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Mortality in the Former Soviet Union
Past and Future

E. Andreev, S. Scherbov, and F. Willekens

WP-93-13
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IIASA

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ABSTRACT

The paper considers the most recent data (1980-1990) on mortality by sex and cause for the former Soviet republics. The following causes were chosen: diseases of the circulatory system; neoplasms; accidents, poisonings and violence; diseases of the respiratory system; infectious and parasitic diseases; digestive system diseases and a group of all others and unknown causes.

The first effort of applying an APC approach to these mortality data by cause of death for the former USSR is performed. The results of this study showed the applicability of a chosen method for interpretation of mortality trends.

Despite the social tension in this part of the world, mortality from most causes of death decreased, though the trend towards mortality decline within the period was uneven. For example mortality trends were influenced by such events as the anti-alcohol campaign, the earthquake in Armenia and the Chernobil catastrophe.

Extrapolating trends of the 1980s for each group of causes, it was possible to expect a general decline of mortality from most causes of death under consideration except neoplasms and chronic diseases that are included in the group "other causes". Mortality from neoplasms showed stable increase. Due to extreme instability of mortality from the causes of death that comprise the group "others and unknown causes", projection for this group was not performed.

According to our projection, in the absence of new cataclysms, life expectancy in all of the former USSR republics except Armenia will increase by one year for males and females by the year 2000. The maximum increase of life expectancy may be anticipated in the Central Asian republics as a result of mortality decline from exogenous causes of death.

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MORTALITY IN THE FORMER SOVIET UNION

Past and future

E. Andreev,[1] *S. Scherbov,*[2] *and F. Willekens*[3]

1. INTRODUCTION

The purpose of the study is to analyze recent trends and to project mortality by cause of death for the former USSR republics. The history of mortality in the former Soviet Union differs from the trends in other regions in several respects. Mortality history is generally studied within the context of the epidemiological transition. The first stage of this transition is the restriction of extraordinary periodical increases of mortality by such causes as particularly dangerous infections (cholera, smallpox, typhus and some others) and famine. The second stage is characterized by further extension and intensification of social control over exogenous factors of immediate impact; as a result mortality, caused by principal infections (first of all child infections, diarrhea, tuberculosis), respiratory diseases (influenza, pneumonia) and some others, decreases drastically or is even eliminated. The second stage manifests itself in the background and is the result of economic growth and industrialization. The mortality level at this stage is substantially influenced by such negative consequences of the industrial revolution as environmental pollution and stressors; as a result the quasi-endogenous mortality (caused by circulatory system diseases and malformations in younger ages as well as by accidents) increases. The third stage is the gradual elimination of negative industrialization consequences and quasi-endogenous mortality along with further eradication of purely exogenous components. These processes are based on measures for environmental protection, improvement of labor and domestic conditions, and promulgation of a healthy, rational mode of life. It increases mean death age by principal endogenous and quasi-endogenous causes of death. The elements of the fourth stage are only beginning to manifest themselves in the countries with minimal mortality levels. The major features of this stage are the further decrease of infant mortality due to preventive measures, efficient treatment of hereditary and congenital diseases, and mass nursing of prematurely born babies. At present the fourth stage can be considered a result of a highly efficient and developed health system.

The subject of the present study is recent mortality, i.e. mortality since 1980. Trends in male and female mortality are studied by cause of death for 12 former Soviet republics. The following groups of causes of death are considered: diseases of the circulatory system; neoplasms; accidents, poisonings and violence; diseases of the respiratory system; infectious and parasitic diseases; diseases of the digestive system and a group of all others and unknown causes. The

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former republics included in the study are: Armenia, Azerbaijan, Byelorussia, Georgia, Kazakhstan, Kirghizia, Moldavia, Russia, Tajikistan, Turkmenia, Ukraine, Uzbekistan. We did not include in our study the former Baltic republics because of the historical specifics of that region's demographic processes, and because all of the Baltic republics had already become independent states when we started the study. We hope that a simultaneous analysis of the 12 republics allows a better understanding of the recent mortality dynamics in the former USSR.

Trends in mortality dynamics in the republics of the former USSR may seem rather logical when compared to the world trends in mortality and the trends anticipated by the theory of demographic transition (Bourgeois-Pichat 1952, 1978) in mortality. Thus despite the mortality increase from neoplasms, the level in many regions remains lower than in developed countries, and the mortality level from numerous chronic diseases that are included in the group "all others and unknown causes" is so low that it advocates for the poor level of differential diagnostics and unjustified transfer of deaths from rare chronic to deaths from diseases of the circulatory system (Andreev 1987, 1988, 1990). Mortality from infectious diseases, diseases of the digestive system and especially respiratory diseases in most of the regions consequently decreases in full agreement with the theory of demographic transition.

The epidemiological transition started later in the former USSR than in Western Europe (Andreev 1992). The first stage of the transition was over at the end of the 19th century, several decades later than in Western Europe. The second stage of transition was over in the mid-1960s in most of the USSR when life expectancy approached the level of the major Western countries. In this period, new negative tendencies emerged in the dynamics of USSR population mortality which was first apparent in the growth of mortality rates of males aged 15-59 and then spread over the female population and older ages (Dmitriyeva and Andreev 1987). The decline of life expectancy compared to 1966 was connected first of all to the increase of mortality of circulatory system diseases and accidents. Thus in 1980 life expectancy of males declined by 3.75 years (by 2.14 years due to circulatory system diseases, by 1.24 years due to accidents) compared to 1966. Life expectancy of females declined by 1.74 years, and the negative influence of mortality growth due to circulatory system diseases and accidents was 2.09 years, being partially compensated by mortality dynamics from other causes of death. A comparison of the data with the general pattern of demographic transition indicates that the dynamics of USSR mortality in the 1960s to early 1980s fully demonstrated the negative aspects that are typical for the second stage of the epidemiological transition.

From the prospect of the dynamics of mortality, the years 1980-1990 seem to look more optimistic than the preceding 15 years (1965-1979), when mortality from chronic diseases and accidents was rising steadily. But the period 1980-1990 is definitely not a homogeneous one.

Using statistical data (without adjustment for infant mortality and mortality in the older ages) we estimated for males and females the change in life expectancy relative to 1980 as a result of age-specific mortality changes of a certain age group due to a particular cause of death (see Figure 1 in Appendix A). The method of components was used for this analysis (Andreev 1982). We can observe that from 1980 until 1984, life expectancy increased slightly due to a decline in diseases of the respiratory system (both sexes), in part due to the age group 0-14, and in accidents (males). In 1984 mortality from diseases of the circulatory system contributed to the decrease in life expectancy compared with preceding years partially because of a severe influenza epidemic in the country; most of the negative effects were produced by the age group 60+.

A rapid increase in life expectancy followed after 1985. Between the beginning of 1985 and 1987, male life expectancy increased by 2.6 years and female life expectancy by 1.1 years due to a reduction in accident mortality. Month-by-month analysis of the dynamics of accident death rates

proves that this decline in mortality is the immediate result of drastic measures taken in May 1985 against drunkenness in the USSR (Andreev 1992). The declining mortality from diseases of the circulatory system and respiratory diseases contributed to a further increase in life expectancy. The major negative contribution to life expectancy (though small) was from neoplasms and a group of causes called "other and unknown". Starting in 1988 negative tendencies in life expectancy especially for males appeared again. For males the decrease in life expectancy was attributed to an increase in mortality from accidents, poisoning and violence, almost entirely in the age group 15-59. For females new tendencies in this group were also negative, although not as pronounced. Diseases of the respiratory system continued to contribute towards an increase in life expectancy for both males and females. Special attention should be drawn to the group of other and unknown causes which includes mortality cases from numerous chronic diseases. Although the mortality from this group of causes is relatively low, the negative jump in life expectancy in 1990 resulted, from our point of view, from a lack of drugs and inadequate treatment especially of patients suffering from numerous chronic diseases.

Variations in mortality are attributed to two factors: contemporary and historical. Contemporary factors are usually referred to as 'period effects'. In the absence of better data, they are approximated by the current time (calendar year). Historical factors represent the influence of the past on current behavior or experience, and are usually referred to as 'cohort effects'. These occur whenever events in the past have a lasting impact that is felt by most people of the same age range (contemporaries, generation). The method of analysis employed to disentangle contemporary and historical factors is age-period-cohort (APC) analysis.

This work continues and extends a study conducted by Willekens and Scherbov (1991, 1992) where a similar approach was used to study mortality in the former Soviet republics without disaggregation by causes of death.

The following section describes the sources of mortality data in the former Soviet Union, and includes a description of the data collection process (registration system) and a discussion of the quality of data. Section 3 reviews the APC model, including a brief history of APC analysis in mortality, and presents the statistical theory underlying the APC model. Section 4 presents the results of the APC analysis and discusses the contribution of historical and contemporary factors to mortality changes by cause of death in 12 republics of the former USSR. The trend analysis constitutes a basis for a scenario of future mortality. This scenario, presented in Section 5, is moderately optimistic and assumes that the former USSR will escape a social catastrophe. Section 6 concludes the analysis of mortality trends in the former USSR. A large set of tables and figures are included in the appendices.

2. MORTALITY DATA

Data on mortality by cause of death within the period of our consideration were based on doctors' verification or medical assistants' death certificates. The latter were common in urban areas, where most of the medical help was provided not by a medical doctor but by a medical assistant.

The death registration system functions in the following manner: a death certificate is issued by a doctor (medical assistant) to the relatives of the deceased (or to some person close to the deceased). They register the death at the civil registration office. Only the death of a baby

younger than six days is registered by medical personnel.[4] Obviously with such a registration system, under-accounting of deaths occurs mostly at the youngest and oldest ages, especially in the muslim regions.

The proportion of autopsies, especially in rural areas, was not high, but in muslim regions (Central Asia, Azerbaijan, part of Kazakhstan, North Caucasus in the Russia Federation and some other regions of Russia) it was almost negligible. In the Russian Federation it made up 33 percent.

A medical doctor or medical assistant identified the cause of death according to the patient's medical history. But if the time period between the last examination and death was long enough, then the cause of death was determined according to the symptoms described by relatives. Under such circumstances the quality of diagnostics could not be high and most of the researchers used data by wide groups of causes of death.

A number of local studies (Nicolskiy 1979; Ministry of Public Health of Russian Federation 1981) prove substantial over-diagnosis of the most common diseases and primarily of all circulatory diseases. At the same time there was an under-diagnosis of infectious diseases, particularly for children, because high mortality from digestive infections was regarded as a drawback of the health care system.

Another paradoxical example: In order to improve the indicators of activity in oncology clinics, in many regions of the country, cancer was diagnosed only for those deceased who were registered in the oncology clinics.

Another source of error appeared during the encoding of data on mortality by cause of death. The combination of less-qualified people responsible for encoding the data, together with inaccurate initial records (sometimes as a result of an overworked doctor making the report) led to an over-accounting of the most common causes of death. Perhaps that is why the proportion of deaths from numerous chronic diseases (of the endocrine system, of the urine-genital system, etc.) in the USSR was relatively low in comparison with developed countries.

Another aspect of the problem concerns data on population size. In the USSR population size was estimated year by year starting with the last census. The data collected were annual number of births, deaths and migration between republics. But often these data were inaccurately counted which led to an accumulation of errors. They were manifested in discrepancies between the next census results and the results of estimation. Census accuracy is also not ideal, but the census results are in general more realistic except perhaps for the mobile age groups (16-24 years of age). Because of this, there was a revision of intercensus data on population after each census. However, no adjustments of mortality and fertility indicators were conducted as a rule.

In our study we used mortality rates by cause of death, evaluated in the Department of Demography of the Institute of Statistics and Economic Studies of the Russian State Committee on Statistics (these data were partly published in State Committee of the USSR on Statistics 1988, 1989, 1990). A special issue with statistical data was planned to be published but failed due to the dissolution of the USSR.

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[4]The Soviet definition of live birth and infant death differed from the one recommended by WHO and used in developed countries: by Soviet definition those babies who have been in gestation less than 28 weeks or are born weighing under 1000 g and die in less than seven days were excluded from live birth. Russia adopted the WHO definition on January 1, 1993.

Evaluation of mortality rates is based upon the data from the state statistics on mortality for 1980-1990 and the data on population size for the beginning and end of each year. Data on population size for 1980-1988 were adjusted using the results of the 1989 census.

Until 1982 data on mortality by cause of death were classified according to the 7th ICD of WHO. After 1982 classification of mortality by cause was made using the 8th ICD revision. In the grouping of causes of death used in our paper (diseases of the circulatory system; neoplasms; accidents, poisonings and violence; diseases of the respiratory system; infectious and parasitic diseases; diseases of the digestive system and a group of all others and unknown causes) the change in ICD revision denoted that in 1980 and 1981 part of those deaths that later on would be classified as deaths from infectious diseases were classified as deaths from diseases of the digestive system.

First, we considered re-estimating mortality rates for 1980-1981 according to the 8th ICD revision. But we found that the transition to the new ICD revision was not immediate. Virtually in 1982-1986 and perhaps even later, a part of the infectious diseases of the digestive system continued to mask under the diseases of the digestive system. At least from the further analysis of the dynamics of period effects for deaths from diseases of the digestive system and infectious diseases, one can obtain no discontinuity related to the adoption of the new ICD revision. We therefore rejected re-estimation of mortality rates for 1980-1981.

3. THE AGE-PERIOD-COHORT (APC) MODEL[5]

3.1. Introduction

The cohort or generation is an important concept in the study of changes in human behavior and experiences over time. The interest in cohort analysis is particularly large when discontinuities occur in trends. Cohort analysis is expected to reveal and quantify the impact in time of these discontinuities. Mannhein, who introduced the generation concept into sociology in 1928, ascribed growing interest in the generation problem to political discontinuities in the late 19th century. The trends that are studied may relate to social, economic, demographic, health or other variables. As a consequence, cohort analysis is broadly applied. For a general review covering several disciplines, see Hastings and Berry (1979). Hobcraft et al. (1985) review demographic studies; Breslow (1985) and Lidell (1985) discuss cohort analysis in epidemiology; Baltes et al. (1979) address cohort studies in psychology and Attias-Dunfot (1988) presents a comprehensive treatment of the cohort (generation) concept and generation theories in sociology (with at least one major omission, namely the classical article by Ryder published in 1965).

In traditional APC analysis, the contemporary factors are approximated by the current period, and the historical factors are represented by the year or period of birth. Current period and period of birth are not causal factors in the analysis. They are crude indications of the macro-setting that changes over time and in which demographic phenomena are embedded. In the traditional analysis, the demographic rates, measured for a given age group during a given period, are decomposed into an effect of age grouping (age effect), an effect of contemporary factors (period effect) and lasting effect of historical factors experienced by the group of people to which the rate applies (cohort effect). A (birth) cohort is generally defined as a group of people born during the same period; in APC analysis, it is interpreted as a group of people who lived through comparable historical or structural contexts (e.g. depression, war period, period of

[5]This section is based on Willekens and Scherbov (1992).

rapid technological change). They may be referred to as 'contemporaries'. Although the impact of past common experiences remaining at the time of observation is likely to differ for each member of the group, there is probably some effect that is still felt by all members of the group. That effect is the cohort effect. APC analysis attempts to unravel inter-cohort differences and intra-cohort variations.

The APC analysis combines the two viewpoints traditionally distinguished by a demographer when analyzing demographic data. One approach examines changes from year to year. Period analysis, as this approach is known, is particularly useful when rapid changes occur, such as technological or legal changes that directly affect the controllability of demographic processes, or a war or a revolution resulting in transitory behavioral changes such as the postponement of births. The other approach, cohort analysis, is better suited for the study of fundamental changes in behavior such as an increase in health conditions and life expectancy. For a comprehensive treatment of APC analysis in demographic and social research, see Mason and Fienberg (1985).

The traditional APC model is not an explanatory model but a statistical accounting scheme. To interpret the period and cohort effects, one must look for attributes of the historical contexts that brought about the effects; the age effects must be related to attributes of human development over the life-span. The new approach to cohort or APC analysis introduces two major changes. First, it adopts a multilevel perspective: the characteristics of a cohort are aggregated outcomes of the individual behavior of cohort members in the societal and technological contexts. In other words, the effects of contemporary and historical factors on demographic change are mediated by individual characteristics, including the stage in the life course. Second, it adopts a process perspective and calls for longitudinal data to investigate the processes as they evolve.

> Nowadays, dying is rarely a sudden event; it is usually the culmination of a lengthy process during which the individual has suffered to a greater or lesser degree from diseases or handicaps which affect his mortality risk. It is thus a complex process (morbidity), the conclusion of which (death) cannot be studied without taking into account the process which preceded it: the population distribution of morbidity is a prime determinant of mortality risks and in turn the selection effects of mortality determine who survives with a chronic degenerative disease (van Poppel 1990, p. 241).

The modern APC analysis is process-oriented and integrates life course analysis into cohort analysis. The integration signifies that events are simultaneously studied in two time scales: age and historical time. This approach is followed by Caselli and Wunsch among others (see e.g. Caselli et al. 1990).

3.2. APC Analysis of Mortality: A Brief History

Although the impact on mortality trends of intergenerational variations in health was recognized in the 1920s, it was not until the 1970s that the cohort perspective was more generally adopted for the analysis of mortality trends. In general, cohort analysis and APC analysis has been motivated by one of two questions. The first focuses on the regularity of observed patterns and is associated with descriptive research; the second emphasizes the underlying mechanisms causing the regularity and is mainly associated with explanatory and epidemiological research (Hobcraft et al. 1985 make the same distinction; see also Hobcraft and Gilks 1984). The two questions are the following:

a. Does an age distribution of a demographic phenomenon (e.g. mortality) exhibit a greater regularity when presented for a cohort than for a particular period? The age profile

exhibited by period data confounds the effect of generational differences. This question is particularly relevant for demographic forecasting.

b. Do events and experiences early in life affect experiences later in life? In this perspective, cohort analysis derives its importance from the plausibility of biological mechanisms rather than from the use in forecasting.

According to Hobcraft et al. (1985, p. 103), Derrick (1927) was the first to argue that cohorts provided a more consistent basis for projecting mortality than did period rates. The conclusion was based on a graphical examination of the logarithms of age-specific death rates for England and Wales from 1841 to 1925, omitting the experience of World War I, which indicated that the ratio of mortality for one cohort to that of another cohort was approximately constant for all ages above 10. Caselli and Capocaccia (1989), however, review a study published in 1912 by Mortana, in which he studied the presence of possible selection effects in infancy on mortality at old ages. Pollard (1987, p. 58) lists studies which found that generation curves exhibit a greater degree of regularity. These studies are published in the 1920s and 1930s; in recent times, this regularity has not been observed to the same extent. Manton (n.d., p. 31) reports that period mortality schedules tend to overestimate cohort mortality rates. This is particularly so when part of the cohort is eradicated by a war. Since relatively healthy persons are selected for active service, they suffer great losses, while less healthy people are more likely to survive. This adverse selection leads to an overestimation of true mortality some decades later (Dinkel 1985, p. 95). The selection is also in effect when mortality is studied by cause of death.

Explanatory research into the mechanisms underlying changes in mortality patterns focus on the impact of early experience on subsequent behavior. Kermack et al. (1934), studying time series of death rates of England, Scotland and Sweden, argued that the cohort differences in mortality were not a consequence of a series of independent conditions affecting successively older ages; instead, the health of a cohort was principally determined by environmental conditions encountered in its first 15 years of life. The authors also found that improvements in early childhood mortality followed mortality improvements in ages of maternity. They argued that early childhood mortality was closely linked to the health and physique of mothers. Kermack et al. adopted the life course perspective on cohort analysis long before it became popular in the 1980s when individual-level data became available. Preston and Van de Walle (1978), studying French data, and Caselli and Capocaccia (1989), using Italian data, demonstrated a positive relation between infant and child mortality and adult or old-age mortality (weakening effect). Others, however, stressed that high infant and child mortality result in lower mortality at higher ages because of a selection effect (e.g. Manton et al. 1981).

The introduction of cohort analysis in public health is generally attributed to Andvord (1921, 1930) and Frost (1939), who showed that apparent changes in age-specific rates of mortality from tuberculosis (TB) could be viewed as translations of declining TB mortality across cohorts with a relatively constant age profile of TB mortality. The authors believed that the TB infection occurred early in life and that the disease has a highly variable incubation period, tending to the lengthy (see Mason and Smith 1985, p. 155). This implies that differences in infection rates in childhood largely determine differences in cohort experience. The authors suggested that, in the absence of effective chemotherapy, successive cohorts moved through life as though they had different probabilities of dying from TB assigned at birth. McKeown (1976), who has carried out one of the most authoritative research into causes of decline in mortality from micro-organisms, argues in the case of TB that changes in the probabilities of dying from TB are preceded and caused by improved nutrition (for a discussion, see Mason and Smith 1985, pp. 156ff.). A major contribution of the study was the demonstration that the age distribution of mortality from TB was constant (regular) in cohorts rather than in periods and that period analysis may lead to erroneous conclusions.

Case (1956) adopted a cohort perspective in the study of lung cancer in England and Wales for the period 1911-1954. The importance of cohort effects rested on the plausibility of biological mechanisms rather than on statistical tests. Case argued that the fact that successively younger cohorts were smoking cigarettes more heavily caused the cohort effects. Other references are listed in the bibliography and Appendix D.

A major research preoccupation of those European countries which were actively involved in World Wars I and II was examining the health and mortality situation at advanced ages of men who saw active service. The studies revealed two major findings. First, it has been shown in France, Italy and the Federal Republic of Germany that male cohorts which participated in World War I subsequently experienced higher mortality than adjacent cohorts who were not involved in the conflict. Second, in Italy and the Federal Republic of Germany, the same excess mortality has been detected among those who were born or were adolescent during the war years (Vallin 1973, 1984 (France); Horiuchi 1983 (Federal Republic of Germany); Caselli and Capocaccia, 1989 (Italy); Caselli et al., 1986 (Italy and France)). Boleslawski (1985) found a similar impact of World Wars I and II in Poland. In France, no notable weakening of the cohorts born during the World Wars was found (Wilmoth et al. 1988, p. 16). Anderson and Silver (1989) studied mortality data from the Soviet Union from 1958-59 to 1986-87 and found that males and females who were born during World War II and males who were adolescent during that time experienced significantly higher mortality as they aged than would have been expected on the basis of their age at a given time and the overall mortality conditions of the given period. The prolonged mortality effect on those who were adolescent during the war is attributed to the lasting effect of malnutrition on cardiovascular development (Horiuchi 1983).

Caselli (1990) reports a remarkable observation for Italy. Very high levels of excess male mortality are found in the late 1960s for cohorts born during or just before World War I. She speculates that better living conditions allow more individuals to survive and make them more resistant to death until around age 50 (Caselli 1990, pp. 239 and 245). In the Soviet Union, the rise in mortality of males in the working ages in the 1960s was attributed to World War II (Bedny and other Soviet scholars, quoted in Anderson and Silver 1989, p. 477). Dinkel (1985) also suggested that the increase in male mortality in the 1960s might be attributed to the weakening effects of World War II. Anderson and Silver are reluctant for such an interpretation of the cohort mortality estimates because they can trace at most only 30 years of the mortality experience of any cohort (Anderson and Silver 1989, p. 492).

3.3. Statistical Theory

The statistical theory of APC models is of a recent date. According to Hobcraft et al. (1985), the first properly identified APC model was specified by Greenberg et al. (1950). The age effects were parameterized through a beta distribution. The first author to make the linear identification constraint explicit was Beard (1963). Examples of APC analysis of mortality trends include Barrett (1973, 1980), Osmond and Gardner (1982), Osmond et al. (1982), Tu and Chuang (1983), Geddes et al. (1985), Mason and Smith (1985), etc. The state-of-the-art in the mid-1980s of the statistical theory of the APC model was discussed by several authors in the book edited by Mason and Fienberg (1985).

The application of an APC model to a time series of age-specific data raises a statistical problem, which is known as the identification problem and which received much attention in the literature. When the data are presented in an age-period table, as is common in APC studies, the cohort cannot unambiguously be identified. For instance, a 20-year old person who experiences an event in 1991, is born in 1970 or 1971. If the event occurs before the birthday, the person is born in 1970. The person belongs to the 1971 birth cohort, however, if the event

occurs after the birthday. The cohort effect cannot uniquely be determined since the cohort is not properly measured. All that can be estimated is the difference between cohort effects. The problem is known as the identification problem. The identification problem is solved by equating two cohort effects or fixing a cohort effect to a given value (aliasing). Analogously, a person born in 1971 experiencing an event in 1991, may be either 19 years of age (if the event occurs before the birthday) or 20 years (if the event occurs after the birthday). If the data are arranged by year of occurrence of the event and year of birth, the age effect cannot be fully disentangled. The reason is not the linear relationship between age, period and cohort, as is suggested in most of the literature, but the inadequate measurement of age, period and cohort (see Willekens and Baydar 1986; Robertson and Boyle 1986; Osmond and Gardner 1989). The measurement problem may be demonstrated graphically with the Lexis diagram (see Appendix C). The identification problem may be removed by

a. proper measurement of the timing of the event (date of occurrence, date of birth and age),
b. combining ages, cohorts or periods such that the number of effects to be determined reduces compared to the number of observations,
c. imposing restrictions on the values of the parameters (identification specifications),
d. substituting the age, period and/or cohort variables by other (better) proxies of life cycle stage, contemporary factors and historical factors, respectively.

The first approach was used by Willekens and Baydar (1986) and Robertson and Boyle (1986). The second approach is adopted in this paper. The third approach is followed in much of the traditional APC analysis (for a review, see Willekens and Baydar 1986). The fourth approach is applied by Heckman and Robb (1985) and Blossfeld (1986) among others. The fourth approach is to be preferred if data permit.

In this paper, the APC model is presented as a special case of a generalized linear model (GLM). A similar approach was adopted by Willekens and Baydar (1986). The number of deaths is a random variable associated with a stochastic process. Model fitting consists of three interrelated steps, following McCullagh and Nelder (1983):

(i) Model Selection (model specification or identification)
The model relates the outcome of the random process to the parameters of the process. The outcome is the number of events (deaths) in a particular interval, or any function of number of events. In this paper, we study the trend in death rates, defined as the ratio of the numbers of deaths and population at risk. The number and types of parameters are determined by the type of data that are available. One parameter is associated with each age, cohort and period.

(ii) Parameter Estimation
Given the model, we have to estimate the parameters from the data and obtain some measure of the accuracy with which we have estimated them.

(iii) Prediction
Prediction is concerned with the outcome of the actual random variable. Prediction is commonly thought of in the context of forecasting a future value of a variable. However, prediction is wider in scope and is used to indicate that the value assigned to a random variable is to be determined.

3.4. Model Selection

Models that we select to represent the data belong to the family of generalized linear models. An important characteristic of GLMs is that they assume independent observations. In case of non-independence, the variances will be larger than in the case of independent observations. It is assumed that deaths are generated by a Poisson process, hence the observed numbers of deaths follow a Poisson distribution. The Poisson assumption is justified when the death rate is low. In that case, the Poisson distribution is an adequate approximation of the binomial distribution, which describes binary response data (e.g. deaths/survivors) (McCullagh and Nelder 1983, p. 74). The assumption that the number of deaths is an outcome of a Poisson process, has become widely accepted in the literature and is implicit in the log-linear analysis of mortality rates (see e.g. Holford 1980; Laird and Olivier 1981; Frome 1983, with a discussion by Nelder 1984; Egidi et al. 1990).

The dependent variable is the death rate, which is the ratio of the number of deaths and the total duration during which the population is exposed to the risk of dying. Since the exposure varies with the death rate, both the numerator and the denominator of the death rate are random variables and are interdependent. The dependence complicates the analysis substantially. Therefore, it is generally assumed that the denominator is fixed, i.e. independent of the number of deaths. If the death rate is small, the assumption is realistic. For a discussion of the issue, see Hoem (1984, pp. 41ff.) and Breslow and Day (1985, p. 57).

A major problem in model selection is the choice of variables to be included in the systematic part of the model. The strategy adopted in this paper is to associate one parameter with each age, period and cohort category.

Let n_{xtc} denote the observed numbers of deaths of age x, period t and cohort c. Let N_{xtc} denote independent random variables having Poisson distribution with positive parameter λ_{xtc}. λ_{xtc} is the product of the death rate and the duration of exposure to the risk of dying in year t by individuals of age x and cohort c, which is assumed to be fixed (L_{xtc}). The true value consists of two components: a systematic component, predicted by the model to be specified, and a random component. To be precise, the random component must be separated into two parts. One is a part due to our ignorance, i.e. the absence of a complete observation; the other part is due to the fact that the outcome of any random process is inherently uncertain even if we have all the necessary data to predict the outcome. No distinction between the two parts is made in this paper.

Let λ_{xtc} denote the systematic component and ε_{xtc} the random component. The model is:

$$n_{xtc} = \lambda_{xtc} + \varepsilon_{xtc} \qquad (1)$$

with $E(n_{xtc}) = \lambda_{xtc}$
$E(\varepsilon_{xtc}) = 0.$

3.4.1. The Systematic Component

The parameter λ_{xtc} of the Poisson distribution is assumed to satisfy a model that is loglinear in a set Θ of unknown parameters. One parameter is associated with each of the ages, cohorts and periods. The systematic component is

$$\lambda_{xtc} = L_{xct}\, \alpha_x\, \beta_t\, \tau_c \qquad (2)$$

where $\Theta = \{\alpha_x, \beta_t, \tau_c\}$ and L_{xct} is the duration of exposure assumed to be given. Model (2) is the multiplicative formulation of the log-linear model. The additive formulation is obtained by taking the natural logarithm of both sides. In that case, the ln of the dependent variable is linear in the parameters.

The unknown parameters must be determined from the data. That involves (i) writing the probability density of the outcomes of N_{xtc}, which gives the probability of observing any of the possible values of N_{xtc}, n_{xtc} say, given the model and data, and (ii) maximizing that probability. The maximum likelihood estimation of the parameters will be discussed after the presentation of the random component.

3.4.2. The Random Component

The independence and Poisson assumptions imply that the random variable N follows a Poisson distribution and that the probability of exactly n_{xtc} deaths in year t of persons of age x and cohort c, is given by the probability density function

$$Pr(N_{xtc}=n_{xtc}) = \exp[-\lambda_{xtc}]\lambda_{xtc}^{n_{xtc}}/n_{xtc}! \qquad (3)$$

The Poisson distribution (3) is a member of the family of exponential probability density functions (McCullagh and Nelder 1983). To show this, we rewrite (3) as follows

$$\Pr(N_{xtc}=n_{xtc}) = \exp[n_{xtc}\ln\lambda_{xtc} - \lambda_{xtc} - \ln n_{xtc}!] \qquad (4)$$

Since the Poisson distribution is a member of the exponential family and the logarithmic transformation of the systematic component is linear in the parameters Θ, it is possible to estimate the parameters of the distribution by maximizing the likelihood of the parameters with respect to the observations on the random variable. We now proceed with the estimation.

3.5. Parameter Estimation

The parameters Θ are estimated by maximizing the likelihood of the outcomes of the independent Poisson processes, given the model (2) and the data. Since the logarithm is a monotonous increasing function, maximization of the log-likelihood is equivalent to maximization of the original likelihood. For a single observation n_{xtc}, the contribution to the likelihood is $n_{xtc}\ln\lambda_{xtc} - \lambda_{xtc}$. The log-likelihood of a set of observed flows n_{xtc}, where each flow is the outcome of a Poisson process with parameter λ_{xtc}, is:

$$L = \sum_{xtc}[n_{xtc}\ln\lambda_{xtc} - \lambda_{xtc} - \ln n_{xtc}!] \qquad (5)$$

The maximization is not affected by the last term of (5), which may therefore be omitted.

If the model would perfectly predict the outcome of N_{xtc}, i.e. the maximum likelihood estimates are equal to the observations themselves ($\lambda_{xtc} = n_{xtc}$ and $\varepsilon_{xtc} = 0$), the likelihood is the maximum achievable, which is generally finite. To evaluate the goodness of fit of the model, we compare the likelihood achieved by the current model to the maximum of the likelihood achievable (i.e. the likelihood achieved by the full model). The logarithm of the ratio is known as the scaled

deviance (see e.g. McCullagh and Nelder 1983, pp. 24-25; GLIM Manual). The deviance is proportional to twice the difference between the log likelihoods:

$$S(n,\lambda) = -2 \ln [L(\lambda,n)/L(n,n)]$$

$$= 2 [\ln L(n,n) - \ln L(\lambda,n)]$$

Large values of S indicate low values of $L(\lambda,n)$ relative to the full model, increasing lack of fit. For the Poisson distribution, the deviance is

$$S(n,\lambda) = 2 \sum_{xtc} [n_{xtc} \ln (n_{xtc}/\lambda_{xtc}) - (n_{xtc} - \lambda_{xtc})] \quad (6)$$

If a constant term ϕ, which is known as the nuisance parameter, is included in the model it is generally the case that $\Sigma(n_{xtc} - \lambda_{xtc}) = 0$ so that

$$D(n,\lambda) = S(n,\lambda)\, \phi$$

may be written in the more usual form of the log-likelihood ratio which is often used as a test in the analysis of contingency tables

$$D(n,\lambda) = 2 \sum_{xtc} n_{xtc} \ln (n_{xtc} / \lambda_{xtc}) \quad (7)$$

In order to determine the unknown Θ parameters with maximum likelihood, we need to maximize the log-likelihood function with respect to the parameters. This results in a set of normal equations which need to be solved for the unknown parameters. The GLIM package, which uses generalized weighted least square, was applied. The weights are inversely related to the variances of the estimates. The algorithm uses the Fisher's scoring method. If the model is log-linear, the scoring method and the Newton-Raphson method reduce to the same algorithm (McCullagh and Nelder 1983, p. 33; Aitken et al. 1989, pp. 324ff.).

3.6. Prediction

The most probable number of deaths that are consistent with the available data and the model are given by the expected values of the N_{xtc}, which is λ_{xtc}. The expected death rate may be written as follows:

$$\lambda_{xtc}/L_{xtc} = \kappa\, \alpha_x\, \beta_t\, \tau_c \quad (8)$$

where the parameters are restricted

$\alpha_1 = 1$, $\beta_t = 1$ and $\tau_c = 1$.

Alternative restrictions may be used.

4. PATTERN OF RECENT MORTALITY CHANGE

4.1. APC Analysis

The age-period-cohort model was applied to a time series of mortality rates by age, sex and cause of death for 12 former Soviet republics. The following groups of causes of death were selected: diseases of the circulatory system; neoplasms; accidents, poisonings and violence;

diseases of the respiratory system; infectious and parasitic diseases; diseases of the digestive system and a group of all others and unknown causes. Data for each cause of death were processed separately. Data on male and female mortality were also processed independently.

The data were available for age groups of five years, for the years 1980 to 1990. Several specifications of the APC model were tested. The final model included the following effects:

- age (17 age groups: below 1, 1-4, 5-9,...75-79),
- period (11 calendar years 1980-1990),
- cohort (2 cohorts[6]: those born before 1941 and those born after),
- region (12 former Soviet republics), and
- interaction effect between age and region and between period and region.

The interaction effect between age and region allows to consider regional differences of age specific mortality; the interaction between period and region quantify regional differences in overall mortality trends.

Computational results of the model are shown in Figures 1-16 (later on all Figures refer to Appendix B if not specially denoted). In order to keep the graphical data presentation to manageable proportions, the republics were divided into two groups taking into account the similarity of the processes. In fact the majority of the republics with muslim population comprised the second group and with non-muslim population the first group.

The aim of trend analysis is to identify major trends and deviations from trends. Significant fluctuations should be separated from random fluctuations. Some of the short-term variations in mortality rates are removed if (i) the years are grouped and the APC model distinguishes a period or cohort parameter for each cluster of years instead of for each year, or (ii) the temporal variation in (annual) period effects is parameterized. To parameterize period effects, a trend model may be used. Short-term variations may also be removed by smoothing the data. Data smoothing should however not remove the peculiarity of the process studied.

To obtain a general evaluation of the APC model for each sex and group of causes of deaths we calculated the coefficient of determination (R^2) - the share of variance of original data accounted by the APC model (Table 1a). This indicator reached the minimum value of 0.936 for males (diseases of the digestive system) and 0.921 for females (accidents, poisonings and violence), indicating a rather high quality of model approximation to empirical data. In general this estimate is close to similar estimates obtained by Anderson and Silver (1989).

Though the model accounted for 12 regions simultaneously, we found it informative to evaluate the accuracy of modelling regional data (Table 1a) using R-squared criteria for each of the republics. The absolute minimum of this indicator constituted 0.759 (Tajikistan, male, diseases of the digestive system), followed by 0.771 (Tajikistan, female, diseases of the digestive system).

To evaluate the goodness of fit for each republic from all causes we introduced the following index of approximation:

[6]The length of the time series did not allow to introduce more cohorts.

$$I^r = \sum_{i=1}^{7} \frac{1}{R_i^0} R_i^r$$

where R_i^r is the determination coefficient for republic r and cause i and $R_i^\bullet$ for all sets of republics and cause i. The best quality of approximation (Table 1b) was thus obtained for Russia, Ukraine and Byelorussia, the worst for the Central Asian republics (excluding Kirghizia) and Azerbaijan.

Linear correlation coefficients of period effects and period life expectancy for each republic and sex are shown in Table 2. Only in Armenia is this indicator lower than 0.8, in more than half of the cases it is higher than 0.9 and in one-third of the cases it is higher than 0.95. This helps to draw the conclusion that estimated period effects describe mortality level almost as well as classic period life expectancy.

4.2. Discussion

The decade 1980-1990 was a period of major events in the former USSR: the Chernobil catastrophe, the earthquake in Armenia, the continuation and end of the Afghanistan war, ethnic conflicts, especially the Armenia-Azerbaijan conflict, and intensive political processes that led to the dissolution of the USSR. To what extent are some of these events reflected in the results of our analysis? Not too much. One can distinctly see only the earthquake in Spitak and the anti-alcohol campaign in 1985. The first event was distinguished by an enormous increase in mortality from accidents and injuries; the second resulted in mortality decrease.

Let us look at the results of the APC analysis presented in Figures 1-16. Each figure corresponds to a particular gender and cause of death. It contains six graphs: standardized regional effects, age effects for Russia, age effects for each of the republics relative to Russia's age effects, and period effects. Relative age effects and period effects are presented for each of the two groups of republics.

Russian age effects were calculated by multiplying the age effects for Russia obtained from the APC model by the APC overall effect and regional effect for Russia. In the same way the age effects for the rest of the republics were obtained and later on they were divided by Russian ones to obtain relative age effects. Period effects were directly taken from the APC model. To evaluate standardized regional effects we used the above-described age effects and UN standard age distribution.

According to standardized regional effects which may serve as an indicator that averages mortality during the decade, males living in Russia and Turkmenia hold a "leading" position in overall mortality closely followed by males from Kazakhstan (a considerable part of whom are ethnic Russians). For females a "leading" position is kept by women living in Turkmenia followed by women from Tajikistan and Moldavia.

Examining age effects one can immediately understand why the males from Russia maintain the "leading" position in mortality. Starting from about 15 years of age (on the line graphs each data point corresponds to the age interval which lies to the right of that point) all republics have mortality age effects lower than the Russian ones, though at younger ages the situation in Russia is not so bad if compared to other republics. Age effect for the second age interval (1-4 years)

in the second group which is comprised mostly of muslim republics in several cases is more than five times higher than in Russia.

Correlation of the period effects with time (trend model) allows us to estimate the mortality trend (Table 3). For all of the republics except Armenia this correlation is negative for all causes of death, which supports the general tendency in the decade towards mortality decline. The only republic whose correlation is positive is Armenia. But that is the result of the earthquake in 1988.

The decade is distinguished by a stable decline of mortality from most of the selected groups of causes of death except neoplasms, diseases of the circulatory system, and the group of all others and unknown causes. Mortality from diseases of the circulatory system showed a stable trend towards the growth in Armenia, and a distinct tendency towards decline in Russia, Ukraine and Moldavia. For females the stable growth was also observed in Uzbekistan. Mortality increase from neoplasms was observed in all the republics except Azerbaijan and Turkmenia. In Georgia and Tajikistan the general trend was not that clearly pronounced.

The natural trend of declining mortality from the causes of death defined by the group accidents, poisonings and violence is displayed for males in all the republics, except, apparently, Armenia, who experienced one jump in period effect in 1988. Russian males keep an exceptional "leadership" in deaths from this cause (Figure 7). For females, besides Armenia there was a slight growth in Turkmenia and stability in Byelorussia. Male mortality decline from diseases of the respiratory system was manifested in all the republics and from diseases of the digestive system everywhere except Tajikistan. Female mortality from diseases of the respiratory system also constantly declined. But in the trends in mortality from diseases of the digestive system the republics were divided. Pronounced decline was observed in Kazakhstan and increase in Kirghizia. Generally speaking, the graphs show the low level of diagnostics for this group of diseases.

Mortality increase from infectious and parasitic diseases was observed in Uzbekistan (though very inconsecutive) and in Turkmenia, where the mortality level from this group of causes of death is rather high. Somehow Turkmenia is located in the area of ecological catastrophe, and high mortality from this group of causes is obviously caused by the lack of clean water. However one should not neglect that the high mortality level from epidemic hepatitis is an artifact that reflects high mortality from chemical affection of the liver (e.g. in Moldavia).

Mortality from causes in the group of all others and unknown causes increased in general everywhere except Azerbaijan. But the dynamics of death rates in different age categories was so irregular that we refused attempts to make mortality projections for this group of causes (Figure 17).

For the regional feature of mortality dynamics a considerable concern is caused by the situation in Byelorussia and Ukraine. Rapid mortality increase from neoplasms and the causes that fall into the category all others and unknown causes may be associated with the consequences of the Chernobil catastrophe. However for a deeper conclusion a detailed regional analysis of mortality by 30-40 causes of deaths should be conducted. But this was not the aim of our study.

Mortality dynamics for males and females from each particular group of causes virtually coincide. This is confirmed by the correlation coefficients that comprise the diagonal in Table 4. Other correlations in Table 5 in most cases reflect trends that have been already identified. Attention may be attracted by the negative correlation of the mortality trend from infectious and parasitic diseases on the one hand and digestive system diseases on the other (-0.4 for males and -0.6 for

females). In 1981 the USSR adopted nine revisions of ICD, and part of the deaths that were previously classified as digestive system diseases starting from that year had to be counted as infectious diseases that apparently did not happen synchronous.

In general a remarkable stability of the overall mortality level in respect to the endogenous impacts should be denoted in the USSR on the one hand and significant fluctuations of the mortality level from a particular cause such as infectious and parasitic diseases, digestive system diseases and the group of all others and unknown causes on the other.

Influenza and digestive infection epidemics are possible reasons of mortality fluctuations. Unfortunately we did not have the data on morbidity that in the USSR as well as in many other countries is unreliable. Therefore we decided to use an indirect indicator of epidemiological conditions in a region within the calendar year. This indicator is an index of mortality seasonal fluctuations. The index was evaluated as a mean relative deviation of monthly number of deaths within the year from the mean for 13 consecutive months that include as the 7-th the current month. Strictly speaking

$$I^e = \frac{1}{12} \sum_{i=1}^{12} \frac{M_i - \bar{M}_i}{\bar{M}_i}$$

where M_i - the number of deaths in i-th month, i = 1,2,...12.

$$\bar{M}_i = \frac{1}{13} \sum_{k=-6}^{6} M_{i+k}$$

where -1 should be regarded as December of the previous year, -2 November, etc. The values of i equal to 13, 14, .. etc. denote January, February, etc., of the subsequent year.

Tables 6 and 7 present correlation coefficients between the indexes of seasonable fluctuations and period effects for all former Soviet republics for each cause of death.

As one can observe from the table, the reasonable level of positive correlation is obtained for the group accidents, poisonings and violence and the group of diseases of the circulatory system. The first correlation to a high extent was predefined by the earthquake in Armenia. But it is not clear what were the real reasons that defined the mortality growth from accidents during the years of instability in monthly dynamics for females in Uzbekistan (correlation coefficient 0.62) or for males and females in Moldavia (correlation coefficients 0.49 and 0.66, respectively).

Seasonal increases in mortality in most of the European republics are strongly pronounced in increases in mortality from diseases of the circulatory system and less pronounced in mortality from respiratory system and infectious diseases. Correlations in the line for digestive system diseases suggest the absence of reliable information on digestive infections because that is the only reason that explains the high correlation of mortality from this group of causes of death with seasonal increases of mortality in Russia, Moldavia, Kazakhstan, Azerbaijan, Tajikistan, Georgia, Turkmenia and Uzbekistan.

To sum up, we can say that the obtained data prove the negative influence of influenza epidemics upon the level of mortality from diseases of the circulatory system, and bring doubt

to the correct diagnoses of diseases of the digestive system and infections in a number of regions of the former USSR.

5. MORTALITY SCENARIO

5.1. Introduction

When projecting mortality, one explicitly or implicitly uses a projection scenario. An analysis of mortality dynamics in the former USSR under conditions of grave economic, social and political crises may convince the researcher to concentrate his attention on the most recent three-year period and to build his projections on the assumption of a rising socio-economic cataclysm. But this type of research is rather useless.

Cautious projections could be elaborated by simply extrapolating current trends which may be justified if one needs to attract attention and to demonstrate that together with economic crises, a demographic crisis is also developing. But that was already understood in the West and in the former USSR.

In our case the projection precaution could not correspond to real mortality dynamics. If the critical tendencies could not be mastered in 1992 or at least in 1993, Russia and other former Soviet republics will be facing either a new totalitarian dictatorship or a civil war, or both. And to anticipate mortality trends in this situation would be worthless.

Thus we tried to build a moderately optimistic projection variant, by default assuming that the former USSR could escape social catastrophe. In our projection we tried to consider the whole period 1980-1990, and if we gave preferences to the most recent years, the weights for that data never point to more than twice as big as the weights for the period 1980-1985. The last assumption is an important element in building our projection scenario that would be further strictly formalized.

Another assumption in our projection scenario is to retain in the future common features in mortality trends for all former Soviet republics. That accompanies the hypothesis on preserving economic and demographic ties (freedom of movement, civilized interregional migration, marriages, etc.) between the former republics. In fact that is another side to our assumption on the possibility of escaping disastrous developments of events. A rapid break of interrepublican relations today, to our minds, may come as a result of social cataclysm or one of the main causes of such a tragedy.

Taking into account these two hypotheses we selected a projection algorithm. We tried to perform projections for each of the seven selected groups of causes of death, and then summed them up to obtain the overall mortality projection.

5.2. Selection of Projection Method

Having ten years of mortality dynamics data, successful projections were difficult using standard methods. From a statistical point of view, having data for a decade allows some justified conclusions on future mortality dynamics for not more than 2-3 years.

We had to find a numerical procedure that allowed us to use in our projections the similarity of the processes in all or at least in most of the republics. The standard methods, based on the approximation of the series by some function of time (linear, exponential, polynomial, etc.) with

subsequent extrapolation did not allow us to implement this idea, though one can imagine a model where one set of parameters is common for all the republics and another set adds the specific features for each republic, thus implementing the hypothesis on a common for all regions' overall mortality dynamics with different starting conditions.

But in our analysis we decided, after a number of numerical tests, to use the following equation:

$$P^r_{t+1}=\sum_{i=0}^{k} a_i \, P^r_{t-i}$$

where P^r_t are the estimates of the period effects in year t and in region r, and a_i equation coefficients.

The use of a finite difference equation is equivalent to the hypothesis that dynamics of period effects are described by a differential equation of **k+1** order. Taking into account the length of the time interval we selected an equation of the second order (k=1). It would be ideal to estimate parameters $\mathbf{a_0}$ and $\mathbf{a_1}$ simultaneously assuming that they are the same for all the republics. Another ideal situation would be to give no preferences for the time intervals within the decade of available data. But in this case we would ignore the real heterogeneity of mortality developments in the republics as well as real shifts in mortality trends. In practice that resulted in a big error of approximation in some cases compared to the levels of indicators with the maximum of the errors corresponding to the year 1990. Naturally that made the value of a projection doubtful.

Analysis of mortality dynamics showed that to reduce the errors of approximation and to obtain satisfactory results, it was sufficient to break down all the republics into two groups with six republics in each group (a slightly different subdivision was performed for mortality projections from the causes of death associated with accidents, poisonings and violence, but we will discuss this issue later on). One could find more sophisticated methods for grouping the republics, but under the risk of being called russia-centrists, we divided the republics into two groups by the similarity of the mortality process in each compared to the Russian republics (Table 8). To create the groups we used the distribution of correlation coefficients for period effects in each of the republics with Russia's period effect.

Another question: should all data for the period 1980-1990 equally participate in estimation of parameters $\mathbf{a_1}$ and $\mathbf{a_2}$? Can we claim that a scenario is good enough if the maximum approximation error corresponds to 1990? The idea to introduce weights is not a new one, but by manipulating the weights one may obtain any desirable result.

Thus we allowed for minimum and maximum weights to differ not more than twice. A natural assumption that the weights are growing with time was also accepted. The weights grew as a geometrical progression with a ratio selected from 1 to 1.1. A particular ratio was selected in the following way: We projected a period effect for the year 1990 using data for 1980-1989. Parameters $\mathbf{a_0}$ and $\mathbf{a_1}$ as well as a geometric progression ratio were obtained as least squares estimates (Figure 18).

After this procedure was defined we did no interference in order to fit the results of the projection to our own a priori judgment. The only group of causes of death where we did interfere was accidents, poisonings and violence, because data on mortality from the accidents for Armenia in 1988 should have been excluded from the model. We faced the problem of how

to define the groups of republics for these specific causes, and where to allocate Armenia. Using our approach for the best approximation for 1990 we have chosen two unequal groups with seven and four republics and placed Armenia in the second group.

Mean relative errors of approximation series of $\mathbf{P}_t^r$ using a finite difference equation (Table 9) demonstrate high precision of fitting.

As one can observe from Tables 1 and 9, mortality from the group of causes "all others and unknown causes" is well described by the APC model and also gives good results in projections for 1990 based on 1980-1989 data. But at the same time this group of diseases is very heterogeneous. On the one hand, this group includes major causes of prenatal mortality and newborn anomalies, and on the other diseases of the urine-genital system, endocrine system, etc. Thus it could have been expected in advance that mortality projections for this group of causes would have complications.

First of all mortality trends for younger ages (0-14) and older than 50 were very different. That forced us to repeat all calculations again but independently for both age categories. But even this did not simplify our job. As a matter of a fact in some of the republics considerable mortality increase from this group of causes of death was observed for the elderly only in 1990, and was not associated with previous history. In the other age groups mortality remained stable (Figure 17). Having too little information for any scientific conclusion in our projections we left mortality from this group of causes unchanged.

5.3. Results of the Projection

The results of our projections (Table 10) in general seem to look rather optimistic. For almost all the republics life expectancy will grow by the year 2000. At the same time in most non-muslim republics (Armenia, Byelorussia, Georgia, Moldavia, Ukraine) that comprise group 1, until 1995 infant mortality death rate is expected to increase (Tables 11 and 12). Between the other "notable" negative shifts we can indicate a mortality increase from neoplasms in the European republics and from diseases of the circulatory system in Central Asia.

The results in Tables 12 and 13 were obtained using methods of component analysis (Andreev 1982). Apparently the results (Table 13) are presented with too high precision. No one can project life expectancy with two numbers after the decimal point. But in this way one can better see the logic of projections.

To evaluate the dynamics of age-specific mortality rates let us examine Figures 19-30, where typical mortality curves are depicted. The projected decline in mortality from accidents, poisonings and violence logically extends age-specific trends in Europe as well as in Asia.

There is no disapproval of projected mortality dynamics from the most important group of causes of death - diseases of the circulatory system (Figures 21 -24), though some irregularity in female projected mortality for the age group 45-49 in Kazakhstan and Georgia attracts attention. But these are the consequences of a chosen method for projection (autocorrelation fluctuations).

Mortality increase from neoplasm in the European region (Figure 25) unfortunately very naturally extends real trends in all age cohorts. Decline of mortality from this group of causes in Asia (Figure 26) reflects the trend of period effects, and is not very distinct. Mortality decline from diseases of the respiratory system is explicit in all age groups both in the European and Asian republics (Figures 27 and 28).

Mortality dynamics from the group digestive system diseases gives some optimism (which continues recent trends) in Moldavia, where mortality from this group of causes holds a substantial share in total mortality. Projected mortality from this group of causes in Asia (Figure 30) is subjected to fluctuations and as we mentioned earlier brings some skepticism for the quality of diagnostics. As far as infections are concerned (we did not show the picture), the mortality dynamics here are very similar to mortality from respiratory diseases.

5.4. What If Our Projection Comes True?

If our rather optimistic projection comes true, then Russia and Turkmenia will retain last place in male life expectancy (next in line at the bottom of the list will be Kazakhstan, where today life expectancy is less than in Russia, but due to rapid decline of exogenous mortality it may become higher) (Figure 31).

For females, in spite of a considerable increase, the lowest life expectancy will remain in Turkmenia and Moldavia (Figure 32). The males of Caucasus will keep ahead, as will the females of Georgia, Azerbaijan and Byelorussia.

The largest difference between male and female life expectancy (Figure 33) will remain in Russia, Ukraine, Byelorussia and Kazakhstan and the smallest will be in Uzbekistan and Tajikistan.

The map of dynamics of life expectancy (Figures 34 and 35) shows that the maximum growth in life expectancy could be anticipated in muslim republics, as a result of mortality decline from exogenous causes of death. The change in overall life expectancy may be decomposed into changes related to the various causes. Figures 36 and 37 show the changes in life expectancy between 1990 and 2000 that may be attributed to expected changes in mortality due to neoplasms. We do not expect a mortality increase due to neoplasms.

Considerable growth of life expectancy in 1960-70 in the West was associated with the decline of mortality from diseases of the circulatory system. Unfortunately, our optimistic projection does not yet predict any shifts in this direction (Figures 38 and 39).

6. CONCLUSION

The most recent data on mortality by sex and causes of death for the former Soviet republics were considered in the paper. A first attempt of applying an APC approach to these mortality data by cause of death showed the applicability of a chosen method for interpretation of mortality trends for our data. It was shown that despite the social tension in this country the mortality from most causes of death decreased, though the trends towards mortality decline within the period was uneven. The consequences of such events as the anti-alcohol campaign, the earthquake in Armenia and the Chernobil catastrophe were obtained as a result of our analysis.

For projection of mortality trends up to the year 2000 we assumed that no social or other global cataclysms will take place. Under this assumption we extrapolated mortality trends of the 1980s using an autoregressive model separately for each cause. Obtained results predict a general decline of mortality from most causes of death under consideration except neoplasms and chronic diseases that are included in the group "other causes". Mortality from neoplasms showed stable increase. Due to extreme instability of mortality from the causes of death that comprise the group "others and unknown causes", projection for this group was not performed, and for

projection of mortality for all causes of death we took an unchanged level of mortality from this group of causes corresponding to the observed rates of 1990.

According to our projection, life expectancy in all of the former USSR republics except Armenia will increase by the year 2000 approximately by 1 year for males and females. The maximum increase of life expectancy may be anticipated in the Central Asian republics as a result of mortality decline from exogenous causes of death.

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APPENDIX A. Historical Decomposition of Changes in Life Expectancy (Figures 1-14)

Figure 1. All causes, USSR, male.

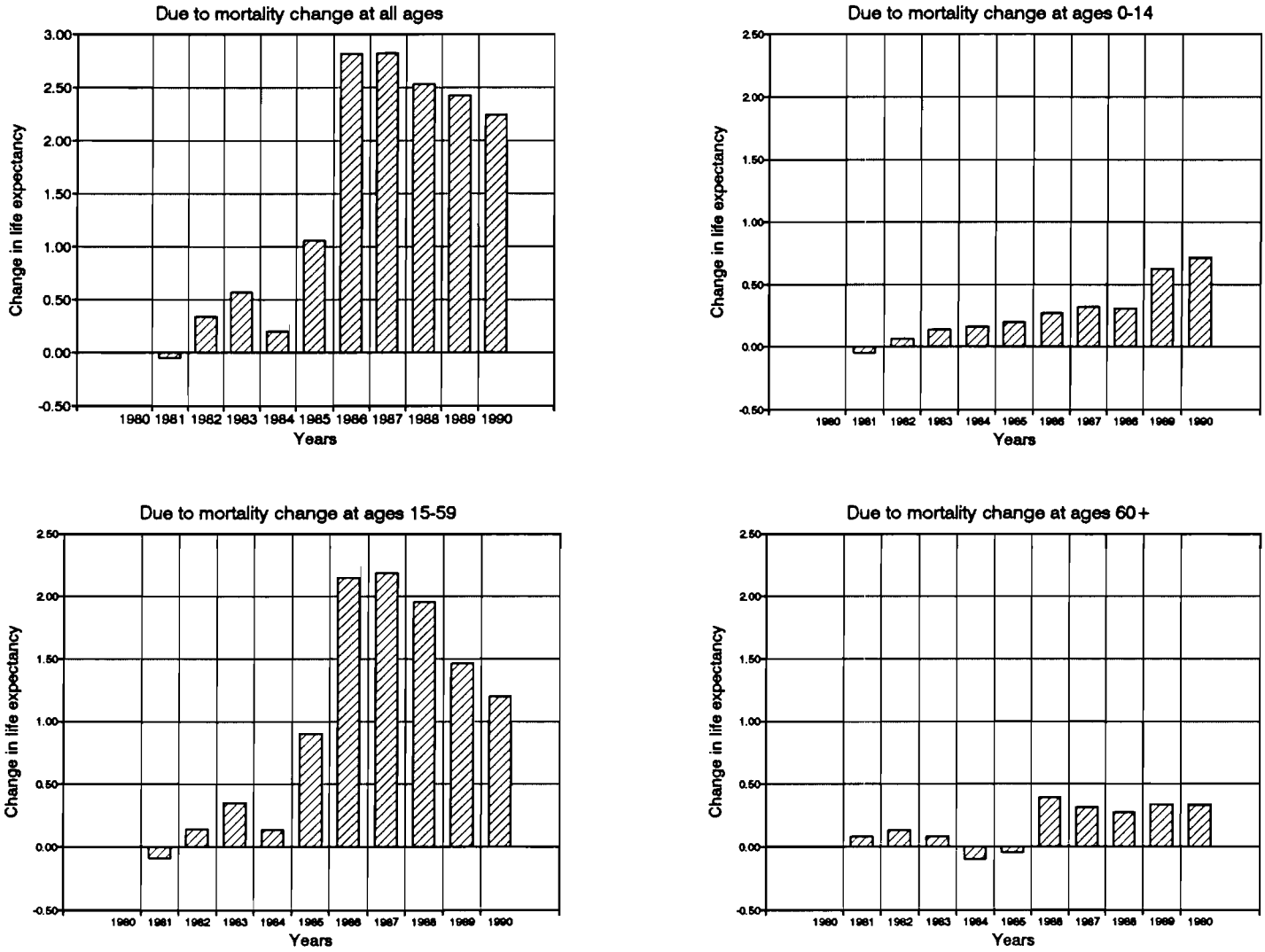


Figure 2. Infectious diseases, USSR, male.

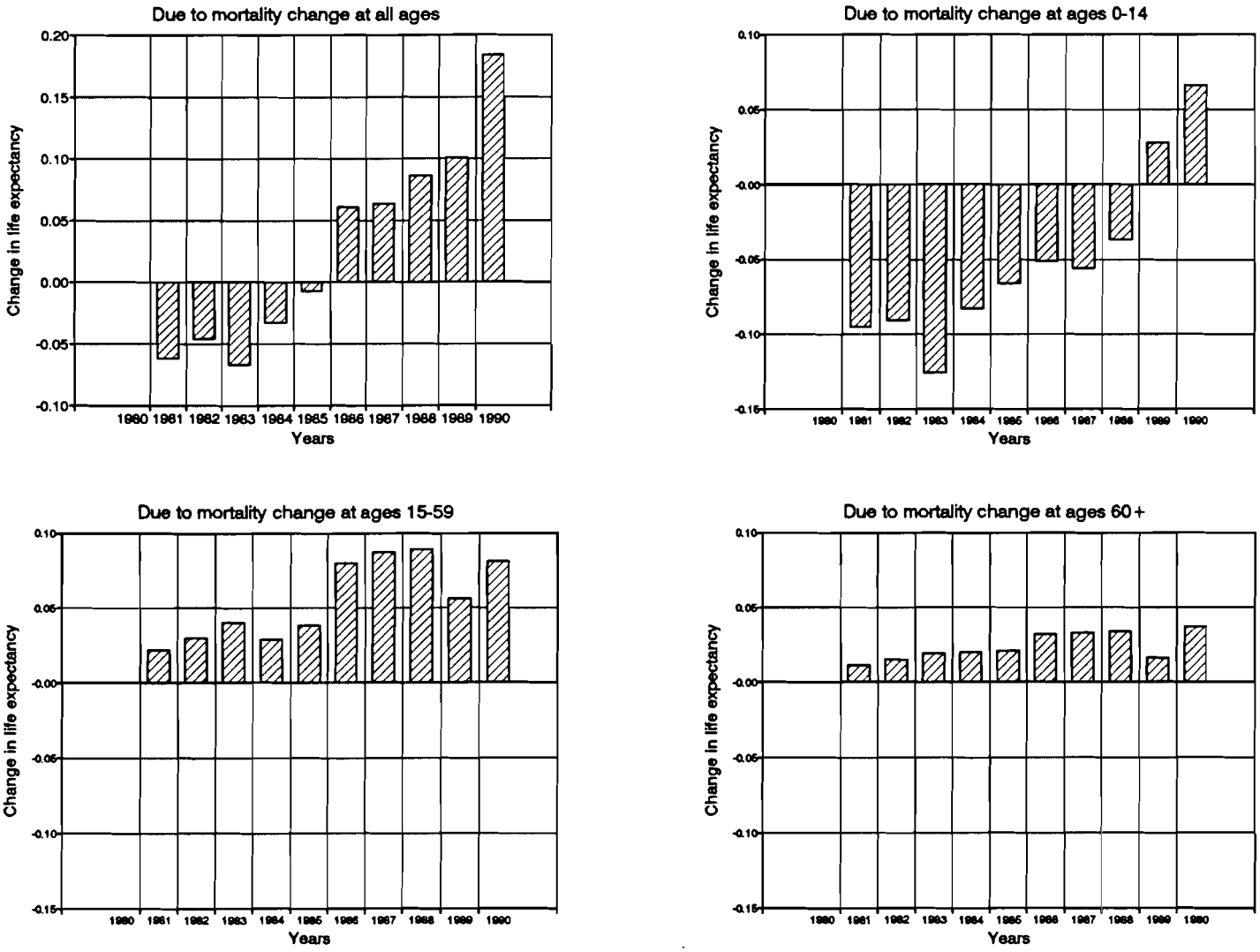


Figure 3. Neoplasms, USSR, male.

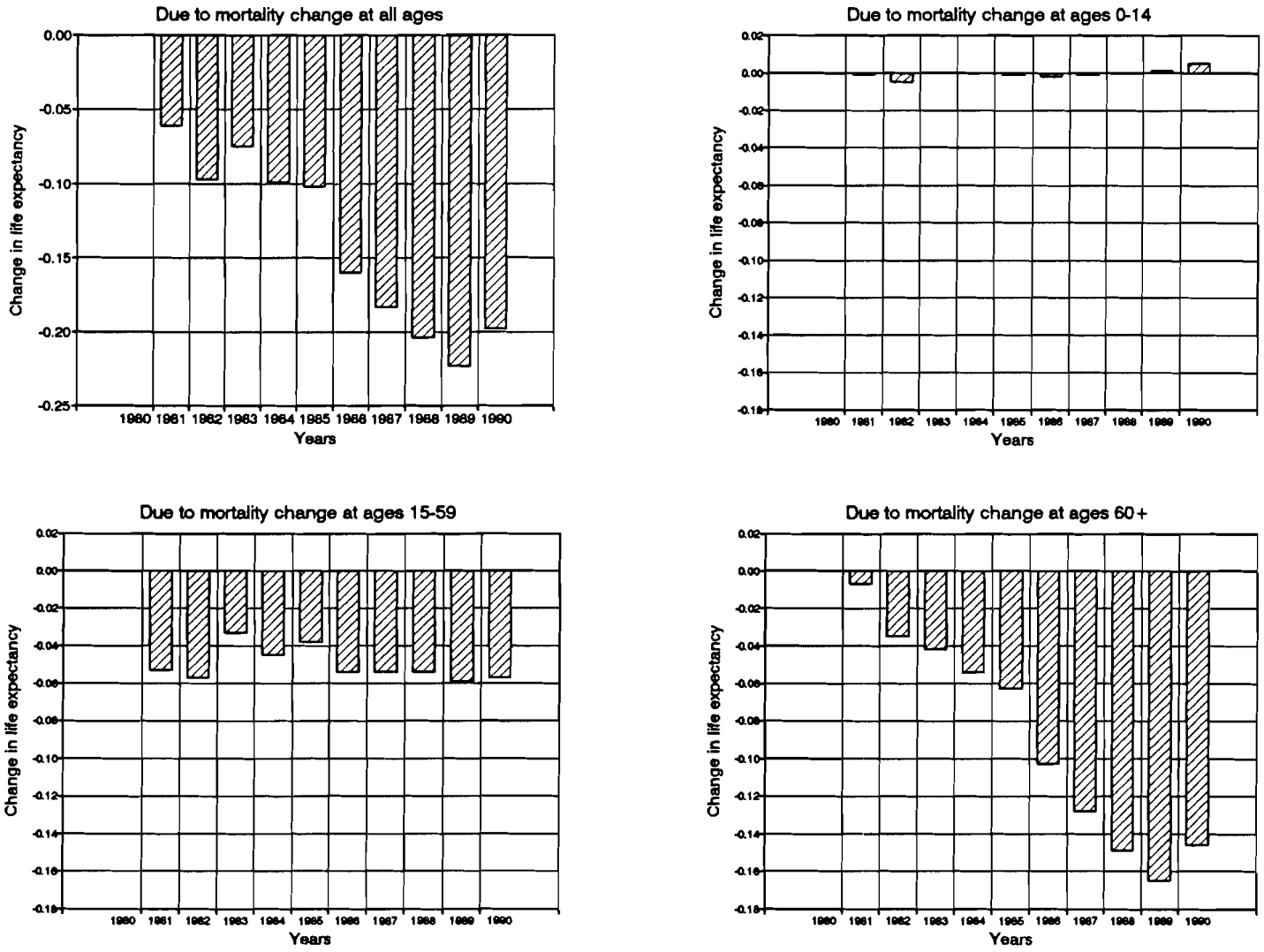


Figure 4. Diseases of the circulatory system, USSR, male.

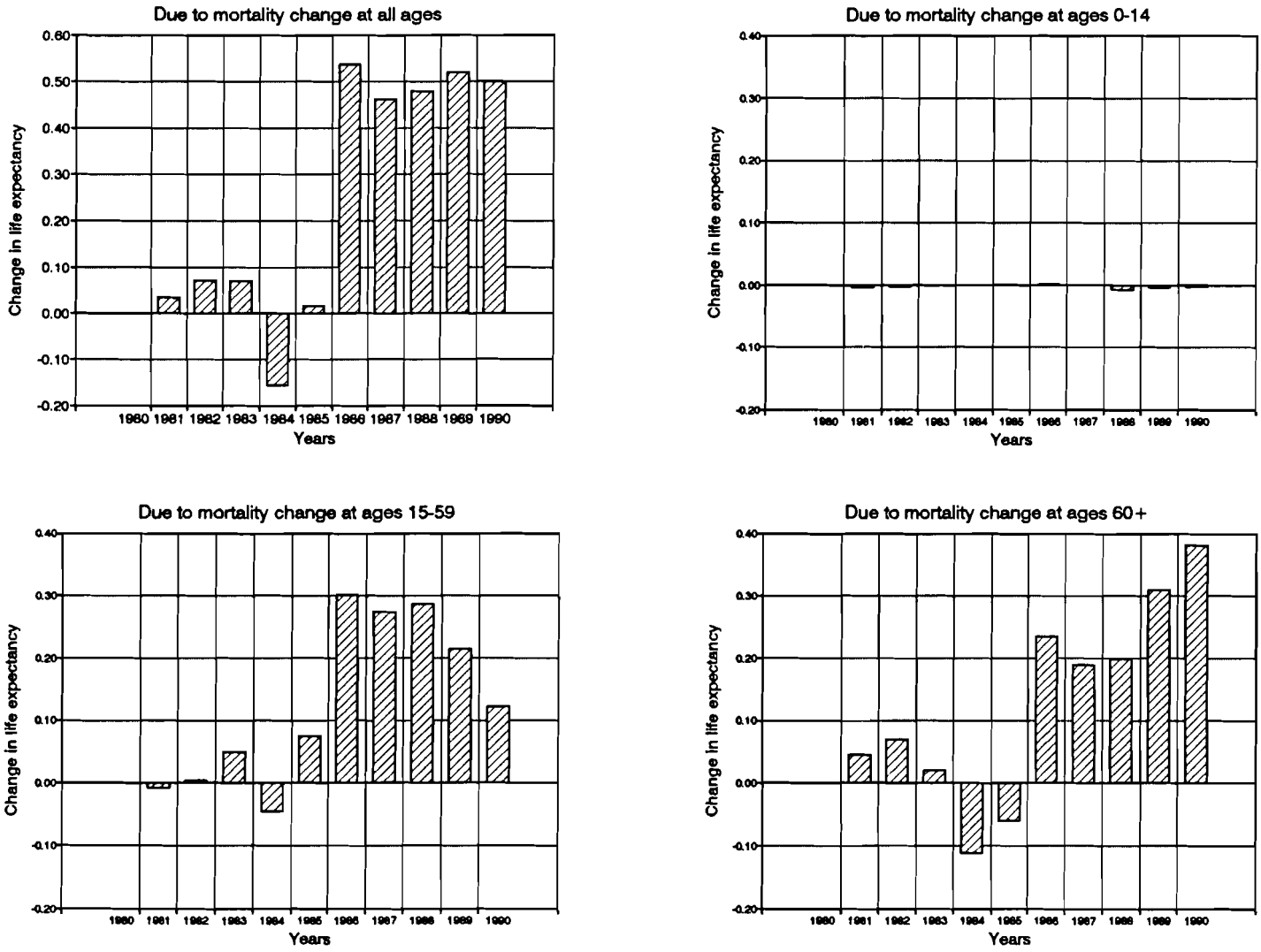


Figure 5. Diseases of the respiratory system, USSR, male.

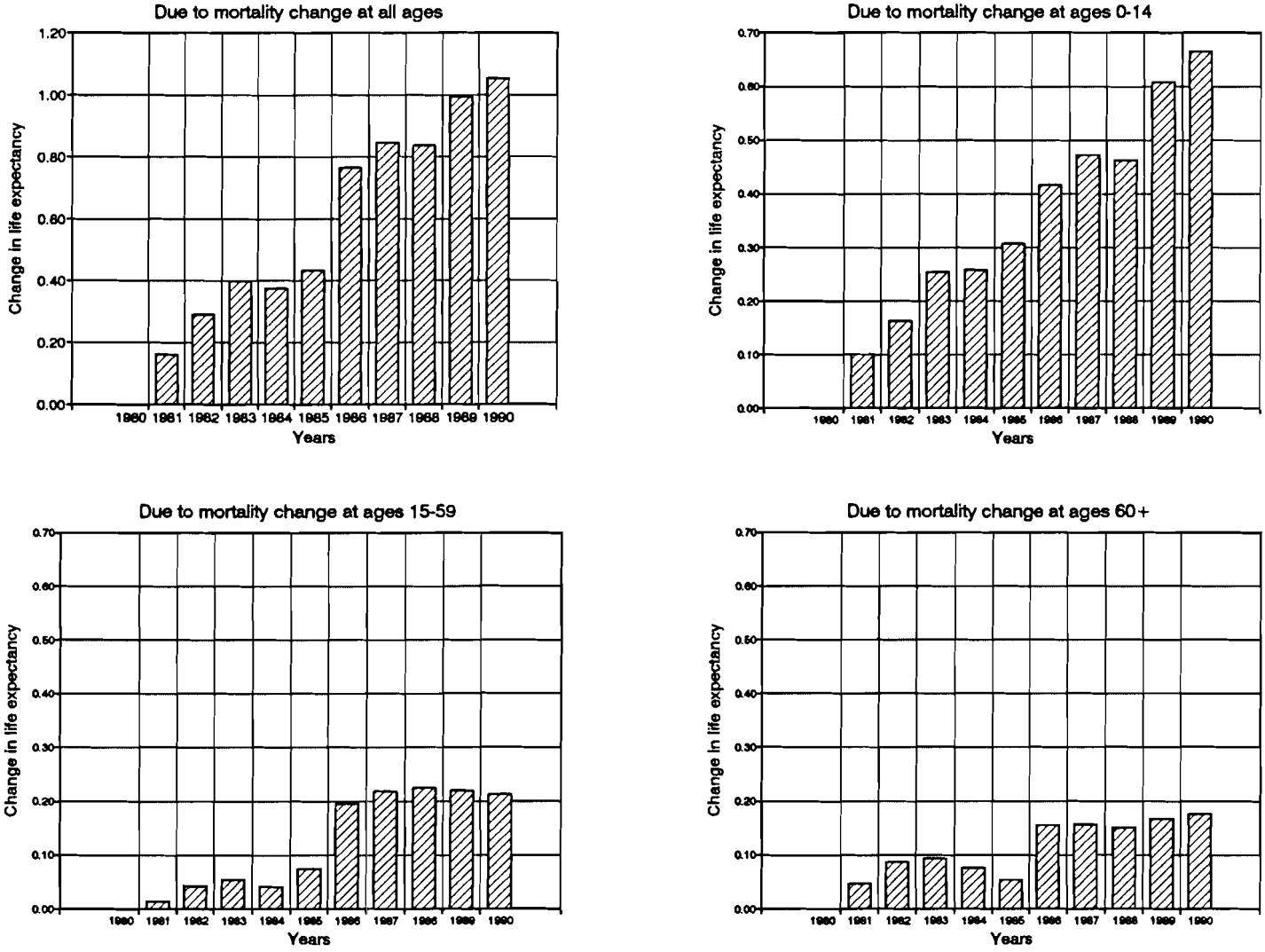
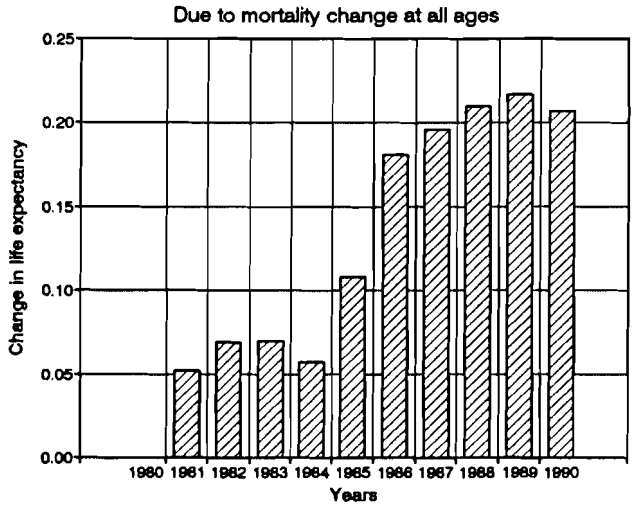
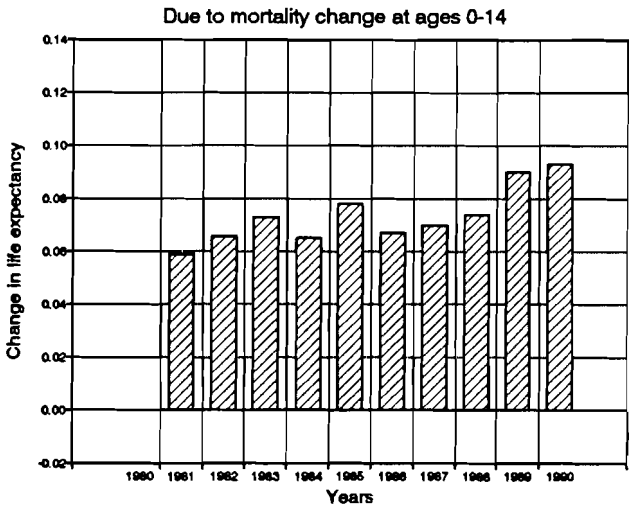
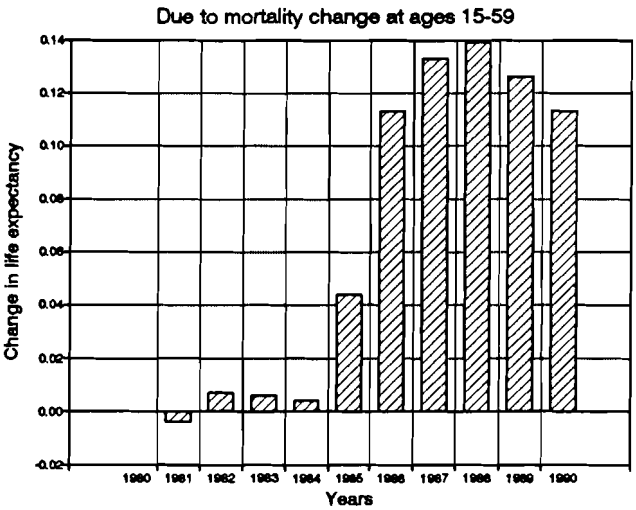


Figure 6. Diseases of the digestive system, USSR, male.







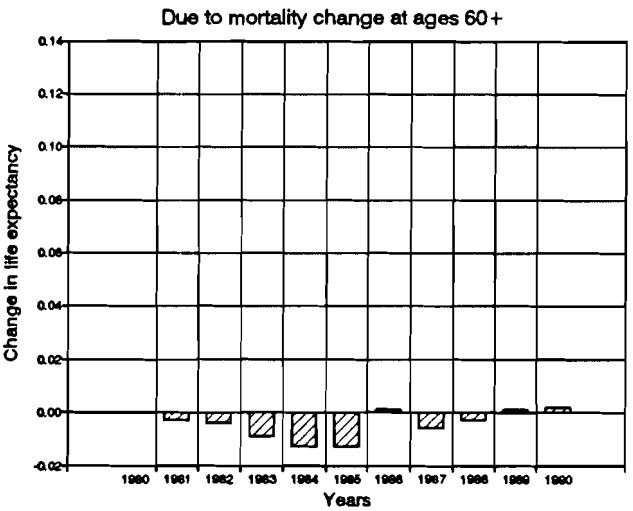


Figure 7. Accidents, poisonings and violence, USSR, male.

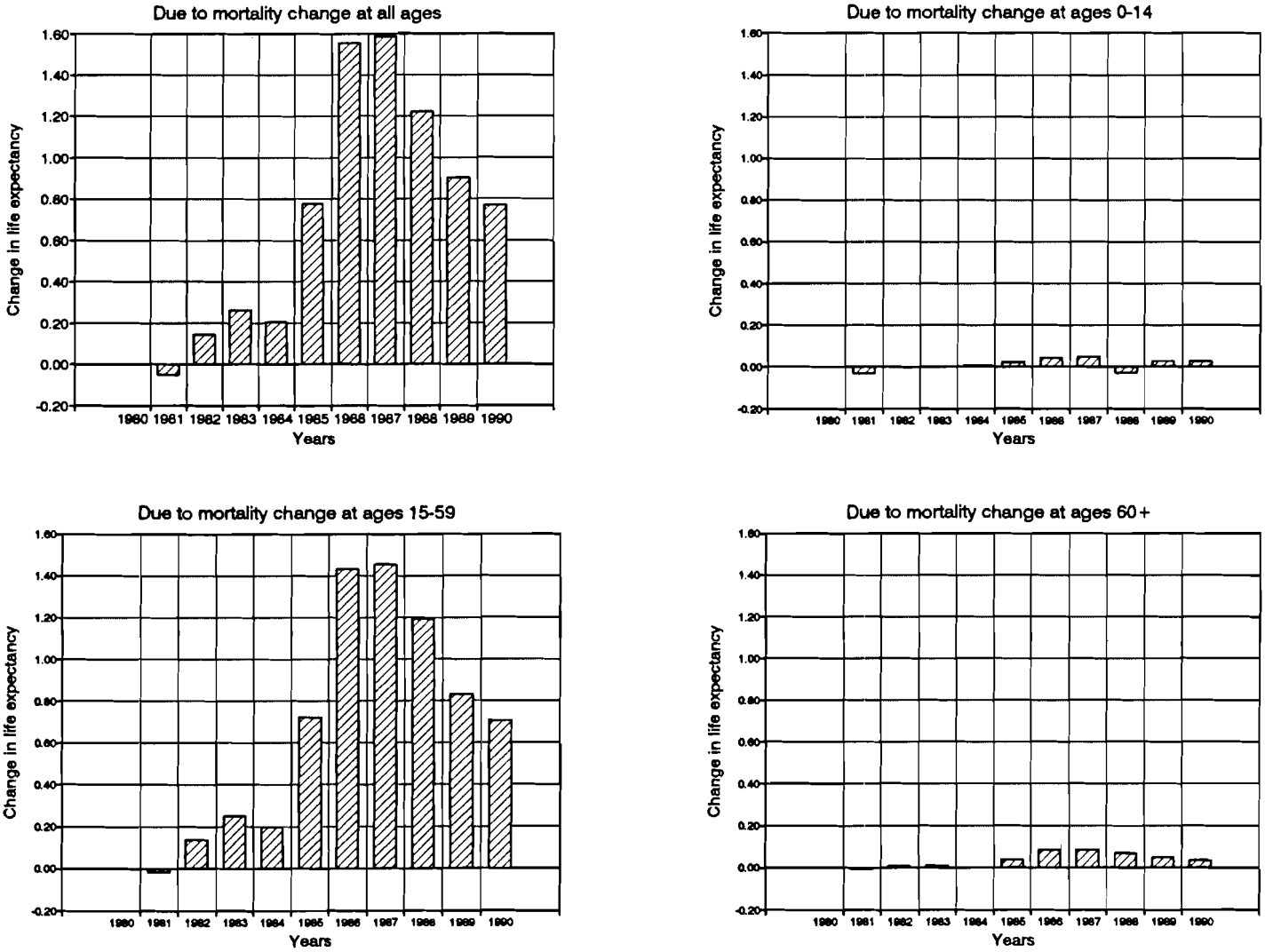


Figure 8. Others and unknown causes, USSR, male.

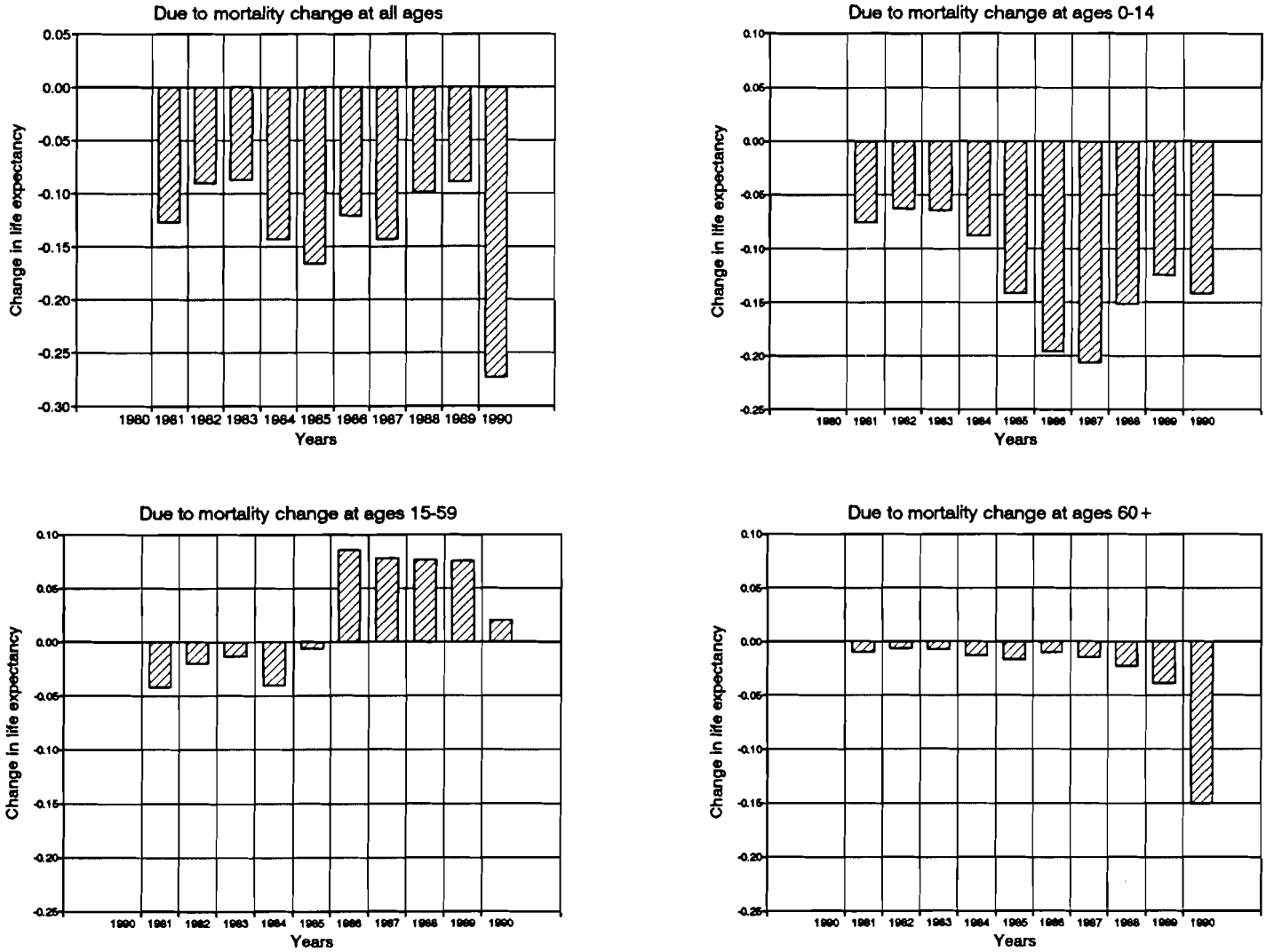


Figure 9. All causes, USSR, female.

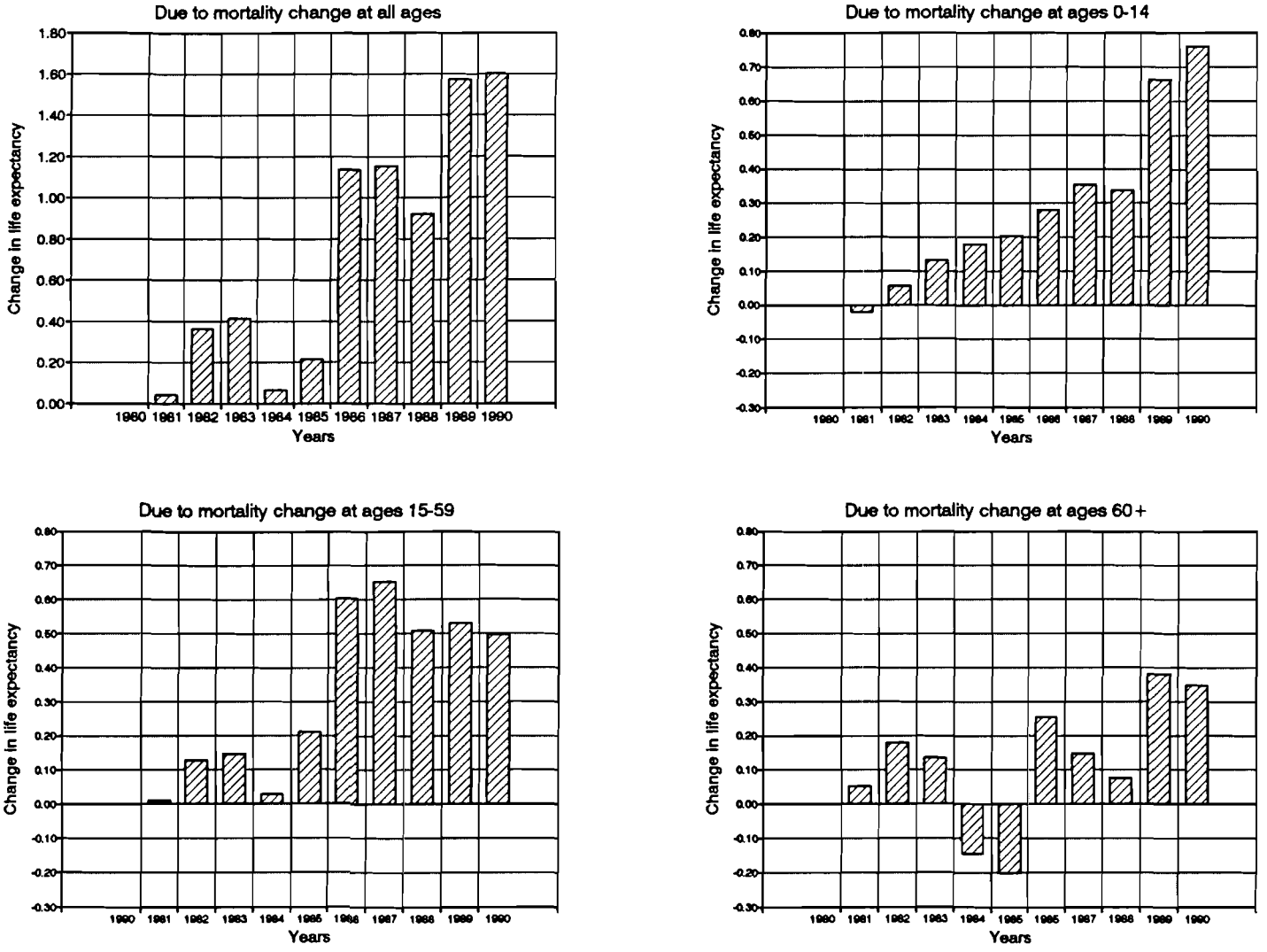


Figure 10. Infectious diseases, USSR, female.

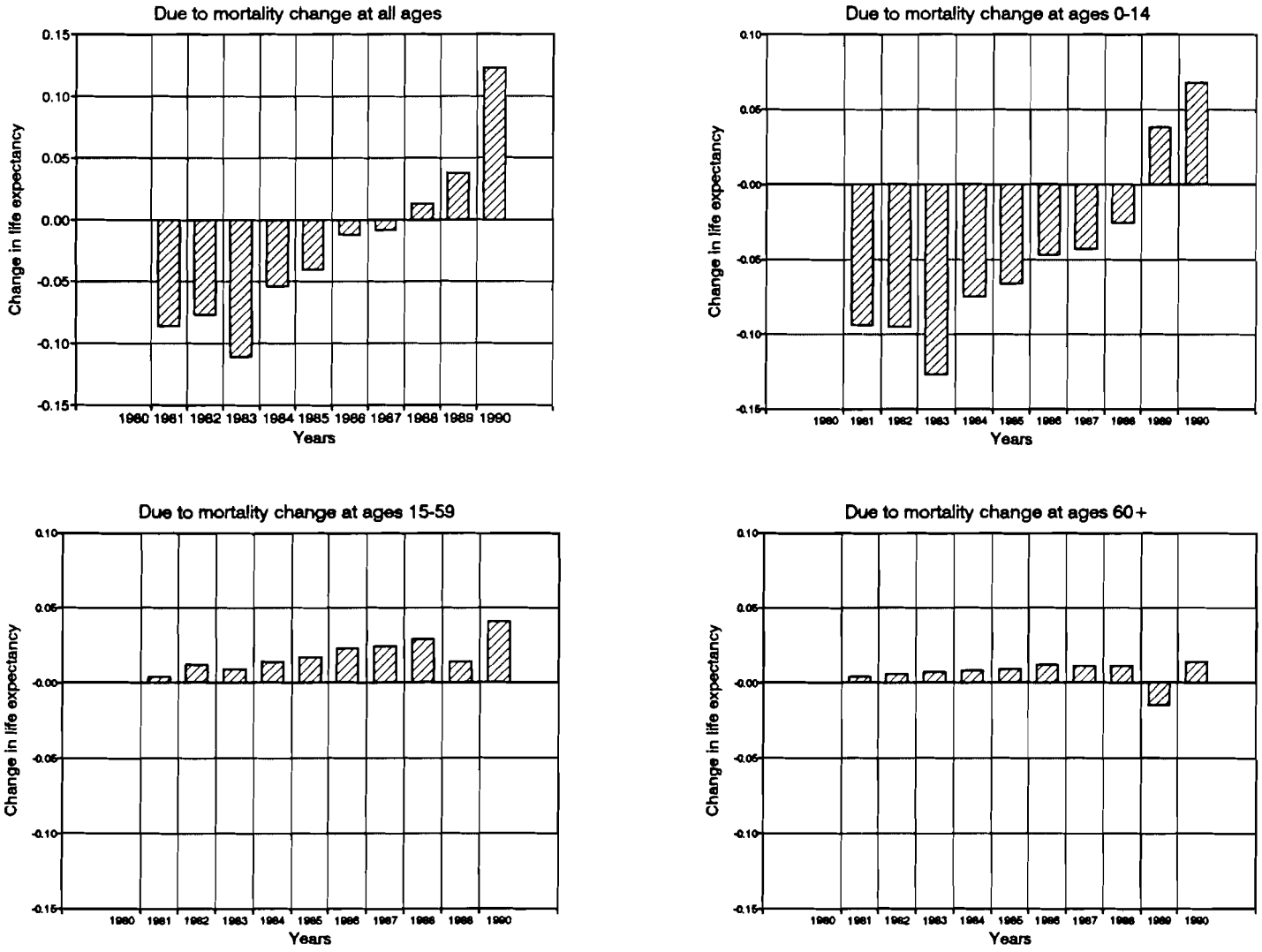


Figure 11. Neoplasms, USSR, female.

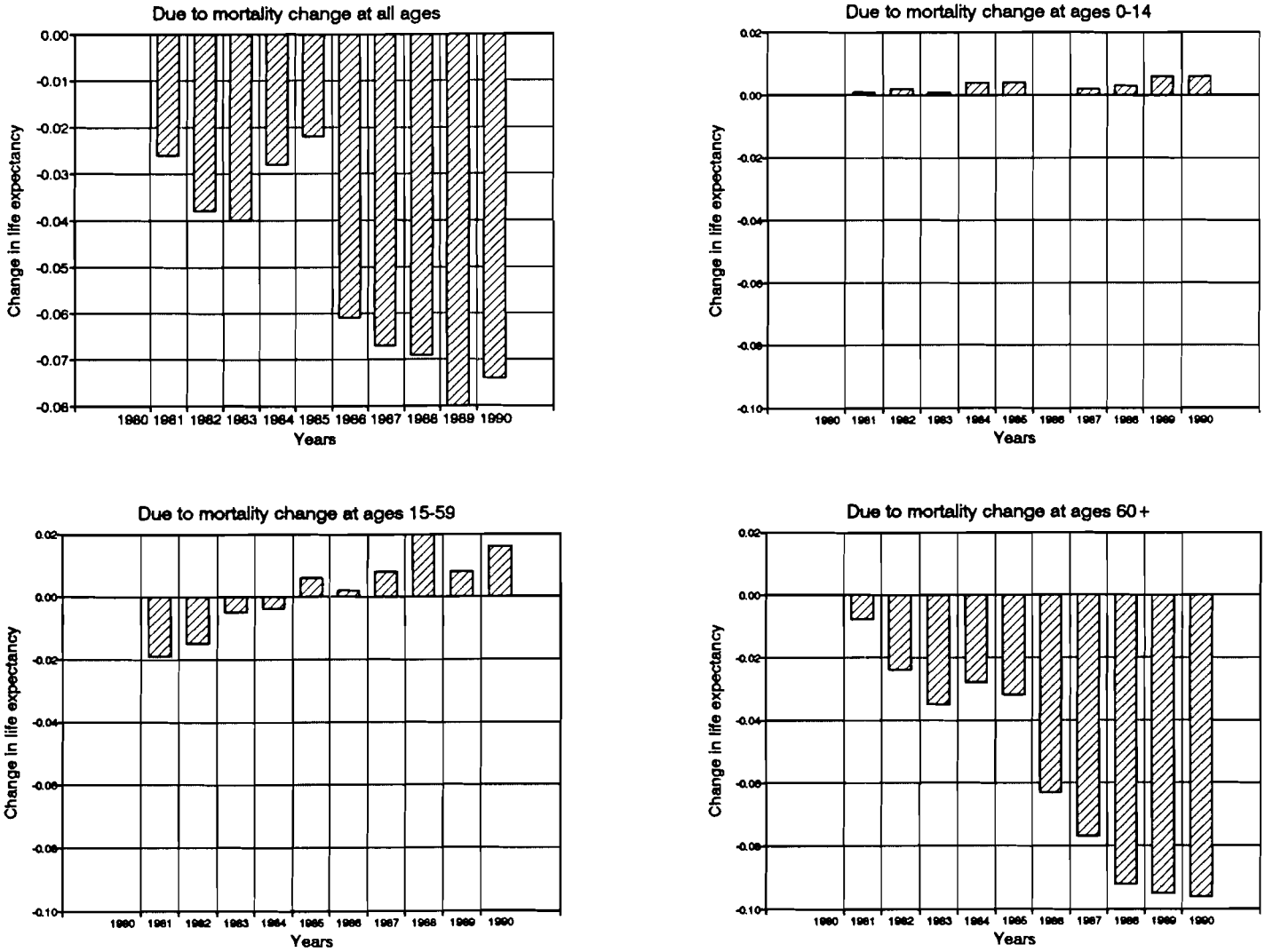


Figure 12. Diseases of the digestive system, USSR, female.

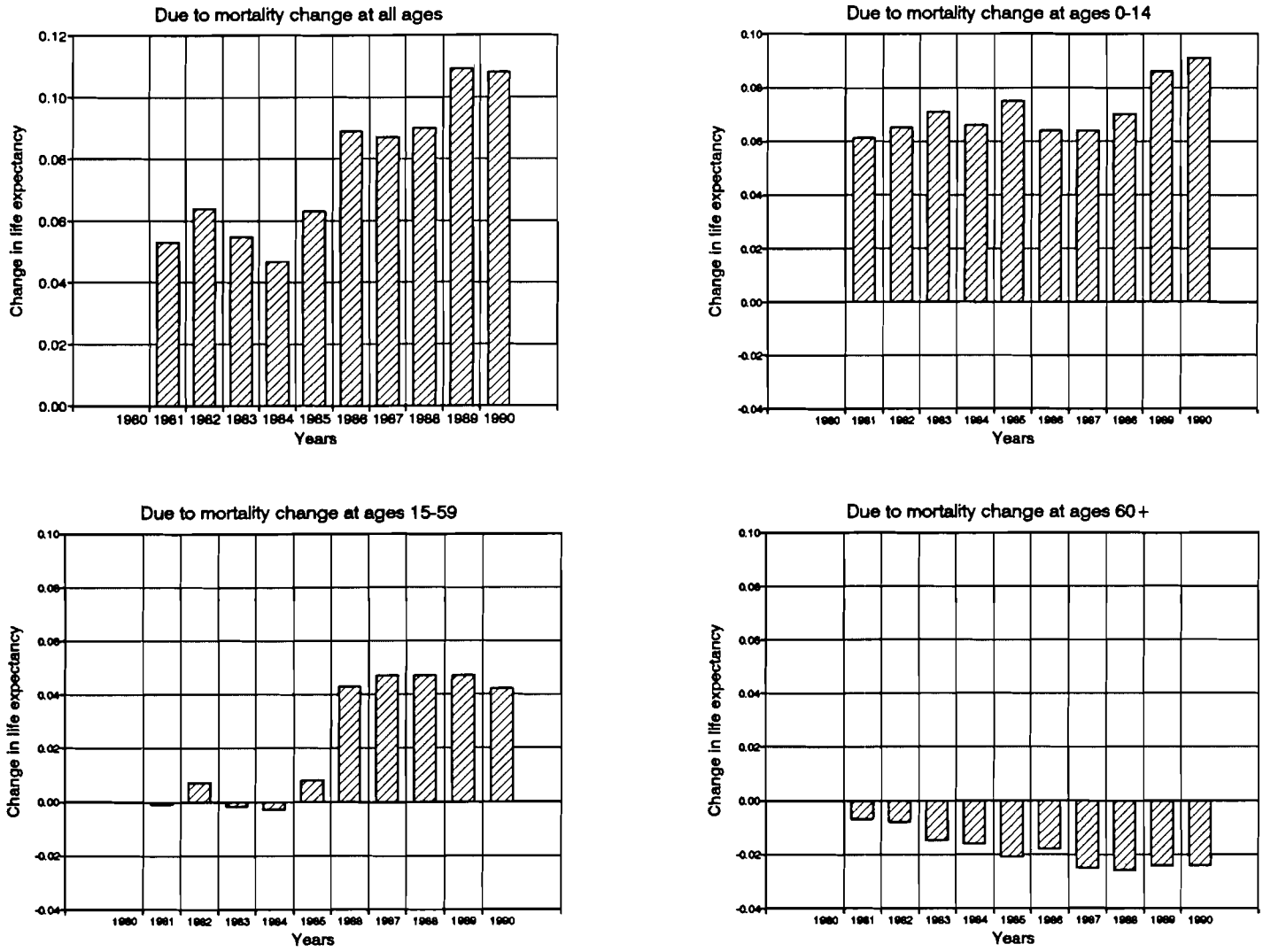


Figure 13. Accidents, poisonings and violence, USSR, female.

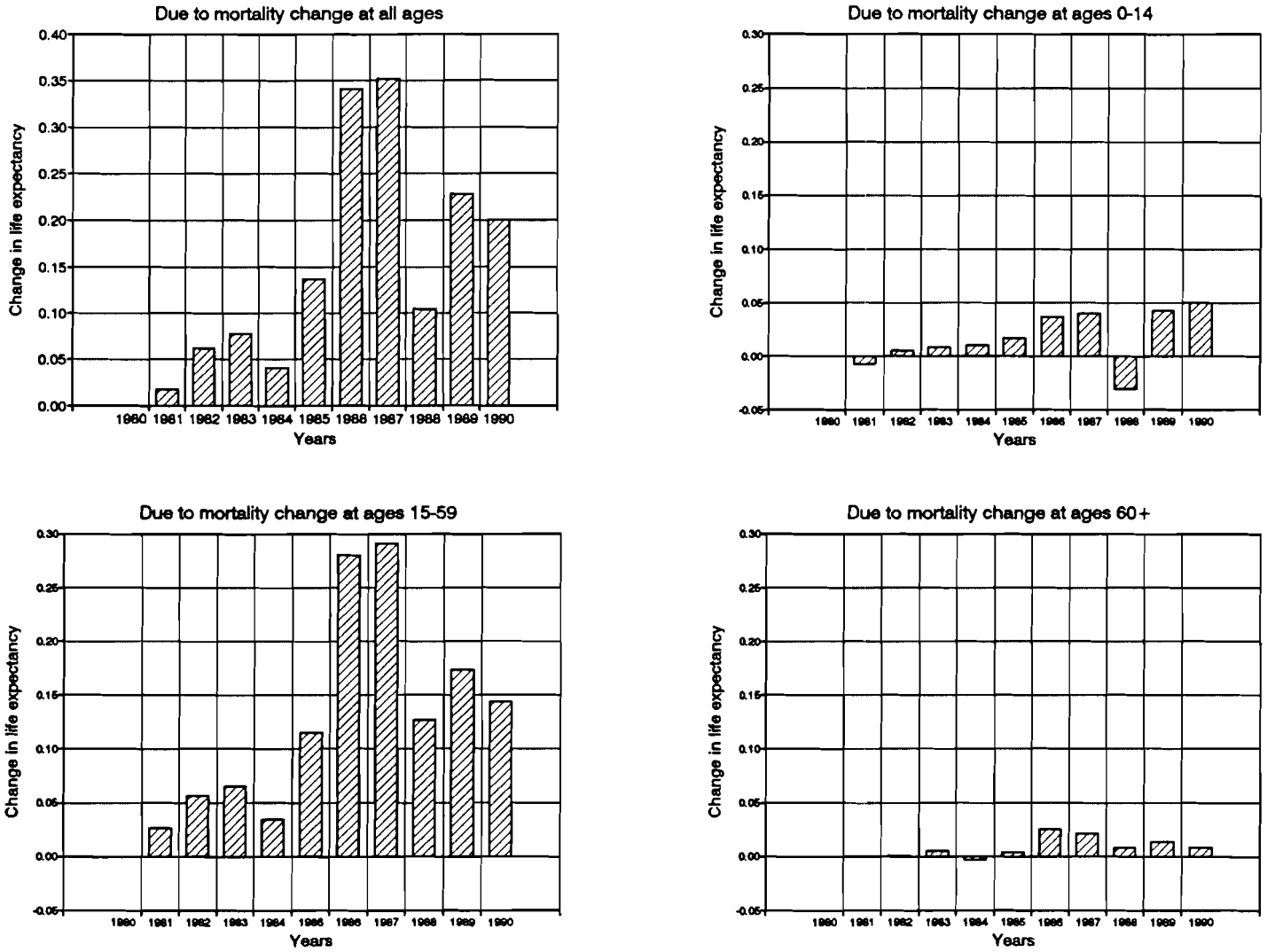
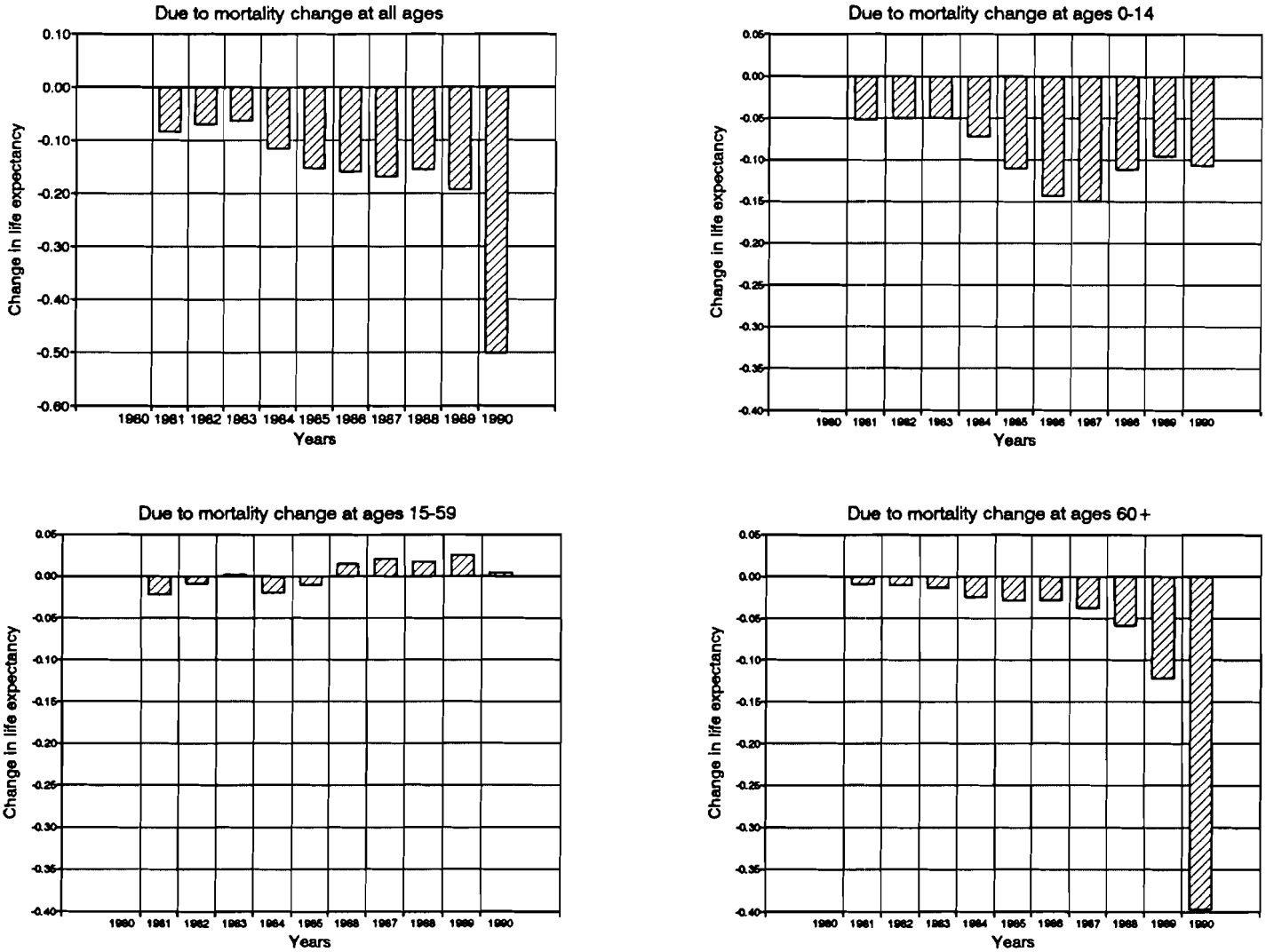
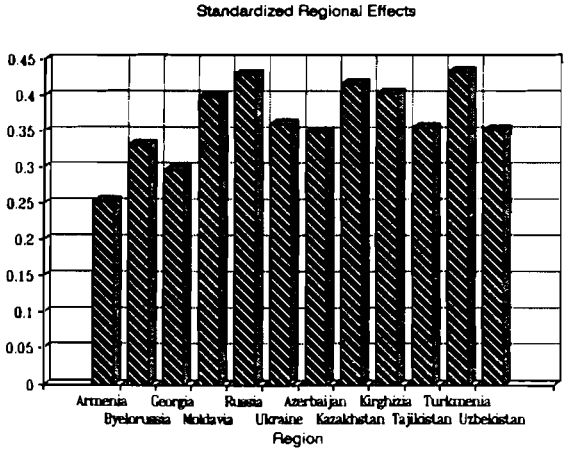


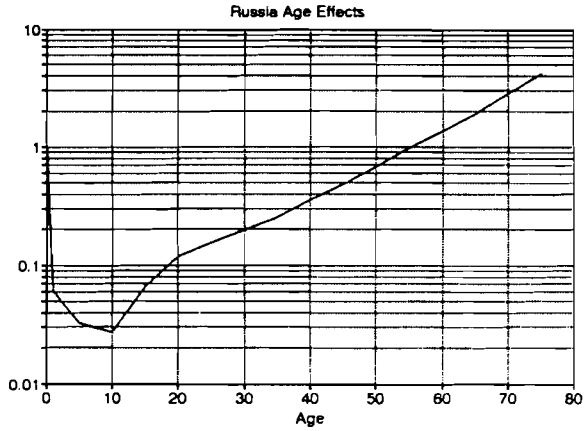
Figure 14. Others and unknown causes, USSR, female.

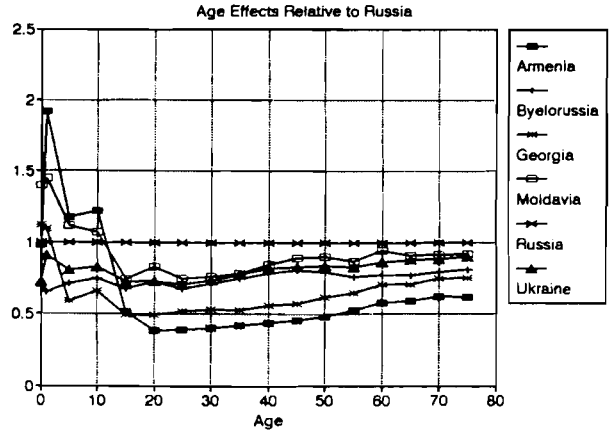


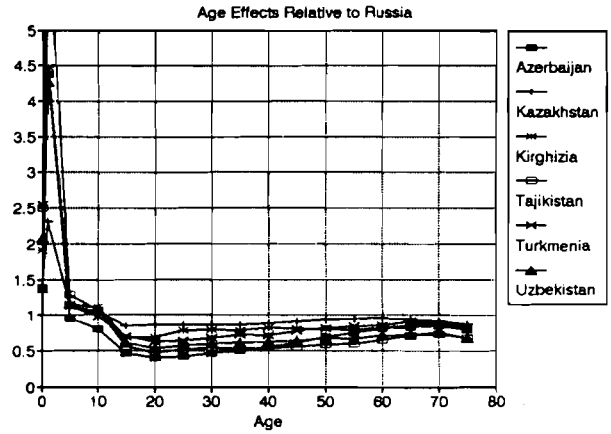
APPENDIX B. Results of the APC Analysis (Figures 1-39 and Tables 1-13)

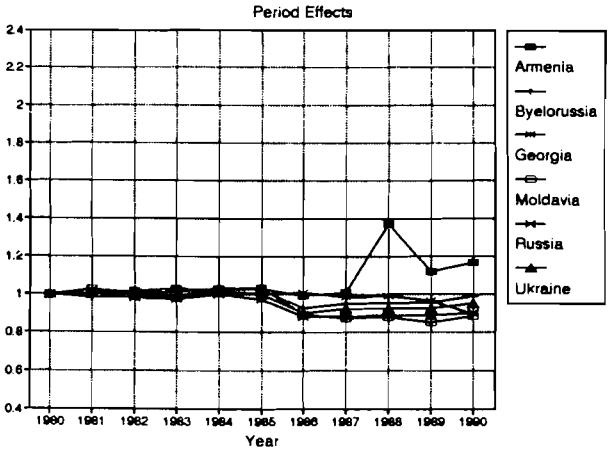
Figure 1. All causes, male.











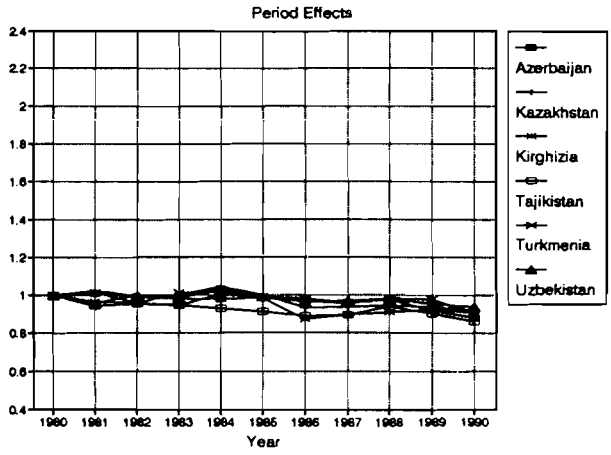
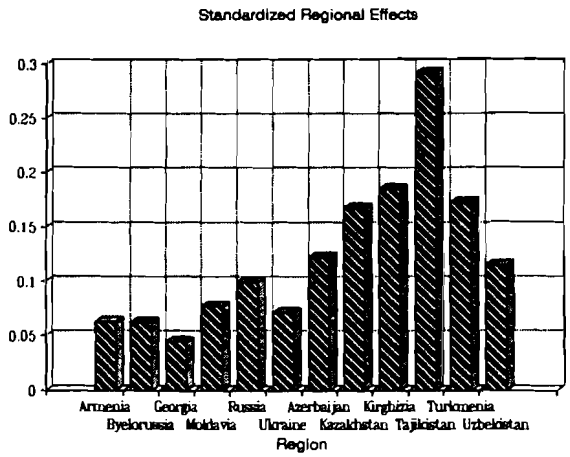
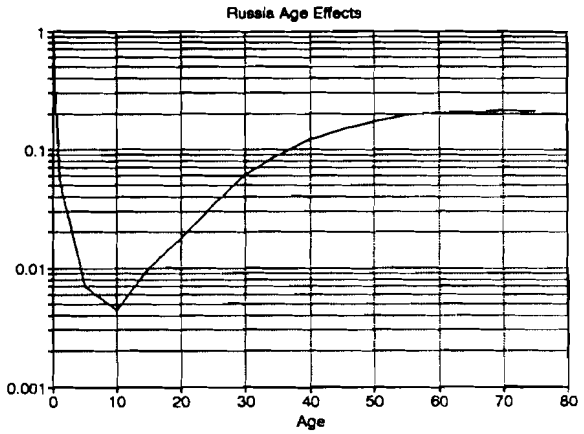
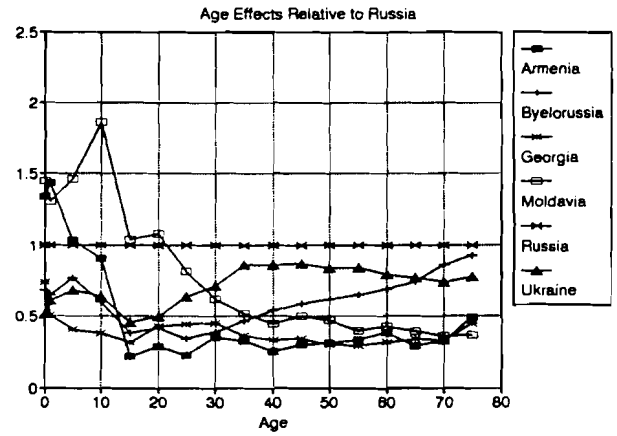
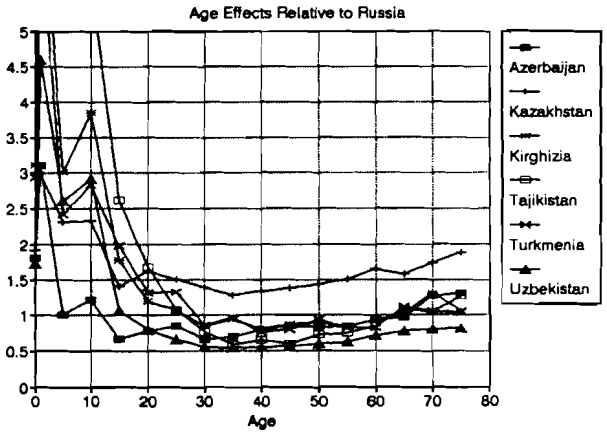


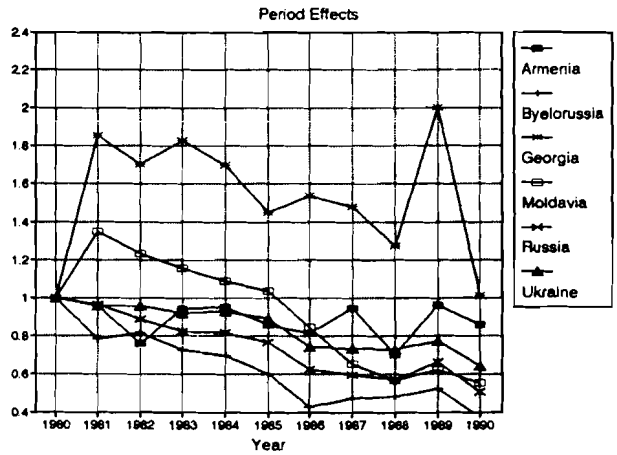
Figure 2. Infectious and parasitic diseases, male.











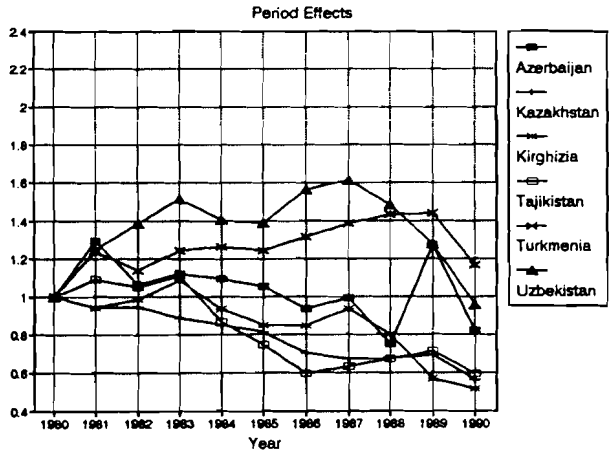
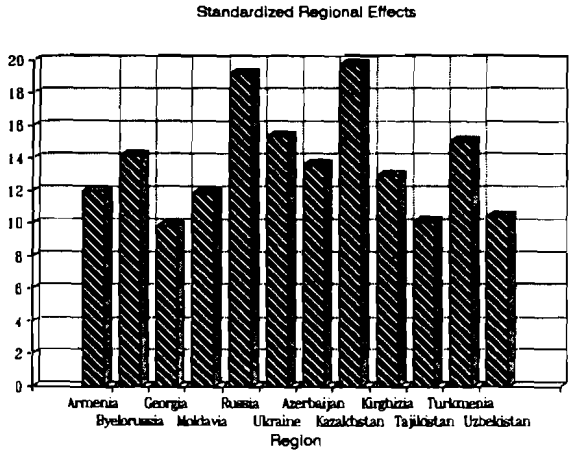
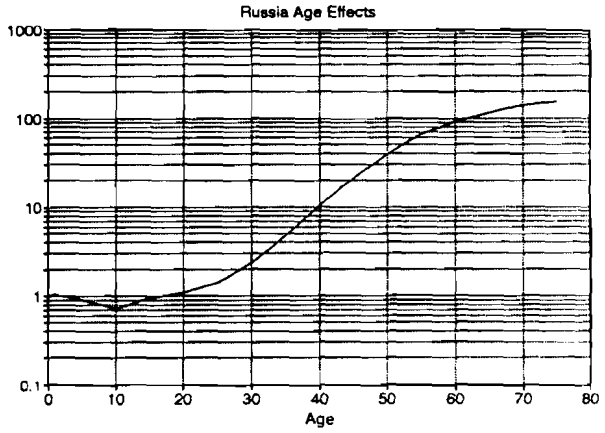
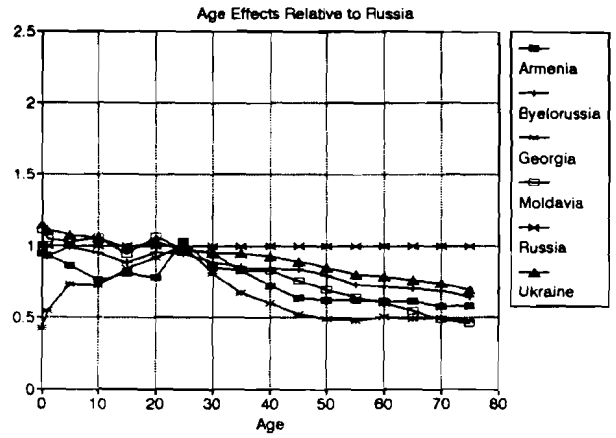
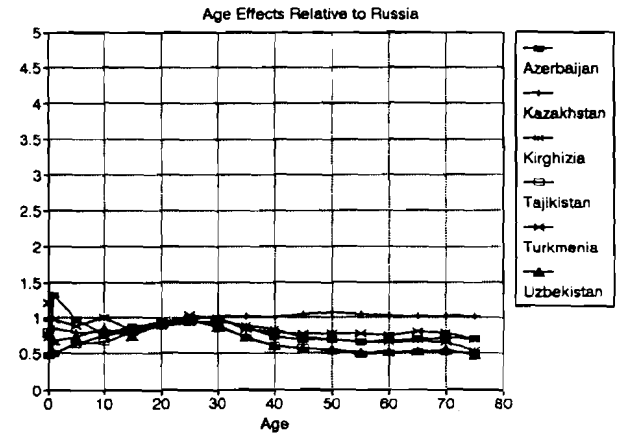


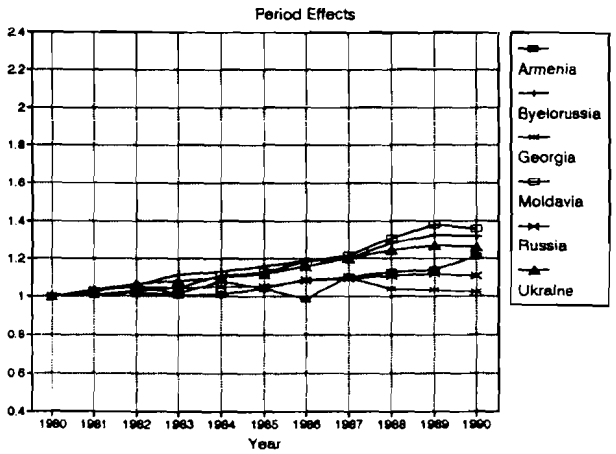
Figure 3. Neoplasms, male.











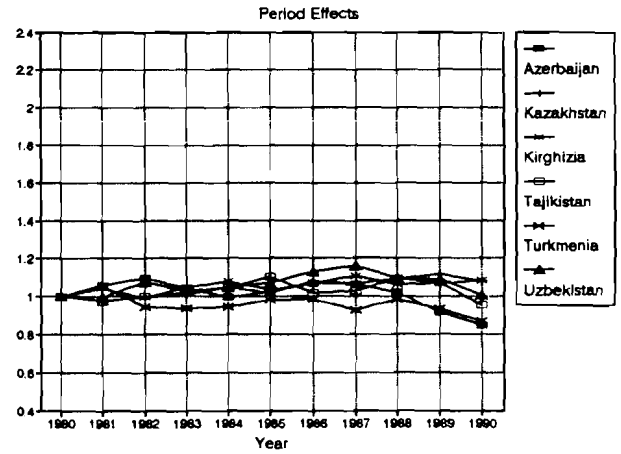
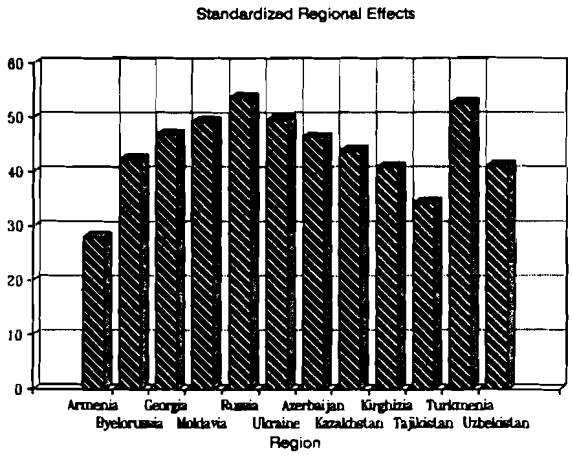
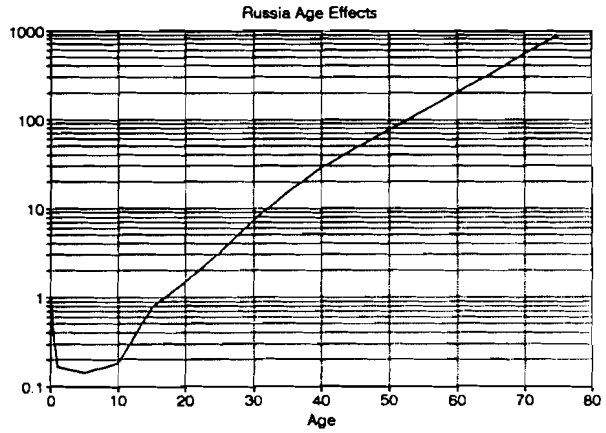
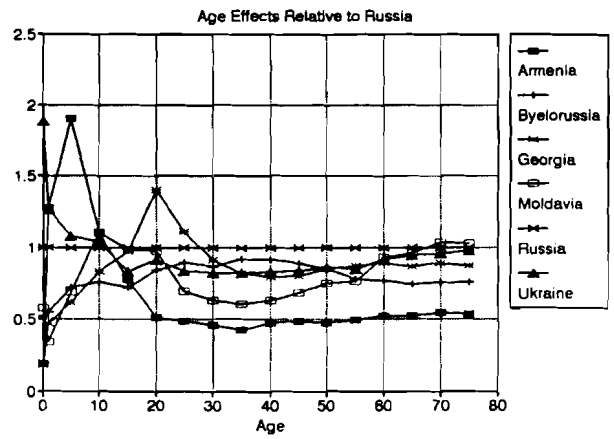
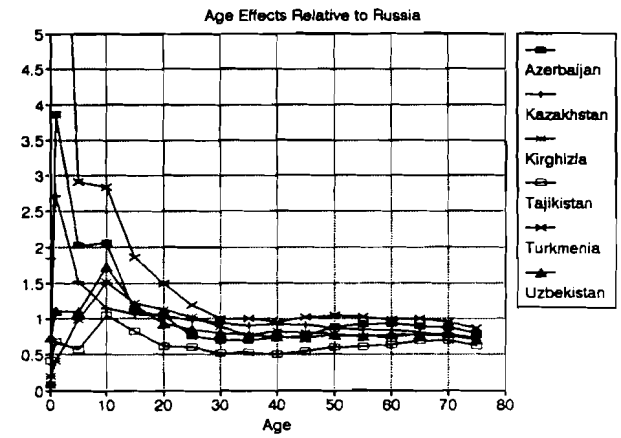


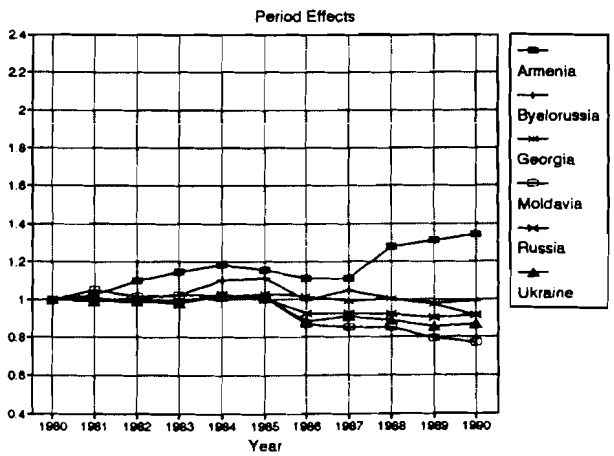
Figure 4. Diseases of the circulatory system, male.











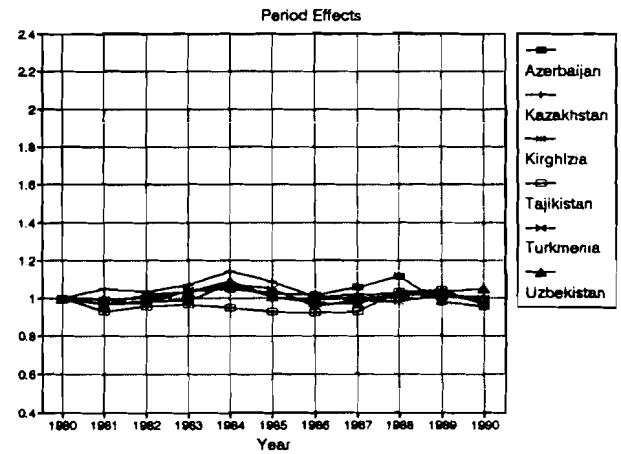
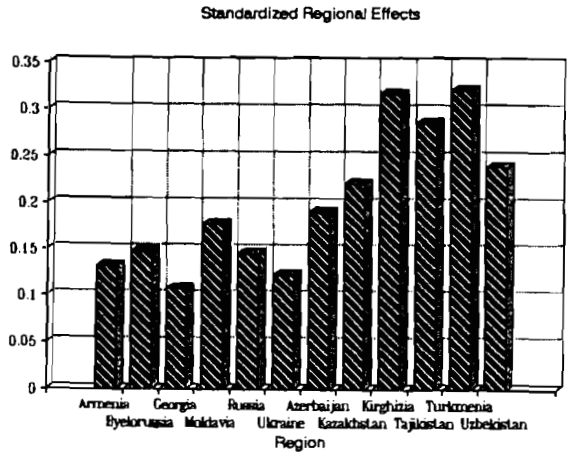
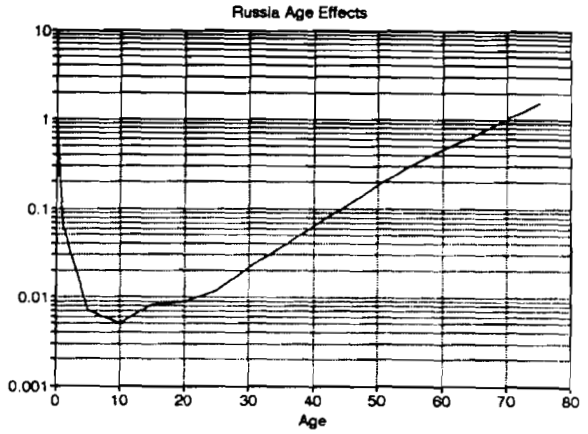
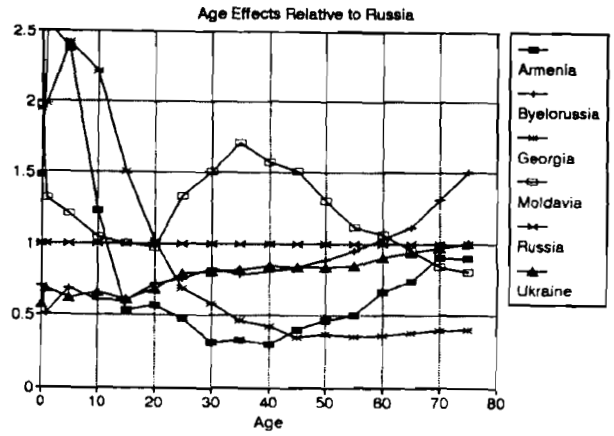
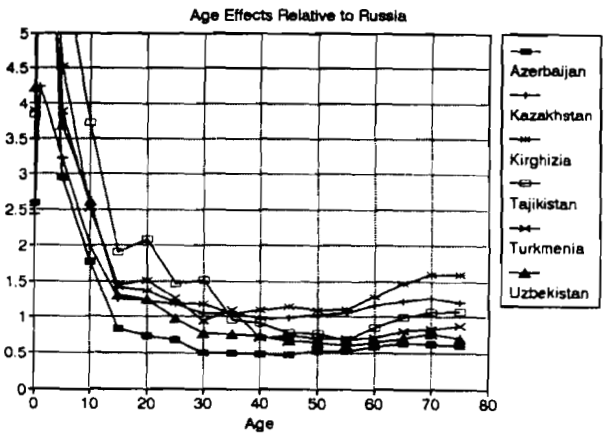


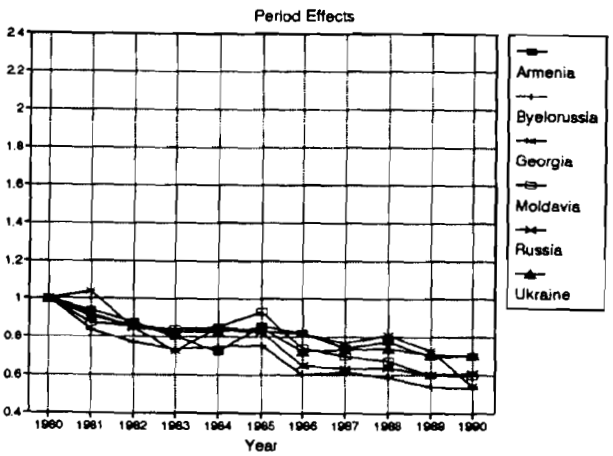
Figure 5. Diseases of the respiratory system, male.











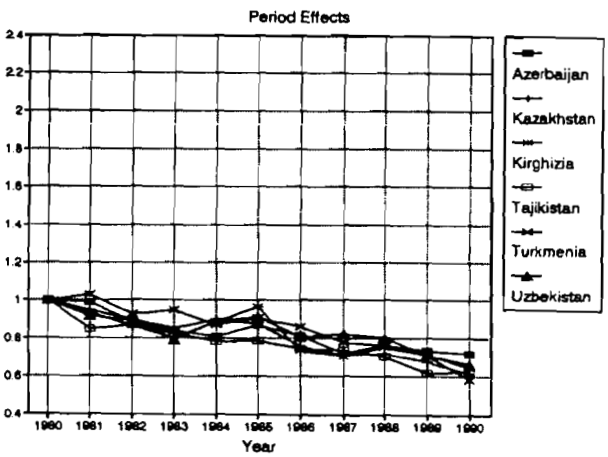
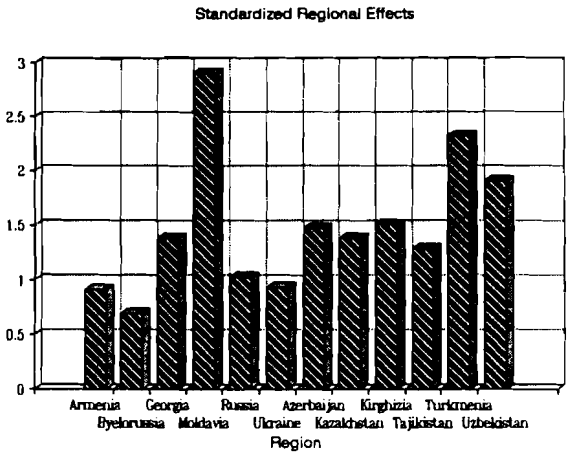
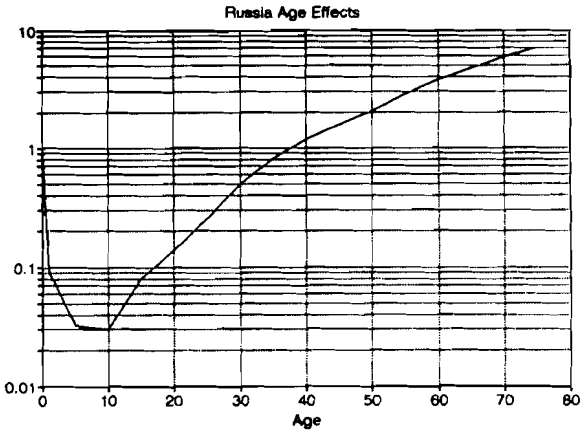
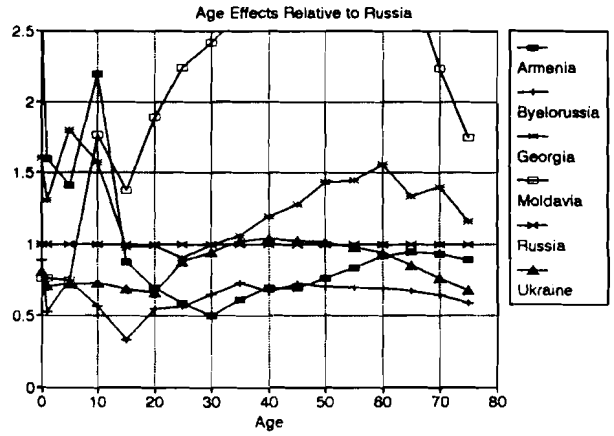
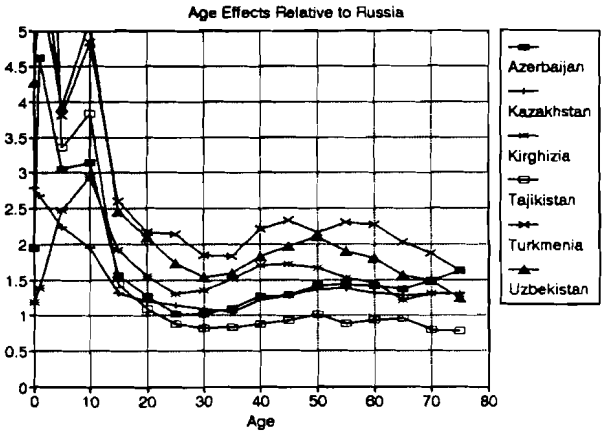


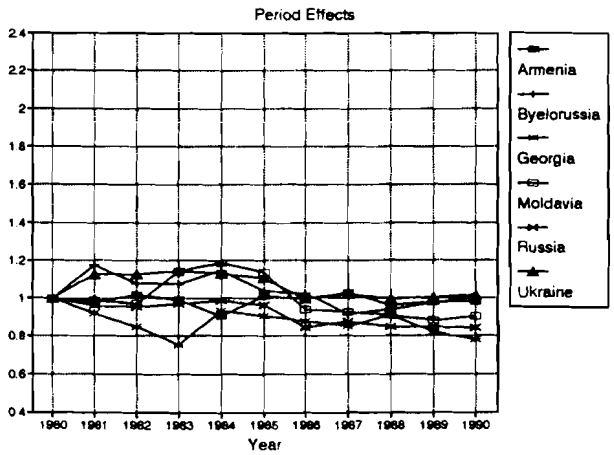
Figure 6. Diseases of the digestive system, male.











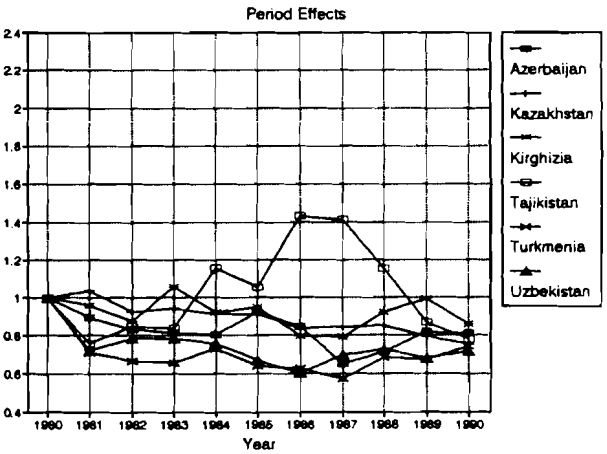
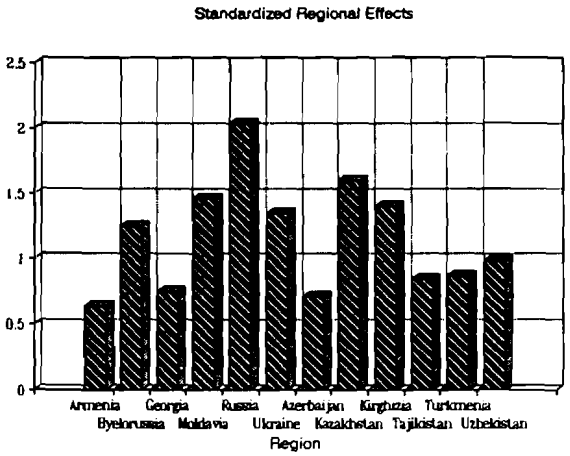
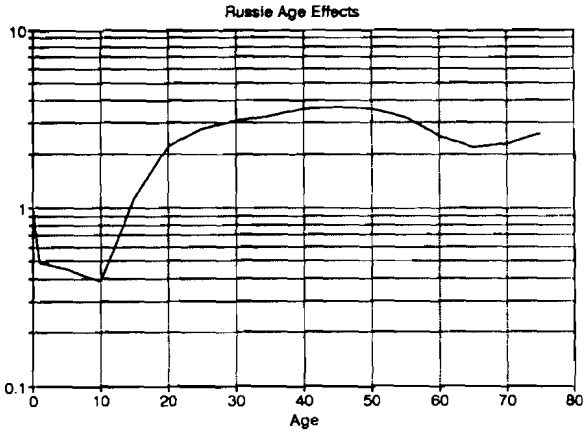
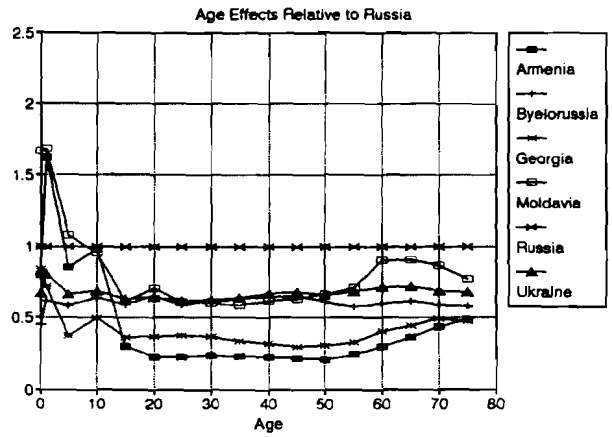
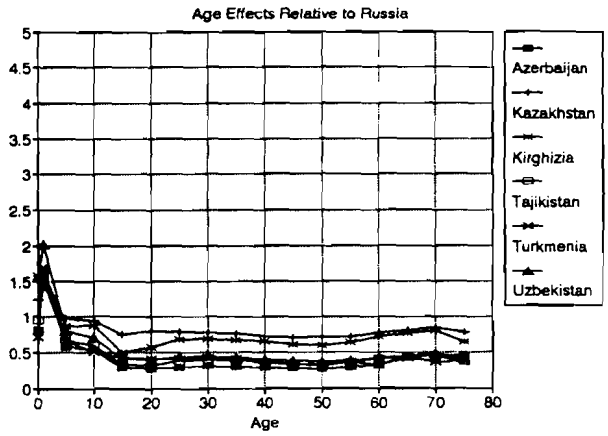


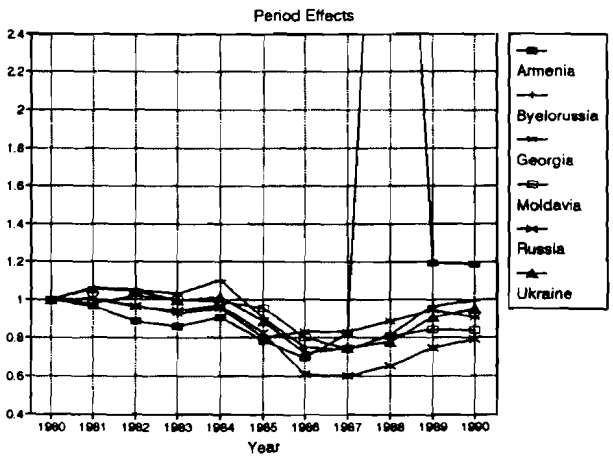
Figure 7. Accidents, poisonings and violence, male.











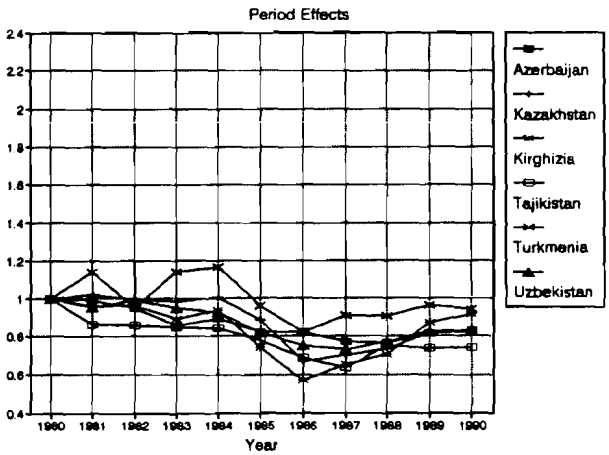
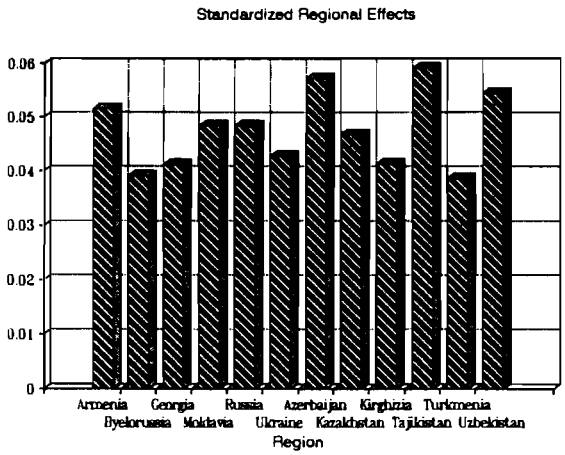
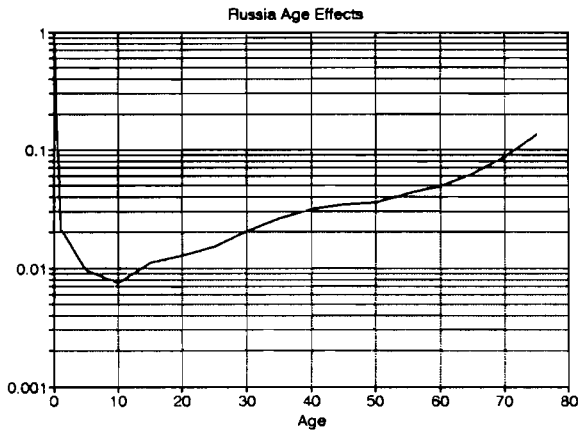
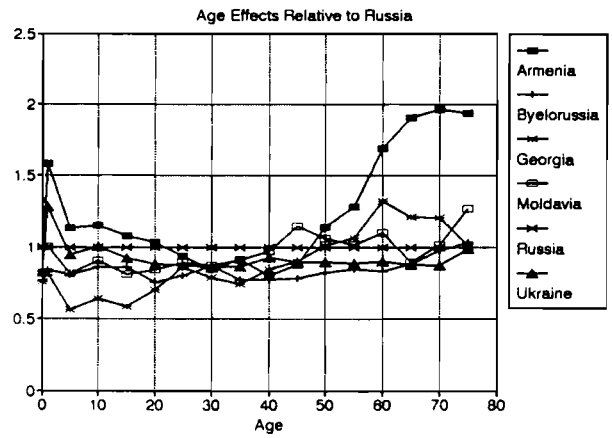
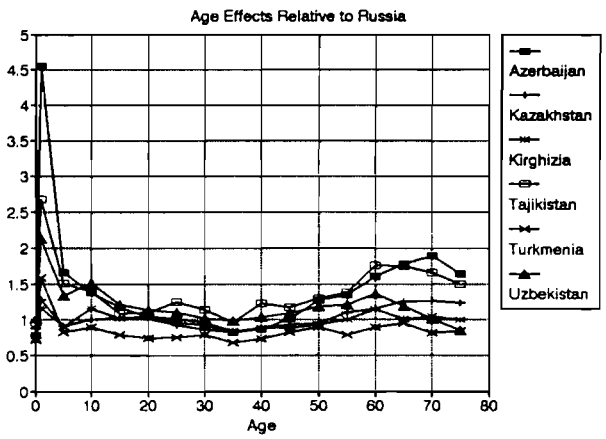


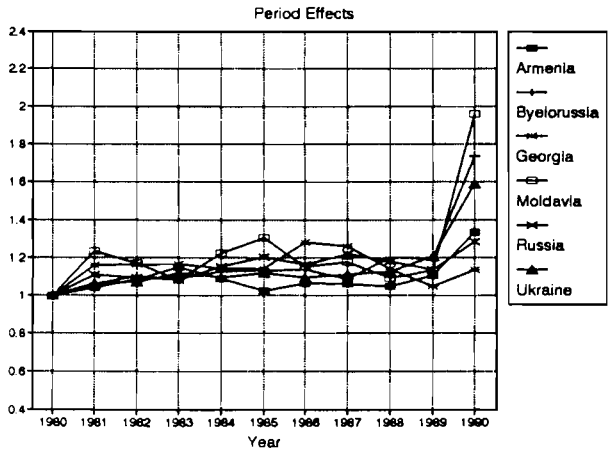
Figure 8. Others and unknown causes, male.











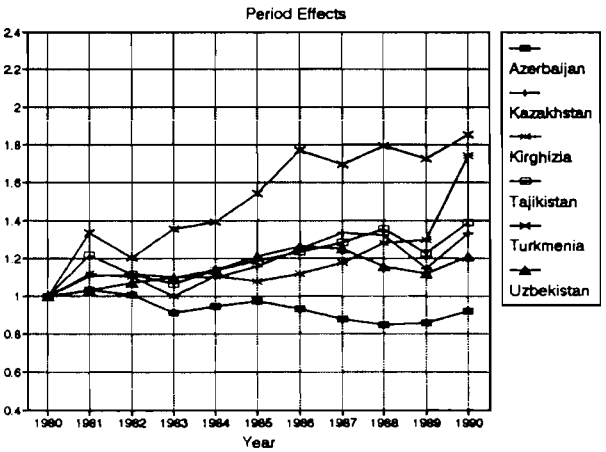
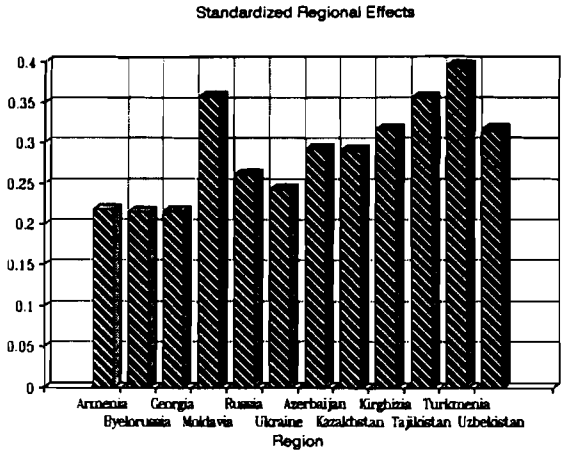
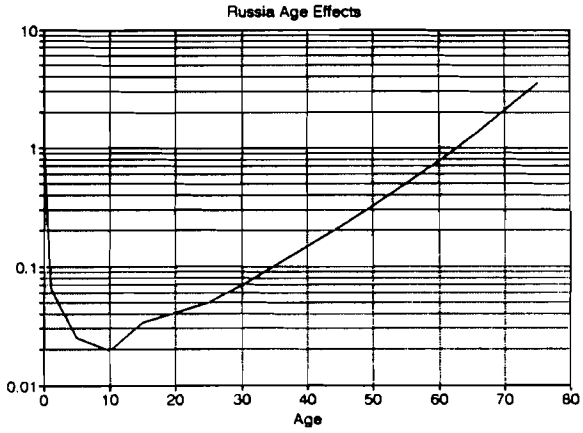
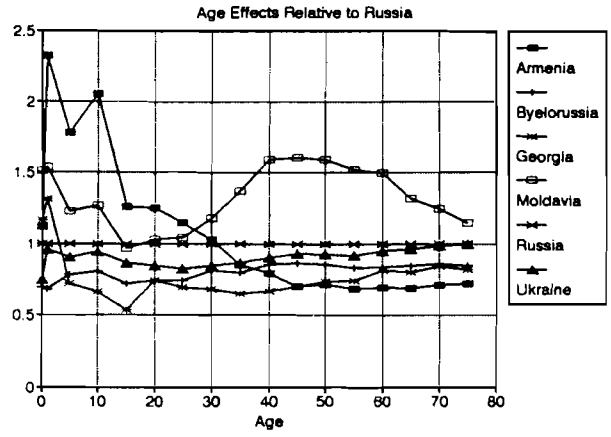
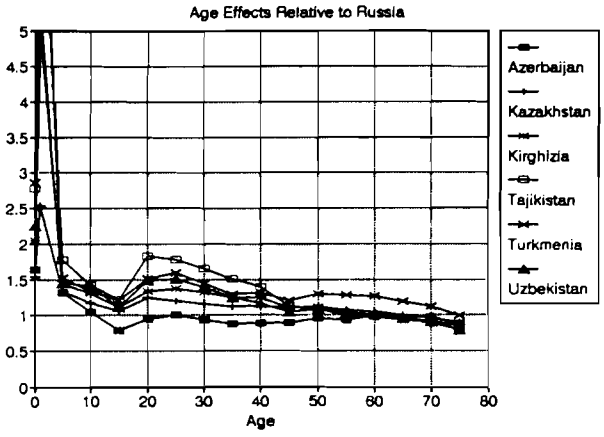


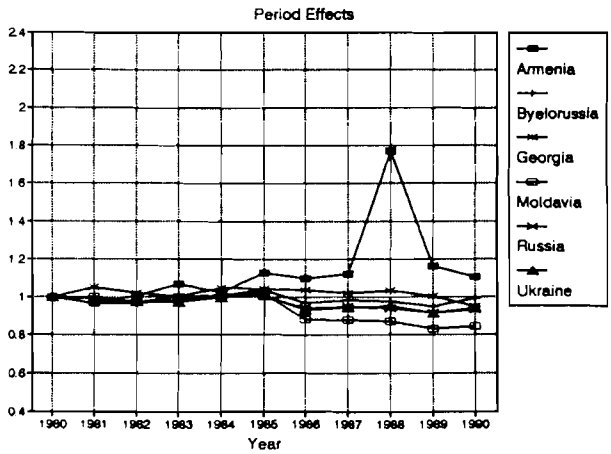
Figure 9. All causes, female.











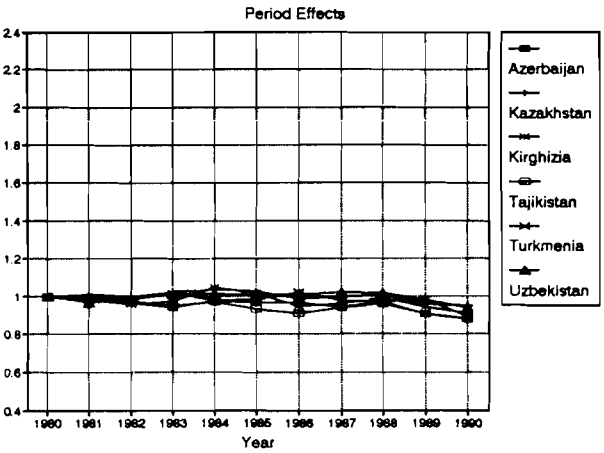
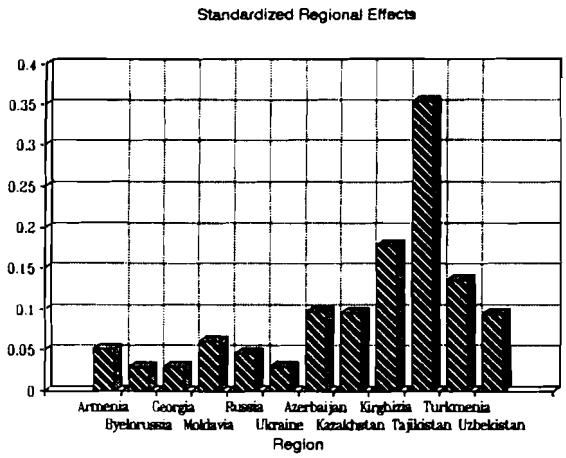
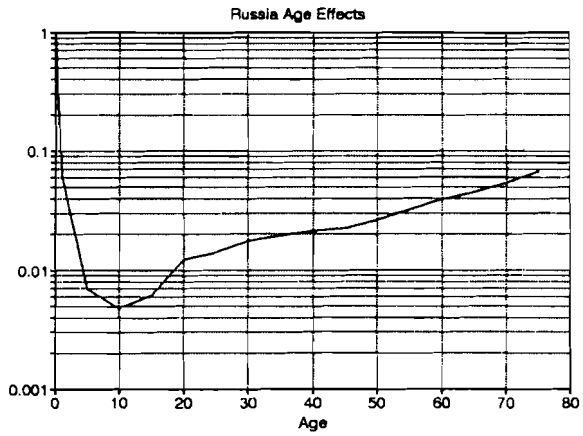
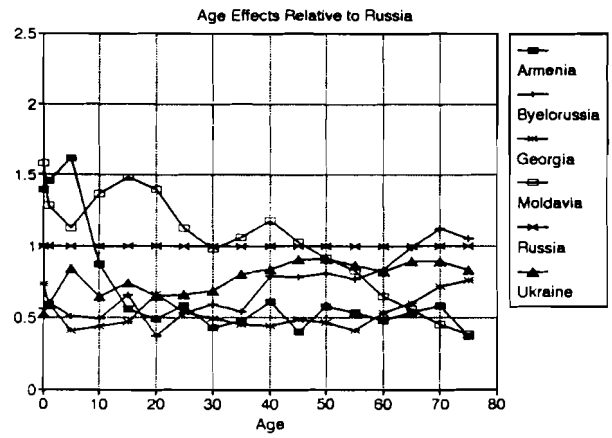
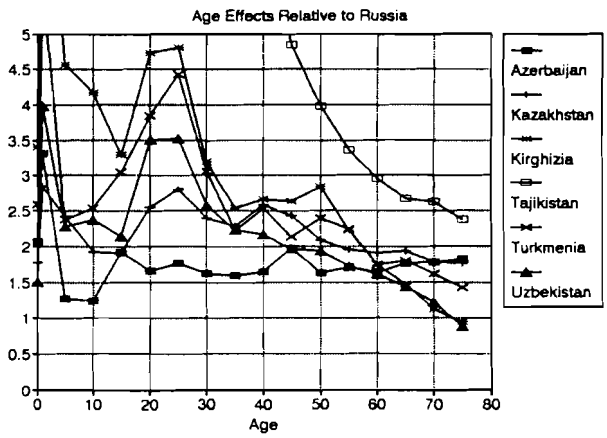


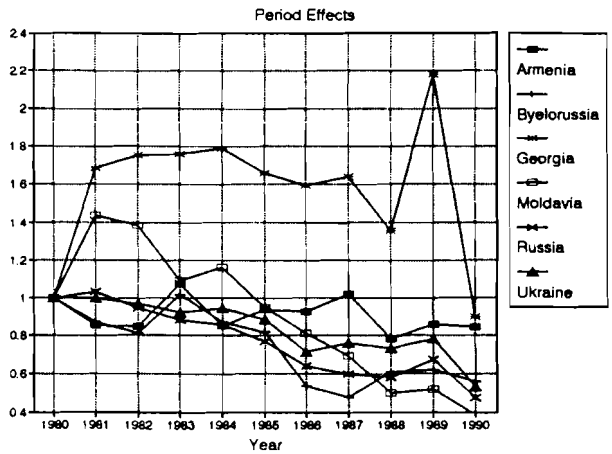
Figure 10. Infectious and parasitic diseases, female.











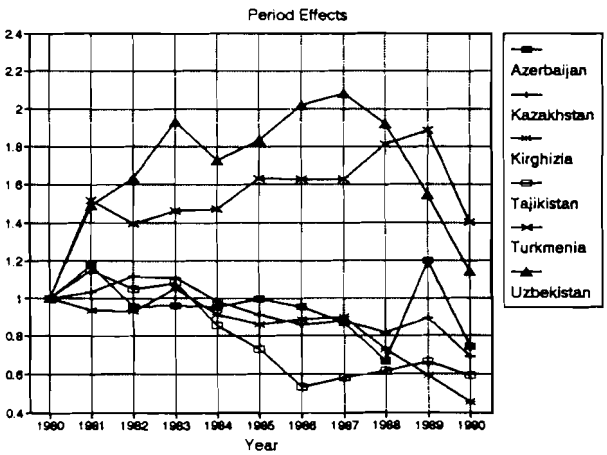
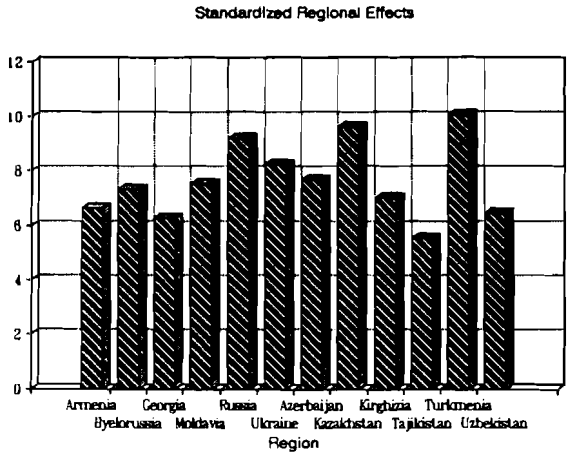
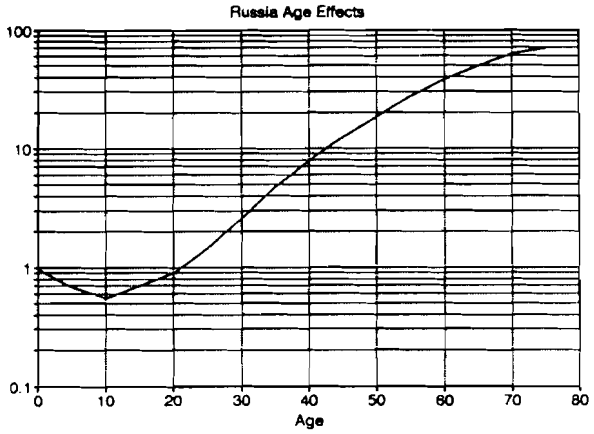
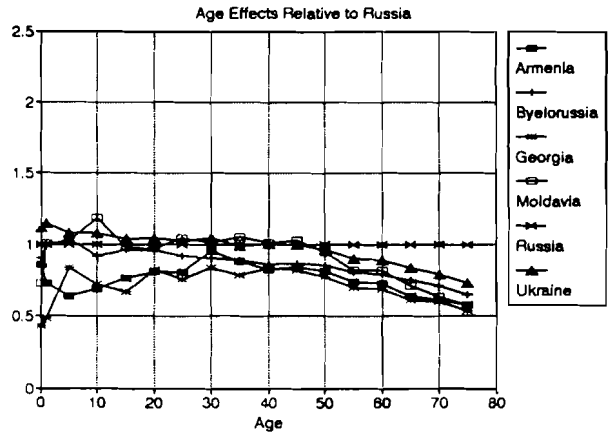
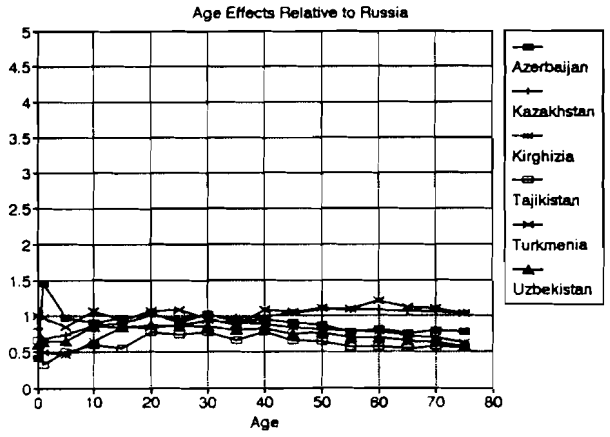


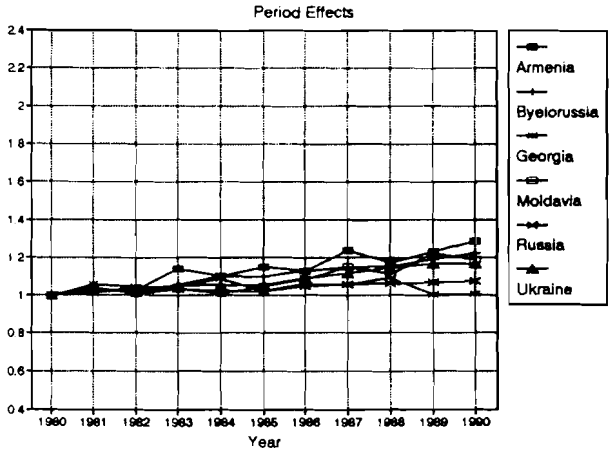
Figure 11. Neoplasms, female.











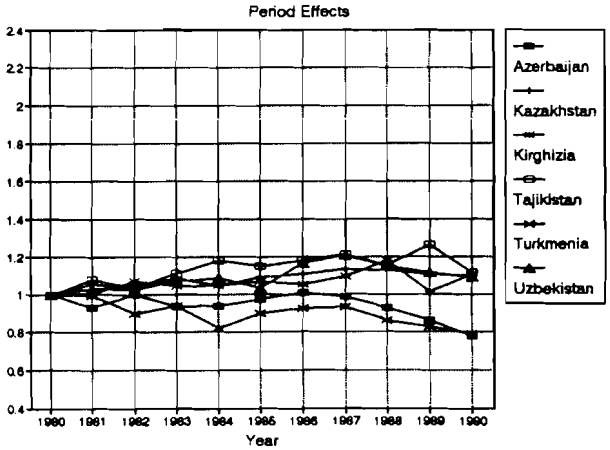
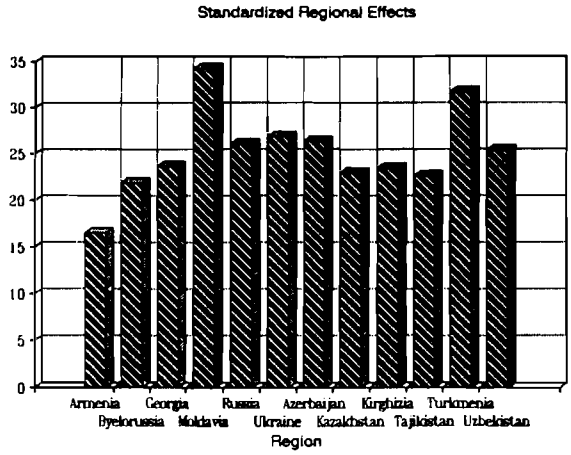
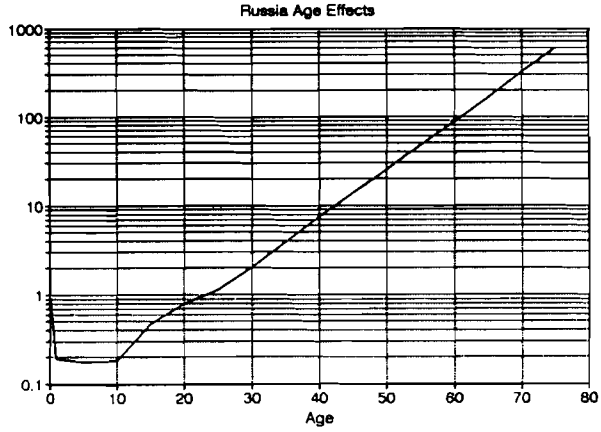
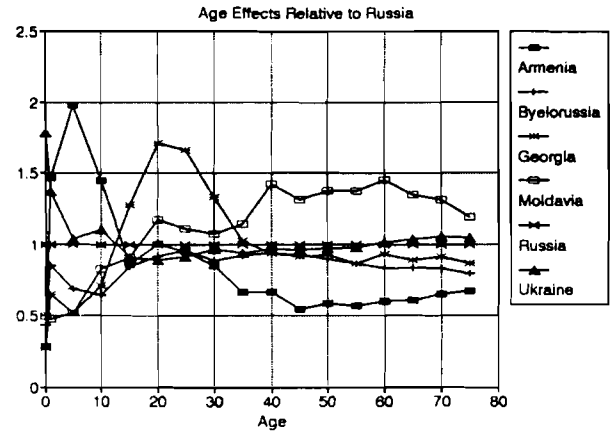
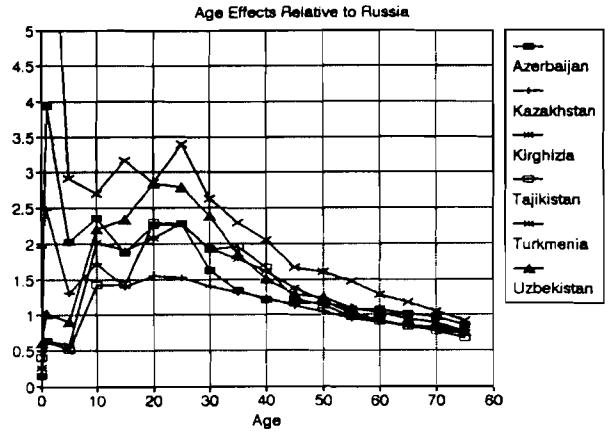


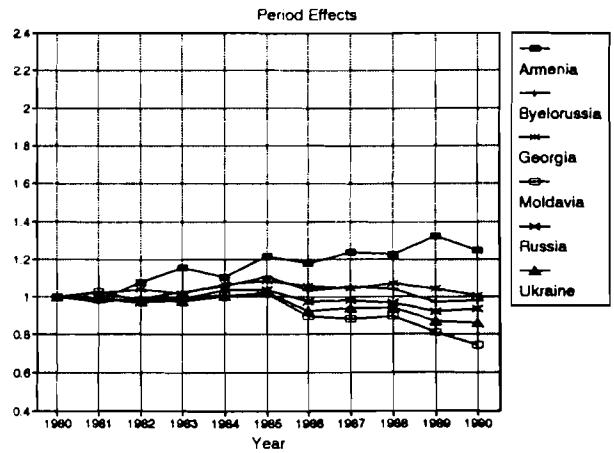
Figure 12. Diseases of the circulatory system, female.











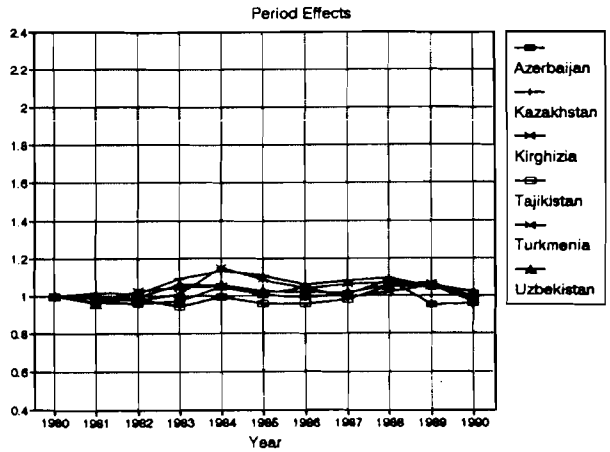
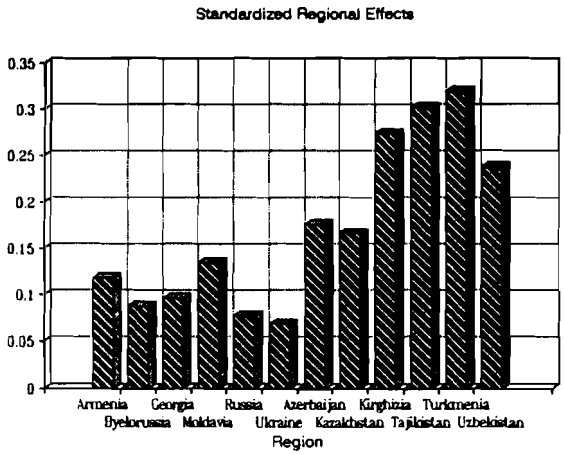
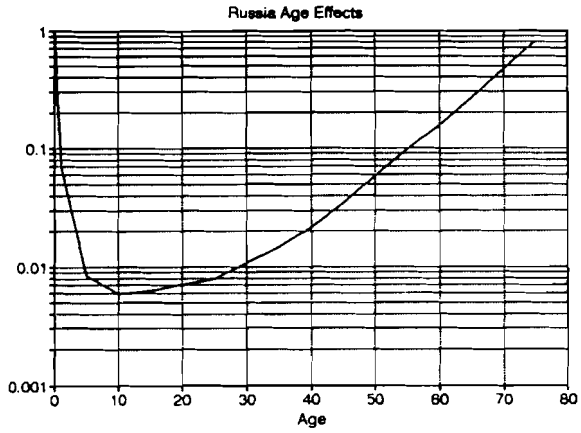
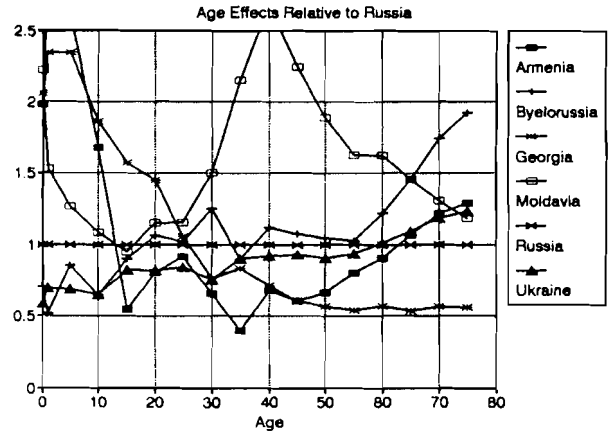
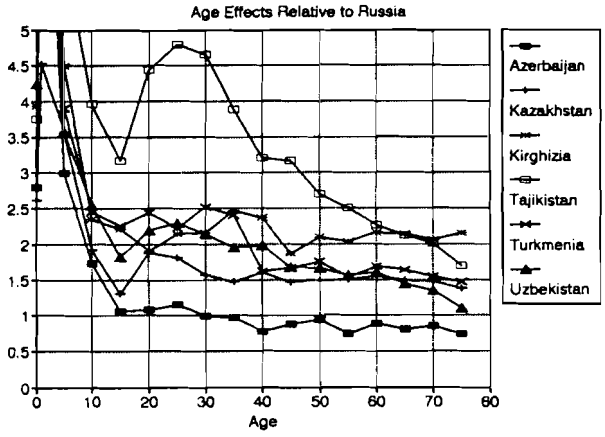


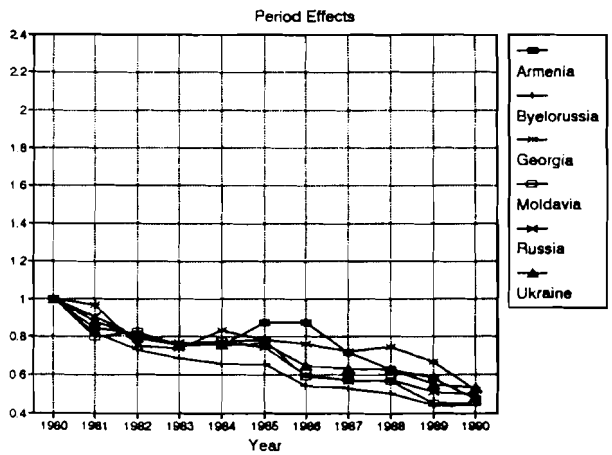
Figure 13. Diseases of the respiratory system, female.











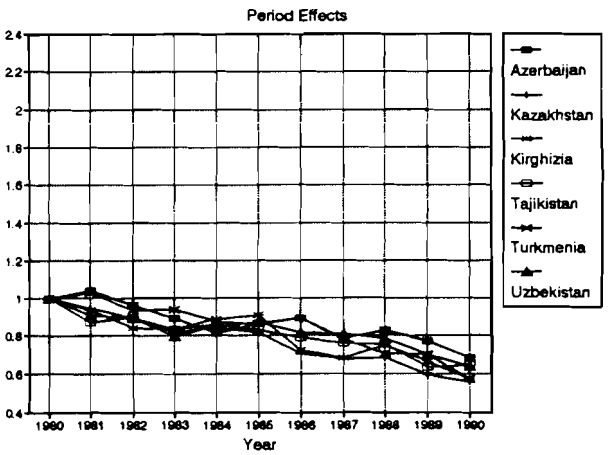
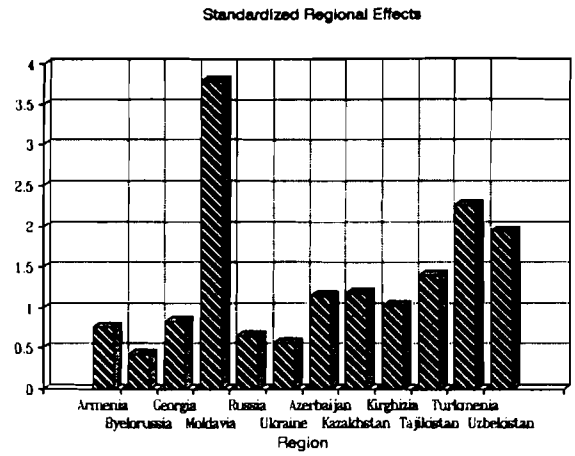
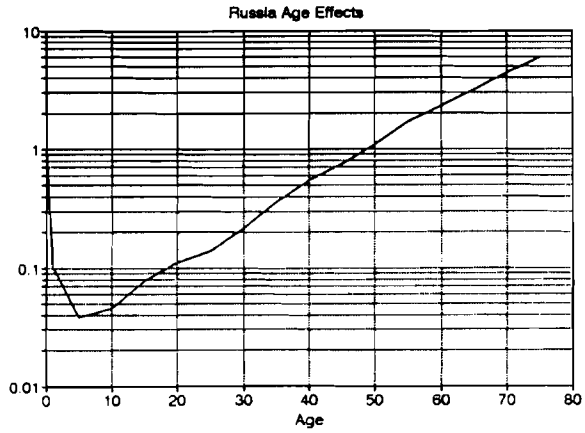
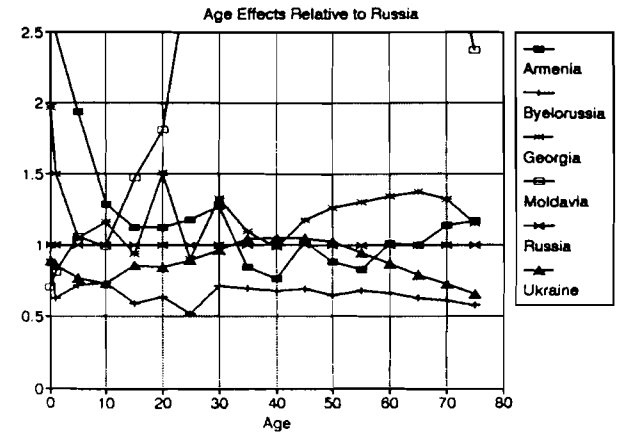
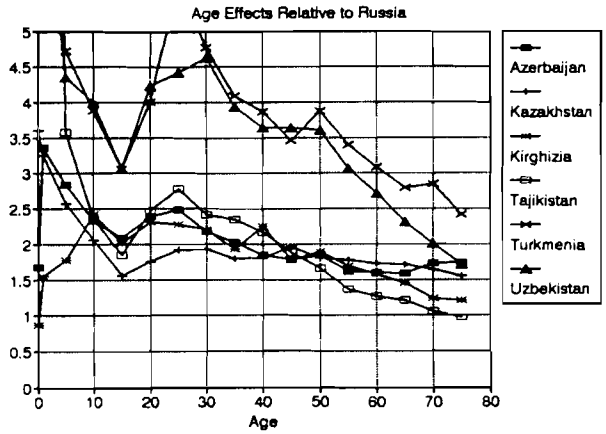


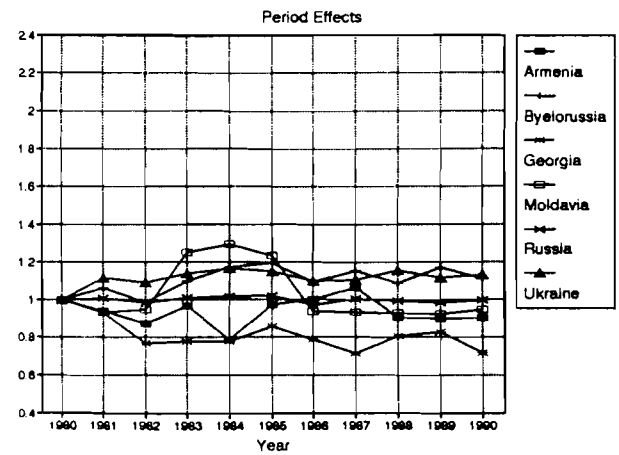
Figure 14. Diseases of the digestive system, female.











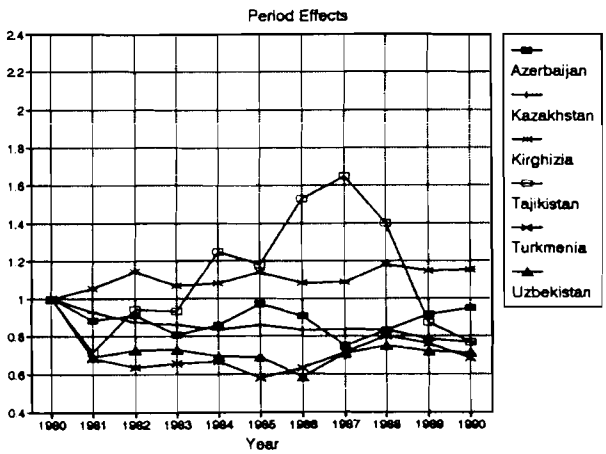
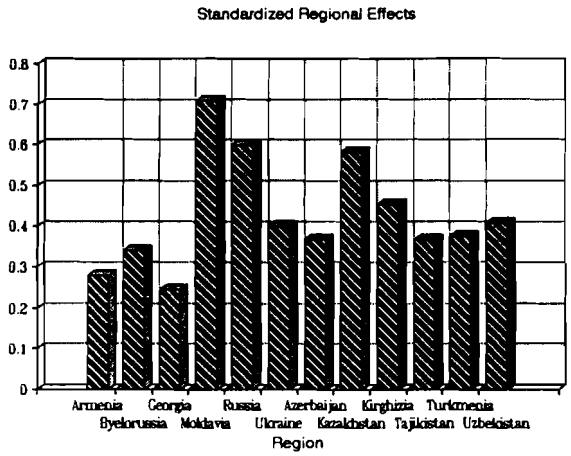
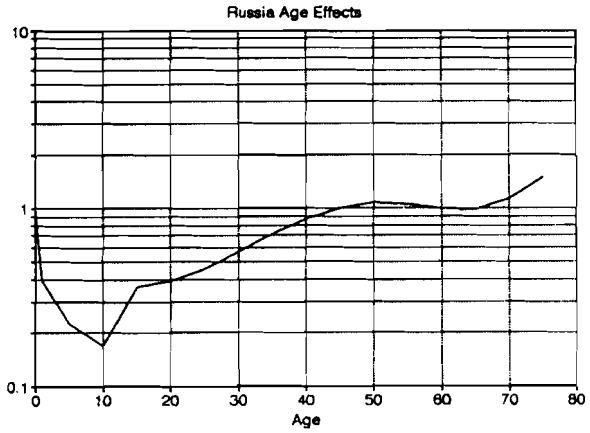
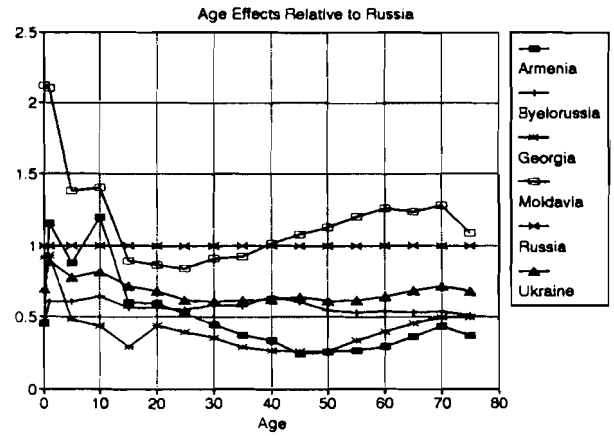
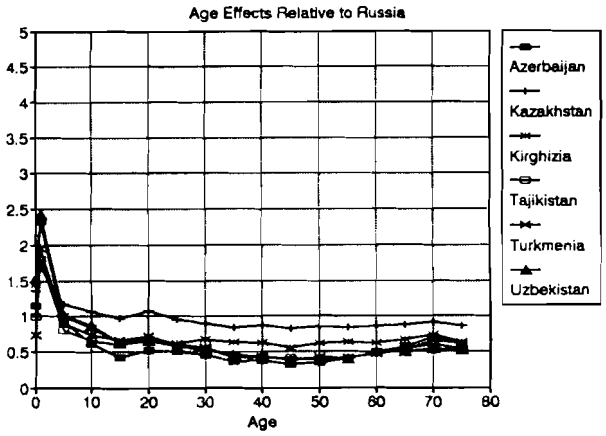


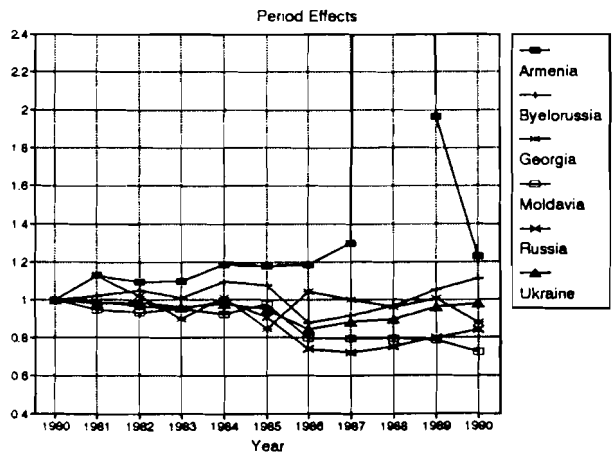
Figure 15. Accidents, poisonings and violence, female.











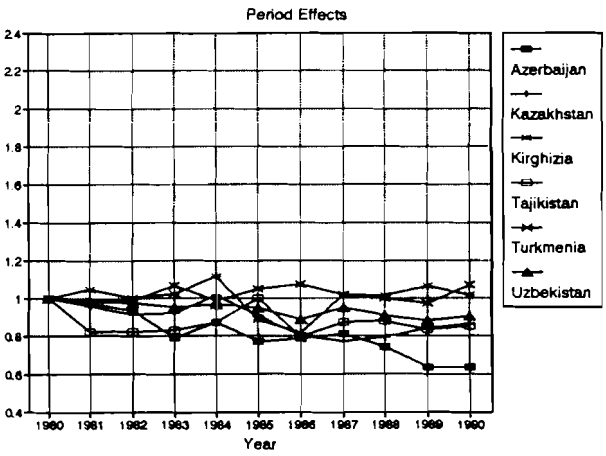
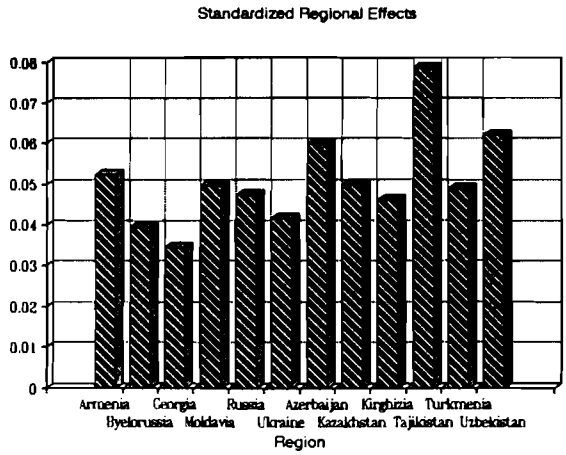
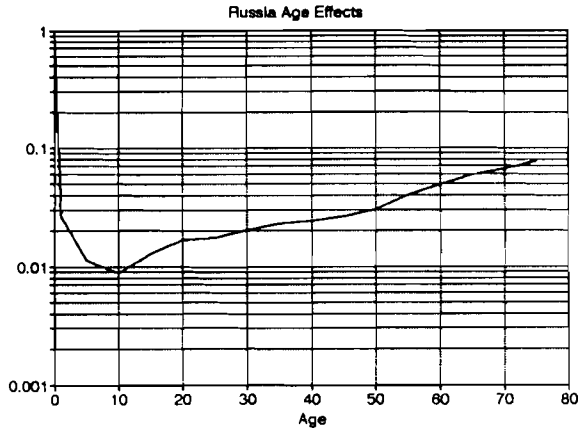
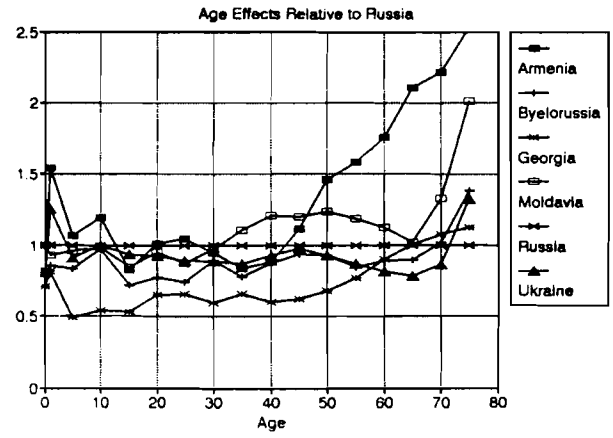
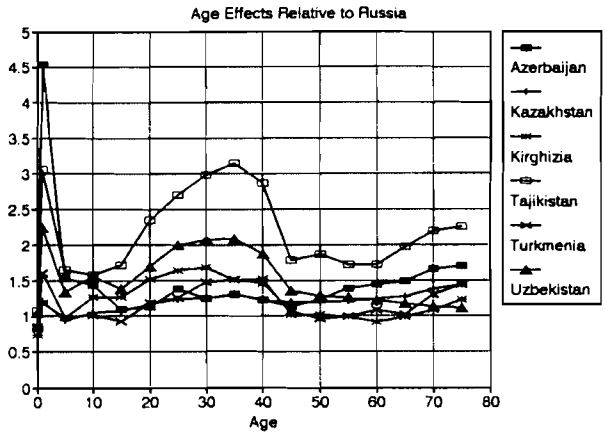


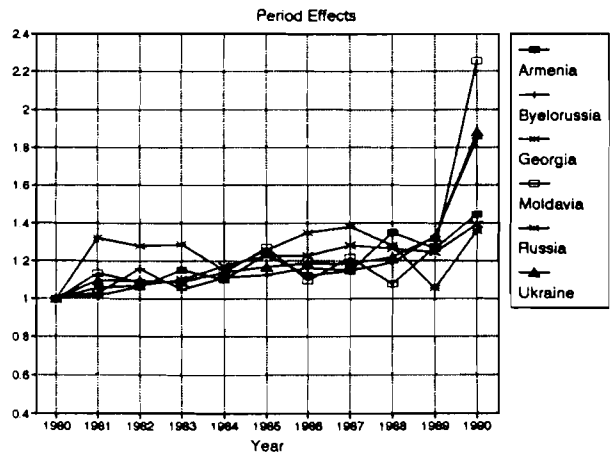
Figure 16. Others and unknown causes, female.











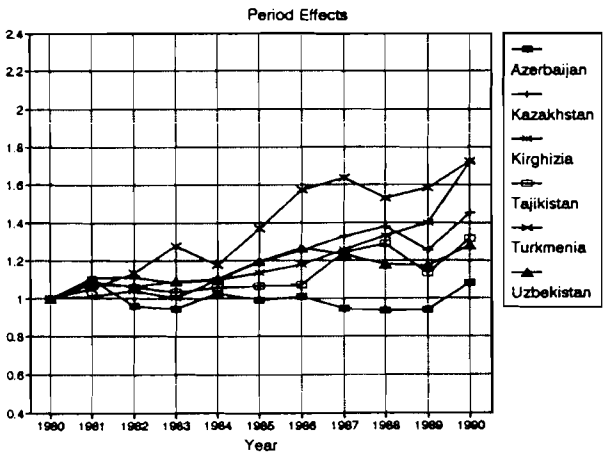


Figure 17. Dynamics of age-specific death rates and period effects for Byelorussia and Moldavia. Others and unknown causes.

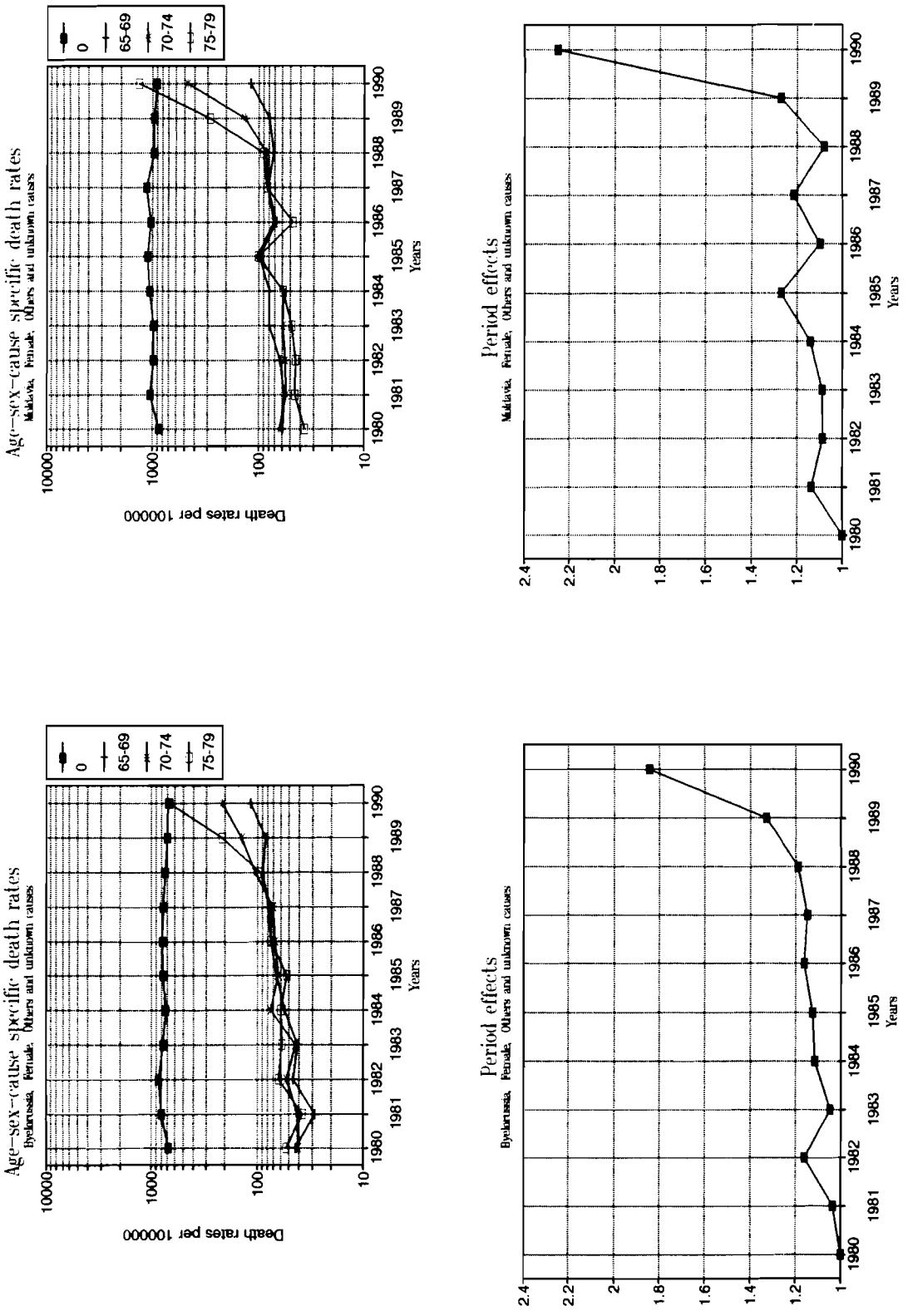


Figure 18. Errors of projection to 1990 as a function of weights. Male. Accidents, poisonings and violence.

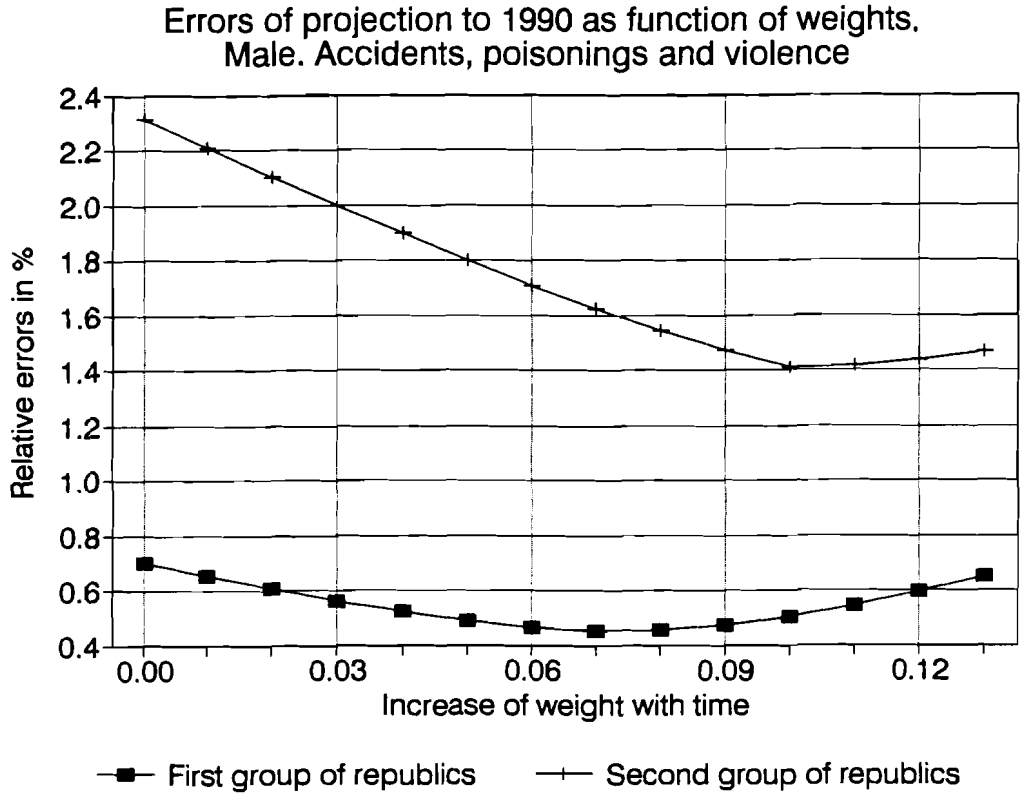


Figure 19. Age-sex-cause specific death rates projections for Uzbekistan. Male. Accidents, poisonings and violence.

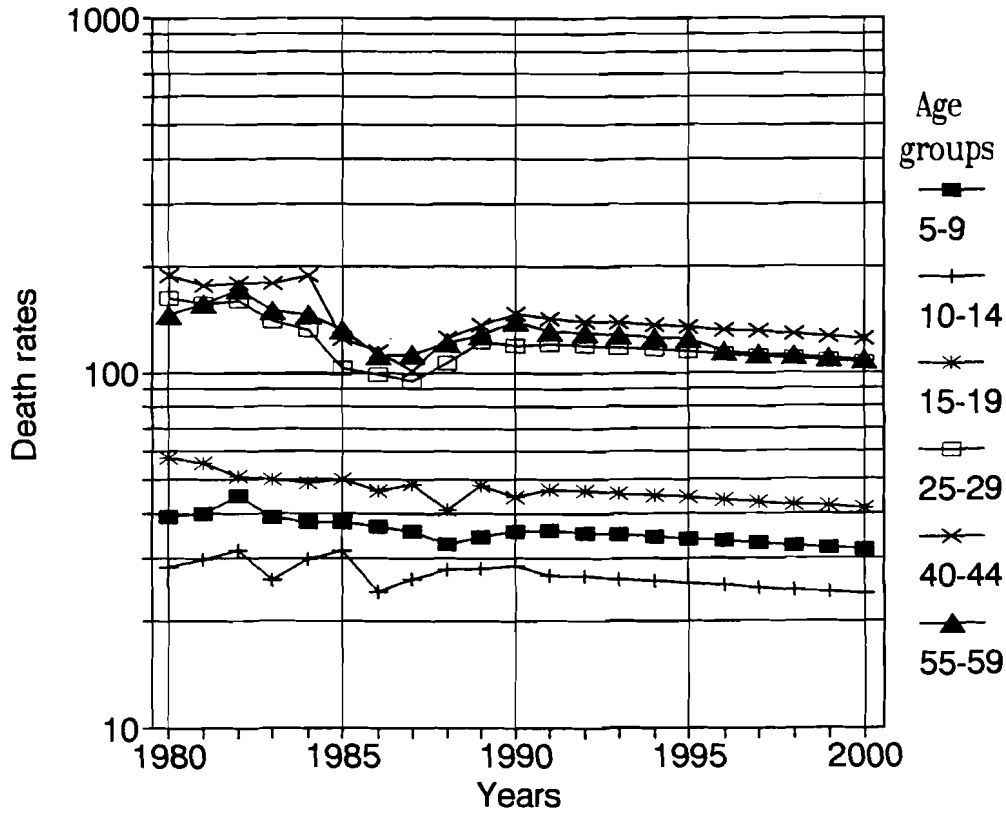


Figure 20. Age-sex-cause specific death rates projections for Russia. Male. Accidents, poisonings and violence.

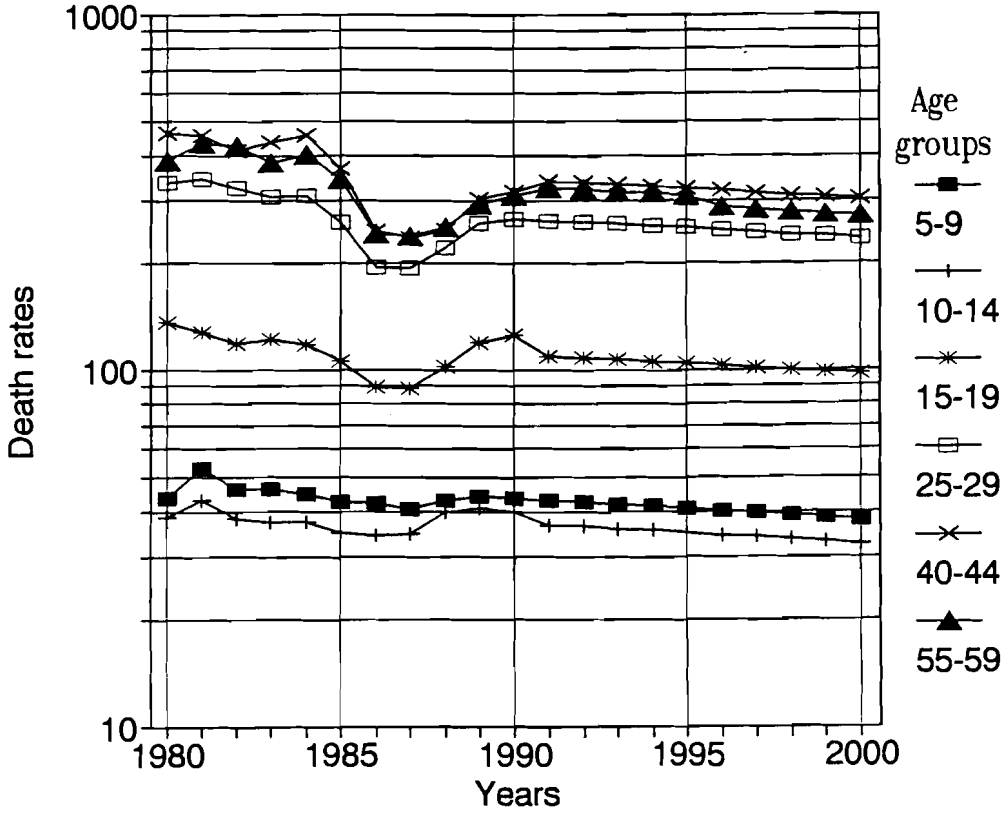


Figure 21. Age-sex-cause specific death rates projections for Russia. Male. Diseases of the circulatory system.

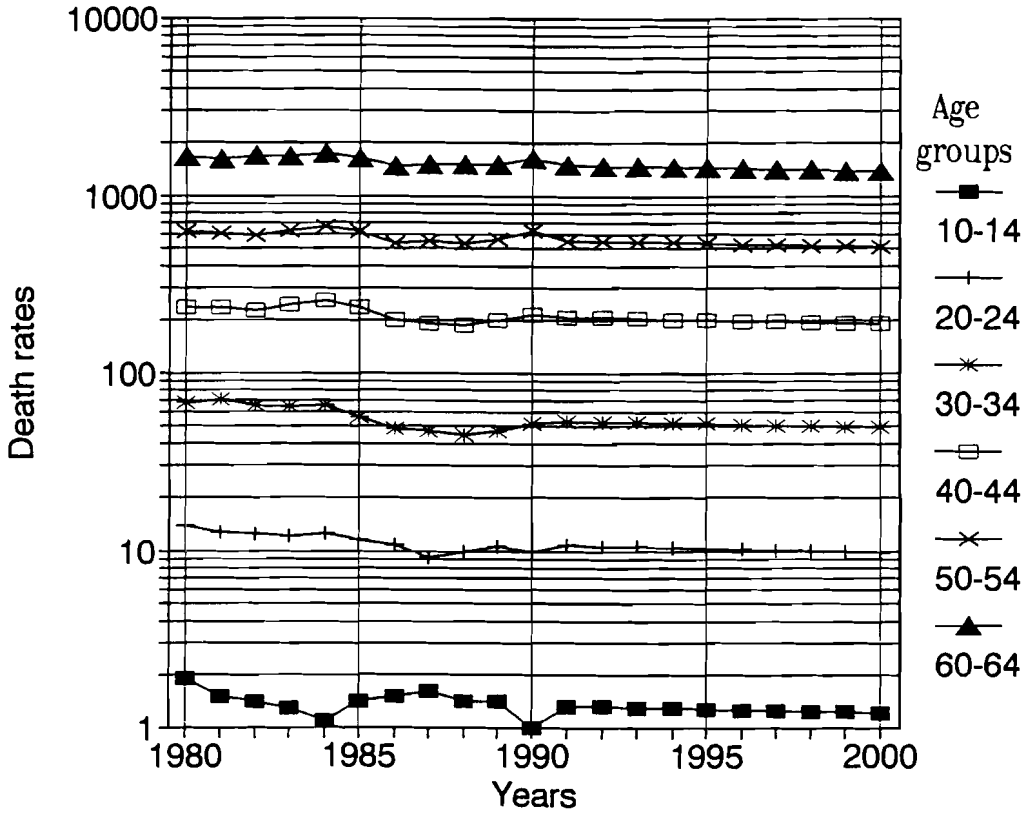


Figure 22. Age-sex-cause specific death rates projections for Kirghizia. Male. Diseases of the circulatory system.

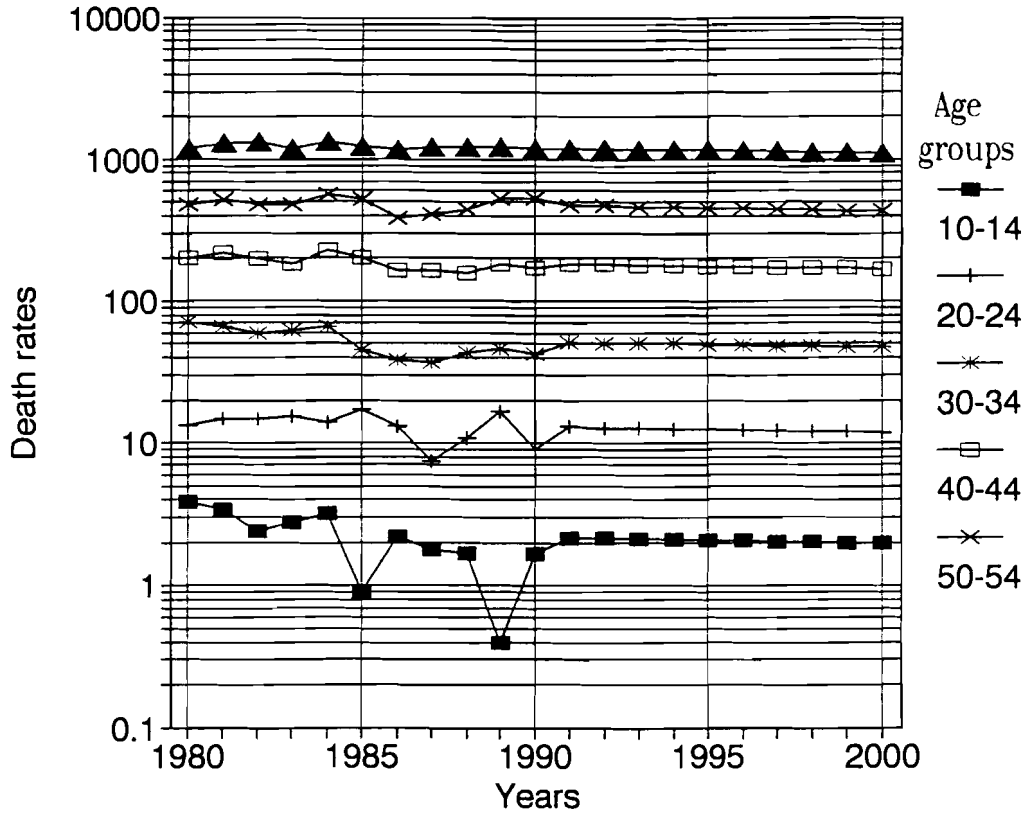


Figure 23. Age-sex-cause specific death rates projections for Kazakhstan. Female. Diseases of the circulatory system.

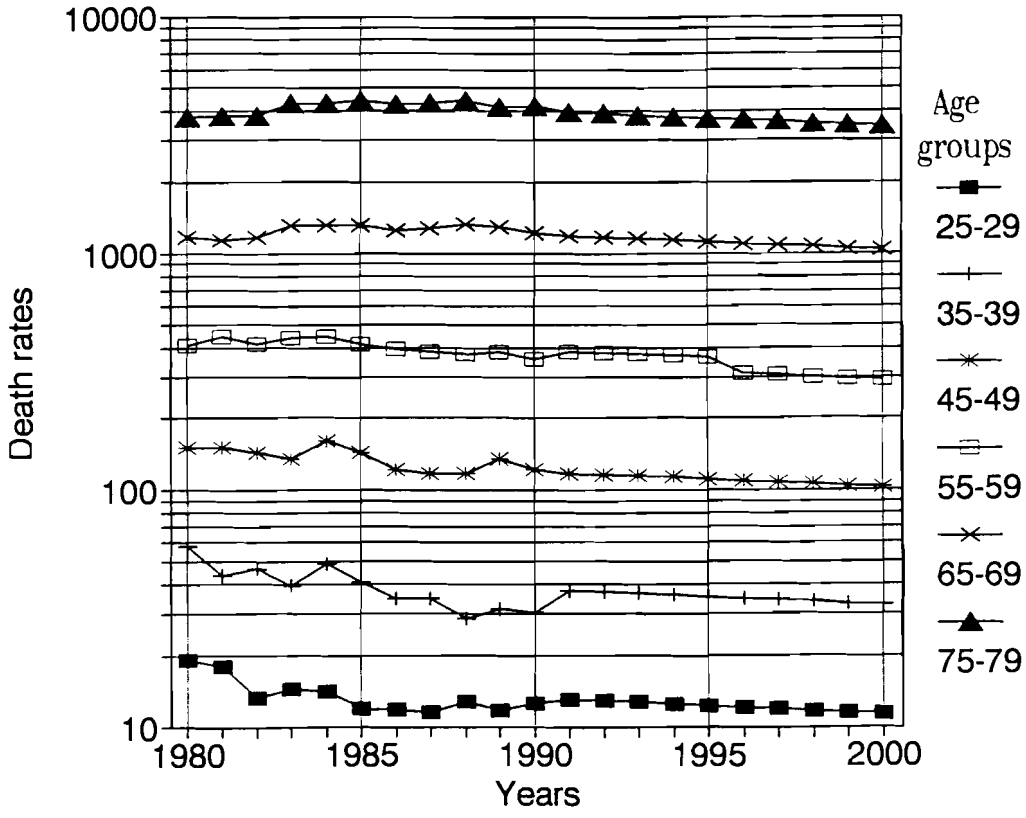


Figure 24. Age-sex-cause specific death rates projections for Georgia. Female. Diseases of the circulatory system.

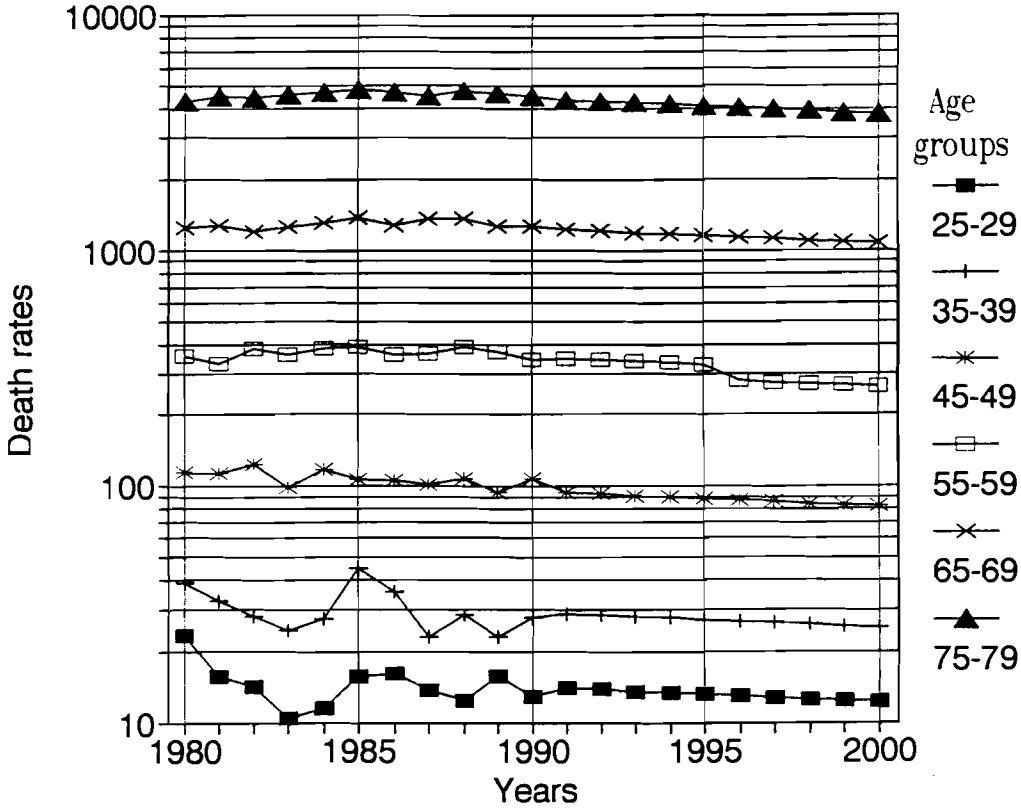


Figure 25. Age-sex-cause specific death rates projections for Byelorussia. Female. Neoplasms.

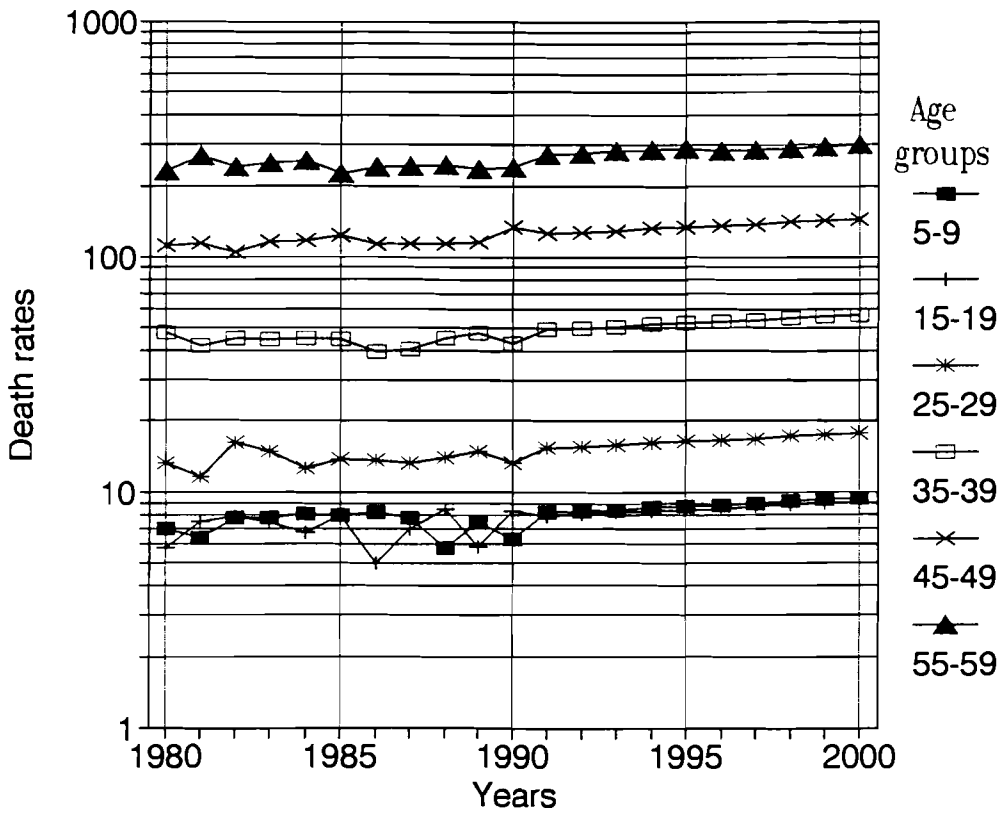


Figure 26. Age-sex-cause specific death rates projections for Turkmenia. Female. Neoplasms.

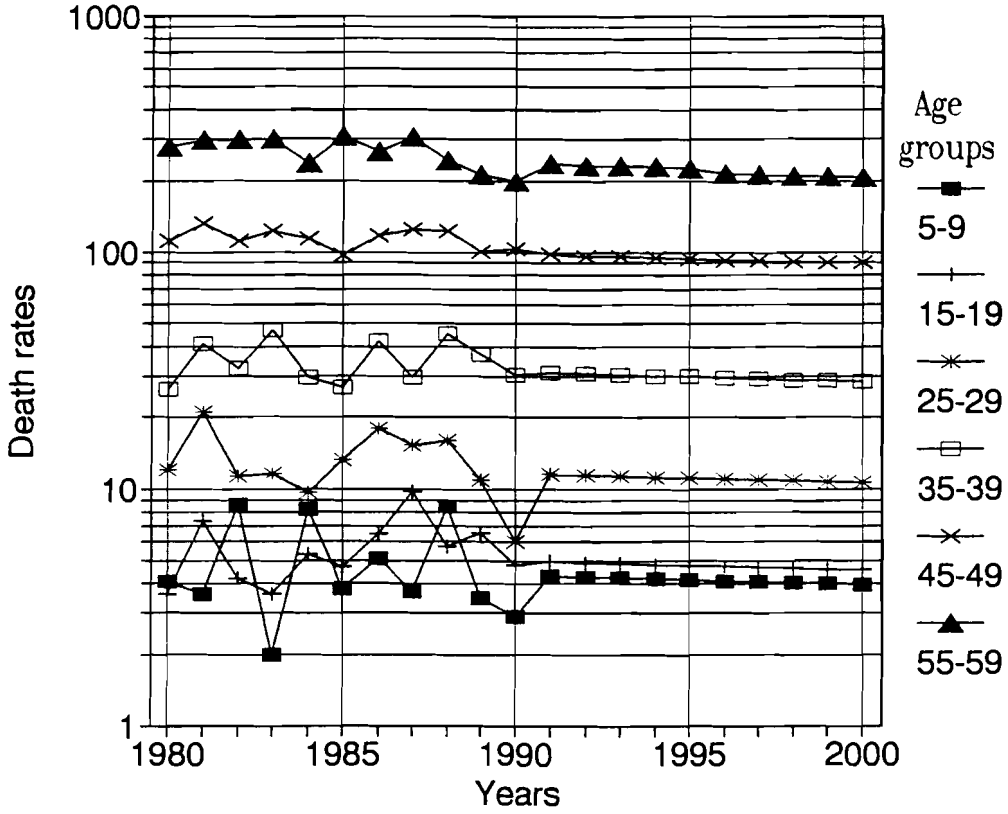


Figure 27. Age-sex-cause specific death rates projections for Ukraine. Female. Diseases of the respiratory system.

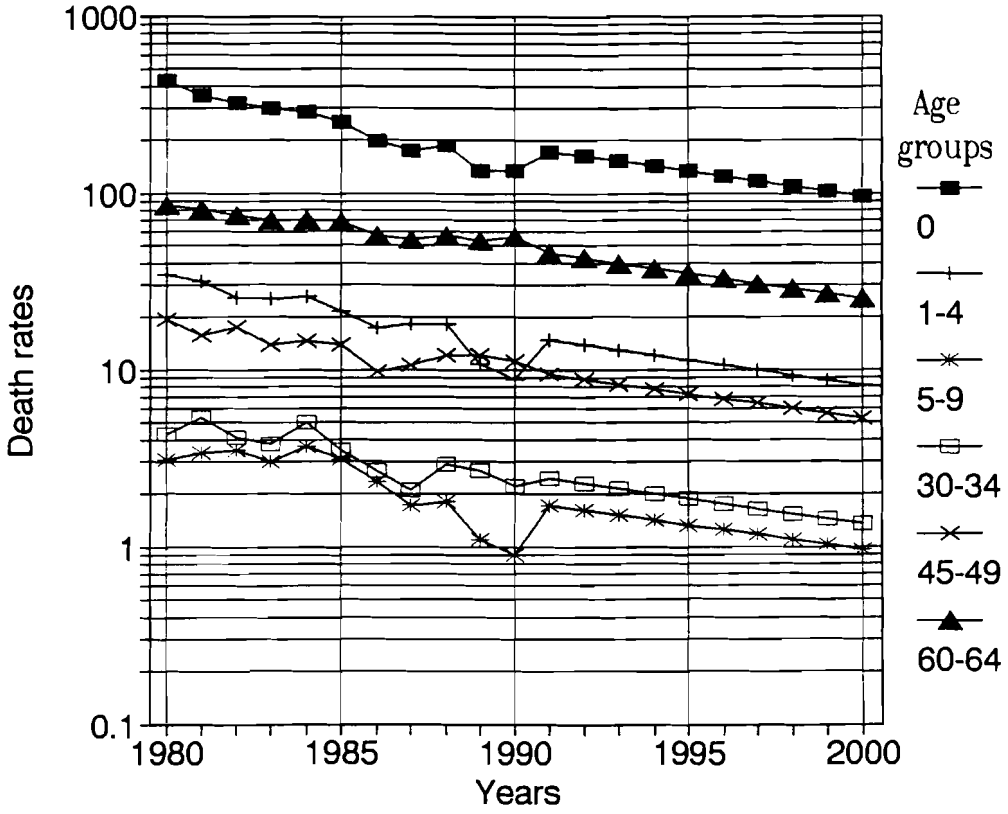


Figure 28. Age-sex-cause specific death rates projections for Tajikistan. Female. Diseases of the respiratory system.

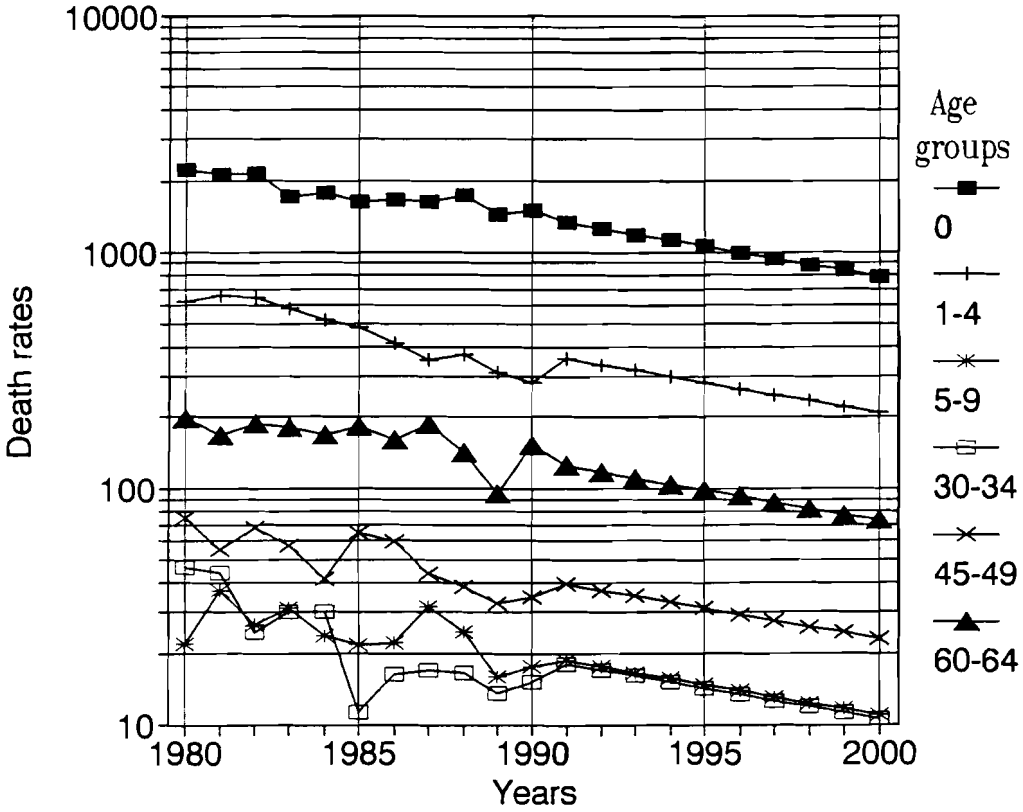


Figure 29. Age-sex-cause specific death rates projections for Moldavia. Male. Diseases of the digestive system.

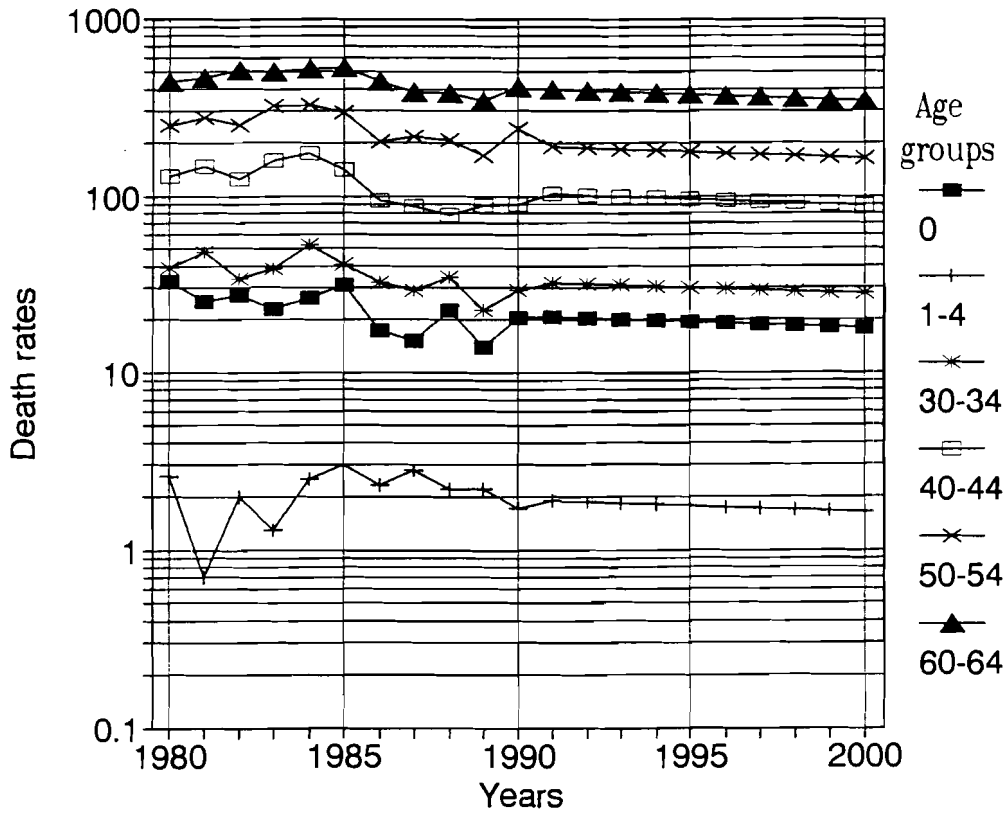


Figure 30. Age-sex-cause specific death rates projections for Tajikistan. Male. Diseases of the digestive system.

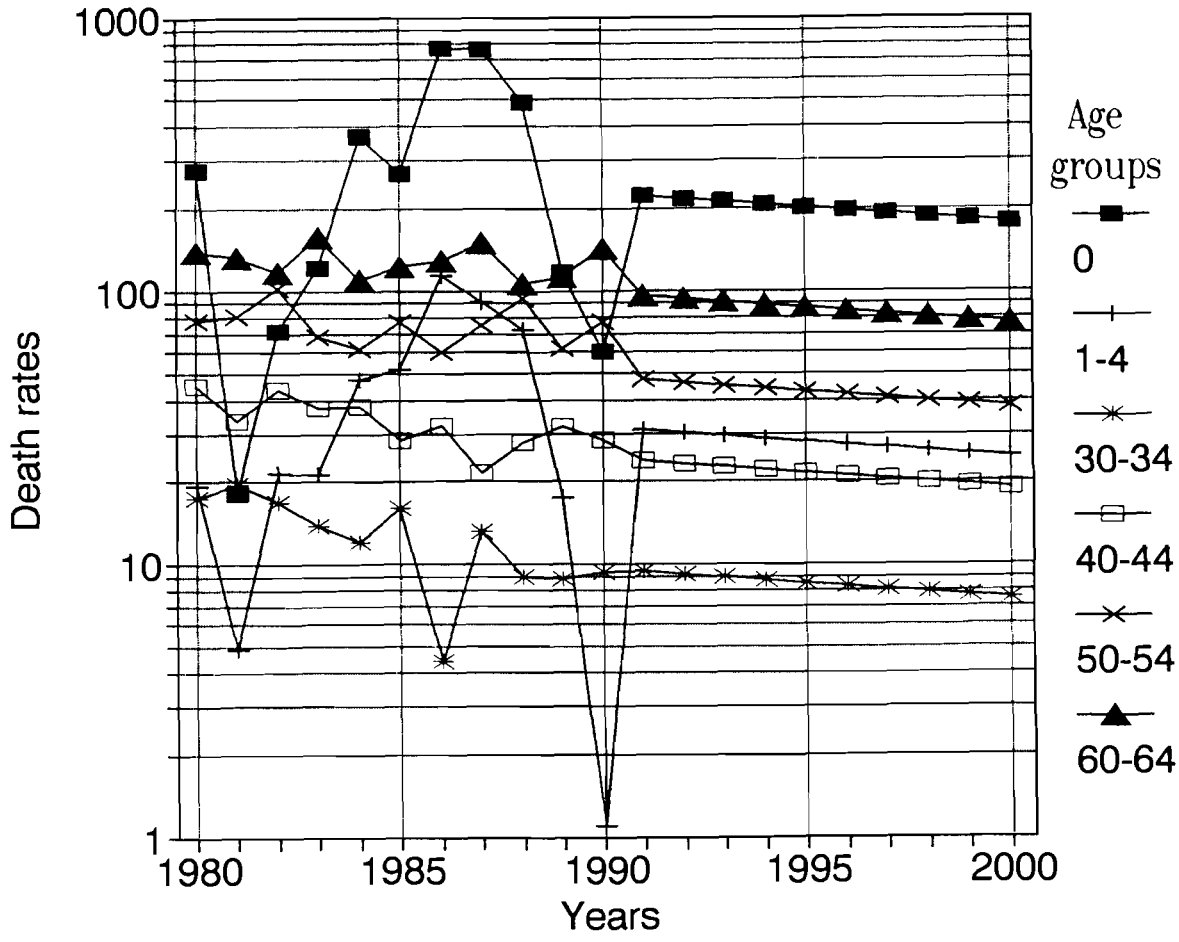


Figure 31. Male life expectancy projections, year 2000.

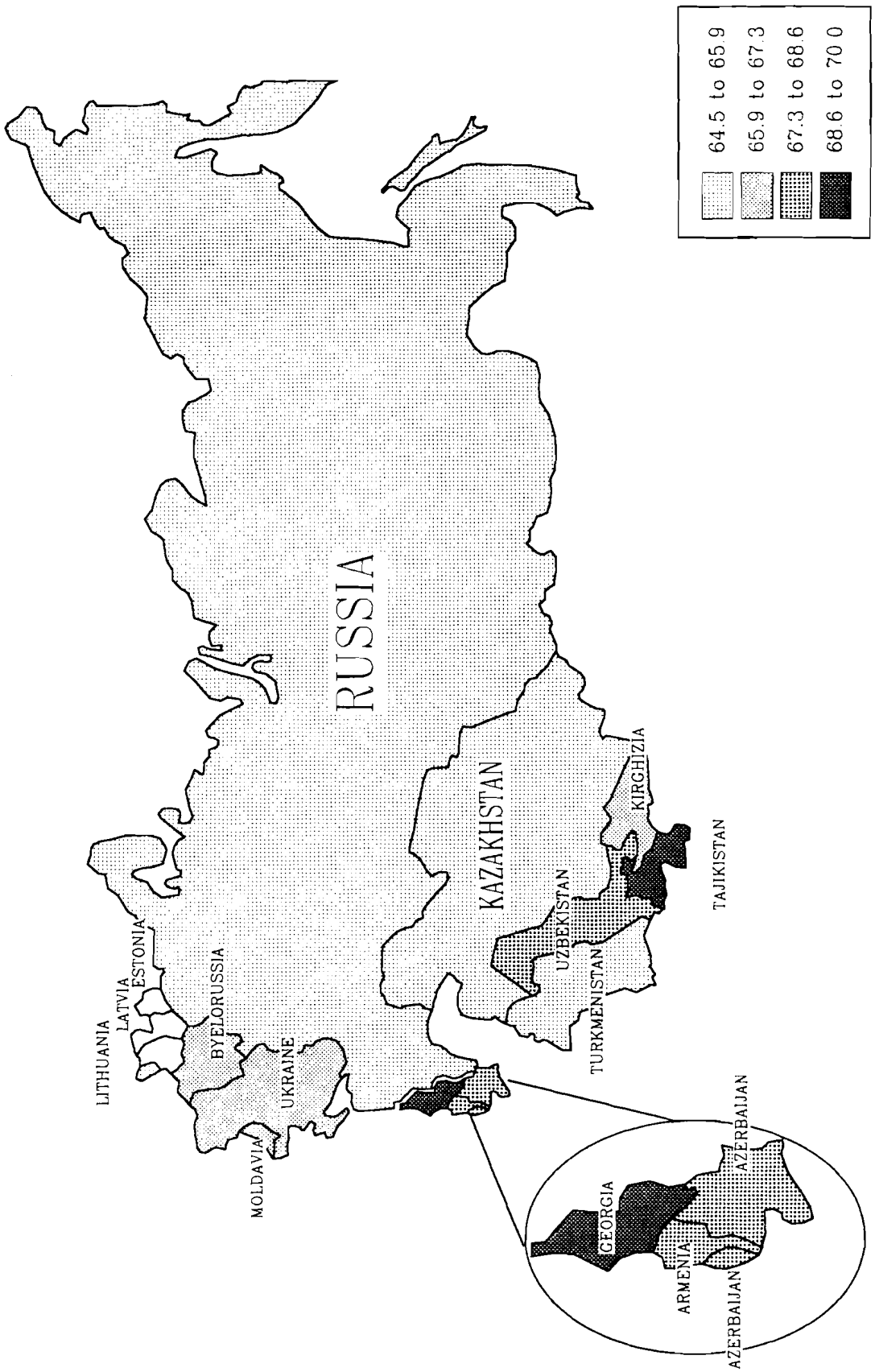


Figure 32. Female life expectancy projections, year 2000.

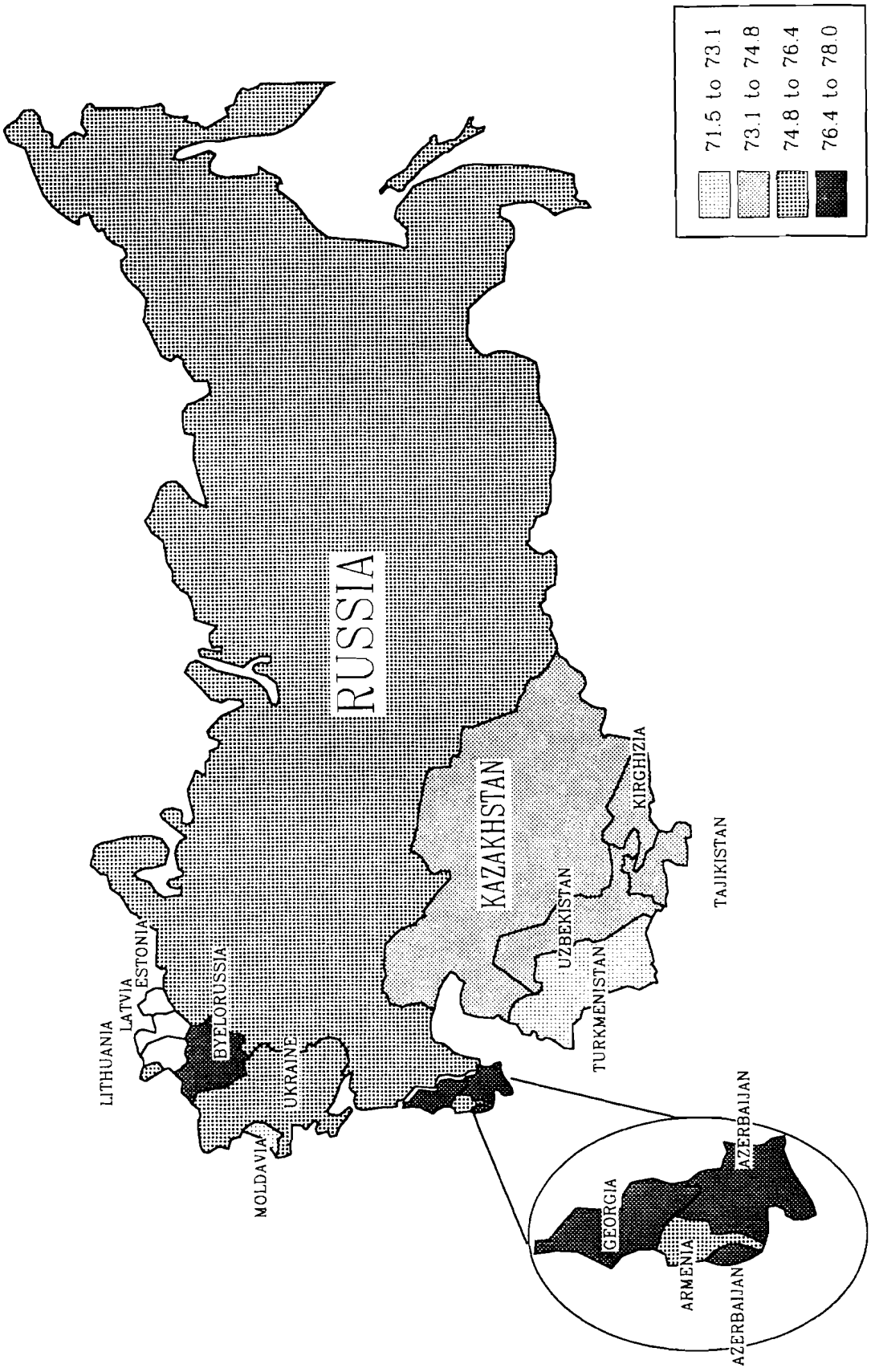


Figure 33. Differences between female and male life expectancy, 1990.

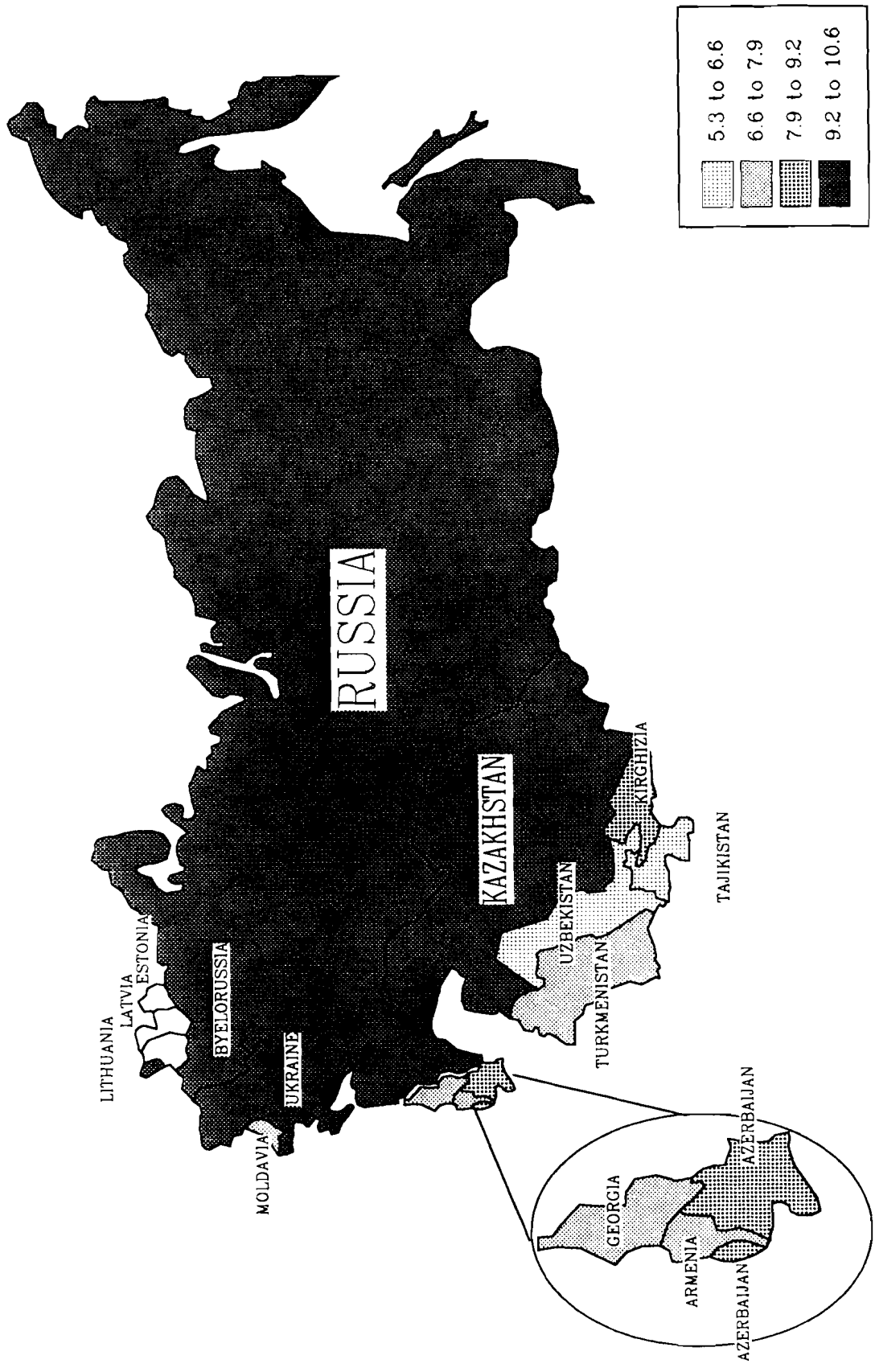


Figure 34. Projected changes in life expectancy for males, 1990-2000.

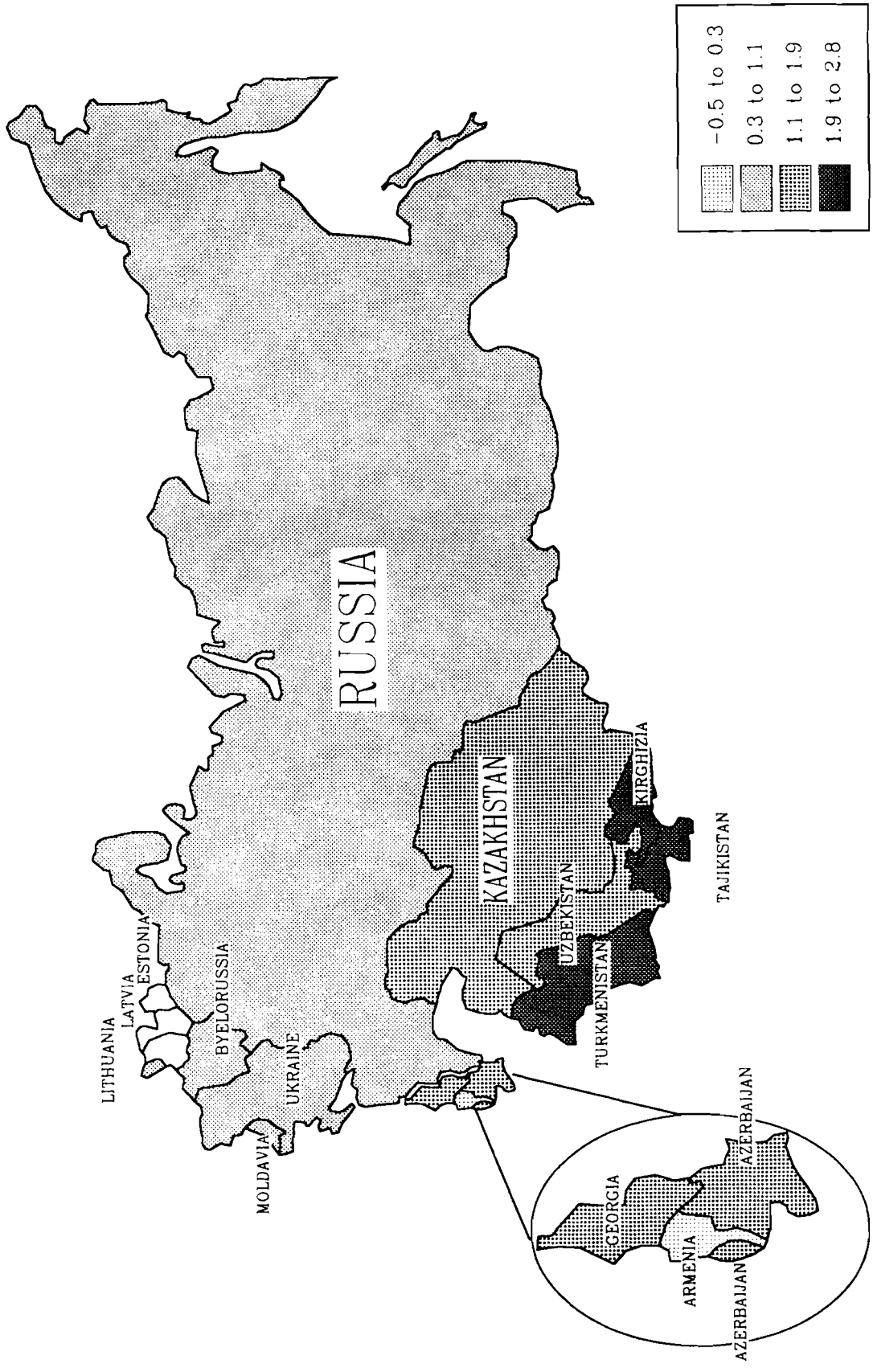


Figure 35. Projected changes in life expectancy for females, 1990-2000.

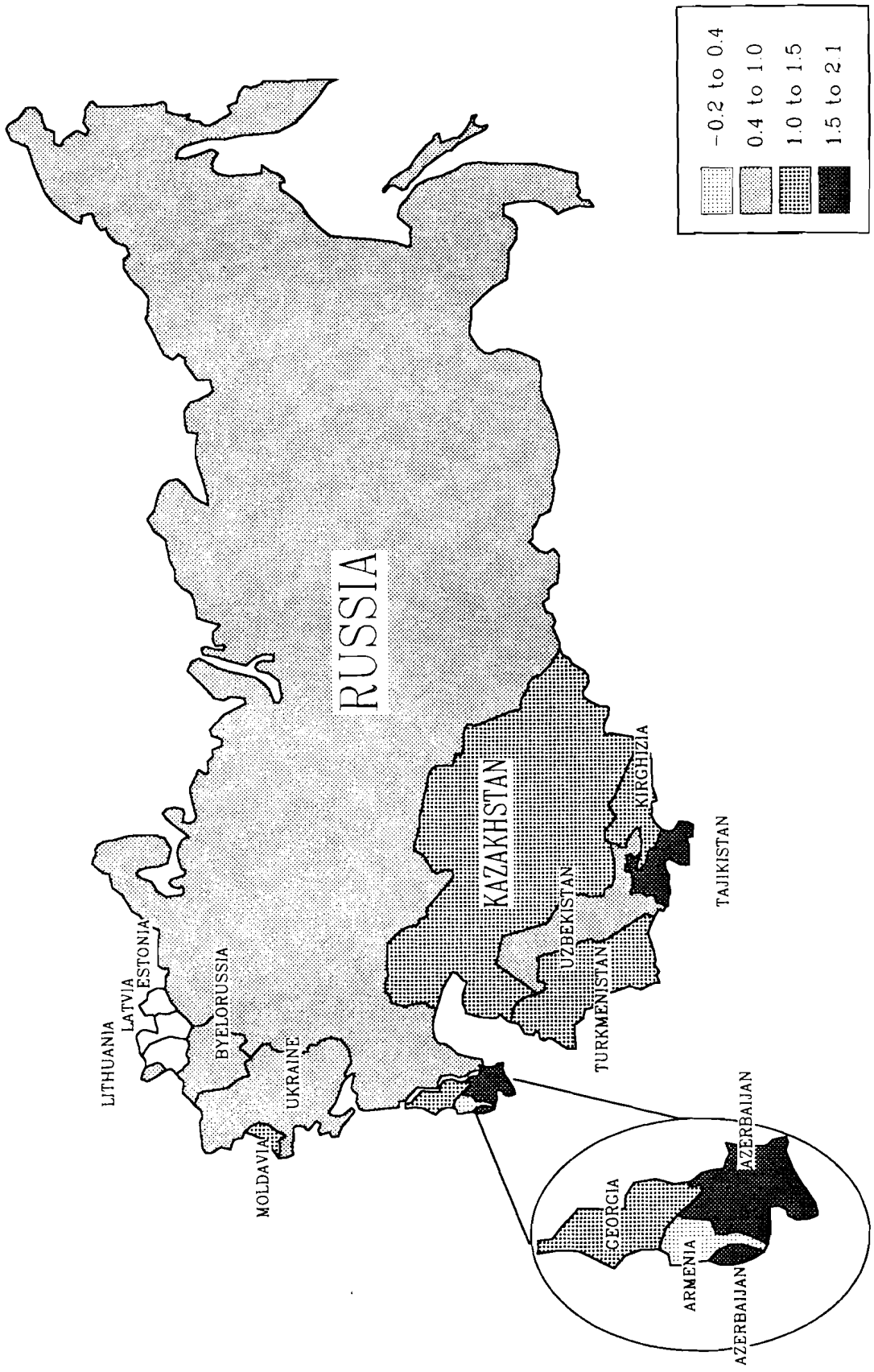


Figure 36. Projected changes in male life expectancy due to neoplasms, 1990-2000.

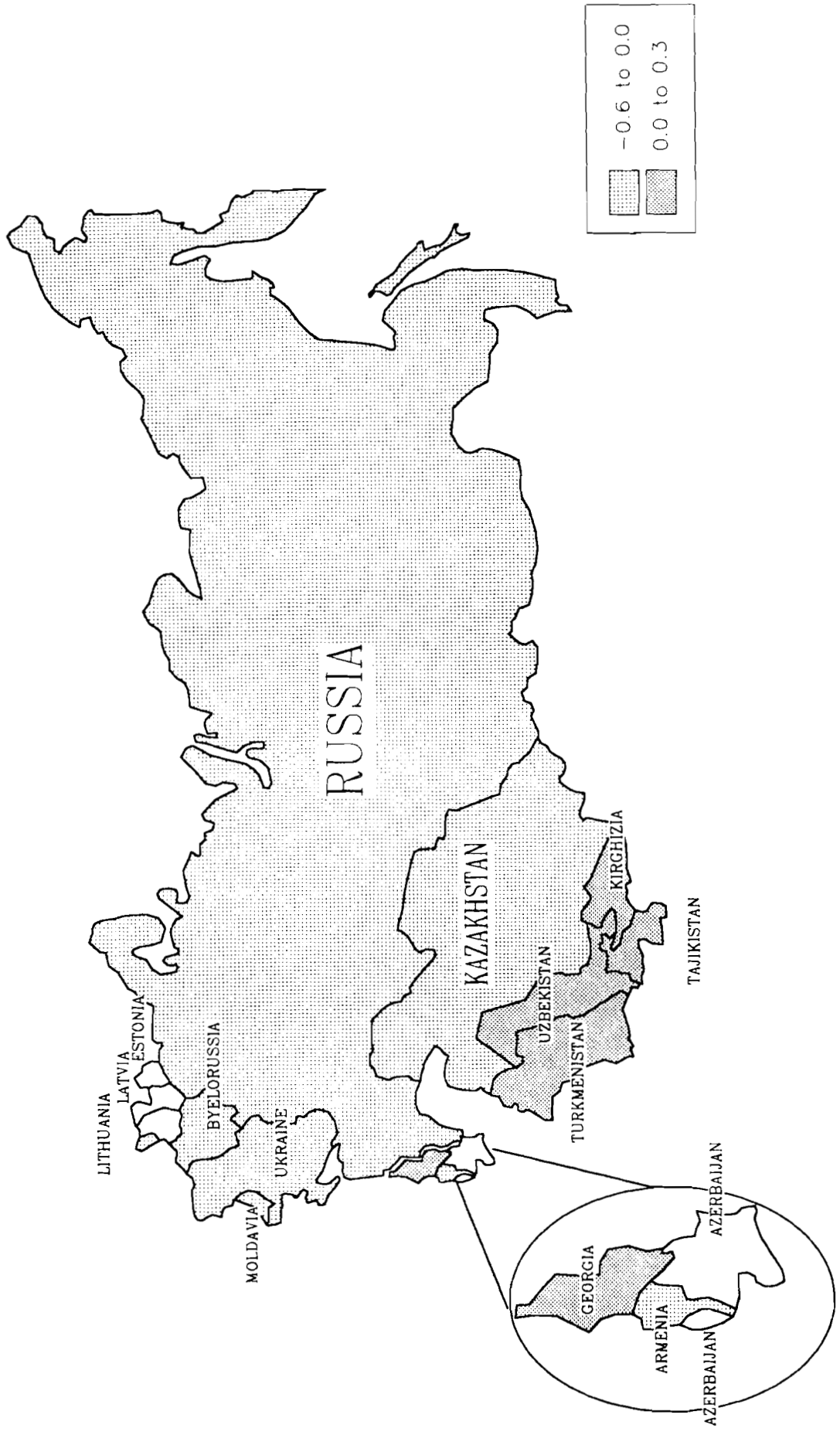


Figure 37. Projected changes in female life expectancy due to neoplasms, 1990-2000.

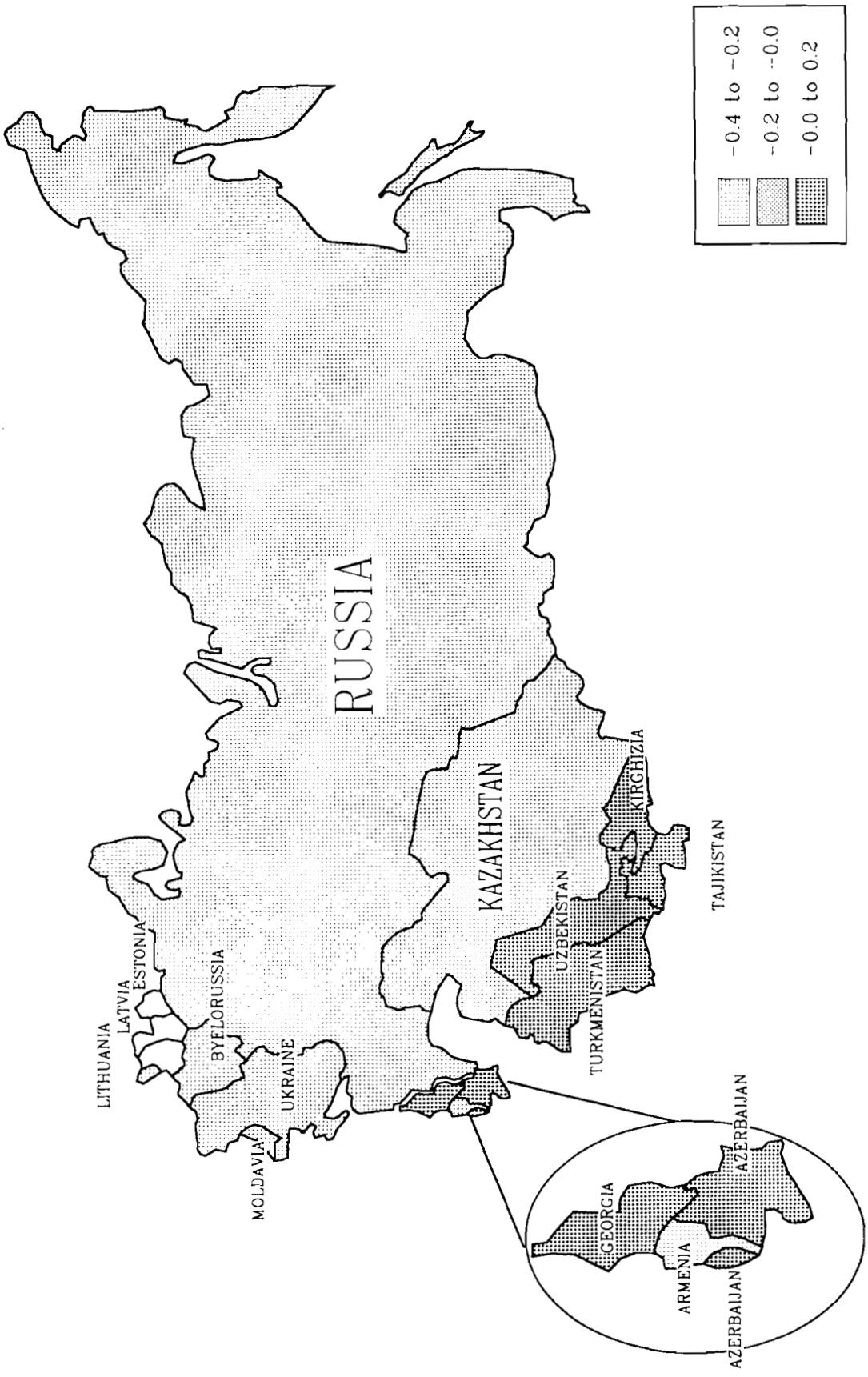


Figure 38. Projected changes in male life expectancy due to diseases of the circulatory system, 1990-2000.

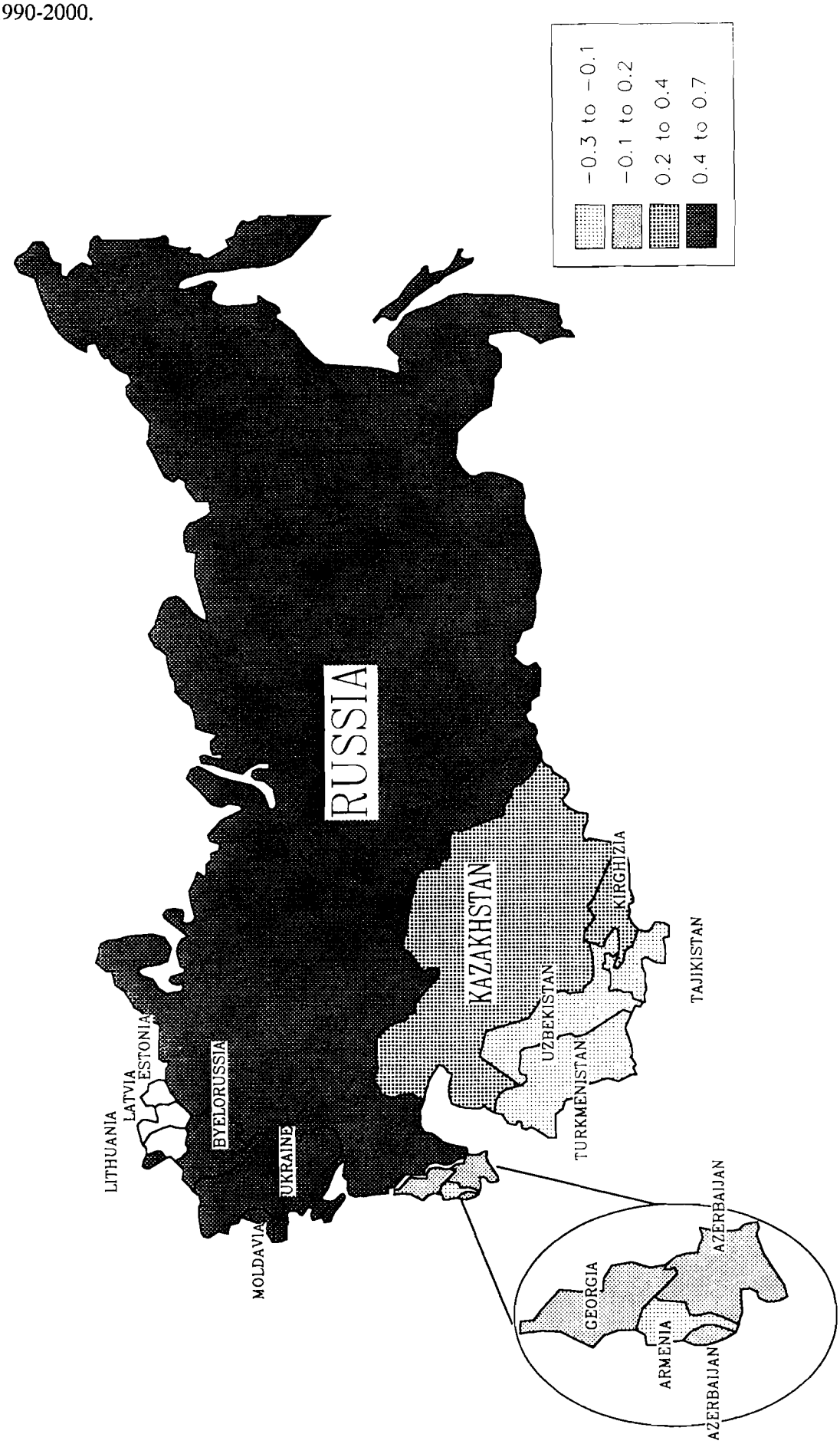


Figure 39. Projected changes in female life expectancy due to diseases of the circulatory system, 1990-2000.

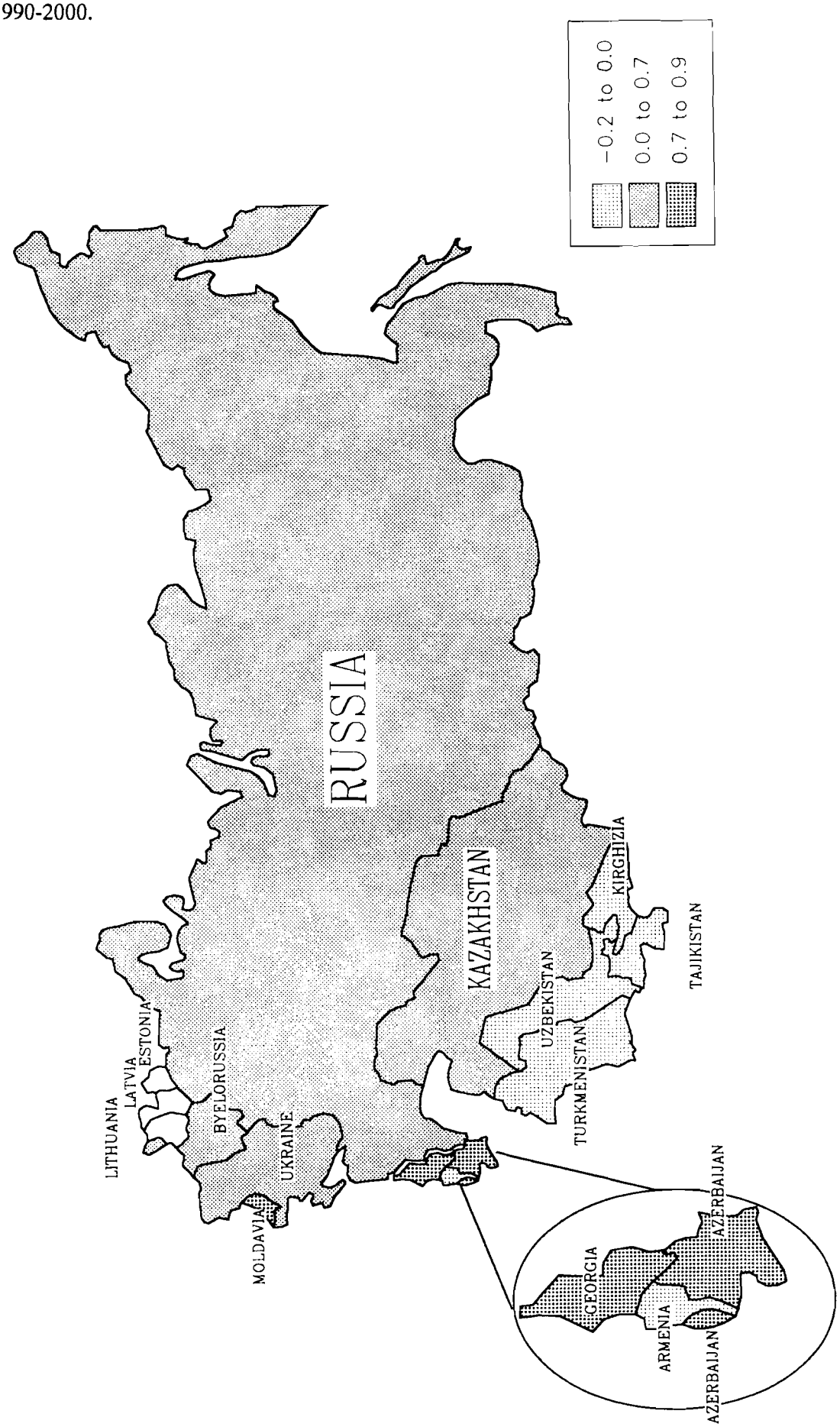


Table 1a. R^2 for each republic and cause of death.

R squared for each republic and cause of death								
Region	All causes	Infectious and parasitic diseases	Neoplasms	Diseases of circulatory system	Respiratory diseases	Digestive system diseases	Accidents, poisonings and violence	Others and unknown causes
Male								
All regions	0.995	0.988	0.995	0.998	0.989	0.936	0.959	0.987
Armenia	0.991	0.991	0.990	0.997	0.978	0.954	0.922	0.995
Byelorussia	0.998	0.981	0.997	0.999	0.996	0.962	0.976	0.980
Georgia	0.997	0.936	0.995	0.999	0.987	0.968	0.919	0.996
Moldavia	0.996	0.986	0.994	0.999	0.952	0.980	0.921	0.967
Russia	0.998	0.983	0.999	0.999	0.988	0.986	0.987	0.997
Ukraine	0.998	0.981	0.998	0.999	0.986	0.973	0.981	0.990
Azerbaijan	0.996	0.976	0.995	0.997	0.987	0.950	0.819	0.991
Kazakhstan	0.997	0.981	0.998	0.999	0.988	0.950	0.970	0.983
Tajikistan	0.988	0.998	0.983	0.993	0.985	0.759	0.826	0.994
Kirghizia	0.992	0.990	0.988	0.996	0.990	0.957	0.930	0.991
Turkmenia	0.996	0.984	0.988	0.997	0.995	0.860	0.819	0.980
Uzbekistan	0.992	0.965	0.994	0.995	0.992	0.865	0.930	0.995
Female								
All regions	0.994	0.993	0.993	0.999	0.993	0.932	0.921	0.983
Armenia	0.968	0.997	0.990	0.996	0.982	0.944	0.913	0.988
Byelorussia	0.998	0.991	0.994	1.000	0.995	0.965	0.942	0.977
Georgia	0.997	0.939	0.993	0.999	0.995	0.943	0.877	0.995
Moldavia	0.996	0.996	0.989	0.999	0.975	0.984	0.947	0.958
Russia	0.999	0.989	0.998	1.000	0.987	0.988	0.956	0.998
Ukraine	0.999	0.986	0.996	1.000	0.986	0.982	0.974	0.985
Azerbaijan	0.995	0.983	0.995	0.998	0.992	0.949	0.869	0.993
Kazakhstan	0.996	0.986	0.997	0.999	0.989	0.919	0.934	0.981
Tajikistan	0.991	0.998	0.986	0.998	0.989	0.771	0.809	0.987
Kirghizia	0.993	0.995	0.981	0.998	0.996	0.964	0.887	0.993
Turkmenia	0.997	0.992	0.991	0.998	0.996	0.833	0.808	0.970
Uzbekistan	0.994	0.985	0.992	0.998	0.996	0.783	0.949	0.993

Table 1b. The total for seven causes of death R^2 for each republic with weight equal to $1/R^2$ for that cause of death.

The total for 7 causes of death R squared for each republic with weight equal 1/R squared for that cause of death			
Male		Female	
Russia	7.09	Russia	7.11
Ukraine	7.06	Ukraine	7.10
Byelorussia	7.04	Byelorussia	7.05
Kazakhstan	7.02	Moldavia	7.04
Kirghizia	6.99	Kirghizia	7.00
Armenia	6.97	Armenia	7.00
Georgia	6.95	Kazakhstan	6.99
Moldavia	6.95	Azerbaijan	6.96
Uzbekistan	6.88	Georgia	6.92
Azerbaijan	6.86	Uzbekistan	6.87
Turkmenia	6.76	Turkmenia	6.76
Tajikistan	6.67	Tajikistan	6.70

Table 2. Correlation of period effects for all causes of death and life expectancy by republics.

Correlation of period effects for all causes of death and life expectancy by republics		
	Male	Female
Byelorussia	-0.989	-0.993
Russia	-0.987	-0.962
Ukraine	-0.972	-0.984
Uzbekistan	-0.946	-0.822
Turkmenia	-0.937	-0.980
Kazakhstan	-0.926	-0.872
Azerbaijan	-0.913	-0.953
Georgia	-0.880	-0.969
Moldavia	-0.871	-0.880
Kirghizia	-0.861	-0.816
Tajikistan	-0.844	-0.931
Armenia	-0.746	-0.565
*/ Regions are ordered by ascending order of male correlations rates		

Table 3. Dependency of period effects from time (correlation time and period effects in the republics).

Dependency of period effects from time (correlation time and period effects in the republics)												
	Russia	Ukraine	Moldavia	Kazakhstan	Kirghizia	Azerbaijan	Tajikistan	Byelorussia	Georgia	Turkmenia	Uzbekistan	Armenia
Male												
All causes	-0.860	-0.739	-0.831	-0.806	-0.681	-0.855	-0.821	-0.384	-0.644	-0.615	-0.561	0.608
Infectious and parasitic diseases	-0.957	-0.937	-0.888	-0.973	-0.831	-0.424	-0.868	-0.926	-0.133	0.654	0.080	-0.308
Neoplasms	0.966	0.989	0.977	0.842	0.797	-0.603	0.278	0.990	0.281	-0.622	0.457	0.847
Diseases of circulatory system	-0.830	-0.855	-0.908	-0.241	-0.014	0.057	0.303	-0.114	-0.435	0.071	0.268	0.884
Respiratory diseases	-0.954	-0.936	-0.913	-0.966	-0.848	-0.927	-0.957	-0.944	-0.808	-0.951	-0.866	-0.850
Digestive system diseases	-0.880	-0.550	-0.502	-0.954	-0.390	-0.605	0.216	-0.614	-0.496	-0.445	-0.621	-0.061
Accidents, poisonings and violence	-0.774	-0.601	-0.811	-0.765	-0.493	-0.849	-0.814	-0.487	-0.538	-0.522	-0.803	0.336
Others and unknown causes	0.812	0.710	0.504	0.811	0.768	-0.804	0.828	0.695	0.186	0.941	0.720	0.538
Female												
All causes	-0.787	-0.770	-0.862	-0.587	-0.482	-0.772	-0.844	-0.121	-0.375	-0.579	-0.154	0.516
Infectious and parasitic diseases	-0.955	-0.910	-0.895	-0.843	-0.847	-0.429	-0.868	-0.826	-0.012	0.667	0.206	-0.331
Neoplasms	0.931	0.979	0.901	0.822	0.579	-0.615	0.735	0.988	-0.034	-0.764	0.694	0.941
Diseases of circulatory system	-0.569	-0.813	-0.884	0.265	0.336	0.095	0.379	0.053	0.272	0.053	0.537	0.922
Respiratory diseases	-0.972	-0.963	-0.950	-0.983	-0.909	-0.907	-0.950	-0.956	-0.853	-0.953	-0.906	-0.837
Digestive system diseases	-0.244	0.483	-0.267	-0.901	0.730	-0.180	0.246	0.588	-0.630	-0.186	-0.424	-0.051
Accidents, poisonings and violence	-0.793	-0.443	-0.901	-0.734	-0.043	-0.935	-0.213	0.021	-0.375	0.245	-0.883	0.326
Others and unknown causes	0.957	0.755	0.608	0.918	0.905	-0.163	0.800	0.743	0.274	0.953	0.861	0.886
*/ Regions are ordered by descending order of female correlations for all causes in Russia												

Table 4. Correlation of period effects for males and females for different groups of causes of death.

Correlation of period effects for males and females for different groups of causes of death									
		Male							
Female		1	2	3	4	5	6	7	8
All causes	1	0.861	0.159	-0.073	0.673	0.240	0.074	0.826	-0.146
Infectious and parasitic diseases	2	0.280	0.941	-0.392	0.155	0.381	-0.495	0.028	0.103
Neoplasms	3	-0.022	-0.384	0.680	0.043	-0.401	0.338	0.007	0.025
Diseases of circulatory system	4	0.604	0.134	-0.238	0.895	0.093	-0.021	0.253	-0.141
Respiratory diseases	5	0.321	0.466	-0.638	0.172	0.935	0.017	0.034	-0.389
Digestive system diseases	6	-0.118	-0.542	0.290	-0.152	-0.088	0.857	-0.058	-0.141
Accidents, poisonings and violence	7	0.615	-0.061	0.056	0.343	-0.002	0.042	0.960	-0.050
Others and unknown causes	8	-0.138	-0.123	0.333	-0.174	-0.523	-0.214	0.027	0.884

Table 5. Correlation of period effects for different groups of causes of death.

Correlation of period effects for different groups of causes of death									
Male									
		1	2	3	4	5	6	7	8
All causes	1		0.279	-0.121	0.772	0.454	0.137	0.727	-0.168
Infectious and parasitic diseases	2			-0.426	0.119	0.450	-0.411	0.023	-0.023
Neoplasms	3				-0.256	-0.500	0.215	-0.004	0.130
Diseases of circulatory system	4					0.183	0.009	0.385	-0.183
Respiratory diseases	5						0.104	0.134	-0.367
Digestive system diseases	6							0.070	-0.252
Accidents, poisonings and violence	7								-0.063
Others and unknown causes	8								
Female									
		1	2	3	4	5	6	7	8
All causes	1		0.187	0.143	0.671	0.157	-0.084	0.834	-0.040
Infectious and parasitic diseases	2			-0.351	0.191	0.397	-0.620	-0.043	-0.045
Neoplasms	3				0.149	-0.455	0.339	0.120	0.193
Diseases of circulatory system	4					0.106	-0.133	0.282	-0.113
Respiratory diseases	5						-0.130	-0.071	-0.583
Digestive system diseases	6							-0.020	-0.102
Accidents, poisonings and violence	7								0.073
Others and unknown causes	8								

Table 6. Correlation of indexes of month variation, of numbers of deaths, and period effects for different groups of causes of death.

Correlation of indexes of month variation of numbers of deaths and period effects for different groups of causes of death		
	Male	Female
All causes	0.487	0.465
Infectious and parasitic diseases	0.118	0.002
Neoplasms	-0.079	-0.026
Diseases of circulatory system	0.359	0.310
Respiratory diseases	0.240	0.205
Digestive system diseases	0.199	0.125
Accidents, poisonings and violence	0.418	0.396
Others and unknown causes	-0.166	-0.133

Table 7. Correlation of indexes of month variation, of numbers of deaths, and period effects for different groups of causes of death by republic.

Correlation of indexes of month variation of numbers of deaths and period effects for different groups of causes of death by republic												
	Russia	Ukraine	Moldavia	Kazakhstan	Kirghizia	Azerbaijan	Tajikistan	Byelorussia	Georgia	Turkmenia	Uzbekistan	Armenia
Male												
All causes	0.268	0.502	0.660	0.345	0.063	0.385	0.443	0.660	-0.038	0.254	0.615	0.698
Accidents, poisonings and violence	0.122	0.127	0.490	0.264	-0.046	0.257	0.257	0.154	0.241	0.129	0.228	0.669
Diseases of circulatory system	0.351	0.554	0.564	0.020	0.137	0.207	-0.469	0.478	0.132	-0.105	-0.212	0.477
Infectious and parasitic diseases	0.182	0.380	0.396	0.531	-0.381	-0.289	0.381	0.401	-0.470	-0.539	0.111	-0.270
Respiratory diseases	0.315	0.446	0.698	0.601	0.138	0.422	0.629	0.572	0.182	0.585	0.770	-0.127
Digestive system diseases	0.372	0.189	0.718	0.435	-0.137	0.443	0.305	0.009	0.434	0.354	0.546	-0.291
Female												
All causes	0.487	0.683	0.694	0.303	0.181	0.435	0.486	0.802	-0.192	0.457	0.607	0.641
Accidents, poisonings and violence	0.216	0.260	0.658	0.447	-0.024	0.324	0.086	0.316	-0.392	-0.191	0.616	0.640
Diseases of circulatory system	0.575	0.616	0.595	-0.058	0.288	0.330	-0.565	0.413	-0.071	0.105	-0.174	0.297
Infectious and parasitic diseases	0.094	0.304	0.289	0.307	-0.317	-0.203	0.357	0.473	-0.385	-0.640	0.042	-0.558
Respiratory diseases	0.272	0.395	0.571	0.537	0.058	0.293	0.649	0.503	0.264	0.685	0.767	-0.280
Digestive system diseases	0.448	0.045	0.694	0.621	-0.045	0.482	0.309	0.108	0.565	0.195	0.476	-0.343
*/ Regions are ordered by descending order of female correlations for all causes in Russia												

Table 8. Correlation of period effects for different groups of causes of death in Russia and other republics.

Correlation of period effects for different groups of causes of death in Russia and other republics												
	Ukraine	Moldavia	Kazakhstan	Kirghizia	Azerbaijan	Tajikistan	Byelorussia	Georgia	Turkmenia	Uzbekistan	Armenia
Male											
All causes	0.969	0.960	0.950	0.914	0.667	0.676	0.774	0.450	0.576	0.618	-0.497
Infectious and parasitic diseases	0.977	0.878	0.984	0.689	0.591	0.899	0.963	0.234	-0.631	-0.220	0.420
Neoplasms	0.986	0.948	0.876	0.735	-0.445	0.283	0.963	0.357	-0.535	0.565	0.791
Diseases of circulatory system	0.985	0.955	0.693	0.459	0.011	-0.404	0.551	0.474	0.188	0.093	-0.619
Respiratory diseases	0.983	0.944	0.973	0.928	0.933	0.922	0.978	0.762	0.880	0.865	0.824
Digestive system diseases	0.709	0.782	0.866	0.534	0.569	-0.284	0.645	0.425	0.428	0.626	-0.127
Accidents, poisonings and violence	0.958	0.953	0.994	0.892	0.871	0.897	0.920	0.768	0.792	0.965	-0.342
Others and unknown causes	0.706	0.721	0.850	0.720	-0.450	0.861	0.708	0.467	0.846	0.833	0.533
Female											
All causes	0.966	0.964	0.837	0.808	0.705	0.687	0.636	0.467	0.328	0.282	-0.421
Infectious and parasitic diseases	0.959	0.910	0.893	0.744	0.600	0.930	0.869	0.199	-0.544	-0.259	0.211
Neoplasms	0.966	0.896	0.807	0.581	-0.580	0.644	0.902	0.007	-0.671	0.734	0.878
Diseases of circulatory system	0.905	0.807	0.511	0.426	0.441	-0.490	0.711	0.380	0.097	-0.066	-0.466
Respiratory diseases	0.991	0.970	0.987	0.948	0.859	0.943	0.985	0.875	0.885	0.901	0.804
Digestive system diseases	0.363	0.754	0.181	-0.200	-0.123	-0.097	0.428	0.133	-0.137	0.142	-0.090
Accidents, poisonings and violence	0.840	0.837	0.968	0.357	0.655	0.240	0.574	0.080	-0.260	0.792	-0.399
Others and unknown causes	0.796	0.697	0.938	0.892	-0.004	0.820	0.766	0.436	0.940	0.929	0.868
*/ Regions are ordered by descending order of female correlations for all causes in Russia											

Table 9. The average errors of projection for 1990 based on data for 1980-1989 (in %).

The average errors of projection for 1990 based on data for 1980-1989 (in %)				
	First group		Second group	
	Male	Female	Male	Female
Infectious and parasitic diseases	1.57	2.02	2.45	2.79
Neoplasms	0.38	0.34	0.67	0.79
Diseases of circulatory system	0.63	0.57	0.61	0.64
Respiratory diseases	1.07	1.07	1.14	1.16
Digestive system diseases	0.85	1.00	1.64	1.87
Accidents, poisonings and violence	1.20	1.00	1.73	1.28
Others and unknown causes	0.95	0.86	1.35	1.98

Table 10. Life expectancy projection.

Life expectancy projection				
Region	1989	1990	1995	2000
Male				
Armenia	69.06	68.69	68.41	68.52
Byelorussia	66.71	66.35	66.80	67.18
Georgia	68.11	69.08	69.54	70.03
Moldavia	65.54	65.11	66.00	66.58
Ukraine	66.09	65.71	66.20	66.62
Russia	64.16	63.90	64.29	64.77
Azerbaijan	66.70	66.97	67.78	68.54
Kazakhstan	63.87	64.06	64.50	65.13
Kirghizia	64.21	64.55	65.20	66.40
Tajikistan	66.72	67.29	68.34	69.46
Turkmenia	61.74	63.12	63.52	64.51
Uzbekistan	66.03	66.40	66.65	67.53
Female				
Armenia	74.96	75.50	75.19	75.32
Byelorussia	76.30	75.87	76.17	76.49
Georgia	75.67	76.58	77.23	78.01
Moldavia	72.26	72.06	72.57	73.07
Ukraine	75.17	74.99	75.30	75.61
Russia	74.51	74.46	74.72	75.08
Azerbaijan	74.36	75.09	76.06	77.21
Kazakhstan	73.19	73.50	73.92	74.52
Kirghizia	72.35	73.05	73.36	74.18
Tajikistan	71.67	72.60	73.42	74.56
Turkmenia	68.27	70.08	70.48	71.49
Uzbekistan	72.13	72.91	73.09	73.83

Table 11. Infant mortality rates projection.

Infant mortality rates projection				
Region	1989	1990	1995	2000
Male				
Armenia	23.3	21.3	22.2	20.5
Byelorussia	13.0	13.5	13.8	13.2
Georgia	21.8	17.9	20.5	18.5
Moldavia	22.3	21.1	22.6	20.6
Russia	19.9	19.6	20.3	19.1
Ukraine	14.5	14.5	15.1	14.4
Azerbaijan	27.8	25.4	24.9	21.7
Kazakhstan	28.3	29.3	27.9	25.3
Kirghizia	35.6	34.0	33.7	30.2
Tajikistan	47.9	45.3	39.2	33.8
Turkmenia	59.3	51.0	48.0	42.7
Uzbekistan	41.5	39.7	38.1	34.0
Female				
Armenia	17.2	16.9	16.4	14.9
Byelorussia	9.9	9.5	9.5	9.0
Georgia	17.1	14.1	14.9	13.0
Moldavia	17.4	16.2	15.9	14.4
Ukraine	10.4	10.7	10.8	10.2
Russia	14.5	14.3	14.2	13.4
Azerbaijan	23.9	20.8	19.6	16.5
Kazakhstan	21.8	23.2	21.0	18.6
Kirghizia	28.7	26.7	23.7	20.3
Tajikistan	37.8	37.9	30.7	25.6
Turkmenia	48.5	40.5	37.2	32.1
Uzbekistan	33.2	30.6	28.6	24.8
Both sexes				
Armenia	20.3	19.1	19.4	17.8
Byelorussia	11.5	11.5	11.7	11.1
Georgia	19.5	16.1	17.8	15.8
Moldavia	19.9	18.7	19.3	17.6
Ukraine	12.5	12.6	13.0	12.4
Russia	17.3	17.0	17.3	16.3
Azerbaijan	25.9	23.2	22.3	19.2
Kazakhstan	25.1	26.3	24.5	22.1
Kirghizia	32.2	30.4	28.8	25.4
Tajikistan	43.0	41.7	35.0	29.8
Turkmenistan	54.1	45.9	42.7	37.6
Uzbekistan	37.5	35.2	33.4	29.5

Table 12. Components of life expectancy dynamics by age groups.

Components of life expectancy dynamics by age groups									
	Male					Female			
Region	Total	0-14	15-59	60+		Total	0-14	15-59	60+
1989-1990									
Armenia	-0.370	0.184	-0.320	-0.234		0.533	0.192	0.047	0.293
Byelorussia	-0.366	0.048	-0.276	-0.138		-0.432	0.010	-0.135	-0.307
Georgia	0.967	0.352	0.044	0.572		0.908	0.320	0.116	0.472
Moldavia	-0.433	0.164	-0.282	-0.315		-0.205	0.160	0.001	-0.365
Ukraine	-0.383	0.024	-0.346	-0.061		-0.188	0.006	-0.086	-0.108
Russia	-0.259	0.042	-0.313	0.012		-0.051	0.042	-0.066	-0.027
Azerbaijan	0.276	0.403	-0.460	0.333		0.731	0.353	0.013	0.365
Kazakhstan	0.190	-0.062	0.042	0.209		0.308	-0.043	0.096	0.255
Kirghizia	0.339	0.329	-0.178	0.188		0.693	0.446	0.000	0.247
Tajikistan	0.568	0.184	0.092	0.291		0.927	0.213	0.212	0.502
Turkmenia	1.382	0.847	0.220	0.315		1.810	0.981	0.231	0.597
Uzbekistan	0.377	0.282	-0.024	0.118		0.782	0.340	0.203	0.239
1990-1995									
Armenia	-0.287	-0.467	0.219	-0.040		-0.302	-0.183	-0.124	0.005
Byelorussia	0.454	-0.054	0.359	0.150		0.302	0.000	0.042	0.259
Georgia	0.455	-0.165	0.574	0.046		0.650	-0.046	0.305	0.390
Moldavia	0.895	-0.169	0.786	0.278		0.519	0.028	0.137	0.355
Ukraine	0.487	-0.074	0.399	0.161		0.312	-0.035	0.079	0.268
Russia	0.385	-0.050	0.306	0.129		0.266	-0.004	0.022	0.248
Azerbaijan	0.807	0.012	0.775	0.019		0.967	0.209	0.406	0.351
Kazakhstan	0.441	0.098	0.197	0.146		0.413	0.092	-0.008	0.329
Kirghizia	0.648	-0.243	0.549	0.341		0.313	0.007	0.124	0.182
Tajikistan	1.051	0.594	0.277	0.180		0.822	0.559	0.081	0.181
Turkmenia	0.394	0.066	0.134	0.194		0.396	0.039	0.190	0.166
Uzbekistan	0.248	-0.037	0.192	0.093		0.173	0.008	-0.020	0.185
1995-2000									
Armenia	0.113	0.185	-0.006	-0.066		0.131	0.173	0.008	-0.050
Byelorussia	0.377	0.063	0.232	0.082		0.322	0.051	0.071	0.201
Georgia	0.493	0.196	0.213	0.083		0.783	0.208	0.222	0.352
Moldavia	0.583	0.181	0.281	0.121		0.493	0.136	0.154	0.203
Ukraine	0.426	0.077	0.257	0.091		0.314	0.054	0.064	0.197
Russia	0.485	0.108	0.308	0.069		0.355	0.084	0.084	0.187
Azerbaijan	0.762	0.407	0.229	0.126		1.153	0.453	0.282	0.418
Kazakhstan	0.634	0.269	0.286	0.079		0.607	0.279	0.131	0.196
Kirghizia	1.208	0.425	0.426	0.357		0.817	0.470	0.224	0.123
Tajikistan	1.119	0.685	0.276	0.159		1.142	0.747	0.272	0.123
Turkmenia	0.992	0.608	0.268	0.116		1.017	0.671	0.255	0.090
Uzbekistan	0.879	0.479	0.285	0.115		0.747	0.479	0.205	0.064

Table 13a. Components of life expectancy dynamics by cause of death, male.

Components of life expectancy dynamics by cause of death, Male								
Region	Total	Infectious and parasitic diseases	Neoplasms	Diseases of circulatory system	Respiratory diseases	Digestive system diseases	Accidents, poisonings and violence	Others and unknown causes
1989-1990								
Armenia	-0.370	0.023	-0.081	-0.068	0.048	-0.034	-0.081	-0.177
Byelorussia	-0.366	0.053	0.034	0.013	0.073	-0.014	-0.066	-0.459
Georgia	0.967	0.215	0.065	0.363	0.280	0.003	0.112	-0.069
Moldavia	-0.433	0.019	0.068	0.062	-0.006	-0.165	0.099	-0.510
Russia	-0.259	0.069	0.024	-0.038	0.020	-0.004	-0.181	-0.149
Ukraine	-0.383	0.054	0.005	0.007	0.014	-0.014	-0.141	-0.308
Azerbaijan	0.276	0.287	0.189	-0.070	0.070	-0.067	-0.112	-0.022
Kazakhstan	0.190	0.078	0.046	0.036	0.231	0.021	-0.041	-0.180
Kirghizia	0.339	0.092	0.013	0.297	0.400	0.056	-0.204	-0.314
Tajikistan	0.568	0.233	0.145	0.406	-0.074	0.071	0.042	-0.255
Turkmenia	1.382	0.258	0.151	0.391	0.746	-0.087	-0.003	-0.075
Uzbekistan	0.377	0.259	0.107	-0.056	0.225	-0.053	-0.019	-0.086
1990-1995								
Armenia	-0.287	0.018	-0.287	-0.130	0.098	0.056	-0.042	0.000
Byelorussia	0.454	0.064	-0.359	0.392	0.170	-0.005	0.192	0.000
Georgia	0.455	-0.092	0.127	0.055	0.158	0.107	0.100	0.000
Moldavia	0.895	0.121	-0.339	0.480	0.165	0.137	0.332	0.000
Ukraine	0.487	0.104	-0.330	0.389	0.118	0.011	0.196	0.000
Russia	0.385	0.110	-0.320	0.275	0.097	0.008	0.216	0.000
Azerbaijan	0.807	-0.074	0.186	0.147	0.343	0.084	0.121	0.000
Kazakhstan	0.441	0.200	-0.348	0.161	0.128	-0.001	0.302	0.000
Kirghizia	0.648	0.015	0.104	0.138	0.174	0.088	0.129	0.000
Tajikistan	1.051	0.403	0.169	-0.096	0.474	0.010	0.092	0.000
Turkmenia	0.394	0.006	0.080	-0.023	0.140	0.071	0.121	0.000
Uzbekistan	0.248	-0.033	0.107	-0.231	0.265	0.038	0.102	0.000
1995-2000								
Armenia	0.113	0.059	-0.250	-0.062	0.225	0.062	0.079	0.000
Byelorussia	0.377	0.035	-0.295	0.215	0.160	0.034	0.227	0.000
Georgia	0.493	0.113	0.129	-0.077	0.176	0.079	0.073	0.000
Moldavia	0.583	0.073	-0.255	0.177	0.247	0.124	0.216	0.000
Ukraine	0.426	0.066	-0.294	0.204	0.173	0.045	0.231	0.000
Russia	0.485	0.072	-0.287	0.215	0.174	0.037	0.275	0.000
Azerbaijan	0.762	0.171	0.140	-0.076	0.381	0.084	0.062	0.000
Kazakhstan	0.634	0.140	-0.304	0.210	0.311	0.047	0.229	0.000
Kirghizia	1.208	0.096	0.158	0.216	0.525	0.086	0.127	0.000
Tajikistan	1.119	0.336	0.131	-0.065	0.510	0.080	0.127	0.000
Turkmenia	0.992	0.235	0.136	-0.075	0.509	0.109	0.078	0.000
Uzbekistan	0.879	0.153	0.128	-0.075	0.442	0.074	0.157	0.000

Table 13b. Components of life expectancy dynamics by cause of death, female.

Components of life expectancy dynamics by cause of death, Female								
Region	Total	Infectious and parasitic diseases	Neoplasms	Diseases of circulatory system	Respiratory diseases	Digestive system diseases	Accidents, poisonings and violence	Others and unknown causes
1989-1990								
Armenia	0.533	0.012	-0.136	0.294	0.218	-0.016	0.471	-0.310
Byelorussia	-0.432	0.019	-0.039	0.312	0.070	0.001	-0.034	-0.761
Georgia	0.908	0.246	0.040	0.409	0.264	0.060	0.057	-0.168
Moldavia	-0.205	0.078	0.021	0.541	-0.039	-0.063	0.118	-0.860
Russia	-0.051	0.059	-0.002	0.097	0.039	-0.007	-0.047	-0.191
Ukraine	-0.188	0.062	0.016	0.392	0.034	-0.012	-0.042	-0.632
Azerbaijan	0.731	0.330	0.129	0.233	0.276	-0.044	-0.018	-0.175
Kazakhstan	0.308	0.147	0.034	0.283	0.103	0.017	-0.052	-0.224
Kirghizia	0.693	0.154	-0.065	0.538	0.508	0.011	-0.041	-0.413
Tajikistan	0.927	0.186	0.197	0.731	-0.021	0.085	0.094	-0.344
Turkmenia	1.810	0.391	0.055	0.651	0.770	0.130	-0.110	-0.078
Uzbekistan	0.782	0.264	0.054	0.267	0.266	0.029	-0.008	-0.090
1990-1995								
Armenia	-0.302	0.028	-0.095	-0.164	0.192	0.029	-0.291	0.000
Byelorussia	0.302	0.044	-0.219	0.354	0.145	-0.006	-0.016	0.000
Georgia	0.650	-0.107	0.076	0.391	0.219	0.034	0.038	0.000
Moldavia	0.519	0.067	-0.225	0.462	0.208	-0.004	0.010	0.000
Ukraine	0.312	0.041	-0.238	0.365	0.116	-0.005	0.033	0.000
Russia	0.266	0.055	-0.213	0.299	0.116	-0.005	0.013	0.000
Azerbaijan	0.967	-0.055	0.046	0.433	0.465	0.048	0.029	0.000
Kazakhstan	0.413	0.128	-0.244	0.264	0.253	-0.011	0.023	0.000
Kirghizia	0.313	-0.003	-0.007	-0.175	0.376	0.079	0.043	0.000
Tajikistan	0.822	0.408	-0.018	-0.174	0.560	0.053	-0.007	0.000
Turkmenia	0.396	-0.072	0.050	-0.096	0.310	0.106	0.098	0.000
Uzbekistan	0.173	-0.037	0.001	-0.162	0.413	-0.004	-0.038	0.000
1995-2000								
Armenia	0.131	0.043	-0.155	-0.014	0.174	0.047	0.036	0.000
Byelorussia	0.322	0.029	-0.180	0.321	0.116	0.014	0.019	0.000
Georgia	0.783	0.087	0.075	0.384	0.172	0.044	0.020	0.000
Moldavia	0.493	0.040	-0.144	0.309	0.176	0.093	0.018	0.000
Ukraine	0.314	0.027	-0.170	0.321	0.105	0.016	0.015	0.000
Russia	0.355	0.039	-0.171	0.336	0.116	0.016	0.020	0.000
Azerbaijan	1.153	0.141	0.074	0.427	0.407	0.084	0.020	0.000
Kazakhstan	0.607	0.115	-0.185	0.337	0.297	0.022	0.020	0.000
Kirghizia	0.817	0.112	0.079	-0.005	0.511	0.080	0.038	0.000
Tajikistan	1.142	0.366	0.072	-0.008	0.613	0.072	0.026	0.000
Turkmenia	1.017	0.264	0.077	0.002	0.551	0.094	0.030	0.000
Uzbekistan	0.747	0.156	0.075	-0.007	0.474	0.035	0.015	0.000

APPENDIX C. The Measurement Issue in APC Analysis, Illustrated by the Lexis Diagram

The objective of APC analysis of a time series of age profiles (age-specific data) is to isolate the effects of the life course, contemporary factors and historical factors. The stages in the life course are approximated by age, the contemporary factors by period, and the historical factors by cohort (year or period of birth or another event-origin).

The separation of age, period and cohort effects requires proper measurement of the age at which the event occurs, the year (period) in which it occurs and the cohort to which the person experiencing the event belongs. Most data that are available for APC analysis lack one of the three variables that characterize the timing of the event. In general, the data are classified by age and period (age-period tables). Cohort experiences are inferred from the diagonals of the table. This approach is the basis of the identification problem. Because the year of birth is unknown for an individual of a given age who experiences an event in a given year, the cohort effect cannot be identified unambiguously.

The Lexis diagram is a two-dimensional diagram locating the events with reference to

- the date of occurrence of the event of interest,
- the date of occurrence of the event-origin (e.g. birth), and
- the duration since the event-origin (e.g. age).

If each individual is under continuous observation, the timing of events can be measured precisely and for each individual a lifeline can be drawn. Appendix Figure C1 shows four lifelines a, b, c and d. Consider lifeline c and let P denote an event occurring at exact age t to a person of exact age x. The individual to which the lifeline c refers is born at exact time t-x. Note that when any two of the three time measures are known, the third can be determined precisely. The age, period and cohort variables are therefore linearly dependent:

$$c = t - x$$

where x denotes age, t period and c cohort.

Even if all events are recorded by a continuous-time observation, the data frequently available to demographers are grouped data. The grouping may be over time, cohort and/or age, yielding discrete time, cohort and/or age intervals. The grouping generally results in intervals of one or five years. A consequence of time grouping is that the location of the event on the lifeline is only known approximately and that we cannot infer any more the exact value of a time variable from knowledge of the two other variables. We may restore the relation if we measure the age, period and cohort intervals.

The discrete time or observation intervals can be visualized in the Lexis diagram. The figure shows an age interval (x,x+1), a period interval (t,t+1) and a cohort interval (t-x-1,t-x), The cohort consists of the group of people who experienced the event-origin in the time period from t-x-1 to t-x. Note that the cohort may be identified by either the year of event-origin (birth) or the age in completed years at time t or t+1. The timing of the event is generally measured by two of the three time variables. The further analysis depends on how the timing is measured. Four cases, known as observation plans, may be distinguished:

A. Cohort (cohort-age) observation:

A cohort observational plan records for a person experiencing an event the cohort to which the person belongs and the seniority in completed years at the time of the event (parallelogram WQSP). The observation interval extends over two calendar years.

B. Period-cohort observation:

A period-cohort observational plan records the calendar year in which the event occurs as well as the cohort to which the person belongs (parallelogram PQRS). The observational plan extends over two cohorts.

C. Period (period-age) observation:

A period observational plan records the calendar year in which an event occurs as well as the seniority of the person in completed years at the time of the event (square PQSV). The period observation interval covers two cohorts.

D. Age-period-cohort observation:

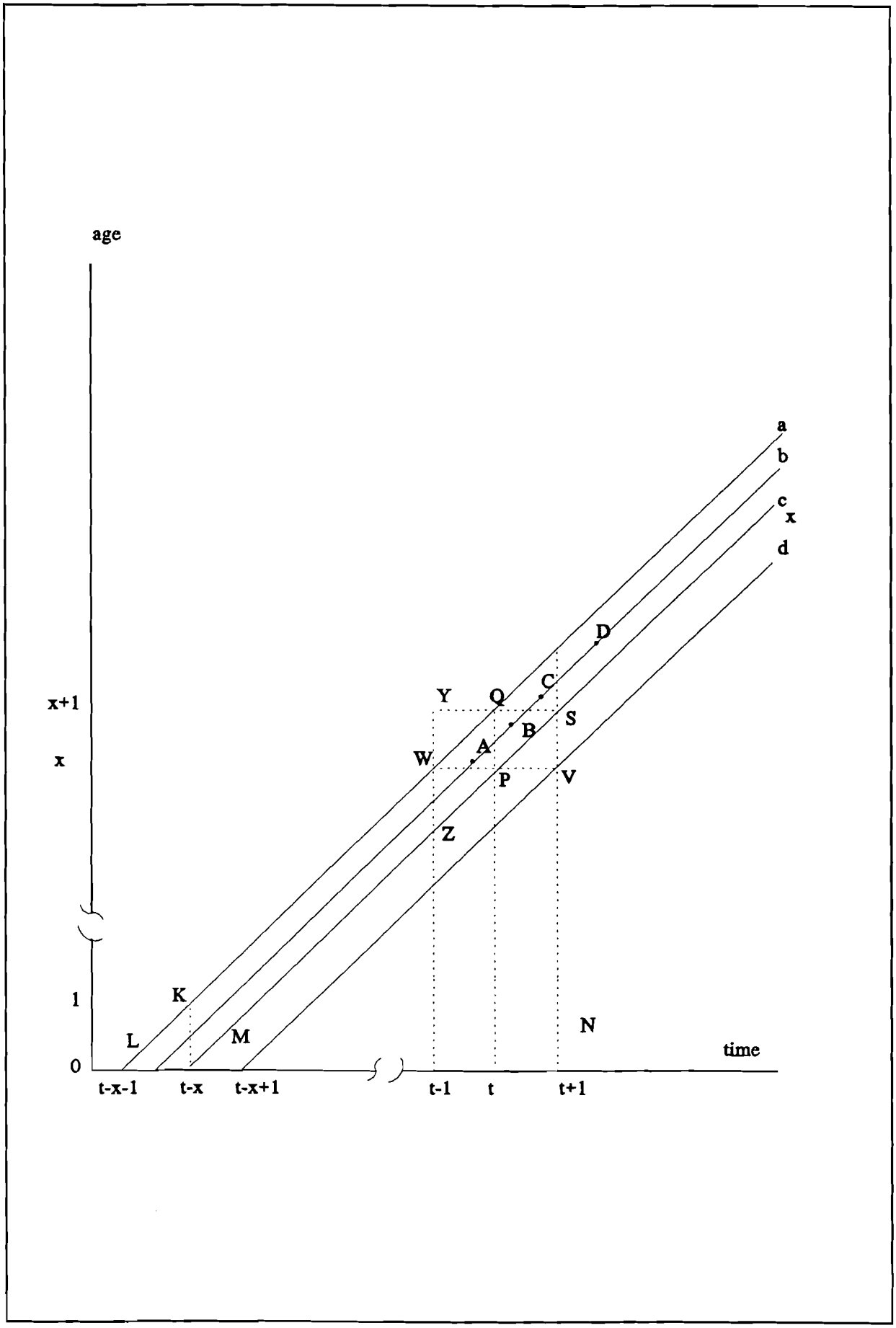
An age-period-cohort observation plan records the calendar year in which the event occurs as well as the seniority of the person in completed years at the time of the event and the cohort to which the person belongs (triangle PQS). The APC observation interval extends over only one period, one age and one cohort. Data presented by age, period and cohort are frequently referred to as doubly classified data.

Most often a demographic time series is represented as a time series of period-age observations. Regarding this representation two remarks can be made:

1. The events (or rates) pertaining to a given age and period category cover the experience of two cohorts.
2. The diagonal sequence of age-by-period classified data fail to cover all the experience of any of these two cohorts.

The first remark can easily be detected in the Lexis diagram. The age-by-period scheme given in the square PQSV covers the events occurring to cohorts t-x-1 and t-x. Hence the relationship "cohort = period - age", that is assumed to be inherent to age, period and cohort as classification variables, does not hold. Strictly speaking, the cohort cannot be predicted from age-period data. The second remark points to the fallacy of the assumption, implicit in most APC analysis, that the diagonal sequences of age-period data suffice to study cohort experiences. Two-factor classified data fail to provide accurate information on the third factor. That is the reason why the identification problem is a measurement problem rather than a model specification problem that is inherent to APC models.

Figure C1. Lexis diagram.



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