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Pension Reform in Taiwan: A Macroeconomic Analysis

Yu-Hsiang Cheng, Huan-Chih Lin, and Atsuko Tanaka*

This paper quantifies the fiscal costs of different policy reforms in Taiwan that achieve the goal of a self-financed pension system. We build a general equilibrium life-cycle model with endogenous labor supply on both intensive and extensive margins, consumption, savings, and benefit claiming. We conduct counterfactual analysis to evaluate the impacts of various reforms that could balance the pension budget while taking current demographic changes into account. We find that the pension system can be self-financed if the government (i) increases income taxes by 5.4%, (ii) increases consumption taxes by 6.2%, (iii) increases pension taxes by 9.3%, or (iv) decreases the pension benefits by 23.5%. We also compare our results with those from a partial equilibrium model, often used in the existing studies. The comparison highlights the importance of the general equilibrium effects and indicates that partial equilibrium analysis underestimates the negative effects on the labor supply.

Keywords: pension reform, labor supply, intensive margin, extensive margin
JEL classification: E2, E6, H5, J2

*The authors are the staff of Public Utilities Section, Department of Public Works, Keelung City Government, Assistant Research Fellow of Institute of Economics, Academia Sinica, Assistant Professor of Department of Economics, University of Calgary. Correspondence: Hsuan-Chih (Luke) Lin, email: linhc@econ.sinica.edu.tw. We are grateful to two anonymous referees, Hung-Jen Wang, Yiting Li, Hung-Ju Chen, Pei-Ju Liao, Wei-Cheng Chen, Hsuan-Li Su, Tzu-Ting Yang and seminar participants at National Taiwan University, National Chengchi University, the Macro-econometric Modeling Workshop 2016, 2017 Conference on Health and Development, and 2017 Conference on Methods and Applications for their useful suggestions and warm encouragement. Hsuan-Chih Lin also thanks Ministry of Science and Technology for financial support (MOST 106-2410-H-001-017). All errors are ours.

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1 Introduction

With aging demographics and generous pension programs, fear of fiscal consequences has attracted public attention and motivated policymakers to consider different possible reforms in many developed countries. In Taiwan, predicted future deficits associated with pension programs are substantial. If no reform is implemented, most pension programs will go bankrupt within 15 years. Numerous discussions and analyses on different reform options have taken place. To evaluate the costs of different proposed reforms, we need a model with endogenous labor supply and benefit claiming in the general equilibrium framework. However, existing studies have considered the reforms by taking the labor supply responses as given. Our paper complements these studies by taking endogenous responses into account and examining the solvency of the system in the long run.

This paper analyzes the fiscal costs of different policy reforms by considering a general equilibrium life-cycle model with endogenous labor supply. In the model, an agent enters an economy with an aging population and a generous pension program. Facing both idiosyncratic and aggregate shocks, the agent makes decisions about labor supply in both intensive and extensive margins, consumption, savings, and benefit claiming. Unlike the existing studies using partial equilibrium analysis, our model allows us to study how agents react to the pension program reform by adjusting their labor supply. We find that regardless of the type of reforms, the effects on macroeconomic indicators and labor market outcomes are qualitatively similar. However, the quantitative effects differ to a great extent. Among the reforms, a consumption tax achieves the goal of a self-financed pension system with the least distortion and the highest ex-ante welfare.

The main challenge in evaluating pension reforms lies in the complexity of the pension system. In many countries, the pension system offers agents various programs in relation to benefit claiming and the timing of their retirement. In analyzing the pension reforms, the Taiwanese pension system gives us an advantage since all the existing pension programs have similar properties. Owing to little heterogeneity across programs, we can capture the Taiwanese pension system by modeling one pension program, called the labor insurance annuity. The labor insurance annuity is the largest program, and covers more than 65% of workers. As in the major pension systems in other countries, the Taiwanese pension program aims at providing insurance after retirement and adopts the pay-as-you-go system, whose benefit

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payment is calculated based on workers' average past earnings. As such, although we tailor our analysis to the Taiwanese system, the implication is applicable to other countries.

Motivated by recent policy discussions, this paper considers the following five options that will self-finance the pension system every year: (i) increasing the income tax, (ii) increasing the consumption tax, (iii) increasing the pension tax, (iv) reducing the pension benefits, and (v) deferring the retirement age. We find that additional taxation ranging from 5.4% to 9.3% or reduction of pension benefits by 23.5% is needed in order to balance the budget.

Our analysis also shows that macroeconomic indicators and labor market outcomes respond substantially to different options; for example, we find that reductions in pension benefits affect the agents' responses the most through a large increase in interest rates, while financing through consumption tax has the least impact, with little effect on interest rates and highest ex-ante welfare. We also find that deferring the pension eligibility age alone does not have a big impact on individuals' decisions in the extensive margin, although the impact happens mostly on the intensive margin. The reason behind this is because worker productivity drops substantially after age 55, and deferring the eligible age is not effective in retaining workers in employment. Thus, deferring the retirement age needs to be combined with other policy reforms to achieve a self-financed pension system.

To highlight the importance of the general equilibrium analysis, which is often ignored in existing studies, we re-conduct each reform under the partial equilibrium framework. Our simulation analysis shows that, regardless of the type of reforms, a decline in the labor force participation rate is much more severe in the general equilibrium framework than in the partial equilibrium framework. Such difference arises because, in the general equilibrium framework, workers respond to the changes in taxation (or retirement age) by adjusting worked hours and savings accordingly. For example, when the tax rate increases (or pension benefit decreases), workers work longer hours and save more in the early stage of their lives so that they can avoid paying tax by stopping working earlier. We conclude that the existing papers using the partial equilibrium framework might underestimate the negative effects of the pension reforms on labor supply.

This paper contributes to the recent discussions on the pension reform in Taiwan by taking into account labor supply response to the reform. The existing papers that analyze the Taiwanese pension reforms take consump-

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tion, savings, benefit claiming, and responses to labor supply as exogenously given, and thus cannot evaluate the long-term consequences of the reform. Many papers regarding the reform can be found in the recent special issue on pension reform at Taiwan Economic Forecast and Policy. To name a few, Wang et al. (2017) study pension reform and analyze how to build a financially sustainable pension system which will maintain at least 30 years' financial adequacy. Tung and Hsieh (2017) apply the generational accounting method to 2014 NTA data and official population projections, and calculate the generational accounts under different scenarios. Shao and Fu (2017) show that multipliers of benefits to contribution vary across generations, ranging from 11 to 38; the earlier into the system, the higher the multiplier. All of these papers use a partial equilibrium framework, which takes the current individuals' responses as given, and hence any endogenous effects cannot be captured. Although Hsu and Liao (2015) study the labor supply responses to the reforms in Taiwan, they look at the national health insurance program. To the best of our understanding, ours is the first analysis of the Taiwanese pension program using a general equilibrium framework.

While our model is tailored to the specific pension system in Taiwan, we contribute to the literature on the pension system by evaluating various reform options under the solvency of the system. Similar issues have been addressed using a general equilibrium framework in the literature studying other countries such as the U.S. or Japan. For example, Kitao (2014) studies the four options that make the social security system in the United States sustainable by considering the general equilibrium effects. Imrohoroglu and Kitao (2012) also use the U.S. data and consider the solvency of the security system with flexibility on benefit claiming. Imrohoroglu, Kitao, and Yamada (2016) apply a similar approach but consider the reform in Japan. Unlike these papers, our paper focuses on comparing various pension reforms, motivated by recent discussions on this topic in Taiwan. In particular, the analyses on the consumption tax, the pension tax, and the pension benefits are new to the literature. In doing so, we highlight that the impacts of a pension reform greatly differ, depending on the type of reforms with respect to the extent of distortion and work disincentive effects. We find that increasing a consumption tax is the most effective way to achieve a self-financed pension system, in that labor supply and savings decisions are less distorted with highest ex-ante welfare, compared to other policy tools (e.g. increasing income tax, increasing pension tax, and decreasing pension

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benefits). While the results are intuitive, our analysis shows the quantitative difference is substantial because the distortion effects are magnified through an upward adjustment of the interest rates.

The rest of the paper proceeds as follows. Section 2 lays out the model, while data and calibration are summarized in Section 3. Section 4 presents the results, and we conclude in Section 5.

2 Model

We build a general equilibrium model in which the tax and social security system are tailored to the systems in Taiwan, by modifying the model in Imrohoroglu and Kitao (2012). There is no aggregate uncertainty in this model, but households face idiosyncratic productivity shocks under a life-cycle model. The model captures how workers endogenously make decisions on labor supply in both intensive and extensive margins, consumption, savings, and benefit claiming.

2.1 Demographics

The economy is populated by overlapping generations of individuals of age $j = 1, 2, \cdots, J$, where J is the maximum possible age. The lifespan is stochastic, where an individual of age j at time t survives until the next period $t + 1$ with probability $s_{j,t}$. The rate of new cohorts entering the economy is n_t.

2.2 Individuals

An individual enters the economy with no assets. For each time t, each individual is endowed with one unit of time, which can be used for market work or leisure. Assuming the individual allocates l unit of time to work, the wage is given by $wz\eta_j l$, where w is the market wage, z is the idiosyncratic labor productivity which follows the first-order Markov process, η_j is the age-specific productivity, and l is the labor hours.

In addition, an individual values consumption and leisure over the life cycle, which utility function is denoted as $u(c, l)$. We assume "warm-glow" utility from leaving bequests, denoted as $u^B(\cdot)$. For simplicity, the government collects bequests and distributes them to the individuals as a lump-sum

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transfer b to the entire population. The discount factor is denoted as β. We further assume that individuals cannot borrow from their future earnings.

2.3 Technology

Production is operated by a representative firm following the constant return to scale technology

$$Y_t = AK_t^{\alpha} L_t^{1-\alpha}, \tag{1}$$

where K_t and L_t are the aggregate capital and labor inputs at time t, and α is the capital share. A denotes the total factor productivity, and capital depreciates at the rate $\delta \in (0, 1)$. We follow the usual competitive market assumption, where firms rent capital and labor units from individuals in a competitive market, denoting r_t and w_t as the factor prices that are equated to marginal productivities.

2.4 Pension system

The basic structure is a pay-as-you-go pension system similar to the current system in Taiwan. The difficulty of modeling the pension system is that Taiwanese pension system has different non-exclusive coverage across occupations and cohorts. To address the complexities of the system, we model the labor insurance annuity in Taiwan, as other systems follow a similar payment schedule.[1]

As for workers' options, the model's features follow closely the current labor insurance annuity. We assume that the individuals decide the amount of the base benefits they would like to accumulate and when to retire. The individuals are allowed to continue working even after claiming retirement.

Specifically, a proportional pension tax τ^{ss} is imposed on the earnings of working individuals up to the maximum amount of y^{ss}. The normal retirement age is j^N. Individuals can begin to receive pension benefit ss once they reach the earliest claiming age j^E. The benefit is adjusted downward if it is claimed before the normal retirement age of j^N, and upward if the claim is postponed after the normal retirement age.

[1] The difference mostly lies in replacement ratios.

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2.5 Government

The government raises revenue from taxation on income $T(\cdot)$; pension tax on earnings τ^{ss}; consumption tax at rate τ^c; and issuance of risk-less debt D_{t+1}. The revenue finances the payment of the pension benefits ss, expenditure of government transfer tr, and the repayment of the debt from the previous period D_t at the interest rate r_t. The government transfer program follows exactly that in Taiwan, which guarantees any individual a minimum consumption level $\underline{c}$. In addition, government spending on programs other than those described above is denoted as G.

2.6 Individuals' problem

Individuals are heterogeneous in five dimensions summarized by a state vector $x = \{j, z, a, e, i\}$, where j denotes age, z is idiosyncratic labor productivity, a are the assets carried over from the previous period, e represents the amount of pension benefits for each individual, and i is an indicator that takes a value of 1 if an individual has already applied for pension benefits and 0 otherwise. The distribution of x is denoted as $\mu(x)$. An individual enters the next period with a new state vector $x' = \{j+1, z', a', e', i'\}$.

The timing of events is given as follows. The individual enters the economy with a state vector x. If the individual's savings a are not enough to cover the minimum consumption $\underline{c}$, the government intervenes through a transfer tr so that all the individual's consumption meet the minimum requirement $\underline{c}$. Then, the individual makes decisions on c, l, i' as the consumption and labor choices, as well as whether to claim retirement this year. The consumption and labor choices will affect the cumulated labor earning e' in the next period. If the individual claims retirement, the state e summarizes the amount of eligible pension benefits. At the end of the period, the idiosyncratic productivity z' is realized. Hence, conditional on survival, the individual enters the next period with a new state vector $x' = \{j+1, z', a', e', i'\}$.

Following the standard convention, we model the individual's program recursively. The value function is given by

$$V(x) = \max_{c,l,i'} \left\{ u(c,l) + \beta E \left[s_j V\left(x'\right) + \left(1 - s_j\right) u^B\left(a'\right) \right] \right\}, \qquad (2)$$

subject to

$$tr = \max\left\{0, \left(1+\tau^c\right)\underline{c} - a\right\}, \qquad (3)$$

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$$k = a + tr - c\left(1 + \tau^c\right), \tag{4}$$

$$a' = (1 + r)k + z\eta_j lw - T\left(rk + z\eta_j lw\right) - 1_{i=0} \cdot \tau^{ss} \min\left\{z\eta_j lw, y^{ss}\right\} + ss(x) + b, \tag{5}$$

$$a' \geq 0, \text{ and} \tag{6}$$

$$e' = f\left(e, z\eta_j lw\right). \tag{7}$$

2.7 Competitive Stationary Equilibrium

In this paper, the goal is to discuss how each reform helps to achieve a self-financed pension system. To do so, we define the competitive stationary equilibrium that has to be satisfied in the benchmark model.

Given a set of demographic parameters $\{s_{j,t}\}_{j=1}^{J}$, $\{n_t\}$, and government policy variables $\{G_t, D_t, ss_t, y^{ss}, \tau_t^{ss}, T(\cdot), \tau_t^c\}$, a competitive equilibrium consists of individuals' decision rules $\{c_t(x), l_t(x), i_t'(x)\}$ for each state vector x, factor prices $\{r_t, w_t\}$, consolidated income tax $\{T(\cdot)\}$, bequest transfer $\{b_t\}$, and the density over state space $\{\mu_t(x)\}$ such that:

1. Individuals' decision rules solve the recursive optimization problem defined in section 2.6.
2. Factor prices are determined competitively. That is,

$$r_t = F_K(K, L) - \delta = \alpha A_t \left(\frac{L_t}{K_t}\right)^{1-\alpha} - \delta, \tag{8}$$

$$w_t = F_L(K, L) = (1 - \alpha) A_t \left(\frac{K_t}{L_t}\right)^{\alpha}. \tag{9}$$

3. Lump-sum bequest transfers equal the amount of assets left by the deceased:

$$b_t = \sum_x a_t(x)\left(1 - s_{j,t-1}\right)\mu_{t-1}(x). \tag{10}$$

4. Labor and capital markets clear:

$$K_t = \sum_x k_t(x)\mu_t(x) - D_t, \tag{11}$$

$$L_t = \sum_x z\eta_j l_t(x)\mu_t(x). \tag{12}$$

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5. The goods market clears:

$$\sum_x c_t(x)\mu_t(x) + G_t + K_{t+1} = Y_t + (1-\delta)K_t. \tag{13}$$

6. The parameters in the tax functions satisfy the government budget constraint:

$$\begin{aligned} &G_t + (1+r_t)\, D_t + \sum_x ss_t(x)\mu_t(x) + \sum_x tr(x)\mu_t(x) \\ &\quad = \sum_x \Big[T\left(z\eta_j w_t l_t(x) + r_t k_t(x)\right) + \tau_t^{ss} \min\left\{z\eta_j w_t l_t(x),\, y^{ss}\right\} \\ &\quad + \tau_t^c c_t(x)\Big]\mu_t(x) + D_{t+1}. \end{aligned} \tag{14}$$

7. The distribution $\mu_t(x)$ is stationary.

3 Data and Calibration

In this section, we will describe the parameterization of the model. To analyze the self-financed pension system in Taiwan, we match the moments from the Taiwanese economy in the 2000s. To be specific, we match the selected moments with those from the model. Table 1 summarizes the calibrated parameters, and more details will be discussed below.

Demographics

One period corresponds to a year. We assume that individuals enter the economy at age 20 ($j = 1$) and live up to 100 years ($J = 81$). The growth rate of the population is set to be 1.91, the growth rate at the year 2015. The conditional survival probabilities by age are also taken from the year 2015.[2] Figure 1 shows the conditional survival probability that we use in the benchmark model.

Preferences

We assume that period utility takes the form:

$$u(c,l) = \frac{\left[c^{\gamma}\left(1-l-1_{i=1}\phi\right)^{1-\gamma}\right]^{1-\sigma}}{1-\sigma}. \tag{15}$$

[2]Please refer to National Development Council for details.

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Table 1: Parameters of the model

Parameter	Description	Value/source
Demographics		
n	population growth rate	0.91% (MOI[1])
$\{s_j\}_{j=1}^{J}$	conditional survival probabilities	MOI
J	maximum age	81 (100 years old)
Preference		
β	subjective discount factor	0.992 (Liu, Meng, and Wang (2014))
γ	weight on consumption	0.363
σ	curvature parameter	4.0
ϕ_1	weight on bequest utility	400.0
ϕ_2	curvature of bequest utility	NT$12,800,000
Labor productivity process		
z	idiosyncratic shocks	PSFD
η_j	age-dependent labor productivity	PSFD
ϕ	fixed cost of working after retirement	56.3
Technology		
α	capital share of output	0.34 (DGBAS[2])
δ	depreciation rate of capital	0.0905 (Liao (2011))
A	scale parameter	1.66
Government		
τ^c	consumption tax rate	5%
$T(\cdot)$	personal income tax	Consolidated income tax in 2014
D	government debt	0.264 (CBT[3])
τ^{ss}	pension tax rate	8.1%
j^N	normal retirement age	41 (60 years old)
j^E	earliest retirement age	36 (55 years old)
y^{ss}	maximum taxable earnings for pension	NT$549,600
$\underline{c}$	consumption floor	NT$150,000

Note: 1: Ministry of Interior. 2: Directorate-General of Budget, Accounting and Statistics. 3: Central Bank of Taiwan.

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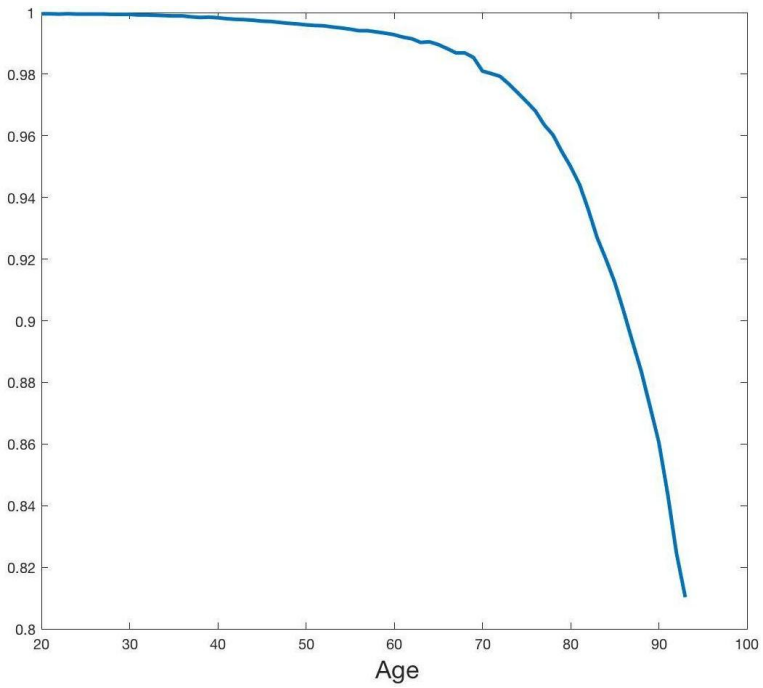


Figure 1: Conditional Survival Probability

γ determines the weight on consumption relative to leisure, which we calibrate so that workers, on average, spend eight hours per day doing market work. We set the value of σ at 4.0, which implies a coefficient of relative risk aversion at 2.17, in line with the macroeconomic literature on consumption. ϕ represents the fixed cost of labor force participation after claiming retirement, which value we set at 0.183 so that workers on average retire at age 56.3, the average retirement age in the 2012 annual report from the Ministry of Labor.

Utility from leaving a bequest a' is defined as

$$u^B(a') = \phi_1 \frac{\left(\phi_2 + a'\right)^{\gamma(1-\sigma)}}{1-\sigma}, \tag{16}$$

ϕ_1 represents the weight on the utility from bequeathing, which we calibrate so that on average the savings by an individual at age 65 is 2.8 million New Taiwan dollars. The parameter ϕ_2 affects the curvature of the utility from

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bequeathing. We set this number to be NT$12,800,000, which lies in the estimates from the literature in French and Jones (2011). The subjective discount factor β is set as 0.992, the estimated value from Liu, Meng, and Wang (2014).

Labor Productivity Shocks

There are two parameters that govern the labor productivity shocks over different cohorts: the deterministic, age-dependent labor productivity η_j and the idiosyncratic shock z. Both parameters are calculated using the Panel Study of Family Dynamics (PSFD) data. We will use the data from 2000 to 2010 and calculate the yearly average. Since the labor insurance system mainly targets blue-collar workers, we restrict our sample to blue-collar workers.

First, we calculate the deterministic, age-dependent labor productivity η_j following the method from Hansen (1993). Let HE_j denote the hourly earnings for the cohorts with age j and HE denote the average hourly earnings for all cohorts. In order to adjust the hours of work across different cohorts, we compute η_j as follows:

$$\eta_j = \frac{HE_j}{HE}. \tag{17}$$

We assume that $\eta_j = 0$ for $j \geq 51$ (70 years old) and no one works after age 70. The derived age-dependent labor is shown in Figure 2.[3]

Second, we use the household income data from 2000 to 2010 to calculate the states of the labor productivity shocks and the corresponding transition probabilities. The states and transition probability are reported in Tables 2 and 3, which are used to approximate the idiosyncratic component z. In other words, we approximate the continuous process z with a four-state Markov process.

Technology

The income share of capital is set at 0.34, which is the value taken from the Directorate-General of Budget, Accounting and Statistics (DGBAS). The

[3]We can observe that the age-specific labor efficiency at age 70 is higher than at age 65 due to measurement errors, since the sample of blue-collar workers at age 70 is smaller. The impact of this abnormal trend is minor and does not affect the main result.

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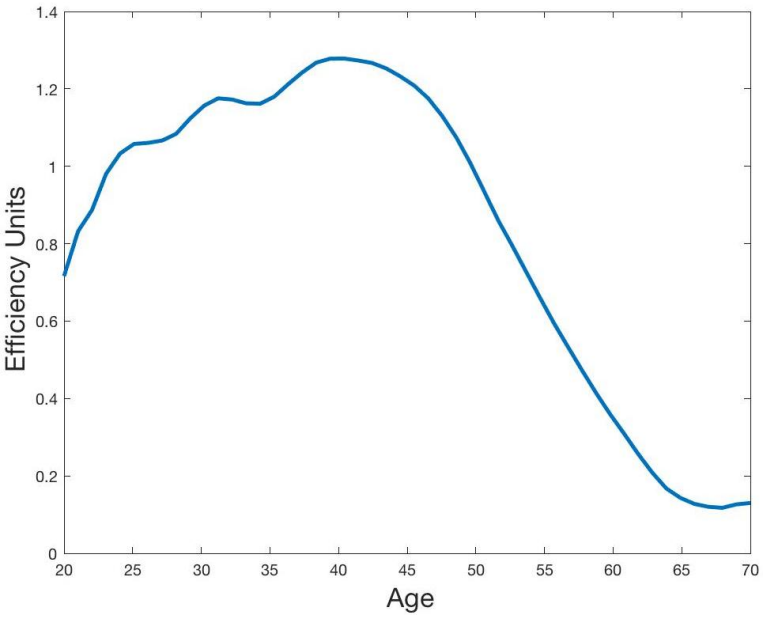


Figure 2: Age-Specific Labor Efficiency Profile. Source: PSFD and author's calculation

Table 2: States of Labor Productivity Shocks

State	Income Range	Average (NT$ in 2005)	As of Sample Mean (2005)
State 1	0–5%	13,171	0.34
State 2	25–50%	26,574	0.68
State 3	50–75%	38,011	0.97
State 4	75–100%	78,697	2.01

Source: PSFD and author's calculation.

depreciation rate of capital is taken from Liao (2011). A is used such that the aggregate output in the benchmark economy is normalized to 1.

Government

Pension System. The pension benefit is calculated as a concave function of an individual's past earnings. As described in Section 2.4, the Taiwanese

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Table 3: Transition Probabilities of Labor Shocks

	State 1	State 2	State 3	State 4
State 1	0.6795	0.1937	0.0799	0.0468
State 2	0.1753	0.5055	0.2383	0.0809
State 3	0.0714	0.1876	0.5121	0.2288
State 4	0.3796	0.0606	0.1196	0.4402

Source: PSFD and author's calculation.

labor insurance formula is complicated. First, the government records each individual with a maximum of five years of earnings, with a lower bound and upper bound. Then the individual is able to choose one of the two formulas that are used to calculate the benefits, both of which relate to the individual's work history. We adopt a similar procedure in this model. First, we keep track of the average past earnings of the individuals, e, which is the average monthly insurance salary. Second, we assume the insured person will select their benefits as the following option:[4]

$$\text{Benefits} = \text{Average Monthly Insurance Salary} \times \text{Coverage Years} \times 1.55\%.$$

Next, we describe how to calibrate e and how to determine the benefits in the model. Since it is computationally difficult to keep track of the entire work history of an individual, we use a concave function to calculate the average monthly insurance salary. The detailed formula is calculated as

$$e' = \frac{(j-1) * e + \frac{z\eta_j lw}{12}}{N} \times 12. \tag{18}$$

This formula captures how the benefits, if workers claim the benefits in the next year, relate to the benefits if workers claim the benefits in the current year. The benefits increase for each additional covered year by $(j-1)*e$ and also reflect changes in the labor earnings $z\eta_j lw/12$. In the actual pension system, we observe that the benefit in the next year increases by 1.55% if the average salary remains the same. Hence we set $N = 60$ so that the increase

[4]Although the insured person can select one of the better options as described in Appendix 5, the individual will select the second option if they contribute to the pension program for more than 10 years.

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in benefits matches the actual benefit increase for each additional covered year.

In Taiwan, workers can begin to receive the pension benefits if they reach the earliest claiming age j^E. As for the coverage years, the benefits are adjusted downward if they are claimed before the normal retirement age j^N and upward if the claim is postponed until 5 years after the normal retirement age. We set the earliest claiming age to be 55 and the normal retirement age to be 60. Retirement benefits depend on age at retirement; the benefits increase by 4 percent if a worker delays retirement by one year.

Transfer, Taxes, Expenditures, and Public Debt. The minimum consumption floor $\underline{c}$ is set at NT$150,000, which corresponds to the monthly minimum living standard of NT$12,500, from the Ministry of the Interior. The government debt D is set at 26.4 percent of the output, which is the average ratio from the Central Bank of Taiwan between 2010 and 2015 and is adjusted by the proportion of workers under labor insurance. The consumption tax is set at 5%, which is the consumption tax rate implemented in Taiwan. For income taxation, we employ a consolidated tax schedule by assuming each individual files taxes as a single worker. That is, we assume each individual has the same deductibles as if he/she were single, and we adopt the 2015 tax rate level. Residuals from the government budget are assumed to be the expenditures of the government (G).

4 Quantitative Analysis

To study different ways to achieve a balanced pension budget, five scenarios are explored. Actions are either to (i) increase the income tax, (ii) increase the consumption tax, (iii) increase the pension tax, (iv) decrease the pension benefits, or (v) defer the retirement age. These five actions are possible reforms that the Taiwanese government considers in order to achieve a balanced pension budget. Official reports about the Taiwanese pension system can be found at the Ministry of Civil Service. This Ministry only releases the reports on the Public Service pension reform, since the details have been recently released. The consequences of these actions will be compared to the steady state equilibrium, conditional on having a balanced pension budget.

The benchmark economy is calibrated to match the Taiwanese economy in the 2000s. In particular, the model shows that the steady state interest rate is 1.56%, and the pension budget balance is around -3.6% of the GDP. In the benchmark economy, around 33% of the workers retire at age 55, and

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10% of them continue to work after retirement. Properties of the steady state equilibrium are presented in the first column of Table 4.

4.1 Policy Experiments

Reforms on the Taxations or the Pension Benefits

We begin by considering the policy experiments as the government increases taxation or reduces the pension benefits. As for the increase in the taxation, we consider the first four cases: an increase in the income tax τ^y, an increase in the consumption tax τ^c, or an increase in the pension tax τ^s, and reducing the pension benefits. All of these actions are analyzed under the condition when the pension budget is balanced.

Our interest is to achieve a self-financed pension system through policy reform. We define the system as self-financed when pension benefits paid equal tax collected. Of course it is natural to only consider the tax collected coming only from the pension tax. However, we assume that the government is able to finance the tax through other policy tools, such as income tax or consumption tax. In other words, we allow the government to allocate a fixed portion of the consumption tax or the income tax to the pension fund and consider how much reallocation is needed. These scenarios are interesting because the government might achieve a self-financed system with lower cost with a particular policy tool when we consider endogenous responses on labor supply, consumption, savings, and benefit claiming.

To illustrate how to balance the budget, we take the increase in the income tax as an example. The government's budget constraint can be expressed as:

$$\begin{aligned} G_t + (1+r_t)\, D_t + \sum_x ss_t(x)\mu_t(x) + \sum_x tr(x)\mu_t(x) \\ = \sum_x \left[T\left(y_t(x) + r_t k_t(x)\right) + \tau^y \left[y_t(x) + r_t k_t(x)\right]\right. \\ \left. + \tau_t^{ss} \min\left\{y_t(x),\, y^{ss}\right\} + \tau_t^c c_t(x)\right] \mu_t(x) + D_{t+1}, \end{aligned} \tag{19}$$

subject to having a balanced pension budget:

$$\begin{aligned} \sum_x ss_t(x)\mu_t(x) = \sum_x \left[\tau^y \left[y_t(x) + r_t k_t(x)\right]\right. \\ \left. + \tau_t^{ss} \min\left\{y_t(x),\, y^{ss}\right\}\right] \mu_t(x). \end{aligned} \tag{20}$$

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In other words, the outflow of the pension funds is the benefits paid, but inflow comes from the pension tax as well as the additional income tax τ^y that has been collected from income but allocated to the pension fund. The changes in the budget constraint for the other reforms can be written in a similar manner.

In the benchmark model, we include the residual term, G, in the government budget constraint. This term captures the residuals that are "thrown into ocean" and play a role to balance the budget. In other words, we allow G to be different for all the reforms shown in Table 4 to Table 7. By keeping the residual term flexible, we impose the same amount of tax as in the baseline model for all the experiments. It allows us to focus on the endogenous responses of an agent in the intensive and extensive margins. Indeed, one may be concerned that the government may adjust its expenditure in counterfactual cases. However, we argue that it is less of a concern by showing that having the residual terms flexible and fixed will produce similar results. In fact, we check the sensitivity of our results by allowing for the amount of tax that could change across different counterfactual reforms. In Section 4.3, we show the results of the case in which we balance the government budget under various reforms with the residual expenditures fixed. We allow the income tax rate to be adjusted. We find that the results are not sensitive to different modeling. We conclude that the effects of the "throwable" term are second-order. Thus, the main results come from the first-order effect of direct changes in the tax.

The results are summarized in the last four columns of Table 4. We compare the effects of the reforms as the changes relative to the benchmark economy, because we emphasize the differences across different steady states.

To achieve a self-financed system, additional income tax of 5.41% has to be imposed, while if the government finances the pension spending by a consumption tax, the additional tax rate is 6.21%. An additional of 9.03% in pension tax or the uniform reduction of 23.56% in the pension benefits is needed in order to achieve the same goal.

As for the macro aggregates, there is no significant change if the government finances the pension spending by a consumption tax, as the interest rate stays roughly the same as the benchmark model. We conclude that increasing the consumption tax is the most efficient way, in that it achieves a self-financed system with the least extent of distortion.

In contrast, financing the pension expenditure through income tax or pension tax will result in a significant distortion: reduction in capital, ex-

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Table 4: Effects of Pension Reforms

	benchmark	τ^y	τ^c	τ^s	ss
Capital (per capita)	—	−4.12%	−0.08%	−4.53%	+6.43%
Labor (per capita)	—	+2.19%	+0.04%	+1.44%	−3.16%
Average work hours	—	−0.22%	+0.41%	+2.88%	+2.66%
Wage	—	−2.17%	−0.04%	−1.42%	+3.26%
Interest rate	1.56%	2.02%	1.57%	1.86%	0.92%
Additional income tax rate τ^y	—	+5.41%	—	—	—
Additional consumption tax rate τ^c	—	—	+6.21%	—	—
Additional pension tax rate τ^s	—		—	+9.03%	—
Additional reduction in pension payments ss	—	—	—	—	−23.56%
SS budget balance (% of GDP)	−3.60%	−3.83%	−3.56%	—	—
Ex-ante Expected Welfare	—	−5.85%	−5.57%	−5.68%	−9.05%
Average retirement age	56.53	56.27	56.36	56.08	55.89
Average assets at 60 (NT$1,000)	3,447	3,174	3,396	3,285	3,895
	—	−7.93%	−1.49%	−4.71%	+12.99%
Retirement percentage					
at 55	33.50%	43.52%	41.69%	53.00%	47.18%
by 60	96.78%	96.03%	95.00%	96.43%	83.78%
by 65	99.37%	98.81%	98.15%	98.61%	84.36%
Labor force participation					
Age (ERA*) – 70	12.20%	10.49%	11.15%	9.08%	11.09%
Age 20 – (ERA*)	91.55%	90.02%	90.24%	89.81%	91.16%

Note: The percentage changes are expressed as the distance from the benchmark (first-column).
*(ERA): Early retirement age. **(NRA): Normal retirement age.
SS budget balance is the steady-state difference between pension tax collected and pension benefits paid.

tensive labor supply (labor force participation) and a rise in intensive labor supply (hours worked) compared to the benchmark case. Similarly, reductions in the pension benefits will lead to a large distortion, but in the opposite direction by pushing the steady state interest rate downward; this reform results in a substantial rise in capital and significant decrease in hours worked. The main difference arises from differential effects on workers' savings. Workers save less if (any kind of) taxes increase, while workers save more when the pension benefits decrease. The results are intuitive; if taxes

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are increased, the future income after retirement remains the same in the relative term; hence, workers reduce their savings by more in the early period without reducing consumption much. In contrast, when the benefits are reduced, workers expect to have less income after retirement and start consuming less and saving more to prepare for the post-retirement period. As a result, the equilibrium interest rate is lower owing to less savings if any taxation is being implemented, while the interest rate is higher owing to more savings if the pension benefits are reduced.

For the labor force participation, all of the reforms result in a decrease in labor force participation, but to a different extent. The change is least significant if the reduction of pension benefits is being implemented, while changing the pension tax affects the participation rates the most. Wages in the steady state equilibrium are lower if the taxation methods are adopted, while wages are higher if the government imposes reductions on the pension benefits.

To interpret these results, we compare to the partial equilibrium analysis used in existing studies. Note that the partial equilibrium analysis is conducted by keeping the behavior of the workers unchanged. From Table 4, workers' behavior is affected substantially in the general equilibrium framework. Compared to the benchmark model, workers' behavior responds to the changes the most if the reforms are being implemented through pension tax or pension benefits, while the reforms in the consumption tax affect workers' behavior the least. This implies that the additional consumption tax will result in a similar steady-state outcome, as the macro aggregates, labor market conditions and workers' behavior respond the least in the general equilibrium setting.

Reforms on the Retirement Age

Next, we consider the policy experiment of changing the early retirement age and normal retirement age simultaneously. In addition, we limit the options for a balanced pension budget to the additional income taxation for comparison to the benchmark model. Table 5 summarizes the results. We find that deferring the early retirement age or normal retirement age does not have a big impact on individuals' decisions in the extensive margins (the labor force participation rate) and in the macro aggregates. Instead, it affects mostly the intensive margins, as the age-specific efficiency units drop a lot after age 55 for blue-collar workers. For the ex-ante expected welfare, we

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Table 5: Effects of Extending the Retirement Age

	benchmark	(ERA*,NRA**) (55,60)	(ERA,NRA) (57,62)	(ERA,NRA) (60,65)
Capital (per capita)	—	−4.12%	−4.35%	−4.49%
Labor (per capita)	—	+2.19%	+2.64%	+2.39%
Average work hours	—	−0.22%	−1.81%	−4.50%
Wage	—	−2.17%	−2.27%	−2.34%
Interest rate	1.56%	2.02%	2.05%	2.06%
Additional income tax rate τ^y	—	+5.41%	+4.64%	+3.12%
SS budget balance (% of GDP)	−3.60%	−3.83%	−3.42%	−2.34%
Ex-ante Expected Welfare	—	−5.85%	−6.46%	−9.88%
Average retirement age	56.53	56.27	57.63	60.16
Average assets at 60 (NT$1,000)	3,447	3,174	2,975	2,374
	—	−7.93%	−13.71%	−31.14%
Retirement percentage				
at 55	33.50%	43.52%	0.0%	0.0%
by 60	96.78%	96.03%	94.80%	87.77%
by 69	99.37%	98.81%	98.63%	98.13%
Labor force participation				
Age (ERA*) – 70	12.20%	10.49%	5.99%	2.37%
Age 20 – (ERA*)	91.55%	90.02%	90.65%	90.77%

Note: The percentage changes are expressed as the distance from the benchmark (first-column).
*(ERA): Early retirement age. **(NRA): Normal retirement age.
SS budget balance is the steady-state difference between pension tax collected and pension benefits paid.

observe that deferring retirement age results in a substantial reductions.

These results indicate that workers' participation decisions do not respond much to changes in the retirement age, while the decisions of hours worked respond substantially. This finding tells us that deferring the retirement age helps to achieve a budget balance, at the cost of substantial change in the average work hours.[5]

[5]It is also interesting to consider the question: "How many years will the retirement age have to rise to balance the pension budget?" However, we have performed the analysis, and the results indicate that the budget is not going to be balanced if we require everyone to retire at age 70. The intuition is because the drop in the age-specific productivity as well as the decision of hours worked respond substantially to the changes in the retirement age.

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Table 6: Effects of Pension Reforms with Fixed Prices

	benchmark	τ^y	(ERA,NRA) (60,65)	$\tau^y(GE)$	(ERA,NRA) (60,65) (GE)
Average net of debt (% of GDP)	—	+10.31%	+7.89%	+18.26%	+14.85%
Capital (per capita)	—	−12.79%	−15.68%	−4.12%	−4.49%
Labor (per capita)	—	+0.00%	+0.00%	+2.19%	2.39%
Average work hours	—	−0.19%	−4.02%	−0.22%	−4.50%
Additional income tax rate τ^y	—	4.95%	3.20%	5.09%	3.12%
SS budget balance (% of GDP)	−3.60%	−3.60%	−2.16%	−3.83%	−2.34%
Average retirement age	56.53	56.59	60.18	56.27	60.16
Average assets at 60 (NT$1,000)	3,447	2,926	2,046	3,174	2,374
	—	−15.13%	−40.64%	−7.93%	−31.14%
Retirement percentage					
at 55	33.50%	32.21%	0.0%	43.52%	0.0%
by 60	96.78%	95.74%	85.70%	96.03%	87.77%
by 69	99.37%	98.91%	98.20%	98.81%	98.13%
Labor force participation					
Age (ERA*) – 70	12.20%	12.68%	2.52%	10.49%	2.37%
Age 20 – (ERA*)	91.55%	91.14%	91.73%	90.02%	90.77%

Note: The percentage changes are expressed as the distance from the benchmark (first-column).
*(ERA): Early retirement age. **(NRA): Normal retirement age.
SS budget balance is the steady-state difference between pension tax collected and pension benefits paid.

4.2 Effects of Price Changes: Partial Equilibrium Analysis

In order to understand the roles of the general equilibrium analysis, we simulate the results under fixed prices. That is, we keep the steady state interest rate and wages in the benchmark model unchanged. For simplicity, we demonstrate the differences from the benchmark model for the reforms on income taxation and deferring the retirement ages. Table 6 summarizes the results. For better comparison, we also list the results from the general equilibrium (GE) in the last two columns of Table 6.

We find that the average net of debt is much less in the partial equilibrium model, as the differences from the benchmark model is +10.31% or +7.89% to +18.26% or +14.85% in the general equilibrium price adjustments. Since the interest rate is fixed at an exogenous level, which is lower than the level in the general equilibrium framework, individuals save much less in the partial equilibrium framework. In addition, wages are fixed at a much higher level compared to the case of the general equilibrium level, and

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Table 7: Sensitivity Tests for Risk Aversion

	benchmark	$\sigma = 3.0$	$\sigma = 3.5$	$\sigma = 4.5$	$\sigma = 5.0$
Capital (per capita)	3.19	3.57	3.33	3.08	3.00
Labor (per capita)	0.26	0.26	0.26	0.25	0.25
Average work hours	0.32	0.32	0.32	0.31	0.31
Wage	2.59	2.68	2.62	2.56	2.55
Interest rate	1.56%	0.83%	1.30%	1.75%	1.87%
SS budget balance (% of GDP)	−3.60%	−4.06%	−3.61%	−3.68%	−3.73%
Average retirement age	56.53	56.51	56.36	56.49	56.56
Labor force participation					
Age (ERA*) – 70	12.20%	12.04%	11.90%	12.18%	12.31%
Age 20 – (ERA*)	91.55%	93.06%	91.64%	91.18%	90.72%

Note: The percentage changes are expressed as the distance from the benchmark (first column).
*(ERA): Early retirement age. **(NRA): Normal retirement age.
SS budget balance is the steady-state difference between pension tax collected and pension benefits paid.

an individual responds by participating more, which results in an increase in labor participation of around 1 percent (the difference between 91.10% and 90.02%). In the general equilibrium framework, workers respond to changes in taxation or retirement age by changing participation, worked hours and savings accordingly. If we restrict our attention to the partial equilibrium analysis, as mostly being conducted for any actuarial reports of the pension reform released by the government, we will underestimate the negative effects and might reach substantially different conclusions.

4.3 Robustness Checks

In this subsection, we will first run a sensitivity analysis to study how various parameter values affect the outcome of the model. Second, we will discuss how the assumption of flexible government expenditure affects the results.

As for the first experiment, we test whether the results are sensitive to risk aversion coefficient σ. Values between 3.0 to 5.0 on σ are tested. The results are summarized in Table 7, and imply that the qualitative outcomes remain unchanged.

Regarding the second concern on flexible government expenditure, we

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Table 8: Robustness Checks

	benchmark	τ^s	(ERA*,NRA**) (57,62)	(ERA,NRA) (60,65)
Capital (per capita)	—	−2.55%	2.11%	1.20%
Labor (per capita)	—	0.20%	−1.07%	−0.61%
Average work hours	—	2.92%	−1.01%	−3.90%
Wage	—	−0.29%	1.08%	0.62%
Interest rate	3.13%	3.18%	2.87%	2.98%
Additional income tax rate τ^y	13.61%	8.84%	11.87%	9.86%
Additional pension tax rate τ^s	—	+8.49%	—	—
SS budget balance (% of GDP)	−3.86%	—	−2.29%	−0.69%
Ex-ante Expected Welfare	—	−0.97%	−0.38%	−3.14%
Average retirement age	56.16	56.01	57.66	60.19
Labor force participation				
Age (ERA*) – 70	9.62%	8.98%	6.73%	4.04%
Age 20 – (ERA*)	88.07%	87.70%	88.20%	86.29%

Note: The percentage changes are expressed as the distance from the benchmark (first-column).
*(ERA): Early retirement age. **(NRA): Normal retirement age.
SS budget balance is the steady-state difference between pension tax collected and pension benefits paid.

conduct the following two experiments. First, we consider the tax reform on increasing pension tax (τ^s) to fully finance the pension payment with fixed government expenditure (G) and government debt (D). In addition, we allow the government to collect additional income tax τ^y to re-balance the budget. Second, we consider the similar retirement age reform without rearranging taxes for the pension budget with with fixed government expenditure (G) and government debt (D). We also assume that the government collects additional income tax τ^y to re-balance the budget.

The results are summarized in Table 8. Compared to the results in Table 4, the distortions are qualitatively similar. As predicted in the previous sections, all reforms are welfare reducing and the reform on the pension tax (τ^s) results in a significant distortion: reduction in capital, extensive labor supply and a rise in intensive labor supply. Thus, the qualitative results do not depend on whether the government expenditure is fixed or not. Although the quantitative results are slightly different from the previous analysis; in this

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sensitivity analysis, we find that the effective tax rate is higher. However, the difference is 4 percentage points and not large.

5 Conclusion

In this paper, we build a quantitative general equilibrium model of overlapping generations of individuals who make decisions on consumption, savings, labor supply on both extensive and intensive margins, and pension benefit claims. We focus especially on macroeconomic effects of various policy reforms toward a self-financed pension system.

We show that to self-finance the pension budget, a tax ranging from 5.4% to 9.9% has to be added, or the pension benefits must be slashed by 23%. However, agents respond differently to different reform options in terms of macroeconomic indicators and labor market outcomes. In addition, reforms to raise the retirement age can have a large impact on the Taiwanese pension system through changes in life-cycle savings and labor supply. We also highlight the importance of the general equilibrium analysis, as a partial equilibrium framework usually underestimates the costs of the reforms.

Note that this paper takes no stand on which reform options are better. The main purpose of this paper is to raise the concern that different reforms can have large impacts through changes in agents' life-cycle savings and labor supply. Most of the actuarial reports on pension reforms released by the government take the partial equilibrium approach, while this paper hopes to fill in the gap through analysis using a general equilibrium framework.

Appendix 1: Pension Systems in Taiwan

In this section, we will describe the four major pension systems in Taiwan– labor insurance, labor pension, public service pension, and national pension — and show the similarities all pension systems share. This explains why this paper focuses on the biggest pension system, the labor insurance system, and why we are able to understand the main driving forces behind all of the other pension programs.

Labor Insurance

The Labor Insurance Program was established in 1950. It was the first compulsory social insurance program in Taiwan. In 2015, the program cov-

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ered approximately 10 million laborers (the population in Taiwan is 23.4 million). The labor insurance program offers payments including old-age benefits, survivor benefits, occupational accident medical benefits, disability benefits, and maternity benefits. The program is supported by a pay-as-you-go system. The premium equals the insured salary of each insured worker times the premium rate. The current premium rate is 9%. For each insured worker, 70 percent of the premium is paid by the employer, 20 percent is paid by the insured worker, and 10 percent is paid by the government.

Since 2009, there are three types of payment for old-age benefits: Old-age Pension Benefit, Old-age Lump Sum Benefit, and One Time Old-age Benefit. After resigning from work and withdrawing from insurance coverage, an insured person can claim one of the three types of benefits if he/she meets the conditions required. The primary conditions for each type of benefit are as follows.

- Old-age Pension Benefit: An insured person who is at least 60 years of age with at least 15 years of insurance coverage.
- Old-age Lump Sum Benefit: An insured person who is at least 60 years of age with less than 15 years of insurance coverage.
- One-Time Old-age Benefit: An insured person who has insurance coverage before the enforcement of Labor Insurance Act on January 1, 2009, and meets one of the following conditions:
  - At least 60 years of age with at least 1 year of insurance coverage.
  - At least 55 years of age with at least 15 years of insurance coverage.
  - At least 50 years of age with at least 25 years of insurance coverage.
  - Insured in the same insured unit for over 25 years.

The payment standards of the three types of benefits are as follows:

- Old-age Pension benefit: The insured person can select the better option from the following two methods.
  - Average Monthly Insurance Salary[6] $\times$ Coverage Years $\times 0.775\% + 3,000$
  - Average Monthly Insurance Salary $\times$ Coverage Years $\times$ 1.55%

[6]The Average Monthly Insurance Salary is calculated by averaging the highest 60 months of Insurance Salary during the insurance coverage years.

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- Old-age Lump Sum Benefit: For every one full year of insurance coverage, one month of average monthly Insurance Salary[7] will be issued. For insurance coverage after 60 years of age, five years is the maximum to be included in the insurance coverage.
- One-Time Old-age Benefit: For every one full year of insurance coverage, one month of average monthly Insurance Salary[8] will be issued; should the total insurance coverage be more than 15 years, then for the term of coverage exceeding 15 years, 2 months of average monthly insurance will be issued for every one extra year of insurance coverage with the highest limit of 45 months. If the insured person is more than 60 years of age and continues to work, then the insurance coverage after 60 years would be counted as five years for the maximum.

An annuity-based system with relatively higher replacement ratio and low tax rates presents the common problems among all the systems in Taiwan. In addition, individuals are eligible to claim pension benefits at a relatively early age, 55, and individuals can continue to work afterwards. Since most of the pension systems in Taiwan share these similarities, we will focus on one of the largest systems, the labor insurance system, and study the effects of different policy reforms.

Labor Pension

The Old Labor Pension Program was established by the Labor Standards Act of 1984. On July 1, 2005, the Labor Pension Act was put into practice and the New Labor Pension System was established to replace the old one. Unlike the Labor Insurance Program, the New Labor Pension System is a fully funded system. Under the new Act, all employers are required to deposit 6% (or more) of a worker's monthly wages into an individual labor pension account managed by the Bureau of Labor Insurance, with ownership going to the worker. Workers adopting the new pension system may begin accumulating their pension accounts as their employers contribute to them. The accounts are portable and will be retained even if workers switch

[7]The Average Monthly Insurance Salary is calculated by averaging the highest 60 months of Insurance Salary during the insurance coverage years.

[8]The Average Monthly Insurance Salary is calculated by averaging the actual months of Insurance Salary starting from 3 years before the month the insured person withdraws from insurance coverage.

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jobs or if business entities shut down or cease operations. According to the Labor Pension Act, the dividends accrued from a worker's pension fund may not be lower than a certain level. In the future, dividends from individual pension accounts may vary due to investment outcomes in the financial markets, but with the guaranteed minimum rate, when a worker eventually receives his/her pension payments, in addition to the principal accumulated from all monthly contributions, they will also collect dividends equivalent to or higher than the guaranteed minimum rate.

Under the new scheme, a worker may begin collecting his or her pension payments upon reaching the age of 60, regardless of employment status. Workers with 15 years or more work seniority can receive monthly pension payments. Workers with less than 15 years of seniority can only receive a lump sum payment.

Public Service Pension

The public service pension system of Taiwan was established in 1943. Since then, the framework and principles that define it as a government-financed superannuation system have remained unchanged. However, the growing financial burdens of the government have posed great challenges to the system. This prompted the government to organize a task force to review the system. The public service pension system was changed on 1 July, 1995, from a totally government-financed system to a Contributory Public Service Pension Fund that is supported by funds jointly contributed by the government and the participants.

Upon the adoption of the new system, the Public Service Pension Fund (PSPF) began paying pension benefits based on years of service. The contribution rates to the Pension Fund by the participants ranged from 8% to 15% of their salary. The Public Service Pension Fund Management Board (PSPFMB) was set up to manage the Fund. Fund participants comprise civil servants, education workers, and military personnel, totaling more than 630,000 persons. The aim of PSPF is to secure and stabilize the income for these retirees so as to facilitate the recruitment of human forces for public service, boost its morale, take care of the aged and their dependents, and establish a sound and solid retirement system.

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National Pension

The National Pension Program was established by the National Pension Act of 2008. The spirit of the National Pension Program is to safeguard people who do not take part in any social insurance program, no matter if they are unemployed or retired. Citizens who are over 25 years of age and under 65 years of age with their household registered in Taiwan shall take part in National Pension Insurance and become insured persons during the period they do not participate in labor insurance, farmer's health insurance, government employee's insurance, and insurance of military personnel. (For detailed rules check the official website of the Bureau of Labor Insurance). The program offers three types of annuity payments, including the Old-Age Pension, Disability Pension and Survivors Pension, as well as two types of lump sum benefits, including the Maternity Benefit and Funeral Benefit. The National Pension Program is a pay-as-you-go system. The insurance premium equals the monthly insured amount times the premium rate. The current monthly insured amount is NT$18, 282 and the premium rate is 8%. The premium sharing ratio varies depending on the income of the insured person.

Those who are insured can claim the Old-age Benefit as long as they reach the age of 65, regardless of how long their insurance period is. The insured person can select the better one from the following two methods:

- Monthly Insured Amount $\times$ Insurance coverage year $\times 0.65\% + 3,628$[9]
- Monthly Insured Amount $\times$ Insurance coverage year $\times$ 1.3%

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[9]This method is not applicable to some kind of individuals. Please check the website of the Bureau of Labor Insurance.

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台灣的年金改革 — 以總體經濟學角度分析

鄭宇翔
基隆市政府工務處公用事業科
林軒馳
中央研究院經濟研究所
田中敦子
卡爾加里大學經濟系

本文爲達到退休金自籌的制度目標, 針對台灣不同年金改革方案下的財政成本進行量化分析。我們建立生命週期的一般均衡模型, 納入集約邊際及外延邊際的勞動供給、消費、儲蓄及退休時機作爲內生變數, 並在考量當前人口結構變化下利用反事實分析法評估各種年金改革方案達到平衡預算的影響。本研究發現, 若政府 (1) 提高綜合所得稅 5.4%、(2) 提高消費稅 6.2%、(3) 提高自提退休金 9.3%, (4) 降低退休給付 23.5%, 將可能達到自籌的年金制度。另外, 本研究發現部分均衡分析可能低估了對勞動供給的負面影響, 而研究結果的差異突顯一般均衡效果的重要性。

關鍵詞: 年金改革, 勞動供給, 集約邊際, 外延邊際
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