Marital Status as a Risk Factor in Life Insurance:
An Empirical Study in Taiwan

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Abstract

Gender and age are the top two risk factors considered in pricing life insurance products. Although it is believed that mortality rates are also related to other factors (e.g., smoking, overweight, and especially marriage), data availability and marketing often limit the possibility of including them. Many studies have shown that married people (particularly men) benefit from the marriage, and generally have lower mortality rates than unmarried people. However, most of these studies used data from a population sample; their results might not apply to the whole population. In this study, we explore if mortality rates differ by marital status using mortality data (1975–2011) from the Taiwan Ministry of the Interior.

In order to deal with the problem of small sample sizes in some marital status groups, we use graduation methods to reduce fluctuations in mortality rates. We also use a relational approach to model mortality rates by marital status, and then compare the proposed model with some popular stochastic mortality models. Based on computer simulation, we find that the proposed smoothing methods can reduce fluctuations in mortality estimates between ages, and the relational mortality model has smaller errors in predicting mortality rates by marital status. Analyses of the mortality data from Taiwan show that mortality rates differ significantly by marital

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status. In some age groups, the differences in mortality rates are larger between marital status groups than between smokers and non-smokers. For the issue of practical consideration, we suggest modifications to include marital status in pricing of life insurance products.

Key Words: Marital Status, Risk Factor, Small Area Estimation, Longevity Risk, Relational Mortality Model

1. Introduction

The premiums of life and health insurance policies are determined according to the risk class of the insured. In general, the elderly and males are charged with higher premiums. In addition, smoking, obesity, and high blood pressure, among other health conditions, are often causes for higher insurance rates. However, in practice, the insured do not necessarily pay more even though they are in higher risk classes, and the insurer needs to consider competition between other companies. For example, many companies in the U.S. use nicotine to classify people into preferred, standard, and substandard statuses. This is not done in Taiwan.

In Taiwan, the premium rates of most policies depend only on age and gender. Taiwanese people are underinsured and the average benefit amount is approximately $17,000 USD (Yue and Huang, 2011), compared to the per capita GDP $20,000 USD in 2011[4]. Partly due to the low benefit amount, less than 10% of policies require health exams. Therefore, it is not easy to classify the insured's risk since there are no ways to obtain results of health exams. Difficulty in verifying the information on application forms is another reason. For example, although many health insurance applications in Taiwan ask the applicants if they are currently smoking, at least 25% do not answer the question honestly according to some insurers (Schwaiger, 2005).

Despite difficulty in acquiring health-related data from the applicants, insurers can still collect valuable information without having to access medical records. Taiwan has had a population register system for more than 100 years, in which information is continuously recorded for all residents of the country[5]. Taiwan's population register system contains useful information, such as the marital status and marital history of each individual. In this study, we shall evaluate if it is feasible to

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[4] Data Source: Ministry of Economic Affairs, Taiwan   http://twbusiness.nat.gov.tw/old/pdf/sec9.pdf

[5] Data Source: United Nations Statistics Division
  http://unstats.un.org/unsd/demographic/sources/popreg/popregmethods.htm

design preferred status insurance products according to marital status using mortality data (1975–2011) from the Taiwan Ministry of the Interior.

The relationship between marriage and life expectancy is well known: The married tend to live longer than the unmarried (single, divorced, and widowed), and also have lower mortality rates (Trowbridge, 1994; Hu and Goldman, 1990; Lillard and Panis, 1996; Yue, 1998). In addition to living longer, it is believed that married couples achieve a stable life and good physical and mental condition through the division of labor; thus, the marriage also plays a role in health protection (Gardner and Oswald 2004, Martikainen et al. 2005, and Van den Berg and Gupta 2008). However, most studies have used data from a population sample; their results might not apply to the whole population.

In this study, we use Taiwan population data provided by the Ministry of the Interior to explore if married people have lower mortality rates than unmarried people. The data are from 1975–2011, sorted into 5-age groups between ages 0 and 99, and divided into three marital statuses: single, married, and divorced/widowed. However, the marital status groups differ considerably by age, and some age groups are very small in number. For example, only 1% of females ages 15–19 are married, and the population size is less than 5,000. Thus, we propose graduation methods and small area life table techniques to reduce fluctuations in age-specific mortality rates for different marital statuses.

In addition, we use the relational approach proposed by Wang and Yue (2011) to model mortality rates by marital status. For computational simplicity, we apply block bootstrap to the proposed model for mortality prediction, and then compare it with some popular stochastic mortality models. We use computer simulation to evaluate the proposed approach.

The Taiwan marital data will be introduced in Section 2, together with the

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graduation methods (especially for small areas) for the mortality rates by marital status and the mortality models. In Section 3, a simulation study of graduation methods is provided first, and then a feasible method is applied to the empirical analysis of mortality rates by marital status. The differences in age-specific mortality rates and life expectancy between marital statuses are also calculated. In Section 4, the proposed mortality approach is applied to model mortality rates by marital status. The results are compared with popular mortality models, such as the Lee-Carter model (1992), Renshaw-Haberman model (2006), and the Cairns-Blake-Dowd model (2006). The final section contains discussions about the study of marital mortality rates and the practical issue of whether marital status can be treated as a risk factor in life insurance products.

2. Data and Methodology

Taiwan marital data can be downloaded from the Taiwan Ministry of the Interior[6]. Table 1 lists the age ranges of population and death records by marital status since 1973, including the lowest and highest ages recorded.

Table 1. Taiwan's Population and Death Records with Respect to Marital Status

Year	Population (Unit: age)	Deaths (Unit: age)
1973–1974	15–50+	N/A
1975–1991	15–50+	15–85+
1992–1993	15–50+	15–95+
1994–1997	15–100+	15–95+
1998–2011	15–100+	15–100+

Because detailed mortality records are only available from 1994 on, we compare

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[6] There are four types of marital status: 1) currently married, and the unmarried, which includes persons who are 2) single (never married), 3) widowed, or 4) divorced. Due to small sample sizes, we combined the divorced and widowed into a single group called divorced/widowed.

mortality rates for Taiwanese females between the periods of 1994–96 and 2009–11 as a demonstration. The mortality rates by marital status in 1994–96 and 2009–11 are shown in the left and right panels of Figure 1, respectively. Mortality rates of the divorced/widowed are the highest, and are significantly different than the other two groups in 1994–96, but overlap with those of the single around ages 45–85 in 2009–11. Similarly, mortality rates of the married overlap with those of the single ages 60 and over in 1994–96, but are significantly lower than those of the single in 2009–11 (except for ages 15–25). Single persons seem to have the smallest mortality improvement among the three marital statuses. Some of the single age groups did not experience any improvement from 1994–96 to 2009–11.
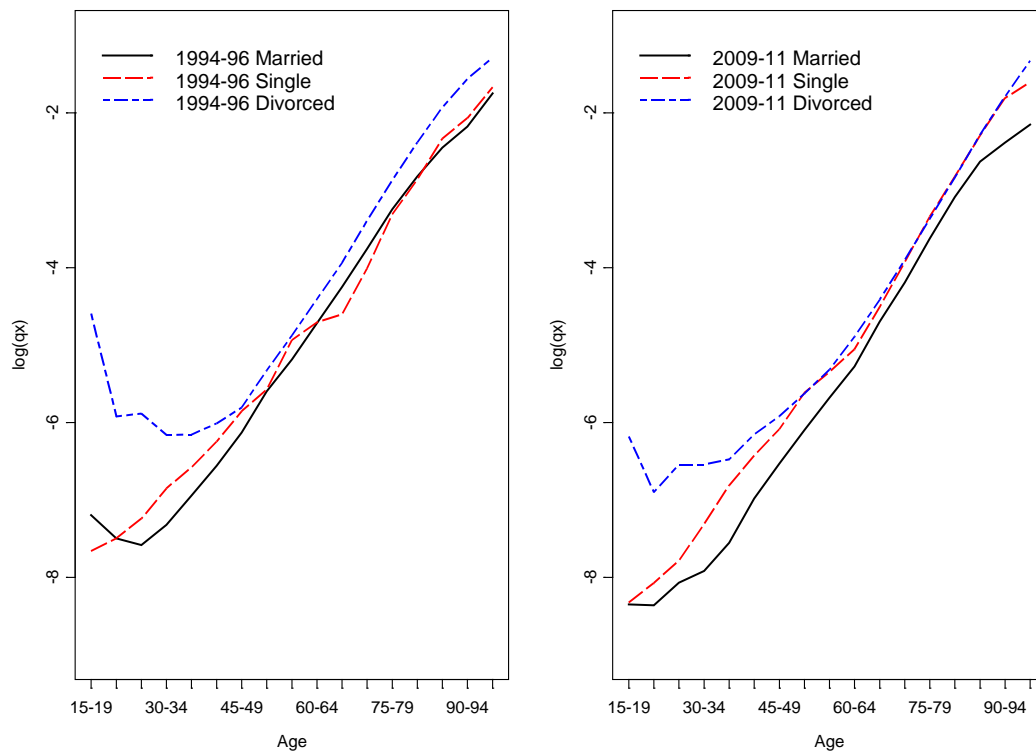

Figure 1. Female Mortality Rates by Marital Status (1994–96 and 2009–11)

Note that marital status varied considerably across age groups. For example, less

than 5% of females ages 20–24 are married in 2011 compared with 70% of females ages 40–44. As a result, the population sizes of each marital status group also vary, and this creates variations in smoothing age-specific mortality rates. Thus, we propose two graduation methods to reduce fluctuations caused by small population sizes: Whittaker Ratio and Partial Standard Mortality Ratio (SMR). The Whittaker Ratio is extended from the Whittaker graduation method (London, 1985), which is to minimize

$$\mathrm{M} = \mathrm{F} + hS = \sum_{x=1}^{n} w_x (v_x - u_x)^2 + h\sum_{x=1}^{n-z} (\Delta^z v_x)^2 , \qquad (1)$$

where u_x and v_x are observed and graduated mortality rates for age x, respectively; w_x is weighted number for age x; n is population size; and h and z are the parameters to be decided. In this study, we let h be the average population size of a single age and $z = 3$, as suggested in previous studies.

The graduated values via Whittaker method can be treated as a compensation between goodness of fit (i.e., retaining the information from observations) and smoothness. The parameter h is the weight, and a larger h indicates a smoother graduated value. The idea behind Whittaker graduation is very similar to the penalized likelihood estimation, choosing the quadratic roughness penalty as the smoothness function (Camarda, 2012). The Whittaker ratio is defined as the ratio of mortality rates between large and small populations.

The partial SMR (Lee, 2003) is a modification of SMR, which is used to smooth mortality rates of small areas using the information (with respect to SMR) from a large area. SMR is often used in epidemiology and is defined as

$$\mathrm{SMR} = \frac{\sum_x d_x}{\sum_x e_x} \qquad (2)$$

where d_x and e_x are the observed and expected numbers of deaths for age x, respectively. Therefore, an SMR greater than 1 or less than 1 indicates whether an area has a higher or lower overall mortality rate, respectively. This is why the SMR can be treated as a mortality index. If the size of a certain age group in the small area is small, the observed mortality rate would fluctuate considerably. The SMR can be used, however, to refine the mortality rate.

For the partial SMR, the graduated mortality rates satisfy

$$v_x = u_x^* \times \exp\left(\frac{d_x \times \hat{h}^2 \times \log(d_x/e_x) + (1 - d_x/\sum d_x) \times \log(\text{SMR})}{d_x \times \hat{h}^2 + (1 - d_x/\sum d_x)} \right), \qquad (3)$$

or the weighted average between raw mortality rates and SMR, where $\hat{h}^2$ is the estimate of parameter h^2 for measuring the heterogeneity (in mortality rates) between the small area and large area. u_x^* is the mortality rate for age x in a large area. To avoid unreasonable results, Lee suggests that

$$\hat{h}^2 = \max\left(\frac{\sum\left((d_x - e_x \times SMR)^2 - \sum d_x\right)}{SMR^2 \times \sum e_x^2} , \ 0 \right). \qquad (4)$$

The larger $\hat{h}^2$ is, the larger the difference in age-specific mortality rates (i.e., mortality heterogeneity, or larger dissimilarity in shape between the age-specific mortality curve of the small population and that of the larger population). When the number of deaths is smaller, there will be greater weight from the large area, and the graduated value equals $\text{SMR} \times u_x^*$ when the number of deaths is zero.

Graduation is one of the methods for constructing small area life tables. Most of the graduation methods, such as moving weighted average and Whittaker method, can be treated as different ways of increasing samples, or reducing the variations of

mortality rates based on the information from the small area. On the other hand, borrowing/combining mortality information with other populations is another way to reduce the variations of mortality rates in the small area. Many authors use two or more populations with similar mortality profiles, together with the choice of mortality models, to stabilize mortality estimates. For example, Dowd et al. (2011) and Jarner and Kryger (2011) proposed a gravity mortality model and the SAINT model, respectively, for two related but different-sized populations. Li and Lee (2005) and Zhou et al. (2013) modified the Lee-Carter model for modeling multiple populations. Cairns et al. (2011) applied the Age-Period-Cohort model combining Bayesian methods for the two populations. Partial SMR can be treated as one way of borrowing information from a large population.

We introduce the proposed mortality model, followed by frequently used mortality models. Wang and Yue (2011) proposed a relational model (RM) defined by

$$r_x(t) = \frac{p_{x+1}(t)}{p_x(t)} \quad , \tag{5}$$

where $p_x(t) = \frac{l_{x+1}(t)}{l_x(t)}$ and l_x are survival probability and the life table function, number of survivors for age x at time t. Wang and Yue suggested using the Brownian motion stochastic differential equations (BMSDE) and block bootstrap simulation to predict the values of $r_x(t)$.

In addition to the proposed mortality model, we also consider the Lee-Carter (LC) model (Lee and Carter, 1992), Renshaw-Haberman (RH) model (Renshaw and Haberman, 2006), and the Cairns-Blake-Dowd (CBD) model (Cairns et al., 2006). If m_{xt} denotes the central death rate for a person aged x at time t, the LC model assumes that

$$\log(m_{xt}) = \beta_x^{(1)} + \beta_x^{(2)} \kappa_t^{(2)} + \varepsilon_{x,t}, \tag{6}$$

with two constraints, $\sum_x \beta_x^{(2)} = 1$ and $\sum_t \kappa_t^{(2)} = 0$, and the parameter $\beta_x^{(1)}$ denotes the average age-specific mortality; $\kappa_t^{(2)}$ represents the general mortality level; and the decline in mortality at age x is captured by $\beta_x^{(2)}$. The mortality level $\kappa_t^{(2)}$ is usually a linear function in time. The term $\varepsilon_{x,t}$ denotes the deviation of the model from the observed log-central death rates and is assumed to be white noise, with 0 mean and relatively small variance. The parameters of LC model can be estimated via the singular value decomposition.

Since the residuals of fitting the LC model are not random (Debón et al., 2008), some studies suggest adding an extra time or cohort component to the LC model. The RH Model can be treated as a version of LC Model with an extra cohort component,

$$\ln(m_{xt}) = \beta_x^{(1)} + \beta_x^{(2)} \kappa_t^{(2)} + \beta_x^{(3)} \gamma_{t-x}^{(3)} \ , \tag{7}$$

where $\sum_x \beta_x^{(2)} = 1, \sum_t \kappa_t^{(2)} = 0, \sum_x \beta_x^{(3)} = 1, \sum_{x,t} \gamma_{t-x}^{(3)} = 0$, and the parameter $\beta_x^{(i)}$, $i = 1, 2, 3$ reflects the age-related effects; $\kappa_t^{(2)}$ reflects period-related effects and represents the general mortality level; $\gamma_{t-x}^{(3)}$ reflects cohort-related effects.

The CBD model is designed to model mortality rates for higher ages, and deal with the longevity risk in pensions and annuities. For the CBD model, it assumes that the mortality rates satisfy

$$\text{logit}\,(q_{xt}) = \log \frac{q_{xt}}{1 - q_{xt}} = \beta_x^{(1)} \kappa_t^{(1)} + \beta_x^{(2)} \kappa_t^{(2)} , \tag{8}$$

where the parameters are $\beta_x^{(i)}$ and $\kappa_t^{(i)}$; $i = 1, 2$ reflects age-related effects and the general mortality level. If we suppose $\beta_x^{(1)} = 1$ and $\beta_x^{(2)} = x - \bar{x}$, then the model has a simple parametric form as follows:

$$\text{logit}\,(q_{xt}) = \kappa_t^{(1)} + \kappa_t^{(2)}(x - \bar{x}) \,. \tag{9}$$

3. Marital Status Life Table

As previously mentioned, the population size of each marital status group varies by age. Thus, we need to look for feasible graduation methods to reduce the fluctuations in mortality rates. We use computer simulation to study if the graduation methods of interest (Whittaker, Whittaker Ratio, and Partial SMR) can reduce the variations of the ungraduated mortality rates. Let the large area be all of Taiwan (population size: approximately 23 million) and the small area be Pen-Hu county (population size: about 100,000). We use the male to demonstrate the effect of graduation. Since Pen-Hu county has only about 50,000 males, the number of elderly is small. Therefore, 17 age groups are considered in the simulation study: 0–4, 5–9, 10–14, …, 75–79, and $\geq$80. Note that the proportions of elderly males ($\geq$ age 65) and oldest-old males ($\geq$ age 85) in Pen-Hu county are 13.5% and 1.1%, both of which are slightly higher than those in Taiwan (10.0% and 0.8%, respectively).

Let q_x^s and q_x^B denote the mortality rates of the small area and large area, respectively. Suppose these two mortality rates satisfy $q_x^s = s_x \times q_x^B$ and there are 7 possible scenarios for the mortality ratio s_x as shown in Figure 2:

- $s_x = 0.8$
- $s_x = 1.0$
- $s_x = 1.2$
- s_x increases linearly with age
- s_x decreases linearly with age
- s_x decreases linearly first and then increases linearly (V-shape)
- s_x increases linearly first and then decreases linearly (reverse V-shape)

The first 3 scenarios are the cases where the SMR can provide good reference information from the large area to small area. The remaining 4 scenarios are designed to create discrepancy, and a single number of SMR will not be enough to provide sufficient information. We expect that graduation results using the partial SMR will be better for the first 3 scenarios but not as good for the remaining scenarios.
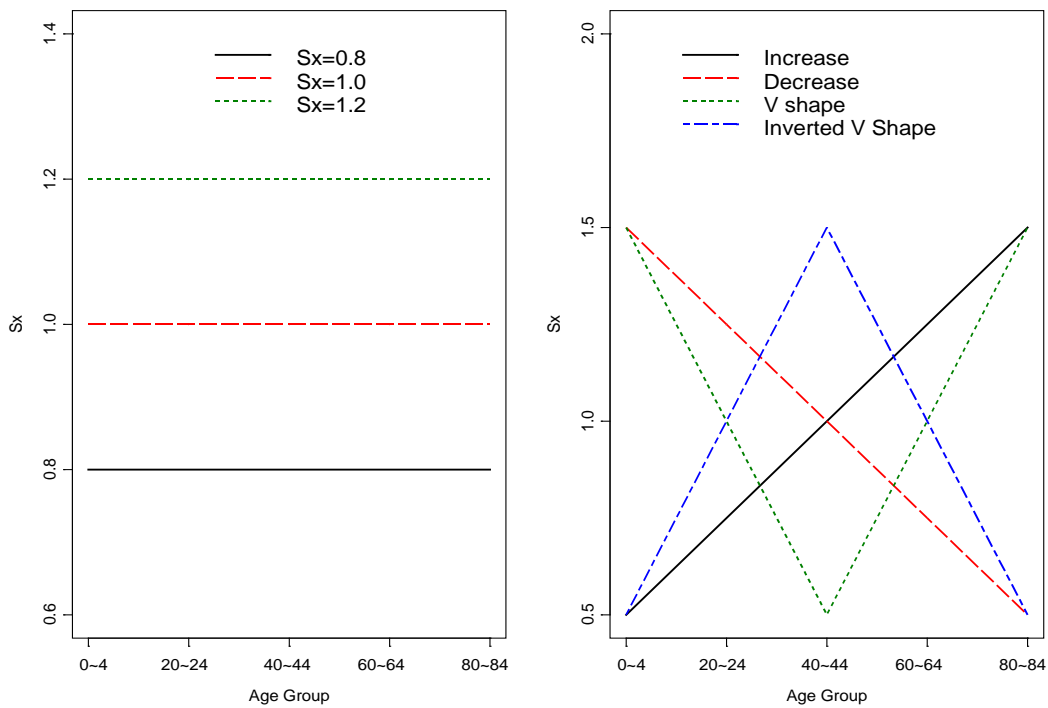

Figure 2. Seven Scenarios of Mortality Ratio s_x

We treat the male mortality rates of all of Taiwan, using the male populations of Taiwan and Pen-Hu as the true values to demonstrate the influence of sample size. Then, we generate numbers of deaths for Taiwan and Pen-Hu county, based on Poisson assumption, thereby producing simulated age-specific mortality rates for Taiwan and Pen-Hu county. Next, we apply three graduation methods to the simulated mortality rates and evaluate which method is the best. The evaluation criterion is the Mean Squared Error (MSE), or the squares of bias and variance of mortality estimate. Table

2 shows the MSE of applying graduation methods for 1,000 simulation runs.

Table 2. MSE of Different Graduation Methods

Unit: 10^{-5}

	80%	100%	120%	Increase	Decrease	V	Reverse V
Raw	5.66	7.05	8.54	9.73	4.73	8.83	5.15
Whittaker	3.52	4.71	6.06	8.06	2.33	8.32	2.75
Partial SMR	1.07	1.37	1.70	7.94	4.06	8.34	4.69
Whittaker Ratio	2.90	4.41	4.58	5.28	2.22	5.13	2.58

Note: The highlighted cells are those with the smallest MSE.

As expected, Table 2 shows that the partial SMR has the best graduation results for the first 3 scenarios; its MSEs are less than one-half of those using other graduation methods. For the remaining 4 scenarios, the Whittaker ratio is the best, and in some cases, the MSEs of partial SMR are larger than those of Whittaker. Nevertheless, application of the Whittaker method (or one of the other two methods) is always better than not using graduation. Note that, as shown in Figure 1, it is likely that mortality rates by marital status do not behave like the first 3 scenarios. Thus, we use the Whittaker ratio method to construct the life table by marital status.

We add another computer simulation to demonstrate that the sample size has a larger influence than age structure of the small area on the graduation of mortality rates. Specifically, we use the Taiwan marital data from 2012. Since the numbers of widowed and divorced in Taiwan are the smallest among the three marital statuses, we treat it as the small area (i.e., replacing Pen-Hu county). Similar to the simulation in Table 2, we use Poisson distribution to simulate the numbers of deaths in both the large area and small area for seven possible scenarios. The MSEs of 1,000 simulation runs are computed for cases of raw data and three graduation methods, as shown in Table 3. Again, compare to the raw data, Partial SMR and Whittaker Ratio have the smallest MSEs (or the largest reduction in MSE). Note that the population sizes of the

widowed/divorced are very small for younger ages (e.g., ages 15–19 and 20–24), and generated 0 deaths in the simulation. Thus, the MSE of Whittaker graduation is the largest. This suggests that the graduation methods should be applied with care.

Table 3. MSE of Different Graduation Methods, Marital Data

Unit: 10^{-3}

	80%	100%	120%	Increase	Decrease	V	Reverse V
Raw	2.14	2.56	3.04	1.88	2.97	4.13	1.51
Whittaker	3.23	4.46	5.97	5.08	4.01	5.45	4.65
Partial SMR	0.38	0.51	0.63	1.78	0.90	0.96	0.57
Whittaker Ratio	0.48	0.65	0.81	1.13	0.86	1.04	0.86

Note: The highlighted cells are those with the smallest MSE.

To construct the life table, we use the Whittaker method to graduate the mortality rates of Taiwan population and then apply the Whittaker ratio to marital mortality rates. We use the most recent available data (2009–2011) to construct life tables. Figure 3 shows the mortality ratios by marital status; it confirms that the Whittaker ratio is appropriate. Furthermore, since the exposures of the oldest-old group are not large, we apply the Gompertz law for the oldest-old and combine with the results of Whittaker graduation, with the highest age at 100[7]. In general, the married tend to have the lowest mortality rates, and the group of divorced and widowed have the highest.

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[7] This construction process is also recommended by the Ministry of the Interior, Taiwan government. http://www.moi.gov.tw/stat
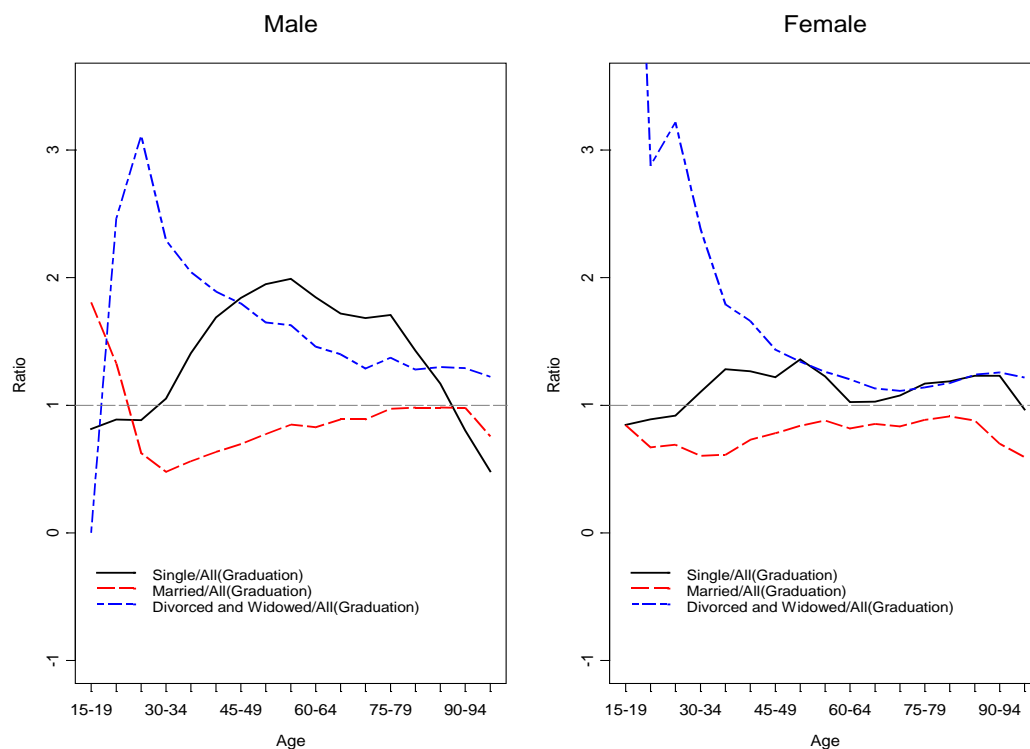
Figure 3. Mortality Ratios of Different Marital Statuses (2009–11)

Note: The ratio is each marital status divided by total population.

Table 4. Complete Life Expectancy of 2009–2011 Taiwan Marital Life Tables

2009-2011 Male Life Expectancy					2009-2011 Female Life Expectancy				
Age	Single	Married	D/W	Total	Age	Single	Married	D/W	Total
30	40.94	48.88	41.80	47.05	30	51.89	54.75	51.02	53.20
35	36.30	44.09	37.57	42.42	35	47.06	49.85	46.37	48.36
40	31.89	39.38	33.48	37.92	40	42.29	44.98	41.74	43.56
45	27.78	34.80	29.57	33.57	45	37.62	40.18	37.15	38.83
50	23.98	30.38	25.80	29.36	50	33.06	35.46	32.62	34.17
55	20.44	26.12	22.15	25.28	55	28.59	30.84	28.17	29.61
60	17.14	22.02	18.62	21.34	60	24.22	26.33	23.82	25.15
65	14.16	18.17	15.29	17.64	65	20.03	21.99	19.66	20.89
70	11.64	14.66	12.29	14.29	70	16.12	17.92	15.77	16.94
75	9.59	11.59	9.66	11.34	75	12.56	14.19	12.24	13.35
80	7.95	8.96	7.42	8.79	80	9.41	10.88	9.15	10.18

Note: D/W indicates the group of divorced and windowed.

Furthermore, we use life expectancy by marital status to demonstrate the

differences by marital status (Table 4). Since the marital data start at age 15 and the highest age for constructing life table is age 100, we only compare life expectancy for ages 30–80. The difference in life expectancy between married and single persons reach the largest value (almost 8 years) at age 30. This difference is very significant in pricing life insurance products. The difference is still noticeable for higher age groups -i.e., at age 65, there is a 4-year difference in life expectancy found between married and single men.

We compare differences in premiums for pricing life insurance products based on whether the insured is married, single, or divorced/widowed. For simplicity, we only compare the married and single. Premiums are for a 20-year payment whole life policy, with an interest rate of 2% or 5%, and highest attained age of 100. Although people can switch between different marital statuses, such as from single to married or from married to divorced, the results for each cell in Tables 5 and 6 are based on the assumption that the insured' marital status stays constant.

Pure premiums per $1,000 USD coverage are shown in Tables 5 and 6, along with the premium ratios, and ratios of married per total population. Similar to the results of life expectancy in Table 4, the married male receives a larger discount in premium than the single male. Premiums for the married males are discounted by about 34% at the 5% rate, and by 22% at the 2% rate. The discount rate is slightly less for the married female at about 16% and 7% for the two interest rates, respectively. Marital status is a significant factor when compared with premium discounts for nonsmokers (14% less than smokers) and persons of normal weight (22% less than obese persons)[8].

Table 5. Pure Premium of 20-Year Payment Whole Life (Interest Rate: 5%)

Age	Male				Female			
	Married	Single	Married/ Single	Married/ Total	Married	Single	Married/ Single	Married/ Total
30	9.73	14.84	0.66	0.88	6.98	8.31	0.84	0.90
35	12.13	18.49	0.66	0.89	8.76	10.36	0.85	0.91
40	15.08	22.72	0.66	0.91	10.99	12.85	0.86	0.91
45	18.64	27.57	0.68	0.93	13.73	15.86	0.87	0.92
50	22.95	33.32	0.69	0.94	17.13	19.56	0.88	0.92
55	28.36	40.59	0.70	0.95	21.39	24.25	0.88	0.93
60	35.48	50.32	0.71	0.95	26.88	30.48	0.88	0.93

Table 6. Pure Premium of 20-Year Payment Whole Life (Interest Rate: 2%)

Age	Male				Female			
	Married	Single	Married/ Single	Married/ Total	Married	Single	Married/ Single	Married/ Total
30	24.57	29.54	0.83	0.95	21.48	23.07	0.93	0.96
35	27.15	32.96	0.82	0.95	23.71	25.46	0.93	0.96
40	30.08	36.75	0.82	0.96	26.19	28.09	0.93	0.96
45	33.36	40.99	0.81	0.96	28.97	31.00	0.93	0.96
50	37.14	46.01	0.81	0.97	32.12	34.30	0.94	0.96
55	41.78	52.42	0.80	0.97	35.85	38.29	0.94	0.96
60	47.89	61.08	0.78	0.97	40.52	43.55	0.93	0.96

Given the results in Tables 5 and 6 and the average coverage of $17,000 USD, the largest premium discount is about $30 USD annually (male aged 60). Provided that the per capita GDP was $20,000 USD in 2011, there is still possible motivation for people to forge marriage. We suggest the insurers to ask the insured to provide proof of marriage annually (which can be seen from the population register) to prevent possible fraud. Because the premium difference is significant, this would penalize singles and reduce their motivation to purchase insurance products. We suggest giving premium discount only to the married people, not charging more for the single people, to avoid the possibility that only the married people purchase the insurance products. The

premium discount of the married status is based on the married over the total population.

4.   Modeling Mortality Rates by Marital Status

In the previous section, we report that the married have lower mortality rates than the unmarried, a statistic that may be used to differentiate premiums in life insurance products. Theoretically, the married are expected to receive discounts in premiums for life insurance products due to their low mortality; yet, longer lifespans mean that they are likely to pay more for annuities than unmarried persons. There are difficulties in charging lower or higher premiums based on marital status, with marketing being a particular challenge. It is quite subjective whether to charge more for certain risk factors, largely determined by each society's sense of fairness and the degree of difficulty of accessing data to identify the risk factors of interest. For example, smoking and obesity are treated as risk factors for life insurance in many U.S. states, but not in Taiwan or Asian countries, where it is difficult to verify these risk factors. In addition, marital data in Taiwan have only recently been made available, and not many countries have similar records. It is difficult to do an international comparison of mortality by marital status.

Another difficulty is changing attitudes toward marriage. For example, people in Taiwan now marry later in life than did previous generations. Before 1990, more than 70% of females aged 25–29 were married, but by 2011, only 20% of females in the same age group were married. The average age of first marriages in Taiwan for females is almost 30, and it is expected to increase in the near future. Even if we can assume that the future trend of marital mortality rates will be stable, the time period of data analyzed in this study is too short to use mortality models to predict the future.

Nonetheless, despite these difficulties, we think that it is possible to consider

marital status in pricing life insurance products. Rather than immediately charging lower premiums to married persons, mortality improvement bonuses (i.e., mortality savings) can be calculated according to marital status. The married will receive more returns if they have better mortality profiles. Alternatively, if the married are to receive a premium discount, insurance companies can require marriage proof when collecting annual premiums to avoid the continuation of bonuses for married persons who become divorced. Marriage proof is a common requirement in Asian countries, such as Taiwan and Japan; it is an official record within the population register system. In addition, many Asian countries are experiencing lower fertility rates and most of their newborns are from married women (96% in Taiwan and 98% in Japan). Encouraging younger people to get married becomes an important policy. Thus, receiving a premium discount would create incentive for the government.

Studying mortality rates by marital status is also important in dealing with the longevity risk. The married may not pay more for annuity products, but insurance companies need to know the impact if more married people purchase annuity. Therefore, in addition to constructing the marriage life table, we also explore mortality improvement by marital status using mortality models. We use cross-validation to evaluate the mortality models using the Taiwan marital data. Before doing the model comparison, we first check the trend of marital mortality rates and verify whether mortality rates (and mortality ratios) are changing in a regular pattern. We use the mortality ratios of the married to the total population as a demonstration.

As shown in Figure 4, we only use data after 1994 since the highest recorded age was at least 90. In order to reduce fluctuations, the moving averages of 3-year mortality ratios are calculated. Thus, the original data are separated into 6 data points, 1994–1996, 1997–1999, …, and 2009–2011. The patterns for both males and females are consistent over time, and the mortality ratios reach the lowest level around ages

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30–34, excluding the elderly cases where population sizes are small. Also, the curves of mortality ratios seem to move to the right gradually, indicating that the changes in mortality rates are likely to be stable. Next, we use stochastic mortality models to explore the feasibility of forecasting mortality rates by marital status.
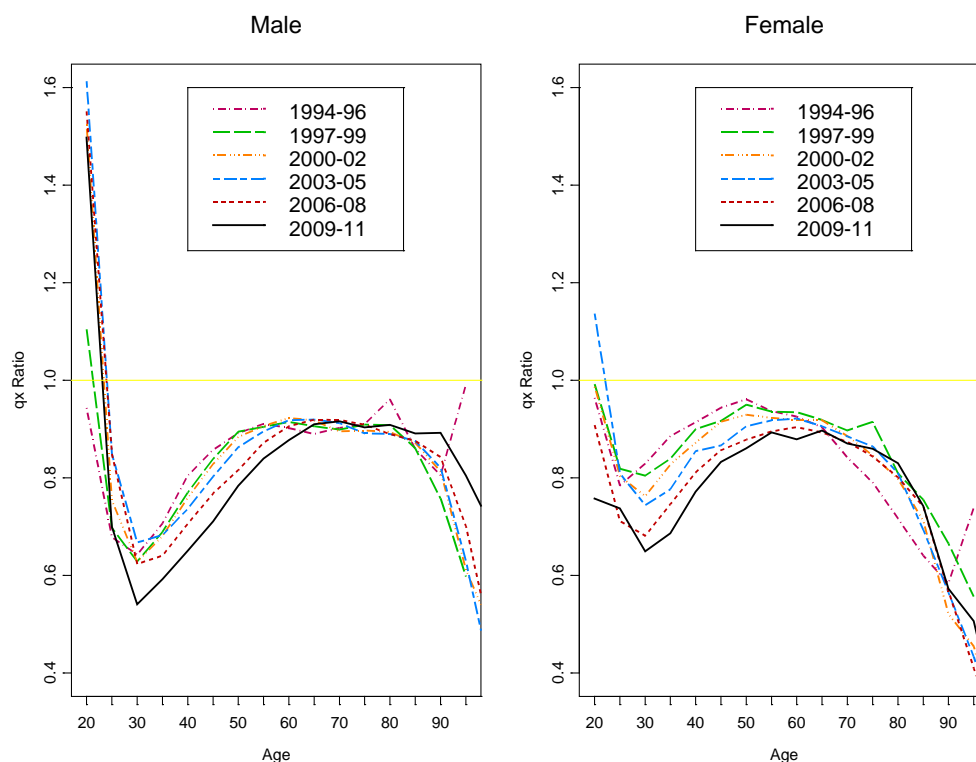

Figure 4. Mortality Ratios of Married compared with Total Population (1994–2011)

Unlike in the previous section, here we focus on modeling mortality rates for the elderly or pricing the annuities. This is also why we chose the RH and CBD models to predict mortality rates by marital status in this study. According to the description of marital data in Table 1, the elderly data are available after 1994. Thus, we only use data from 1994–2011 for mortality modeling. In particular, we focus only on the data from 1996–2010, using the 10-year period of 1996–2005 as the training data and the 5-year period of 2006–2010 as the testing data. We further consider two cases, one for ages 30–94 and the other for ages 65–94.

The four mortality models considered in this study usually apply different methods to predict future mortality rates. For the LC model, the time series approach is a popular choice in many studies and we also use it here. The forecast in using the CBD model is similar to that using the LC model, although computer simulation can be used. For the RH and RM models, we chose the block bootstrap simulation for predictions. In particular, the median of 1,000 block bootstrap simulation is treated as the predicted value.

The model comparison is based on the mean absolute percentage error (MAPE), or

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\frac{\left|Y_i - \hat{Y}_i\right|}{Y_i}\times 100\% ,\tag{10}$$

where Y_i and $\hat{Y}_i$ are the observed and predicted values for observation i, $i = 1, 2, \ldots, n$. According to Lewis (1982), a prediction with MAPE less than 10% is treated as highly accurate, and a MAPE greater than 50% is considered inaccurate.

Tables 7 and 8 show the prediction errors, with respect to MAPE, for predicting the age groups of 30–94 and 65–94. Since the numbers of deaths among the divorced/widowed group are 0 in many age groups, we combine the statuses of single, divorced, and widowed into one unmarried group. As expected, the prediction errors for the 30–94 age group are larger than the 65–94 group since more ages are covered. All models achieve accurate predictions for short-term prediction, but we need to use a longer period of data for further comparisons. For short-term prediction, the proposed relational model (RM) has the smallest overall MAPE and outperforms other mortality models in almost all cells of Tables 7 and 8. Interestingly, the LC model is still very competitive.

Table 7. Prediction MAPE (%) of Mortality Models (Ages 30–94)

	Married		Un-married		Single		Average
	Male	Female	Male	Female	Male	Female	
LC	17.3	14.3	6.4	10.0	8.1	15.7	12.3
CBD	8.6	8.7	10.2	15.7	17.7	19.2	12.5
RH	32.7	31.0	5.3	21.0	4.1	23.7	19.7
RM	6.9	5.8	4.4	4.5	7.8	11.6	6.2

Table 8. Prediction MAPE (%) of Mortality Models (Ages 65–94)

	Married		Un-married		Single		Average
	Male	Female	Male	Female	Male	Female	
LC	4.8	7.8	4.8	4.9	9.2	14.8	7.0
CBD	4.5	9.1	5.8	3.7	11.5	14.3	7.2
RH	8.8	9.5	7.3	3.9	8.3	15.6	8.0
RM	3.5	6.6	5.2	3.3	10.0	11.3	5.7

Note that, as mentioned in the previous section, graduation methods can help reduce fluctuations in mortality rates. Thus, we also consider the possibility of smoothing mortality rates before implementing the mortality models. The graduation methods considered are the partial SMR and Whittaker ratios, and the mortality model is RM. Since the population sizes of the divorced and widowed are the smallest, we only show the prediction accuracy of these two cases.

Since the prediction results are similar for 30–94 and 65–94 age groups, we show only results for the 30–94 age group (Table 9). The graduation methods can reduce the estimation errors of mortality rates (Tables 2 and 3); however, there is no guarantee that they have smaller prediction errors as well. Although applying graduation is intended to reduce fluctuations in raw data, these methods may alter the information carried in the original observations. In other words, the graduation process should be applied with care and, if possible, we recommend plugging the original data into mortality models in order to avoid the discrepancy caused by applying different

graduation methods.

Table 9. Prediction MAPE (%) of Applying Graduation Methods (Ages 30–94)

Models	Widowed		Divorced	
	Male	Female	Male	Female
RM	53.0	33.1	8.4	17.7
Partial SMR	24.1	28.1	14.2	35.0
Whittaker Ratio	25.3	25.9	12.0	33.6

5.   Conclusion and Discussion

Gender and age are the risk factors considered most often in pricing life insurance products. Many studies confirm that the life expectancy and health of individuals are related to factors other than gender and age, such as smoking and obesity, but including them in the consideration of pricing may not be feasible in practice. Regardless, harmful activities are often underreported. It is believed that smokers generally have higher mortality rates than nonsmokers; however, it is difficult to verify whether the insured are smokers in Asian countries. In addition, the coverage in Taiwanese life insurance policies is usually low. Thus, most policies do not require health exams, and there is no way to check if the insured are overweight.

In Taiwan, we can still collect useful information about the insured without performing a medical exam. Since Taiwan has used the population register system for more than 100 years, the official documents of individual records can be found in every county office, even if the applicants do not reside in that county. One can get copies of the household registration transcript in less than one hour. These official documents contain useful information, such as the marital status and history of each individual. In this study, we explore whether it is feasible to treat marital status as a risk factor in life insurance products using Taiwan's marital mortality database.

The empirical study of Taiwan mortality by marital status confirms that married people have the lowest mortality rates and highest life expectancy. Comparing with the unmarried, married males seem to benefit more than married females. For example, for married and single individuals aged 15, the married male is expected to live about 8 years more than the single male, while the difference for the female is only about 3 years. Moreover, if the premiums of life insurance policies are calculated according to an individual's marital status, the discount in premiums for the married over the single can be as much as 40%. The amount of discount is even larger than discounts offered to nonsmokers compared with smokers, and to persons of normal weight compared with obese persons. This confirms that marital status is a feasible factor to be included in pricing and marketing life insurance products in Taiwan.

In this study of modeling mortality rates by marital status, we find that the proposed relational model (RM) has the smallest prediction errors, with respect to MAPE (mean absolute percentage error), and is slightly better than LC, RH, and CBD models. In addition, the prediction errors of all mortality models are significantly smaller for the elderly group (65 and over) than those for the younger population (ages 30–64). This might suggest that mortality improvements are not the same for different ages. However, since we only analyze Taiwan data, and our data period is too short, we need to collect more data to confirm our findings.

In this study, we also evaluate methods for smoothing mortality rates of small areas. The proposed methods include information from a large area to reduce fluctuations in mortality rates in small areas. Treating Taiwan as the large area and Pen-Hu county as the small area, we find that the partial SMR and Whittaker ratio have the smallest MSEs. We recommend the Whittaker ratio method. Furthermore, we find that all graduation methods can help to reduce the MSE of mortality rates, comparing to ungraduated mortality rates.

Note that, although we find mortality rates of the married are lower, we cannot conclude that being married causes people to live longer. In Taiwan, the proportion of married people is higher among those with higher income and higher education. We cannot tell whether marriage, higher income, or higher education causes people to live longer. On the other hand, the marital data used in this study are at the aggregate level. It will be more reasonable to use individual data and the idea of multiple decrements to construct the life table by marital status.

Acknowledgments

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