SOCIOECONOMIC DETERMINANTS OF MORTALITY IN EUROPE: VALIDATION OF RECENT MODELS USING THE LATEST AVAILABLE DATA AND SHORT-TERM PROJECTIONS

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Resum.- En l'article es realitzen unes projeccions per causa de mort, basant-se en aquells models que incloguin, en la seva formulació, variables no demogràfiques. La mortalitat total, la mortalitat per càncer de pulmó, la mortalitat per causa cardíaca i el suïcidi, es projecten per separat, pel període comprès entre finals dels anys setanta-principis dels vuitanta i fins a la segona meitat dels anys noranta, per Europa Occidental i Europa de l'Est i per sexe. Les projeccions a curt termini es calculen per a 2010. Degut al pas del temps entre l'exposició i l'efecte sobre la salut d'una variable particular, per elaborar les projeccions i, pel que fa a les variables independents, s'han emprat les dades més recents, mantenint-les constants en tots els anys. Els resultats per a la mortalitat total mostren que en la majoria dels països d'Europa Occidental, la disminució observada des de finals dels anys setanta es mantindrà pels homes però probablement s'estabilitzarà en les dones. Continuarà també el descens en la majoria de països d'Europa de l'Est.

Paraules clau- Mortalitat, Causes de mort, determinants socioeconòmics, model multivariant, projeccions, Europa Occidental, Europa de l'Est.

Resumen.- En el artículo se realizan unas proyecciones por causa de muerte, basándose en aquellos modelos que en su formulación incluyan variables no demográficas. Se proyecta por separado la mortalidad total, la mortalidad por cáncer de pulmón, por causa cardiaca y por suicidio, para el período comprendido entre finales de la década de los setenta-principios de los ochenta y hasta la segunda mitad de la década de los noventa, para Europa Occidental y Europa del Este y por sexo. Las proyecciones a corto plazo se calculan para el 2010. Debido al transcurso del tiempo entre la exposición y el efecto sobre la salud de una variable concreta, para elaborar las proyecciones y, para las variables independientes, se han utilizado los datos más recientes, manteniéndolos constantes en todos los años. Los resultados para la mortalidad total muestran que en la mayoría de los países de Europa Occidental, la disminución observada desde finales de los años setenta parece mantenerse en los hombres, pero probablemente se estabilice entre las mujeres. Continuará también el descenso para la mayoría de países de Europa del Este.

Palabras clave.- Mortalidad, causas de muerte, determinantes socioeconómicos, modelo multivariante, proyecciones, Europa Occidental, Europa del Este.

Abstract.- The main purpose of this paper is to produce cause-specific mortality projections from models that include non-demographic variables in its model formulation. Total mortality, lung cancer, heart disease and suicide are modelled separately for the period between the late 1970s/early 1980s to the second half of the 1990s for Western and Eastern Europe and men and women. Short-term projections are made to 2010. The models are also validated by comparing modelled with observed standardised death rates. Because of the time lag between exposure and health effect of a particular variable, which is often a matter of years, current observations for the independent variables were used for the projections or when predictions were necessary, the latest available value was held constant for the required years. The results for total mortality showed that in most Western European countries, the observed decline since the late 1970s is set to continue in the near future for men, but is likely to level off among women. The decline that has been observed in most Eastern European countries since the mid- to late 1990s is predicted to continue.

Key words.- Mortality, causes of death, socioeconomic determinants, multivariate modelling, projections, Western Europe, Eastern Europe.

Résumé.- Le propos principal de ce travail est de fournir des projections de mortalité par cause du décès, en utilisant une modélisation qui incluse des paramètres non démographiques. On projette de façon séparée la mortalité totale, celle due au cancer du poumon, aux maladies cardiaques et au suicide à partir de modèles basés sur les données d'observation sur la période de la fin des années 1970-début des années 1980 jusqu'à la seconde moitié des années 1990, pour l'Europe occidentale et orientale, et par sexe. Les projections sont à court terme, à l'horizon 2010. Les modèles sont validés en comparant les indices de mortalité observés avec les standardisés. Du fait du décalage temporel entre période d'exposition au risque et effet sur la santé d'une variable particulière, ce qui souvent est une question de plusieurs années, les données des variables explicatives furent utilisées pour les projections jusqu'à la période actuelle, et leur valeur maintenue constante dans le futur. Les résultats pour la mortalité totale montrent que dans la majeure partie des pays d'Europe occidentale, la baisse observée depuis la fin des années 1970 continuera dans le futur proche pour les hommes, mais probablement s'interrompra ou se ralentira pour les femmes. La baisse de la mortalité dans les pays d'Europe de l'Est depuis la fin des années 1990 devrait se poursuivre dans les années à venir.

Mots clés.- Mortalité, causes de décès, déterminants socio-économiques, modèle multivarié, projections, Europe Occidentale, Europe de l'Est.

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SOCIOECONOMIC DETERMINANTS OF MORTALITY IN EUROPE: VALIDATION OF RECENT MODELS USING THE LATEST AVAILABLE DATA AND SHORT-TERM PROJECTIONS

1.- Introduction

The main purpose of this article is to test earlier made models of cause-specific mortality that included exogenous variables with the latest available data and to provide short-term projections for a selection of European countries. The models, that include separate ones for Eastern and Western Europe and for men and women, are derived from the results of research that was conducted as part of a PhD thesis (Spijker, 2004). The main objective of this research was to *"assess the importance of socioeconomic factors on mortality differences across Europe over time and between countries or regions to determine which factors should be incorporated into future mortality scenarios"* (*ibid.* p. 7). Other factors were only of interest if they intervened in the association between socioeconomic factors and mortality, or if their effect was considerable. The time frame of the analysis was from the late 1970s/early 1980s to the second half of the 1990s[1]. The interest of the PhD research did not lie in the explanation of the disease processes leading to death (as this is covered by other disciplines), but in the identification of socioeconomic factors that have caused international differences in mortality and changes over time. The research framework was therefore set at the macro level for which the analyses required aggregated mortality and exogenous data instead of individual-level data that link mortality with socioeconomic and other characteristics of the deceased, although individual-level studies did form an important basis for the selection of exogenous variables. Both the identification of the health-related economic and other variables that ought to be incorporated in mortality projections and the quantification of the sensitivity of these variables were the main

[1] The two other demographic components, fertility and migration, were dealt with in concurrent projects (Jennissen, 2004; Sobotka, 2004). Each project was part of the umbrella project entitled: "*Towards a dynamic scenario model for economic determinants in population dynamics"* that sought to design a new methodology to formulate consistent European population scenarios based on the explicit association between economic and demographic processes in Europe in order to manifest the consequences of a continuation in the socioeconomic development in Europe and the enlargement of the European Union in future demographic developments.

contributions of the thesis and thus made the groundwork for the mortality projections that are presented here.

2.- Background

The improvement that has been made in life expectancy in Western Europe during the latter part of the 20th century has been mainly due to rapidly declining death rates in the advanced ages, as mortality at young ages was already very low. Epidemiologists consider this period of change the fourth phase of the epidemiological transition and have labelled it as the '*age of delayed degenerative diseases*' (Olshansky and Ault, 1986). During this period, a cause-of-death shift also occurred within the group of degenerative diseases as the proportion of cancer mortality slowly increased at the cost of circulatory system diseases. Conversely, in Eastern Europe, countries have remained in the third transition phase of the epidemiological transition, i.e. the *age of degenerative and man-made diseases*, as between the early 1970s and late 1990s life expectancy at birth stagnated and even declined in the countries of the former Soviet Union. As a consequence, most current East-West mortality differences are reflected in differences in circulatory system diseases as well as external causes of death.

Analysing mortality by cause of death is a first step in the understanding of mortality differences over time or space, as its aetiology (cause) provides us with some knowledge of the risk factors of the disease. For instance, reductions in behavioural risk factors and improvements in health care have been identified as the main determinants for the recent changes in mortality. However, although the majority of the most prevalent causes of death have several risk indicators in common, a change in one of those risk indicators does not affect each cause of death to the same degree, as causes of death may have one or several very important risk indicators. Moreover, there may also be variation in time between exposure of a particular risk indicator and its effect on different diseases. These are important considerations in both the analyses of mortality differences and well as projections.

While the third and fourth stages of the epidemiological transition served as the general context within which the current mortality pattern in Europe is placed, in order to obtain a clear overview of the important factors that affect health, the different analyses were set within the framework of the life course. Although the studies were ecological in design, it was assumed that also at the population level, determinants of health related to the life course could be identified[2]. For instance, the propensity to smoke or other types of risk behaviour do not occur randomly, but are determined by a wide range of distal factors throughout life, including both socioeconomic and macroeconomic factors. For instance, it has been consistently shown at the level of the individual that manual workers show more adverse risk behaviour and are expected to live shorter than non-manual workers. Therefore, a change or difference in the composition of the population in terms of economic structure is also likely cause changes or differences in behavioural risk factors, which will be reflected in cause-specific mortality patterns, usually at some later period in time. This inherent time delay between the exposure (such as being unemployed) and its (indirect) association with mortality is also why the life course approach has been applied to this research, as the risk of an exposure accumulates over time. It was considered that by calculating cause-specific time lags for each variable that was used in the analysis some of this time effect could be taken into account.

It should be mentioned that in any social research study it is impossible to obtain an independent effect of each variable because of multicollinearity. Illustrations were therefore also given of how associations between one variable and a mortality indicator sometimes dramatically changed after including one or several additional variables. This problem is somewhat reduced when a wide range of variables are included in the analysis. Moreover, in ecological studies it is not possible to control for other factors in the same way as in individual-level studies, but as in each multivariate analysis there was a reasonable selection of exogenous variables, the established associations were unlikely to be spurious when they coincided with similar results that have been found at the individual level.

3.- Data and method

Given the historical differences in economic development within Europe, it was decided to conduct two sets of analyses for the period between the late 1970s/early 1980s and the late 1990s, namely one for the Western and one for the Eastern European countries (labelled 'West' and 'East'). The main source for the national age-, sex- and cause-specific mortality data and age- and sex-specific population data was the *WHO Mortality Database*[3]. Both the mortality and

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[2] Although no causal relationship may be inferred at the individual level from an association that may be established in the analysis later between a variable and the mortality outcome (Valkonen, 1993; Gravelle, 1998).

[3] Pertains to the data that were available at 30-01-2001.

population data were already in, or could be aggregated to, the required 19, generally five-year, age intervals (0, 1-4, 5-9, 10-14, …, 80-84, 85+). The mortality data contained causes of death that were coded according to the 8th, 9th or 10th revision of the International Classification of Diseases (ICD). Causes of death were selected on the basis of its relative importance, the quality of its registration and the documented association with socioeconomic factors[4]. The nine that were eventually chosen covered respectively, 83% and 81% of total mortality in the selected Western and Eastern European countries (see Tables 1 and 2). Due to international inconsistencies in the registration of ischaemic heart disease (IHD) (ICD-9 410-414) and other heart disease (ICD-9 415-429), a general heart disease category was formed by subtracting the cerebrovascular disease (CRB) deaths from the entire circulatory system disease category. A similar aggregation has also been done in the past (e.g. Law and Wald, 1999; Murray and Lopez, 1996). Moreover, the most important macro-determinants of the specific heart and other circulatory system diseases, as well as the symptoms and proximate causes (e.g. hypertension and smoking) are similar. Lung cancer and prostate cancer were subtracted from total cancer to create the category 'remaining cancer'. Although this remains a rather heterogeneous cause-of-death group, containing over 200 types of cancer, the disease process is the same – only the location varies. Moreover, they also share important disease determinants such as smoking, alcohol consumption and insufficient intake of fibre, fruit and vegetables.

The explanatory variables for which data could be obtained are, together with their sources, listed in Table 3. Data on pollution, unemployment, smoking, fruit and vegetable consumption and government health expenditure as a percentage of GDPc could only be acquired for Western Europe[5]. The age-standardised cause-specific death rate (SDRs) that was calculated using the 1970 WHO standard population for Europe served as the dependent variable[6]. Pooled cross-section and time-series analysis was employed to analyse the data, using the statistical programme EViews. This tool pools the time-series data for each country in order to obtain a data set of N*T observations. By treating time and space as one dimension, the model explains the cross-country and inter-temporal variations in mortality simultaneously, producing a single effect for each independent variable.

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[4] This last criterion was in accordance with the main objective of the research on which this paper is based on (see Introduction).

[5] Data on the consumption of cereals and government health expenditure in purchasing power parities were also obtained, but were shown to be highly correlated with, respectively, fruit and vegetable consumption and GDPc. They were therefore excluded from the main analyses.

[6] In due course, the SDRs will be recalculated with the 1990 WHO Standard Population for Europe.

Table 1.- Countries and years for which cause-specific mortality and population data were obtained, and their ICD codes[a]

Western Europe	77	78	79	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**
Austria	8	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	10	10
Belgium	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9						
Denmark	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	10	10	10	10	10	10	10			
Former FRG	8	8	9	9	9	9	9	9	9	9	9	9	9	9													
Finland	8	8	8	8	8	8	8	8	8	8	9	9	9	9	9	9	9	9	9	10	10	10	10	10	10	10	10
France	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	10	10		
Greece	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	
Italy	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9		
Norway	8	8	8	8	8	8	8	8	8	9	9	9	9	9	9	9	9	9	9	10	10	10	10	10	10	10	
Sweden	8	8	8	8	8	8	8	8	8	8	9	9	9	9	9	9	9	9	9	9	10	10	10	10	10		
Switzerland	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	10	10	10	10	10	10	10		
United kingdom	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	Est	10	10	
Eastern Europe																											
Belarus					9	9	Est	Est	9	9	9	9	9	9	Est	9	9	9	9	9	9	9	9	9	9	10	10
Bulgaria					9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Former Czechoslovakia					9	9	9	9	9	(9)	(9)	(9)	(9)	(9)	(9)												
Czech Republic										9	9	9	9	9	9	9	9	10	10	10	10	10	10	10	10	10	10
Slovak Republic										Est	Est	Est	Est	Est	Est	9	9	10	10	10	10	10	10	10	10	10	
Estonia					9	9	Est	Est	9	9	9	9	9	9	9	9	9	9	9	9	10	10	10	10	10	10	
Former GDR					9	9	9	9	9	9	9	9	9	9													
Hungary					9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	10	10	10	10	10	10	10	10
Latvia					9	9	Est	Est	9	9	9	9	9	9	9	9	9	9	9	10	10	10	10	10	10	10	10
Russian Federation					9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	10	10	10	10	
Ukraine					9	9	Est	Est	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	

[a] In the "year" columns, "8", "9", and "10" refer to the mortality data that were classified according to the ICD-8 (A-list), ICD-9 (B-list and country-specific codes for Switzerland and the New Independent States), and ICD-10 revisions. The Slovak data for 1986-91 were obtained by subtracting the number of deaths and population of the Czech Republic from the data that were obtained for Czechoslovakia. For these years, Czechoslovakia was excluded from the main analysis. Data for missing years were interpolated when data for surrounding years were available (e.g. Belarus 1983 = 1982 + 1/3*(1985-1982)). The data were used for the construction of the cause-of-death models in the original analysis (Spijker, 2004), while the coloured cells indicate the data that were recently obtained for the validation analysis that was conducted for this paper. Population data were obtained for the same years as the mortality data.

Table 2.- Causes of death selected for analyses, their ICD codes and contribution to total male mortality in Western and Eastern Europe between the late1970s/early 1980s and the late 1990s

Cause of death	ICD-8	ICD-9	ICD-10	West[a]	East[a]
				SDR per 100000	
Total mortality	**000-E999**	**000-E999**	**A00-Y89**	**1065**	**1745**
Lung cancer	161-162	161-162	C32-C34	7.8%	5.8%
Prostate cancer	185	185	C61	2.5%	0.8%
Remaining cancer	Rest of 140-239	Rest of 140-239	Rest of C00-D48	16.0%	10.4%
Cerebrovascular disease	430-438	430-438	I60-I69	9.7%	14.8%
Heart disease	Rest of 390-458	Rest of 390-459	Rest of I00-I99	32.0%	36.0%
Respiratory system diseases	460-519	460-519	J00-J99	8.8%	7.2%
Chronic liver disease and cirrhosis	571	571	K70-K76	2.4%	1.5%
Traffic accidents	E800-E845	E800-E848	V00-V99	2.2%	2.1%
Suicide	E950-R959	E950-R959	X60-X84	1.9%	2.7%

[a] *See Table 1 for the countries in each analysis.*

In order to capture country-specific elements, such as the effect of the Soviet political system on economic and educational factors in Eastern European countries and the former Soviet Union, or dietary factors other than the consumption of alcohol, fruit and vegetables, and cereals, dummy variables were initially considered as an option. However, due to the frequent occurrence of a ‘near singular matrix’ in the estimated residual correlation matrix, dummy variables were not incorporated. Instead, in order to capture some of the country-specific elements, fixed effects were calculated (i.e. distinct intercepts estimated for each country). When results showed a structural pattern in the error-term of the model, as indicated by the Durbin-Watson (DW) test, it indicated the presence of autoregression (AR) and so an AR(1) term would be included. AR means that the probability of a positive/negative error term at time t, following a positive/negative error term at time t-1, is larger than that of an error term with a reversed sign. In the event of positive autoregression, an error-term at time t that is under- or over-estimated will be similarly under- or over-estimated at time t+1. Negative autoregression indicates the opposite: an under- or over-estimation of the error-term is followed by an over- or under-estimation. Each model also includes a term representing mortality at time t-1, since the level of mortality largely depends on the level of the previous year. Since it was assumed that cross-section heteroskedasticity was present, cross-section weights were also included.

In order to compare the coefficients of the covariates, elasticities were calculated (see Spijker, 2004: pp. 94-95). Since mortality at time t-1 was included, the models are dynamic ones and therefore both short- and long-term elasticities can be determined. Short-term elasticity is a form of standardised measure that estimates the relative change in the cause-specific mortality rate as a consequence of a relative change in a determinant. Since mortality at time t also depends on mortality at time t-1, and therefore in turn on t-2, t-3, etc., any independent variable also has long-term effects. For instance, an economic shock such as the sudden emergence of unemployment will effect mortality not only in year t, but also in years t+1, t+2, t+3, etc. The extent of the long-term effect depends on both the strength of the direct effect and the proximity of mortality at time t with that of the previous year. In case an exogenous variable has a large long term effect on a particular cause of death, this would be an important fact to consider when mortality is projected.

Before starting the pooled cross-section and time series analysis, lags were calculated for the exogenous variables because it was considered that the influence on mortality patterns of economic and other variables is usually not contemporaneous, but the result of many years of exposure. A common example of this is smoking and lung cancer. Lags, however, are seldom incorporated in mortality analysis and, even when they are included, they do not always give the desired result (e.g. Judge, 1995). The effect of smoking is better known, as it is a proximate risk indicator with a profound impact on population health. Epidemiological research has indicated that, for individuals, a substantial decline in smoking levels instigates a fall in IHD mortality approximately 15 years later, while for lung cancer the lag is approximately 30 years (Ruwaard and Kramers, 1993). Because lags vary according to the a priori outcome, i.e. the cause of death, establishing the correct time lags is a difficult process and therefore they have been determined by a combination of theoretical reasoning (life course perspective and the aetiology of the disease), the available time series and empirical tests. In most cases the method employed was to conduct a pooled cross-section and time-series analysis for a range of lags for each variable separately that also included mortality at time t-1, an autoregressive term if needed[7] and cross-section weights. The results were then compared and the lag corresponding to the highest value was taken as the 'true' one. As other, often interrelated, factors were omitted, the association between the variable under consideration and the mortality indicator was not always in the expected direction. In these instances, the lag with the coefficient closest to zero was selected.

[7] The autoregressive term was excluded when it was insignificant in the calculation of one or more of the lags in a cause-specific model or when the model had not converged after 1000 iterations at p=0.0001.

Due to the rapid economic transformation and larger fluctuations in life expectancy in Eastern Europe, it was decided to conduct this lagging exercise separately for the two European analyses, though no further distinction was made between men and women. Lag values are given in Table 3, but a more detailed description of specific outcomes is given in Spijker (2004, pp 95-96).

For the model validation exercise, two comparisons are made. Firstly between the actual and modelled SDRs for the original time series; and secondly, by comparing the modelled values with the SDRs that were calculated for the most recent years that the WHO Mortality Database currently[8] has available but were not represented when the models were constructed (see Table 1). This second comparative analysis effectively tests implicitly the predictive value of the models. For each model, some simple short-term projections (up to 2010) were also made. For the purpose of this paper, only the results for total mortality, lung cancer, heart disease and suicide are presented and discussed.

With regard to most exogenous variables, data for additional years had to be obtained in order to be able to conduct the model validation exercise and make the short-term projections, but this particularly concerned those variables for which no or a small time lag was incorporated. In case no new data could be obtained, own estimations were made. Some of the original data sources also contained updates, including improved estimates of data that were used in the construction of the original models (in particular with regard to alcohol consumption). Several other adjustments were also made. Firstly, it was decided to employ the natural log of GDP per capita rather than the actual value as done earlier, because it is generally considered that the additional health effect of a certain amount of income decreases with increasing income. Secondly, the smoking variable was not judged to be very accurate for modelling purposes, because annual consumption for a population is a period measurement and does not represent life-time exposure. Neither do the data distinguish between smokers and non-smokers and the eventual sex-specific values were estimated from total consumption and male and female smoking prevalences. Although the introduction of time lags partly accommodated life-time exposure, the smoking data, often with own estimates, did not go further back than 1960, making it difficult to estimate meaningful lags.

The observed lung cancer mortality rate was therefore considered to be a more appropriate smoking indicator[9] and so it was included for the same smoking-related cause-of-death models

[8] Mortality data as of 04-03-2005.

[9] This has also been done before (see e.g. Barendregt et al., 2002)

as before, except for lung cancer itself for which the original variable was used. In this way, it was also possible to test the influence of tobacco on Eastern European mortality. The scenario estimates for lung-cancer were subsequently used to estimate the other smoking-related causes of death (including total mortality). Thirdly, with regard to total mortality and heart disease, the protective and detrimental effects of alcohol were tested simultaneously, rather than choosing the most influential of the two, as was done in the original research: for the Western European analyses only the long-term protective effects of alcohol were tested (which is thought to reduce the risk of the thickening of the arteries, a risk factor of IHD) by lagging the variable by 15 years, and for Eastern Europe only the short-term detrimental effects of alcohol (e.g. the increased risk of sudden IHD and stroke due to "beer bingeing") were considered. Finally, there were some changes in the lags that were used, the most important one being that the lag for unemployment now coincided with the one for the two employment variables, because the employment structure is influenced by changes in (structural) unemployment.

Using the original sample of countries and years but with the updated and corrected data and other changes, the data were remodelled. Besides the fact that the rerunning of the models gave different variable coefficients than before, most models did not have exactly the same components as before. Due to the correlation between related variables (e.g. between industrial employment and GDPc), the inclusion (or alteration) of one may make another variable insignificant. Models were even more sensitive when there was a high level of autocorrelation. This was one reason why the outcomes of both the "saturated" and "best models" were given in the PhD thesis, but for projections it makes little sense to include all variables when just a few are relevant. However, it is nevertheless important to bear in mind that what a variable "represents" is more general than the measurement itself. To give an example, the proportion of the workforce in secondary sector employment is not just a pure labour variable, but also represents other aspects, such as socioeconomic development (countries with a high proportion of industrial employment usually have a lower GDPc and a less well educated population than countries with a larger service sector), and even behaviour (manual labourers are generally less health conscious, as they smoke and drink more and eat less healthy food). As the less reliable smoking variable was replaced by sex-specific lung cancer mortality rates as a proxy for lifetime smoking, the association between the other variables and mortality that are also associated with smoking changes as smoking is better controlled for. The most profound differences with regard to the original models as a result of the latest changes include:

i. The Eastern European models that now contained the new smoking variable.

ii. Male total mortality in Western Europe. The smoking proxy caused the dietary factor fruit and vegetable consumption to become insignificant. The inclusion of alcohol consumption without a lag caused the previous significant association between divorce and total mortality to disappear.

iii. Female total mortality model in Western Europe. The appropriateness of introducing lung cancer as a separate variable is demonstrated here, as in the original model tobacco consumption was not significant and even negatively significant in the model that included all variables.

iv. With regard to heart disease has alcohol also a long-term protective effect in Eastern Europe at the population level and a detrimental short-term effect in Western Europe.

v. Due to the use of different sources (surveys vs. census), changes in definitions, and lack of long time series of the employment structure variables, it was impossible to construct a consistent and international and time comparable database. Moreover, the short time series did not allow for the computation of an appropriate lag. Nonetheless, when the association between industrial or agricultural employment and mortality was significant, its direction was consistent with the literature.

vi. The Western European models for women appeared least similar to the original ones.

The updated model results form the basis of the model validation exercise and the projections:

4.- Results I: the original cause- and sex-specific models for Western and Eastern Europe

In the original analysis, the results of two types of models were presented: 'complete' models that included all selected exogenous variables, designed to determine the validity of a series of theoretical premises; and 'best' models that only included the statistically significant variables for the purpose of scenario making. However, to reduce the size of the paper, reference is only made to the best models and the variable elasticity tables are left out. The same applies to the discussion of age-specific and country-effects, although the latter ones are given in the tables.

Table 3.- Overview of exogenous variables and their sources

Variable	*Abbreviation*	*Measured as*	*Source*
Per capita Gross Domestic Product	GDPc	Geary Khamis PPPs in 1990 US$	1
Income inequality	GINI	A value between 0 and 1 indicating the distribution of income	2
Education	EDU	Number of years of education	3
Secondary sector employment	IND	% of the labour force employed in the secondary sector	4
Primary sector employment	AG	% of the labour force employed in the primary sector	4
Divorce	DIV	Divorce Rate per 100 marriages	5
Alcohol	ALC	Alcohol consumption – litres of pure ethanol per person per year (age 15+)	6, 11
Pollution	POL	Sulphur Oxides (1000 tonnes) per km^2	7,8
Urbanisation	URB	Percentage of the population resident in urban areas.	9
Unemployment	UNEMP	Total unemployed as % of labour force	10
Smoking	TOBAC	Tobacco consumption – grams per person per year (age 15+)	11
Fruit	FRUIT	Average amount of fruits and vegetables available per person per year (kg)	12
Cereals	CEREAL	Average amount of cereals available per person per year (kg)	12
Health Care (GDP)	HCGDP	Governmental expenditure on health as a % of GDP	11
Health Care (PPP)	HCPPP	Governmental expenditure on health in PPPs per capita	12

1. Groningen Growth and Development Centre (2005); Maddison (2001); OECD (2005a)
2. WIDER (2000; 2004); World Bank (2002). Other sources include: for Switzerland, Flückiger (2002); for Norway, Statistics Norway (1999); for several Eastern European countries, Svenjar (2001); for Russia and the Ukraine, Gregory (date unknown).
3. Barro and Lee (2000). For most countries, the data covered the period 1960-1990/2000 at five-year intervals. The intermediate years were fitted by means of a first-and-second order function.
4. Data for Western Europe were obtained from Eurostat (2002); for Eastern Europe from ILO (2002); for former Czecholovakia from Federální Statistický Úřad (various years); for the Czech Republic from Český Statistický Úřad (various years). Updates from OECD (1999; 2004)
5. For most countries, data were obtained from Eurostat (2002; 2005); for the USSR successor states, Czechoslovakia and West Germany, some data were obtained from the Council of Europe (2001) and CIS STAT (1998).
6. Tekin (2002); Treml (1997); WHO (1999; 2004).
7. Lefohn et al. (1999).
8. Eurostat (2002); OECD (2005b)
9. United Nations (2004).
10. For Belarus, Bulgaria, the Czech Republic, Hungary, Latvia and the Slovak Republic registered unemployment; source Western Europe: OECD (Main Economic Indicators) and Eurostat (Eurostatistics, ESVG-Aggregates) in: Gärtner (1999); source Eastern Europe: ILO (2002); source Ukraine: CIS STAT (1998); source updates: European Commission (2005)
11. OECD (2001; 2005b); 12. WHO (2002; 2005).

Table 4.- Variable-specific lags (in years) applied to the variables in the pooled cross-country and time-series analyses[a]

	Gdp –	Gini +	Edu –	Ind +	Ag	Urb	Div +	Alc	Unemp +	Lung can +	Pol +	Fruit –	Cereals –	Hcgdp –	Hcppp –
Western Europe															
Total	15	10	15	5	5	0	10	0/15	5	0	10	5	5	1	1
Lung	15	10	15	5	5	0	10	5	5	10 (tobac)	10	5	5	1	1
Prostate	15	10	15	7	7	0	10		7	0		6	6	3	3
Cancer_rem	15	10	15	5	5	0	10	5	5	0		5	5	2	2
Heart	15	10	15	5	5	0	10	0/15	5	0	10	7	7	5	5
Crb	15	10	15	0	0	0	10	0	0	0		5	5	1	1
Resp	15	10	15	7	7	0	10	10	7	0	15	5	5	1	1
Ldc	3	3	15	3	3	0	10	0	3			5	5	1	1
Traffic	1	0	0	0	0	0	3	0	0					5	5
Suicide		5	0	0	0	0	1	0	0					5	5
Eastern Europe															
Total	0	0	10	7	7	0	1	0/15	1	0					
Lung	10		10	5	5	0	10	10							
Prostate	15		15	10	10	0	10			0					
Cancer_rem	10		10	10	10	0	10	10		0					
Heart	0	1	15	10	10	0	1	0/15		0					
Crb	0	0	15	3	3	0	1	0	3	0					
Resp	10	5	15	5	5	0	1	0		0					
Ldc	0	0	15	5	5	0	1	0	1						
Traffic	1	0	0	0	0	0	5	0	0						
Suicide	0	0	0	0	0	0	0	0	0						

[a] The sign next to a variable indicates documented directions of association. In the case of agriculture and urbanisation, there is no clear uniform pattern, while alcohol was considered to be negatively associated with heart disease and positively to the other causes of death.

Table 5.- Results from the pooled model for the different causes of death:"West" analysis

Men	total	lung	prostate	cancer_rem	heart	CRB	resp	LDC	traffic	suicide
Cause at t-1	0,84 ***	0,90 ***	0,71 ***	0,86 ***	0,86 ***	0,76 ***	0,21 ***	0,86 ***	0,65 ***	0,86 ***
lnGDPc	-35,51 ***	-1,56 **	1,74 ***			-8,79 ***	-38,24 ***		-4,29 **	
GINI					0,92 **		0,29 *	0,07 ***		0,02 **
EDU					-7,67 ***					-0,57 ***
IND	0,87 *			0,21 **	1,01 **	0,41 ***			0,18 ***	0,04 **
AG				-0,19 **	-1,33 ***		0,67 ***		-0,26 **	-0,12 ***
DIV			0,03 ***			0,08 **	0,49 ***		0,03 **	
ALC+	4,14 ***			0,44 ***		1,21 ***	0,90 ***	0,55 ***	0,15 *	0,09 ***
ALC-					-0,95 ***					
POL	2,25 **	0,36 ***			1,44 *		5,72 ***			
URB		-0,34 ***							-0,28 ***	
UNEMP			0,06 *	0,24 ***				0,02 *	-0,16 **	
LUNG	0,77 ***	0,37a *	0,02 **	0,04 **	0,20 *	0,17 ***	0,17 **			
FRUIT		-0,01 **		-0,02 **						
HCGDP			-0,24 **	-0,58 **					-0,40 *	
AR(1)	-0,47 ***	-0,32 ***		-0,34 ***						
Fixed Effects										
Austria	345,15	41,56	-8,47	13,92	56,12	64,49	346,54	-3,40	65,67	7,46
Belgium	295,04	51,46	-8,32	10,43	13,64	50,89	322,82	-7,19	74,72	6,59
Switzerland	342,43	40,55	-6,32	13,93	41,14	57,38	367,96	-7,58	62,60	7,45
West Germany	323,91	46,45	-7,94	14,01	37,94	59,57	327,83	-6,02	67,92	5,36
Denmark	363,02	48,64	-8,26	16,04	59,08	58,63	357,49	-6,02	69,72	7,70
Finland	371,59	38,83	-8,01	11,65	58,08	66,57	382,00	-4,09	64,22	9,69
France	312,06	45,49	-8,78	15,64	24,39	50,00	345,07	-8,88	68,05	5,82
Greece	316,24	41,95	-11,26	19,51	46,34	70,18	314,46	-7,51	70,26	5,37
Italy	317,86	44,29	-10,96	16,81	17,87	61,15	351,35	-5,44	66,60	3,26
Norway	401,03	43,38	-5,17	17,57	58,60	76,32	386,58	-3,52	66,60	7,36
Sweden	391,53	46,09	-6,59	14,16	64,41	70,65	368,06	-4,04	66,86	7,04
United Kingdom	326,39	46,02	-10,13	10,81	26,54	60,50	363,82	-6,15	66,04	4,23
Durbin-Watson	2,02	2,13	2,29	2,01	2,37	2,28	2,13	2,11	2,22	2,19
R2 adj	98,92	99,75	98,44	99,81	98,85	98,36	94,61	99,51	96,57	97,65

Women	total	lung	breast	cancer_rem	heart	CRB	resp	LDC	traffic	suicide
Cause at t-1	0,64 ***	0,79 ***	0,79 ***	0,91 ***	0,90 ***	0,79 ***	0,18 ***	0,80 ***	0,56 ***	0,83 ***
lnGDPc	-64,32 ***	1,16 ***				-11,72 ***	-30,87 ***		-1,29 *	-0,84 ***
GINI					0,26 **		0,14 *	0,02 ***		
EDU			-0,57 **		-1,75 *					-0,22 *
IND	3,35 ***		0,07 **	0,20 ***	0,50 **	0,61 ***			0,11 ***	0,05 ***
AG	-2,23 **	0,07 ***	-0,22 ***	-0,17 ***	-0,65 **	-0,46 *			-0,10 **	-0,07 ***
DIV	0,38 **	0,02 ***	0,04 ***			0,12 ***	0,28 ***		0,01 **	0,01 **
ALC+	4,25 ***			0,12 **	0,89 **	0,33 *	0,41 ***	0,26 ***	0,05 *	0,05 ***
ALC-					-0,86 ***					
POL	3,43 ***						1,97 ***			
URB		0,10 ***		-0,20 ***			-0,28 **	0,05 ***	-0,07 ***	
UNEMP				0,12 **		0,17 **	0,55 ***	0,01 **		
LUNG	0,75 *	0,24a **					0,66 ***			
FRUIT	-0,13 ***		-0,01 *	-0,01 ***		-0,02 *				
HCGDP		-0,07 **	-0,41 ***						-0,21 **	
AR(1)				-0,32 ***	-0,37 ***			-0,35 ***		
Fixed Effects										
Austria	673,27	-15,47	12,49	16,51	15,23	105,79	298,90	-4,17	17,53	9,57
Belgium	638,89	-18,81	13,60	21,52	5,57	101,17	293,63	-6,71	20,20	9,75
Switzerland	661,99	-15,96	14,08	14,83	5,39	103,68	313,35	-5,63	17,06	10,19
West Germany	629,37	-17,80	13,17	19,48	7,41	100,13	298,60	-5,71	18,07	8,90
Denmark	693,63	-13,39	15,08	23,25	12,83	102,43	307,85	-5,77	19,04	10,49
Finland	698,48	-15,99	11,51	16,01	12,56	106,30	312,22	-4,43	17,32	10,06
France	625,02	-17,52	12,02	16,49	3,89	98,60	304,06	-6,58	18,65	9,23
Greece	744,75	-16,02	17,28	20,62	22,05	128,92	293,78	-5,54	19,89	9,33
Italy	682,28	-15,91	13,68	18,09	6,84	108,72	300,07	-4,25	17,47	8,41
Norway	708,74	-15,70	11,99	20,46	11,97	108,91	328,98	-4,36	17,90	10,04
Sweden	678,09	-17,37	11,11	20,41	12,39	101,92	316,27	-5,10	18,20	9,71
United Kingdom	642,36	-14,48	12,12	20,30	4,96	102,21	319,89	-6,05	16,93	8,20
Durbin-Watson	2,45	2,39	2,46	2,10	2,10	2,29	2,10	2,01	2,11	2,24
R2 adj	98,83	99,59	99,33	99,83	99,42	98,89	94,58	99,21	97,20	97,56

Method: GLS (Cross Section Weights)
Sample: 1977 1999; Total panel (unbalanced) observations 243
* p< 0.10; ** p<0.05; *** p<0.01 (one-sided)
a Coefficient for the tobacco variable, multiplied by 1000.

Table 6.- Results from the pooled model for the different causes of death:“East” analysis

Men	total	lung	prostate	cancer_rem	heart	CRB	resp	LDC	traffic	suicide
Cause at t-1	0,61 ***	0,82 ***	0,52 ***	0,51 ***	0,68 ***	0,71 ***	0,55 ***	0,34 ***	0,69 ***	0,61 ***
lnGDP	-61,31 *		3,77 ***		-27,01 *				7,43 ***	-9,72 ***
GINI	2,94 **				1,48 **			0,21 ***		
EDU	-28,08 *	-3,41 ***			-18,11 **	-3,43 *	-5,37 ***		5,23 ***	
IND				0,94 ***	6,36 ***	1,29 ***	0,46 *	0,18 ***	0,36 ***	0,48 ***
AG									-0,12 *	0,34 ***
DIV				0,23 ***		0,18 *	0,17 ***			0,24 ***
ALC+	19,95 ***	0,81 ***		0,40 ***	5,56 ***	2,05 ***	1,11 ***	0,70 ***	0,25 *	0,47 **
ALC-					-2,39 *					
LUNG	3,79 ***			0,35 ***	0,37 *		0,36 ***			
URB	11,40 ***	0,71 ***	0,15 ***	-0,40 *		1,66 ***	-2,57 ***			
UNEMP								0,19 ***		
AR(1)								0,61 ***		
Fixed effects										
Bulgaria	6,33	-17,83	-35,99	16,36	182,81	-92,12	191,64	-3,77	-116,79	56,15
Belarus	98,31	-5,81	-36,32	30,91	272,30	-97,97	209,40	-8,66	-119,57	63,58
Czech Republic	-223,03	-12,09	-32,33	36,17	162,38	-131,48	189,22	-4,09	-127,35	57,79
Czechoslovakia	-108,19	-6,78	-33,32	28,02	156,25	-114,72	194,91	-0,48	-127,26	59,47
East Germany	-170,40	-21,50	-35,56	26,38	231,62	-151,80	223,79	-1,58	-128,11	67,14
Estonia	-45,74	-14,49	-34,42	28,79	240,79	-104,47	170,98	-9,68	-114,58	67,74
Hungary	-127,94	-4,13	-28,46	37,62	184,63	-104,22	155,25	38,41	-116,30	68,77
Latvia	-98,26	-13,84	-34,76	29,20	220,73	-95,43	171,45	-13,84	-110,47	65,85
Russia	-93,79	-10,34	-39,06	30,14	200,29	-88,21	211,47	-11,30	-120,88	66,17
Slovak Republic	2,75	-2,57	-31,65	32,40	195,87	-112,74	162,19	7,78	-120,95	60,07
Ukraine	26,55	-7,80	-37,03	24,66	246,24	-90,45	208,01	-2,33	-118,61	57,30
Durbin-Watson	1,64	2,04	2,11	2,32	1,76	1,91	2,00	1,99	1,75	1,88
R2 adj	99,2708	99,801	99,102	99,906	99,489	98,371	92,814	97,70	93,533	97,465

Women	total	lung	breast	cancer_rem	heart	CRB	resp	LDC	traffic	suicide
Cause at t-1	0,71 ***	0,87 ***	0,72 ***	0,67 ***	0,66 ***	0,78 ***	0,44 ***	0,61 ***	0,57 ***	0,63 ***
lnGDP		1,22 ***		-7,05 ***	-23,01 **		12,75 ***	0,96 **	2,33 ***	-1,00 ***
GINI	1,68 ***				0,76 **			0,07 ***	0,03 ***	
EDU	-28,40 ***	-0,34 ***	1,19 ***	-1,56 ***	-15,70 ***	-4,36 ***	-2,59 ***		0,64 **	-0,02 ***
IND	2,24 *		0,08 **	0,55 ***	3,64 ***	0,31 **	0,51 ***	0,09 ***	0,13 ***	0,11 ***
AG			0,11 **				0,37 **	0,11 ***		0,10 ***
DIV				0,09 **				0,03 ***	0,01 **	0,04 ***
ALC+	6,31 ***	0,08 ***		0,35 ***		1,19 ***		0,24 ***	0,21 ***	0,03 **
ALC-					-2,61 ***					
LUNG							0,79 ***			
URB	4,79 **		0,21 ***			0,88 ***	-2,73 ***	0,15 ***	0,15 **	
UNEMP									0,03 **	
AR(1)										
Fixed Effects										
Bulgaria	-37,47	-7,57	-22,59	73,93	300,79	-9,96	78,52	-26,94	-41,74	4,72
Belarus	25,90	-7,46	-25,02	80,31	342,12	-7,87	84,89	-26,87	-41,20	4,43
Czech Republic	-79,31	-6,30	-23,45	90,96	295,12	-24,35	89,17	-27,62	-45,18	4,61
Czechoslovakia	-32,83	-7,13	-21,53	87,69	291,07	-16,02	89,18	-26,34	-44,54	4,76
East Germany	-67,17	-7,49	-23,93	84,33	354,24	-37,81	113,53	-27,02	-44,69	6,59
Estonia	-60,65	-8,08	-21,67	86,27	313,61	-15,01	68,29	-28,82	-41,59	6,07
Hungary	-12,68	-5,38	-17,83	90,72	324,13	-17,77	54,61	-16,98	-41,10	8,68
Latvia	-62,58	-8,02	-21,53	84,31	313,51	-10,12	71,60	-28,63	-40,54	6,39
Russia	-42,39	-7,39	-25,12	82,73	318,62	0,70	96,43	-28,03	-43,16	5,88
Slovak Republic	-0,23	-7,38	-20,52	84,18	322,32	-20,93	57,52	-22,77	-41,36	3,94
Ukraine	18,36	-7,05	-23,82	78,34	345,86	-2,23	83,10	-25,69	-41,51	4,15
Durbin-Watson	1,87	2,31	2,34	2,23	1,95	1,90	2,01	2,03	1,90	2,27
R^2 adjusted	99,23	99,31	99,61	99,93	99,16	98,69	94,11	95,13	94,09	98,33

Method: GLS (Cross Section Weights)
Sample: 1981 1999; Total panel (unbalanced) observations 206
* p< 0.10; ** p<0.05; *** p<0.01 (one-sided)

As the results indicate, each model fitted the data very well: the adjusted R^2 values ranged from 92.8% to 99.9%. In fact, it appeared that both mortality at time t-1 and the exogenous factors were independently able to accurately predict mortality. The contribution of mortality at time t-1 is not surprising however: most deaths are the result of lifetime accumulations of health risks and exposures and therefore the probability of death will not fluctuate that much from year to year.

The R^2 values also remained about the same in each model when mortality at time t-1 was removed (not shown here), but this term was retained in order to obtain a better estimate of the effect of the exogenous variables. Without it, models showed high negative autocorrelations, even with an additional AR(1) term. The high R^2 was also in part due to the inclusion of cross-country weights (to eliminate cross-section heteroskedasticity) and fixed effects (i.e. country-specific intercepts).

One point to bear in mind when interpreting the results is that, in many instances, the exogenous variables have been lagged by different times depending on the cause of death and also by different amounts in Eastern and Western Europe. In regard to the latter, the effect on mortality of several of the variables appeared to be more immediate in Eastern than in Western Europe. This was particularly the case with absolute and relative income and divorce. GDPc, the proportion of the workforce employed in the industrial sector and the amount of alcohol consumed were the variables that were most frequently significant. Agricultural employment, divorce and smoking can be added to this list for Western Europe, and education and urbanisation for Eastern Europe.

Results for men showed that GDP per capita (GDPc) was significant in six out of the ten models in both Eastern and Western Europe, but its elasticity for total mortality was higher in Eastern Europe, something which was expected given the fact that GDPc and mortality are not linearly associated and therefore health gains in the poorer East are greater with an equal amount of extra wealth. Among both sexes, the Eastern European results also showed that GDPc was significant in two of the models pertaining to causes of death that have been linked with psychosocial factors, i.e. heart disease and suicide, while in the Western European analysis, these causes were only associated with relative prosperity. The association between GDPc and traffic accidents was positive rather than negative in Eastern Europe, perhaps because cars were a luxury product for most people. For women, GDPc also showed a positive association with lung cancer, thus indicating that for them it is still a welfare disease. These different results imply that the effect of GDPc on health appears is not the same between the two Europe’s and to some extent between men and women.

In the models for Western Europe, income inequality was also significant for chronic liver disease and cirrhosis (LDC) and respiratory system diseases, although in each instance its absolute effect on mortality was low, as often other, related factors (GDPc, unemployment) were also significant. In the "East" analysis income inequality also had an impact, even on total mortality, something that did not occur in Western Europe. Given the fact that during the socialist period there were few international differences in income inequality, this result was less expected and shows that it takes little time before a sudden rise in income inequality affects mortality at the population level.

In both Europe's and for men and women, the proportion of industrial employment in the workforce was an important explanatory factor in the models of remaining cancer, heart disease, CRB, traffic accidents and suicide, as well as for total mortality in Western Europe and LDC and respiratory system diseases in Eastern Europe. On each occasion it was significant, it demonstrated a detrimental effect, also after including other risk factors like smoking or alcohol consumption. Although the effect of improved occupational safety standards independent of the employment structure could not be tested, it seems more likely that the improvement (or difference) in wealth emanating from the larger (different) share in service sector industries was associated with health, rather than the factors inherent to social class differences in health, as in the instances when industrial employment was not significant it occurred after including GDPc (e.g. male lung cancer in Western Europe). While short-term elasticities were quite low, particularly in the Western European models, the long-term effect of industrial employment on mortality was more substantial, particularly for remaining cancer, heart disease and traffic accidents (results not shown). When agricultural employment was significant, the association was usually negative with mortality in Western Europe and positive in Eastern Europe and rural life seemed to benefit particularly Western European women.

At the population level the effect of unemployment on mortality was minor. This was explained by the fact that the low level of unemployment in the Western European countries that were studied (after lagging it 15 years, the average was just 3%) a very high relative risk is needed to have some bearing on international mortality differences or changes over time. However, given the increases in unemployment since the 1980s and its recent emergence in Eastern Europe, unemployment is likely to become a more important factor.

The importance of education as an independent health-promoting factor associated with the acquisition of knowledge related to health-damaging behaviours rather than just economic development was perhaps more evident in Eastern than in Western Europe. This was because when GDPc also showed a significant protective effect in the models of total mortality, heart disease and suicide, education was negatively significant. A clear independent association of education in the analyses of Western Europe was established for breast cancer, heart disease and suicide. The first two associations suggest that health-related knowledge, both in terms of behaviour and the ability to optimise the use of health services might be indispensable in the fight against these diseases. It should be mentioned that with regard to the Eastern European models for traffic accidents, the association with education was positive, which may therefore be related to prosperity.

The only social factor that was tested was divorce. While mortality has been declining in Western Europe between the late 1970s and late 1990s, the level of divorce has seen a steady increase and indeed divorce appeared to have had a significant counter effect on this trend regarding several of the selected causes of death, particularly for women. A future consequence may therefore be that in those countries where divorce is still a recent or minor phenomenon (particularly in southern Europe) continued increases in divorce are likely to have an impact on future levels of mortality. Results of the analysis also showed that the magnitude of the effect of divorce was larger in Eastern Europe than in the West, which was perhaps the result of higher general levels of psychosocial stress (not shown). Although the literature suggests that divorce is more detrimental to the health of men than that of women, at the population level, the elasticities were very similar (results not shown).

The models also included several behavioural factors. The results showed that at the population level, two types of associations exist between the consumption of alcohol and mortality: negative in the long term with regard to heart disease and a positive (i.e. detrimental) short/intermediate term effect for most other causes of death, including total mortality, as well as heart disease in Eastern Europe, i.e. alcohol showed both effects there. The positive short-term association with both total and heart disease mortality is possibly because of traditions in "binge drinking" that is known to elevate the risk of sudden IHD. The effect of smoking was measured by the association of lung cancer mortality with the specific cause of death category (except for lung cancer itself of course, in which case the less reliable tobacco consumption variable was used for Western Europe (there was no data for Eastern Europe). Results showed that smoking had the largest impact on differential mortality for Western European men, being significant for all natural causes of death for which it was tested, although in Eastern Europe it was significant for total mortality, remaining cancer, heart disease, and respiratory system diseases. Among women, it particularly lacked an association with circulatory system diseases. Although most countries had their smoking peak around 1980, towards the end of the 1990s country differences were just as large as in 1960. Given the time delay that it takes for smoking to have a fatal impact on health, it is expected that smoking will continue to be an important factor in mortality differences between countries in Europe well into the 21st century, particularly for women where the effect is just being felt. The effect of fruit and vegetable consumption could only be tested for Western Europe and results were as expected, as significant effects were found for total mortality and breast cancer (both women only), lung (men only) and remaining cancer. As the west and north of Europe still lag behind in consumption levels compared to southern Europe more health gains can still be made there. This of course applies even more to Eastern Europe and the former Soviet Union. Due to insufficient data, the two other variables, pollution and government health expenditure, could only be tested for Western Europe, but they only had a small effect on mortality at the population level.

5.- Results II: model validation and short-term projections for lung cancer, heart disease and suicide

The models were validated by comparing the observed with the modelled SDR's for each country and year that the model calculations were based on. The general model is given by the equation:

$$SDR_{cst} = C_i + \Sigma\, \beta X_{j,t\text{-}x,i} + \mu_t \text{, where}$$

SDR_c = the standardised death rate for cause of death *c*
s = sex
t = year
C = fixed effect
i = country *i*
X_j = the dependent variable j
β = the model coefficient of the dependent variable Xj
x = the lag time (in years)
μ = the disturbance term[10]

Considering the model results in Table X, the general male lung cancer mortality model for Eastern Europe is therefore equivalent to:

$$SDR_{lung,t,i} = C_i + 0{,}8157{*}SDR_{lung,t\text{-}1,i} - 3{,}4103{*}EDU_{t\text{-}10,i} + 0.8083{*}ALC_{t\text{-}10,i} + 0{,}7103{*}URB_{t,i}$$

From this model we can subsequently estimate the lung cancer mortality rate in one of the modelled countries for any of the years during the study period (except the first year) with the known observed level of the year before and the specified exogenous characteristics at time *t* - lag *x*. For instance, the modelled lung cancer rate for Bulgaria in 1999 would be:

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[10] When the autoregressive term AR(1) is included in the model, $\mu_t = \rho\mu_{t-1} + \varepsilon_t$, where ρ is the first order serial correlation coefficient and ε_t the *innovation* in the disturbance. In effect, the AR(1) model incorporates the residual from the past observation into the regression model for the current observation (see Quantative Micro Software, 1994: pp. 301-3).

$$SDR_{lung,1999,BG} = -17,83 + 0,8157*61,46 – 3,4103*8,58 + 0,8083*11,75 + 0,7103*68,62 = 61,28$$

The actual value equalled 62,26, which amounts to a difference (disturbance) of 0,98 deaths per population of 100,000 or 1,6%. The results for total mortality, lung cancer, heart disease and suicide are given in Figures 1-4.

The predictive value of the models could be tested with the additional mortality data that were recently obtained by comparing the latest mortality figures with their modelled equivalents. These were calculated by introducing the required variable values into the earlier-made models. To illustrate this with the same example as before, the observed lung cancer rate for Bulgaria in 2003 was 65,06. According to the model this should have been:

$$SDR_{lung,2003,BG} = -17,83 + 0,8157*63,07 – 3,4103*9,08 + 0,8083*10,10 + 0,7103*69,75 = 60,63$$

Due to the (lagged) increase in education and (lagged) decrease in alcohol consumption, lung cancer mortality should have declined during these four years, but it increased instead, suggesting some underspecification of the model. The subsequent male lung cancer mortality scenario for Bulgaria may therefore not be very realistic. Nevertheless, as we shall see, for both total mortality and the three causes of death investigated, the differences between the modelled and actual values are generally small. The sometimes unrealistic projections, like the one mentioned here, may therefore be due to unlikely projected values for some of the exogenous variables that were often estimated by the author. Obviously, one reason why the disturbances are often small is due to the fact that previous year's mortality was included in the model. Therefore, when differences were large and fluctuated from being positive to negative this was in part due to large yearly fluctuations in mortality and/or the exogenous variables. It was perhaps therefore that the most accurate models appeared to be for the countries with the largest populations and those of Western Europe, as this was where the year-to-year mortality fluctuations were smallest. Nevertheless, three-year moving averages were calculated of the modelled results in order to eliminate the most erratic residuals. The main findings may be summarised as followed.

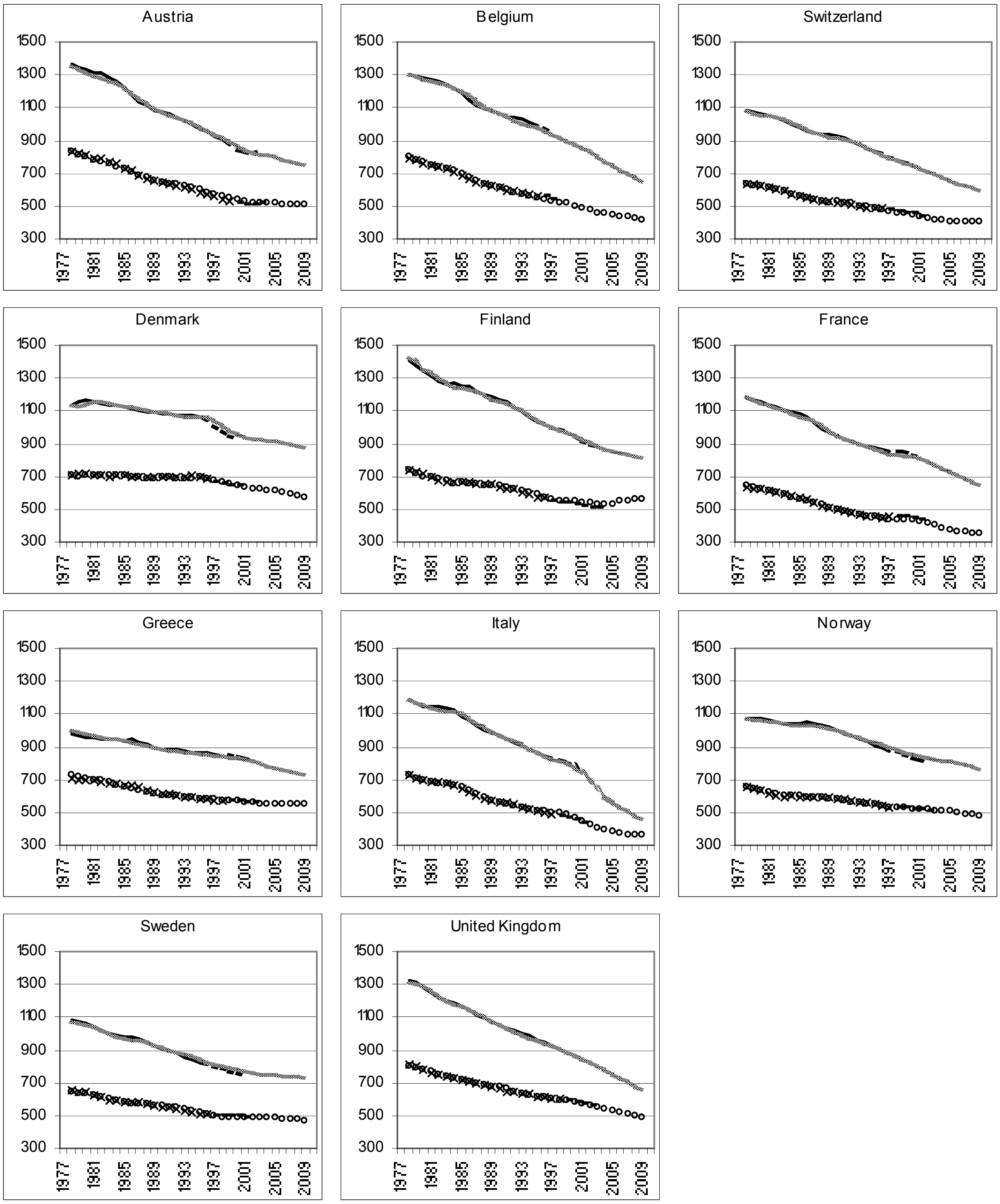
5.1.- Total mortality

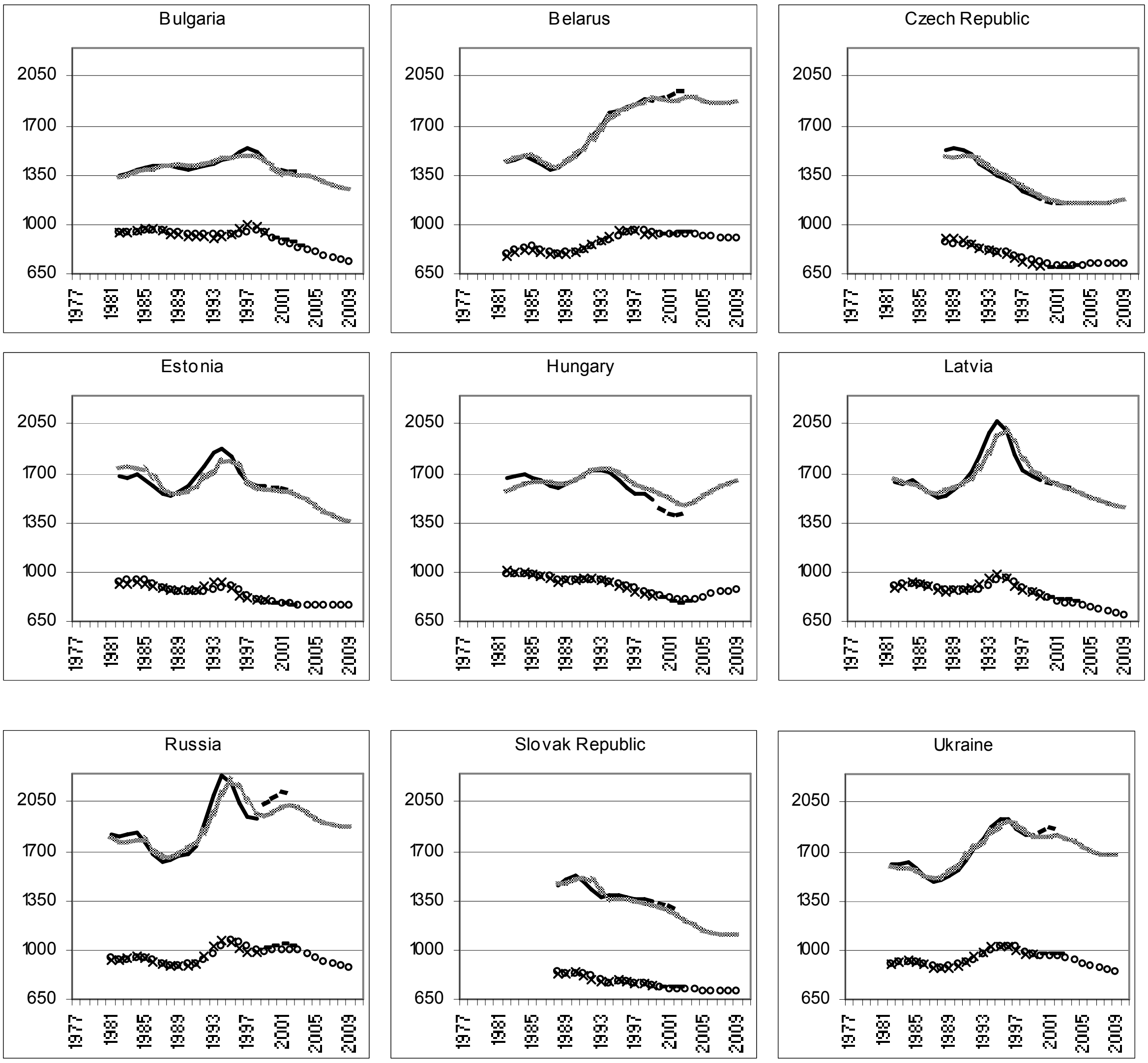
Although the modelled values for the Western European countries appear to coincide almost perfectly with the observed ones within the range used to construct the models, this is not entirely the case, as the scaling of the graphs obscures some of the differences. The maximum deviance that was recorded was around 2,8% for men (French males, 1988) and 4,1% for women (Greek women, 1986), both equivalent to about 27 deaths per population of 100,000. Differences were also quite limited with regard to the two to six additional years that were used to validate the models. The most obvious discrepancies were for Finnish women (larger decline than predicted) and France (a levelling off instead of the predicted continuation of the decline in mortality).

On the contrary, there were larger differences between the observed and modelled values for Eastern Europe. In maximum relative differences were 7,2% for Latvian men (1993) and 5,9% for Estonian women (also 1993), exactly when mortality was at its highest point. Absolute differences were therefore much higher than observed for Western Europe (in these two cases respectively 142 and 54 deaths per population of 100,000). As one of the most important variables that was used to predict mortality for one year was mortality rate of the year before, this difference is not so surprising when there are large annual changes in the mortality rate as was the case here. For this reason were the predicted levels of mortality for the latest available years also different from the observed levels when there was a sudden trend break, although the modelled values generally followed the same trend as observed, albeit with a year's delay and less acute. See for instance the result for Russian men.

With respect to the projections, male total mortality in Western Europe is set to continue its decline as observed since the late 1970s. In some instances, this decline in the short term may be accelerated (e.g. in Greece and Italy) or continue at a slower pace (the four Nordic countries). Female mortality is not as likely to decline very rapidly and its current trend may level off (Austria, Switzerland, and Greece) or mortality may even increase (Finland). With respect to Eastern Europe most countries in the sample have clearly recovered from the mortality crisis of the 1990s, although in many cases their mortality levels are still above that of the mid-1980s. Nevertheless, predictions are that most mortality levels will continue to decline at a similar pace. Exceptions are Belarus, where still no decline as taken place at levels are predicted to remain at its current level until 2010; The Czech and Slovak Republics, where the sharp decline during the last decades are predicted to come to a halt; and Hungary, where a sharp increase in mortality is predicted. While large sex-differences exist in the absolute level of total mortality in Eastern Europe, there are few sex-differences in terms of relative mortality change between the beginning and the end of the current decade.

Figure 1.- Observed and modelled total mortality rate for a selection of Western and Eastern European countries, 1977/81-2010

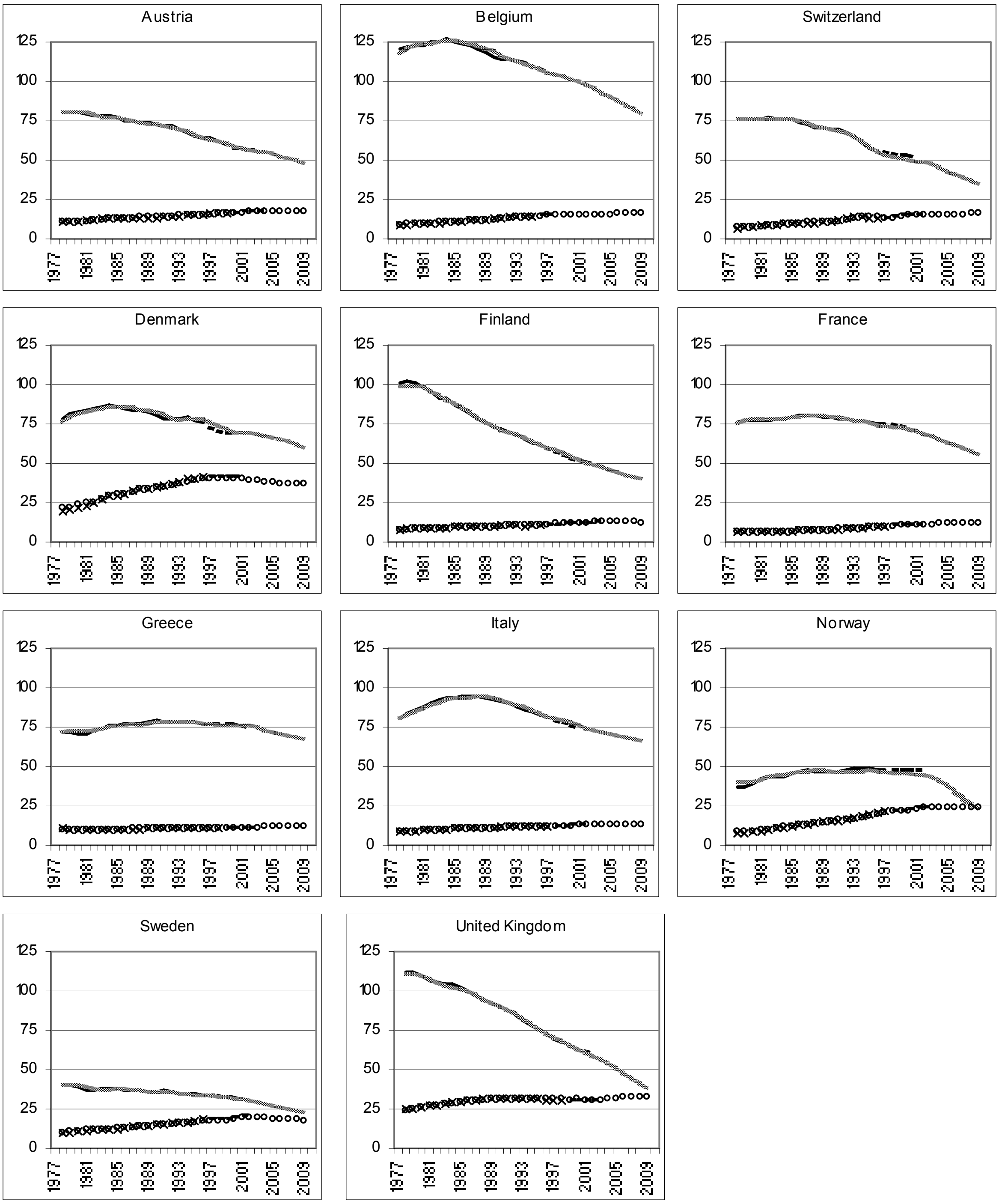


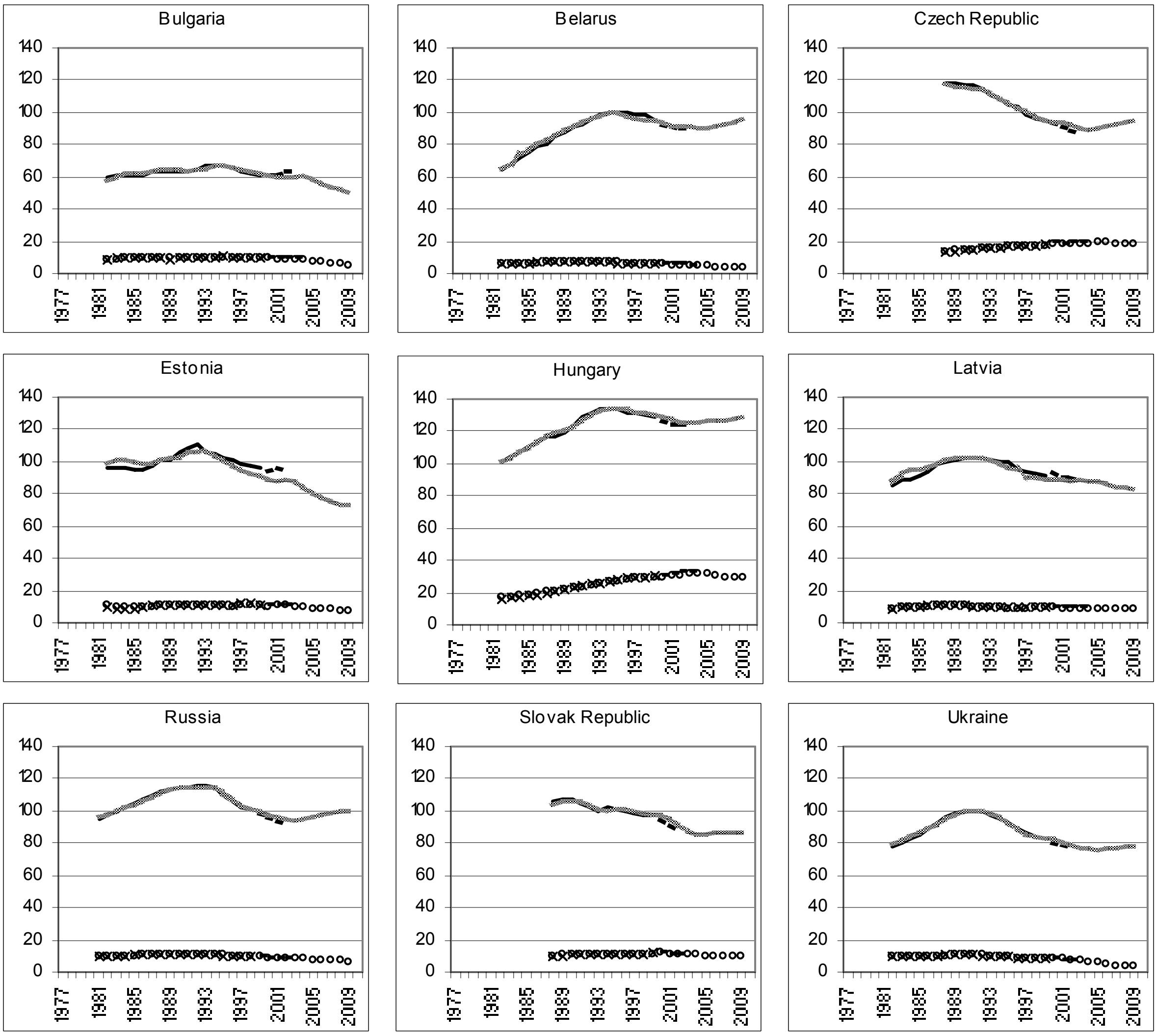


5.2.- Lung cancer

Although the quality of the smoking variable in the Western European analysis for lung cancer was not as optimal as desired due to the large number of estimations that were made, the absolute difference between the observed and modelled values was never more than 3 deaths per population of 100,000 for men and 2 for women, although due to the very low level of mortality among women in most countries, relative differences were usually larger than observed for men (a maximum of 13,5% in Norway, in 1978). Even though no smoking data was used to model the Eastern European data, the modelled rates were also very similar to the observed ones with maximum differences of 6 per 100,000 for men (Latvia, 1984) and 1 per 100,000 for women (Estonia, 1983 and 1996), when the lung cancer mortality rate was between 60 and 130 for Eastern European men and 5 and 30 for Eastern European women.

Figure 2.- Observed and modelled lung mortality rate for Western and Eastern European countries, 1977/81-2010





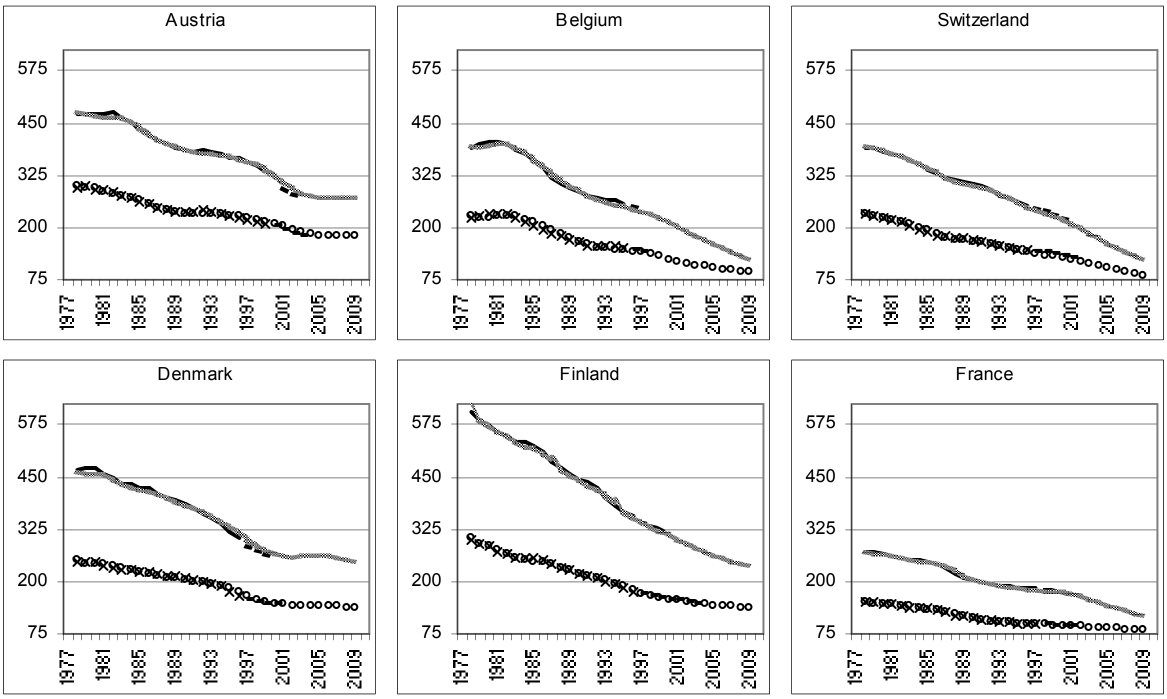
Somewhere in the 1990s most Western European countries began to see a drop in male lung cancer mortality. According to the projections, this is set to continue in the same linear function in the second half of this decade. In Norway, where mortality levels since the late 1980s have been stable at just under 50 deaths per population of 100,000, the decline is set to take place during the forecasted period. Western European women experienced a different smoking pattern than men, as smoking was popularised much later. For this reason, lung cancer mortality levels are still increasing in most countries, although a levelling off has either been recently observed or is predicted for the near future. For Denmark and Sweden a small decline is even predicted. While gender differences were very large for some countries in the beginning of the sample period, up to more than 100 deaths per population of 100,000 for Belgium, Finland and the UK, 30 years later this difference is decreasing fast and in the case of Norway, Sweden and the UK, set to converge by around 2010.

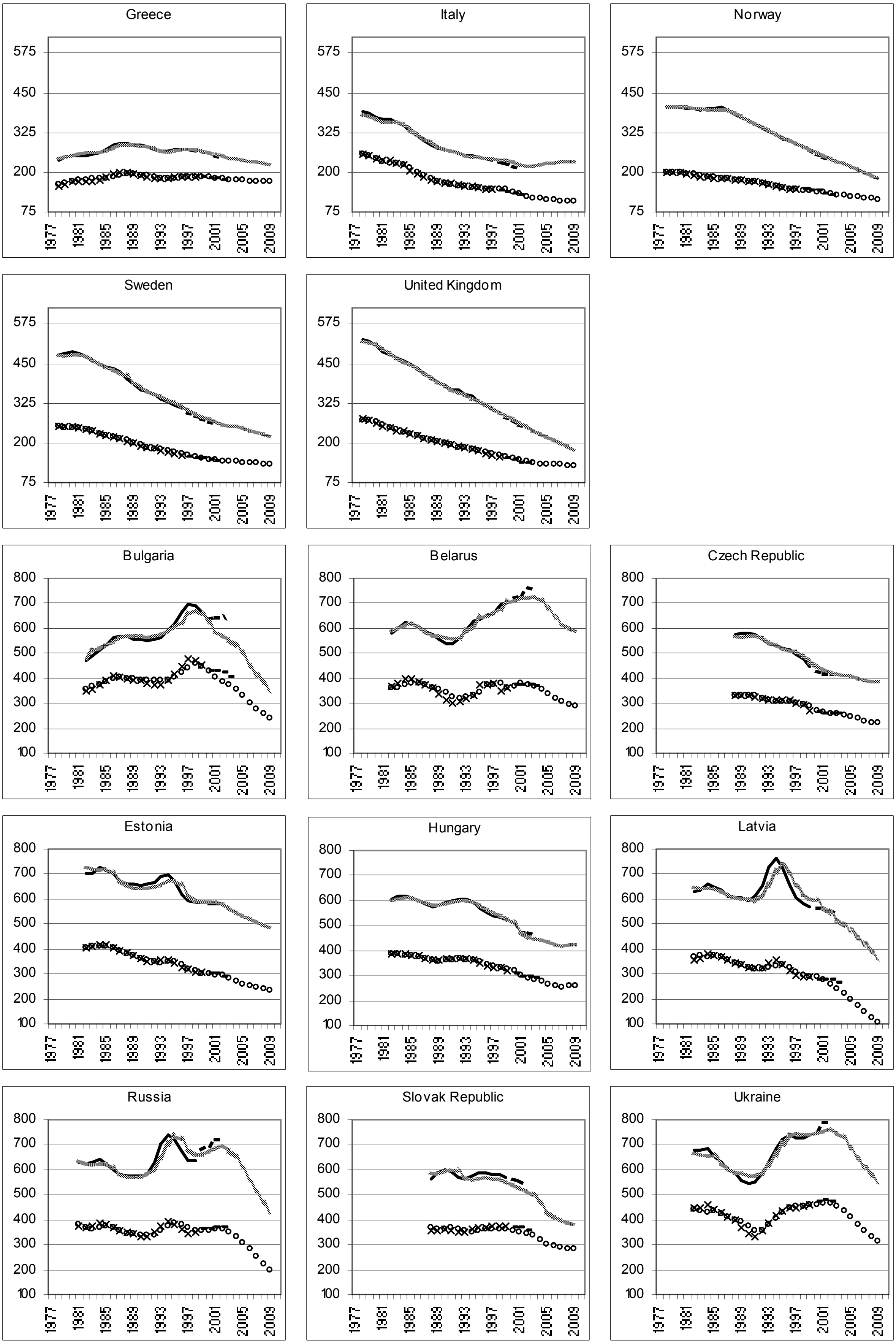
In Eastern Europe, the male lung cancer epidemic was at its height somewhat later and with generally higher levels than in Western Europe. Moreover, most predictions seem to suggest a levelling off in the decent decline. Female mortality levels are generally lower in the East than in the West, whereby for most countries the current and predicted trend would suggests a levelling off of the increase or slight decline in the mortality rate. In fact, the pattern (but not the absolute level) of the current (since the turn of the century) and predicted lung cancer mortality is very similar for men and women. With regard to the projections this comes with little surprise, as the value of the input variables are the same except for mortality at time t-1 (remember that there were no sex-specific smoking data). In other words, there are fewer (predicted) male-female differences in the pattern (but not absolute level) of lung cancer mortality in Eastern Europe than in Western Europe.

5.3.- Heart disease

What is striking with regard to the heart disease trend within Western Europe from the late 1970s until the latest available year (about 2003) is, with the exception of Greece, the uniformity (i.e. continual decline) between not only the countries, but also between men and women.

Figure 3. Observed and modelled heart disease mortality rate for Western and Eastern European countries, 1977/81-2010




Greece
Italy
Norway
Sweden
United Kingdom
575
450
325
200
75
1977
1981
1985
1989
1993
1997
2001
2005
2009
Bulgaria
Belarus
Czech Republic
Estonia
Hungary
Latvia
Russia
Slovak Republic
Ukraine
800
700
600
500
400
300
200
100

The difference between the observed and predicted values was therefore usually no more than a few percentage points and the model fitted the data for the additional years very well. For example, the absolute difference in Finland for the additional six years that were obtained to validate the model was never more than 6 deaths per population of 100,000 (or 1,9%) among men or 3/100,000 (or 1,6%) among women.

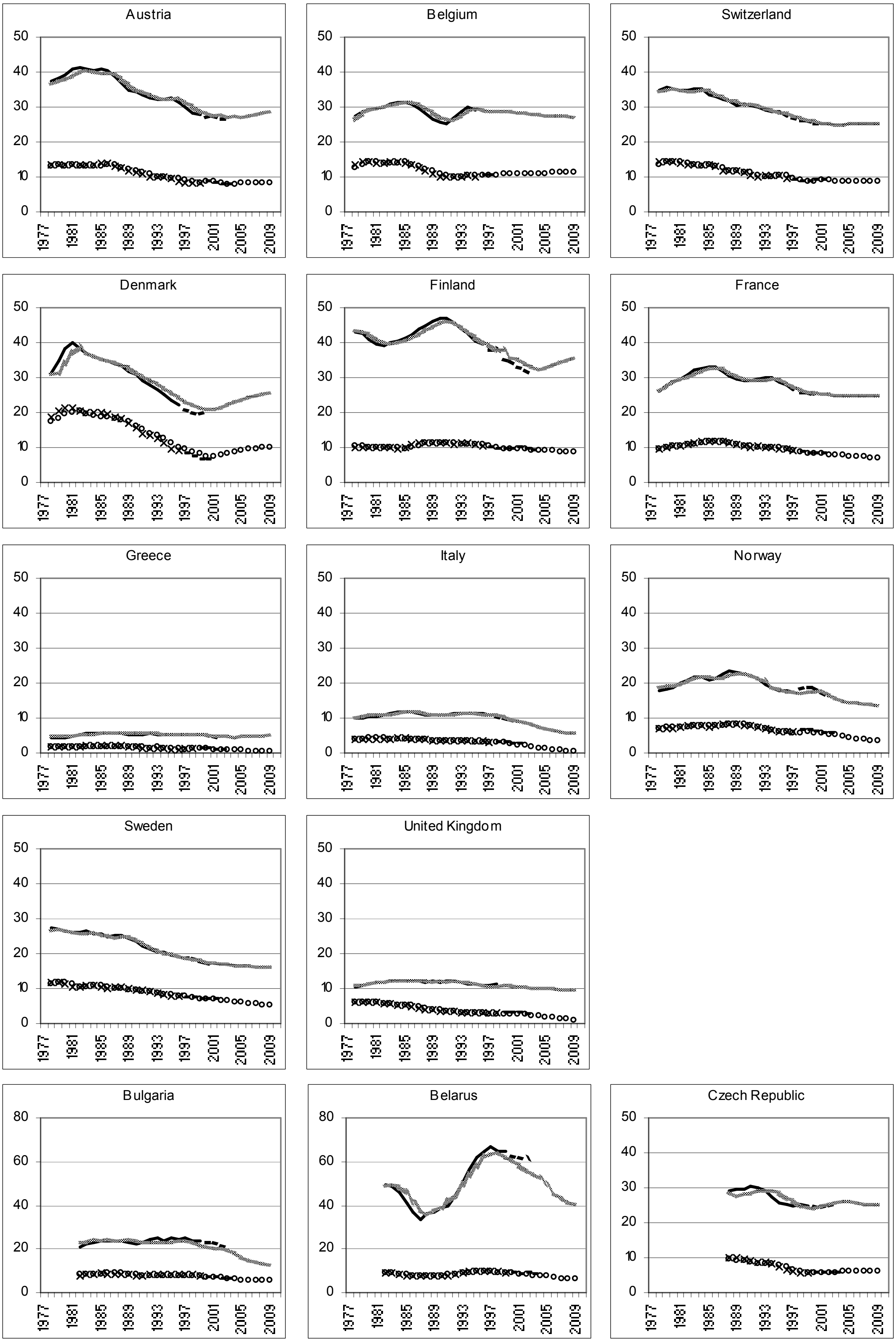
In Eastern Europe, while some countries (e.g. Estonia and Latvia) show signs of recovery after the increase during the 1990s all but the Czech and Slovak Republics and Hungary experienced, in other countries mortality continues to increase (e.g. Russia) or show signs of levelling off (e.g. Bulgarian men). The differences between the observed and modelled rates are larger than in Western Europe, although there are no great discrepancies with the general mortality trend. Differences are largest around the period of sudden increases or decreases in mortality when the modelled trend tends to lag a year behind the observed trend. Only with regard to Bulgarian and Ukrainian men did the observed morality rate for the validation years not quite follow the modelled rate. With regard to the projected rates, there are basically three trends. Firstly, a continuation of the decline that has been observed throughout the entire study period in most of the Western European countries. The second observed trend is the levelling off in the rate of decline. In the case of Italy, where current rates are already low, this may suggest that, at least in the short term, possible further gains in survival from this disease are limited.

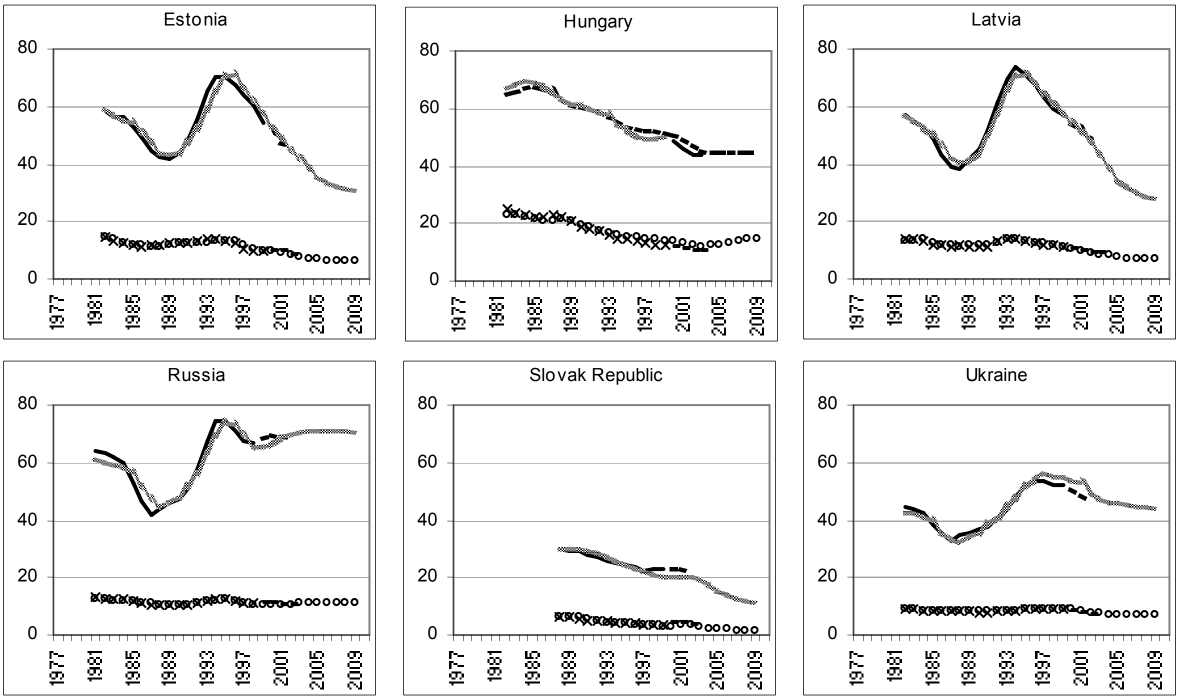
In the case of Austria and Denmark this appears to be the effect of smoking, which hampers further decline. With regard to Hungary, where this trend is also predicted even though current levels are still relatively high, it may suggest that especially the social and economic conditions are still not right to allow heart disease to continue its rapid decline. The third observed trend is the sudden decline that is predicted in most Eastern European countries where the mortality rate has only recently showed signs of recovery or which will take place during the predicted period. Again, while absolute sex differences in heart disease mortality are large, the observed and proposed trends between men and women are similar.

5.4.- Suicide

Modelled and observed rates appear very similar in most countries. Minor differences are observed in most Eastern European countries and in Austria, Denmark and Norway, though no more than 1 or 2 deaths per 100,000.

Figure 4. Observed and modelled suicide mortality rate for Western and Eastern European countries, 1977/81-2010





Perhaps the least reliable result is that of the Slovak Republic, as the modelled results for the last 5 years for which data were available, including the three years that did not partake in the model sample, were consistently lower than the observed values. With regard to the projected level of mortality for Western Europe, a decline is foreseen in Italy, Norway, Sweden and for Belgium males, little change in the current level in Austria, Switzerland, France (men), Finland (women) Greece and the UK and a possible increase in Denmark, Belgium females and Finnish men. With regard to Eastern Europe absolute levels were on the whole substantially higher. This was especially the case for males, where some of the countries experienced a sharp rise during the mid-1990s as a result of economic and political uncertainty, although since then levels have declined or are set decline in the projected period. It is perhaps curious that in the Czech Republic, that throughout the study period had one of the lowest levels of suicide, levels are not predicted to change by much, while its neighbour the Slovak Republic where past suicide levels were very similar, a continual decline is expected. Other exceptions are Hungary, where levels are set to stabilise (and slightly increase among women), Russia and the Ukraine, where male levels are predicted to remain at the height that they have experienced since the early 1990s. In both Europe's, there doesn't seem to be a convergence between men and women in the mortality rate for suicide.

6.- Summary and conclusion

The main purpose of this paper was to test cause-specific mortality models that were based on both mortality indicators and exogenous variables. These models were derived from earlier research that assessed the importance of socioeconomic and other factors on mortality differences across Europe over time and between countries to determine which factors should be incorporated into future mortality scenarios (Spijker, 2004). Western and Eastern Europe and men and women were analysed separately, whereby model estimates from the original sample were compared with recently obtained data. Subsequently short-term projections were produced on the basis of the model results. The time frame of the original analysis was from the late 1970s/early 1980s to the second half of the 1990s, with projections to 2010. Because of the time lag between exposure and health effect of a particular variable, which, in the case of most causes of death, is often a matter of years, current observations were used for the short-term projections and no attempt was made to produce different scenarios. In those instances where predictions for the independent variables were necessary, usually the latest available value was held constant for the required years or, as in the case of GDPc and unemployment, it was based on published forecasts until 2006 and held constant thereafter when no time lag was required.

Besides total mortality, causes of death were also analysed. For the purpose of this paper, only the results for lung cancer, heart disease and suicide were provided. The reason for studying causes of death is that they provide knowledge of disease determinants and can therefore be considered as the first step towards possible explanation for mortality differences. But also for projection purposes using cause-specific rather than total mortality trends has been preferred in the past, particularly for short-term forecasting, because of the simplicity of the parameterisation functions for mortality by cause and by the fact that epidemiological knowledge can be used in formulating hypotheses (Tabeau et al., 2001).

Another important aspect of the analysis was the pooling of the countries. Due to the different political and economic past between Eastern and Western Europe several exogenous variables were not considered as being comparable, for which reason the analysis was split into two, although separating Europe into a northern, western, southern, central and a former Soviet Union cluster could have been another option. However, these clusters are more homogeneous, which may cause certain variables to become unimportant in explaining within-cluster differences even though they are known to cause international mortality differences (e.g. dietary factors when only analysing Mediterranean countries).

One important difference with the original models on which this paper is based was the use of lung cancer mortality as an indicator for life-time smoking exposure for the causes of death other than lung cancer that are also known to be associated with smoking. Although this meant that the coefficient for smoking of the lung cancer model could not be compared with the other models, it was considered to be a more reliable smoking indicator than when annual tobacco consumption data is used. Another variation from the earlier models was the simultaneous testing of the positive long-term and negative short-term health effect of alcohol for total mortality and heart disease. Results showed that at the population level part of the country and time differences in heart disease among Western European women and Eastern European men were explained by both current and lagged consumption of alcohol, while only the beneficial effects proved significant in the model for Western European men and Eastern European women.

With regard to the results, the most important independent variable was perhaps mortality at time t-1. It was a conscious decision to include this as one of the explanatory variables, as it was considered that under normal conditions, mortality does not change radically from one year to the next, because intrinsically, the timing of death is determined by a multitude of factors across the life course, some of which originate even before birth and which cannot be unveiled with cross-sectional population-level data. On the other hand, it was thought that the yearly fluctuations in mortality or gradual changes could be modelled by exogenous variables, as these would be the result from more short-term economic, social and behavioural changes. Thus it was not surprising to see that the variable lag times that were calculated for the Eastern European models were often shorter than in Western Europe due to the economic, political and social uncertainties there in the 1990s. This particularly pertained to the economic variables, GDPc and income inequality, the latter of which even had an impact on total mortality, even though income inequality has only been high in recent years. With regard to the original models, each variable was significant in one or more of the cause-specific models, thus indicating that not only economic factors play a role in explaining mortality differences over time and between countries, but also social, environmental and behavioural factors, and not only for men, but also for women, and in different types of political and economic settings.

For total mortality, lung cancer, heart disease and suicide, model values were tested against the original data, as well as newly obtained data in order to ascertain if the models could also be applied beyond the sample range. For total mortality differences were no more than 27 deaths per population of 100,000 for both men and women in the Western European sample countries, while larger discrepancies between the observed and modelled values were established for several of the Eastern European countries. This was particularly the case around the years of mortality crisis and recovery, although only in terms of the magnitude and timing of the mortality change, as in general the modelled mortality trend was in the right direction. Results showed that in Western Europe, male mortality is set to continue its decline as observed since the late 1970s, either in accelerated fashion or at a slower pace, while female mortality is less likely to decline very rapidly and its current trend may level off in some countries or, in the case of Finland, mortality may even increase. In Eastern Europe total mortality is predicted to continue its decline since the mid- to late 1990s, with Belarus, Hungary and Russia as exceptions. Overall, there is still little sign of a narrowing in the sex difference in total mortality in Eastern Europe as is the case in Western Europe, even for the forecasted period. With respect to lung cancer, the most obvious result was that sex differences in mortality has already narrowed drastically in most Western European countries and is predicted to converge in Norway, Sweden and the UK, as male mortality continues to decline and female mortality to rise or level off. In Eastern Europe, lung cancer mortality is still a relatively unimportant cause of death among women, while male levels are generally higher than in Western Europe, and show little sign of declining in the near future. Also with regard to heart disease there were few differences between the modelled and observed mortality rates for the Western European models. The declining trend that is observed for most countries is set to continue, albeit at a slower pace in those countries with already low levels, particularly among women. Results could indicate a minimum level of about 75 deaths per population of 100,000 in the future, at least for women, although male levels are slowly converging. The latter also applies to Eastern Europe, but levels are still much higher there. Nevertheless, contrary to total mortality a continuation of the current decline is projected for all countries and for both men and women.

The last result that was discussed was suicide. Again, the observed and modelled mortality rates were very similar, and for most Western countries both male and female levels are set to change very little, which means that the sex differences will remain about the same until the end of the projected period. In the case of Eastern Europe, patterns are much less uniform for both men and women, but it seems that levels are predicted to decline in those countries with the most favourable economic situation.

The aim now is to seek ways to further improve the methodology of modelling cause-specific mortality with non-demographic variables and to integrate the results in a multidisciplinary population projection. It may be that the models are too general, as we know from the concept of competing causes of death and the associated problem of inaccuracies of the cause-of-death statistic, that particularly at very old ages, the underlying cause of death is less the result of a clearly-defined aetiological (causal) path than the random result of a more generalised deterioration of the capacity for life (Rosenberg, 1993). Therefore, because mortality from chronic diseases increases with age and in an ageing population such as that of Europe most mortality occurs at old age, it may be best to exclude deaths above the age of 85 or 90. For these oldest-old only all-cause mortality should therefore be modelled. But also other age-groups should perhaps be modelled separately, for instance, infant mortality, ages 1-24 , 25-64, 65-84, as the models include exogenous variables and a variable will not have the same association with each age, e.g. unemployment has little relevance for the non-working age population, or the meaning of the association changes with age, e.g. industrial employment for infant mortality may be an indicator the parental socioeconomic context, while for adults this may indicate their own socioeconomic context. Finally, while the theoretically basis of integrating non-demographic factors in mortality models is discussed at greater length in the original PhD thesis (Spijker, 2004), one aspect that should be elaborated more on in future is the link between the observed and predicted cause-specific mortality trends with the corresponding trends of the relevant independent variables.

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