Mortality Differential & Social Insurance: A Case Study in Taiwan

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Mortality reduction has been a common phenomenon in almost all countries and it occurs at all ages. The trend of mortality improvement usually differs across subpopulations, with respect to gender, geographic area, or other socioeconomic variables. The ignorance of mortality differentials could result in adverse selection and problems of pricing and liability, and this would happen to the public pension plans as well. For example, to deal with the rapid population aging and prolonging life in Taiwan, there are quite a few public pension plans for groups classified according to their occupations in recent years. However, the benefits of these pension plans are different, partly due to the issuing time when the Taiwan economics was in good or bad shape. Taiwan government looks to unify these plans to achieve social fairness and financial solvency, and to give same benefit to retired citizens, regardless of their occupations.

We analyze the data from the National Pension Insurance and Farmer Health Insurance, and evaluate whether it is feasible to unify these two public pension plans. We first compare the mortality profiles of these two groups, in terms of social economic status, geometric region, and socioeconomic attributes (e.g., population density, income, education, and medical environment). We also implement the Lee-Carter model to the mortality rates from both groups and explore whether the differences in mortality improvement would jeopardize the unification of two social insurance systems. We found that the mortality rates of two systems and the mortality improvement behave differently, and it is not feasible to apply a single rate to the insureds from two groups. Unifying the National Pension Insurance and Farmer Health Insurance should be handled with care.

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1. Introduction

Mortality improvement has been a popular research topic in demographic studies since the end of last century. Governments, private sectors, and individuals are all interested in the prolonging life expectancy and its impacts.[5] Longevity risk is one of the well-known challenges related to the mortality improvement, and the interest is particularly in the reduction of mortality rates and its effect on the life planning after retirement. Seeking the solutions to these challenges is surprisingly difficult, since it requires knowledge about the application domains (e.g., public and private pension systems), as well as the factors associated with the challenges. For example, the needs of retirement life can be separated into three categories: financial, health, and living (e.g., long-term care), and the solutions to these needs can be very different.

Mortality models are a frequently used tool to describe how the mortality rates change with time, and quite a lot of models were proposed in recent years. Many aspects need to be considered in modelling the mortality rates, such as mortality trend, slope, and differential[6] (Zhu et al., 2015), in order to capture the characteristics of mortality profile. However, the mortality profiles vary across countries and their trend are obviously dissimilar for different age groups in a country. As a result, the performance of mortality models is thus data-dependent and no mortality models can dominate other models, suggested by the previous studies (e.g., Wang et al., 2016). Still, the mortality models can be used to deal with the challenges of mortality improvement but we need to find the feasible models according to the characteristics

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[5] International Actuarial Association set up a Mortality Task Force which transformed into the Mortality Working Group in November 2009. It focuses on the study of global mortality and the trends of future mortality, as well as how mortality affects insurance products and social security system.

[6] Population Issues Working Group (PIWG) and the Mortality Working Group (MWG) of the IAA hosted a seminar on Current Developments in Aging and Mortality on April 2017. The seminar topics covered important current issues such as whether current levels of mortality improvements are slackening off, whether we have the right assumptions regarding mortality at high ages, and how mortality is likely to change in the future and what might drive these changes.

of mortality data.

As for the mortality characteristics, there have been many studies in mortality trends and slopes, and this study will focus on the mortality differential. In particular we are interested in the influence of mortality differential on the public pension plans. The motivation behind is the rapid population aging in Taiwan. Both the proportion of elderly (age 65 and beyond) population and life expectancy increase significantly in Taiwan for the last 20 years. Taiwan government issued quite a few public pension plans, but most of them used almost identical life tables, ignoring the mortality differential among the insureds with different occupations or socioeconomic status (Madrigal et al., 2011; Villegas and Haberman, 2014). The risk beneath inappropriate assumption is similar to that of longevity risk.

The mortality differential can also result in adverse selection and financial sustainability. Pokorski (1994) pointed out the cause of the failure of the early private life insurance system was due to neglecting the insured age and health status which could result in adverse selection. Not only private life insurance, social security systems need to face adverse selection. Beauchamp and Wagner (2013) found that insured living longer would apply for delayed retirement in order to receive more annuity payments. If the pricing of social insurance does not take individual mortality differential into consideration, the premium will be underestimated. Hosseini (2015) discovered that the people with higher mortality rates would choose private insurance, afraid of not receiving the corresponding annuity from social security system.

We should use the data from Taiwan's public pension plans to verify the mortality differential and its impacts. In particular, we choose the data from National Pension Insurance and Farmer Health Insurance, during the period of 2008-2015. We explore if there exists mortality differential between the insureds with different attributes, such occupations and living areas. In addition to exploratory data analysis, we also consider the Lee-Carter model and regression to evaluate the mortality differential and trend. The remainder of this study is organized as follows. Section 2 presents the data and methodology, and Section 3 describes the results of exploratory data analysis, following by the regression analysis in Section 4. Finally, Section 5 presents concluding remarks and policy implications.

2. Data and Methodology

We first describe the data and methodology used in this study, to explore and evaluate the factors associated mortality differential. We use the datasets from Taiwan's public pension plans: National Pension Insurance (NPI) and Farmer Health Insurance (FHI). Both data were collected by Bureau of Labor Insurance (BLI), an organization whose primary mission is the service related to labor insurance, including occupational injury insurance. The FHI started in 1985 and the NPI started in 2008. In order to let the analysis results be compatible, we also restrict the FHI data used and choose the data period from October 2008 through September 2015 for both insurance.

Table 1 shows the basic description of insureds in both insurance plans during the study period. The population size of FHI is smaller, about 6-7% Taiwan's population, and it keeps declining every year. The FHI covers the Taiwan's citizens who occupation is agriculture. Agricultural products only account for 1.82% Taiwan GDP in 2016 and they keep shrinking. The population aging of agricultural population is more obvious than other occupations. The proportion of NPI insureds is 19.6% in 2008 and it increases dramatically ever since. The main reasons of quick increasing trend are the coverage of housewives, part-time workers, and self-employed. Due to the slow growth of Taiwan economics in recent years, more people are forced to work part-time without the coverage of pension plans from employers.

Table 1. Summary of Bureau of Labor Insurance (2008-2015)

Year	National population (1)	No. Farmer Insured (2)	Proportion (2)/ (1)	No. Pension Insureds (3)	Proportion (3)/ (1)
2008	23,037,031	1,581,119	6.9%	4,520,508	19.6%
2009	23,119,772	1,546,615	6.7%	5,439,303	23.5%
2010	23,162,123	1,514,354	6.5%	6,112,493	26.4%
2011	23,224,912	1,484,175	6.4%	6,645,742	28.6%
2012	23,315,822	1,460,261	6.3%	7,160,262	30.7%
2013	23,373,517	1,414,733	6.1%	7,637,861	32.7%
2014	23,433,753	1,355,276	5.8%	8,069,598	34.4%
2015	23,468,748	1,312,191	5.6%	8,384,216	35.7%

We will continue the data exploration of two public pension plans in the next section, and should give a brief introduction of the methods used in this study. The Lee-Carter model (Lee and Carter, 1992) is used to describe the mortality trend, where it assumes the logarithm of central death rates m_{xt} (or mortality rates) satisfy

$$\ln m_{x,t} = \alpha_x + \beta_x \kappa_t + \varepsilon_{x,t} \, , \tag{1}$$

where

α_x describes the average age pattern of mortality over time,

β_x is the deviations from the average pattern,

κ_t describes the variation in the level of mortality over time, and

$\varepsilon_{x,t}$ is the error term.

The Lee-Carter model is a popular mortality model and it can be used to measure the age-wise mortality improvement. We will use it to compare the mortality trend of two insurance plans.

We also use regression analysis to compare the mortality differential. The goal is to find risk factors associated with the mortality $q'_{x,t}$ in year t for insured age x. The independent variables include the insured identity, underprivileged group, and residential area, and their interaction effects. The insured identity is a dummy variable, indicating either NPI or FHI. The factor underprivileged group is a factor defined by Taiwan government, and low-income and disability are two of the conditions used by government. Also, although Taiwan is not a big island, the difference of life expectancy is pretty significant and it can be 10 or more years. In general, people in cities and northern Taiwan tend to live longer, and thus the residential areas are divided into north, central, south, east, and remote islands.

Since the factor age plays an important role in modelling mortality rates, we should first apply the Lee-Carter model to eliminate the influence of age. An then we use the residuals of Lee-Cater model to analyze the impact of mortality differentials $D_{i,t}$ in year t for risk factors i. Moreover, exposures $exp_{i,x,t}$ in year t for insured age x and risk factor i were taken as weights to average mortality differentials. To facilitate the assessment of mortality differentials, the model is given by

$$D_{i,t} = \sum_{x} \left(q_{x,t,i} - q'_{x,t} \right) \times \frac{exp_{i,x,t}}{\sum_x exp_{i,x,t}}$$

$$= \beta_0 + \beta_1 z_{i,type} + \beta_2 z_{i,weak} + \beta_3 z_{i,type} z_{i,weak} + \sum_{k:area} \beta_k z_{i,k} + \varepsilon_i \quad \ldots (1)$$

where the subscript *type* means the insured that is identified by NPI or FHI, the subscript *weak* means the underprivileged groups (low-income or disable), and the subscript *area* means the residential areas.

3. Exploratory Data Analysis

We should continue the data exploration of two public pension plans, with respect to gender, age distribution, and residential areas. Table 2 below shows the gender ratio of the insureds and there is no significant difference in the gender ratio, although the proportion of male insureds of FHI is slightly higher and that of female insureds of NPI is slightly higher. This is an expectable result since there are quite many housewives in NPI. The gender ratio is closer to 50-50 for both insurance.

Table 2. Gender ratio of National Pension and Farmer Health Insurance.

Year	Male/Female Farmer Health	Male/Female National Pension
2008	51% / 49%	48% / 52%
2009	51% / 49%	48% / 52%
2010	51% / 49%	49% / 51%
2011	51% / 49%	49% / 51%
2012	51% / 49%	49% / 51%
2013	51% / 49%	49% / 51%
2014	50% / 50%	49% / 51%
2015	50% / 50%	49% / 51%
Average	51% / 49%	49% / 51%

Table 3 and 4 show the age distributions of the insured of NPI and FHI, respectively. Most of the NPI insureds are young adults and more than 50% are between ages 30-49, with average age between 44 and 45 years old. On the other hand, since the farmer workers are older adults, about half of the FHI insureds are over 65 years old, resulting in the average ages 62 to 65, much older than the average age of the NPI insureds. Also, the proportion of older populations in FHI is increasing and this indicates that fewer younger people are willing to become farmers.

Table 3. Age distribution of National Pension Insurance.

Age	2008	2009	2010	2011	2012	2013	2014	2015
25 -29	14.0%	15.4%	16.0%	15.4%	14.0%	12.7%	11.6%	10.8%
30 -34	13.3%	14.5%	15.8%	16.8%	17.7%	18.1%	18.1%	17.6%
35 -39	12.0%	11.9%	12.0%	12.5%	12.9%	13.5%	14.1%	14.7%
40 -44	12.2%	12.0%	11.8%	11.7%	11.6%	11.5%	11.4%	11.5%
45 -49	11.1%	10.7%	10.5%	10.3%	10.2%	10.1%	10.1%	10.1%
50 -54	12.0%	11.1%	10.2%	9.7%	9.5%	9.4%	9.5%	9.5%
55 -59	13.1%	11.9%	10.6%	9.7%	9.0%	8.8%	8.5%	8.3%
60 -64	11.0%	10.0%	9.4%	9.3%	9.2%	9.0%	8.8%	8.6%
Over 65	1.5%	2.5%	3.7%	4.7%	5.8%	6.9%	8.0%	8.9%
Average	44	44	44	44	44	44	44	45

Table 4. Age distribution of Farmer Health Insurance.

Age	2008	2009	2010	2011	2012	2013	2014	2015
15-24	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
25 -29	1.4%	1.4%	1.2%	1.0%	0.9%	0.8%	0.7%	0.6%
30 -34	3.2%	3.1%	2.8%	2.5%	2.2%	2.0%	1.7%	1.5%
35 -39	4.9%	4.6%	4.2%	3.9%	3.6%	3.3%	3.1%	2.9%
40 -44	7.1%	7.0%	6.6%	6.2%	5.7%	5.3%	4.9%	4.6%
45 -49	7.9%	7.9%	7.8%	7.7%	7.5%	7.2%	7.0%	6.8%
50 -54	8.4%	8.5%	8.5%	8.6%	8.9%	9.0%	9.0%	8.9%
55 -59	9.0%	9.1%	9.3%	9.3%	9.3%	9.5%	9.5%	9.5%
60 -64	8.6%	8.5%	9.1%	10.0%	10.6%	11.1%	11.2%	11.4%
Over 65	49.3%	49.6%	50.2%	50.7%	51.2%	51.7%	52.8%	53.8%
Average	62	62	63	63	64	64	65	65

In addition to the age distribution, the analysis of residential areas can provide us other aspects of data. Figure 1 shows the distribution of residential areas of NPI and FHI, and most of the NPI insureds are in the northern area, while most of the FHI insureds are in the central and southern areas. Table 5 shows the proportions underprivileged groups in NPI and FHI, respectively. The proportion of underprivileged groups of FHI decreases yearly but that of NPI increases annually.

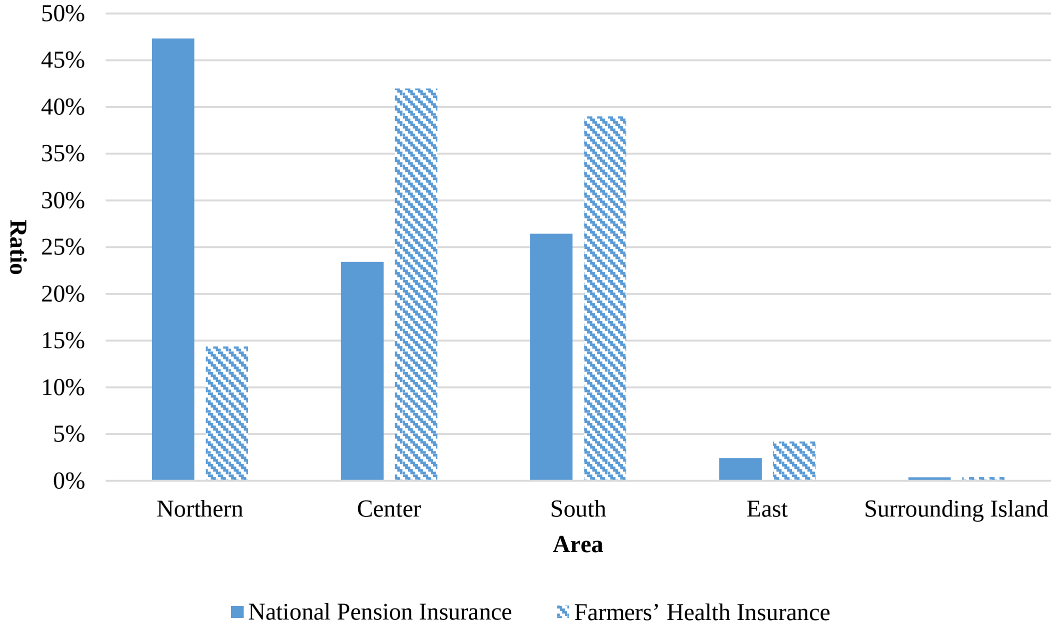

Figure 1. The proportion of population distribution in counties

Table 5. Proportions of underprivileged groups in NPI and FHI

Year	Underprivileged Groups of FHI	Underprivileged Groups of NPI
2008	9%	10%
2009	9%	9%
2010	10%	8%
2011	10%	8%
2012	10%	7%
2013	10%	7%
2014	11%	7%
2015	11%	6%
Average	10%	7%

Next, we compare the mortality trend of NPI and FHI. The mortality rates of NPI (Figures 2 and 3) decrease slightly annually, with the line of year 2008 on the top and that of year 2015 on the bottom. On the other hand, the mortality improvement of FHI is not as obvious (Figures 4 and 5), with a lot of fluctuations between years. Still, the mortality improvement is noticeable and we apply the Lee-Carter model to capture the trend with respect to age and time. The residuals of Lee-Carter model will be evaluated other risk factors.

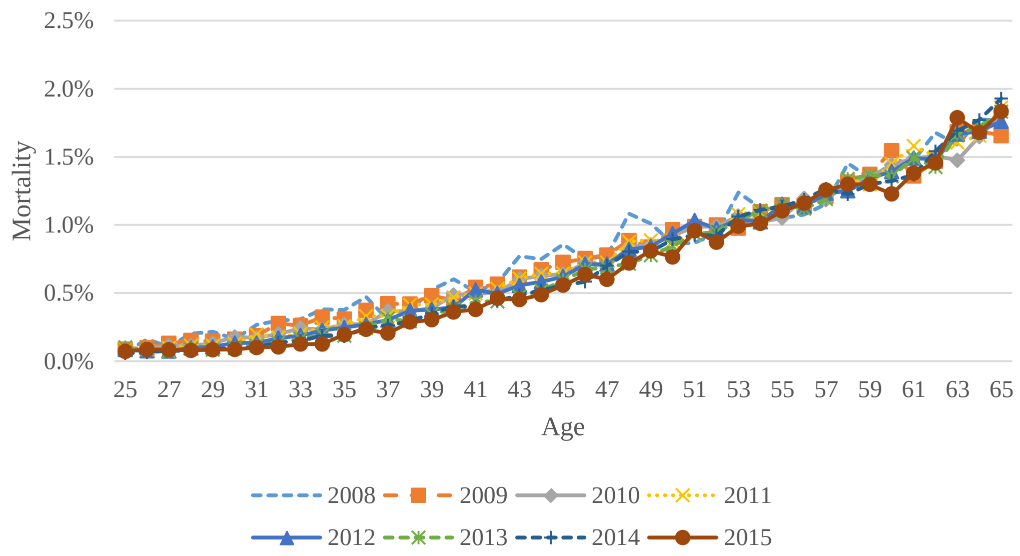

Figure 2. Male’s mortality of National Pension Insurance

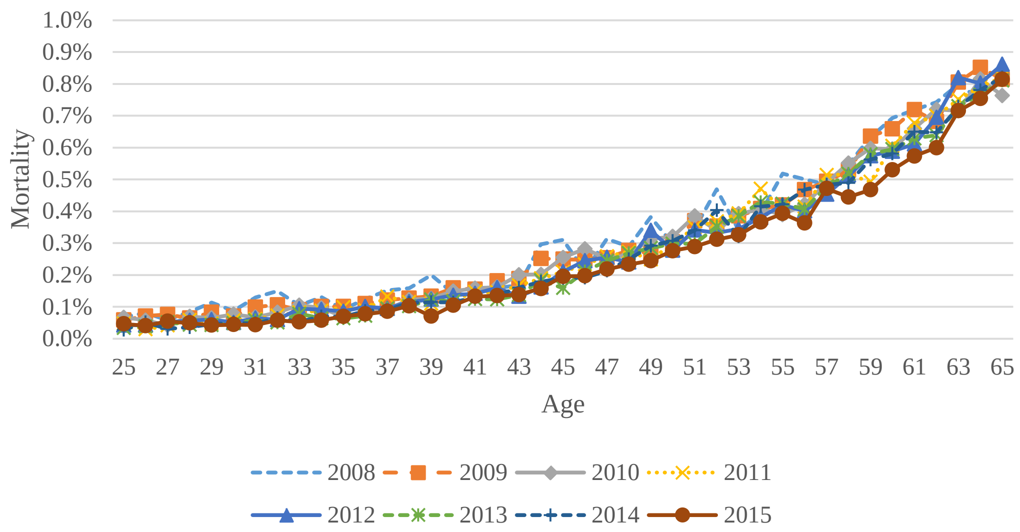

Figure 3. Female’s mortality of National Pension Insurance

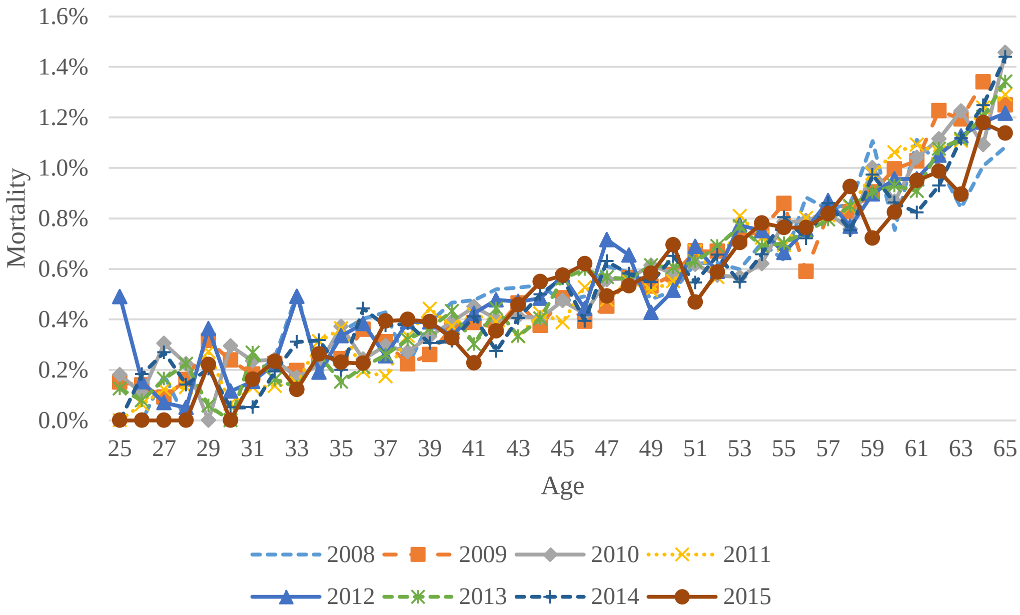

Figure 4. Male's mortality of Farmer Health Insurance

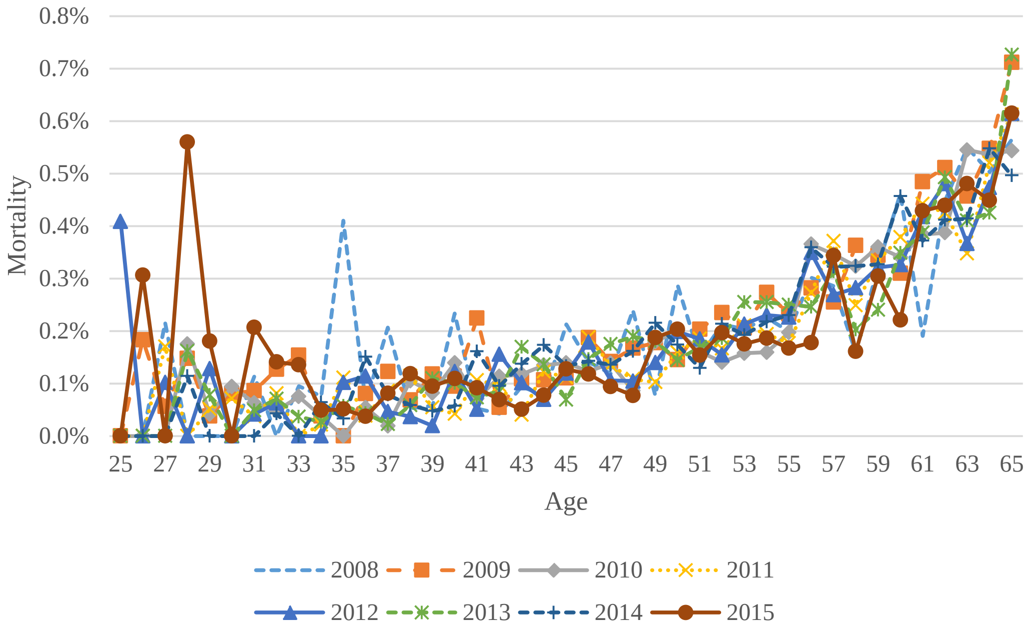

Figure 5. Female's mortality of Farmer Health Insurance

We further compare the overall mortality rates of NPI and FHI. Since there are 8 years of data, we consider the average mortality rates to simplify the discussion. In addition to these two insurance, we include 2015 Taiwan's Abridge Life Table

(Figures 6 and 7). In general, the mortality rates of NPI are the highest, while those of FHI are the lowest. The high mortality rates of NPI are expectable, since many of them have part-time or self-employed job and thus have lower incomes. But, interestingly, the farmers in FHI usually have lower incomes as well and not live in cities. We are interested in knowing why the FHI insureds have lower mortality rates.

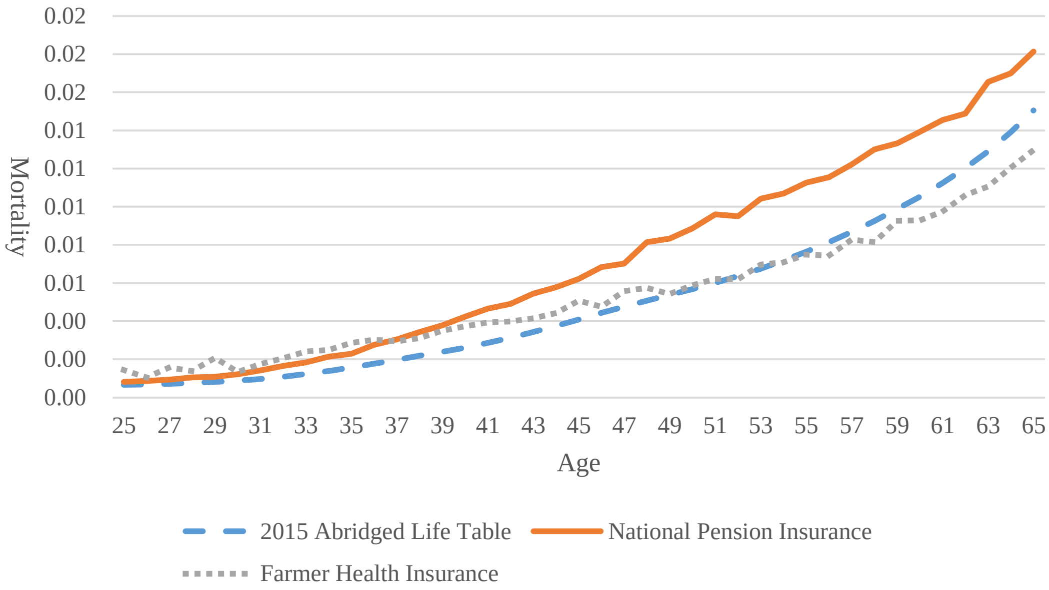

Figure 6. The comparison of male mortality (2008-2015)

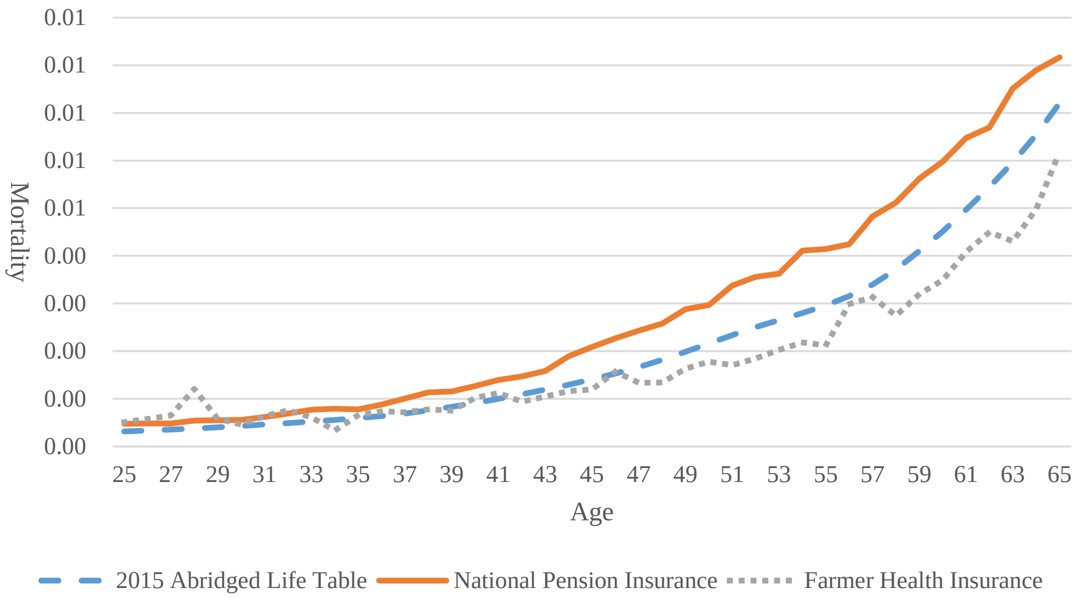

Figure 7. The comparison of female mortality (2008-2015)

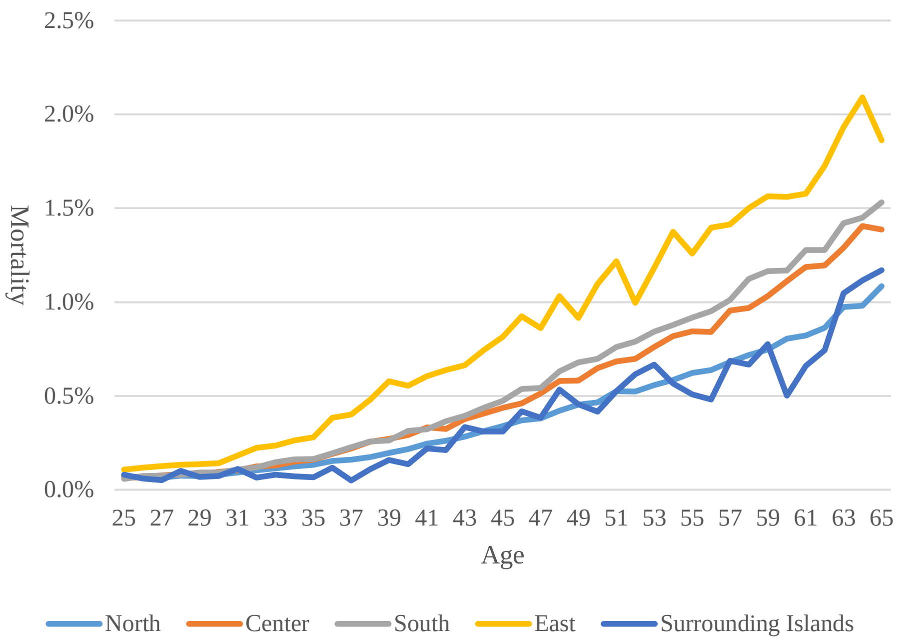

Figure 8. Mortality differential w.r.t. residential areas (NPI)

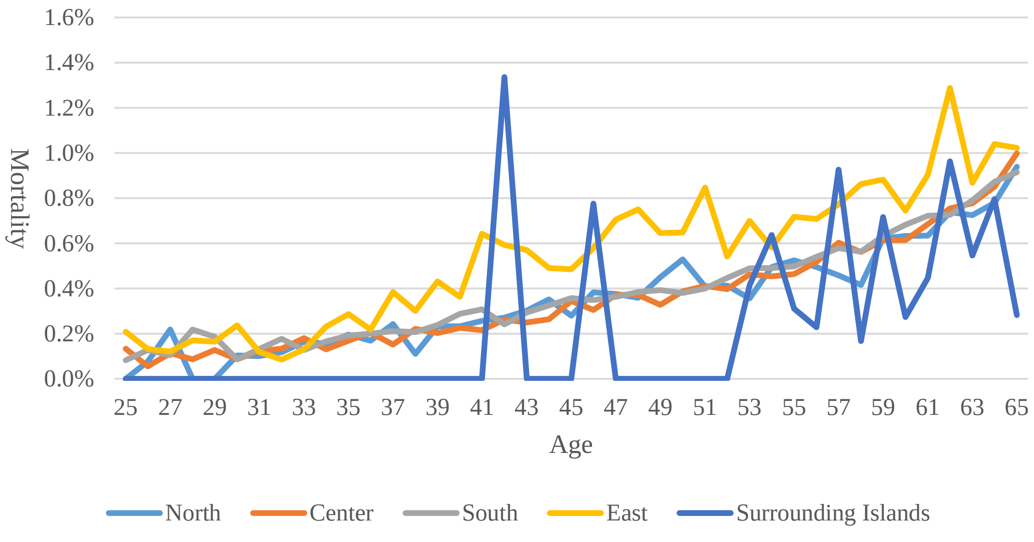

Figure 9. Mortality differential w.r.t. residential areas (FHI)

A further analysis of residential areas gives us more information (Figures 8 and 9). The population sizes of surrounding islands are too small, creating large mortality fluctuations between ages, and it is difficult for mortality comparison, although it seems that the mortality rates of surrounding are not higher than those of the northern Taiwan. Otherwise, no matter for the case of NPI or FHI, people in the northern area have the lowest mortality rates, and those in the eastern area have the highest mortality rates. This matches to the national averages. We should use regression analysis to further explore mortality differential according to the factors discussed in this section.

4. Regression Analysis of Mortality Differential

Following the previous section, in addition to mortality improvement, the mortality rates of NPI and FHI are also related factors such as underprivileged group and residential areas. We first apply the Lee-Carter model to remove the influence of age and time, and then treat the model's residuals as the dependent variable and use regression analysis to further verify the factors associated with mortality differential. Independent variables included in the regression analysis are insured identity (National Pension Insurance or Farmer Health Insurance), underprivileged groups, and residential areas. The interaction of the insured identity and the underprivileged groups is added into the model. To facilitate the assessment of mortality differentials, the model is given by

$$D_{i,t} = \beta_0 + \beta_1 x_{i,type} + \beta_2 x_{i,weak} + \beta_3 x_{i,type} x_{i,weak} + \sum_k \beta_k x_{i,k} + \varepsilon_i.$$

where the subscript *type* means the insured identity (0: National Pension Insurance, 1: Farmer Health Insurance), the subscript *weak* means the underprivileged groups (0: non-vulnerable and 1: vulnerable), and the subscript k means the residence city including northern area, central area, southern area, eastern area, and surrounding islands. We should treat the northern area (with the lowest mortality rates) as the benchmark.

Note that the method of ordinary least squares (OLS) assumes constant variance (homoscedasticity), which is not practical. Instead, we use the weighted least squares (WLS) for regression analysis and the parameters are derived via

$$\mathrm{Q}_w = \sum_i w_i(y_i - \beta_0 - \beta_1 x_{1i})^2.$$

The results of empirical analysis via WLS are shown in Table 6. As expected, the variables showing obvious differences are all significant, after the standardization of Lee-Carter model.

Table 6. Regression analysis of mortality differential (WLS)

Variable	β	Standard error	t-value	p-value
Intercept	-0.00123	0.00007	-16.60588	<0.0001**
Insured Identity	-0.00203	0.00017	-12.07025	<0.0001**
Underprivileged Groups	0.01061	0.00020	54.29593	<0.0001**
Central Area	0.00094	0.00012	7.70503	<0.0001**
Southern Area	0.00129	0.00012	10.91251	<0.0001**
Eastern Area & Surrounding Islands	0.00287	0.00029	9.88834	<0.0001**

Among all variables, the insured identify shows that there are significant differences between the mortality rates of NPI and FIH. It is not reasonable to combine these two insurance plans since their insureds do not have the same mortality rates and their differences become larger as the age. Besides, these two public pension plans have different coverage and benefit amount, in addition to the premium amount and schedule. (Note: The coverage and benefit of FHI generally are better than those of NPI.) If Taiwan government intends to combine these two public pension plans, then we need to decide the premium and benefit first, as well as their calculations. It would create social chaos if we reduce the FHI benefits or increase the risk of financial crisis if we enhance the NPI coverage.

The result related to the variable residential area also needs attention. In Taiwan, more people are moving to the cities (i.e., domestic migration), especially to the cities in northern Taiwan. Right now, more than 38% of Taiwan people gather in the three cities in northern Taiwan, accounting less than 10% population of Taiwan. If the overall conditions of living in big cities can be associated to living longer, more people in northern Taiwan would increase the financial burden to the public pension system.

Note that we also conducted residual diagnosis of regression analysis. The residuals of OLS fail the assumption of constant variance and normality. On the contrary, the residuals of WLS do not reject the hypothesis that they are normally distributed and have constant variance. Also, the lack-of-fit test also supports the use of WLS.

5. Conclusion and Discussions

Mortality models are often used to deal with the challenges of mortality improvement. The studies of mortality models often focus on aspects such as mortality trend, slope, and differential (Zhu et al., 2015). Many past studies focused on the mortality trend or mortality slope, while the goal of this study is on the mortality differential. We are interested in the influence of mortality differential on the public pension plans. One of the motivations is that most of Taiwan's public pension plans used almost identical mortality assumption (i.e., same life tables), ignoring the mortality differential among the insureds with different occupations or socioeconomic status. This would incur adverse selection and risk of financial insolvency for the public insurance.

In this study, we analyzed the data from the National Pension Insurance and Farmer Health Insurance (data period: 2008-2015), two public pension plans in Taiwan, and evaluated whether it is feasible to unify these two plans. We found that, after normalized by the Lee-Carter model and removing the age and time effects, the mortality differential does exist. First of all, the mortality rates of National Pension Insurance and those of Farmer Health Insurance are distinct, and we don't recommend unifying these two plans. Another finding is the mortality differential with respect to residential areas. People live in cities usually have more medical and social resource, and thus they tend to live longer.

Note that the result of our regression analysis is based on the Lee-Carter model, using its residuals for the regression analysis. Both the exploratory data analysis sustains the mortality reduces with time and the residual diagnosis supports the regression analysis. Still, the result of regression analysis can be very different if we choose other mortality models, such as age-period-cohort model (Cairns et al., 2006) and Renshaw-Haberman model (Renshaw and Haberman, 2006), instead of the Lee-Carter model. Of course, we can also apply generalized linear models (GLM) to include all variables for the study of mortality differential. (Note: Most mortality models can be treated as a special case of GLM.)

The empirical study of mortality differential in Taiwan also suggests that it is not appropriate to apply the mortality rates of whole population to subpopulations, without data exploration. For example, National Pension Insurance started in 2008 but there were no experienced data before and Taiwan government decided to apply the mortality rates of Taiwan's abridged life tables. However, the comparison between National Pension Insurance mortality rates and Taiwan's abridged life tables (Figures

6 and 7) show apparent differences. Since many countries have been experiencing rapid population aging and prolonging life expectancy, there are growing needs in social insurance and public pension. However, choosing inappropriate assumption of mortality rates would jeopardize the insurance system.

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