North American Actuarial Journal, 0(0), 1–11, 2020

ISSN: 1092-0277 print / 2325-0453 online
DOI: 10.1080/10920277.2019.1651660

Routledge Taylor & Francis Group

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Mortality Differential and Social Insurance: A Case Study in Taiwan

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The mortality differential is important information for planning social insurance programs, such as health insurance and public pensions. It can be used to evaluate whether certain areas need more medical facilities and traffic infrastructure. The ignorance of mortality differentials can result in adverse selection and problems of pricing and liability. In this study, we use mortality models to estimate the mortality differentials of two social pension plans in Taiwan, National Pension Insurance (NPI) and Farmer Health Insurance (FHI), which account for more than one-third of the population of Taiwan (about 9 million). We compare the mortality profiles of the two pension groups in terms of economic status and geographic region. Empirical study leads to several policy implications, such as the feasibility of unifying the FHI and NPI systems, reallocating more premium subsidy according to mortality difference and corresponding annuity cost, and the antiselection effect in suburban areas with lower annuity costs and lower willingness to pay premiums.

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 prolonging life expectancy and its impacts.[1] 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 the effect of such reduction on life planning for 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.

Other than prolonging life, mortality differential is another issue that has received a lot of attention in recent years. The ignorance of mortality differentials can result in adverse selection and problems of pricing and liability, which can happen to both social and commercial insurance. Mortality models are a popular tool to capture and model the characteristics of mortality profile, such as mortality trend, slope, and differential[2] (Zhu et al. 2015). However, mortality profiles vary across countries and their trends 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. Still, the mortality models can be used to deal with the challenges of mortality improvement, but we need to find models that are feasible in terms of the characteristics of mortality data.

Considering mortality characteristics, there have been many studies in mortality trends and slopes, and this study focuses on the mortality differential. In particular, we are interested in the influence of mortality differential on the public pension

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[1]The International Actuarial Association (IAA) 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 the social security system.

[2]The Population Issues Working Group (PIWG) and the Mortality Working Group (MWG) of the IAA hosted a seminar on current developments in aging and mortality in 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.

TABLE 1
Summary of Bureau of Labor Insurance (2008–2015)

Year	National population (1)	Number if Farmer insureds (2)	Proportion (2)/(1)	Number of 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%

plans. The motivation behind this is the rapidly aging population in Taiwan. Both the proportion of the elderly (age 65 years and beyond) in the population and life expectancy increased significantly in Taiwan over the last 20 years. The 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 underlying this inappropriate assumption is similar to that of longevity risk.

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

This study uses the data from Taiwan's two public pension plans to verify the mortality differential and its impacts. In particular, we chose the data from National Pension Insurance (NPI) and Farmer Health Insurance (FHI), during the period of 2008–2015. We explore whether there exists a mortality differential between the insureds with different attributes, such as occupations, income, or health status and living areas. We first apply the Lee–Carter (Lee and Carter 1992) model to remove the influence of age and time, and then treat the model's residuals as the dependent variable, using regression analysis to identify the factors associated with the mortality differential. Variables included in the regression analysis are insured identity (NPI or FHI), underprivileged groups, and residential areas. The empirical results led to several policy implications, such as the feasibility of unifying FHI and NPI systems, reallocating more premium subsidy according to mortality difference and corresponding annuity cost, and the antiselection effect in suburban areas with lower annuity costs and lower willingness to pay premiums, as mentioned in Hosseini (2015).

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. EXPLORATORY DATA ANALYSIS

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

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% of Taiwan's population, and it keeps declining every year. FHI covers those of Taiwan's citizens who occupation is agriculture. The proportion of NPI insureds was 19.6% in 2008 and it has increased dramatically since then. The

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
Age Distribution for National Pension Insurance

Age (years)	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

main reasons of for the quickly increasing trend included the coverage of housewives, part-time workers, and the self-employed. Due to the slow growth of the Taiwan economy in recent years, more people have been forced to work part-time without the coverage of pension plans from employers.

We continue the data exploration of the two public pension plans, with respect to gender, age distribution, and residential areas. Table 2 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 many housewives in NPI. The gender ratio is closer to 50–50 for both insurance programs.

Tables 3 and 4 show the age distributions of those insured by NPI and FHI, respectively. Most of the NPI insureds are young adults and more than 50% are between the ages 30 and 49 years, 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 average ages 62 to 65 years, much older than the average age of the NPI insureds. Also, the proportion of older populations in FHI is increasing, which indicates that fewer younger people are willing to become farmers.

In addition to the age distribution, the analysis of residential areas can provide us other aspects of information. 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 lists the proportions of underprivileged individuals in NPI and FHI. The proportion of underprivileged groups of FHI decreases yearly but that of NPI increases annually.

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 the year 2008 at the top and that of the year 2015 at the bottom. On the other hand, the mortality improvement of FHI is not as obvious (Figures 4 and 5), with a lot of fluctuations among 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 the Lee–Carter model will be used to evaluate other risk factors.

TABLE 4
Age Distribution for Farmer Health Insurance

Age (years)	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

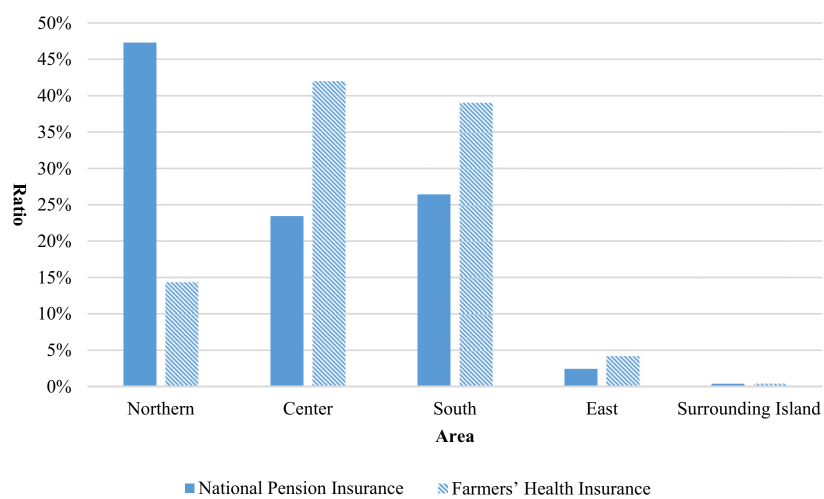

FIGURE 1. The Proportion of Population Distribution in Counties.

TABLE 5
Proportions of Underprivileged Individuals in NPI and FHI

Year	Underprivileged individuals of FHI	Underprivileged individuals 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%

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 programs, we include 2015 Taiwan's Abridged 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

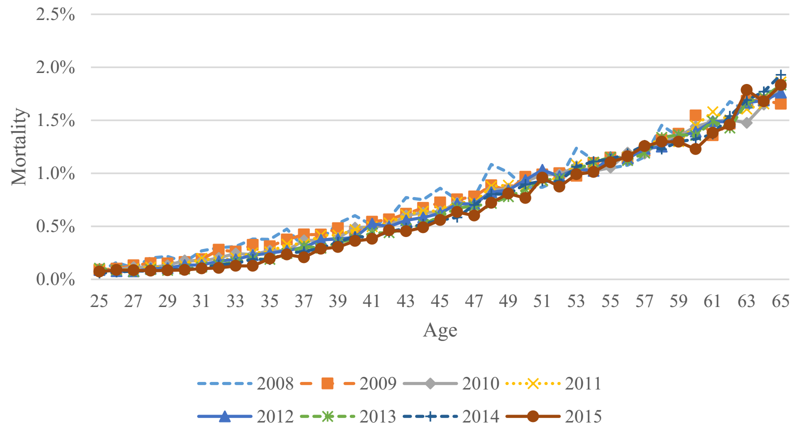

FIGURE 2. Male Mortality for National Pension Insurance.

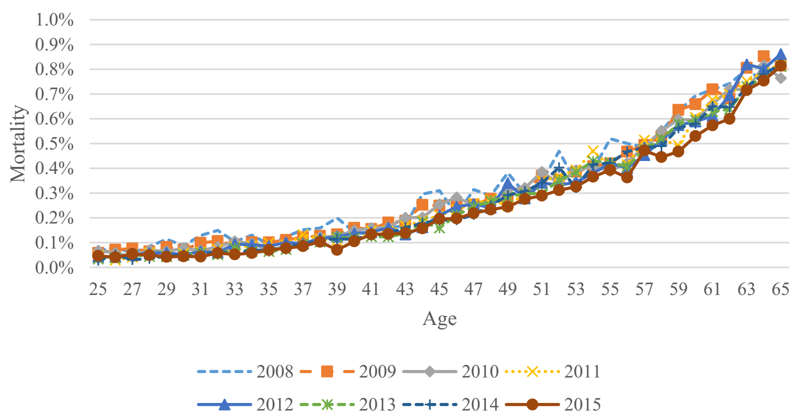

FIGURE 3. Female Mortality for National Pension Insurance.

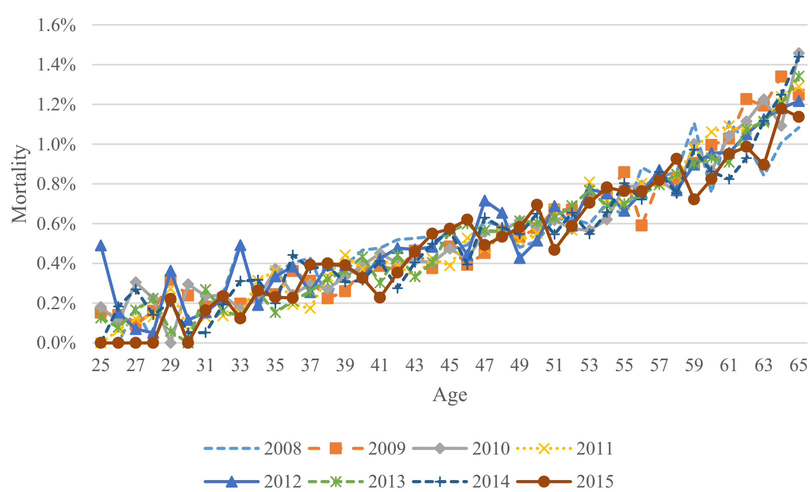

FIGURE 4. Male Mortality for Farmer Health Insurance.

mortality rates of NPI insureds are expectable, since many of them have part-time or self-employed jobs and thus have lower incomes. But, interestingly, the farmers in FHI usually have lower incomes as well and do not live in cities. We are interested in knowing why the FHI insureds have lower mortality rates.

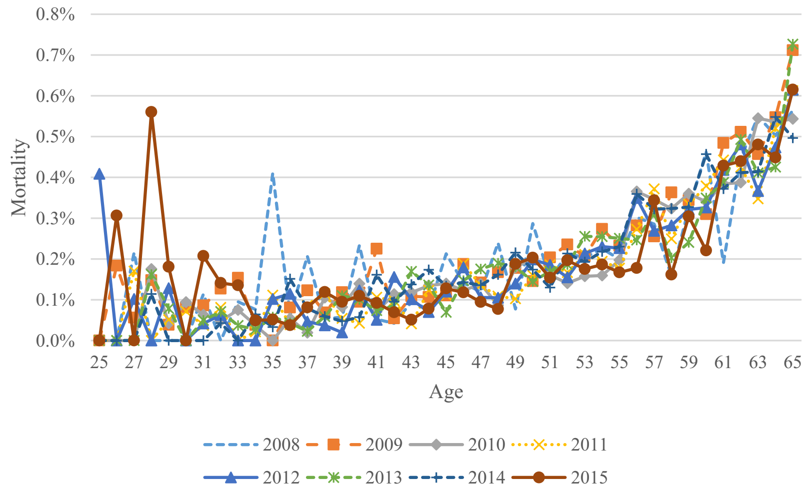

FIGURE 5. Female Mortality for Farmer Health Insurance.

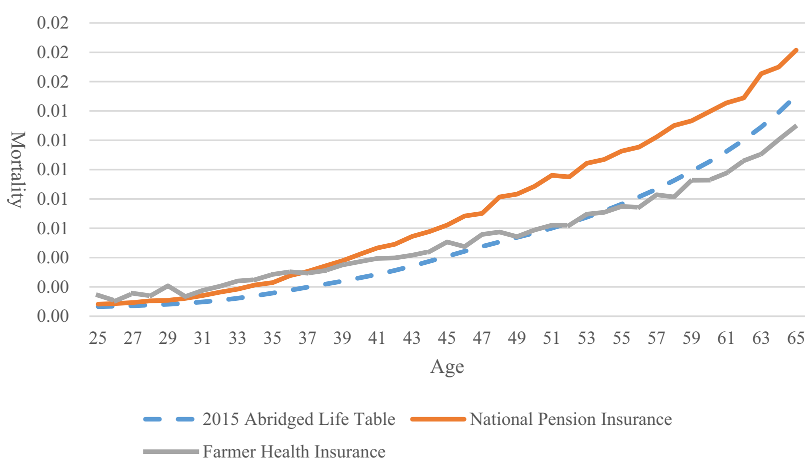

FIGURE 6. The Comparison of Male Mortality (2008–2015).

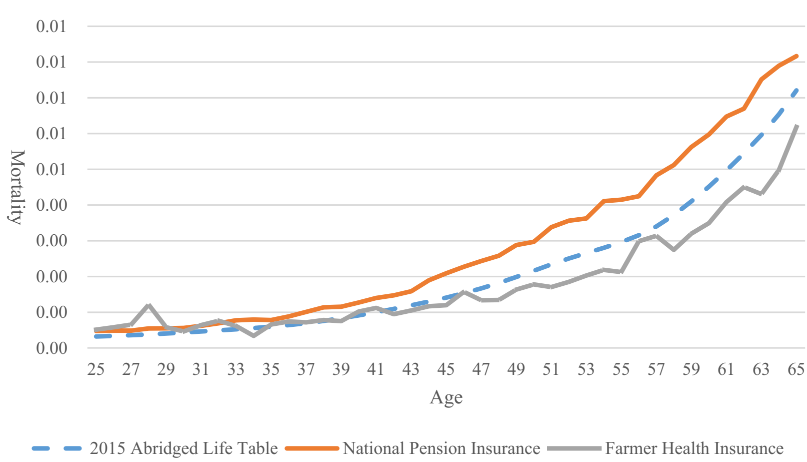

FIGURE 7. The Comparison of Female Mortality (2008–2015).

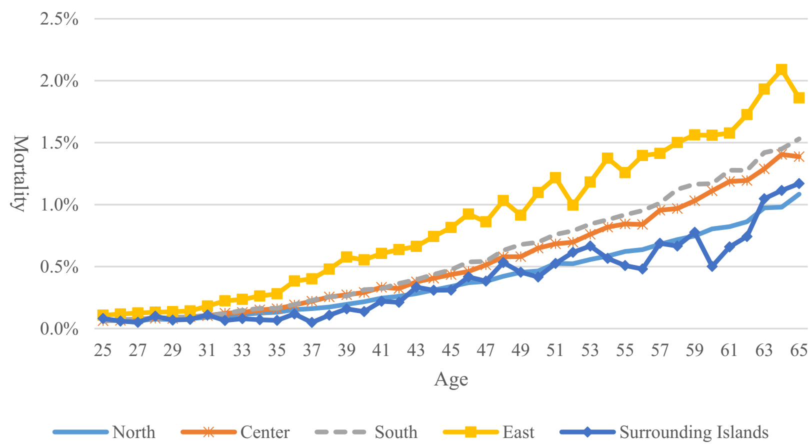

FIGURE 8. Mortality Differential With Respect to Residential Areas (NPI).

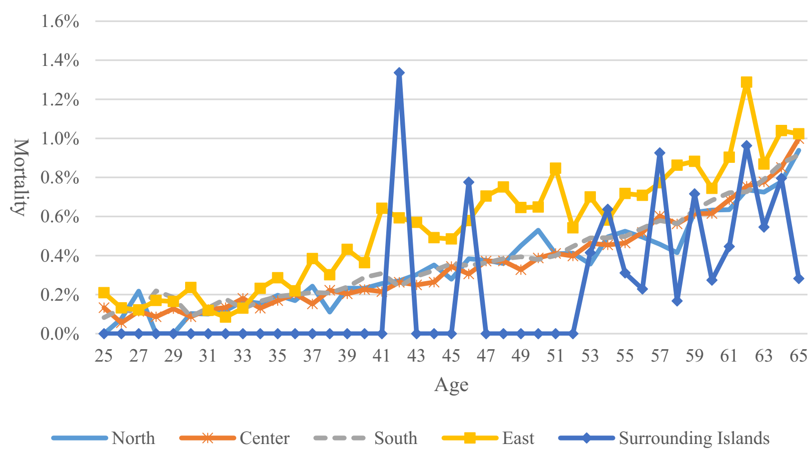

FIGURE 9. Mortality Differential With Respect to Residential Areas (FHI).

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 to make a mortality comparison, although it seems that the mortality rates of the surrounding islands are not higher than those of northern Taiwan. Otherwise, no matter whether insured by 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 with the national averages. We should use regression analysis to further explore mortality differential according to the factors discussed in this section.

A further analysis of underprivileged groups gives us more information (Figure 10). We compare the mortality rates of NPI and FHI between underprivileged groups and other insured. Since there are 8 years of data, we consider the average mortality rates to simplify the discussion. No matter whether the insurer is NPI or FHI, the mortality rates of underprivileged groups are the highest, while those of other insureds are the lowest.

3. REGRESSION ANALYSIS OF MORTALITY DIFFERENCE

The mortality rates can be characterized with insured identity (NPI or FHI) representing the employment status, income or health status (nonvulnerable or vulnerable groups), and residence area (northern, central, southern, eastern, and surrounding island areas), which enables us to implement regression analysis to examine the significance of these effects. Notably, mortality rates are highly tied to ages and gender, and it is difficult to add an age effect to the regression model due to its special nonlinear pattern. Therefore, we employ a two-stage estimation method. That is, we first use the Lee–Carter model to obtain an overall estimate of mortality rate $\hat{q}_{x,t} = \hat{\alpha}_x + \hat{\beta}_x \cdot \hat{k}_t$ where $\hat{\alpha}_x$ describes the average age pattern of mortality over time, $\hat{\beta}_x$ is the deviations from the average pattern, and $\hat{k}_t$ describes the variation in the level of mortality over time. The next stage is to apply the residuals of the Lee–Carter model to analyze the impact of mortality differentials by

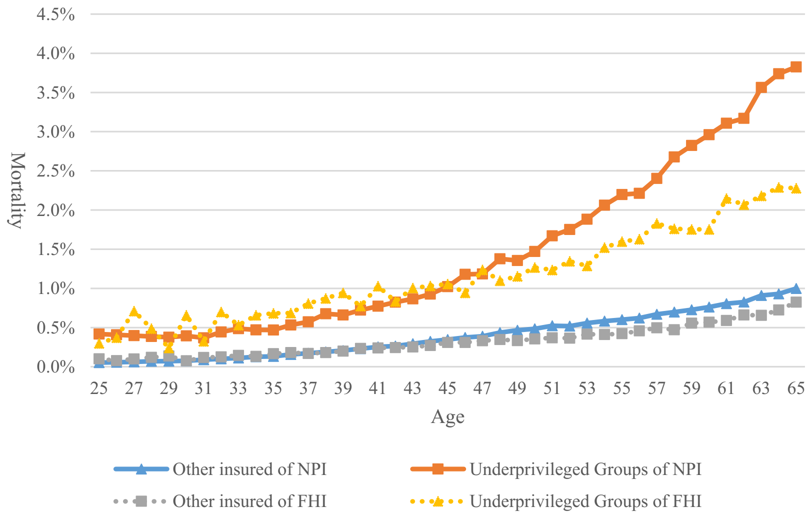

FIGURE 10. The Comparison of Mortality Differential.

$$D_{type, weak, area, t} = \sum_{x} \left(q_{type, weak, area, x, t} - \hat{q}_{x, t} \right) \times \frac{w_{type, weak, area, x, t}}{\sum_{x} w_{type, weak, area, x, t}},$$

where the residual $D_{type, weak, area, t}$ is classified by *type*, *weak*, and *area* with t observed yearly data. The subscript *type* represents the factor of the insured being covered by NPI or FHI, the subscript *weak* indicates the underprivileged groups (low-income or disabled), and the subscript *area* indicates the residential areas. Moreover, the numbers of exposures $w_{type, weak, area, x, t}$ in year t for insured age x and risk factors (*type*, *weak*, and *area*) were taken as weights to average mortality differentials.

Secondly, we perform linear regression with independent variables including 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 from Figure 10. To facilitate the assessment of mortality differentials, the model is given by

$$D_{type, weak, area, t} = \beta_0 + \beta_1 x_{type} + \beta_2 x_{weak} + \beta_3 x_{type} x_{weak} + \sum_{area} \beta_{area} x_{area} + \varepsilon_{type, weak, area, t}, \tag{1}$$

where the subscript *type* indicates the insured identity (0: NPI, 1: FHI), the subscript *weak* represents the underprivileged groups (0: nonvulnerable, 1: vulnerable), and the subscript *area* indicates the residence city (0: northern area, 1: central area, 2: southern area, 3: eastern area, and 4: surrounding islands). We should treat the northern area (with the lowest mortality rates) as the benchmark. Additionally, we have eight yearly samples with $t = 1, \ldots, 8$.

Among all variables, the insured identify shows that there are significant differences between the mortality rates for 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 with increasing age. Besides, these two public pension plans have different coverage and benefit amounts, in addition to the premium amount and schedule. (Note: The coverage and benefit of FHI generally are better than those of NPI.) If the 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.

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 Northern Area consisting of three main cities (Taipei, New Taipei, and Taoyuan Cities). 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.

According to the analysis result, we find it necessary to consider the mortality difference from underprivileged groups between NPI and FHI, within each residential area, while adding the interaction factor *type* × *weak* × *area* to the WLS model. To facilitate the assessment of mortality differentials, the revised model is given by

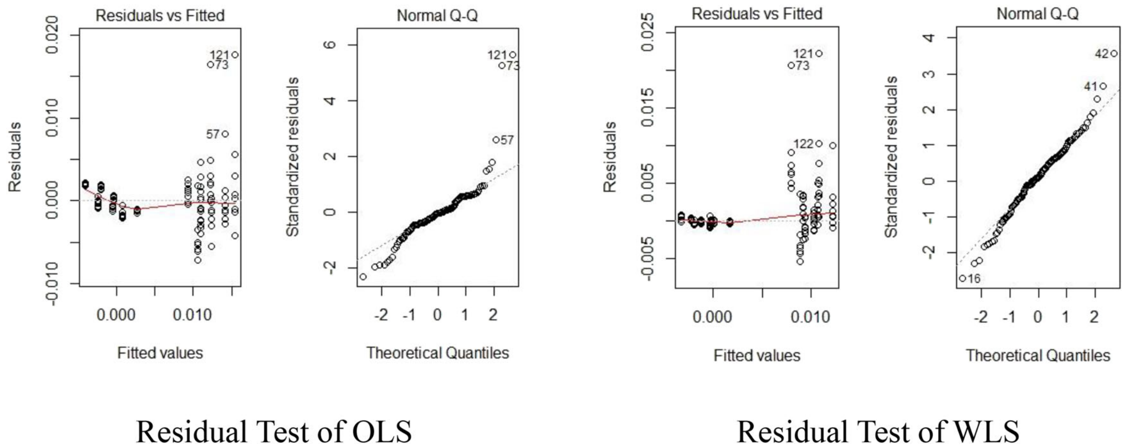

FIGURE 11. Residual Diagnosis of Model 1.

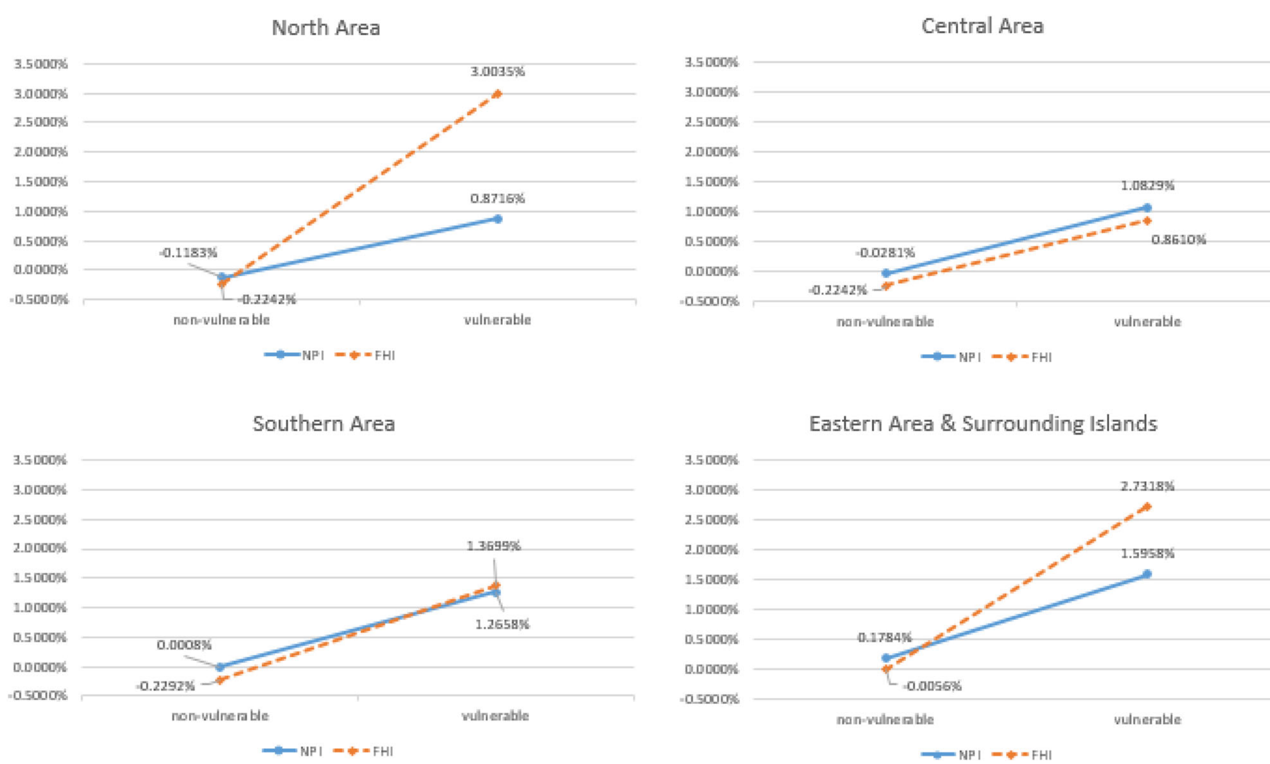

FIGURE 12. The Mortality Differential of NPI and FHI in Underprivileged Groups.

$$D_{type,weak,area,t} = \beta_0 + \beta_1 x_{type} + \beta_2 x_{weak} + \beta_3 x_{type} x_{weak} + \sum_{area} \beta_{area} x_{area} + \beta_4 x_{type} x_{area} + \beta_5 x_{weak} x_{area} + \beta_6 x_{type} x_{weak} x_{area} + \varepsilon_{type,weak,area,t}. \tag{2}$$

Figure 11 indicates that the residuals of ordinary least square (OLS) regression fail the assumption of constant variance and normality. On the contrary, the residuals of weighted least square (WLS) regression weighted by the number of exposures $w_{type,weak,area,x,t}$ do not reject the hypothesis that they are normally distributed and have constant variance.

The results of empirical analysis are shown in Table 6. Comparing to OLS, WLS achieves higher goodness of fit in terms of R-squared, which supports the use of WLS. Model 2 achieves a higher R-squared than that of Model 1. Most of the

TABLE 6
Regression Analysis of Mortality Differential

	Model 1 (OLS)		Model 1 (WLS)		Model 2	
Variable	β	p Value	β	p Value	β	p Value
Intercept	–0.00048	0.52603	–0.00123	<0.0001**	–0.00118	<0.0001***
Type	–0.00196	0.01575	–0.00203	<0.0001**	–0.00155	<0.0001***
Weak	0.01141	<0.0001**	0.01061	<0.0001**	0.00949	<0.0001***
Central area	–0.00158	0.05084	0.00094	<0.0001**	0.00090	<0.0001***
Southern area	0.00009	0.90936	0.00129	<0.0001**	0.00117	<0.0001***
Eastern area and surrounding islands	0.00322	<0.0001**	0.00287	<0.0001**	0.00265	<0.0001***
Type×weak	0.00326	0.00473	0.00060	0.37787	0.00762	<0.0001***
Type×central area					–0.00026	0.48111
Type×southern area					–0.00077	0.03830*
Type× eastern area and surrounding islands					–0.00064	0.33424
Weak×central area					0.00104	0.00287**
Weak×southern area					0.00257	<0.0001***
Weak×eastern areaand surrounding islands					0.00248	<0.0001***
Type×weak×central area					–0.01074	<0.0001***
Type×weak×southern area					–0.00666	<0.0001***
Type×weak×eastern area					–0.00221	0.38609
R^2	86.22%		96.77%		98.56%	
Adjustment R^2	81.80%		96.61%		98.36%	

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

mentioned variables in model 1, such as *type*, *weak*, and *area*, are still significant. Specially, the interaction *type* × *weak* becomes significant, accompanied by the *area* factor. This is the so-called Simpson Paradox, which implies that the interaction *type* × *weak* varies by area factor.

To examine Model 2, we take the average of $D_{type,weak,area,t}$ for each combination of *type* × *weak* × *area*, as presented in Figure 12. Accordingly, the difference for the increases in $D_{type,weak,area,t}$ with *weak* between *type* FHI and NPI in the northern area is higher that for the central, southern, and eastern and surrounding island areas, which coincides with the negative and decreasing-magnitude coefficients of interaction *type* × *weak* × *area* of Model 2 in Table 7.

4. 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 the mortality differential on the public pension plans. One of the motivations for such interest is that most of Taiwan's public pension plans used almost identical mortality assumptions (i.e., the 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 programs.

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 normalizing by the Lee–Carter model and removing the age and time effects, a mortality differential does exist. First, 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 a mortality differential with respect to residential areas. People living in cities usually have more medical and social resources, and thus they tend to live longer.

In terms of policy implications, the significant negative effect of *type* indicates that FHI is subject to a higher annuity cost than NPI. This may indicate that employment status is related to higher mortality rate, since the NPI insureds are unemployed temporarily or permanently. Also, the apparent mortality difference between NPI and FHI implies their annuity costs are different. Therefore, we suggest the Taiwan government treat NPI as a compulsory insurance program rather than a voluntary insurance program.

The analysis result for the factor *weak* implies that a lower annuity cost is associated with the people with poor economic status and unhealthy physical condition, that is, the people requiring more protection. We suggest that the premium subsidy can be connected to the annuity costs in terms of *weak*. For the factor *area*, the analysis results imply a higher mortality rate or lower annuity cost for the southern and eastern areas, comparing to those of the northern and central areas. The premium payment rates among the insureds of the northern, central, southern, and eastern areas also follow similar order, at 29.9%, 13.2%, 14.3%, and 1.5%, respectively. Accordingly, the areas with lower annuity costs (such as southern Taiwan) suffer an unwillingness to pay the premium, which may indicate the antiselection noted by Hosseini (2015).

In addition to policy implications for social security, the analysis results of *type* and *weak* in this study may provide implications for commercial insurance as well. For example, we can use the results in, for example, underwriting and risk classification, and make the insurance products more competitive in pricing.

ACKNOWLEDGMENTS

We appreciate the insightful comments from the editor and two anonymous reviewers, which helped us to clarify the context of our work.

FUNDING

This research was supported in part by a grant from the Ministry of Science and Technology in Taiwan, MOST 108-2410-H-004-076.

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