CONTOUR MAPS OF LEADING CAUSES OF DEATH: AN OVERVIEW OF THE ITALIAN EPIDEMIOLOGICAL TRANSITION IN THE XX CENTURY

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Introduction

In 1971, following the unprecedented increase in life expectancy in developed countries, Abdel Omran[1] put forward a theory describing for the first time the decrease of infectious diseases, which had gradually been replaced by chronic diseases. It was labelled "epidemiological transition" and, initially, comprised the following stages: 1) The "age of pestilence and famine", dominated by recurrent mortality crises when life expectancy at birth was more or less 30 years (a phase indicated in the mortality transition pattern as "pre-transitional"); 2) the "age of receding pandemics", during which some infectious diseases became less important and the sharp decline in mortality in the early years of life brought life expectancy to 50 years (start of the mortality transition); 3) the "age of degenerative diseases", is characterized by the predominance of chronic diseases and the stabilization of mortality at a low level (end of the mortality transition period).

According to Omran, with the third age the advances in life expectancy in the mid-1960s slowed down or, in some cases, stopped, with the rise of new endemic diseases, whether degenerative (e.g. cardiovascular diseases, cancers, diabetes, metabolic disorders). France Meslé and Jaques Vallin[2] consider Omran's division into three ages as accurately reflecting reality up until the end of the 1960s, when he wrote his first article – a period in which the improvements in life expectancy were slowing down, particularly for men.

However, events swiftly belied Omran's model. From the early 1970s on, life expectancy in all western countries once again began to increase for men too, driven by a clear reduction in mortality for cardiovascular diseases. Following these new behaviours and the resulting increase in survival, Jay Olshansky and Brian Ault,[3] and Richard Rogers and Robert Hackenberg[4] imagined a "fourth phase" of epidemiological transition. The first two authors suggested that the mortality model by cause had remained the same because the age of death had shifted forward, while the second two spoke rather of the start of a new era, where the most important advances in survival had been and would be achieved thanks to the reduction in mortality brought about by the adoption of new and healthier life styles.

[1] A. R. Omran, *The epidemiological transition: a theory of the epidemiology of population change*, «Midbank Memorial Fund Quarterly», XLIX, 1971, 4, pp. 509-538.
[2] F. Meslé, J. Vallin, *The Health Transition: Trends and Prospects*, in G. Caselli, J. Vallin, G. Wunsch (eds.), *Demography, Analysis and Synthesis*, Amsterdam, Elsevier-Academic Press, 2006, pp. 247-259.
[3] J. Olshansky, B. Ault, *The fourth stage of the epidemiological transition: the age of delayed degenerative diseases*, «The Midbank Quartely», LXIV, 1986, 3, pp. 355-391.
[4] R. G. Rogers, R. Hackenberg, *Extending Epidemiologic Transition Theory,* «Social Biology», XXXIV, 1987, 3-4, pp. 234-243.

In 1983, Abdel Omran[5] recognized the existence of one and possibly two additional phases to his initial theory of the epidemiological transition, accepting the suggestions of Jay Olshansky and Brian Ault, but pointed out that the new mortality models would be accompanied by the emergence of new diseases (HIV, Ebola, SARS, etc.) and the revival of other former diseases (such as, for example, cholera and tuberculosis).

Omran's fourth phase of epidemiological transition has been questioned.[6] According to France Meslé and Jacques Vallin, his initial idea was based mainly on the conceptualization of the transition from the old stable regime of high mortality in the past to a new stable regime of low mortality. The transition would be protracted and would follow the same pattern of the three phases (or four, according to other authors) without changing the prevailing nosological framework Omran described. Obviously, this interpretation clashes with reality. The new era of advances in survival that had begun in the 1970s was based on a significant change in the epidemiological situation of the cardiovascular revolution. Detailed analyses have shown that this change is something quite distinct from the slump in infectious diseases. For this reason France Meslé and Jacques Vallin (2006) proposed a substantial modification of Omran's model of epidemiological transition and the reappraisal of it by other authors, suggesting a new model that would follow «the semantic shift proposed by Julio Frenk et al.[7] and include within the wider concept of "health transition" an initial phase (that described by Omran) of life expectancy gains, attributed mainly to the decline in mortality due to infectious diseases, followed by a second phase dominated by the decline in cardiovascular diseases, leaving open the possibility of identifying later phases, such as that suggested by Shiro Horiuchi[8] for cancer and perhaps senescence».[9]

In this paper, we revise trends and differentials in cause-specific mortality, in Italy, during the last century, looking at the epidemiological transition, exploiting a simple but powerful tool for descriptive and explorative analysis: the surface by age and time of leading causes of death.[10]

The types of representation most used by demographers are based either on mortality rates by age or mortality rates by calendar year (or by year of birth). A third solution consists of graphic representations of surfaces of mortality rates over age and time in a way similar to contour maps widely used in depicting spatial patterns. Contour maps can be readily adapted to represent any surface that is defined over two dimensions.[11] This solution permits demographers to analyze mortality patterns from a perspective different from that offered by the usual graphs of mortality rates at selected ages over time (in a surface from left to right) or a selected times over age (from bottom to top), that is to visualize the interaction of age, period, and cohort effects (by reading a surface diagonally), and thus stimulate a deeper

[5] A. R. Omran, *The Epidemiological Transition Theory. A Preliminary Update*, «The Journal of Tropical Pediatrics», XXIX, 1983, 6, pp. 305-316.

[6] B. Fetter, *The Epidemiologic Transition: One, Many or None?*, «Health Transition Review», VII, 1997, 2, pp. 235-237; F. Meslé, J. Vallin, *The Health Transition*.

[7] J. Frenk, J. L. Bobadilla, C. Stern, T. Frejka, R. Lozano, *Elements for a theory of the health transition*, «Health Transition Review», I, 1991, 1, pp. 21-38.

[8] S. Horiuchi, *Epidemiological transition in human history*, in *Health and Mortality: Issues of Global Concern*, New York, United Nations, 1999, pp. 54-71.

[9] F. Meslé, J. Vallin, *The Health Transition: Trends and Prospects,* p. 250.

[10] E. Barbi, G. Caselli, A. Yashin, *Age and Time Patterns of Mortality by Cause in Italy: A Mortality Surface Approach, Proceeding of the XLII Scientific Meeting of the Italian Society of Statistics*, Padova, CLEUP, 2004.

[11] W. B. Arthur, J. W. Vaupel, *Some General Relationships in Population Dynamics*, «Population Index», L, 1984, 2, pp. 214-226; G. Caselli, J. W. Vaupel, A. Yashin, *Mortality in Italy: Contours of a Century of Evolution*, «Genus», XLI, 1985, 1-2, pp. 39-55; G. Caselli, J. Vallin, J. W. Vaupel, A. Yashin, *Age-specific Mortality Trends in France and Italy since 1900: Period and Cohort Effects*, «European Journal of Population», III, 1987, pp. 33-60.

understanding of the evolution of mortality over age and time and its possible social and biological determinants.[12]

In this paper mortality surfaces are used in a different way: they describe the predominant cause of death at a given age and time. First, considering the Italian mortality data by age and sex for large groups of causes of death, we review the epidemiological transition in Italy through the mortality surfaces of the first leading cause of death from 1895 to 1994. Second, focusing on the last stage of the epidemiological transition, we analyze the mortality profiles through the surfaces of the first leading locations of malignant neoplasms and cardiovascular diseases from 1969 to 2001.

1. *Data*

A long series of mortality data have been used to construct our mortality surfaces. First, we refer to annual probability of dying for men and women from 1887 to 2001. Up to 1994, these data come from period life table computed by Graziella Caselli. The remaining data have been taken from ISTAT life table (1999-2003).

Regarding mortality data by cause, we depict a first mortality surface for men and for women, which describes the various phases of the epidemiological transition from the beginning up to 1994, for large groups of causes of death. Annual probabilities of dying by cause are taken from previous papers by Graziella Caselli[13] and subsequent updates. In these studies, in order to highlight the diseases of the *ancien régime*, greater focus has been given to the most important infectious diseases (the first three categories plus part of the fourth in Table 1). Moreover, the causes of death have been grouped following the aetiology of the morbidity process. Thus, for instance, in the case of infectious diseases, in the various International Classifications (ICD), several infections have not been classified in this group but in that of the respiratory system (e.g. acute bronchitis and pneumonia) or in that of the digestive system (e.g. appendicitis). These data refer to an appropriate cause-specific classification, which made it possible to work on homogeneous groups throughout the period considered, that is 1895-1994 (ICD2-ICD9).

Clearly, despite solving formal problems relating to the comparability of the disease classifications adopted in different calendar years, the data contain more substantial problems related to increased capacity and usage in diagnosis over time. The aggregation level of the causes selected for analysis permits these inconveniences to be limited to the greatest extent possible.

[12] J. W. Vaupel, *The long-term pattern of adult mortality and the highest attained age: discussion on the paper by A.R. Thatcher*, «Journal of the Royal Statistical Society/A», 1, 1999, pp. 31-43; E. Barbi, *Assessing the rate of ageing of the human population*, «MPIDR Working Paper WP-2003-008», 2003.

[13] G. Caselli, *Mortalità e sopravvivenza in Italia dall'Unità agli anni '30*, in *Popolazione, Società, Ambiente*, Bologna, Editrice Clueb, 1987; G. Caselli, *Transition sanitaire et structure par cause de la mortality. Anciennes et nouvelles causes*, «Annales de Démographie Historique», I, 1989, pp. 55-77.

Tab. 1. *Groups of causes of death according to the International Classifications*

Causes of death	ICD-2 (1909)	ICD-4 (1929)	ICD-7 (1955, list A)	ICD-8 (1965, list A)	ICD-9 (1975, list A)
Tuberculosis	13-15	10, 11	1-5	6-10	020-025
Infectious diseases of respiratory system (bronchitis, pneumonia and influenza)	9, 20-21, 22	8, 26, 27	88-93	90-93	320- 323
Infectious diseases of digestive system	1-2, 10-11, 25-26	1-2, 24, 29-30	12-14, 16, 36, 102, 104 part, 132 part	1-5, 30, 100	010-016, 05-051, 342
Other infectious diseases and other diseases of respiratory system	3-8, 12, 17, 23, 31	3-7, 9, 12, 13, 14, 28, 35	6-11, 15, 17-20-23-31, 32-35, 37-43, 71, 87, 94-97, 102, 104, part, 115	11-29, 31-44, 72-89, 94-96, 116	030-038, 040-048, 052-054, 060-078, 220, 310-315, 324-327, 394 part
Cancers	16, 30	15, 16	44-60	45-61	080-179
Cardiovascular diseases	18, 19	22, 24, 25	70, 79-86	80-88	250-305, 309
Senility, ill-defined and unspecified causes	34, 38	39, 43	136, 137	136, 137	460-467
Accidents	35, 36	40-42	138-150	138-150	AE470- AE562
Other causes	Remainder	Remainder	Remainder	Remainder	Remainder

Starting from 1969, when the ISTAT database by cause becomes available, we constructed mortality surfaces referring to subgroups of diseases within the two leading groups of causes of death which characterize the more recent mortality profiles by age and cause, that is cardiovascular diseases and cancers (Table 2).

Annual cause-specific probabilities of dying have been computed assuming that causes of death act independently of one other.[14]

All mortality surfaces in this paper have been performed using *Lexis*, a software devised by Kirill Andreev[15] at the *Max Planck Institute for Demographic Research*.

[14] N. Keyfitz, *Applied Mathematical Demography*, New York-Berlin, Springer-Verlag, 1985.

[15] K. F. Andreev, *Demographic surfaces: estimation, assessment and presentation, with application to Danish mortality, 1835-1995*, PhD Dissertation University of Southern Denmark, Odense, 1999.

Tab. 2. *Subgroups of causes of death within cardiovascular diseases and cancers*

Causes of death	ICD-9 (analytic list)
Cardiovascular diseases	**390-459**
Cerebrovascular diseases	430-438
Ischaemic heart diseases	410-414
Hypertensive disease	401-405
Atherosclerosis	440
Rheumatic heart diseases	393-398
Other	Remainder
Cancers	**140-239**
Respiratory system	160-165
Digestive tract	150-159
Breast cancer for women	174
Genitourinary system	179-189
female	179-184.9, 188, 189
male	185-189
Lymphatic system	200-208
Others	Remainder

2. *Trends and Differentials in Mortality in Italy: 1887-2001*

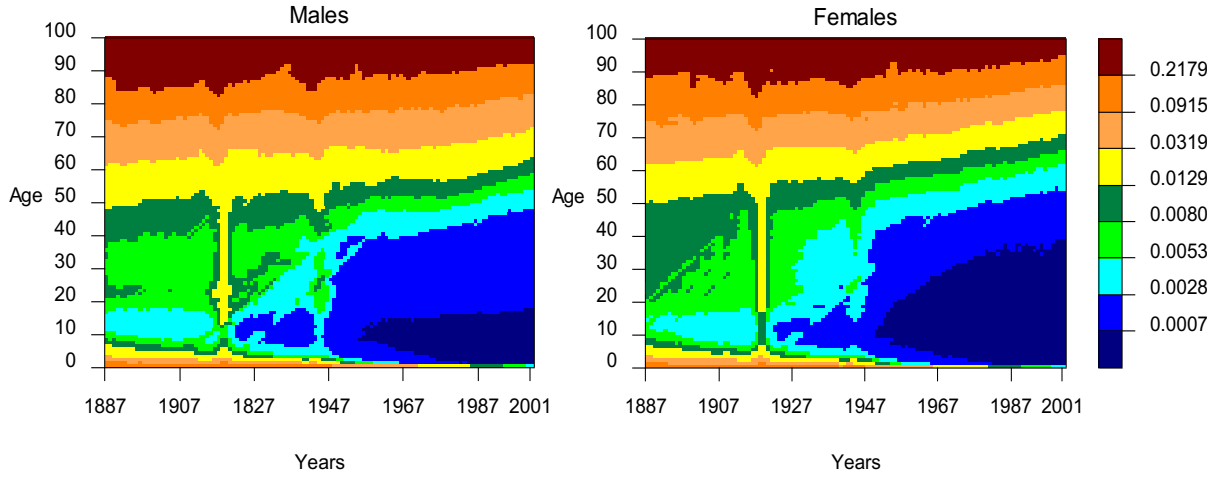
Figure 1 depicts the classic surface of age-specific death probabilities of Italian men and women over the period 1887- 2001. The serious crises in mortality (*period effects*) due to the two World Wars and the Spanish flu are easily traced on the maps by the elongated rays of high mortality crossing all ages.

For male cohorts most directly involved in the First World War, and for male and female cohorts that were born or grew up during the war years, a diagonal spur of high mortality indicates serious negative effects linger on for some years after the conflict. These findings have been acknowledged and explained by several previous studies. Out of the five and a half million Italian men who survived the First World War, about 85% were invalids or ill at the end of the conflict. For cohorts born or passing through adolescence during the War, the Spanish flu and the disastrous economic and nutritional results of the war caused long-term effects of debilitation (*cohort effects*).[16]

The mortality profile by age radically changed during the XX century. In the first part of the 1900s, infant and young mortality rapidly declines while the gain made at later ages is marginal.

Starting from the second half of the century, when infant mortality has reached minimum levels, adult and young-old mortality began to decrease. From the mid-1970s, a new phase took off and mortality rates started declining even for the elderly. In this process, Italian women enjoy a considerable advantage over men. By the 1950s, female mortality declines visibly even at older ages while male mortality rates hardly changed before the 1970s, especially at ages above 60. After the 1970s, although the reduction, as said, concerns even male mortality, this took place at a slower pace for men than for women. In very recent years, the patterns for the two sexes seem to converge: while women are experiencing a constant pace of decline, for men the mortality reduction is accelerating.

Fig. 1. *Probability of dying for Italian men and women from 1887 to 2001*



[16] C. Gini, L. Livi, *Alcuni aspetti delle perdite dell'esercito italiano*, IV, «Metron», 2, 1924; G. Mortara, *La salute pubblica in Italia durante e dopo la Guerra*, Bari, Laterza, 1925; G. Caselli, J. W. Vaupel, A. Yashin, *Mortality in Italy*; G. Caselli, R. Capocaccia, *Age, Period, Cohort and Early Mortality: An Analysis of Adult Mortality in Italy*, «Population Studies», XLIII, 1989, pp. 133-153.

3. *The epidemiological transition in Italy and the emerging of a new era*

A better understanding of the mortality transition and the differences in gender mortality trends are possible by looking at the patterns of cause-specific mortality by age.[17] Figure 2 shows the first leading group of causes of death from 1895 to 1994 for both sexes, from birth to age 99. Accounting for the concept of "leading cause by age", these maps can summarize the epidemiological transition through one sole graph. Although, here, causes of death are aggregated perhaps in too large groups, all the phases of the transition clearly emerge. The essential features and gender differences in times and ways of the change from a situation in which infectious diseases predominated among causes of death to a more modern regime in which cardiovascular diseases and cancer are the most important causes of death are immediately understandable.

At the end of the XIX century and until the eve of World War II, as well known, the leading diseases among infants and children are infectious diseases, both those of the digestive and respiratory systems. Poverty and malnutrition were responsible for typical summer diseases like diarrhoea, and winter diseases like bronchitis and pneumonia. The dramatic decline of infant and childhood mortality after the 1950s is due to a progressively diminishing role of these groups of causes, although mortality from these causes remained higher in Italy than in the rest of Europe until as late as the 1970s and the 1980s.[18] In the same period, among youngsters and young adults, for both women and men, tuberculosis is dominant. Until World War I the predominant causes of death among men aged between 40 and 60, are bronchitis, pneumonia and influenza. It is well visible for both sexes, besides the effects of violent deaths due to World War I for men, the severe impact of the Spanish flu in 1918. From age 50 to age 80, the leading causes of death are those included in the group of cardiovascular diseases.

At the top left of Figure 2, the yellow area delineates mortality for the group of senility, ill-defined and unspecified diseases, showing the difficulty of classification of certain types of diseases in the past, and the low consideration for people dead after age 80.

Up to the mid of XX century, when new treatments lead to a health revolution, infectious diseases of any nature were the leading cause of death up to age 50, although their incidence decreased starting from the 1930s.

In the second part of last century, accidents are the leading causes among young men whereas for women this group of causes became the most important only starting around 1975 and in the age group 15-25. What is remarkable for young men is the loss of importance of this group of causes starting from the beginning of the 1990s, for the age group 25-40. This may be due to the impact of a new disease, namely AIDS, which at that time was classified as "other diseases".

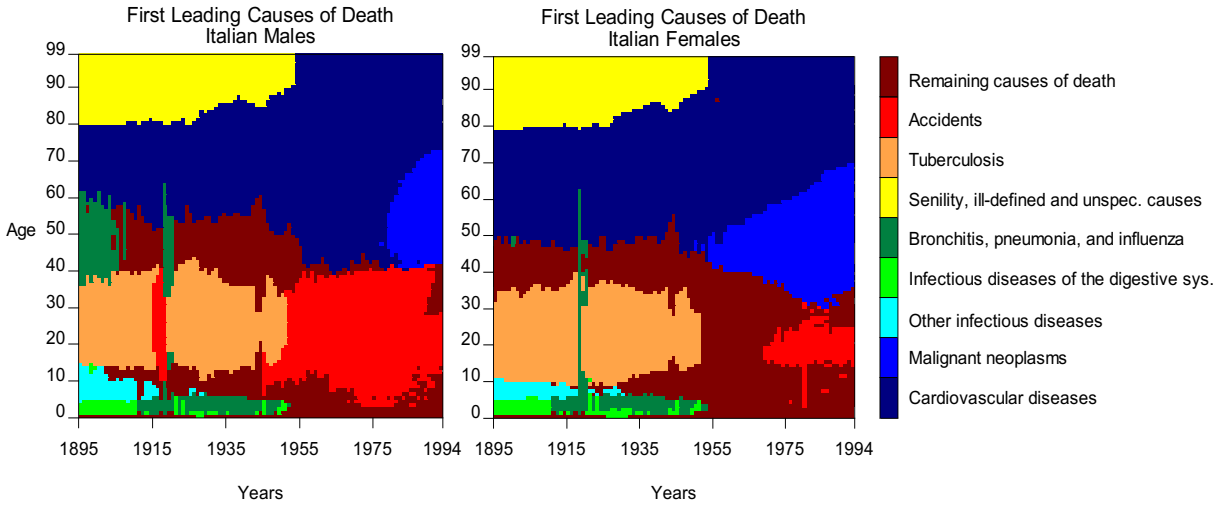
The passage from left to right of figure 2 clearly indicates the two fundamental changes of the epidemiological transition from infectious diseases to degenerative diseases and from the incidence of mortality at young ages to that of mortality at older ages. By the 1960s, cardiovascular diseases have become the main cause of death for adults and the elderly, both in men and in women. For women, the predominant role of cardiovascular diseases very soon gives way to the influence of cancer for certain age groups. The importance of cancer progressively increases and by mid 1980s

[17] G. Caselli, *Health transition and cause specific mortality*, in R. Schofield, D. Reher, A, Bideau (eds.), *The decline of mortality in Europe*, Clarendon Press, 1991.

[18] G. Caselli, *National Differences in the Health Transition in Europe*, «Historical Methods», XXIX, 1996, 3, pp. 107-125.

this disease category becomes the leading cause of death during the middle ages of life up to the age of 70 for both women and men. Moreover, better diagnosis procedures may have eliminated the uncorrected attribution of some diseases to mortality for senility, ill-defined and unspecified diseases. During the last 30 years, the drop in mortality from cardiovascular diseases leads to an increase of the importance of mortality from cancer, announcing a new era in mortality patterns.

Fig. 2. *First leading cause of death by age and sex in Italy from 1895 to 1994*

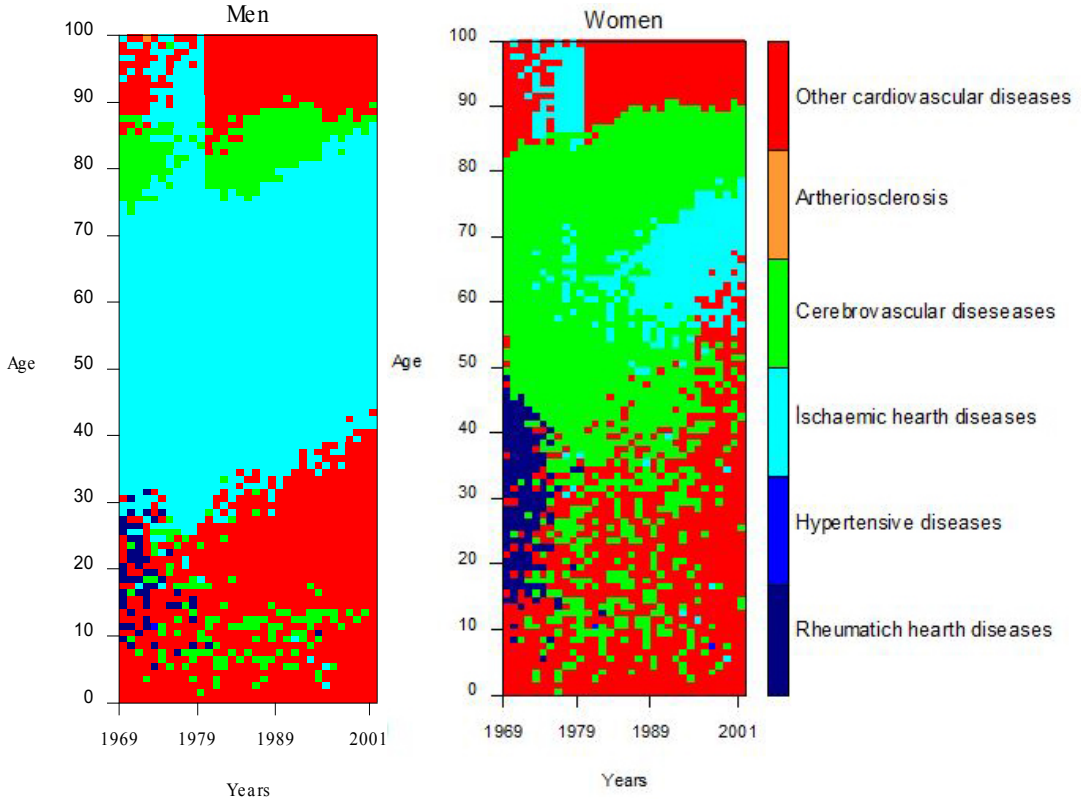


4. *Patterns of Mortality from Cardiovascular Diseases and Cancers: towards emerging profiles*

A more in-depth analysis is possible when distinguishing between the main causes of death composing the large group of cardiovascular diseases and that of cancers. Table 2 shows the specific causes of death in which the two groups have been classified.

Figure 3 immediately shows the well-known different patterns between men and women. For men, the dominant cause is ischaemic heart diseases from age 30 to 80 whereas, for women, in good part of the same area, this is cerebrovascular diseases. Also, it is well visible the announced shift to older ages of these degenerative diseases. This may be due to the joint effect of the availability of new treatments and, even more important, of a more spread prevention among the younger generations because of higher level of education. What it is interesting here, when all cardiovascular diseases are decreasing, is the increasing role of ischaemic heart diseases for women starting from the 1990s in the age group 55-75. New treatments and medical tools have been less effective on ischaemic heart diseases than on other cardiovascular diseases.

Fig. 3. *Profiles for the first leading causes of death among the group of cardiovascular diseases by age and sex in Italy from 1969 to 2001*



The clear cut visible in figure 3 after age 80 around 1976 is probably due to classification errors in the passage from the 8th to the 9th ICD.

As previously said, this kind of map allows us to focus on the profile of mortality by cause but not on the level of the various causes of death. Looking at the classic surface of mortality from the entire group of cardiovascular diseases, it emerges that there is a progressive reduction of mortality at all ages, even at the oldest ones, and that at age below 40 the level of mortality is negligible (Figure 4).

Fig. 4. *Mortality surface from the group of cardiovascular diseases by age and sex in Italy from 1969 to 2001*

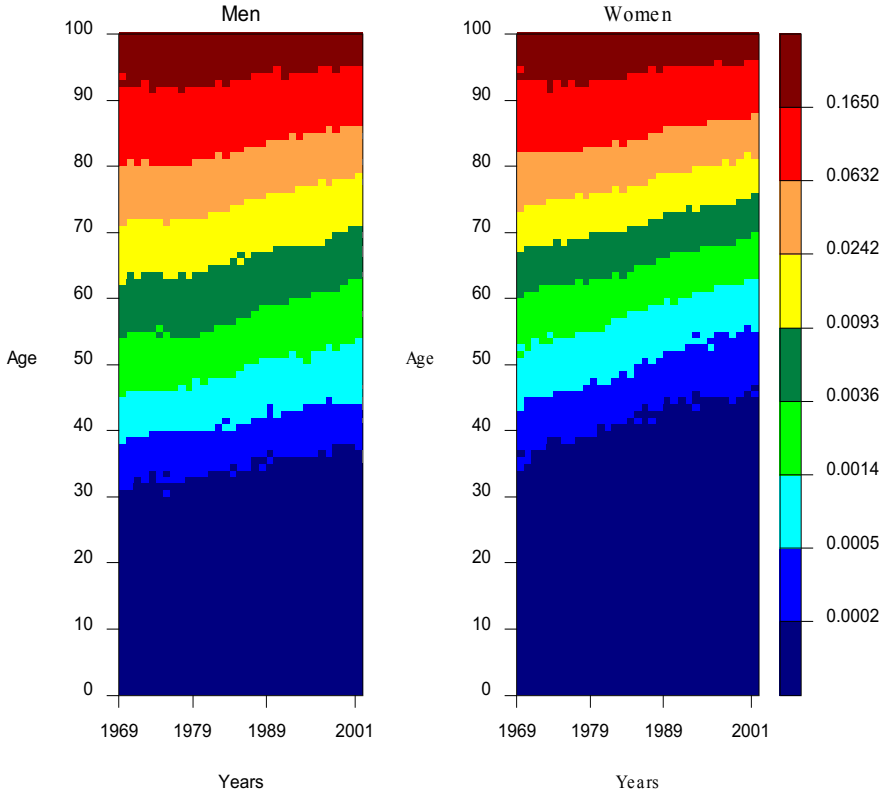


Figure 5 shows the first leading location among the main categories of cancer, for men and women, from 1969 to 2001. As expected, the picture shows the predominant role of cancer of the respiratory tract for men from age 40 to 70, breast cancer for women from age 30 to 55, and cancer of the digestive tract at older ages for both sexes. It is interesting to notice that, for men, the predominance of cancer of the respiratory tract shifts over time towards older ages whereas for women the age range of the predominant category (breast cancer) stays more or less constant over time. For children and youths, the cancers are predominantly related to the lymphatic system and those included in the subgroup of "other cancers".

Looking at the classic surfaces for the two sex-specific main cancers (Figure 6), for men, mortality from cancer of the respiratory tract, after an implacable resistance, entered a diminishing phase at the end of the 1970s between ages 40 and 70. This can be seen as a long-term cohort effect of those generations who experienced healthier habits, including lower tobacco consumption. For women, on the contrary, although values are much lower, mortality from cancer of the respiratory tract, starting from the 1980s, is increasing especially between ages 40 and 60. This negative trend may be linked to the

spread of harmful, traditionally male behaviours among women and may contribute to a possible future reduction of the mortality gap between men and women.

Breast cancer has also continued to increase especially for the elderly women until the end of 1980s, and then has begun to decrease in particular from age 40 to 70. Prompt diagnosis and new effective therapies have contributed to the mortality decrease or to postponing death. This pattern has contributed to the general reduction in female mortality due to cancer.

Fig. 5. *Profiles for the first leading causes of death among the group of cancers by age and sex in Italy from 1969 to 2001*

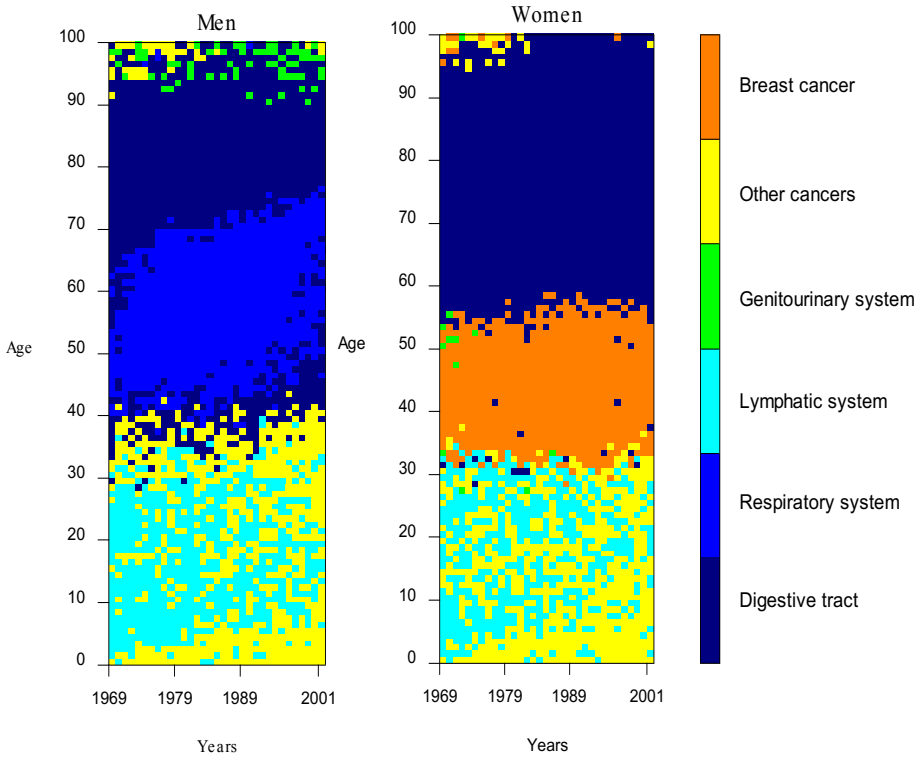
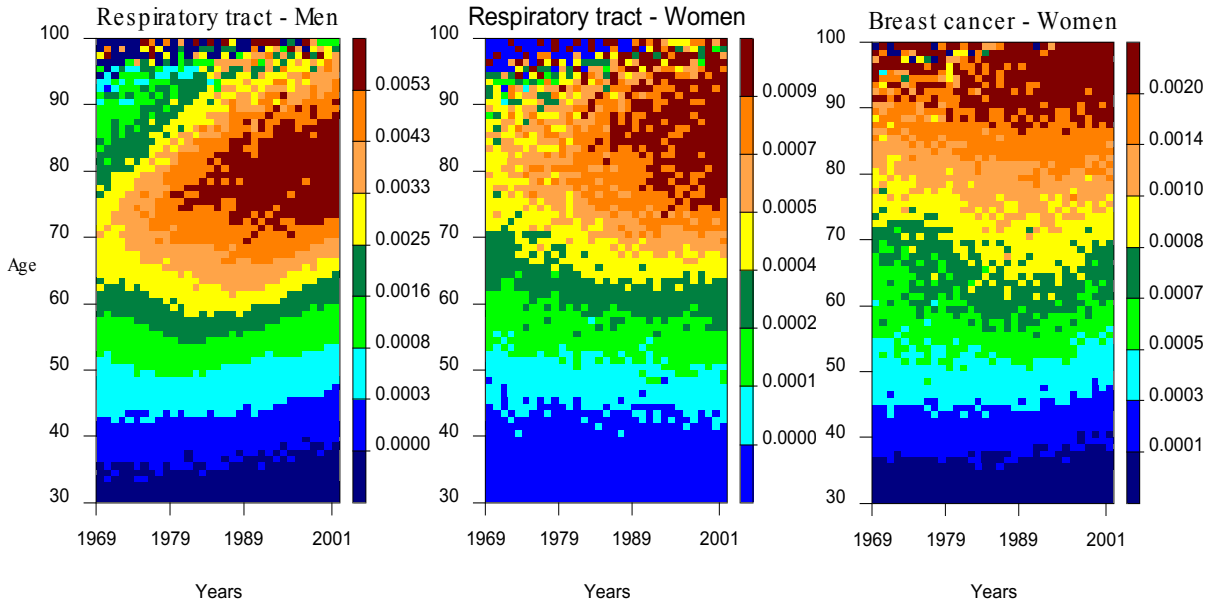


Fig. 6. *Evolution of mortality due to cancer of respiratory tract and breast cancer by age (30 and over) and sex in Italy from 1969 to 2001*



5. *Concluding Remarks*

In this paper we provided a detailed picture of the trends and changes in cause-specific mortality that occurred in Italy, from 1895 to 2001, by using a simple and effective method that proved useful in the descriptive and explorative analysis of the epidemiological transition: the contour maps of leading causes of death.

The clear and comprehensive view of the study phenomenon is of crucial importance for the discussion on future mortality trends: the course of the two emerging predominant causes of death – cardiovascular diseases and cancers – will more and more govern the overall mortality pattern and the differences between sexes and countries. In this context, the approach followed in this study seems very promising. Following the principle of Chinese boxes, it enables us to easily single out the underlying mechanisms of much more complex systems. The full and detailed picture can help then to direct the public policy towards more suitable and prompt interventions. The recent and accelerating reduction of mortality from breast cancer is a good example of the positive effects of a more widespread screening among women. In the future, for instance, mortality due to cancer of the respiratory tract in women may benefit from similar measures and come to a halt of its negative trend. As a consequence, the expected reduction of the male-female mortality gap might be negligible or not confirmed at all.

Moreover, the method presented in this study can be fruitfully used for teaching purposes because it is possible to visualize long and complex demographic processes through one sole image. Furthermore, persistent long-term trends but even sudden changes in the age-period- cohort components of mortality, and their possible interactions, are easily readable, thus permitting us to forecast more reliable future scenarios.

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