J. of Population Studies
18 : 99-114, 1997, Population
Studies Center, NTU.

Modelling the Relationship between Cause-of-death Structure and Overall Mortality: The Case of Mauritius

Sulaiman M. Bah*

(ABSTRACT)

This paper aims to model the relationship between cause of death structure and overall mortality in the Island of Mauritius. The study period extends over an 18 year period from 1969 to 1986 and ten groups of causes of death were studied. During this period, Mauritian mortality for both males and females, underwent a transition from predominance of infectious diseases to that of degenerative diseases. Three models were fitted to the male and female data, a linear model, a curvilinear model and a multiple linear model which incorporates the concept of Epidemiologic Transition. It was found that the linear model fitted female data very well while the multiple linear model fitted male data quite well. The curvilinear model generally did not perform well on either the male or female data. From these findings, the paper concludes that in the indirect estimation of cause-of-death structure, information on overall mortality alone will not suffice, supplementary information on the Epidemiologic Transition is needed especially where the mortality pattern is undergoing a rapid change.

Key Words: causes of death, epidemiologic transition, cause-of-death structure, linear model, curvilinear model, indirect estimation

* Professional Associate, Population Studies Center, Univ. of Western Ontario, Canada and Lecturer, Dept. of Statistics and Demography, Univ. of Swaziland, Swaziland.

人口學刊第18期
頁99-114，民國86年6月
台北：台大人口研究中心

死亡結構導因與死亡率之關連模型：以模理西斯爲例

Sulaiman M. Bah*

（中文摘要）

本文目的在於建立一個死亡結構導因與整體死亡率關連的模型，研究跨越1969至1986共十八年，以及考慮十類死亡導因於研究中。由於在該期間模理西斯的人口死亡導因由傳染疾病爲主轉變爲非傳染性疾病爲主的情形，作者乃建立三種流行病轉型有關之模型（線性、曲線、多重線性），來分析死亡結構。作者發現線性模型之於女性資料以及多重線性模型對於男性資料的適合情形較強；因而建議未來研究，在間接推估死亡結構導因時，光採用整體之死亡率是不足的，應輔以流行病移轉資訊，這種方法對於分析死亡型態快速變遷的地區更爲有用。

關鍵字：曲線模型，死亡導因，流行病的轉型，間接推估，線性模型

* Professional Associate, Population Studies Center, Univ. of Western Ontario, Canada and Lecturer, Dept. of Statistics and Demography, Univ. of Swaziland, Swaziland.

J. of Population Studies
18 : 99-114, 1997, Population
Studies Center, NTU.

Modelling the Relationship between Cause-of-death Structure and Overall Mortality: The Case of Mauritius

Sulaiman M. Bah*

Introduction

The indirect estimation of cause-of-death structure has received renewed interest in the works of WHO and that of the World Bank (Bulatao, 1993; Murray and Lopez, 1994). The estimates are used independently and as input data for other decision-making models in the health sector. The theoretical framework underlying these estimates is the modelling of the relationship between cause-of-death structure and overall mortality. Hence, the importance of this area of research cannot be underestimated. While the relationship has been studied using data from Developed countries there has been little on conducting similar studies using data from Developing countries. Understandably, this is mostly due to the lack, or inadequacy, of data on causes of death. The study of Palloni and Wyrick (1981) is one of the few studies done on exploring this relationship using data from Developing countries. In their study, they used Latin American data covering the period 1950-1975. They observed a cause-of-death structure made up of very high proportion of diarrhoea and to a lesser extent, of respiratory causes of death. However, over the period under study, they did not find any significant shifts in change in the cause-of-death structure.

Unlike many other African countries, cause-of-death data is readily available in Mauritius and its quality is reputably very good. In one study on the trends in cause-of-death structure of Mauritius, it was found that significant shifts in cause-of-death structure did take place over the 1970s and 1980s. The changes in cause-of-death structure was summarized as follows:

* Professional Associate, Population Studies Center, Univ. of Western Ontario, Canada and Lecturer, Dept. of Statistics and Demography, Univ. of Swaziland, Swaziland.

> 'The trend in the age-standardized cause-specific death rates have shown that changes (took) place in both the magnitudes of the rates as well in their rankings. Few of the causes like diseases of the circulatory system, nutritional disorders and digestive system showed rise meanwhile others such as infectious diseases, respiratory diseases, and 'all others' showed decline. Yet others like neoplasms, external causes of injury and poisoning and congenital malformations did not show any much change.' (Bah, 1992:151)

This paper however, seeks to go beyond describing change in cause-of-death structure and looks at the relationship between cause-of-death structure and overall mortality in Mauritius.

It is obvious that when all the specific causes-of-death rates are added up, they do sum up to the overall death rate. That in itself does not deter modelling the trend of a specific group of causes of death and that of overall mortality. As it turns out, the outcome cannot always be predicted since the different causes of death exhibit different trends, sometimes quite different from that of the overall mortality. It is the trend of the predominant cause-of-death that will determine the trend of overall mortality irrespective of the trends of the other causes of death. If the cause of death structure changes slowly over time, then a linear model will be able to capture the relationship of the trend in a specific cause of death and that of overall mortality. This has been proven true in the work of Preston and Nelson and reiterated in the other subsequent studies on cause-of-death structure. However, when the cause-of-death structure is changing fairly rapidly, this linear model can hardly be adequate to capture such changes.

Method and Material

The data used for the analysis is based on information from censuses and from vital statistics on causes of death in Mauritius. The period under study is from 1969 to 1986. The Island of Mauritius is well known for its high quality censuses and vital statistics (UNFPA, 1982). These vital statistics are submitted to the WHO data bank in Geneva from which the data set used in this study was obtained. The causes of death in that data base were classified according to the eighth and ninth revisions of the international classification of diseases (ICD-8 and ICD-9 respectively). The

International Classification of Diseases include codes for more than 1000 different causes of death. It would be very impractical to analyse each of these individual causes separately. The feasible solution is therefore to group these causes into a manageable number of broad categories. Fortunately, the WHO itself has grouped the causes into seventeen broad categories (or chapters). The grouping of the WHO manifest classification using both the aetiological and the anatomical axes. Because of small cell sizes, some of the seventeen broad categories needed to be collapsed further. In the analysis of causes of death by Preston and Nelson (1974), 11 broad groups were used; in the work of Palloni and Wyrick (1981), 14 broad groups were used and in the analysis by Hakulinen et al. (1986), 7 broad groups were used. Following such precedence, in this work, 10 broad groups are used. Eight WHO categories were accepted as they were, two WHO categories were collapsed into one and all the rest were grouped under the residual, 'Others and unknown.' The final list and their equivalent codes in ICD-8 and ICD-9 are given in Table 1. The re-grouping of these causes of death also help to minimize the problems of incomparability in the two revisions.

The ages of death are conventionally grouped in five year age groups (the exception being that of the age groups 0-1,1-4 and the last open interval). For the same reason of cell size, it is again impractical to perform analysis for each of the 17,18 or 19 age-groups (depending on which age is used as the last open interval). In addition, some causes of death are only restricted to specific age groups. A feasible solution here is using age-standardization. The standardization also has the advantage of removing the effect of changes in age-structure which is very desirable for analysis over a long period. This practice has also been adhered to in all the major studies on cause -of-death structure.

In this study, the standard population used to obtain the standardised rates was the average of the total census population for 1972 and 1983. Such a population was found to be ideal since the study period extended from 1969 to 1986.

For each of these eleven groups of causes, the age-standardised cause-specific death rate is computed separately for gender for each year. The age-standardised cause-specific death rate Mi is defined as:

$$M_i = \sum_{J=1}^{N} C_J^S \cdot M_{ij} \qquad (1)$$

Table 1

Causes of death categories used in the analysis, their abbreviations and their codes in the ICD-8 and ICD-9 lists

Category	Abbreviation used	Codes in the ICD-8 A-List (1965)	Codes in the ICD-9 Basic Tabulation List (1975)
1. All Causes	ALLC	A1-AE150	01-E56
2. Infectious and Parasitic Diseases	INF	A1-A44	01-07; 2% of Remainder of 34; 320-323
3. Neoplasms	NEO	A45-A61	08-17
4. Endocrine and Nutritional Disorders	NU	A62-66	18-19
5. Diseases of the Circulatory System	CIR	A80- A88	25-30
6. Diseases of the Respiratory	RES	A89, A94-96	31-32
7. Diseases of the Digestive System	DIG	A97-104	33-34
8. Complications Due to Pregnancy, Childbirth and Puerperium	PRG	A112-118	38-39; 41
9. Congenital Malformation and Diseases of Infancy	CON	A126-135	44-45
10. External Causes of Injury and Poisoning	INJ	AE138-AE150	E47-E56
11. Others and Unknown	OTH	All the rest	All the rest

Sources: W.H.O. (1967, 1977); Hakulinen et al. (1986) Table 1.

where

c_j^s is the proportion of the standard population in the j^{th} age interval
M_{ij} is the age-cause-specific death rate in the j^{th} age interval for the ith cause of the death.

Following the precedence of Preston and Nelson (1974) (which has been replicated in other works such as those of Lopez and Hull (1983), Hakulinen et al. (1986) and Bulatao (1993)) two models were initially used in studying the relationship of cause-of-death structure to overall mortality; a linear model given as:

$$M_i = a_i + b_i M \tag{2}$$

a curvilinear model given as:

$$M_i = a_i + b_i M + C_i M^2 \tag{3}$$

where,

M_i represents standardized cause of death rate for cause i,

M represents standardized cause of death rate for overall mortality

and a_i, b_i and c_i are regression coefficents.

These two equations only relate overall mortality to cause-specific mortality. Recently, Bah (1995) had suggested that the epidemiological transition experienced in a country should be included in the modelling of overall mortality and cause-specific mortality. Earlier, Hakulinen et al. (1986) had suggested that in the indirect estimation of cause-of-death structure from overall mortality for specific countries, supplementary appraisal of epidemiological and other health-related data would be necessary. In line with such thinking, a third model was fitted.

This model is given as:

$$M_i = a_i + b_i M + C_i ET \tag{4}$$

where,

ET is a dummy variable representing the stage in epidemiologic transition, 1 represents the transition phase from the second to the third stage and 0 otherwise (in the third stage of the epidemiologic transition).

In the earlier mentioned study on mortality decline in Latin America, a dummy

variable for time period (representing change in cause of death structure) was also employed. Its use was defended as follows:

> "Clearly, the most adequate cutting point to study changes in the structure of causes of death is some year within a period during which the mortality transition changed pace." (Palloni and Wyrick, 1981: 196).

In the case of Mauritius, its epidemiolgic and health transition has been described by Bah (1992). In that study, it was argued that in Mauritius, the change from the second to the third stage had taken place in the early 1970's, from about 1969 to 197 5 (with very slight difference for males and females). As such, ET was coded 1 for the period 1969-1974 for males (for females from 1969 to 1975) and coded 0 afterwards. The results of fitting model 1 (the linear model) is shown in Table 2.

From the table it can be seen that the linear model fits the female data better than that of males. For females, after fitting the regression model on each of the 10 causes of death, the r^2 and b_i values were found to be significant in 7 of them (5 at $p<.01$ and 2 at $p<.5$) . The causes of death found to be significant at the 1% level were: Infectious and parasitic diseases (INF), diseases of the circulatory system (CIR), diseases of the respiratory system (RES), complications due to pregnanacy, childbirth and the puerperium (PRG) and 'others and unknown' (OTH). The causes of death found to be significant at the 5% level were: Diseases of the digestive system (DIG) and Congenital malformations and diseases of infancy (CONG). With the exception of CIR, the b_i values for all the other significant causes of death were positive indicating that the trend in these causes (a declining one) was in the same direction as that of overall mortality. On the other hand, CIR showed rise over the study period. The causes which did not prove significant are: Neoplasms (NEO), Endocrine and nutritional disorders (NU) and External causes of injury and poisoning (INJ). Not surprisingly, these causes of death have already been shown to exhibit fluctuations in their trends (Bah, 1992).

For males, the linear model did not fit quite well. The causes of death which were found to be significant at the 1% level were RES, INJ and OTH while INF proved to be significant at the 5% level. With the exception of INJ, the r^2 values for all the causes were much lower than corresponding values for females. The b_i values for these

Table 2

Coefficients of correlation between standardized death rates from all causes and from each cause, Mauritius, 1969-86

Causes of death	Parameters of the simple linear equation of the form $M_i = a_i + b_i M$ (Standard error of b_i in parentheses)					
	Males			Females		
	a_i	b_i	r^2	a_i	b_i	r^2
1. INF	-.001185	.307040* (.129843)	.259*	-.002074	.540759** (.034373)	.939**
2. NEO	.000411	.015626 (.019322)	.039	.000442	-.00315 (.011049)	.005
3. NU	.000201	.009739 (.027694)	.008	.000356	-.010411 (.021762)	.014
4. CIR	.003292	.005242 (.178080)	.000	.003046	-.199568** (.034107)	.682**
5. RES	-.000079	.030814** (.010304)	.359*	-.000118	.041581** (.006894)	.695**
6. DIG	.000409	.003917	.001	.000069	.012917*	.252*
7. PRG	-------	--------	----	-.000075	.022538** (.003090)	.769**
8. CONG	.000580	-.011193 (.019210)	.021	.000190	.028195* (.011441)	.275*
9. INJ	.000106	.058968** (.019555)	.362**	.000298	-.004574 (.007077)	.025
10. OTH	-.003816	.587617** (.098681)	.689**	-.002136	.571737** (.045918)	.906**

*: $p < .05$, **: $p < .01$

causes were all positive showing a general decline with the decline in overall mortality. All other causes of death proved to be insignificant.

In other to improve on the linear model, especially for males, a curvilinear model was fitted to the same data. The results are shown in Table 3.

This second model did not seem to have improved the fit for males. For two causes of death, RES and INJ, the p values actually reduced from 1% level to 5% level while for INF the p value showed improvement from 5% level to 1% level. OTH retained its significance at 1% level under both models. Beside these four causes of death which were already significant in the first model, only one cause of death became significant which was not significant before and that was NU. The r^2 value for this cause of death increased significantly from .008 to .531. In the curvilinear model, both the b_i and c_i values for NU were significant at 1% level. As has been mentioned earlier, the trend for this cause of death was a non-linear one. For females, all the causes of death in the linear model retained their significance in the curvilinear model with the exception of DIG which lost its significance.

To further improve on the linear or curvilinear model, the Epidemiological Transition concept was incorporated and the resulting multiple linear model was run. The results are shown in Table 4.

The table shows marked improvement on the male data. The causes of death with significant r^2 values increased in number from 5 under the curvilnear model to 8 under the present model. INF and OTH still remained highly significant but now with much higher values of r^2 at .922 and .855 respectively. INF now appears positively highly significant and CIR negatively highly significant. CIR, DIG and INJ proved to be highly negatively significant while NU and CONG show slight significance at the 5% level. For females, this third model does not show much improvement over either the first or second model. In fact CONG which was significant in the curvilinear model even became insignificant.

Discussion

From the results it can be seen that model 1 fitted the female data best while

Table 3

Coefficients of correlation between standardized death rates from all causes and from each cause, Mauritius, 1969-86

Causes of death	Parameters of the curvilinear equation of the form, $Mi = a_i + b_i M + c_i M^2$ (Standard error of b_i and c_i in parentheses)							
	Males				Females			
	a_i	b_i	c_i	r^2	a_i	b_i	c_i	r^2
1. INF	-.025570	5.606851* (2.227145)	-285.036682* (119.623629)	.462**	.002487	-1.001182* (.395517)	127.002816** (32.511897)	.970**
2. NEO	.001104	-.134990 (.387161)	8.100510 (20.795056)	.049	.000918	-.1640961 (.175697)	3.256414 (14.442479)	.058
3. NU	.007410	-1.557090** (.383351)	84.267867** (20.590408)	.531**	-.000728	.356089 (.342777)	-30.186978 (28.176608)	.084
4. CIR	.026424	-5.022374 (3.342472)	270.3974 (179.529712)	.131	.005491	-1.026310 (.514731)	68.093653 (42.311416)	.728**
5. RES	-.00037	2.094554 (.206851)	-3.428068 (11.110320)	.363*	-.000606	.206531 (.104278)	-13.586191 (8.571760)	.738**
6. DIG	.004053	-.788107 (.523477)	42.597021 (28.116832)	.134	.002985	-.064730 (.088646)	6.395389 (7.286746)	.289
7. PRG	----	-----	------	---	-.0002176	.070644 (.048947)	-3.962268 (4.023506)	.783**
8. CONG	.000073	.098870 (.385822)	-5.919503 (20.723126)	.026	.001005	-.247357 (.172848)	22.696009 (14.208268)	.381*
9. INJ	.002768	-.519582 (.364298)	31.115844 (19.567045)	.454*	.000155	.043601 (.114982)	-3.968021 (9.451596)	.037
10. OTH	-.016090	3.255199 (1.863813)	-143.469072 (100.108480)	.727**	-.0088352	.836465** (.468874)	-186.53560** (38.541904)	.963**

*: $p < .05$, **: $p \leq .01$

Table 4

Coefficients of correlation between standardized death rates from all causes and from each cause, Mauritius, 1969-86

Causes of death	Parameters of the multiple linear equation of the form $M_i = a_i + b_i M + c_i ET$ (Standard error of b_i and c_i in parentheses)							
	Males				Females			
	a_i	b_i	c_i	r^2	a_i	b_i	c_i	r^2
1. INF	-.001044	.258909** (.043742)	.098668** (.008744)	.922**	-.001367	.402684** (.061484)	.044183* (.017243)	.958**
2. NEO	.000404	.018110 (.018941)	-.005093 (.003786)	.143	.000484	-.011512 (.023568)	.002676 (.006610)	.016
3. NU	.000183	.015933 (.023599)	-.012698* (.004717)	.331*	.000053	.048783 (.043293)	-.018942 (.012141)	.152
4. CIR	.003115	.065440 (.093507)	-.123406** (.018692)	.744**	.002957	-.182298* (.072972)	-.005532 (.020465)	.683**
5. RES-	.000075	.029447* (.010061)	.002804 (.002011)	.432*	-.000064	.031082* (.014459)	.003360 (.004055)	.708**
6. DIG	.000382	.012849 (.016724)	-.018309** (.003343)	.667**	.000034	.019636 (.011763)	-.002150 (.003299)	.273
7. PRG	----	-----	-----	---	-.000099	.027240** (.006482)	-.001505 (.001818)	.779**
8. CONG	.000592	-.015429 (.016481)	.008683* (.003294)	.331*	.000190	.028219 (.024537)	-.000008 (.006881)	.275
9. INJ	.000094	.062898** (.017422)	-.008056* (.003483)	.530**	.000341	-.013034 (.014972)	.002707 (.004199)	.052
10. OTH	-.003733	.559348** (.069885)	.057951** (.013970)	.855**	-.002544	.651383** (.095646)	-.025486 (.026824)	.912**

*: $p < .05$, **: $p < .01$

model 3 fitted the male data best. This finding is in line with previous research on the epidemiological transition experienced in Mauritius. During the transition from the second to the third stage, certain causes of death like INF, decline in magnitude while others like CIR increase in magnitude. The relative difference between these two opposing trends is what determines the direction of overall mortality. In the early 1970's when Mauritius was undergoing transtion from the second to the third stage, two different scenarios arose. For females, declining trend was greater than the rising trend while for males the opposite was true. In other words, the effect of the transition was more adverse for males than for females. For this reason, linear model fitted the female data very well while the epidemiologic transition model fitted the male data best. Notwithstanding that males and females were undergoing the transition at about the same period, the fact that the effect of the transition was far stronger in males than in females means that the linear model could not fit the data for both sexes.

The main application of this research is in the studies of the indirect estimation of cause- of-death structure. Most of these studies are based on model 1 and to a less extent on model 2. First, the research has shown that there is need for model 3 especially in situations where the effects of the epidemiologic transition were profound. Second, model 1 does not fit in all situations. The common procedure adopted in the indirect estimation of cause-of-death structure is to run model 1 on countries whose data is available then use the regression coefficients to derive estimates of cause-of-death structure for other countries using information on overall mortality (and in some cases broken down by sex and broad age groups). As long as these methods fail to incorporate the epidemiological experiences in the modelling process, the exercise will fall short of achieving its aim. In addition to the above remarks, Bah (1995) cautioned that these kinds of regression models in general will not be much applicable in countries where 'counter-transitions' are being experienced. This is a result of the uniform decline embodied in the regression model which cannot capture rises which follow declines.

Conclusion

This paper aimed to model the relationship between cause-of-death structure and

overall mortality in the Island of Mauritius. During the period under study, Mauritian mortality for both males and females, underwent a transition from predominance of infectious diseases to that of degenerative diseases. Three models were fitted to the male and female data; a linear model, a curvilinear model and a multiple linear model which incorporates the concept of Epidemiologic Transition. It was found that the linear model fitted female data very well while the multiple linear model fitted male data quite well. The curvilinear model generally did not perform well on either the male or female data.

The purpose of the paper is not to obtain coefficients that can be used for the indirect estimation of cause-of-death structure. For that purpose, a much larger data base covering several countries will be needed. The purpose of the paper is to show that supplementary epidemiological information is indeed needed, in addition to information on overall mortality. It was Lopez and Hull (1983) who first mentioned the need for supplementary epidemiological information to be used in conjuction with the regression methodology. This was reiterated by Hakulinen et al. (1986). It was Bah (1995) who wrote a critique of the regression methodology in the light of contemporary theories of mortality and causes of death. In that paper, he specified that the stage in the epidemiological transition theory needed to be taken into account in employing this regression methodology. The contribution of this present paper is to illustrate how this is done and to lend further support on the proposition of Bah (1995).

Notwithstanding the above remarks, the coefficients obtained in this paper could be of some use to some small Asian or Latin American countries provided that they are also fairly advanced in their epidemiological transition. In order to obtain the rate for specific causes, the standardized rates for overall mortality need to be computed and substituted in the regression equation. To put it simply, if the age structure of the country in question does not differ much from that of Mauritius, its overall crude death rate could be used since it is a form of standardized rate (with the population of the country in question being used as the standard rather than that of Mauritius). As a rule of thumb, if the life expectancy at birth is between 50 and 69 years the country could be said to be in the second stage. If the life expectancy is between 70 and 75 years, it could be said to be in the third stage.

In conclusion, the paper has argued that in the indirect estimation of cause-of-death structure, information on overall mortality alone will not suffice, supplementary information on the Epidemiologic Transition is needed especially where the mortality pattern is undergoing fairly rapid changes.

Acknowledgement

I am grateful to the WHO for providing the data on causes of death and population of Mauritius that was used in this analysis. I am also grateful to anonymous reviewers who made useful comments on an earlier draft.

References

Bah, S.M

1992 "Epidemiologic and Health Transition in Mauritius." *Journal of Population Studies* 15: 137-159.

1994 "The Influence of Cause-of-death Structure on Age Patterns on Mortality in Maurtius." *Social Biology* 41(3-4): 212-228.

1995 "Estimation of Cause-of-death Structure in Africa and Contemporary Theories of Mortality." *Social Biology* 42: 3-4.

Bulatao, R.

1993 "Mortality by Cause, 1970-2015." In: *The Epidemiological Transition: Policy and Planning Implications for Developing Countries.* Edited by J. Gribble and S. Preston. National Academy Press , Washington D.C.

Hakulinen T. et al.

1986 "Estimation of Global Mortality Pattern by Cause of Death." In Hansluwka, H. et al.(eds.). *New Developments in the Analysis of Morality and Causes of Death.* Amarin Press, Bangkok.

Lopez, A. D. and Hull, T.H.

1983 "A Note on Estimating the Cause-of-death Structure in High Mortality Populations." *Population Bulletin of the United Nations* No.14: 1982.

Murray, C. and Lopez, A.

1994 "Global and Regional Causes-of-death Patterns in 1990." *Bulletin of the World Health Organization.* 72: 447-480.

Omran, A.

1971 "The Epidemiological Transition." *Milbank Memorial Quarterly Fund.* 49: 509-538.

Palloni, A. and Wyrick, R.

1981 "Mortality Decline in Latin America: Changesin the Structure of Causes-of-death, 1950-1975." *Social Biology* 28(3-4): 187-216.

Preston, S. H. and Nelson, V.E.

1974 "Structure and Change in Causes-of-death: An International Summary." *Population Studies* 28,1:19-51.

Preston, S.H.

1976 *Mortality Pattern in National Populations, with Special Reference to Recorded Causes of Death.* Academic Press, New York.

W.H.O.

1967 *International Classification of Diseases.* W.H.O, Geneva.

W.H.O.

1977 *International Classification of Diseases.* W.H.O, Geneva.

UNFPA

1982 *Population Policy Compendium, Mauritius.* United Nations, New York.