style) (Caselli and Egidi, 1981; Caselli et al., 1993) - impeded any important gains being made in adult and elderly mortality, particularly among the more economically active.

With the completion of the transition process and the decline in early mortality, geographical differences were transformed into more or less their present form (figure 1). In the 1990's an average 3 years' life expectancy at birth separated men in the North from those in the South and Centre. For women the situation changes somewhat, with similar life expectancy levels at birth in the North and certain southern regions, and higher survival levels in the Centre.

As far back as the early decades of the XX century adult and elderly male mortality in the South was on average lower than northern and especially Alpine regions. The geographical features of elderly female mortality were quite different, with some southern regions highly penalised. Geographical discontinuities have reduced their magnitude during the last twenty years but they are still significant today, especially for the elderly.

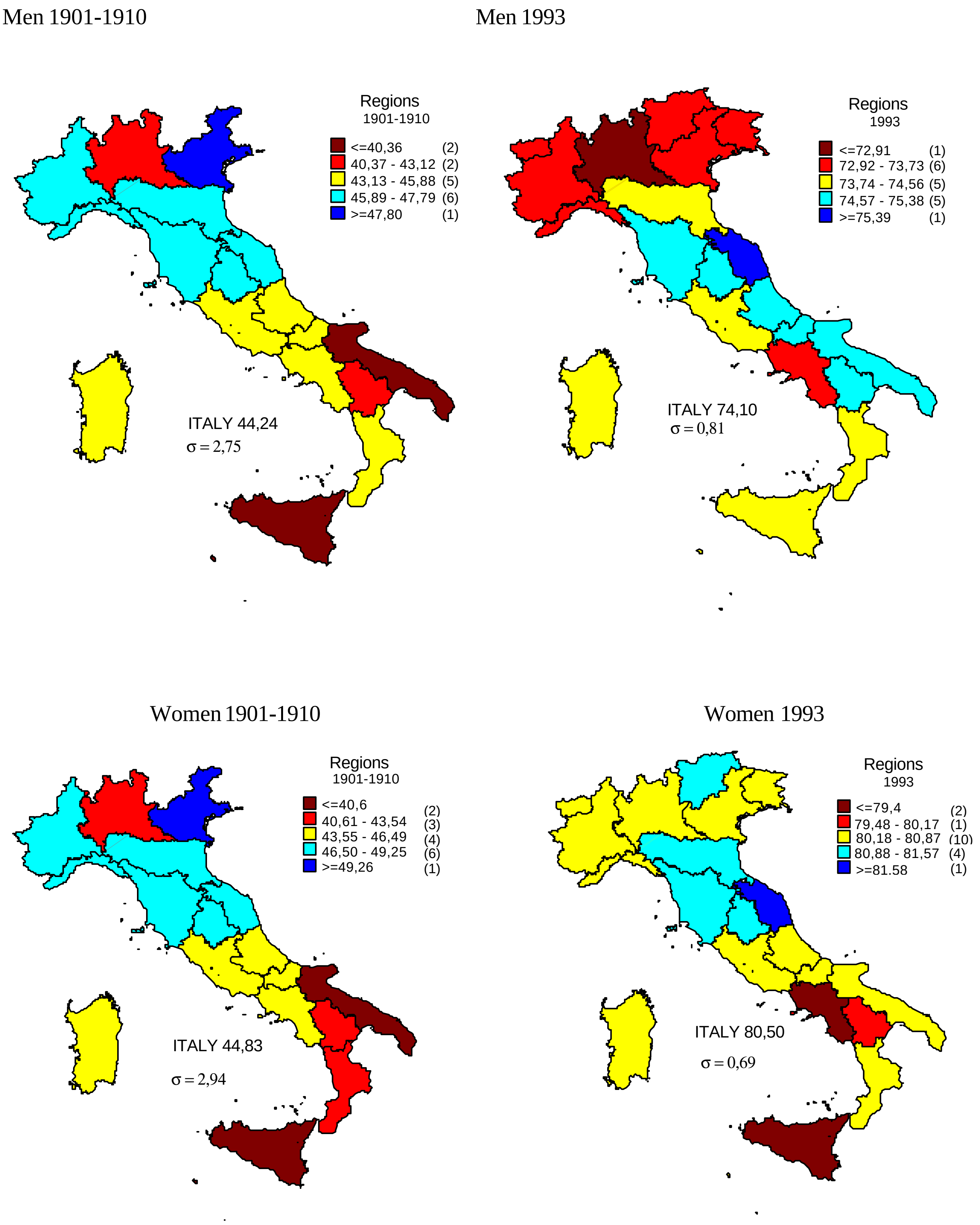

Figure 1. Variations in life expectancy at birth for men and women in Italian regions, 1901-10 and 1993

This paper, by considering longitudinal data, analyses geographical differences in mortality among the old and oldest old, taking into account mortality experienced at earlier ages. A widely held but not fully explored explanation for regional differences in mortality at old ages links mortality levels among the elderly to those experienced at previous ages in the cohort of origin. In other words, mortality among today's elderly should reflect their former life history. If living conditions during infancy and youth are particularly unfavourable, is this an handicap as far as future survival is concerned? Or, does a cohort, pre-selected by these greater risks, then find itself at an advantage as the weaker components are lost earlier on? Our goal is to shed light on the role played by selection or debilitation factors on elderly survival for populations affected differently by mortality at previous ages.

The paper is organised as follows. First, we describe mortality data by age, sex and cohort of four selected regions, each indicative of an economic, social or health care context or, again, a different mortality pattern. Then, adapting a statistical model that includes possible selection effects since birth to mortality data by cohort of the selected regions only available from age 60, we try to understand the impact of mortality experienced at earlier ages on regional mortality differences among the elderly. Finally, after estimating the probabilities of death from age 30 to age 59 for the four regions, we further investigate the role of selection and debilitation processes by applying a frailty model, fixing the frailty distribution at age 30.

2. Data and Descriptive Analysis

A number of previous studies, considering men and women together, highlighted the existence in Italy of at least four areas of mortality, each characterised by a particular intensity or specific age or sex structure: North, Centre, South and Sicily (Caselli and Egidi, 1980). To represent the four geographical areas with high or low mortality for men and women four indicative regions were selected: Lombardy, in the North, which during the second half of the 1800's enjoyed an advantage compared with the national average (DIRSTAT, 1881, Bellettini, 1980; Breschi and Livi Bacci, 1986), that had turned into a disadvantage by the early 1900's, for men especially (Caselli, 1987); Tuscany, for the Centre, which has always enjoyed low male and female mortality for all ages (Caselli 1987); Calabria, for the South, that due to high infant and youth mortality (Breschi and Livi Bacci, 1986, Caselli 1987), was one of the most disadvantaged regions during the 1800's until after World War II, and thereafter one of the regions with the lowest adult and elderly mortality; Sicily, with a quite favourable mortality throughout the 1800's for both sexes, continuing so for men but turning into a disadvantage for adult and elderly women in more recent years, placing them on a par with high mortality for the North (Caselli, 1987).

Probabilities of death calculated from observed mortality data (available from age 60) of cohorts born in 1891 and 1892 in the four selected Italian regions are depicted in figure 2 for both men and women (Caselli, 1983; Caselli and Reale, 1999).

For men, the mortality trajectory between 60 to 80 years for these two cohorts is quite different, according to region (figure 2). So, too, is their mortality history for previous ages. (tables 1 and 2). While mortality for the young in Lombardy is 3-4% higher than in Calabria and Sicily, for adults, especially aged 30 to 60 years, the probability of death is as much as 15-16% higher than the other two. This gap reaches 28% for 60-79 year olds. The gap between the two Southern regions and Lombardy only begins to narrow for 80 year olds.

For women differences in adult ages are even higher than for males when comparing Lombardy and Sicily (22% higher probability), being considerably reduced however for 60 to 80 year olds (5% difference). When these ages are considered, Tuscany is the region with the lowest mortality. When focusing on 80 year old women, as for men, differences tend to fade, often disappearing altogether (figure 2).

By reconstructing the “mortality history”, using longitudinal data, a parallel may be drawn between age and historic period, generating a number of interesting links and connections.

Italian 1891-92 male cohorts lived at a key moment in history. They were 23-26 years old during World War I and spent their working lives involved in the reconstruction of the post World War I and World War II years. The industrial development which occurred in the North and in particular in Lombardy, left the South untouched, that even today is under industrialised. Thus, it is no surprise to discover that these cohorts (which at a national level, similar to all cohorts caught up in the country's economic reconstruction, have a relatively higher adult mortality than other generations; Caselli and Capocaccia, 1989) had different experiences, according to region and the differences in mortality levels increased throughout their working lives (table 2). What is remarkable, is that differences rise at retirement age. For the cohorts looked at here this occurred in the early ‘60’s, when the industrial boom in Lombardy was in full swing and the region was at the forefront in Italy with regard to economic well-being and the quality of health care. It was to be expected that cohorts at an elderly age in Lombardy would enjoy more favourable survival than their peers in Calabria or in Sicily, industrially underdeveloped and with poor health care. That the mortality trajectories are the opposite to those expected is difficult to interpret. It could be hazarded that negative health outcomes of risks experienced during the working age in the North continue to be manifest even after retirement.

On the other hand, Tuscany, representing a central area of Italy with lower mortality at all ages, promoted a process of development that was more environment friendly and subsequently less damaging to health. Increased wellbeing went hand in hand with a more controlled and planned development in industry, and technological progress in agriculture, along with the promotion of healthy lifestyles.

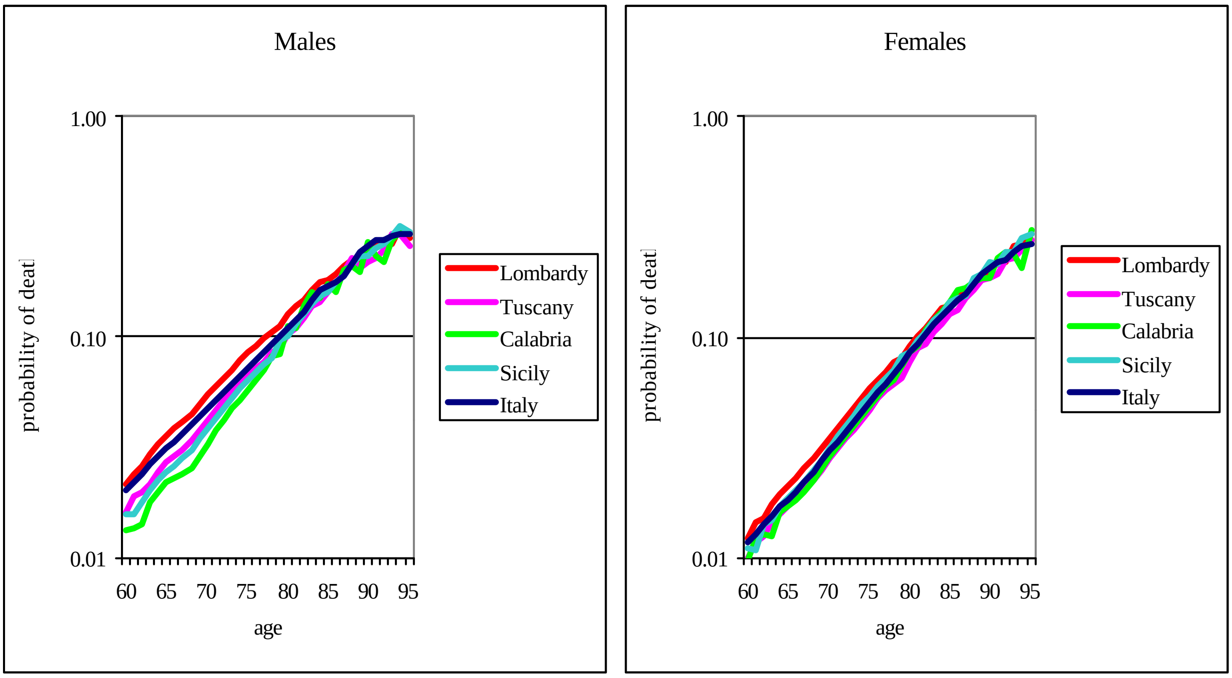

Figure 2. Probability of death (log scale) from age 60 to 95 of cohorts born between 1891 and 1892 for the selected regions and Italy.

Table 1. Infant mortality of cohorts born between 1891 and 1892 for the selected regions and Italy.

Regions	Men	Women
Lombardy	205.5	171.8
Tuscany	179.2	156.9
Calabria	197.4	188.0
Sicily	199.5	193.3
Italy	196.8	175.7
Source: Livi Bacci, 1962		

Table 2. Probability of death (per 1000) and life expectancy at various ages of cohorts born between 1891 and 1892 for the selected regions and Italy.

Men								
Regions	Probability of death					Life expectancy		
	30	60	80	30-59	60-79	30	60	80
Lombardy	5.44	21.75	126.16	240.48*	703.38	38.7*	15.2	5.3
Tuscany	5.58	16.27	102.94	222.37*	607.94	40.5*	17.2	6.0
Calabria	5.45	13.25	112.05	206.37*	547.82	41.8*	18.3	5.8
Sicily	5.07	15.70	101.76	208.05*	588.30	41.3*	17.6	5.9
Italy	6.73	19.74	109.43	265.20	645.99	38.6	16.4	5.8
Women								
Regions	Probability of death					Life expectancy		
	30	60	80	30-59	60-79	30	60	80
Lombardy	6.33	12.42	90.91	195.48*	549.08	42.2*	18.5	6.5
Tuscany	5.76	9.94	77,67	173.20*	473.55	44.2*	20.0	7.1
Calabria	5.98	9.70	85.13	176.24*	485.56	43.7*	19.7	6.6
Sicily	4.83	11.08	85.21	160.07*	519.20	44.0*	19.2	6.6
Italy	6.08	12.22	86.38	192.23	514.57	42.9	19.2	6.8

*Estimated probability of death.

3. Method

In the attempt to shed light on geographical differences in survival, it is thought that mortality trajectories underlie various selection and debilitation mechanisms and that these have unfolded differently depending on geographic origins and sex. The frailty model, introduced by James Vaupel, Kenneth Manton and Eric Stallard in 1979, is a statistical model that incorporates mortality selection and, hence, can analyse mortality patterns of heterogeneous populations where individuals differ in their susceptibility to disease and death. It usually provides a good fit, particularly at old ages when, due to the selection process towards low-frailty individuals, the mortality curve decelerates.

Let

$$m(x,z) = zm_0(x)$$

be the force of mortality at age x for an individual with unobserved frailty z, where $m_0(x)$, the *baseline hazard function*, is the force of mortality at age x for a standard individual, that is an individual with frailty equal to 1. Then, the force of mortality for a cohort of individuals is:

$$\overline{m}(x) = \overline{z}(x)m_0(x)$$

where $\overline{z}(x)$ is the average frailty of the surviving cohort. If frailty is gamma distributed with mean 1 and variance s^2, then the observed force of mortality in a population at age x is:

$$\overline{m}(x) = \frac{m_0(x)}{1+s^2H_0(x)} \qquad (1)$$

where $H_0(x) = \int_0^x m_0(t)dt$ is the cumulative hazard function of the standard individual. Note that s^2 is the variance of the frailty distribution *at birth*. Since, very often, frailty models are used to analyse adult and old mortality, the model (1) may be written in the following form:

$$\overline{m}(x) = \frac{m_0(x)}{1 + s^2 \int_{x_0}^{x} m_0(t)dt} \qquad (2)$$

where $\int_{x_0}^{x} m_0(t)dt$ is the cumulative hazard function of the standard individual from the starting age x_0. In this case, s^2 indicates the variance of the frailty distribution *at the starting age of observation* x_0.

In this paper, we are interested in verifying the impact of selection effects in elderly mortality and possible links with mortality at previous ages. Accordingly, assuming that the selection process starts from age zero, we analyse observed elderly mortality (from age 60 to age 95) and also take into account that part of infant, young and adult mortality which is not observed (from age 0 to age 59) and could be affected by heterogeneity in frailty. That is:

$$\overline{m}(x) = \frac{m_0(x)}{1 + s^2\left(H_0(x) - H_0(x_0) + H_0(x_0)\right)} = \frac{m_0(x)}{1 + s^2\left(\int_{x_0}^{x} m_0(t)dt + H_0(x_0)\right)} \qquad (3)$$

where $H_0(x_0)$ is a parameter of the model that indicates the cumulative hazard function of the standard individual from birth to age x_0. If the estimated value of $H_0(x_0)$ is positive then selection effects have a role before the starting age of observation x_0 and, consequently, the average frailty of the cohort decreases before age x_0 (after this age, it continues to decrease because of the cumulative hazard function from age x_0). On the contrary, if the estimated value of $H_0(x_0)$ is negligible (or alternatively the parameter is not statistically significant), then selection is not active at infant, young and adult ages. Thus, the variance of the frailty distribution at birth and that fixed at age x_0 are set at the same value and, obviously, in this case, model (3) is identical to model (2).

In our analyses, we have assumed that the baseline function follows a Gompertz-Makeham curve, that is $m_0(x) = a\,exp(bx) + c$. The model has been estimated using the maximum likelihood method.

4. Results and Discussion

Model (3), illustrated in the previous Section, has been applied to the four selected Italian regions and to Italy to evaluate the impact of the selection process during the cohort's entire life course on geographical differences in survival at old ages. The model is fitted to data for cohorts born between 1891 and 1892, from age 60 to age 95 for both women and men (see Appendix). The starting age 60 is simply the lowest age at which data are available. Age 95 was chosen as the upper limit because of the many fluctuations in regional data over this age (figure 3).

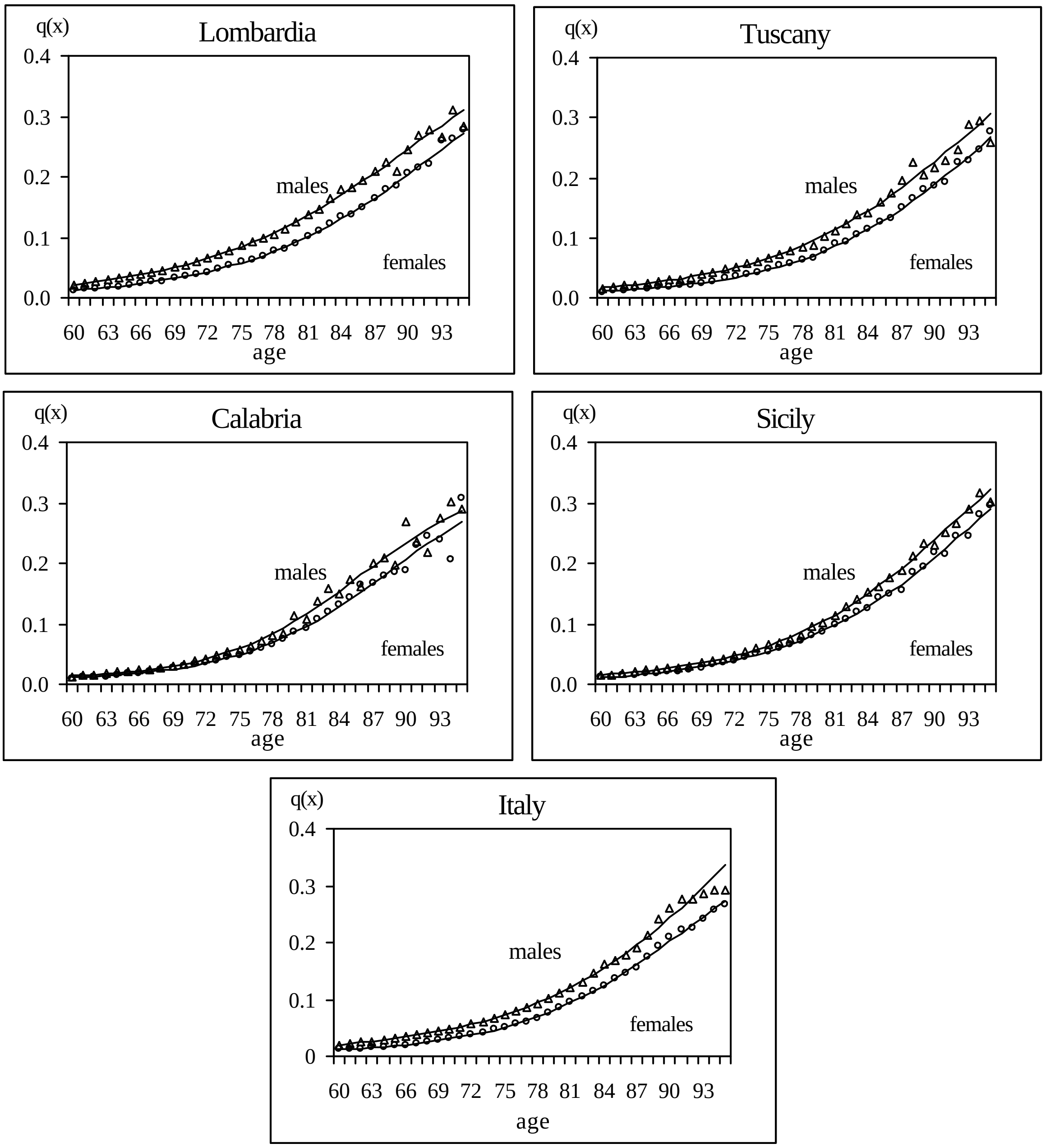

Figure 3. Estimated (solid line) and observed mortality curve for male and female cohorts born between 1891 and 1892 from age 60 to age 95.

Generally speaking, the selection process does not seem active before age 60 in almost all the regions analysed and in Italy (table 3). Alternatively and, perhaps, more reasonably, it may be said that, before age 60, selection and debilitation balance each other out: on the one hand, population heterogeneity has been increased by debilitation, that is acquired frailty; on the other, the variance in frailty has been reduced by selection effects. As a result, average frailty does not decrease due to the cumulative hazard function suffered by the cohort up to age 60, even for those regions where women and/or men suffered a higher level of mortality before that age, as shown in Section 2. Clearly, even at the beginning of the demographic transition, the mortality level at infant, young and adult ages, in the various regions of Italy, does not seem to cause predominant selection effects, such as to outweigh possible debilitation effects. The estimated parameter H is set at a low value for men in Lombardy and Italy and for women in Tuscany and Italy (values below 0.05). This means that, for these geographical areas and sexes, the impact of selection, although very small, occurs even before age 60. For men in Tuscany, Calabria and Sicily and for women in Calabria and Sicily the estimated parameter H is statistically insignificant. The fits with the model where H is set equal to zero, lead to very similar estimates of the other parameters. Thus, we can interpret the parameter s^2 as the variance of frailty at age 60. The degree of population heterogeneity arises from both innate and acquired frailty and reflects whichever influence of debilitation, compensation, as well as selection up to this age.

Lombardy, for women, is a case apart in that debilitation seems to have a role in the population before age 60. The parameter H assumes a negative, statistically significant value which may suggest a different interpretation. Although the applied model does not take debilitation into account explicitly, the negative value of the parameter H might be seen as a debilitation effect in the population. Accordingly, the average frailty of the cohort decreases as the cumulative hazard suffered by the cohort increases, but this process is somehow limited by the degree of debilitation of the cohort which, in determining the average frailty of the cohort, acts in the opposite direction. Here, however, the negative value of the parameter H has only a very slight impact on the cohort's average frailty and, even in the case of women in Lombardy, the fit with the classic frailty model (H=0) yields similar results.

The selection process, therefore, only seems to be predominant starting at young-old ages (around 60 years). But, even at these ages, the degree of heterogeneity in the population is quite limited for most of the regions analysed (table 3). Calabria, which enjoys the most favourable mortality conditions at old ages (60-79 years), shows the greatest heterogeneity for both males and females ($s^2_{males} = 0.38$ and $s^2_{females} = 0.30$). The life-table ageing rate (Horiuchi and Coale, 1990), that is the age-specific rate of mortality change with age, is clearly bell-shaped with a peak around age 75 (figure 4). On the contrary, in Lombardy, the most disadvantaged region at the same ages, values of the variance of frailty distribution are much lower for both males and females, though by no means the lowest ($s^2_{males} = 0.14$ and $s^2_{females} = 0.16$). The resulting pattern of the life-table ageing rate is completely different (figure 4): highest values are attained at relatively young-old ages and soon decline as the population is increasingly selected towards low-frailty individuals. Tuscany shows quite a limited degree of heterogeneity for women and the lowest value for men ($s^2_{males} = 0.13$ and $s^2_{females} = 0.16$), whereas for women the lowest degree of heterogeneity has been found in Sicily ($s^2_{males} = 0.16$ and $s^2_{females} = 0.13$). In both these regions and for men especially, where mortality conditions are closer to the national average, the life-table ageing rates show less pronounced patterns.

Table 3. Parameters with standard errors of the frailty model fitted to the mortality data of the cohorts born between 1891 and 1892 from ages 60 to 95.

Fitted Parameters	Lombardy			
	Males		Females	
	Est.	S.E.	Est.	S.E.
a	0.02031	0.00308	0.01120	0.00104
b	0.10070	0.00870	0.11102	0.00506
c	0.00101	0.00364	0.00091	0.00131
s^2	0.13537	0.04625	0.16061	0.03360
H	0.03010	0.00616	-0.01252	0.00195
Loglikelihood	-99309		-119006	
Fitted Parameters	**Tuscany**			
	Males		Females	
	Est.	S.E.	Est.	S.E.
a	0.01292	0.00205	0.00765	0.00100
b	0.10879	0.00864	0.11840	0.00690
c	0.00363	0.00256	0.00257	0.00138
s^2	0.12560	0.05123	0.15567	0.04875
H	0.07429	0.12263	0.01876	0.00243
Loglikelihood	-49971		-59006	
Fitted Parameters	**Calabria**			
	Males		Females	
	Est.	S.E.	Est.	S.E.
a	0.00511	0.00355	0.00570	0.00202
b	0.16155	0.01295	0.14299	0.00973
c	0.00878	0.00193	0.00506	0.00156
s^2	0.38445	0.08698	0.29919	0.06914
H	0.18557	3.38685	0.18438	1.23459
Loglikelihood	-17123		-26352	
Fitted Parameters	**Sicily**			
	Males		Females	
	Est.	S.E.	Est.	S.E.
a	0.00992	0.00374	0.01026	0.00095
b	0.12179	0.00761	0.11251	0.00270
c	0.00521	0.00184	0.00000	0.00040
s^2	0.15541	0.04582	0.12545	0.02446
H	0.09755	5.05344	0.09660	0.84772
Loglikelihood	-54052		-66573	
Fitted Parameters	**Italy**			
	Males		Females	
	Est.	S.E.	Est.	S.E.
a	0.01424	0.00064	0.00824	0.00028
b	0.10795	0.00235	0.12118	0.00183
c	0.00537	0.00075	0.00352	0.00038
s^2	0.14093	0.01384	0.19521	0.01278
H	0.06420	0.01811	0.04129	0.00213
Loglikelihood	-813476		-893309	

The two opposite patterns of the life-table ageing rate for Calabria and Lombardy might give scope to the role exercised by the selection process. In Calabria, where, as discussed above, the elderly mortality is lower than in Lombardy, mortality deceleration starts at older ages. The shift of the deceleration to older ages in the region with the lowest mortality may be seen as evidence for the role of selection (Horiuchi and Wilmoth, 1998).

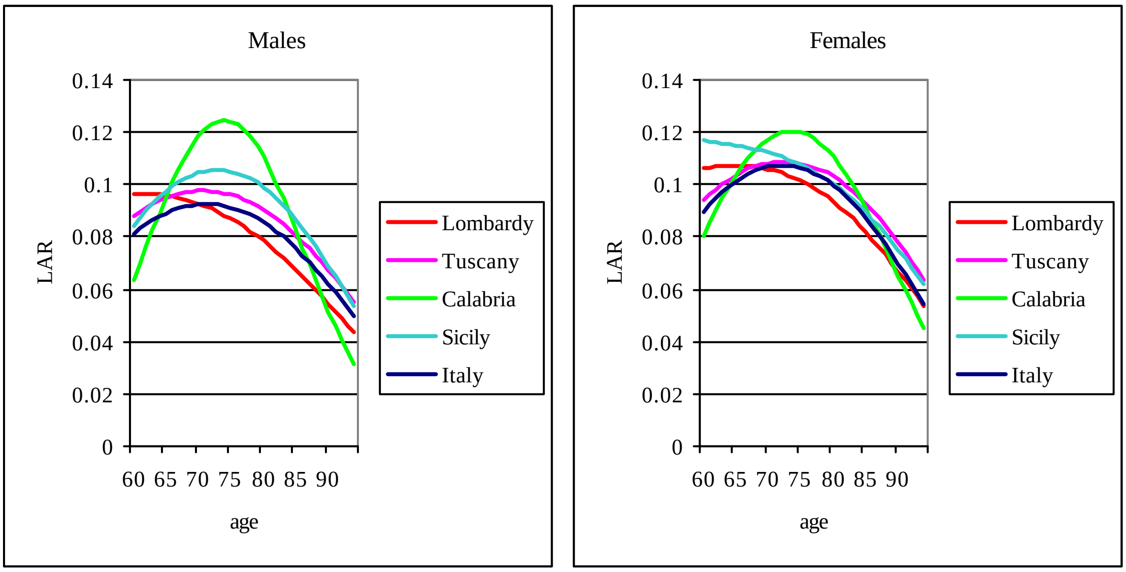

Figure 4. Age-specific rate of mortality change with age of the cohorts born between 1891 and 1892 from ages 60 to 95 for the selected regions and Italy.

The convergence among regional mortality levels observed after age 80 may be seen as the result of what happened between ages 60 and 79, in the various regions, in terms of mortality and, hence, selection. Or, this could be merely traced to a threshold effect, in that each individual sooner or later is doomed to die. On the other hand, in Italy as elsewhere in the developed world, over the last few decades, more and more persons, today as many as 50%, reach their 80th birthday. Therefore, the convergence in regional mortality trajectories, already observable at that age, cannot be attributed solely to a threshold effect. A process of selection necessarily plays a crucial role.

A previous study, by Massimo Livi Bacci (1962), on the role of debilitation and selection in regional mortality differences in Italy, found a positive correlation between mortality levels in infancy and in old ages for cohorts born between 1871 and 1891 in sixteen regions. The author argues that many important events may occur from birth to old age and hence a possible selection effect due to high infant mortality should only have a slight impact on mortality at old ages. On the contrary, although the positive correlation found does not itself demonstrate the role of debilitation, he suggests that lower mortality rates at old ages are to be expected in those regions with low infant mortality and *viceversa.* The well-known study by Kermack, McKendrick and McKinley (1934) shows that debilitation events are primarily important during the first 15 years of life. Later, Samuel Preston and Etienne van de Walle (1978) conclude that cohort mortality is affected by childhood debilitation. Somewhat more recently, the study by Graziella Caselli and Riccardo Capocaccia (1989), points out that if living conditions during the early period of life are unfavourable, negative effects could continue during adulthood and would entail greater vulnerability in the survivors up to age 45. At older ages selection would be active and would lead to a reduction in the number of highly vulnerable individuals.

These arguments motivated a further analysis of regional mortality data, taking 30 as a starting age. It was possible to estimate probabilities of death between ages 30-59 as period regional life tables are available for the years 1921-22, when the cohorts born in 1891-92 reached their 30th birthday. Probabilities of death between ages 30-45 for the four regions have been estimated considering the mortality age-structure at national level for the same cohorts (cohort life tables for Italy are available since 1861), whereas those between ages 45-59 were estimated by interpolation (see Appendix). Model 2 illustrated in Section 3 has been applied to the four selected regions and to Italy from age 30 to age 95. The underlying assumption is that debilitation is active only up to age 30. After this age, eventual debilitation events are unable to introduce new frail individuals or are counter-balanced by selection. To reveal possible different patterns of selection and to pinpoint when selection effects start being significant, the cumulative hazard function in model 2 has been split into two parts, the first integral being defined from the starting age of observation 30 to age 60.

Results from this application follow the same direction as those found in the previous analysis (table 4), although differences in heterogeneity in the four regions are less pronounced. Calabria still shows the higher levels of variance in frailty for both men and women ($s^2_{males} = 0.24$ and $s^2_{females} = 0.32$), followed by Lombardy ($s^2_{males} = 0.21$ and $s^2_{females} = 0.29$). The lowest levels of heterogeneity are found in Sicily ($s^2_{males} = 0.12$ and $s^2_{females} = 0.23$). It emerges again that selection begins at young-old ages, between ages 50 and 60, depending on the region.

That the selection process for men is somewhat more precocious in Lombardy ($H(60) = 0.16$) than in the other regions is confirmed and more evident whereas, in Calabria, it is the most delayed ($H(60) = 0.05$). Figure 5 shows that for men in Lombardy estimated heterogeneity at the upper ages is lower, albeit only slightly, than that for Tuscany Calabria, and Sicily. The decline in the average frailty has been more marked in Lombardy (though this does not mean that, for this region, individuals are, on average, more robust). Thus, overall the selection effect had a greater impact, at least for males, in this region.

For women, as shown in Section 2, mortality differences are less pronounced and, as a consequence, there are no significant differences in selection patterns. Table 4 shows that the values of the cumulative hazard function up to age 60 for the various regions and Italy are set between 0.04 and 0.06. Moreover, figure 5 shows that, starting already from age around 75-80, the degrees of heterogeneity in frailty are very similar for the selected regions and Italy.

Whether it is the “selection hypothesis” rather than the “debilitation hypothesis” that has a role in differentiating mortality by region and sex is hard to identify, it being quite difficulty to distinguish between the effects of selection or debilitation. The two processes not only act differently but they are also interdependent: debilitation that partly causes population heterogeneity results in a subsequent selection that in turn affects the impact of debilitation (Vaupel et al., 1988). The results, however, allow us to make some speculations. We have just seen that, for men, in Lombardy, the selection effects are significant at younger ages, say, at about age 50, whereas in Calabria the selection process is predominant only after age 60. Then, why do mortality levels for these two regions not start converging between ages 60-79? We are inclined to believe that if the selection process had not got off to an early start in Lombardy then perhaps the mortality differences with respect to the other regions between ages 60-79 would be even more evident, causing a higher average frailty at these ages for this region. If this is so, the advanced selection process should have counter-balanced, at least to some extent, debilitation acquired at younger ages and, in particular, during the working age. In our opinion, the divergence in the mortality curves for 60-79 year olds between Lombardy, and particularly Calabria, suggests that negative health outcomes of risks experienced during the working age generated such high subsequent mortality as to anticipate the impact of selection in the former region. This precocious selection would have generated the later (after age 80) convergence of regional mortality curves.

The smaller gap between adult and elderly male mortality levels in Sicily and in Calabria has, anyway, a differential impact on selection processes. For Sicilians, at a slight disadvantage, selection occurs earlier ($H(60) = 0.09$ for Sicily versus $H(60) = 0.05$ for Calabria). This causes a convergence of the mortality curves already at 75 years (figure 2).

Results obtained for males in Tuscany could provide a key to understanding the role played by early-life selection in determining elderly mortality differences. Elderly and adult mortality levels, as emerged in tables 2 and figure 2, are similar to those observed for Sicily (and partly for Calabria). Infant mortality (table 1), however, in Tuscany is much lower and subsequently a more reduced selection effect compared to Sicily could be expected. Despite these marked differences in infant mortality between the two regions, equally marked differences in the corresponding selection models did not emerge. Table 4 shows that variance in frailty and the cumulative hazard function up to age 60 are close for both regions ($s^2 = 0.15, H(60) = 0.11$ and $s^2 = 0.12$ $H(60) = 0.09$ for Tuscany and Sicily, respectively). This bears out Livi (1962) when he maintained that any effect of infant mortality on mortality for elderly ages could only be slight and would in any case be compensated for by the possible effects of mortality at other ages that could act in the opposite direction.

Table 4. Parameters with standard errors of the frailty model fitted to the mortality data of the cohorts born between 1891 and 1892 from ages 30 to 95.

Fitted Parameters	Lombardy			
	Males		Females	
	Est.	S.E.	Est.	S.E.
a	0.00058	0.00004	0.00016	0.00001
b	0.11335	0.00181	0.13082	0.00192
c	0.00436	0.00014	0.00533	0.00010
s^2	0.21291	0.01817	0.28754	0.02029
Loglikelihood	-150261		-167418	
H(60)	0.15672		0.06358	
Fitted Parameters	**Tuscany**			
	Males		Females	
	Est.	S.E.	Est.	S.E.
a	0.00039	0.00004	0.00011	0.00001
b	0.11357	0.00264	0.13211	0.00274
c	0.00504	0.00019	0.00493	0.00013
s^2	0.15167	0.02620	0.24799	0.02942
Loglikelihood	-73312		-80177	
H(60)	0.10721		0.04718	
Fitted Parameters	**Calabria**			
	Males		Females	
	Est.	S.E.	Est.	S.E.
a	0.00011	0.00002	0.00007	0.00001
b	0.13863	0.00519	0.14540	0.00428
c	0.00585	0.00028	0.00531	0.00019
s^2	0.24206	0.04630	0.31585	0.04243
Loglikelihood	-24576		-36036	
H(60)	0.05469		0.03827	
Fitted Parameters	**Sicily**			
	Males		Females	
	Est.	S.E.	Est.	S.E.
a	0.00032	0.00003	0.00015	0.00001
b	0.11648	0.00250	0.13016	0.00240
c	0.00471	0.00017	0.00398	0.00012
s^2	0.12045	0.02352	0.23175	0.02478
Loglikelihood	-77583		-88610	
H(60)	0.09436		0.05905	
Fitted Parameters	**Italy**			
	Males		Females	
	Est.	S.E.	Est.	S.E.
a	0.00055	0.00001	0.00015	0.00000
b	0.10806	0.00067	0.12874	0.00071
c	0.00612	0.00006	0.00530	0.00004
s^2	0.13526	0.00652	0.24104	0.00737
Loglikelihood	-1278000		-1250021	
H(60)	0.13198		0.05776	

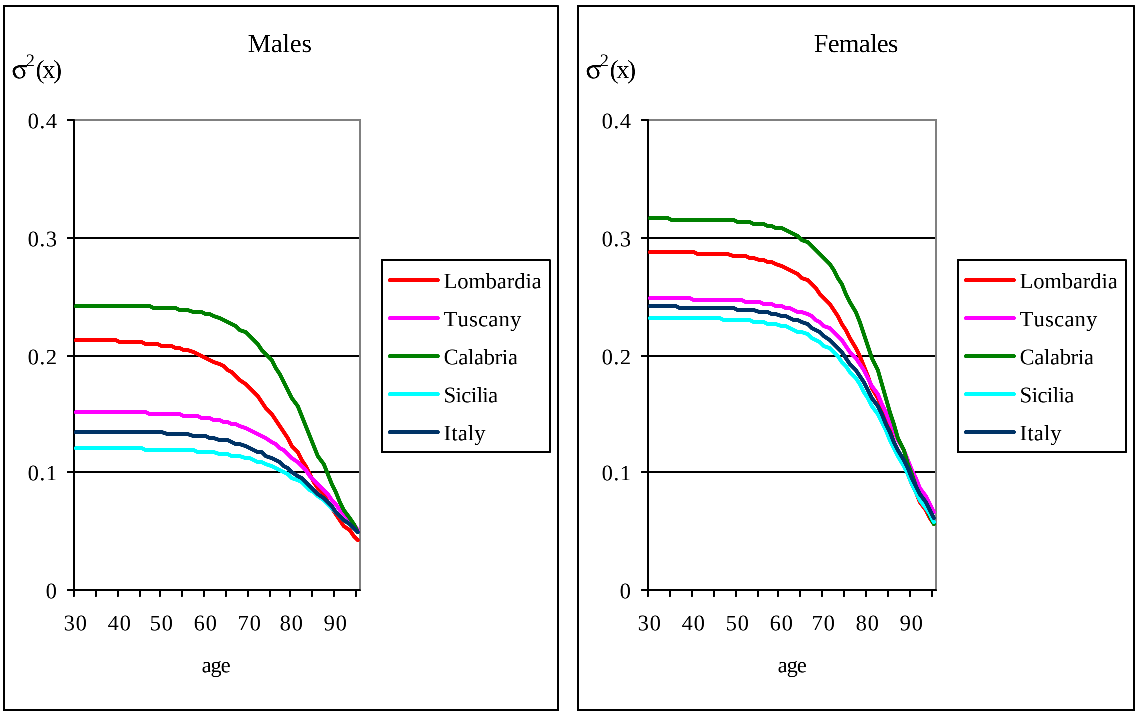

Figure 5. Variance in frailty of the cohorts born between 1891 and 1892 from ages 30 to 95 for the selected regions and Italy.

5. Conclusions

This paper deals with the question whether elderly mortality differences observed in various Italian regions may be linked to different mortality levels at earlier ages and whether this may be explained by different selection or debilitation mechanisms. These questions are partially answered.

First, we applied a model that includes possible selection effects since birth to mortality data by cohort for Italy and four selected regions with different mortality patterns from age 60 to age 95. It was found that selection is not active or does not predominate possible debilitation events between birth and age 60. Only for men in Lombardy and Italy and for women in Tuscany and Italy, does selection have a slight impact before this age. Thus, we are not able to establish if and eventually how mortality early in life affects elderly mortality. However, the different degrees of heterogeneity at age 60 estimated in the various regions are the result of how the selection and the debilitation processes acted together at previous ages. After age 60, selection is active in all the regions analysed. This process and, hence, mortality experienced only at older ages, contributes to the convergence among regional mortality levels observed after age 80.

Secondly, after estimating the probabilities of death from age 30 to age 59 for the four regions and assuming that debilitation is not predominant after age 30, we further investigated the role of selection by applying a frailty model, fixing the frailty distribution at age 30. Results confirmed that selection is predominant only at young-old ages, between ages 50 and 60, depending on the region. The existence of different patterns of selection, at least for men, has been pinpointed, the process being more precocious in Lombardy than in other regions, with possible effects on subsequent cohort mortality. Moreover, the case of

Tuscany provides some evidence for the minor impact of infant mortality on elderly mortality.

APPENDIX

Probabilities of death of the cohort born in 1891 and 1892 from ages 30 to 95 for Italy and the selected regions. Values in italics are estimated.

	Men					Women				
age	Italy	Lombardy	Tuscany	Calabria	Sicily	Italy	Lombardy	Tuscany	Calabria	Sicily
30	0.00673	*0.00544*	*0.00558*	*0.00545*	*0.00507*	0.00608	*0.00633*	*0.00576*	*0.00598*	*0.00483*
31	0.00681	*0.00533*	*0.00547*	*0.00534*	*0.00497*	0.00593	*0.00610*	*0.00555*	*0.00577*	*0.00466*
32	0.00712	*0.00559*	*0.00574*	*0.00560*	*0.00521*	0.00590	*0.00608*	*0.00554*	*0.00575*	*0.00464*
33	0.00721	*0.00585*	*0.00600*	*0.00586*	*0.00545*	0.00592	*0.00613*	*0.00557*	*0.00579*	*0.00467*
34	0.00711	*0.00574*	*0.00588*	*0.00575*	*0.00535*	0.00592	*0.00611*	*0.00556*	*0.00578*	*0.00467*
35	0.00695	*0.00554*	*0.00569*	*0.00555*	*0.00517*	0.00558	*0.00582*	*0.00529*	*0.00550*	*0.00444*
36	0.00714	*0.00564*	*0.00579*	*0.00565*	*0.00526*	0.00553	*0.00573*	*0.00521*	*0.00541*	*0.00437*
37	0.00732	*0.00590*	*0.00605*	*0.00591*	*0.00549*	0.00552	*0.00578*	*0.00526*	*0.00546*	*0.00441*
38	0.00737	*0.00598*	*0.00614*	*0.00600*	*0.00558*	0.00543	*0.00571*	*0.00519*	*0.00539*	*0.00435*
39	0.00749	*0.00602*	*0.00617*	*0.00603*	*0.00561*	0.00543	*0.00554*	*0.00504*	*0.00523*	*0.00423*
40	0.00748	*0.00606*	*0.00621*	*0.00607*	*0.00564*	0.00540	*0.00558*	*0.00508*	*0.00527*	*0.00426*
41	0.00745	*0.00614*	*0.00629*	*0.00615*	*0.00572*	0.00539	*0.00561*	*0.00511*	*0.00530*	*0.00428*
42	0.00746	*0.00607*	*0.00623*	*0.00608*	*0.00566*	0.00544	*0.00560*	*0.00510*	*0.00529*	*0.00428*
43	0.00778	*0.00622*	*0.00638*	*0.00624*	*0.00580*	0.00557	*0.00569*	*0.00518*	*0.00538*	*0.00435*
44	0.00821	*0.00662*	*0.00679*	*0.00663*	*0.00617*	0.00572	*0.00586*	*0.00533*	*0.00553*	*0.00447*
45	0.00833	*0.00679*	*0.00697*	*0.00680*	*0.00633*	0.00580	*0.00598*	*0.00544*	*0.00565*	*0.00456*
46	0.00849	*0.00734*	*0.00737*	*0.00711*	*0.00673*	0.00599	*0.00628*	*0.00567*	*0.00586*	*0.00484*
47	0.00877	*0.00793*	*0.00780*	*0.00744*	*0.00715*	0.00619	*0.00659*	*0.00590*	*0.00607*	*0.00514*
48	0.00953	*0.00857*	*0.00825*	*0.00777*	*0.00759*	0.00661	*0.00692*	*0.00614*	*0.00630*	*0.00545*
49	0.01101	*0.00926*	*0.00873*	*0.00813*	*0.00807*	0.00734	*0.00727*	*0.00639*	*0.00653*	*0.00578*
50	0.01301	*0.01001*	*0.00924*	*0.00850*	*0.00857*	0.00840	*0.00763*	*0.00665*	*0.00677*	*0.00613*
51	0.01532	*0.01082*	*0.00978*	*0.00888*	*0.00910*	0.00951	*0.00801*	*0.00693*	*0.00701*	*0.00651*
52	0.01629	*0.01169*	*0.01035*	*0.00929*	*0.00967*	0.00995	*0.00841*	*0.00721*	*0.00727*	*0.00690*
53	0.01538	*0.01264*	*0.01095*	*0.00971*	*0.01028*	0.00953	*0.00883*	*0.00750*	*0.00754*	*0.00732*
54	0.01394	*0.01365*	*0.01159*	*0.01015*	*0.01092*	0.00905	*0.00927*	*0.00781*	*0.00781*	*0.00777*
55	0.01290	*0.01476*	*0.01226*	*0.01061*	*0.01160*	0.00856	*0.00974*	*0.00813*	*0.00810*	*0.00824*
56	0.01428	*0.01595*	*0.01298*	*0.01109*	*0.01232*	0.00902	*0.01022*	*0.00847*	*0.00840*	*0.00875*
57	0.01495	*0.01723*	*0.01373*	*0.01160*	*0.01309*	0.00977	*0.01073*	*0.00881*	*0.00871*	*0.00928*
58	0.01638	*0.01862*	*0.01453*	*0.01212*	*0.01391*	0.01063	*0.01127*	*0.00917*	*0.00903*	*0.00984*
59	0.01824	*0.02013*	*0.01538*	*0.01267*	*0.01478*	0.01162	*0.01183*	*0.00955*	*0.00936*	*0.01044*
60	0.01974	0.02175	0.01627	0.01325	0.01570	0.01222	0.01242	0.00994	0.00970	0.01108
61	0.02129	0.02387	0.01919	0.01368	0.01587	0.01323	0.01466	0.01190	0.01236	0.01095
62	0.02288	0.02614	0.01972	0.01430	0.01806	0.01424	0.01512	0.01249	0.01295	0.01427
63	0.02544	0.02937	0.02173	0.01799	0.02013	0.01589	0.01748	0.01455	0.01269	0.01493
64	0.02881	0.03280	0.02466	0.01987	0.02252	0.01784	0.01933	0.01586	0.01605	0.01704
65	0.03148	0.03592	0.02688	0.02195	0.02443	0.01956	0.02116	0.01729	0.01723	0.01850
66	0.03315	0.03867	0.02888	0.02285	0.02610	0.02064	0.02303	0.01850	0.01842	0.02013
67	0.03493	0.04144	0.03102	0.02409	0.02814	0.02248	0.02540	0.02025	0.01973	0.02211
68	0.03783	0.04509	0.03392	0.02559	0.03097	0.02476	0.02813	0.02235	0.02239	0.02490
69	0.04239	0.04966	0.03776	0.02901	0.03458	0.02794	0.03142	0.02519	0.02538	0.02798
70	0.04782	0.05515	0.04234	0.03300	0.03902	0.03180	0.03509	0.02844	0.02900	0.03165
71	0.05210	0.06033	0.04703	0.03768	0.04321	0.03523	0.03897	0.03168	0.03225	0.03538
72	0.05690	0.06570	0.05160	0.04246	0.04771	0.03881	0.04299	0.03472	0.03600	0.03960
73	0.06075	0.07168	0.05635	0.04745	0.05263	0.04225	0.04769	0.03779	0.03965	0.04431
74	0.06515	0.07829	0.06134	0.05229	0.05863	0.04655	0.05268	0.04183	0.04423	0.04934

Follow Appendix

	Men					Women				
age	Italy	Lombardy	Tuscany	Calabria	Sicily	Italy	Lombardy	Tuscany	Calabria	Sicily
75	0.07159	0.08540	0.06671	0.05735	0.06426	0.05262	0.05842	0.04707	0.04918	0.05465
76	0.07770	0.09195	0.07232	0.06367	0.06925	0.05813	0.06400	0.05291	0.05462	0.05968
77	0.08447	0.09903	0.07788	0.07103	0.07491	0.06376	0.07008	0.05813	0.06010	0.06536
78	0.09182	0.10541	0.08522	0.08139	0.07961	0.06974	0.07676	0.06183	0.06432	0.07101
79	0.09958	0.11302	0.08854	0.08410	0.09663	0.07810	0.08123	0.06561	0.07379	0.08163
80	0.10943	0.12616	0.10294	0.11205	0.10176	0.08381	0.09090	0.07767	0.08513	0.08521
81	0.11827	0.13717	0.11069	0.10883	0.11382	0.09266	0.10111	0.08932	0.09140	0.09747
82	0.13274	0.14570	0.12242	0.13674	0.12724	0.10281	0.11110	0.09262	0.10706	0.10649
83	0.14589	0.16274	0.13740	0.15850	0.13975	0.11506	0.12219	0.10668	0.12037	0.11971
84	0.15525	0.17890	0.14275	0.15043	0.15345	0.12340	0.13424	0.11515	0.13112	0.12682
85	0.17010	0.18280	0.15930	0.17329	0.16042	0.13721	0.13878	0.12759	0.14409	0.14305
86	0.18157	0.19469	0.17374	0.16107	0.17603	0.14944	0.14971	0.13291	0.16332	0.15071
87	0.18772	0.20821	0.19681	0.20020	0.18887	0.15321	0.16514	0.14909	0.16677	0.15408
88	0.20844	0.22326	0.22573	0.20962	0.21232	0.17075	0.17871	0.16393	0.17857	0.18602
89	0.21297	0.20965	0.20446	0.19599	0.23346	0.18047	0.18412	0.18145	0.18654	0.19420
90	0.22663	0.24576	0.21653	0.26718	0.23094	0.19841	0.20474	0.18518	0.18722	0.21851
91	0.24080	0.26898	0.22799	0.23443	0.25091	0.21336	0.21370	0.19273	0.23079	0.21540
92	0.25700	0.27660	0.24770	0.21864	0.26634	0.22128	0.22026	0.22616	0.24456	0.24400
93	0.27856	0.26546	0.28979	0.27396	0.28927	0.24428	0.26010	0.22992	0.23825	0.24563
94	0.28560	0.31140	0.29358	0.30138	0.31578	0.25370	0.26396	0.24711	0.20746	0.28035
95	0.28401	0.28307	0.25927	0.29048	0.30029	0.27430	0.27626	0.27600	0.30894	0.29634

Acknowledgements

The authors wish to thank James Vaupel and Anatoli Yashin for their valuable comments and suggestions.

REFERENCES

BELLETTINI Athos, 1980. – Il quadro demografico dell’Italia nei primi decenni dell’Unità nazionale, in Atti del I Congresso di Storia del Risorgimento italiano, Bologna, Istituto per la storia del Risorgimento Italiano, p.***.

BRESCHI Marco and LIVI BACCI Massimo, 1986. – Saison et climat comme contraintes de la suivie des enfants. L’expérience italienne au XIXè siècle, *Population*, n°. 41, p. ***.

CASELLI Graziella, 1983. – Il contributo dell’analisi per generazioni allo studio della geografia della mortalità, *Genus*, vol. XXXIX, nn° 1-4, p. 37-60.

CASELLI Graziella, 1987. – Mortalità e sopravvivenza in Italia dall’Unità agli anni ‘30, in *Popolazione, società e ambiente*, Bologna, Editrice CLUEB, p.275-309.

CASELLI Graziella, and EGIDI Viviana, 1980. – Le differenze territoriali di mortalità in Italia. Tavole di mortalità provinciali (1971-72), Istituto di Demografia dell’Università di Roma, n.32.

CASELLI Graziella, and EGIDI Viviana, 1981. – L’analyse des données multidimensionnelles dans l’étude des rélations entre mortalité et variables socio-économiques d’énvironnément et de comportément individueles, *Genus*, vol. XXXVII, nn° 3-4, p. 57-91.

CASELLI Graziella, and CAPOCACCIA Riccardo, 1989. – Age, period, cohort and early mortality: an analysis of adult mortality in Italy, *Population Studies*, n° 43, p. 133-153.

CASELLI Graziella, and REALE Alessandra, 1999 . – Does cohort analysis contribute to the study of the geography of mortality ?, *Genus*, vol. LV, nn° 1-2, p. 27-59.

CASELLI Graziella, CERBARA Loredana and LETI Giuseppe, 1993 . – The geography of adult mortality: Results from the fuzzy clumping method, *Genus*, vol. IL, nn° 1-2, p. 1-24.

DIRSTAT, Popolazione, 1881. – Movimento dello Stato Civile, Anno XIX, Roma, ***p.

HORIUCHI Shiro and COALE Ansley, 1990. – Age Patterns of Mortality for Older Women: an Analysis using the Age-specific Rate of Mortality Change with Age, *Mathematical Population Studies*, vol. 2(4), 245-267.

HORIUCHI Shiro, WILMOTH, John. R., 1998. – Deceleration in the age pattern of mortality at older ages, *Demography*, 35, 4, 391-412.

KERMACK K. O., MC KENDRICK G. and MCKINLEY P.L., 1934. – Death rates in Great Britain and Sweden: some general regularities and their significance, *Lancet*, 698-703.

LIVI BACCI Massimo, 1962. – Alcune considerazioni sulle tendenze della mortalità senile e sull'eventuale influenza selettiva della mortalità infantile, *Rivista Italiana di Economia, Demografia e Statistica*, vol. XVIII, n. 3-4, 60-73.

PRESTON Samuel H., van de WALLE Etienne, 1978. – Urban French mortality in the nineteenth century, *Population Studies*, 32, 275-297.

VAUPEL James W., MANTON, Kennet G., STALLARD Eric, 1979 . – The Impact of Heterogeneity in Individual frailty on the Dynamics of Mortality, *Demography*, n° 16 , p. 439-454.

VAUPEL James W., YASHIN Anatoli, MANTON Kenneth G., 1988. – Debilitation's aftermath: stochastic process models of mortality, *Mathematical Population Studies*, Vol. 1(1), 21-48.