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# Essays in Retirement Security

## **Abstract**

The first chapter “Investment Patterns in Singapore’s Central Provident Fund System” investigates how plan participants in a national defined contribution system invest their pension accumulations. I find that only a small fraction of participants elects to invest in outside investment products like professionally-managed mutual funds. Simulation results using cost data from over 200 funds demonstrate that the minimum hurdle rate of return a fund must generate is about five percent a year. Accordingly, more policy attention can be devoted to lowering fund commission charges and rationalizing the investment menu offered to participants.

In the second chapter “Longevity Risk Management in Singapore’s National Pension System”, I evaluate the money’s worth of life annuities and discuss the implications of the government entering the insurance market as a public-sector provider for annuities. I find that commercial insurers offer competitively-priced annuities with money’s worth ratios averaging 0.95, which are on par with those in other developed countries. On the other hand, the new annuities launched by government under an annuitization mandate are estimated to provide money’s worth ratios exceeding unity. This will benefit annuitants on average but implies that the annuity mandate will be expensive for the government if current pricing continues.

The third chapter “Beyond Age and Sex: Enhancing Annuity Pricing” assesses how adopting more detailed pricing schemes may help reduce adverse selection in annuity markets. Prices of standard annuity products in the United States do not currently reflect buyers’ personal characteristics other than age and sex. I show that several readily-measurable risk factors can significantly increase explained variability in mortality outcomes in a proportional hazards framework and use them to construct alternative pricing schemes. Simulation results show that more detailed pricing may help reduce adverse selection in annuity markets because shorter-lived groups are made much better off (and thus enter the market) while longer-lived groups are made only slightly worse off (and thus remain in the market).

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ESSAYS IN RETIREMENT SECURITY

Hung Yee Fong

A DISSERTATION

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For the Graduate Group in Managerial Science and Applied Economics

Presented to the Faculties of the University of Pennsylvania

in

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ESSAYS IN RETIREMENT SECURITY

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2011

Hung Yee Fong

*To My Parents –  
Francis & June Fong*

*To My Mentor –  
Dr. Olivia S. Mitchell*

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Joelle HY. Fong

April 2011

## **ABSTRACT**

### **ESSAYS IN RETIREMENT SECURITY**

Hung Yee Fong

Supervisor: Olivia S. Mitchell

The first chapter “Investment Patterns in Singapore’s Central Provident Fund System” investigates how plan participants in a national defined contribution system invest their pension accumulations. I find that only a small fraction of participants elects to invest in outside investment products like professionally-managed mutual funds. Simulation results using cost data from over 200 funds demonstrate that the minimum hurdle rate of return a fund must generate is about five percent a year. Accordingly, more policy attention can be devoted to lowering fund commission charges and rationalizing the investment menu offered to participants.

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## CHAPTER 1

### Investment Patterns in Singapore's Central Provident Fund System<sup>1</sup>

In the four short decades between 1990 and 2030, the global tally of persons age 60+ will burgeon from 500 million to almost 1.5 billion individuals. As much of this demographic aging will take place in Asia, it follows that retirement systems in Asia will come under substantial pressure. This paper focuses on one of Asia's most famous retirement programs, Singapore's national defined contribution program known as the Central Provident Fund (CPF). Our goal is to review how workers are allocating their retirement saving across the various investment options made available under the CPF, and to assess whether alternative investment choices might enhance retirement saving. In particular, we address four questions:

- What fund choices are currently available for workers covered by the CPF, and how do people allocate their retirement saving?
- How do these investment patterns vary according to participant characteristics, and how do they compare to those in other countries?
- How do investment options outside the government default investment pool compare, in terms of fees and charges?
- What policy conclusions may be derived regarding the current investment mix provided for retirement saving?

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<sup>1</sup> This chapter is published in the *Journal of Pension Economics and Finance* (Cambridge University Press). See Benedict SK. Koh, Olivia S. Mitchell, Toto Tanuwidjaja, and Joelle HY. Fong, 2008, Investment patterns in Singapore's Central Provident Fund System, *Journal of Pension Economics and Finance*, Volume 7(1), pp. 37-65.

In what follows, we first outline the structure of Singapore's retirement system, focusing on the links between the national mandatory provident fund structure and other types of asset accumulation in the nation. Next, we show how government policy has influenced asset accumulation and investment patterns.<sup>2</sup> Subsequently, we explore several questions about asset allocation patterns by demographic attributes. Last, we assess how the fees and charges associated with investing in a CPF unit trust can impact the investment return over various time horizons.<sup>3</sup> Since workers who default their money to the CPF fund receive a guaranteed 2.5% return on his Ordinary Account and 4% on his Special Account, this means that hurdle rates for money market and equity funds are rather substantial. These high hurdle rates help explain why few CPF account holders invest outside the default government investment pool. On the other hand, inertia probably explains why many employees let their funds sit in bank accounts earning low interest rates, rather than opting for either the CPF fund or other permitted investments.

## **1.1 Investment Patterns**

The CPF in Singapore was first established in 1955 as a forced savings program;<sup>4</sup> half a century later, it has evolved into a wide-ranging social security system

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<sup>2</sup> This paper does not focus on decumulation patterns; these have been studied by Chen et al. (1997; 1998); Doyle et al. (2004), and Fong (2002).

<sup>3</sup> In the United States, a unit investment trust generally refers to a fixed, unmanaged portfolio of income-producing securities. Shares in the trust are sold to investors who received capital gains, dividend payments and interest at regular periods. A unit investment trust is typically considered a low-risk, low-return investment. Unit trusts in Singapore are more comparable to mutual funds in the US.

<sup>4</sup> Low and Aw (1997) trace the historical roots of the Singaporean CPF; see also Low and Aw (2004).

covering 3.1 million CPF members, of whom 1.46 million are active (as of 12/06).<sup>5</sup> Since its inception, the CPF has been a defined contribution plan financed by mandatory levies on employees' regular monthly earnings up to an earnings cap. Contribution rates and caps have varied over time, with current rates amounting to between 8.5% and 33% of salary depending on the employee's age, and the ceiling is set at \$4,500 per month<sup>6</sup> (in 2006; see Table 1.1). Initially all contributions were held in a single account, but over time additional accounts were created. Of most interest for our purposes, the Ordinary Account (OA) and Special Account (SA) concepts were introduced in the late 1970s; the former is intended for financing of home purchases, insurance premiums, education expenses, and other saving, while the Special Account, created in 1977, is mainly targeted toward old-age saving. The Medisave account, introduced in 1984, is designed to be spent on medical care expenses and catastrophic illness insurance (see Figure 1.1).

*[Figure 1.1 and Table 1.1 here]*

Total CPF contributions vary with age, and so too does the breakdown of the allocations across accounts. Currently young workers ( $\leq 35$  yrs old) have 6% of their total contributions dedicated to the Medisave account, 22% of their totals to the Ordinary Account, and 5% to the Special Account. By contrast, older workers (age  $>55-60$ ) contribute 18.5% of covered pay split 8%, 10.5%, and 0%, respectively, across the three accounts. Figure 1.2 and Table 1.2 depict the time pattern of OA and SA contribution rates for a "prime-age worker" in the 35-45 age range. Such an

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<sup>5</sup> Active CPF members are persons with at least one contribution in the current or preceding three months.

<sup>6</sup> The exchange rate as of December 2006 was S\$1=US\$0.64.

individual would have had to contribute 10 percent of covered earnings in the 1950s to the single pooled account, with the rate rising steadily to 37 percent by 1979 when the Special Account was created. Thereafter, the non-medical savings portion of the CPF for this prime-age group of workers – that is, just the OA and SA combined elements – rose to 46% of covered pay by 1983, and then fell to the mid-to-low 30's over the 1990s. By the end of the 1990s, in response to the Asian financial crisis, the CPF savings contribution for OA and SA combined was slashed to 23%, and it now stands at 26% of covered pay.

*[Table 1.2 and Figure 1.2 here]*

The flow of funds into the CPF over time has resulted in substantial asset accumulation by scheme participants. Contributions to the OA, SA, and Medisave accounts total S\$16.1B and CPF balances stand at S\$119.8B (12/05), or about three-fifths of Singapore's GDP that year.<sup>7</sup> As shown in Table 1.3, the growth rate of the CPF asset pool has averaged over 7% per annum since 2003.

*[Table 1.3 here]*

When the CPF was first established, the Provident Fund Board centrally directed all investible funds and a government-set rate of return was paid on the assets. This annual percentage return was set in 1955 at 2.5%, a figure that rose to 5% in 1963, and peaked at 6.5% in the mid-1980s (see Table 1.4). Thereafter, the return was gradually reduced to around 2.5-3% through the mid-1990s. The SA rate was set at 1.25 percentage points above the OA/Medisave rate in mid-1995, and raised to 1.5 percentage points in July 1998. There has been no change in the OA and SA rates since

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<sup>7</sup> Singapore's 2005 GDP at current market prices was S\$194.2B (Source: [www.singstat.gov.sg](http://www.singstat.gov.sg)).

mid-1999; the annual OA rate is 2.5% and the SA return is 4%. As explained by the CPF Board, the actual return paid for the Ordinary Account is the higher of this floor, or the “market-related interest rate (based on the 12-month fixed deposit and month-end savings rates of the major local banks)”.<sup>8</sup> For the Special and Retirement Accounts, members earn additional interest of 1.5 percentage points above the normal CPF interest rate.<sup>9</sup> In other words, the Board guarantees a relatively safe minimum nominal return, and it also offers participants the possibility of upside potential should the bank rate rise. As shown in Table 1.4 (Panel B), the Medisave account return was raised in October 2001 to the SA rate, to help members build up the Medisave balance faster.

*[Table 1.4 here]*

Since the system’s inception 50 years ago, the “default” investment under the Provident Scheme has always been the CPF fund, so that workers would earn whatever rate of return was set by the CPF Board as explained above. Nevertheless, over time, participants have been permitted to use some of their OA and SA assets for other purposes. In 1968, then Prime Minister Lee Kuan Yew introduced the Home Ownership Scheme (HOS), which permitted workers to borrow against CPF accumulations for the purchase of public housing built under the auspices of the Housing Development Board (the government authority controlling most of the island’s

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<sup>8</sup> See <http://mycpf.cpf.gov.sg/Members/Gen-Info/Int-Rates/Int-Rates.htm>.

<sup>9</sup> Asher (1999) notes that this rate is set as a weighted average of the 12-month deposit rate (80%) and last-month savings deposit rate (20%) subject to a minimum 2.5% nominal return, revised quarterly. He also argues that actual CPF returns probably returned 5% on average, on an internationally invested asset pool of about S\$60B over the last decade, though no firm data are provided on the investment mix and returns of the CPF portfolio.

housing stock).<sup>10</sup> In 1978, CPF savers were permitted to purchase shares in the Singapore Bus Service Scheme, and in 1981, private home purchase was permitted with CPF funds. As of 1986, members were allowed to purchase commercial properties with their CPF savings and also to move into the Approved Investment Scheme arrangement (CPF Board 2005e). Subsequently, in 1993, the Board instituted an Investment Schemes (IS) approach which further widened the range of permissible assets in which CPF savers could invest. At first members were permitted to invest only a portion of their OA and SA savings in approved assets, but the portion was raised to 100% for the SA as of 2001.<sup>11</sup>

The range of products in which CPF members can invest is quite diverse. In 2006, for instance, OA funds could be invested in fixed deposits, corporate bonds, property funds and equities traded on the Singapore stock exchange, bonds guaranteed by the Singapore government, Statutory Board bonds, annuities and endowments, investment-linked insurance products, unit trusts, exchange traded funds, fund management accounts and gold. Portfolio limits apply to specific asset families; for instance, as noted in Table 1.5, a participant can invest only up to 10% of his investible saving in gold, and only up to 35% of his investible saving in shares, property funds/REITs, and corporate bonds. A slightly narrower set of investment products has been allowed for Special Account monies; the list most notably excludes fund management accounts, shares, property funds/ REITS, corporate bonds, gold, investment-linked insurance products, unit trusts and exchange traded funds in the

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<sup>10</sup> See McCarthy et al. (2002), CPF (2005e), and Low and Aw (1997) for further discussion of the housing loan arrangements.

<sup>11</sup> For details see <http://mycpf.cpf.gov.sg/Members/Gen-Info/FAQ/investment/CPF-Invscheme.htm>.

Higher Risk category of the CPFIS Risk Classification System. The list of financial service providers currently allowed under the CPF Investment Scheme appears in Table 1.6. Mandatory savings are made to three accounts, namely the Ordinary, Special, and Medisave funds. At year-end 2005, CPF members held some S\$120B (or about US\$74B) allocated roughly half to the Ordinary Account, 17% in the Special Account, 29% in a medical care savings account, and the rest in “Retirement and Other” (see Figure 1.3). Total cumulative contributions to the CPF scheme since inception stood at S\$268.8B (as of 05 Financial Year End).

*[Tables 1.5 and 1.6, and Figure 1.3 here]*

Table 1.7 and Figure 1.4 show, on a cumulative basis, that some 59% of OA savings have been utilized for housing and 12% for investment. This implies that about 29% of cumulative contributions have remained in the OA fund, where they currently earn 2.5% annual (nominal) interest. The reverse is true for the funds in the SA, where account holders have left the bulk of their saving (80%) deposited with the CPF. A possible explanation for the strong tendency of investors to leave their SA money with the CPF is that the SA has traditionally paid a higher return compared to the OA. In addition, account holders may be less willing to assume higher risk for their retirement accounts. Further detail on how CPF members deployed their funds over the years is provided in Figure 1.5. It shows that the bulk of the CPF saving (44%) has gone to the purchase of residential and investment properties. A sizeable portion (29% of cumulative CPF funds) remains in the OA and SA earning guaranteed interest.

*[Table 1.7, and Figures 1.4 and 1.5 here]*

Currently, about 55% of active members invest in the CPFIS scheme in their OA accounts, though only about 10% of total accumulated saving has thus far been devoted to investment instruments and insurance linked products. Panel A in Figure 1.6 shows that, of funds in the CPFIS-OA investment scheme, 63% is held in insurance products, 25% is invested in shares and 11% is in unit trusts. Interestingly, the negligible 0.64% held in other instruments such as fixed deposits, bonds, Exchange Traded Funds (ETFs), gold, property funds, and fund management accounts, suggests that most investors do not fully utilize the menu of investment options they have been offered. Panel B in Figure 1.6 shows that in the CPFIS-SA investment scheme, on the other hand, most participants held insurance products to the tune of 86% of their saving. Remaining funds (14%) were invested primarily in unit trusts. In other words, the asset allocation patterns of OA and SA monies have been starkly different to date: participants seem prepared to take more risk with their OA funds compared to their SA saving. It would appear that the SA funds are put in a separate “mental account” targeted to retirement and are not generally actively managed.<sup>12</sup>

*[Figure 1.6 here]*

## **1.2 Asset Allocation Patterns in CPF Investment Scheme (CPFIS)**

Next we develop a more detailed view of CPFIS asset allocation patterns, focusing on age, sex, and income patterns; the analysis is based on aggregate data as

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<sup>12</sup> The data in Figures 1.7-1.10 refer to a September year-end, which differs from the December year-end data given in CPF Annual Reports.

individual-account records are not available for research.<sup>13</sup> Figure 1.7 shows that participants who elected to invest outside the CPF default fund committed most of their funds to three investment instruments, namely, insurance products, shares, and unit trusts. Both men and women devoted similar percentages of their money to unit trusts, and both invested less in instruments such as gold, bonds, fixed deposits, ETFs, and property funds. Yet men tended to be slightly more proactive in their investments: they invested 28% of their funds in shares, compared to 21% for women. Conversely, women were more likely to opt for insurance products (68%), compared to men (60%). This is similar to US research on retirement account holders, which finds that higher income men tend to seek riskier investments and trade more in their accounts (Mitchell et al. 2005).

*[Figure 1.7 here]*

It is also of interest to ask whether investment behavior becomes less risky as workers age. Only a partial picture is available as we have information only on the CPFIS-OA accounts but not participants' entire portfolios. Nevertheless, Figure 1.8 shows that CPF investors appear more rather than less devoted to risky investments as they age. Thus, the mature (56+) age group commits a higher proportion to stock investments and less to insurance products, compared to younger age-groups. We also find that the youngest workers are more likely to delegate portions of their saving accounts to investments managed by professionals, as seen from their higher holdings

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<sup>13</sup> These tabulations as of 2004 were kindly provided by the CPF Board. To date no data have been made available on the broader investment portfolios of individual investors; accordingly we can report asset allocation of investors in the CPF-IS scheme but we cannot link the IS accounts to CPF holdings to ascertain workers' overall portfolios. Future research will attempt to match individual records to evaluate the larger picture of IS versus non-IS holdings.

of unit trusts (14%); by contrast, the mature group tends to invest more heavily in shares on their own. In data not shown, older women prove slightly more conservative, investing more in insurance products than men. These general patterns again conform to US findings, where higher income, older men are more likely to hold riskier portfolios as compared their female and younger counterparts - and trade more, as well, often to their detriment (Mitchell et al. 2006).

*[Figure 1.8 here]*

Another perspective is offered in Figure 1.9, which displays investment scheme asset allocation patterns by risk category and participant salary levels. We group the CPFIS products into three, namely insurance products, relatively less risky products (bond and fixed deposits), and relatively more risky products (which include shares, unit trusts, exchange traded funds, gold and property funds).<sup>14</sup> The income categories we tabulate focus on low earners (earning less than S\$1,500/mo.), low-middle (S\$1500-3,500/mo.), high-middle (S\$3,500-6,000/mo.), and high (S\$6,000+/mo.).<sup>15</sup> Here we see that low and lower-middle earners are less likely to hold risky investments, with at least 70% of their CPFIS portfolios held in insurance products. As salary levels rise, the fraction in insurance products falls, first to 63%, and then to under 50% for the highest earners. Conversely, higher-earners hold between one-third and half of their investment accounts in risky forms, a finding consistent with international research (Mitchell et al. 2005).

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<sup>14</sup> In future work we hope to disaggregate the insurance products into investment-linked products, which are likely more risky than endowment funds.

<sup>15</sup> Retirees and non-retirees with no monthly earnings are excluded as the data do not allow us to distinguish between these two groups.

*[Figure 1.9 here]*

Overall, the observed regularity is that people who move their funds to the CPFIS system tend to buy insurance products, and this holds across age, sex, and income groups. This is not due to preferential tax treatment on income received from insurance products, since investment profits and interest earned from investments, most dividends, and income received from CPFIS annuities paid directly as cash, are currently not taxable.<sup>16</sup> Rather, it may be that in Singapore as elsewhere, insurance agents are successfully able to emphasize the joint appeal of protection and investment (especially for investment-linked insurance products), which seems particularly attractive for CPF money that cannot be accessed until the age of 55.

### **1.3 Analyzing the Impact of Fees and Charges for CPFIS Options**

As noted above, additional investment choices have been added over the years, to the menu of funds into which CPF participants may invest their mandatory savings. As of 2006, there were some 400 investment portfolios on offer to CPF participants. Naturally, this additional diversity of fund choices imposes on participants the responsibility to devote more attention to the risks and benefits of diversifying outside the traditional CPF fund managed by the government. Diversification into other assets outside the traditional CPF portfolio also brings with it the potential for high management fees and commissions associated with having many small funds.

With such a rich offering of investment options, it is of interest to inquire whether CPFIS participants have been successful in growing their retirement saving.

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<sup>16</sup> As per [mycpf.cpf.gov.sg/Members/Gen-Info/FAQ/Investment/INV.htm](http://mycpf.cpf.gov.sg/Members/Gen-Info/FAQ/Investment/INV.htm).

Recently the story has not an encouraging one, as shown in Table 1.8 (for Fiscal Years 2004-2006). Here almost half of CPFIS-OA investors (48%) incurred losses from investing on average, while one-third realized profits equal to or less than the default OA rate of 2.5%. Only one-fifth of the investors made net realized profits in excess of the OA interest rate. This poor investment performance has not gone unnoticed by policymakers. Indeed Prime Minister Lee Hsien Long expressed concern in 2005 regarding the CPFIS scheme, pointing to high investment fees and expenses as an explanation for low returns:

“[W]e must help CPF members to earn better long term returns on their savings. Over the years, we have opened up the CPF Investment Scheme (CPFIS) and given members considerable latitude to invest their CPF savings as they judge best. However, this has not always worked out as well as we hoped, because the options available to the members are not well tailored to their needs, and it is difficult to educate members adequately on how to plan for their long term needs. *Almost three-quarters of the members who invested under CPFIS from 1993 to 2004 would have been better off leaving their savings with the Board. In particular, those who invested in unit trusts and investment-linked products (ILPs) have generally received mediocre returns.* One important reason why CPFIS returns have been mediocre is the high cost of investing. For example, the annual cost to investors in a retail unit trust in Singapore is typically double that of the US. This is because the market is fragmented, many of the unit trusts and ILPs are small, and the overheads and fees are high.” (CPF 2005f).

*[Table 1.8 here]*

To explore the range of charges levied under the CPF investment schemes, we assembled Table 1.9 from the CPF Board’s website, which presents a rather bewildering array of fees for different investments and a wide diversity of front end commissions, back end loads, and annual service charges. For instance, the holder of a unit trust may pay sales charges, transaction fees, service charges, annual fund operations fees, performance fees, and sometimes redemption charges. Purchasers of investment-linked

insurance products also pay transaction and service fees as well as sales charges, expense ratios, performance fees, and redemption charges. Compared to the US institutional market, there would appear to be far more diversity and complexity in the Singapore case (Mitchell 1998).

*[Table 1.9 here]*

As these may be perplexing to many participants, we next turn to an evaluation of how such costs can impact the return of retirement savings for a typical CPF-IS unit trust investor over different time horizons. Our strategy is to isolate the impact of costs from returns, allowing us to compute the rate of return that an investor requires so as to ‘cost-recover’ the expenses over different time horizons. Accordingly, in what follows, we develop a “hurdle rate” notion which asks what the investor’s net return would have to be, after costs, so the investor would do better than simply defaulting his money into the government-run fund. Specifically, we simulate the effect of transaction costs on an investment of \$1 held for 1 year (short term), 5 years (medium term), and 10-20 years (long-term), after subtracting cost components of the unit trust investments. In the simulation, we assume that the prices of unit trusts remain unchanged so the change in the fund position reflects solely cost impacts; we also assume that management fee and other annual operating costs are fixed at the current average rates relevant to the four fund types appearing in Table 1.10: equity, balanced, income and money market funds (based on Mercer’s risk classification system).<sup>17</sup> Average costs by fund types are

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<sup>17</sup> Different unit trusts may have different investment objectives, different styles of management and different levels of equity risk depending on their portfolio allocation. This is recognized by Mercer Investment Consulting, CPF Board’s consultant, which has developed a risk classification system for the CPFIS that assigns various risk levels to permitted investments. The unit trust or ILP with a greater

presented in Table 1.10 from a sample of 235 unit trusts representing 97% of the CPFIS unit trust universe (as of 30 June 2006).

*[Table 1.10 here]*

These average transaction costs by fund type are applied to a \$1 investment held for various time periods assuming the fund earns a zero rate of return.<sup>18</sup> For year 1, we apply both the one-off sales load and annual operating costs, where the sales load comprises both front-end and back-end sales charges, while operating costs include fees for management, custodian, trustee, administration, and other major fees paid by the unit trust out of the fund's net asset value; the performance fee is excluded.<sup>19</sup> Thereafter annual charges are subtracted as relevant. Table 1.11 (Panel A) summarizes the results, where we see that the \$1 investment steadily eroded by annual operating costs assuming zero returns. For the 10-year holding period, the \$1 invested in the average equity fund would be predicted to shrink to \$0.772, sliding further to \$0.626 by Year 20. Expenses are lower for income funds: the same \$1 invested there would be worth \$0.874 in Year 10 and \$0.781 by Year 20. Using these results, we next compute the annual rate of return required for the investor to 'cost-recover' for each fund type, which appear in Table 1.11 (Panel B). Not surprisingly, a longer holding period is beneficial in that a

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proportion of its assets invested in the more volatile stock market will have a higher equity risk. Based on its level of equity risk, a unit trust or Investment Linked Product is assigned one of the four risk categories.

<sup>18</sup> Of course investors may consider both fund performance and costs simultaneously, though doing so may be distortive since fund performance is uncertain and fluctuates widely, while transaction costs can be estimated with a fair amount of certainty.

<sup>19</sup> These are estimated using the total expense ratio publicly reported by Investment Management Association of Singapore (IMAS). Expense ratios are supposed to be calculated according to IMAS guidelines (see IMAS 2005), and they are furnished by fund management companies and insurers and made available to the public through the quarterly Performance and Risk Monitoring Reports for CPFIS-included funds published by Standard & Poor / CPF and found on IMAS website.

lower rate of return is needed to ‘cost-recover.’ This is mainly because the one-off sales loads are spread over a longer period.

*[Table 1.11 here]*

To complete the picture, we then compute the minimum hurdle rate of return that a fund must generate if it is to beat the guaranteed returns attainable by leaving one’s money in the government-managed account, currently, 2.5% and 4% for OA and SA monies, respectively. Results for CPFIS unit trusts are provided in Table 1.11 (Panel C), where over a 1-year period, the OA hurdle rate ranges from 3.3% for money market funds, to 9.4% for equity funds. Over a 20-year period they range from 3.2% for the money market funds to 4.8% for equity funds. For SA account holders over the same 1-year period, the hurdle rate is 4.8% for money market funds and 10.9% for equity funds. Over a 20-year time frame, it is 4.7% for money market and 6.3% for equity funds. Such high threshold returns may rationalize why so many CPF accountholders leave their investible funds in the default OA and SA accounts.

#### **1.4 Lowering Costs for CPFIS Investors**

In recent years, steps have been taken to better inform members about investment options and expense ratios. For instance, the Investment Management Association of Singapore (IMAS) recently published standardized cost formulae across funds ([www.fundsingapore.com](http://www.fundsingapore.com)). Nevertheless CPF members must still factor in additional investment costs not commonly wrapped into expense ratios, including back-and/or front-end loads, annual asset-based and fixed charges, and wrap fees; these have yet to be collated into an easy-to-understand format.

In late 2005, the CPF Board announced several requirements for funds seeking to be newly included in the CPFIS menu; one change was such funds would be required to meet a higher relative performance standard than previously required, such that the fund had to have a minimum of a 3-year performance record that could not fall below the top 25 percentile of funds in a global peer group.<sup>20</sup> As this standard exceeds the older benchmark of top 50 percentile, it is likely to represent an improvement over past practice. Nevertheless, some degree of subjectivity remains as the evaluators take into account the fund managers' capabilities, the fund's investment philosophy, the quality of the fund's research and analysis; and the way the fund constructs and implements its portfolio. Furthermore, funds already on the CPFIS permitted list are not held to these new standards. A second change adopted by the Board in late 2005 was the explicit introduction of expense ratio targets for the first time. The expectation is that: "[t]he CPF Board will therefore ...(induce) lower cost ratios, enhance transparency to help members make informed choices, and encourage consolidation among the funds to achieve greater economies of scale."<sup>21</sup> Specifically, any new fund must have an expense ratio below the median of existing CPFIS funds in its risk category. In practice this implies that so-called 'higher risk' funds investing mainly in equities will be held to a cap of 1.95 percent of assets per year; 'medium to high' risk funds holding both equities and bonds must charge less than 1.75 percent of assets; 'low to medium' risk funds investing in bonds or fixed income must charge less than 1.15 percent pa; and 'lower risk' funds (money market funds) cannot exceed an annual expense ratio of 0.65 percent

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<sup>20</sup> See CPF (2005*d*), though it is not easy to determine which specific funds constitute each global peer group by asset class/strategy.

<sup>21</sup> Source: CPF (2005*f*).

(CPF 2005*d*). While a full-scale comparison of these expense ratios with international charges is beyond the purview of this paper, it is clear that the CPF costs are still not on the low side. For instance, a recent review of US fund expenses found that the asset-weighted average expense ratio for stock funds was 1.13 percent, and for bond funds at 0.9 percent in 2005 (ICI, 2006) – and these figures include a pro-rata share of front-end loads. Furthermore, most US investors held their money in lower-cost funds. Consequently, adopting an expense target as in Singapore is a positive step, though focusing on the median fund charge in Singapore, exclusive of front end loads, may still produce costs that are high by developed-country standards.

The issue of fees and charges remains one of national concern, as evidenced by a recent CPF Board statement that in the future, front load charges will be capped at 3 percent (as of 7/1/07) in addition to the already announced expense ratio caps (from 1/1/08) (CPF 2006*a*). This is a significant reduction from the 5 percent front load often charged by CPFIS funds in the past, and these changes represent positive steps to bring the cost of CPF Investment Scheme nearer to developed country standards.

## **1.5 Discussion and Conclusions**

Singapore has one of the world's lowest fertility rates (at around 1.2 per 1,000),<sup>22</sup> and longest life expectancies (over age 80 at birth),<sup>23</sup> so this nation is aging quickly. Indeed, in the next two decades, it will overtake all but Japan in its fraction of population elderly. Accordingly, it is valuable to assess how the Singaporean Central

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<sup>22</sup> The Singapore fertility rate in 2000 was reported as 1.2 by the US Census Bureau ([www.census.gov](http://www.census.gov)). Singaporean sources place it a little higher, at around 1.6, but declining (SDOS 2006).

<sup>23</sup> See for instance, Clark (1999).

Provident Fund (CPF) might become more effective in building retiree wealth. Thus far, it appears that the bulk of workers' saving (44%) has gone to purchase homes, leading to an asset rich, cash poor phenomenon (McCarthy et al. 2002). We have also shown that contributors tend to default their remaining saving to the CPF government-managed investment pool. The few participants who elect outside investment products tend to be high-income males, rather than lower paid workers and women. High expenses and fees, as well as inertia, rationalize why few CPF account holders invest outside the default government investment pool.

More attention could be devoted to lowering fund expenses and commissions in the CPFIS system. It would be useful to aggregate the myriad of data on fees, expenses, loads, wrap fees, and other charges as they are dispersed across numerous websites and expressed in different terms depending on the specific product in question. It could be helpful for the CPF to develop a single easy-to-use web calculator making these comparisons simpler. For instance, a drop list could illustrate for each fund the component costs over a range of holding periods. It would be useful to show itemized costs well as an all-in annualized cost, for the various products projected over various periods (e.g. 1, 5, 10, 20 years).

It might also be beneficial to streamline and rationalize the investment menu offered to participants. Currently more than 400 funds are offered to CPF investors, but this list includes few index-linked funds, ETFs, or life-cycle funds, and no inflation protected instruments are currently on offer.<sup>24</sup> Furthermore, while new funds are

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<sup>24</sup> It would also be of interest to offer inflation-indexed bonds, as these make good sense for the retirement decumulation phase (Brown et al. 2000).

screened for cost efficiency, more stringent criteria might be adopted to screen out under-performing existing funds at regular intervals.

It might be useful to consider consolidating participants' investments to bring about more competition to drive down costs. One interesting development in this context is the advent of low-cost Life Cycle funds which might be adopted as the "default" investment mix for otherwise naïve or underconfident investors. Employees could then be automatically defaulted into a balanced fund based on their age, unless they actively select some other investment portfolio. In Chile, for instance, pension managers offer up to five funds, ranging from "Fund A" which holds 80% of the portfolio in equities, to "Fund E" which holds 100% fixed income; "Funds B-D" hold intermediate percentages in equities. Active workers may elect up to two funds at a time offered by a single money manager, and they will be automatically transitioned to more conservative portfolios as they age, unless they elect otherwise (Arenas de Mesa et al. forthcoming). A low-cost Life Cycle approach might be useful in the Singaporean case, in view of many affiliates' inertia regarding investment choices.

It could also be useful and important to educate CPF investors regarding capital market risk and return, as the government seeks to streamline the range of investment choices and bring down expenses. The US experience with investment education suggests that even relatively well-educated subjects can have a hard time understanding and acting on information regarding mutual fund charges (Choi et al. 2005; Lusardi and Mitchell 2006). To the extent that individual investors are poorly equipped to make investment choices in their retirement accounts, this will place greater burden on

policymakers' shoulders to fashion the best possible environment for strengthening retirement security.

Finally, policymakers may seek to restrain the amount of retirement saving going into property purchases so that CPF participants have sufficient funds to finance their retirement years. An alternative may be for the financial sector to spur the growth of reverse mortgages permitting homes to be pledged to financial institutions, in return for a retirement annuity; this is made complex by the fact that most (85%) homeowners purchase housing development flats (public housing) on leasehold from the government. Another option might be to allow homeowners to freely rent out their apartments for income; while steps are being taken in this direction, numerous restrictions remain on the use of these apartments, including rental. Removing these restrictions may alleviate the asset rich, cash poor syndrome.

**Table 1.1: Annual Earnings Ceiling for CPF Contributions**

<b>Year</b>	<b>Salary Ceiling</b>
2006	\$4,500
2005	\$5,000
2004	\$5,500
2003	\$6,000
2002	\$6,000
2001	\$6,000
2000	\$6,000
1999	\$6,000
1998	\$6,000
1997	\$6,000

Source: CPF Annual Reports, various years ([http://mycpf.cpf.gov.sg/cpf/about-us/ann-rpt/ann\\_report.htm](http://mycpf.cpf.gov.sg/cpf/about-us/ann-rpt/ann_report.htm)).

**Table 1.2: Contribution Rates to CPF Ordinary and Special Accounts over Time: % of Covered Earnings (workers age 35-45)**

As of	Ordinary Account (OA)	Special Account (SA)	OA + SA Together
Jul-55 °	10	0	10
Sep-68 °	13	0	13
Jan-70 °	16	0	16
Jan-71 °	20	0	20
Jul-72 °	24	0	24
Jul-73 °	26	0	26
Jul-74 °	30	0	30
Jul-75 ° *	30	0	30
Jul-77	30	1	31
Jul-78	30	3	33
Jul-79	30	7	37
Jul-80	32	6.5	38.5
Jul-81	38.5	4	42.5
Jul-82	40	5	45
Jul-83	40	6	46
Jul-84	40	4	44
Jul-85 **	40	4	44
Apr-86	29	0	29
Jul-88	30	0	30
Jul-89	30	2	32
Jul-90	30	3.5	33.5
Jul-91	30	4	34
Jul-92	29	4	33
Jul-93	29	4	33
Jul-94	29	4	33
Jan-99	23	0	23
Apr-00	23	2	25
Jan-01	23	6	29
Oct-03	20	6	26
Jan-05	20	6	26
Jan-06	20	6	26

Notes:

° Single pooled account

\* Maximum contribution increased from \$450 to \$600 per month

\*\* Maximum contribution increased from \$2,500 to \$3,000 per month

Source: CPF Annual Report 2005 and <http://mycpf.cpf.gov.sg/Members/Gen-Info/Con-Rates/ContriRa.htm>.

**Table 1.3: Contributions and Balances in the CPF**

A. Member CPF Annual Contributions and Year-End Account Balances Through Time  
(S\$ Billions)

<b>Year</b>	<b>Contributions (\$B)</b>	<b>Account Balances (\$B)</b>
1993	10.4	52.3
1994	11.3	57.6
1995	13.5	66.0
1996	14.6	72.6
1997	15.9	79.7
1998	16.0	85.3
1999	12.8	88.4
2000	14.1	90.3
2001	18.3	92.2
2002	16.2	96.4
2003	15.9	103.5
2004	15.3	111.9
2005	16.1	119.8

Source: CPF Annual Report, 2005.

B. Member Balances by Account: 2005

	<b>S\$B</b>	<b>%</b>
Ordinary Account	\$58.6	49%
Special Account	\$20.1	17%
Medisave Account	\$34.8	29%
Retirement Account & Others	\$6.4	5%
<b>Total Members' Balance</b>	<b>\$119.8</b>	<b>100%</b>

Source: CPF (2005a).

**Table 1.4: CPF Interest Rates over Time****A. CPF Interest Rate Paid on All Accounts: 1955-1995**

<b>Year</b>	<b>Interest Rate Per Annum (%)</b>	<b>Year</b>	<b>Interest Rate Per Annum (%)</b>
1955 – 1962	2.5	Jan-Jun 1989	3.1
1963	5	Jul-Dec 1989	3.39
1964 – 1966	5.25	Jan-Jun 1990	3.77
1967 – 1969	5.5	Jul-Dec 1990	3.88
1970 – 1973	5.75	Jan-Jun 1991	4.85
1974 – Feb 1986	6.5	Jul-Dec 1991	4.54
Mar-Jun 1986	5.78	Jan-Jun 1992	4.59
Jul-Dec 1986	5.38	Jul-Dec 1992	3.31
Jan-Jun 1987	4.34	Jan-Jun 1993	2.62
Jul 1987 – Dec 1987	3.31	Jul 1993 – Dec 1994	2.5
Jan-Jun 1988	3.19	Jan-Jun 1995	3.1
Jul-Dec 1988	2.96		

**B. Higher CPF Interest Rates Paid Mid-1995 onwards for Special, Retirement, and Medisave Accounts**

<b>Year</b>	<b>Interest Rate Per Annum (%)</b>	
<u>From 1 July 1995</u>	<b>Ordinary and Medisave Accounts</b>	<b>Special and Retirement Accounts</b>
Jul-Dec 1995	3.82	5.07
Jan-Jun 1996	3.52	4.77
Jul 1996 – Jun 1998	3.48	4.73
Jul-Dec 1998	4.29	5.79
Jan-Jun 1999	4.41	5.91
Jul 1999 – Sep 2001	2.5	4
<u>From 1 October 2001</u>	<b>Ordinary Account</b>	<b>Medisave, Special and Retirement Accounts</b>
Oct 2001 – Dec 2006	2.5	4

**Notes:**

1. The Special Account, Medisave Account and Retirement Account were introduced in July 1977, April 1984, and January 1987 respectively.
2. From 1955 to 1976, CPF interests were credited and compounded annually.
3. From 1977 to 1985, CPF interests were credited quarterly and compounded annually.
4. From 1986 to present, CPF interests are computed monthly and compounded and credited annually.
5. From 1 July 1999, CPF interests are reviewed quarterly.

Source: [http://mycpf.cpf.gov.sg/Members/Gen-Info/Int-Rates/Int-Rates\\_Arc.asp](http://mycpf.cpf.gov.sg/Members/Gen-Info/Int-Rates/Int-Rates_Arc.asp)

**Table 1.5: Financial Instruments Available for Investment in the CPF Ordinary and Special Accounts**

CPFIS-OA	CPFIS-SA
<p><i>Full Ordinary Account savings can be invested in:</i>            Fixed Deposits            Singapore Government Bonds            Statutory Board Bonds            Bonds Guaranteed by Singapore Government            Annuities            Endowment Insurance Policies            Investment-linked Insurance Products            Unit Trusts            Exchange Traded Funds            Fund Management Accounts</p> <p><i>Up to 35% of investible savings<sup>#</sup> can be invested in:</i>            Shares            Property Funds (or real estate investment trusts)            Corporate Bonds</p> <p><i>Up to 10% of investible savings<sup>#</sup> can be invested in:</i>            Gold (currently only UOB offers new gold investments)</p>	<p><i>Full Special Account savings can be invested in:</i>            Fixed Deposits            Singapore Government Bonds            Statutory Board Bonds (Secondary Market only)            Bonds Guaranteed by Singapore Government            Annuities            Endowment Insurance Policies            Selected Investment-Linked Insurance Products*            Selected Unit Trusts*            Selected Exchange Traded Funds*</p>

Notes:

# Investible savings refer to the net Ordinary Account balance after withdrawals for education and investment.

\* Those found in the lowest three tiers of the CPFIS Risk Classification System Table unless otherwise stated. The risk classification tables for unit trusts, investment-linked insurance products and exchange traded funds can be found at [www.cpf.gov.sg/cpf\\_info/Benefits/Asset/Assetenh.asp](http://www.cpf.gov.sg/cpf_info/Benefits/Asset/Assetenh.asp).

Annuities, endowment insurance policies, investment-linked insurance products must be offered by insurance companies included under CPFIS. For endowment policies, maturity date must not be later than the member's 62<sup>nd</sup> birthday. Unit trusts and investment-linked insurance products must be managed by Fund Management Companies included under CPFIS. Fund managers are required to invest according to the Investment Guidelines set by CPF Board. Exchange traded funds must meet guidelines set by CPF Board and be listed on the Singapore Exchange-Securities Trading. Fund managers of fund management accounts are required to invest according to the Investment Guidelines set by CPF Board. Shares of Companies, Units of Property Funds or Property Trusts and Corporate Bonds (CPFIS-OA only) must be offered by companies incorporated in Singapore. Also, they must be fully paid ordinary or preference shares or corporate bonds listed on the Singapore Exchange-Securities Trading (SGX-ST).

Source: <http://mycpf.cpf.gov.sg/Members/Gen-Info/FAQ/Investment/INV.htm>

**Table 1.6: Service and Product Providers Included Under the CPFIS**

<b>Other Companies</b>	<b>Fund Management Companies</b>
<i>Fixed Deposit Banks:</i>	1. Aberdeen Asset Management Asia Ltd
1. DBS Bank Ltd	2. ABN AMRO Asset Management (Singapore) Ltd
2. Oversea-Chinese Banking Corporation Ltd	3. AIG Global Investment Corporation (Singapore) Ltd
3. United Overseas Bank Ltd	4. Alliance Capital Management (Singapore) Ltd
	5. Allianz Global Investors Singapore Limited
<i>Insurance Companies:</i>	6. APS Asset Management Pte Ltd
1. American International Assurance Co Ltd	7. AXA Rosenberg Investment Mgmt Asia Pacific Ltd
2. Asia Life Assurance Society Ltd	8. Capital International Research & Management Inc
3. Aviva Ltd	9. Commerzbank Asset Management Asia Ltd
4. AXA Life Insurance Singapore Pte Ltd	10. Credit Agricole Asset Management Singapore Ltd
5. Great Eastern Life Assurance Co Ltd	11. DBS Asset Management Ltd <sup>2</sup>
6. HSBC Insurance (Singapore) Pte Ltd	12. Deutsche Asset Management (Asia) Ltd
7. Manulife (Singapore) Pte Ltd	13. Fidelity Investments (Singapore) Limited
8. NTUC Income Insurance Co-operative Ltd	14. First State Investments (Singapore) <sup>2</sup>
9. Overseas Assurance Corporation Ltd	15. Goldman Sachs (Singapore) Pte Ltd
10. Prudential Assurance Co Singapore Pte Ltd	16. Henderson Global Investors (Singapore) Ltd
11. UOB Life Assurance Ltd	17. HSBC Investments (Singapore) Ltd <sup>2</sup>
	18. ING Investment Mgmt Asia Pacific (Singapore) Pte Ltd
<i>Investment Administrators:</i>	19. INVESCO Asset Management Singapore Ltd
1. dollarDEX Investments Pte Ltd	20. Legg Mason Asset Management (Asia) Pte Ltd
2. iFAST Financial Pte Ltd	21. Lion Capital Management Ltd
3. Navigator Investment Services Ltd	22. NTUC Income Insurance Co-operative Ltd <sup>1</sup>
	23. Prudential Asset Management (Singapore) Ltd
	24. Schroder Investment Management (Singapore) Ltd <sup>2</sup>
	25. SG Asset Management (Singapore) Ltd
	26. State Street Global Advisors Singapore Ltd
	27. Templeton Asset Management Ltd
	28. UBS Global Asset Management (Singapore) Ltd
	29. UOB Asset Management Ltd <sup>2</sup>

**Notes:**

1. Can only manage investment-linked insurance sub-funds under CPFIS unlike the rest of the FMCs which can manage unit trusts, ILP funds/ sub-funds, exchange traded funds and fund management accounts under CPFIS.

2. FMCs which offer Fund Management Account services.

Source: <http://mycpf.cpf.gov.sg/Members/Gen-Info/FAQ/Investment/INV-Asset-Enhance.htm>.

**Table 1.7: Cumulative Use of CPF Funds as of End 2005**

<b>Fund Balances and Total Withdrawals</b>	<b>Amount (S\$B)</b>
<b>Fund Balance:</b>	<b>119.78</b>
OA	58.57
SA	20.05
Medisave	34.76
Retirement & Others	6.40
<b>Education Scheme Withdrawal</b>	<b>0.50</b>
<b>Investment Schemes Withdrawal</b>	<b>27.90</b>
CPFIS-OA	22.91
CPFIS-SA	4.99
<b>Special Discounted Shares Scheme</b>	<b>1.92</b>
<b>Property Scheme withdrawal</b> (public, residential & non-residential properties schemes)	<b>117.38</b>

Note: Net amount withdrawn under Medishield, Medisave, Home Protection, Dependent Protection, Minimum Sum, Section 15 & 25 withdrawals not included.

Source: Data kindly provided by the CPF Board.

**Table 1.8: Realized Profits/Losses for Investments Held Under the CPFIS Ordinary Account (FY04-06)**

	<b>FY 2006</b> <i>1 Oct 05 - 30 Sept 06</i>	<b>FY 2005</b> <i>1 Oct 04 - 30 Sept 05</i>	<b>FY 2004</b> <i>1 Oct 03 - 30 Sept 04</i>	<b>3-year average</b>
Members who made net realized profits <i>in excess of</i> the OA interest rate of 2.5% %	180,000 23%	147,000 19%	128,000 17%	<b>20%</b>
Members who made realized profits, <i>but equal to or less than</i> OA rate %	257,000 32%	250,000 33%	240,000 33%	<b>33%</b>
Members who made realized losses %	362,000 45%	363,000 48%	370,000 50%	<b>48%</b>

Note: Constructed from CPFIS Profits/ Losses for the Financial Year ended 31 September 2005 & 2006.  
Source: CPF (2005c) and [mycpf.cpf.gov.sg/NR/rdonlyres/D324F161-1F6A-4699-A6BA-C5ACA0E11C5F/0/IE\\_reportpl.pdf](http://mycpf.cpf.gov.sg/NR/rdonlyres/D324F161-1F6A-4699-A6BA-C5ACA0E11C5F/0/IE_reportpl.pdf).

**Table 1.9: Charges Incurred for Investments under the CPFIS**

<b>Type of Investments</b>	<b>Agent Bank's Charges (under CPFIS-OA)</b>	<b>Other Charges<sup>1</sup> (under CPFIS-OA &amp; CPFIS-SA)</b>
<b>Fixed Deposit (FD)</b>	<p><i>Transaction Fee</i> \$2/FD placement/refund of proceeds upon FD maturity or termination</p> <p><i>Service Charge</i> \$2/FD/quarter, min. charge between \$2-5.</p>	<p><i>Other Charges</i> NA</p>
<b>Shares, Bonds (incl. Statutory Board Bonds) &amp; Listed Property Trusts/ Funds traded on SGX</b>	<p><i>Transaction Fee</i> \$2-\$2.50 per lot, max of \$20-\$25/ transaction</p> <p><i>Service Charge</i> \$2/counter/quarter, w. min. charge between \$2-5.</p>	<p><i>Broker's commission<sup>2</sup></i> 0.4-0.5% of trade contract value, subject to min of \$40/trade</p> <p><i>Central Depository (Pte) Ltd's fees</i> 1) Clearing fee of 0.05% on trade contract value, subject to max of \$200. 2) \$0.50/transaction</p>
<b>Singapore Government Bonds &amp; Statutory Board Bonds traded through bond-dealers</b>	<p><i>Transaction Fee</i> \$2-\$2.50/lot, max of \$20-\$25/ transaction</p> <p><i>Service Charge</i> \$2/counter/quarter, w. min. charge \$2-5.</p>	<p><i>Bond-Dealer's Charges</i> \$0-50 per transaction</p>
<b>Investment-linked Insurance Products</b>	<p><i>Transaction Fee</i> Between \$2-\$2.50/transaction.</p> <p><i>Service Charge</i> \$2/policy/quarter, w. min. charge \$2-5.</p>	<p><i>Sales Charge</i> Between 0-5% (reflected in bid-offer spread<sup>3</sup>) and 1- 5.75% of premium paid and/or \$0-\$150/ single premium policy</p> <p><i>Expense Ratio<sup>4</sup></i> 0.3-4.4% of NAV<sup>5</sup></p> <p><i>Redemption Charge</i> 0-7% of NAV and/or \$0-\$42.75.</p> <p><i>Annual Performance Fees</i> 0-20% of excess returns over benchmark for underlying fund.</p> <p><i>Insurance Administration /Coverage Charges</i> \$0-5/month per policy.</p> <p><i>Surrender Charges</i> 0-4% of the surrender value.</p>
<b>Endowment Policies and Annuities (Single Premium Type)</b>	<p><i>Transaction Fee</i> \$2-\$2.50/transaction.</p> <p><i>Service Charge</i> \$2/policy/quarter, min. charge of \$2-5.</p>	<p><i>Total Distribution Cost (TDC)<sup>6</sup></i> 1-6.2% of Single Premium</p>

Type of Investments	Agent Bank's Charges (under CPFIS-OA)	Other Charges <sup>1</sup> (under CPFIS-OA & CPFIS-SA)
<b>Unit Trusts<sup>7</sup></b>	<i>Transaction Fee</i> \$2-2.50/lot, max of \$20-25/ transaction. <i>Service Charge</i> \$2/unit trust fund/quarter, min. charge between \$2-5.	<i>Sales Charge</i> 0-5% (reflected in the bid offer spread) of initial amount invested. <i>Expense Ratio<sup>8</sup></i> 0-7.1% of NAV <i>Redemption Charge</i> 0-6% of NAV <i>Annual Performance Fees</i> 0-30% of excess returns over benchmark for unit trust

Notes:

<sup>1</sup>These charges are estimates only and may not be exhaustive. CPF members are advised to check with the product providers on the full range of charges payable. Charges also exclude GST, unless otherwise stated.

<sup>2</sup>Broking fees are fully liberalized now and the charges depend on the broking houses. The broker's commission mentioned is the range that majority of the broking houses are charging.

<sup>3</sup>Bid-offer spread is the difference between the price at which the product is offered for sale ("offer") and the price at which the product provider will redeem the product ("bid")

<sup>4</sup>Includes Annual Management Fees which range from 0.10% to 1.85% of NAV

<sup>5</sup>Net Asset Value (NAV) is the total market value of the securities in a fund's portfolio divided by the number of units currently outstanding

<sup>6</sup>Total Distribution Cost (TDC) refers to the total costs that an insurance company is expected to incur and includes commissions and cost of benefits and services paid to the distribution channel

<sup>7</sup>Generally, online fund distributors charge lower front-end fees than brick-and-mortar distributors like banks and brokerages.

<sup>8</sup>Includes Annual Management Fees which may range from 0% to 3% of NAV.

Source: <http://mycpf.cpf.gov.sg/Members/Gen-Info/FAQ/Investment/INV.htm>

**Table 1.10: Sales Loads and Expense Ratios for CPFIS Unit Trusts**

<b>Risk category</b>	<b>Type of fund</b>	<b># Funds</b>	<b>Average sales load</b>	<b>Average expense ratios</b>
Higher risk	Equity	167	4.9%	2.07%
Medium-high risk	Balanced	26	4.8%	1.93%
Low-medium risk	Income	39	2.1%	1.12%
Lower risk	Cash	3	0.1%	0.71%
<b>Total N Funds</b>		<b>235</b>		

Note: The sales load comprises both front-end and back-end sales charges. Annual operating costs comprise fees for management, custodian, trustee, administration, and other major fees paid by the unit trust out of the fund's net asset value, and is estimated using the total expense ratio publicly reported by Investment Management Association of Singapore under its Fund Information Service website ([www.fundsingapore.com](http://www.fundsingapore.com)).

Source: Authors' computations using fund prospectuses and IMAS-reported expense ratios as at 30 Jun 2006.

**Table 1.11: Simulation Study of Impact of Fund Expenses by Fund Type for Alternative Holding Periods**

A. Fraction of Value Remaining After Expenses Assuming Zero Investment Return, by Fund Type and Holding Period

<b>Fund type</b>	<b>Year 1</b>	<b>Year 5</b>	<b>Year 10</b>	<b>Year 20</b>
Equity	0.931	0.857	0.772	0.626
Balanced	0.934	0.864	0.784	0.645
Income	0.968	0.925	0.874	0.781
Money market	0.992	0.964	0.930	0.866

B. Percentage of \$1 Investment Eroded by Expenses Assuming Zero Investment Return, by Fund Type and Holding Period (%)

<b>Fund type</b>	<b>Year 1</b>	<b>Year 5</b>	<b>Year 10</b>	<b>Year 20</b>
Equity	-6.9%	-3.0%	-2.6%	-2.3%
Balanced	-6.6%	-2.9%	-2.4%	-2.2%
Income	-3.2%	-1.5%	-1.3%	-1.2%
Money market	-0.8%	-0.7%	-0.7%	-0.7%

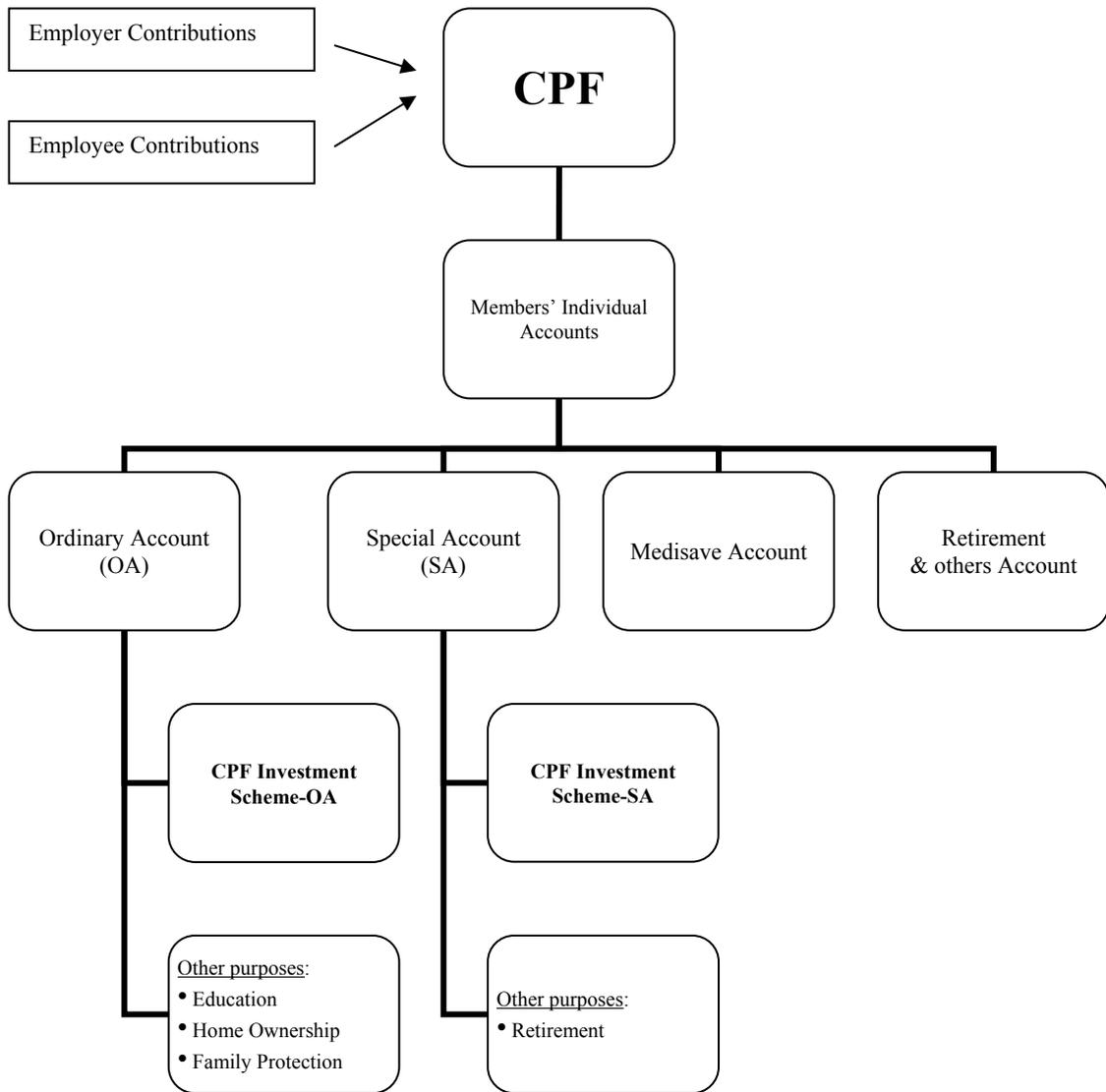
C. Minimum Investment Return (Hurdle Rate) Required to Beat CPF Default Interest Rate on Ordinary Account (OA) and Special Account (SA), by Fund Type and Holding Period

<b>Fund type</b>	<b>Hurdle rates for OA</b>				<b>Hurdle rates for SA</b>			
	<b>Year 1</b>	<b>5</b>	<b>10</b>	<b>20</b>	<b>1</b>	<b>5</b>	<b>10</b>	<b>20</b>
Equity	9.4%	5.5%	5.1%	4.8%	10.9%	7.0%	6.6%	6.3%
Balanced	9.1%	5.4%	4.9%	4.7%	10.6%	6.9%	6.4%	6.2%
Income	5.7%	4.0%	3.8%	3.7%	7.2%	5.5%	5.3%	5.2%
Money market	3.3%	3.2%	3.2%	3.2%	4.8%	4.7%	4.7%	4.7%

Notes: This simulation study assumes that the prices of unit trusts remain unchanged so the change in the fund position solely reflects cost impacts on a \$1 investment over 1 year, 5 years, 10 years, and 20 years. Costs include the one-off sales load and the annual operating costs for each of the four fund types as presented in Table 1.10. The sales load comprises both front-end and back-end sales charges. Annual operating costs comprise fees for management, custodian, trustee, administration, and other major fees paid by the unit trust out of the fund's net asset value, and is estimated using the total expense ratio publicly reported by Investment Management Association of Singapore (IMAS) under its Fund Information Service website ([www.fundsingapore.com](http://www.fundsingapore.com)). The performance fee is excluded from the total expense ratio.

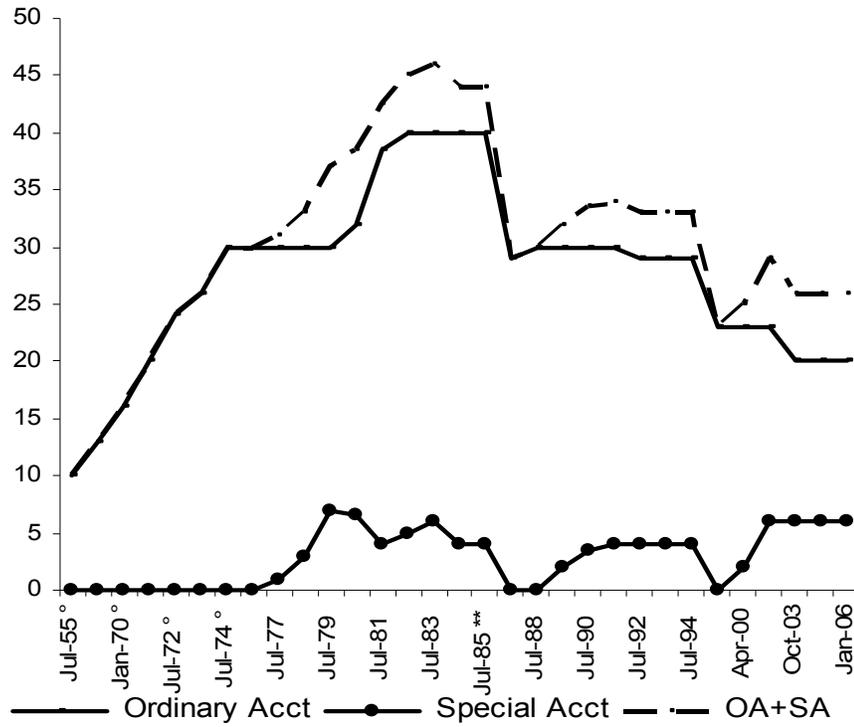
Source: Authors' computations using fund prospectuses and CPF (2006).

**Figure 1.1: Central Provident Fund Overview**



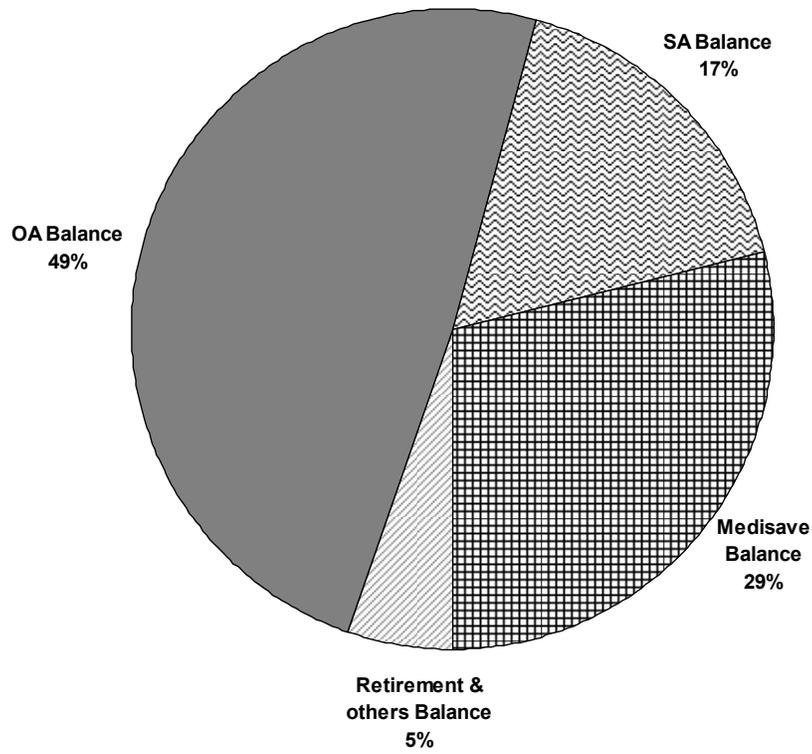
Source: Adapted from Low and Aw (2004).

**Figure 1.2: Contribution Shares to CPF OA and SA Accounts over Time: % of covered earnings (workers age 35 -45)**



Source: Table 1.2

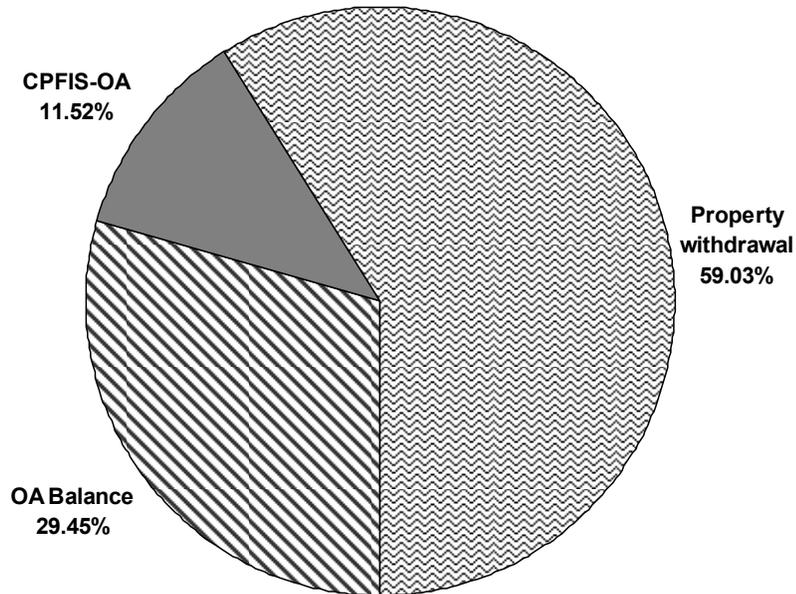
**Figure 1.3: Balances in Specified CPF Accounts**



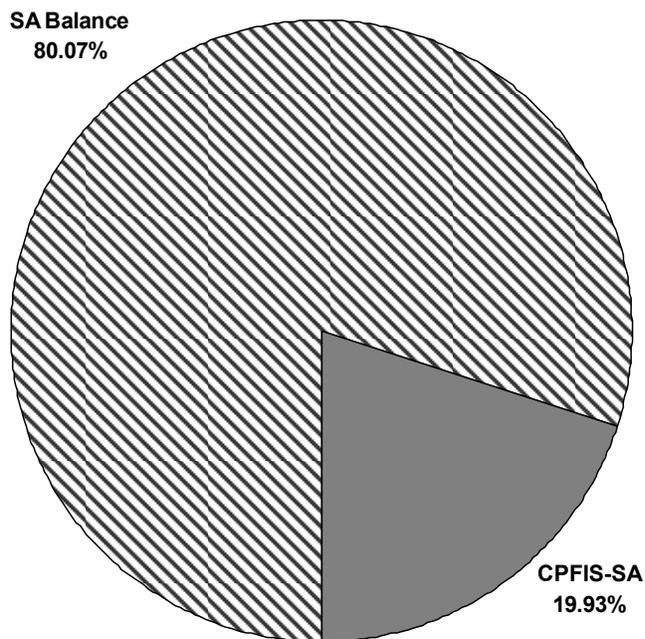
Source: Table 1.7.

**Figure 1.4: Portion Invested and Balance Remaining in CPF Ordinary and Special Accounts**

A. Portion of Balance Remaining in OA Account vs. Portion Used for Investment

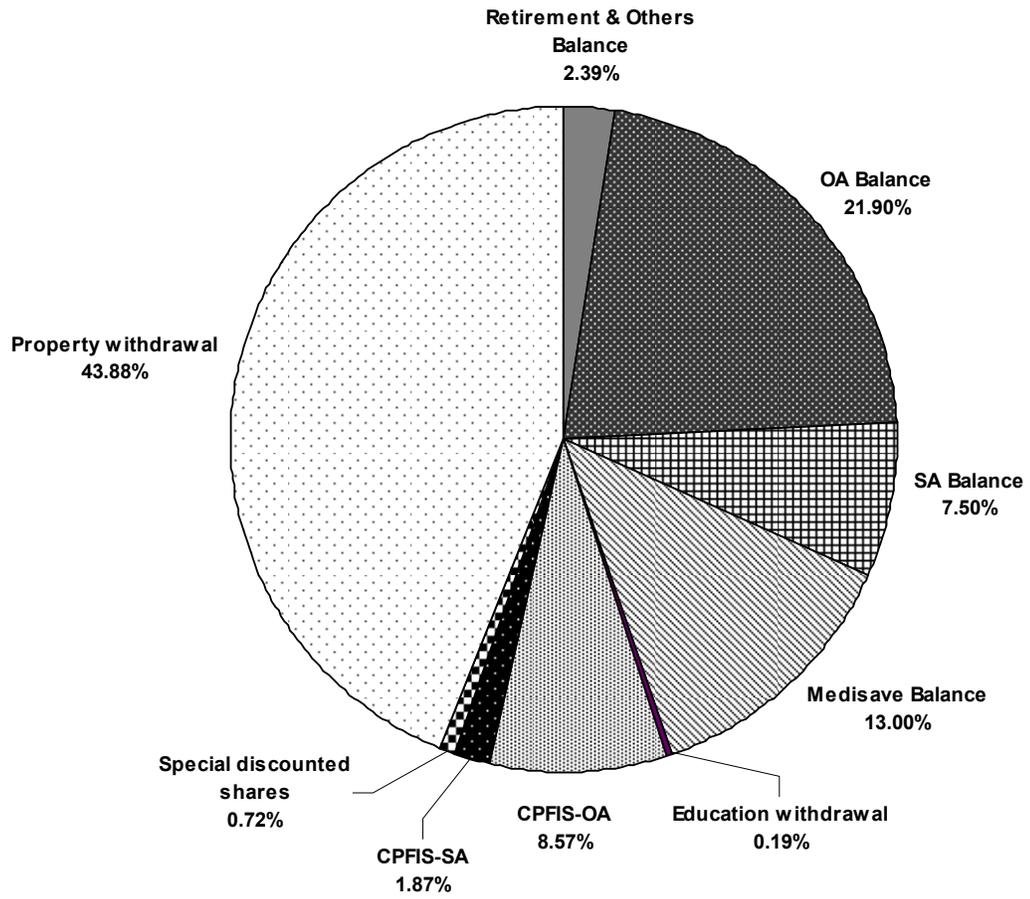


B. Portion of Balance Remaining in SA Account vs. Portion Used for Investment



Source: Table 1.7

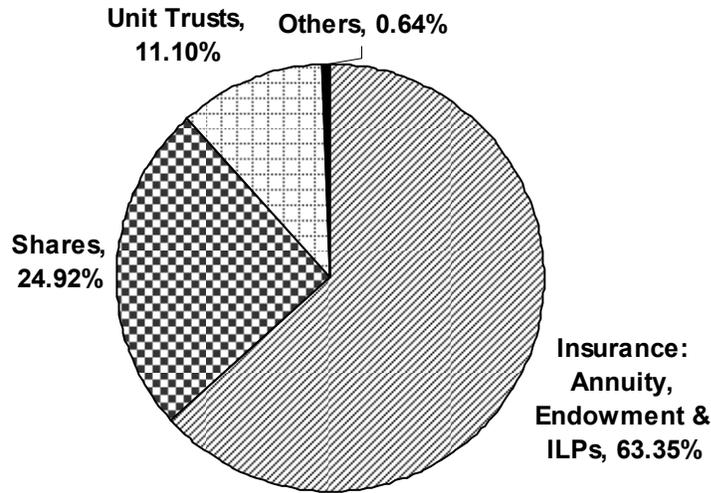
**Figure 1.5: Cumulative Use of CPF Funds (OA and SA combined)**



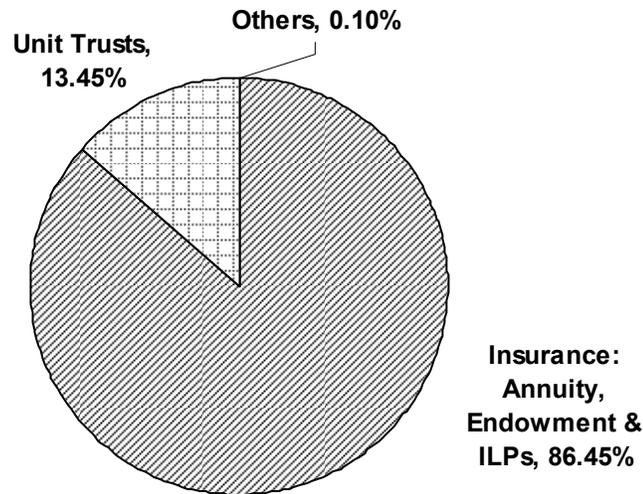
Source: Derived from Table 1.7.

**Figure 1.6: Allocation of Investments across CPFIS Accounts**

A. CPFIS Ordinary Account



B. CPFIS Special Account

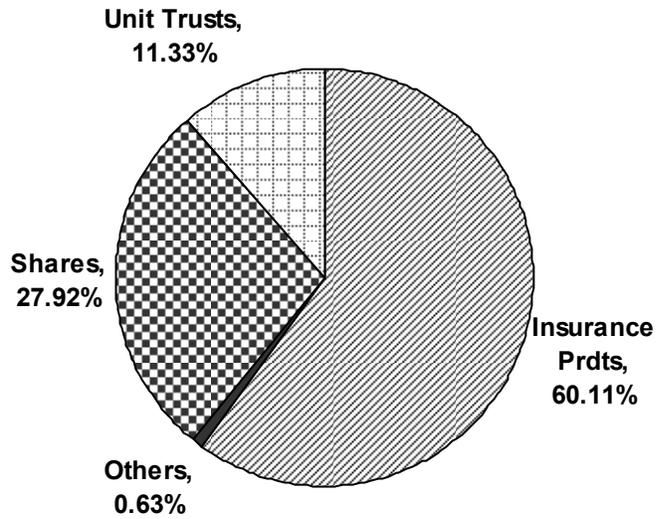


Note: For CPFIS Ordinary Account, “Others” include fixed deposits, bonds, ETFs, gold, property funds, and fund management accounts. For CPFIS Special Account, “Others” include fixed deposits and bonds only.

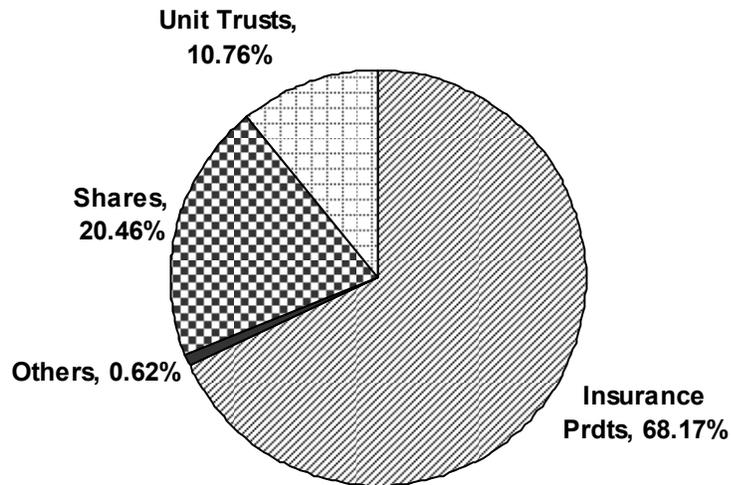
Source: CPF (2005c).

**Figure 1.7: Investment Patterns in CPF Ordinary Accounts by Sex**

**A. Men**



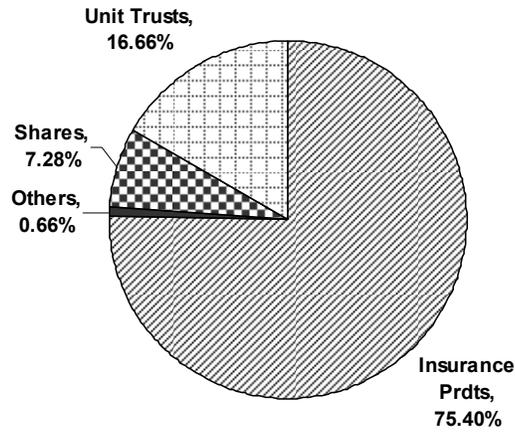
**B. Women**



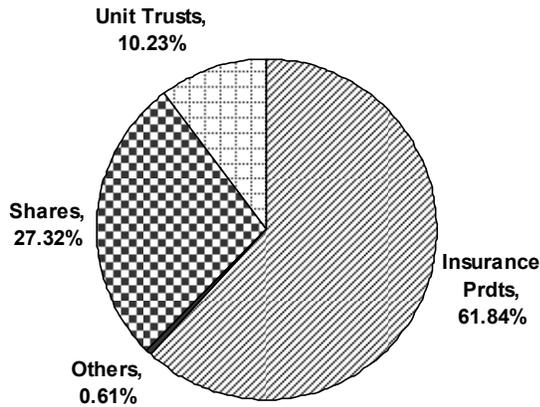
Note: "Others" include ETFs, gold, fixed deposits, bonds, and property funds.  
Source: Data kindly provided by CPF Board; values as of Sept 30, 2005.

**Figure 1.8: Investment Patterns in CPF Ordinary Accounts by Age**

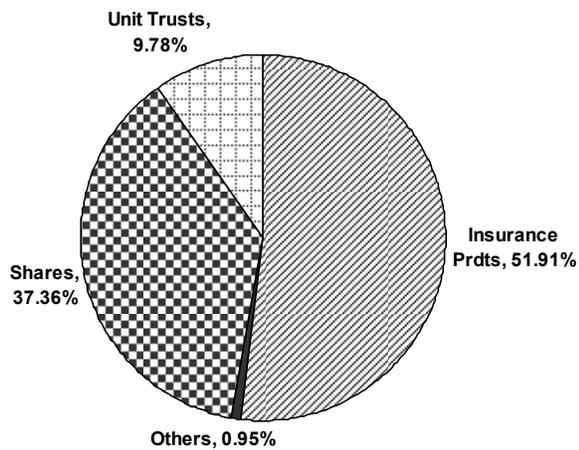
A. Young Adult (21 - 35 years)



B. Middle Age (36 - 55 years)

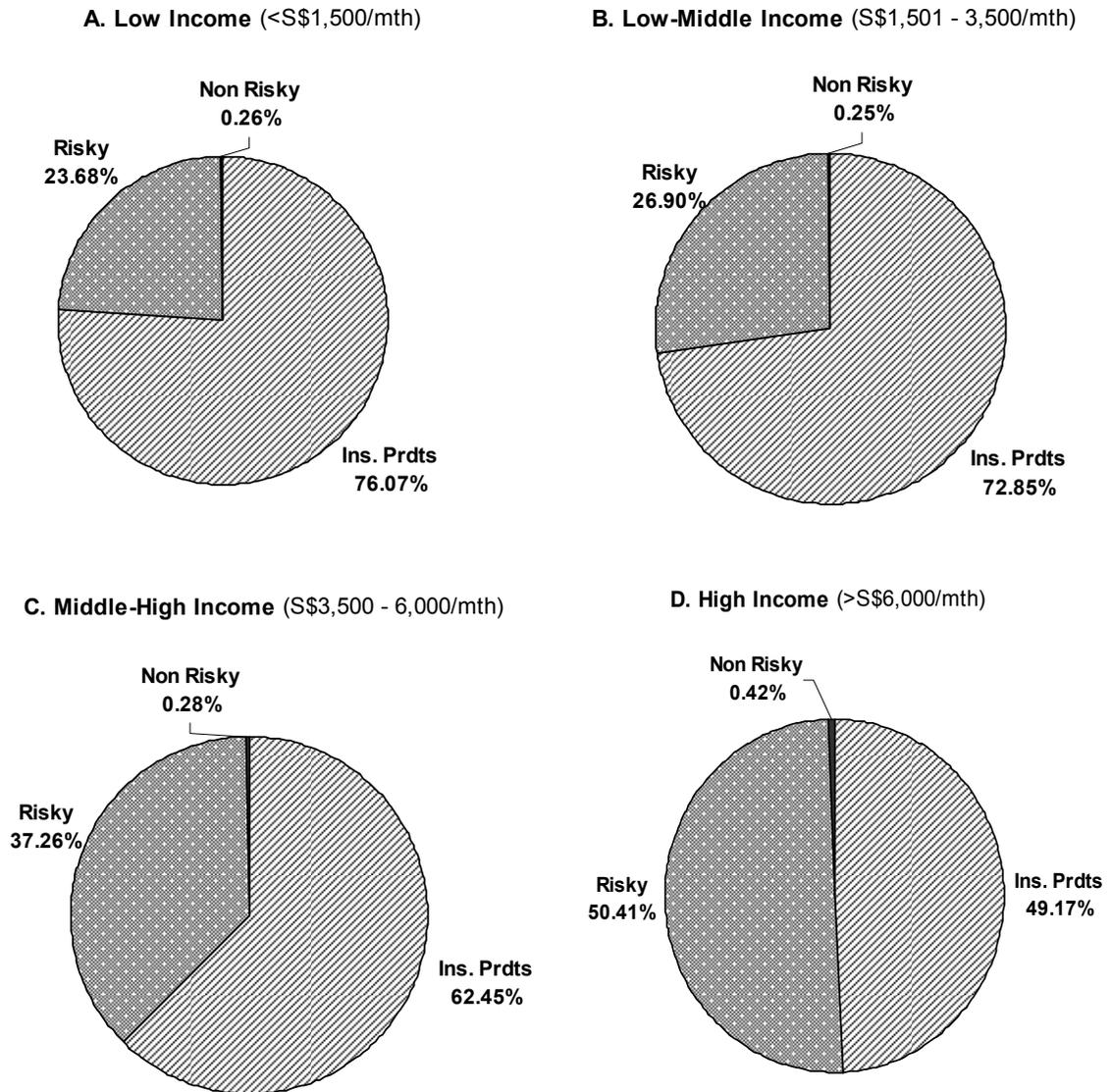


C. Mature ( $\geq 56$  years)



Notes: "Others" include ETFs, gold, fixed deposits, bonds, and property funds.  
 Source: Data kindly provided by CPF Board; values are as of Sept 30, 2005.

**Figure 1.9: Investment Patterns in CPF Ordinary Accounts by Risk Type and Income**



Note: Participants with positive income only are included. Risk level of insurance products cannot be evaluated.

Source: Data kindly provided by CPF Board; values as of Sept 30, 2005.

## CHAPTER 2

### Longevity Risk Management in Singapore's National Pension System<sup>25</sup>

While defined contribution (DC) pensions have enjoyed varying degrees of success during the accumulation phase, proponents of the DC model now confront the larger question of how participants will manage their capital throughout the payout phase so as not to run out of money in retirement. Not surprisingly, governments have become involved in this decision, as in the case of Switzerland where annuitization is the default payout modality; given a choice, most retirees elect to annuitize (Bütler and Teppa 2007). The U.K. has a long history of annuitization for those holding private DC pension accounts, yet retirees have substantial leeway over how much to annuitize and when (Finkelstein and Poterba 2002, 2004). And in Chile, workers have long been given a choice between phased withdrawal and annuitization when they claim their pensions (Mitchell and Ruiz 2010).

In contrast to such flexibility over annuitization, the Central Provident Fund (CPF) of Singapore has recently announced that retirement assets held by its citizens in the national defined contribution plan must be mandatorily annuitized so as to better protect retirees against the possibility of outliving their wealth. At the same time, the government has decided to enter the insurance market as a provider for these annuities. This paper evaluates the money's worth of privately-offered annuities prior to the

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<sup>25</sup> This chapter has been accepted for publication in the Journal of Risk and Insurance (John Wiley and Sons). See Fong, J.HY., O.S. Mitchell, and B.SK. Koh, 2011, Longevity Risk Management in Singapore's National Pension System, Journal of Risk and Insurance, *Forthcoming*.

reform, discusses the impact of the government mandate, and assesses how the entry of the government as an annuity provider is shaping the nation's insurance markets. Our results are of interest for several reasons. First, the CPF is widely acknowledged as one of the world's largest – and arguably most successful – defined contribution schemes. Accordingly it is valuable to see how this system is handling the challenges of a rapidly aging population. Second, we seek to determine whether market failure – i.e. low value-for-money annuities – prompted the government to enter the insurance market as an annuity provider, and whether the new government-offered annuities will provide greater value to retirees.

We show that competitively-priced life annuities were offered by private insurers in Singapore prior to the reform, with money's worth ratios in the 0.88-1.05 range for males – on par with those in many other countries. Moreover, adverse selection costs were reasonable, on the order of 3.3 to 5.6 percentage points. The new government-offered annuities are estimated to provide money's worth ratios exceeding unity, benefitting annuitants on average but also implying that the annuity mandate will be expensive for the government if current pricing continues.

These findings are relevant to the current debate about how to best deploy annuities to manage longevity risk, within the context of a defined contribution scheme. On the positive side, mandating annuitization can reduce loads and adverse selection and can help retirees better manage the risk of outliving their income, as detailed by Emms and Haberman (2008) and Horneff et al. (2008). Yet on the negative side, mandating can also pose challenges. For instance, making annuity purchase compulsory

produces utility losses for less risk-averse retirees.<sup>26</sup> Also, if left to private annuity providers, market distortions can arise: for instance, in the U.K. Murthi, Orszag and Orszag (2000) describe falling annuity yields, high markups on annuities, and ‘mis-selling’ incidents, which they attributed to a captive yet privately-run insurance market. By contrast, the Singaporean approach shows that a national government can both mandate and provide a risk-pooling scheme. Yet there are also risks in government provision, in that private insurers may be crowded out in the process. Indeed in Singapore, all but one of the eight private insurers stopped selling CPF-compliant annuities between 2007 and 2009. Whether this crowd-out effect is short-term or permanent remains an open question and an important one to address in future research.

## **2.1 Background**

Established in 1955, the Central Provident Fund is the mainstay of Singapore’s old-age system. It is one of the world’s largest defined contribution schemes with about 3.23 million members; the program also faces a rapidly aging population due to one of the world’s lowest fertility rates (1.29 per female) and longest life expectancies (80.6 years at birth).<sup>27</sup> The government of Singapore has recently introduced the concept of a national longevity insurance scheme to address the challenges of increasing life expectancy given population aging (CPF 2009*a*). As of 2013, annuitization, rather than the current phased withdrawal approach, will become the mandatory vehicle for a portion of CPF retirement saving under the auspices of the regulatory public agency

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<sup>26</sup> See for example, Mitchell et al. (1999) and Blake, Cairns, and Dowd (2003).

<sup>27</sup> Figures for 2007 year-end from the Singapore Department of Statistics (SDOS 2008*a*).

known as the CPF Board. Under the CPF LIFE scheme, new annuity products began to be offered in September of 2009.

Prior to this reform, the government had established the concept of a Minimum Sum (MS) which required participants at age 55 to set aside for retirement a specific dollar value of assets from their total CPF accumulations;<sup>28</sup> excess accumulations could be withdrawn as a lump-sum.<sup>29</sup> This Minimum Sum had to be preserved to age 65 (previously 62) before any drawdowns were permitted, and the default decumulation option after that was a phased withdrawal scheme paying benefits over about 20 years (or until the balance was exhausted). This framework exposed participants to significant longevity risk, since about half of all age-65 members would be expected to outlive their assets (CPF 2008). Those having the full Minimum Sum amount in cash could voluntarily buy a life annuity from private insurers, but this group was a small fraction of the total. Among the active members who turned 55 in 2008, only about one-third had accumulated the required MS (CPF 2009*b*). And only one in six eligible to do so actually elected to buy an annuity from private insurers under the MS Scheme,<sup>30</sup> perhaps because the phased withdrawal payout of S\$790 was higher compared to an average monthly annuity payment of S\$520.<sup>31</sup> Another reason might be costs; indeed

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<sup>28</sup> The required Minimum Sum is set by the CPF and increases each year. It was S\$80,000 in 2003, S\$99,600 in 2007 and it is expected to be about S\$134,000 in 2013 (CPF 2008 and 2009*b*).

<sup>29</sup> If a member's total balance is higher than the Minimum Sum, any remaining balance can be withdrawn as a lump sum. If the total balance is less than the Minimum Sum, the following withdrawal rules currently apply to members who reach age 55 between 1/1/2010 and 6/30/2010: if the balance  $\leq$  \$5,000 one may withdraw everything; if  $\$5,000 < \text{total balance} \leq \$16,667$  one may withdraw \$5,000 and set aside the remainder in the Retirement Account; and if  $\$16,667 < \text{total balance} \leq \$167,143$  one may withdraw 30% of the balance and set aside the remainder in the Retirement Account (CPF 2009*c*).

<sup>30</sup> See Fong et al. (2010).

<sup>31</sup> This applies to a member with the full Minimum Sum of \$99,600 at age 55 (as of 2007) (CPF 2007). Under phased withdrawal, he could draw down his balance plus interest via monthly payouts of \$790 and the flow would continue for 20 years at which point the balance is likely to be exhausted.

Prime Minister Lee suggested as much in stating that “frankly speaking, the returns have not been very attractive, (and) the costs have been high.” (SPMO 2007).

In 2007, the Singapore Government convened a National Longevity Insurance Committee (NLIC) to study the feasibility of the national longevity insurance scheme. After extensive hearings and review, it concluded:

*“The operation of the scheme will involve significant mortality and investment risks over a very long time horizon....The committee notes the difficulties that some annuity providers abroad had run into when various risks were not properly managed. In some circumstances, provider risked insolvency as they were unable to meet liabilities... Members of the public have therefore expressed a preference of the CPF Board to administer the scheme due to the favorable CPF interest rates....participants will need to have confidence in this national scheme to provide for their retirement, the operator must engender public trust and have strong administration capability.” (CPF 2008).*

In other words, the Committee argued that the government should offer annuities due to greater public trust and perhaps greater efficiency, and indeed it is possible that a government-run pooling scheme could benefit from better annuity pricing through economies of scale and lower administrative loads. Furthermore, if it could become the primary provider, it could pool sufficient annuitants such that the average mortality risk of the pool would decrease. Mitigating these advantages include concern about whether the public sector would have sufficient in-house expertise and might crowd out commercial insurers. In any event, in February 2008, the government mandated life annuities and also required the CPF Board to operate a national longevity insurance scheme that would “give Singaporeans confidence that the scheme will be properly administered” (CPF 2008). Personnel from the Ministry of Manpower and the CPF Board devoted almost two years to design the system, consulting industry professionals

in the process. The launch of the pilot program in September 2009 was accompanied by intensive public education through the media, road-shows, and pamphlets, and it generated substantial interest: since launch, over 30,000 members committed about S\$1.5 billion to the CPF LIFE scheme (CPF 2010).

In what follows, we assess whether unattractive annuity yields and high costs were, in fact, problematic in the Singaporean context and thus might rationalize government provision.

## **2.2 Methodology**

A large literature focuses on measuring the money's worth of annuities in Western countries. Consistent with that opus, we define the money's worth ratio (MWR) of a payout annuity as the ratio of the expected present discounted value (EPDV) of annuity payments to the initial premium (Mitchell et al. 1999). Whereas a fairly priced annuity with no loadings will have a MWR of unity, in the real world, privately-sold annuities have MWRs of less than one due to administrative costs and adverse selection. Adverse selection occurs in a voluntary market since those who elect to purchase a payout annuity tend to live longer than those who do not; adverse selection raises prices for all those who do purchase. Adverse selection costs are computed as the difference between the MWRs using annuitant versus population survival tables (Mitchell et al. 1999). Many prior studies have used the MWR notion to measure value for money in a range of annuity products including constant and rising payout products, joint-and-survivor annuities, and annuities with guarantee periods (cf. Mitchell et al. 1999; Brown et al. 2001; Finkelstein and Poterba 2002, 2004; Thorburn et al. 2005).

The annuities offered under the Singaporean CPF scheme are somewhat different from products on offer elsewhere, as they include a guaranteed amount if the death of the insured occurs in a specified time frame. Specifically, when the insured dies, the beneficiary receives the guaranteed amount of the single premium plus accrued interest (if any) less total amount of annuity payouts already made (if positive).<sup>32</sup> The refund, which is a lump-sum payment to the beneficiary, provides an element of capital protection.<sup>33</sup> Accordingly, the expected present discounted value (EPDV) of a nominal annuity with a guaranteed amount may be written as follows:

$$\text{EPDV} = \sum_{t=0}^{D-1} {}_t p_a \cdot q_{a+t} \cdot v^{t+1} G_{t+1} + \sum_{t=D}^{\infty} ({}_t p_a \cdot q_{a+t} \cdot v^{t+1} G_{t+1} + {}_t p_a \cdot v^t A_a), \quad (1a)$$

where  $G_{t+1} = \max\{0, \text{premium} + \text{accrued interest} - \text{total annuity payouts received prior to time } t + 1\}$ .

In Equation (1a),  $a$  is the age at which the annuity is purchased,  $t$  represents the number of months beyond the annuity start date,  $A_a$  refers to the fixed monthly nominal annuity payout for the individual purchasing the annuity at age  $a$ ,  $v^t$  is the nominal discount rate at month  $t$  based on a riskless term structure, and  ${}_t p_a$  is the probability that an individual of age  $a$  survives after  $t$  months. To account for the guarantee amount and the deferral period, we also define  $D$  to be the deferred period (expressed in months),  $G_{t+1}$  is the death benefit at time  $t + 1$ , and  ${}_t p_a \cdot q_{a+t}$  is the probability of an annuitant

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<sup>32</sup> Accrued interest is accumulated from age 55 when the premium is paid to the point where payouts start (at age 62 in 2007). Not all annuities incorporate the accrued interest component in the guaranteed amount on death. Accrued interest ranges from 0% to 2.5% per annum in 2007; see Table 2.1.

<sup>33</sup> This is somewhat similar to the money-back annuities available in other countries. For example, value-protected annuities that were introduced in the U.K. in 2006 feature partial money-back option where the lump-sum death benefits are permitted up to age 75, and are taxed (Boardman 2006).

age  $a$  surviving to  $t$  months and then dying between month  $t$  and month  $t + 1$ . The first term in Equation (1a) captures the guarantee amount to the beneficiary if the insured dies during the deferral period, while the second term reflects benefits paid to the insured if he lives to the point when payouts start. Alternatively, the formula can be more neatly presented per Equation (1b) where the first summation accounts for the death benefit arising from the money-back guarantee, and the second summation captures the annuity benefit over the lifetime of the individual:

$$\text{EPDV} = \sum_{t=0}^{\infty} {}_t p_a \cdot q_{a+t} \cdot v^{t+1} G_{t+1} + \sum_{t=D}^{\infty} {}_t p_a \cdot v^t A_a, \quad (1b)$$

To implement the EPDV valuation for Singapore, we use the newly released population mortality tables from Singapore Statistics (SDOS 2008b) having a limiting age of 100; we then cohortize the population tables (as cohort mortality tables are unavailable) using period life tables. Thus having a year 2007 period life table, we compute:

$$\hat{q}_x(2007 + t) = q_x(2007) \times (\beta_x)^t, \quad (2)$$

where  $q_x(2007)$  is the annual mortality rate for age  $x$  in year 2007,  $\hat{q}_x(2007 + t)$  is the estimated annual mortality rate for age  $x$  in year  $(2007 + t)$ , and  $\beta_x$  represents the estimated annual mortality improvements for an individual aged  $x$  extrapolated from mortality changes between 1990 and 2005. As in previous studies, mortality improvement rates are projected from the abridged period population tables for Singapore published by the World Health Organization (various years).

Little is publicly known on actual annuitant mortality experience in Singapore. Insurance industry practice and previous research including Fong (2002) has adopted the UK annuitant mortality experience with adjustments for local conditions, similar to what is done in Australia. The Monetary Authority of Singapore (MAS) in its capacity as insurance regulator requires firms to employ the UK a(1990) Ultimate Tables rated down five years for reserves and liability valuations pertaining to annuities sold (MAS 2008a).<sup>34</sup> Accordingly, we use the a(1990) tables with a five-year setback to estimate the annuitant experience for our valuation year, and then we cohortize the resulting annuitant tables.<sup>35</sup> We compute cumulative survival probabilities from the cohort tables as follows:

$${}_t p_a = \prod_{j=0}^{t-1} (1 - q_{a+j}), \quad (3)$$

where  ${}_t p_a$  is the cumulative probability of a person aged  $a$  surviving for  $t$  years, and  $q_{a+j}$  is the probability of a person age  $(a + j)$  dying within the year. These cumulative survival probabilities are sex-specific and calculated on a monthly basis to match the frequency of the annuity payouts. In addition, we apply a uniform distribution of deaths (UDD) assumption to reflect mortality patterns in Singapore. We justify using UDD for fractional ages within a year due to the lack of variation in Singapore's weather (so

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<sup>34</sup> The Sixth Schedule of the Insurance Regulations 2004 stipulates that insurers may employ the rates in the UK a(90) tables with a five-year setback to value their annuity liabilities. Previously, Insurance Regulations 1992 required insurers to employ the a(1990) tables with a two-year setback. The a(1990) tables are constructed based on UK annuitants' mortality experience from 1967-70 with mortality improvements projected to 1990. By applying the 5-year setback, we effectively age the tables to Year 2007 and then cohortize for the MWRs.

<sup>35</sup> As a robustness check, we verify that our calculations yield a lower mortality for annuitant cohort than the population cohort; for instance, a 65-year-old male in the general population has a mortality of 0.01028 compared to 0.00933 for an annuitant.

death rates are unlikely to vary seasonally).<sup>36</sup> We match the limiting age of the population group with that of the annuitant group by extrapolating population mortality estimates to the common maximum age of 117 to properly capture the longevity tail risk in the population group.<sup>37</sup> This improves comparability between the two groups by ensuring that a person drawn randomly from the population also has some probability of survival leading to annuity payouts even at the tail end, rather than being curtailed at 100 years of age.

Figure 2.1 compares the cumulative survival probabilities we derive for the general Singaporean population and for annuitants. The Figure shows the probability that a 55-year old man (or woman) will survive to various ages given mortality rates for the population at large, as well as those for annuitants. Not surprisingly, the average 55-year old annuitant has a higher survival probability at all ages, implying some adverse selection costs to be discussed below.<sup>38</sup>

*[Figure 2.1 here]*

The EPDV calculation requires a term structure of interest rates; we judge the Singaporean Treasury bond rates as most appropriate since the MSS annuities are viewed as capital protected. Prices and yields of the Singapore Government Securities

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<sup>36</sup> Various actuarial assumptions could be used for fractional ages within a year, including a uniform distribution of deaths, a constant force of mortality, or a hyperbolic pattern (Bowers et al. 1997). Prior studies on MWR have not explicitly specified assumptions for fractional ages within a year (e.g. Doyle et al. 2004). For a plot of our values of  ${}_t p_{55} \cdot q_{55+t}$  derived from the UDD assumption, see *Appendix Figure 2.1*.

<sup>37</sup> We use population period tables from Singapore Statistics. These tables had applied the Coale-Kisker method to project mortality at higher ages, using a separation factor of 0.5 (SDOS 2008b). Given  $q_x$  for ages 85 -99, we back out the death rates ( $m_x$ ) and observe that the change in  $m_x$  between each age interval is constant at about 9.3%. Extrapolating this constant graduation rate, we then derive the  $q_x$  for ages 100 - 117.

<sup>38</sup> Finkelstein and Poterba (2002) attributed these mortality differences largely to socio-economic, or passive, selection effects.

Treasury bonds obtained from MAS (2008*b*) are used to compute the riskless spot rates to proxy the yields on hypothetical zero coupon bonds.<sup>39</sup> To obtain the full term structure, we then linearly interpolate between intervals where spot rates are unavailable, for instance between the 7- and 10-year spot rates.<sup>40</sup>

### **2.3 Results: MWRs for Voluntary Private Annuities**

Prior to the mandatory annuity reform, plan participants with sufficient cash could voluntarily purchase a life annuity from 7-9 insurers participating in the market; the firms included some international players with Singaporean offices (e.g. AIA, Prudential, and HSBC Insurance), as well as several local insurers.<sup>41</sup> This program promoted annuity purchase among CPF participants; Fong (2002) estimated that as at 2000, about 87 percent of all Singapore annuitants had purchased their policies through this scheme. The annuity premium equaled the prevailing Minimum Sum for the year, and insurers were free to determine participant payouts and guarantee amounts. In 2007, for instance, in exchange for a lump-sum premium at age 55 of S\$99,600, monthly annuity payouts beginning at age 62 varied as outlined in Table 2.1. The nine annuities on offer by eight commercial insurers were similar in that the standard deviation in

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<sup>39</sup> The first year rate is derived from the 1-year Treasury bill; thereafter, the 2, 5, 7, 10, 15 and 20-year Treasury bond rates as of 2007 are used to estimate the riskless spot rates. Our annual spot rate ranges from 1.4% to 3.44%. Since maximum duration available is only 20 years, we then extrapolate the last spot rate into the future, yielding a nominal riskless term structure of interest rates on Singapore's Treasury bonds.

<sup>40</sup> See *Appendix Table 2.1* for a list of key inputs compared to those used in two earlier money's worth studies for annuities in Singapore.

<sup>41</sup> As at Dec 2007, three insurers accounted for almost 80% of the total market share for individual annuity policies, inclusive of annuity purchases using non-CPF pension saving (MAS 2007). In particular, a home-grown co-operative, NTUC Income, has long been the market leader with 58% market share and about 38,000 annuity policies in force as at end 2007. Great Eastern Life and UOB Life have approximately 11% market share each, higher than that of AIA (8.5%) and Prudential (1.6%).

payments was only about five percent. All annuities had fixed nominal payouts; two also promised a non-guaranteed annual bonus payment depending on the insurer's performance. Level monthly payouts ranged from S\$495-559 for males and S\$441-514 for females; the guaranteed amount upon death was at least the premium S\$99,600 and several annuities paid interest of 0.5-2.5%.

*[Table 2.1 here]*

Using these annuity quotes in Equation (1) generates the desired MWRs reported in Table 2.2. Here we see that, per premium dollar, the typical male annuitant would have anticipated receiving an average of \$0.947 and the female \$0.955 in 2007. It is also of interest that the NTUC Income co-operative offered the highest money's worth ratios of 1.047 (males) and 1.081 (females); these exceeded the private insurer average by 10.5 and 13.1 percent, respectively.<sup>42</sup> We measure the cost of adverse selection as the difference in the MWR using population versus annuitant tables. Our values of 3.3–4.1 percentage points (or cents per \$1 premium) for males and 4.2–5.6 for females are comparable to the U.K. figure of 4.6 reported by Finkelstein and Poterba (2002) but below the 6 and 10 percentage points found for Australia and U.S. respectively (Doyle et al. 2004; Mitchell et al. 1999). In terms of proportion, we see from the Table that adverse selection costs accounted for about 47% of the total loadings, which is quite reasonable compared to other countries. For example, in the U.S., Brown et al. (2001) found that roughly half of the cost of purchasing a voluntary annuity could be attributed to adverse selection.

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<sup>42</sup> NTUC Income is a non-profit oriented co-operative for the Workers' Union. This result is consistent with NTUC Income's mission to return the majority of profits to policyholders (NTUC Income 2009).

*[Table 2.2 here]*

The reasonable adverse selection costs observed in the private annuity market in Singapore may be partly attributed to the unique characteristics of the MS Scheme annuities. For one thing, the premium guarantees contribute significantly to reducing adverse selection; indeed in results not reported here in detail, removing the embedded guarantee would increase adverse selection by 20-26 percent. Also important is the deferral period on these annuities (between ages 55 and the benefit-claiming age). Without this, adverse selection would have been higher by 9-13 percent. In any case, the annuity marketplace prior to the most recent reform offered relatively competitively priced products, by world standards, with reasonable adverse selection costs.

## **2.4 Sensitivity Analysis**

As noted earlier, annuitant mortality rates for Singapore are derived from UK annuitant tables, due to lack of annuitant experience in Singapore. To evaluate how sensitive our results are to variations in mortality, we modify the tables to allow life expectancy to vary by two years on either side of our base case annuitant estimates, dated from the year of purchase. The mortality of a 57-year-old then represents a +2-year adjustment and the mortality of a 53-year-old represents a -2-year adjustment. Results in Table 2.3 (Panel A) show that lightening mortality by two years exacerbates adverse selection, while the opposite holds when mortality is made heavier. In addition, the adjustments make slightly more difference to the adverse selection results for males than females. We also explore sensitivity to interest rate variations. The Singapore government bonds were used to derive the riskless term structure. The spot rate on the

20-year bond (3.44%) was used as a proxy for the long-term interest rate for periods beyond 20 years. Sensitivity testing using 50 and 100 basis points around the central case shows that money's worth values are sensitive to these changes, as Table 2.3 (Panel B) indicates. In any event, our estimates of adverse selection remain robust.

*[Table 2.3 here]*

## **2.5 Results: MWRs for Mandatory Annuities**

Under the new CPF LIFE scheme introduced in 2009, participants may either purchase a private annuity or select from a menu of government-offered annuity products called the CPF LIFE plans. Initially the intention was to provide a dozen different payout options outlined in 2008, but the menu was later pared back to four plans in 2009 after public feedback suggested that too much choice was confusing. The final four are known as CPF LIFE Basic, LIFE Balanced, LIFE Plus, and LIFE Income. Table 2.4 presents illustrative payouts for the various LIFE plans as the government's proposals evolved, for an annuity premium of half the estimated Minimum Sum or S\$67,000 in 2013.<sup>43</sup> For that premium, benefit payouts were initially set to be quite generous: in six of the 12 original plans proposed in early 2008, monthly payouts would have ranged from S\$560-650 for males and S\$540-590 for females. By September of 2009, when the final LIFE plans were launched, promised monthly payouts had been adjusted downward to about S\$524-636 for men and S\$500-553 for women.

*[Table 2.4 here]*

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<sup>43</sup> By 2013, the prevailing Minimum Sum is expected to be about S\$134,000 (S\$99,600 in 2007). The CPF estimated that of the approximately 35,000 active members in the 2103 cohort of members turning age 55, about 60% will have at least S\$67,000 in cash in their Retirement Accounts (CPF 2008).

Table 2.4 also shows the ‘annuity component’ expressed as a percentage of the annuity premium. That is, the CPF LIFE products split the premium paid into a term and an annuity component. The first covers payouts from age 65 to the vesting age which differs across the plans; any unused balance from the term component and interest from it is fully refundable to one’s heirs. The annuity component finances payouts from the vesting age to death with no funds passed on to the beneficiary. Thus the four finalized LIFE plans provide a range of trade-offs, balancing providing for oneself and leaving a bequest for one’s beneficiaries. In practice, the transition from the term to the annuity component is purely procedural and does not affect monthly benefits to any CPF member in receipt, with the interest from the annuity component being non-refundable to individual participants as it funds the CPF LIFE scheme. In other words, interest forfeited represents participants’ opportunity cost of joining the LIFE plan. This cost is factored into the money’s worth computations by means of a guaranteed amount  $G_t$  that falls as the retiree ages. While the LIFE Plus and LIFE Income plans both feature only an annuity component, the LIFE Plus product permits some bequest whereas LIFE Income allows none.<sup>44</sup> A retiree who opts for the LIFE Income product received a higher monthly payout while alive, making the product most appealing to unmarried or childless individuals. By comparison, the LIFE Basic plan provides for the highest bequest amount in exchange for the lowest monthly payouts by allocating most to the term component. The LIFE Balanced plan provides an intermediate mix.

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<sup>44</sup> The bequest on the LIFE Plus plan is the unused portions of the annuity component (which in this case is equal to the premium paid). Refund equals premium paid less annuity payouts already made. Members who join CPF LIFE may not withdraw unless they have medical grounds of shortened life expectancy, or if they are leaving Singapore and West Malaysia permanently with no intention of returning to either country. Members are also not allowed to change their LIFE plans after joining the scheme (CPF 2009*d*).

Since these annuities are being mandated, we generate money's worth values using Singapore population mortality tables. Results in Table 2.4 show that the government LIFE plans offer excellent value-for-money to annuitants.<sup>45</sup> For instance, using the riskless term structure with a long-term rate assumption of 3.44 percent, MWRs range from 1.24-1.31 for males and 1.26-1.34 for females. These values are far above those provided by the privately-provided life annuities where it will be recalled that mean MWRs were 0.947 for men and 0.955 for women (using annuitant mortality). It might be thought that the interest rate environment in Singapore is unusually low, so we recomputed the MWRs using a higher long-term rate of 4.44 percent (close to the yield of the longest-term 10-year bond in 1998); under these circumstances, the MWRs appear in brackets in the last four rows of Table 2.4. The higher interest rate assumption still yields MWRs of 1.10-1.15 for males and 1.09-1.14 for females.

Looking at the patterns of benefit values, it is interesting to note that the LIFE Income (sans bequest) and LIFE Plus (low bequest) plans provide higher MWRs than do the other two plans, implying a small penalty if participants elect a plan that includes bequests. Also it is apparent that as the design was fine-tuned over time, MWRs were dialed down; perhaps policymakers realized that the early pricing was overly generous. Yet even so, MWRs of the CPF LIFE payouts remain at or slightly above unity,

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<sup>45</sup> Based on communications with the CPF Board, we also assume interest rates are compounded and credited annually to the Retirement Account (RA), but if the member dies in any month, any interest earned up to that point in time is immediately credited and so refunded. Even when a member reached vesting age, any unused balance in the RA continues to earn interest. If the member adds top-ups to the RA, this also forms part of the principal and earns interest. On death, any unused balance in the RA is refunded. For the original 12 plans, the extra 1% earned on the total MS is allocated pro-rata to the RA and pooled interest based on the component balances for each month. However, for the final four plans, the extra 1% earned on the total MS is allocated entirely to the RA. Finally, if the member dies after vesting age, any unused balance of the annuity component (except for the LIFE Income plan), will be refunded to his beneficiaries.

compared to the lower values of private insurer annuities that had been available. The government's higher payout results in part from lower administrative loads compared to those levied by private insurers, and in part from less adverse selection due to the compulsory annuitization (though above we had indicated this was relatively small in Singapore).<sup>46</sup> A long-term rate assumption set closer to historical norms also generates MWR values closer to one.

As the administrator, the CPF Board determines the premium and payouts with advice from independent actuarial consultants, so the new design may intentionally include a small subsidy to CPF members so as to jump-start the new scheme. Indeed the government has offered a sign-on bonus (called the L-bonus) for the first five cohorts of members joining CPF LIFE for whom the scheme is voluntary.<sup>47</sup> Also our computations assume constant nominal payouts though in fact, payouts may vary in the future, depending on the future evolution of interest rates and mortality. Though the CPF Board can adjust payouts periodically to reflect actual mortality experience and investment return, it is noteworthy that it has assured members that adjustments will usually be small so that nominal payouts are anticipated to remain relatively stable over time (CPF 2009*d*).<sup>48</sup>

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<sup>46</sup> Similarly, in the U.S. context, Abel (1986) showed that because the U.S. Social Security system is compulsory, it is immune to adverse selection and a fully funded system can offer a rate of return equal to the actuarially fair rate based on population average mortality.

<sup>47</sup> The L-Bonus is targeted at lower and middle-income CPF members age 46-50 in 2008. It is given to these members when they enroll in the CPF LIFE scheme at age 55. In fact, the LIFE Plus plan, which provides a higher monthly payout and leaves less bequest for beneficiaries has proven most popular in the pilot launch (CPF 2010); over half of the members selected it. In addition, more than S\$60 million of LIFE Bonus (L-Bonus) has been given to about 70% of the members for joining the scheme.

<sup>48</sup> Responding to members seeking to join CPF LIFE ahead of the official launch date of 2013, the CPF Board began offering LIFE plans in September of 2009 to members born in 1954 or before. Inasmuch as annuitization is not yet mandatory, this first phase of CPF LIFE operates on a voluntary opt-in basis (from 2013, annuitization will be mandatory). Younger members will be auto-included in the LIFE

## 2.6 Discussion and Conclusion

A topic of substantial interest to international policymakers is whether a national annuitization scheme should be administered by the private or the public sector.<sup>49</sup> Having a single provider can reduce costs through economies of scale, and a government-run scheme may be perceived to be safer by retirees than private insurers which may face bankruptcy (Babbel and Merrill 2007). In the Singaporean case, the Civil Service is regarded as one of the most efficient bureaucracies in the world with a high standard of discipline and accountability (Heritage.org 2010) and the fact that the CPF has traditionally paid interest on annuities at a rate pegged to the 10-year Singapore Treasury bond plus 1 percent with a 2.5 percent floor implies that citizens tend to view such returns as risk-free (given the AAA rating of government bonds). It is therefore interesting that the annuities offered by Singapore's CPF LIFE scheme appear to be priced very favorably to the consumer compared to other developed countries (see Table 2.5). Our preliminary evidence therefore could indicate that Singapore has been able to pass cost savings from scale economies and onto annuitants.

*[Table 2.5 here]*

It is also worth noting that, while CPF members may still buy life annuities from a private insurer, few firms appear to be able to compete. That is, there were nine

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Balanced plan if they have at least \$40,000 cash savings in their Retirement Account as of age 55. Members with less than S\$40,000 can opt-in if they wish (CPF 2009d). The cut-off for auto-inclusion into CPF LIFE was selected to balance the level of monthly income and the percentage of active CPF members automatically included. At S\$40,000, it is estimated that some 70% of active members will be automatically included from the first cohort (i.e. those who turn age 55 in 2013; CPF 2009f).

<sup>49</sup> Here we do not take up the question of whether mandatory annuitization is welfare enhancing, a topic explored in some detail by Brown (2003).

private insurance companies offering annuities in 2007, but only one remained by late 2009. The withdrawal of insurers from the annuity market may be of concern to policymakers if product innovation and pricing pressure requires competition among product providers in the industry. In addition, by marketing both life insurance and life annuities, insurers would be expected to benefit from some natural hedging across the two products. It is possible that private annuity providers could refocus their business outside the CPF scheme for retirees seeking to annuitize non-pension wealth. Also since the amount that CPF members can annuitize via the CPF LIFE product is capped at the stipulated Minimum Sum amount, wealthy individuals could still turn to commercial annuities. Moreover, the life annuities currently offered by the government are nominal and not inflation-adjusted and hence retirees may find some benefit from inflation-linked payouts, not currently available under the CPF LIFE system.

These findings are also of interest in nations where governments are increasingly concerned about annuitization in defined contribution plans. For instance, in the U.S. 401(k) pension marketplace, few retirees convert their assets into insured payout products and instead take their money as a lump sum (Brown et al. 2001). In response, to protect against longevity risk, some have proposed making annuitization the default payout mechanism from a defined contribution pension. For instance, Gale et al. (2008) recommend that 401(k) assets be automatically directed into a “trial” payout product unless the retiree affirmatively elects not to participate. After 24 monthly payments from the automatic payout plan, the retiree could either do nothing and be defaulted into a permanent income distribution plan, or elect an alternative

distribution option. By making it easier for retirees to purchase lifetime income plans, it is anticipated that these would become a better value for the average consumer.

We conclude that Singapore's recent move to mandate annuities under the national defined contribution pension system represents a logical step toward national longevity risk management. By establishing the government as an annuity provider, the CPF Board may have taken advantage of scale economies and reduced the pricing impact of adverse selection, given that the latter was found to be quite a substantial proportion of total loadings. Furthermore, the aggressive annuity pricing is creating public buy-in for the new mandate, while indirectly working to compensate less risk-averse individuals in terms of foregone equity premium. One offset may be that private insurers have been crowded out, in part because the CPF-designed product pays participants more than what commercial insurance companies had offered. Without competition, it is unclear whether annuity pricing will continue to be attractive and whether product innovation will continue in Singapore. Related questions, as yet unsettled, have to do with whether favoring annuity payments over payments to survivors is politically sustainable, and how long the government will be able to continue subsidizing payouts.

**Table 2.1: Monthly Nominal Payouts for Life Annuities purchased at the Minimum Sum of S\$99,600 (2007; S\$ per month; entry age of 55)**

Company & Product	Monthly payout		Guaranteed amount on death (less annuity payments)
	Male (S\$)	Female (S\$)	
<i>Non-participating Annuities</i>			
Asia Life Assurance	505.47	454.47	Premium.
American International Assurance (AIA)	530.87	513.94	Premium.
Aviva	559.00	507.00	Premium + accrued interest compounded at 1% p.a. to commencement date of annuity.
Great Eastern Life (GE Life I)	535.35	484.30	Premium + interest accumulated at 0.75% p.a. to age 62.
Great Eastern Life (GE Life II) [Note: This product includes long term care benefit.]	494.26	440.73	Premium + interest accumulated at 0.5% p.a. to age 62.
Overseas Assurance Corporation (OAC)	535.35	494.26	Premium + interest accumulated at 0.75% p.a. to age 62.
Prudential Assurance	518.44	449.87	Premium.
<b>Sub-average</b>	<b>525.53</b>	<b>477.80</b>	
<i>Participating Annuities</i>			
HSBC Insurance	474.00 (541.58)	458.00 (525.58)	Premium + interest accumulated at 2% p.a. to age 62.
NTUC Income Co-op	523.50 (591.08)	490.25 (557.83)	Premium + interest accumulated at 2.5% p.a. and bonuses to age 62.
<b>Sub-average</b>	<b>498.75</b>	<b>474.13</b>	
<b>Overall Average</b>	<b>519.58</b>	<b>476.98</b>	

Source: Authors' computations from CPF (2007).

Notes: p.a. denotes per annum. Monthly payouts for a nominal deferred annuity purchased at age 55 with payments starting at age 62. The single premium is the Minimum Sum of S\$99,600 for members age 55 (7/07-6/08). The MS Scheme currently guarantees named beneficiaries a given *amount* in the event of annuitant's death equal to the (positive) difference between the guaranteed amount and annuity payments made. Previously (in 2000) most MS annuities were guaranteed for a certain *period* so if death occurred during the guaranteed period, remaining annuity payments would be converted into a lump sum paid to beneficiaries. Bonus rates depend on company performance; NTUC Income's annual bonus rates were 1-3.5% historically (NTUC 2009) and a 2% bonus is used in NTUC Income benefit illustrations. Original payouts without bonus expressed without brackets; figures in brackets incorporate bonus component assuming an annual projected bonus rate of 2%.

**Table 2.2: Money's Worth Ratios and Adverse Selection Costs for Nominal Life Annuities Offered by Private Insurers under the CPF Plan (2007)**

Company & Product	Male			Female		
	Pop. MWR	Ann. MWR	Adverse Selection	Pop. MWR	Ann. MWR	Adverse Selection
<i>Non-participating Annuity</i>						
Asia Life Assurance	0.861	0.896	3.47	0.840	0.885	4.44
AIA	0.907	0.943	3.62	0.943	0.995	5.20
Aviva	0.943	0.982	3.98	0.930	0.981	5.14
GE Life I	0.910	0.947	3.71	0.893	0.941	4.78
GE Life II	0.846	0.879	3.34	0.818	0.860	4.22
OAC	0.907	0.945	3.74	0.908	0.957	4.98
Prudential Assurance	0.879	0.915	3.62	0.833	0.876	4.37
<i>Participating Annuity</i>						
HSBC Insurance	0.933	0.969	3.59	0.969	1.021	5.20
NTUC Income Co-op	1.006	1.047	4.09	1.024	1.081	5.61
<b>Mean</b>	<b>0.910</b>	<b>0.947</b>	<b>3.69</b>	<b>0.906</b>	<b>0.955</b>	<b>4.88</b>

*Source:* Author's computations, see text.

*Notes:* "Pop." refers to the general population group and "Ann." refers to the annuitant group. Money's worth ratios are in decimals and adverse selection costs are in percentage points. Computations pertain to a CPF participant who purchases the MS Scheme annuity at entry age 55 for a premium of S\$99,600 and starts receiving payouts at age 62. The term structure of interest rate uses derived spot rates for 1, 2, 5, 7, 10 and 20-year bonds with linear interpolation between years.

**Table 2.3: Robustness Analysis for Nominal Life Annuities Offered by Private Insurers under the CPF Plan (2007)**

A. Sensitivity to Alternative Mortality Assumptions

<b>Mortality rates</b>	<b>Male</b>			<b>Female</b>		
	<b>Ann.</b>	<b>Pop.</b>	<b>AS</b>	<b>Ann.</b>	<b>Pop.</b>	<b>AS</b>
2 years lighter	0.962		6.05	0.972		7.11
Base case	0.939	0.901	3.80	0.951	0.901	5.03
2 years heavier	0.917		1.57	0.929		2.86

*Source:* Authors' computations.

B. Sensitivity to Alternative Long-Term Interest Rate Assumptions ( $\pm 0.5\%$  and  $\pm 1\%$ )

<b>Long-term interest rate</b>	<b>Male</b>			<b>Female</b>		
	<b>Ann.</b>	<b>Pop.</b>	<b>AS</b>	<b>Ann.</b>	<b>Pop.</b>	<b>AS</b>
2.44%	1.067	1.010	5.70	1.110	1.033	7.69
2.94%	0.998	0.951	4.66	1.024	0.961	6.22
3.44% (base)	0.939	0.901	3.80	0.951	0.901	5.03
3.94%	0.889	0.858	3.10	0.889	0.849	4.07
4.44%	0.846	0.821	2.51	0.837	0.804	3.28

*Source:* Authors' computations.

*Notes:* "Pop." refers to the general population group and "Ann." refers to the annuitant group. This analysis uses the average annuity payouts (with bonus) of the private annuities given in Table 2.1. For the base case of 3.44%, the MWR values of this pseudo average-payout annuity are slightly lower than the mean of the individual MWR values reported in Table 2.2 because the individual computations incorporate interest accrued during the deferral period where applicable.

**Table 2.4: Illustrative Payouts and Money’s Worth Ratios of CPF LIFE Plans**  
(annuity premium of S\$67,000; various dates)

LIFE plans	Male			Female		
	Monthly payout (S\$)	Annuity component	MWR	Monthly payout (S\$)	Annuity component	MWR
<b>Proposed LIFE plans (as at February '08):</b>						
Refund 90	560	6%	1.306	540	8%	1.350
Refund 85	590	13%	1.315	560	16%	1.361
<b>Refund 80</b>	<b>610</b>	<b>24%</b>	<b>1.331</b>	<b>570</b>	<b>28%</b>	<b>1.371</b>
Refund 75	630	41%	1.341	580	45%	1.374
Refund 70	640	66%	1.323	590	68%	1.370
Refund 65	650	100%	1.284	590	100%	1.311
<b>LIFE plans (as at June '09):</b>						
LIFE Basic	519	6%*	1.264	496	8%*	1.308
<b>LIFE Balanced</b>	<b>556</b>	<b>24%*</b>	<b>1.313</b>	<b>515</b>	<b>28%*</b>	<b>1.355</b>
LIFE Plus	590	100%	1.308	531	100%	1.332
LIFE Income	632	100%	1.287	549	100%	1.313
<b>LIFE plans (as at September '09):</b>						
LIFE Basic	524	8.6%	1.240 [1.099]	500	13%	1.255 [1.088]
<b>LIFE Balanced</b>	<b>561</b>	<b>30%</b>	<b>1.252</b> <b>[1.110]</b>	<b>520</b>	<b>35.5%</b>	<b>1.270</b> <b>[1.098]</b>
LIFE Plus	594	100%	1.315 [1.149]	535	100%	1.340 [1.142]
LIFE Income	636	100%	1.294 [1.119]	553	100%	1.322 [1.118]

*Source:* Authors’ computations; see text. Payout data obtained from CPF website (CPF 2008 and CPF 2009e).

*Notes:* The default plan offered at each point in time is bolded. Computations pertain to a CPF participant who joins the LIFE plan at age 55 for a premium of S\$67,000, and starts receiving payouts at age 65. In particular, the parameter inputs generating this set of illustrative payouts in the CPF web calculator assume the Singaporean worker was born June 1958 (so he is age 55 in 2013); AV=“More than S\$11,000”; AI=“More than S\$54,000”. The premium paid is split into a term component and an annuity component. The term component funds payouts from age 65 to the vesting age; vesting age differs across plans. The annuity component, expressed as a percentage of the annuity premium, funds payouts from the vesting age to death. The reported payouts are indicative only; actual payout will depend on actual CPF interest rates and mortality experience. CPF interest is computed monthly, reviewed quarterly and, compounded and credited annually. Figures marked with (\*) are estimated. Money’s worth ratios are computed using the riskless term structure of interest rate with long-term interest rate assumption of 3.44% and assume constant payouts over the participant’s lifetime. The assumed CPF interest rate is 4% with the statutory additional 1% paid on the first S\$60,000. The guaranteed amount refunded to the beneficiary upon the annuitant’s death is the unused amounts left in the annuitant’s CPF retirement account (term component plus any interest earned) and the unused amount of the annuity component (if refundable). MWR in brackets [ ] are based on an alternative long-term interest rate assumption of 4.44%.

**Table 2.5: International Comparison of Money's Worth Ratios**

Country	Study	Valuation Date	MWR (65-year old male; annuitant mortality)	Cost of Adverse Selection as % of Total Loading
US	Friedman and Warshawsky (1988)	1983	0.868	35.0%
US	Mitchell et al. (1999)	1995	0.916	54.3%
UK <sup>a</sup>	Finkelstein and Poterba (2002)	1998	0.988	91.1%
		1998	0.962	62.0%
Singapore	Fong (2002)	2000	0.933	13.0%
Singapore	Doyle et al. (2004)	2000	0.947	4.7%
Australia	Doyle et al. (2004)	2000	0.939	49.7%
Singapore <sup>b</sup>	This study	2007	0.947	41.1%
		2008 - 2009	1.10 - 1.15	-

Source: Authors.

Notes: All the MWR values reported for Singapore are based on a 55-year old male instead of a 65-year old male. Total loading is defined as one minus money's worth of annuity for an individual from the general population.

<sup>a</sup> Results are reported in separate rows for the U.K. voluntary, and compulsory, annuity markets respectively. Data in both markets are drawn from annuities offered by commercial insurers.

<sup>b</sup> Results are reported in separate rows for annuities offered by commercial insurers, and new annuities offered by the CPF Board, respectively. MWR values for the latter are based on September 2009 LIFE plan payouts and a long-term interest rate assumption of 4.44%.

## Appendix Table 2.1: Assumptions used in Money's Worth Computations for Life Annuities under the CPF MS Scheme

This Table summarizes the data and results for various studies that assessed the money's worth of life annuities offered by private insurers under the CPF Minimum Sum scheme. The three main inputs used in the money's worth computation are annuity quotes, annuitant and population mortality rates, and interest rates.

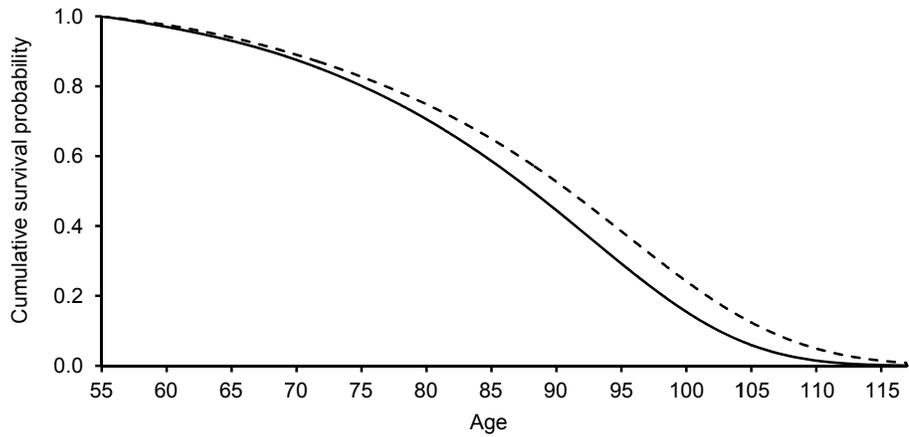
	Fong (2002)	Doyle, Mitchell, and Piggott (2004)	<i>This study</i>
<b>Valuation Date</b>	2000	2000	2007
<b>Sample chosen</b>	Subset of 8 non-participating annuities & 1 participating annuity.	Subset of 5 non-participating annuities with a 15-yr guarantee period or similar.	All MSS annuities: 7 non-participating & 2 participating annuities.
<b>Model</b>	MWR model with 15-year certain.	MWR model with 15-year certain.	MWR model for annuities with guaranteed amount. See Equation (1) in text.
<b>Mortality Assumptions</b>			
<i>Annuitant</i>	a(90) with 2-year setback; limiting age used is 109.	a(90) with 2-year setback; limiting age used is 109.	a(90) with 5-year setback; limiting age used is 117.
<i>Population</i>	Derived from 1960 and 1990 Ordinary Male and Female Lives Tables (Singstat). Limiting age of 99.	Abridged life tables for Singapore (World Health Organization). Limiting age of 100.	2007 complete life tables for Singapore resident population (Singstat), plus extrapolate from age 100 to limiting age of 117.
<b>Interest Rate Assumption</b>	Flat interest rate (proxy by the 10-year Government bond yield of 4.6%).	Term structure (yield curve with long-term rate assumption of 4.76%).	Term structure (yield curve with long-term rate assumption of 3.44%).
<b>MWR results for 55-year-old Male</b>			
<i>Annuitant</i>	0.997	0.947	0.947
<i>Population</i>	0.986	0.945	0.910
<i>Adverse selection</i>	1.10	0.26	3.69

*Source:* Authors' computations; see text.

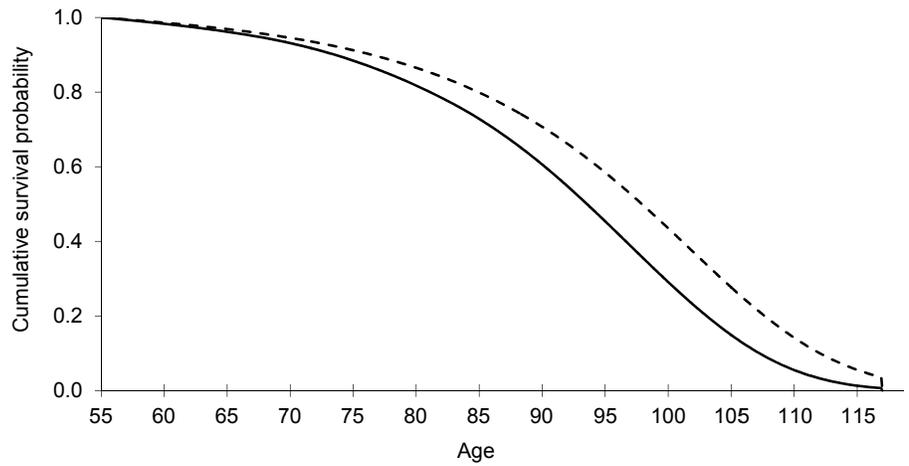
*Notes:* A total of 13 MSS life annuities were offered in July 2000 of which 9 were flat-rate annuities, 2 were participating annuities, and 2 were increasing annuities. The increasing annuities offered by AIA were dropped after that year (*Source:* Personal communication from CPF Board). The a(90) table refers to the UK a(1990) period life table for annuitants. It is based on UK annuitants' experience from 1967-70, with mortality improvements projected to 1990. Because of lack of annuitant experience in Singapore, previous studies used the a(90) and with a two-year setback to account for lower mortality among annuitants. A two-year setback means that a 65-year-old is treated as having the same mortality rate as a 63-year-old has in the initial table. Money's worth ratios are in decimals and adverse selection costs are in percentage points.

**Figure 2.1: Cumulative Cohort Survival Probability: General Population and Annuitant Groups (conditional on attaining age 55; limiting age of 117; 2007)**

A. Singaporean Males



B. Singaporean Females



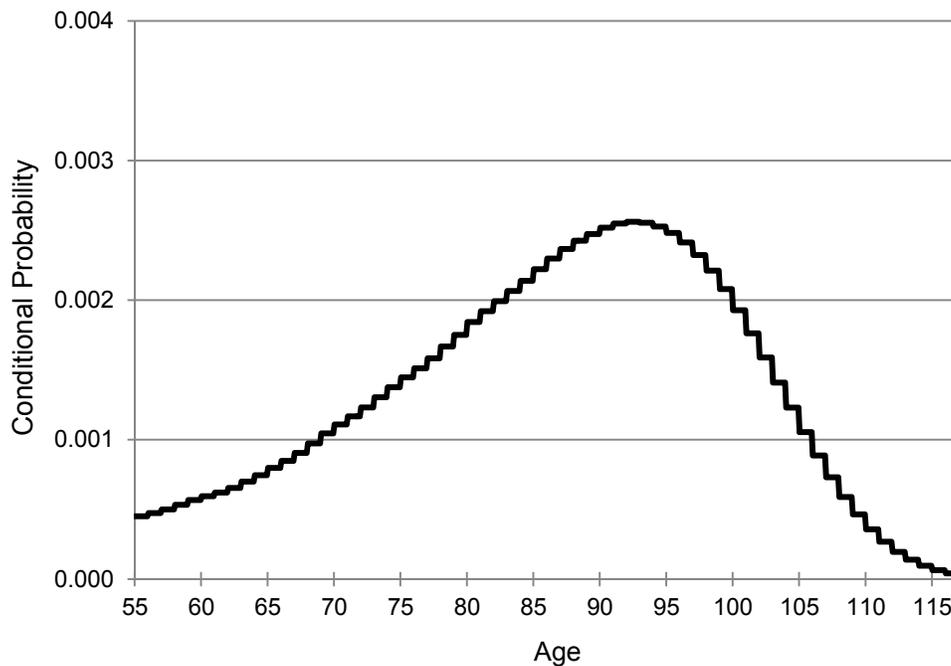
Legend: 

— Population	- - - - Annuitant
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Source: Authors' computations; see text.

### Appendix Figure 2.1: Density Function of the Age-at Death random variable

This Figure plots  ${}_t p_{55} \cdot q_{55+t}$  for a random male drawn from the population who purchases an annuity at age 55 in 2007. It shows the probability of death between month  $t$  and month  $t + 1$  (conditional on living to month  $t$ ). The function increases from age 55 to about age 95 where the rise in  $q_{55+t}$  outweighs the decline in  ${}_t p_{55}$ . In the advanced ages, the opposite occurs and the probabilities fall. The jags in the plot indicate that within each year, the probabilities are level consistent with the UDD assumption. Because the limiting age is set at 117, any remaining probability mass is assigned to the tail resulting in heaping at that outside age.



Source: Authors.

## CHAPTER 3

### **Beyond Age and Sex: Enhancing Annuity Pricing**

How annuities are priced is of central concern to retirement decision-planning for individuals, and also for defined contribution plans. Annuities offer valuable longevity insurance against outliving one's assets by providing a periodic income for life in exchange for an upfront premium. But currently in U.S. and Canada, prices of standard retail annuities do not reflect buyers' personal characteristics other than age and sex. This lack of information in prices generates two concerns. Firstly, because insurers do not account for individual economic or health status, people who anticipate living longer can self-select into annuities. Empirical studies have shown that adverse selection exists in annuity markets (Mitchell et al. 1999; Finkelstein and Poterba 2002). Secondly, it may lead to consumer perception that standard annuities are only priced for those in very good health (Stewart 2007; Brown and McDaid 2003). Negative consumer perception may frustrate policymakers' efforts to expand the use of these lifetime income instruments in employer-sponsored or government-run defined contribution plans around the world.

The notion of using more risk-classes to price standard retail annuities has gained support in recent years, largely motivated by an interest in growing the life annuity market. In an OECD study, Stewart (2007) suggests that annuity providers should be permitted to put people into different risk categories to allow for more pricing flexibility, reduce adverse selection, and increase consumers' trust in the pricing of

annuity products. In fact, some major U.K. insurers have already begun using more personal characteristics such as client postcodes, marital status, and tobacco use, to price their standard payout annuities (Banking Times 2008). Nonetheless, these insurers are still struggling to define suitable pricing factors and work out the specifics (e.g. how to classify individuals who have two addresses). Given the precedence of risk-class pricing in life insurance and auto insurance, there is strong reason to believe that using more indicators of life expectancy, other than just sex and age, might be a natural evolution for retail annuity pricing.

A large literature focuses on measuring the money's worth of annuities and reports, in a voluntary purchase environment, that annuitants obtain higher money's worth from annuity purchase than would the population if all were to purchase.<sup>50</sup> This difference is quantified as the adverse selection cost. For example, Mitchell et al. (1999) estimates adverse selection cost to be about 54% of total loadings in the U.S. annuity market. In smaller annuity markets such as Singapore and Australia, estimates are also about 40 to 50% (Fong et al. 2011; Doyle et al. 2004). Researchers have also shown that the extent of adverse selection observed in actual annuity markets depends on market type and product line. In particular, adverse selection is lower in compulsory markets as compared to voluntary ones, and also for annuities with period-certain guarantees as compared to those without guarantees (Finkelstein and Poterba 2002).<sup>51</sup> Since information asymmetry arises because annuity buyers have "private" information about

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<sup>50</sup> See for example, Mitchell et al. (1999) and Finkelstein and Poterba (2002).

<sup>51</sup> In 1998, the U.K. compulsory annuity market was much larger than the voluntary market; there is less scope for adverse selection in the former because participants in defined contribution occupational, or personal, pension plans must annuitize their resources (Finkelstein and Poterba 2002). Less adverse selection is observed for annuities with longer period-certain guarantees primarily because of shorter-lived individuals self-select into annuities with longer guarantee periods.

their mortality, the extent of adverse selection is likely to depend on pricing structures as well. It would seem that incorporating more personal characteristics in annuity pricing can help reduce adverse selection. Yet investigations of this kind are challenging for a number of reasons, including the need to construct plausible alternative pricing schemes, and having to model selection effects as pricing structures evolve.

The primary contribution of this paper is to use longitudinal micro data from the Health and Retirement Study (HRS) to develop alternative pricing structures and examine their impact on annuitization values accruing to different demographic groups. Using a proportional hazards framework, I show that several readily-measurable risk factors can significantly increase explained variability in mortality outcomes. Adding the ten best-ranked factors to age and sex increases explained variation from 6.7% to 29.7%. Assuming one or more of these pricing factors are adopted, I then simulate annuity prices for a variety of pricing schemes and compute the annuitization value accruing to a given demographic group under each scheme. Both the financial value and utility value of longevity insurance are assessed.

The impact of risk-class pricing on adverse selection is not straightforward. The need to collect more information may result in insurers imposing higher administrative fees. Even if a rating class is justified, insurers may not have the flexibility to introduce large disparity in prices in actual markets. Annuity purchase decisions are also influenced by many factors other than just the financial return from annuities. It is, however, widely believed that more detailed pricing reduces information asymmetries between the insurer and the insured and thus will reduce adverse selection. My paper

contributes to this discussion by highlighting two effects that may occur when more pricing factors are implemented: (1) shorter-lived groups will be sufficiently induced to buy annuities and enter the market, and (2) longer-lived groups will still be incentivized to stay in the annuity market. Overall, this will allow annuity markets to *grow* causing the extent of adverse selection to fall.<sup>52</sup>

Compared to prior population-based studies on mortality, this paper is distinguished by its effort to understand how several less conventionally-used variables relate to retirement mortality. For instance, birth region is a truly exogenous demographic variable but it is seldom used in empirical studies. Recently, Sloan et al. (2010) find that being foreign-born is associated with lower mortality hazards.<sup>53</sup> Cognition is another interesting variable to examine in relation to older adults. For example, Mehta et al. (2003) find cognitive function to be independently associated with mortality among elderly adults above age 70 in the Asset and Health Dynamics Among the Oldest Old (AHEAD) study. This study is therefore informative regarding the potential for these less conventional variables to serve as suitable pricing factors for annuities.

Section 1 outlines some possible impediments to risk-class pricing, and highlights recent efforts by commercial insurers to incorporate more personal

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<sup>52</sup> Point (2) is necessary because the co-existence of longer-lived and shorter-lived groups is what distinguishes the standard annuity market (which is the focus of this paper) from an impaired annuity market where detailed annuity underwriting is already in place. Impaired annuities are discussed later in Section 1.1.

<sup>53</sup> Several studies controlled for *current* residence instead, which is possibly endogenous to current mortality. For example, Dupre et al. (2009) controlled for whether a respondent lives in the South. Sloan et al. (2010) included dummies for whether a subject lives on a farm, and whether he is foreign-born. Glymour et al. (2008) study the risk of first stroke among the HRS participants and specifically incorporated an indicator for Southern birth-state (also known as the stroke belt).

characteristics in annuity pricing. Section 2 describes the data and methodology. Section 3 presents results from the proportional hazards regressions, and demonstrates how risk-classification sharpens age-at-death predictions. Section 4 reports simulated annuity premiums and assesses the financial value of annuities accruing to various demographic groups under different pricing schemes. Section 5 examines the value of annuities on a utility-adjusted basis in an environment of mortality heterogeneity. Section 6 concludes.

### **3.1 Background**

#### ***Pricing Structure of Annuities***

The extent of underwriting varies across different types of annuities.<sup>54</sup> At one end of the spectrum are pension annuities and the U.S. Social Security pension system. Job-based pension annuities are priced based on age (Brown 2002; US Supreme Court 1988).<sup>55</sup> Similarly, benefit payouts under the U.S. Social Security program are also purely based on the age of annuitization.<sup>56</sup> Any differences along gender, racial, or education lines are disregarded. In contrast, the retail annuity providers are permitted to use gender-specific pricing. In U.S. and Canada, standard retail annuities are priced

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<sup>54</sup> Life insurance companies collect information about individuals before deciding at what price to sell insurance to them. Applicants for insurance are individually interviewed (often by means of a written questionnaire), and sometimes examined by a medical practitioner. This process is called “underwriting”.

<sup>55</sup> In *City of Los Angeles v. Manhart*, 435 U.S. 702 (1978), it is ruled that section 703(a)(1) of the Civil Rights Act of 1964 barred requiring women to contribute more than men to pensions to receive the same benefits. Later, a landmark Supreme Court decision in *Florida v. Long* similarly ruled that only unisex mortality lifetables may be employed in the pricing of pension annuities (US Supreme Court 1988).

<sup>56</sup> Social Security refers to the federal Old Age, Survivors and Disability Insurance (OASDI) Program, which is a comprehensive federal benefits program developed in 1935. The Social Security is a pay-as-you-go defined benefit pension system funded through dedicated payroll taxes, and benefit payments are made monthly to eligible individuals.

based on age, sex, and the amount of money annuitized (Brown and McDaid 2003). Females typically pay a higher premium than males under this pricing structure because they are expected to live longer. In addition, Stewart (2007) reports that differential pricing policy between races is allowed in the European Union.

At the other end of spectrum are so-called impaired or enhanced annuities. Impaired annuities were introduced in the U.K. around 1995 and since then, this market segment has grown in size and importance.<sup>57</sup> Impaired annuities are sold to retirees with profiles of high mortality (e.g. those in poor health) or those in nursing home care. It is estimated that as many as 40 percent of U.K. annuity purchasers can qualify for impaired annuities (The Investors Chronicle 2008). Underwriting for impaired annuities is via a health questionnaire (mild medical conditions), and a medical report (for more severe medical conditions such as heart attack, or cancer). Individuals who qualify for such annuities enjoy lower premiums. In U.S. and Canada, impaired life annuities are available but the market is small (Rusconi 2008; Brown and McDaid 2003). Such annuities are only offered to individuals who can prove that they are in substandard health via a medical certificate.

The focus of this paper is the pricing of standard annuities. Although impaired annuities represent a growing niche in the annuity markets, they are limited to people who are of substandard health and thus of less relevance to say, an average retiree of average health who wishes to annuitize. The current pricing structure of standard retail

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<sup>57</sup> Impaired annuities were introduced in the U.K. around 1995 by a company called Stalwart, which was later acquired by GE Capital (Bestwire 2010). Impaired annuity sales in the U.K. totaled £1.26 billion (€1.51 billion) in the first six months of 2010. The full-year sales figure for 2009 was £1.78 billion, up from £419.6 million in 2001. Companies currently active in this market segment include Aviva, Canada Life, and Legal & General.

annuities leaves much room for pause. This is because there are no obvious regulatory barriers to risk-classification (aside from using sensitive factors like race), and the insurance industry has a ready technology given their experience in the life insurance business.

One possible impediment may be costs. According to a Deloitte 2008 benchmarking study of 15 U.S. life insurers, an insurer typically spends approximately one month and several hundred dollars underwriting each applicant (Batty et al. 2010). While a few hundred dollars is not necessarily cost-prohibitive for life insurance products, it may be so for annuities. This is because annuities are relatively low-margin financial products, and insurers already view them as not very profitable relative to other product lines (Orth 2008). The underlying reason is due to very thin annuity markets. Existing research shows that the voluntary markets for individual immediate annuities in U.S., Australia, France, Germany, Italy and Japan are small (MacKenzie 2006; Brown 2001; Knox 2000).<sup>58</sup> In addition, underwriting can be costly in terms of buyer fraud. Brown and McDaid (2003) provide the analogy of an applicant who smokes cigarettes for a period of time to get better annuity rates. Likewise, an applicant may exaggerate her health problems to qualify for lower premiums.

A second reason pertains to the lack of annuitant mortality data. To justify placing applicants into different pricing categories, there must be some actuarial basis indicating how mortality differs among those groups. Because the insured population is

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<sup>58</sup> Several reasons have been suggested to explain the lack of demand for annuities (or the so-called annuity puzzle). Among the explanations are the role of adverse selection and administrative load factors (Mitchell et al. 1999; Finkelstein and Poterba 2002), bequest motives (Abel and Warshawsky 1988), the ability of risk-pooling within families (Kotlikoff and Spivak, 1981), and precautionary savings.

not the same as the noninsured population, insurance companies typically collect mortality experience of their applicants over a long period of time to facilitate such analysis. A case in point is the smoker/nonsmoker rating class used in the life insurance markets. In the 1960s, U.S. life insurance companies still charged the same rates to smokers and nonsmokers (SOA, 1983), and it was only after two decades that sufficient mortality experience emerged allowing actuaries to construct smoker/nonsmoker mortality tables. These developments in turn led to cigarette smoking being adopted as a rating class in life insurance policies.<sup>59</sup> Similarly, substantial information on annuitants needs to be collected before mortality differentials amongst risk-groups with different demographic characteristics can be analyzed. Thus far, this has been an uphill task because of the very thin annuity markets. Stewart (2007) reports that a surprisingly large number of developed countries still lack the demographic data necessary to construct accurate mortality projections for annuitants, and use lifetables from other countries with richer annuitant experience such as U.K. and U.S.<sup>60</sup>

Regulatory restrictions may also play a role. For instance, sex has long been employed as a rating class in life insurance whereby women pay lower premiums than men because statistics show that women live longer. Yet in March 2011, the European

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<sup>59</sup> Smoker/nonsmoker rates for life insurance policies are also successfully introduced with new underwriting assistance such as blood tests (Brown and McDaid 2003).

<sup>60</sup> Stewart (2007) also suggests that segmented mortality data on annuitants can be collected by governments, or alternatively, by a cooperative arrangement among insurers willing to cost-share. Currently, U.S. insurers typically use the RP-2000 annuitant lifetable as a reference (McCarthy and Mitchell 2010). The RP-2000 annuitant life table is provided by the Society of Actuaries, and constructed based on actual annuitant experience from plan years 1990 through 1994. In U.K., pensioner and annuitant lifetables are available from the Continuous Mortality Investigation committee, and are prepared based on actual annuitant experience collected from U.K. insurance companies. Annuitant lifetables are distinct from actuarial tables used in valuing life insurance policies (e.g. the 2001 Valuation Basic Table).

Court of Justice ruled that the widespread practice of charging men and women different rates for insurance is illegal and has set out to overhaul the pricing of insurance policies across Europe by end 2012 (WSJ.com 2011). The U.S. prohibits using sex in job-based pension annuities although it is allowed as a rating class for retail annuities.

### ***Movement towards Risk-based Pricing***

The notion of using more risk-classes to price standard retail annuities is largely motivated by an interest in growing the life annuity market. In an OECD study, Stewart (2007) suggests that insurers should be permitted to risk-categorize annuitants to allow for more pricing flexibility and to increase consumers' trust in the pricing of annuity products. Similarly, Brown and McDaid (2003) stress that workers will ideally want to annuitize at fair-market rates that reflect their personal mortality profiles. Evidence from other insurance markets suggests that effective underwriting can also alleviate adverse selection problems. For instance in life insurance, Cawley and Philipson (1999) present convincing evidence that life insurers may be better at identifying mortality risk than individuals themselves. Similarly, McCarthy and Mitchell (2010) find that U.S. and U.K. insurers' screening of poorer risks in life insurance reduces asymmetric information held by policyholders. In auto insurance, Chiappori and Salanie (2000) conclude that "...the information at the [auto insurers] company's disposal is extremely rich and that, in most cases, the asymmetry, if any, is in favor of the company."

In the U.K., commercial insurers have begun using risk-based pricing for standard annuities. In 2008, Norwich Union – an insurer with about 10 percent market share – started using client postcodes, marital status, and tobacco use, to price its

annuities (Banking Times 2008). Other major insurers like Prudential, and Legal & General, have also justified using postal codes on the premise that those who reside in more affluent areas tend to be longer-lived. In fact, U.K. market players observe that the differentiation between impaired annuities and standard (non-impaired) annuities have started to blur (Bestwire 2010). These developments represent a positive step towards annuity risk-class pricing. Going forward, there is strong reason to believe that the movement towards risk-class pricing for standard annuities may be sustained and eventually extend to the rest of the world.

Nonetheless, there is currently no consensus on which risk-classes may be most suitable. While insurers have experience in underwriting life insurance policies, it remains the case that some conventionally-used factors are difficult to verify, for example lifestyle habits or participation in hazardous activities like sky diving. Certain risk factors are also mutable, such as smoking, which leaves insurers susceptible to buyer fraud.<sup>61</sup> In addition, there are factors not explored in other forms of insurance pricing that tend to help explain longevity; for instance, several studies have found that intelligent people live longer (Deary 2008; Hauser and Palloni 2010). Notably, Brown and McDaid (2003) identify 10 potential risk-classes, including education, income, and occupation, race, health behavior, and religion, based on a literature review of mortality studies.<sup>62</sup> Among this list, however, several factors are possibly correlated while other

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<sup>61</sup> Mutable factors are those which can be modified by the individual, and thus hard to verify. This is in contrast to fixed factors. See Bond and Crocker (1991) for a detailed analysis of the implications of mutable risk classification characteristics. In the context of annuity policies, an analogy is a person who starts to smoke heavily in order to pass off as someone who is shorter-lived in order to qualify for a lower annuity premium.

<sup>62</sup> Base on a review of 45 empirical papers, Brown and McDaid (2003) highlight 10 factors that seem important in predicting mortality after retirement, in addition to age and sex. They are (in no particular

factors (e.g. health behavior) are not easily measurable. Also, the study did not give a sense of which variables are more important than others.

The next section develops a risk-classification approach by picking out several “readily-measurable” risk factors that may explain longevity. “Readily-measurable” factors includes exogenous variables (like birth region, race, and parental factors), or predetermined factors (like education), or objectively-measured factors (like body mass index and cognition). These factors are desirable from an insurer’s standpoint because they are not too costly to collect, easy-to-verify, and also tend to be difficult to fake. This helps to address issues such as the costs of underwriting and buyer fraud.

### **3.2 Data and Methodology**

To study predictors of mortality among adults near retirement, I use data from the Health and Retirement Study.<sup>63</sup> The HRS is an ongoing panel study of Americans over the age of 50 conducted every other year since 1992, and it features questions on health, economic status, retirement plans, cognition, pensions, family structure, and expectations. The baseline birth cohort interviewed comprised respondents born 1931 – 1941; other cohorts were added in later waves. This paper focuses on individuals in the baseline cohort who were surveyed biannually from 1992 through 2008, providing nine waves of panel data.<sup>64</sup> The initial response rate in 1992 is 82%, and subsequent

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order): race, education, income, occupation, marital status, religion participation, health behaviors (lifestyle and use of health services), smoking, alcohol, and obesity.

<sup>63</sup> See Juster and Suzman (1995) and HRS (2008) for details about the HRS multistage sample design, enrollments, implementation, and response rates.

<sup>64</sup> The HRS sample cohort (those first interviewed in 1992) comprised 12,521 respondents, including spouses (HRS Tracker 2009, p.19) After excluding 2,770 respondents not born between 1931 and 1941, and 470 proxy respondents, the reduced sample is 9,281.

reinterview response rates are well above 90% on average (HRS 2008). Out of a possible sample of 9,281 respondents, I exclude 11 persons because of faulty or incomplete information on survival status, and 223 respondents (2.4%) with no available follow-up data. The analysis sample is consequently restricted to 9,047 respondents. *Appendix Table 3.1* provides basic descriptive statistics.

### ***Measures***

*Survival status and duration.* All-cause mortality is the outcome of interest. HRS tracking efforts, along with a linkage to the National Death Index, allows mortality to be measured very accurately between survey waves. Death is defined as the “time-to-failure” event, based on the reported month/year of death and respondents’ wave-by-wave vital status in the Tracker 2008 (v1.0) file.<sup>65</sup> No information on the cause of death was obtained. In the small number of cases where the exact date of death is unknown ( $n=10$  with no information and another  $n=5$  with death year only), a death year is imputed based on the respondent’s specific wave-by-wave vital statuses, and a death month using a random integer from 1 to 12.<sup>66</sup> If an individual is known to be alive in a given year, her survival status is carried back if it is missing in earlier waves. Subjects who cannot be identified as deceased, or who survived through 2008 are considered

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<sup>65</sup> For the 1,905 failure events, 88.2% (or 1,680 cases) of the death years are obtained from HRS records, 11.3% (215) from NDI records, and 0.5% (10) imputed based on the wave-by-wave vital status. We rely primarily on the year/month of death obtained by HRS through interviews with surviving spouses, or exit interviews with surviving relatives. Where exit interviews are either not obtained, or incomplete, we use the NDI information also available from the HRS Tracker file. The procedure is consistent with HRS’ advice that both sources of information (namely HRS and NDI) should be used to classify vital status in any analysis (HRS Tracker 2009, p. 12). In addition, HRS also seeks matches to the NDI for persons who were reported as deceased or who are not known to be alive through contact during tracking. Accordingly, we rely on the NDI alive/deceased flags, and death match scores to verify respondent vital status in 2008.

<sup>66</sup> These respondents were assumed to have died in the year between the two-year interval where their vital status switched from ‘alive (or presumed alive)’ in one wave to ‘dead’ in the next wave.

censored. Event variables indicating failure by wave is coded “1” if the individual died in that wave, “0” if the individual was alive and responded to an interview, and “missing” otherwise.<sup>67</sup> All time variables including interview dates and death dates are expressed in months.

*Age and sex.* The initial risk variables of interest are those currently used in annuity pricing: age and sex. Both are defined at baseline and available from Tracker 2008. In particular, baseline age (representing birth cohort) is modeled as a continuous variable, and separately as categorical dummies, to test the difference in effects. Three sets of risk adjustments are then introduced to empirically determine their associations with mortality: conventional exogenous factors, less-conventional exogenous factors, and conventional endogenous factors.<sup>68</sup>

*Conventional, readily-measurable factors.* These include race (white/nonwhite), education ( $\geq 12$ / $< 12$  years), whether married (no/yes), prior health history, and BMI (underweight/normal weight (ref.)/overweight). They are so-called conventional because these sociodemographic variables are commonly used as controls.<sup>69</sup> The correlations between race and mortality, and education and mortality are well documented (Preston et al. 1996; Sorlie et al. 1992; Deaton and Paxson 2001; Kitagawa and Hauser 1973). In general, these correlations work in the direction that whites live longer than blacks, and more highly educated live longer than less educated individuals.

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<sup>67</sup> The event variable is coded “missing” as long as there was no response in a wave. This could be because respondents have permanently attrited from the study, or they failed to respond to interview during a particular wave but were known to be alive in a later wave. For the latter, their alive status is not imputed into the “missing” since I have no information on the time-varying covariates in that missing wave.

<sup>68</sup> These variables are all obtained from the RAND version J dataset (RAND 2010).

<sup>69</sup> For instance, Idler and Angel (1990), Hurd and McGarry (2002), Glymour et al. (2008), and Sloan et al. (2010).

For older individuals near retirement, it is posited that education and marital status are predetermined factors. Educational attainment is a reasonable proxy for lifetime financial resources, and appropriate since other social-economic status (SES) measures (current income, current wealth, and current occupation) are probably endogenous. Likewise, I control on prior health history instead of subjective self-assessments of current health.<sup>70</sup> Health history is obtained from doctor-diagnosed disease conditions (whether a doctor ever told them they have chronic diseases such as hypertension, diabetes, arthritis, chronic lung disease, stroke, or heart attack). Prior literature suggests that such “ever-have” disease conditions are highly predictive of mortality.<sup>71</sup> BMI is also included since it can be measured objectively and easily, and is highly relevant given that a current issue of interest is how obesity relates to mortality and morbidity among older adults.<sup>72</sup>

*Unconventional, readily-measurable factors.* These include birth region (Northeast (ref.), Midwest, South, West, Foreign-born), cognition scores (0-40), parental education ( $\geq 12$ / $< 12$  years), and parental longevity. Birth place/region is seldom

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<sup>70</sup> Some studies have shown that objective measures are better predictors of mortality than subjective measures. For example, using a broad-based sample of U.S. adults aged 25–74 years from the National Health and Nutrition Examination Survey, Idler and Angel (1990) find that age, race, smoking, unemployment, alcohol use, illness symptoms, and marital status, are more predictive of survival than either self-assessed health.

<sup>71</sup> Using waves 1 and 2 of the HRS, Hurd and McGarry (2002) find that ever-have disease conditions especially cancer, heart attack, stroke, and diabetes to be highly predictive of mortality among individuals age 46-65. The study also shows low/high BMI to be associated with increased mortality although both variables were not statistically significant in the logit regressions. Chronic illnesses and categorical variables for BMI are similarly used to predict mortality for the HRS sample in other studies (e.g. Dupre et al. 2009, and Siegel et al. 2003). Although these variables are self-reported in the HRS survey, they are still arguably objective since weight and height are anthropometric measures, and the ever-have disease condition question is phrased in terms of a doctor diagnosis.

<sup>72</sup> The three BMI categories are based on the widely-adopted World Health Organization definition of underweight (BMI $<18.5$ ), normal weight ( $18.5 \leq$  BMI $<25$ ), overweight ( $25 \leq$  BMI $<30$ ), and obese (BMI $\geq 30$ ). See SOA (2010) for an excellent review of empirical studies on obesity and its relation to mortality and morbidity.

investigated as a predictor of mortality possibly because it is not available in many datasets. Most studies using HRS data did not control for this variable; Sloan et al. (2010), however, find that being foreign-born is associated with lower mortality hazards. Similarly, parental SES factors are not commonly used by researchers perhaps because adult mortality is believed to be better predicted by personal factors. Nonetheless, parental longevity has been shown to affect subjective survival expectations which in turn predict mortality (e.g. Hurd and McGarry 2002). Thus I control for parental education as well as parental longevity since they are exogenous and may turn out to be suitable risk-classes.<sup>73</sup>

Another explanatory variable of interest is cognitive ability, since it has been demonstrated that intelligent people live longer (Deary 2008). Among the various pathways proposed are that people with higher intelligence may be more well-organized, conscientious individuals; they may also tend to be more educated, work in healthier environments, and engage in healthier behavior (do not smoke, exercise, better diets, avoid accidents). Thus, cognition is a plausible risk-class for annuitants (who tend to be older adults) and an added advantage is that cognition is objectively-measured in the HRS.<sup>74</sup>

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<sup>73</sup> HRS contains information on the parents' vital status and current age (age at death if deceased). I create a continuous variable using parent's current age (or age at death) minus sex-specific life expectancy, divided by 10. The life expectancy used for fathers is age 65, which is an average of the life expectancies of a 15-year old male and 30-year old male in 1931 and 1941, weighted by the respondent sample composition. The life expectancy used for mothers is age 69. For example, mother's longevity will be negative if the mother died before 69 but positive if the mother survived past 69. Parents' vital status is not used directly because it is dependent on the respondent's age at time of interview and thus not reflective of parental longevity.

<sup>74</sup> The HRS is one of the first national health surveys to measure cognitive health at the population level, and cognitive tests are administered based on well-validated measures developed from psychological research on intelligence and cognition (Herzog and Wallace 1997). In this paper, cognition scores are obtained from the Imputation of Cognitive Functioning Measures 1992-2006 (V1.0) dataset which

*Conventional, endogenous factors.* Prior research has emphasized the importance of self-ratings and self-assessments of health in predicting mortality (e.g. Idler and Benyamini 1997). Despite endogenous factors not being the focus of this paper, it is important to assess how their inclusion may affect the predetermined and/or exogenous covariates. Specifically, I use self-reported health (excellent (ref.), very good, good, fair, and poor), whether currently smoke (no/yes), ever smoked, and ever drink.

### ***Estimation Models***

Proportional hazard (PH) regression analysis is used to (1) assess the bivariate relationship of each additional predictor variable with longevity, controlling for age and sex; and (2) construct a multivariate equation estimating the independent effects of the more detailed list of prognostic factors. An important strength of the hazard framework is its ability to properly treat right-censored data. Respondents who survived the entire observational window from baseline to 2008 were treated as censored after their 2008 wave interview. For others not known to be dead but who attrited from the study at various time points, their data are censored as of the last interview date. Consider the general form of the PH function:

$$h(t|\mathbf{x}_j) = h_0(t) \cdot \exp(\mathbf{x}_j\boldsymbol{\beta}), \quad (1)$$

where  $h(t|\mathbf{x}_j)$  is the resultant hazard rate for the  $j^{\text{th}}$  subject in the data, given survival time  $t$  and the subject's vector of covariates  $\mathbf{x}_j$ . It is also called the mortality risk (or force of mortality).  $h_0(t)$  is the baseline hazard function (i.e. hazard when all

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contains imputations for cognitive functioning data for HRS 1992 through 2006 (Fisher et al. 2009). In 1992 and 1994, only questions pertaining to a respondent's memory skills (immediate / delayed word recall) were asked. As such, the cognition score defined at baseline is the 1992 memory status score (scale 0-40). From 1996 onwards, the HRS included additional questions pertaining to a respondent's mental status (e.g. Serial 7s test, backwards counting etc.).

independent variables are set to their reference categories), and  $\beta$  is the vector of regression coefficients to be estimated. Equation (1) states that the death hazard that subject  $j$  faces is multiplicatively proportional to the hazard everyone faces, modified by his personal characteristics expressed as a vector  $\mathbf{x}_j$ .

Within the general class of PH models, I specifically estimate two types. First, the Cox (semi-parametric) model is employed because of its flexibility (it does not require assumptions about the underlying hazard function); the shape of the hazard function  $h_0(t)$  is unconstrained. Cox models have been widely applied in previous mortality studies using the HRS data (e.g. Sloan et al. 2010; Dupre et al. 2009; Lee et al. 2008; Siegel et al. 2003; and Mehta et al. 2003). Second, I consider a parametric alternative by imposing a Gompertz form on the underlying hazard function. It is well-documented that in past-middle adult ages (age 40 – 90) the mortality curve displays a regular and nearly exponential increase that can be represented by the Gompertz function (Gompertz 1825; Preston et al. 2001; Bongaarts and Feeney 2002).<sup>75</sup> Thus, the Gompertz form is suitable since the sample of HRS respondents is age 51 – 77 over the observational window.<sup>76</sup>

The Gompertz PH model is implemented with the following hazard and survivor functions:

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<sup>75</sup> The Gompertz model might actually underestimate mortality at ages under 40 and overestimate mortality at the oldest ages over 80 or 90. The Makeham-Gompertz and logistic models have been proposed to address these deviations. Nonetheless, for many purposes, the Gompertz model provides a satisfactory fit to adult mortality rates for ages between 40 and 90. I refer interested readers to Preston et al. (2001).

<sup>76</sup> Using Cox-Snell (Cox and Snell 1968) residuals, I also find that the ‘Gompertz’ form fits the data best compared to other parametric forms (e.g. the ‘Weibull’, ‘Log-logistic’, and ‘Lognormal’). The cumulative hazard function (estimated with Cox-Snell residuals using the Gompertz form) lies very close to the 45-degree reference line.

$$h(t|\mathbf{x}_j) = \exp(\gamma t) \exp(\mathbf{x}_j \boldsymbol{\beta}), \quad (2)$$

$$S(t) = \exp\{-e^{\mathbf{x}_j \boldsymbol{\beta}} \gamma^{-1} (e^{\gamma t} - 1)\}, \quad (3)$$

where  $\gamma$  is the additional parameter to be estimated from the data. Empirically, I find that the Gompertz function fits the survival function for both sexes exceptionally well in part because the sample respondents are all above age 50; most however have not reached the advanced ages of 80 or 90 by the 2008 wave. Results from the Cox regressions are nearly identical to those from the Gompertz approach (further evidence that the Gompertz function appropriately parameterizes the underlying baseline hazard); hence I present only the latter. Moreover, the parametric approach allows us to obtain more efficient estimates of the coefficients than the semi-parametric model, because it exploits all information in the data; the Cox model only compares subjects at failure times. Statistical analyses are conducted using *STATA* 11.0 software,<sup>77</sup> and weighted to account for over-sampling of blacks, Hispanics, and Floridians in the HRS.

One important issue to consider in the estimation is whether the hazard functions for males and females have different shapes. If the hazards for sexes are not proportional, then subsequent estimations need to be separated by sex. Results from fitting stratified models reveal that the hazards are proportional and thus a combined analysis is reasonable.<sup>78</sup> Furthermore, hazard plots for both sexes are nearly parallel over the entire follow-up period. Another concern might be the nonlinearity of age and

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<sup>77</sup> See Cleves et al. (2010) for an overview of survival analysis using *STATA*'s *STSET* procedures.

<sup>78</sup> To test for differences in shape between the hazards for males and females, I include an ancillary gamma parameter in the Gompertz distribution to allow both the scale and shape of hazard to vary by sex (complete stratification). I find that coefficients do not differ, irrespective of whether we constrain the hazards to be of the same shape, or allow them to vary. This implies that the effect of sex on the shape of the hazard is not significant, up to a scale change. Stratification involving the Cox model leads to the same conclusion.

the interaction of age with analysis time.<sup>79</sup> Nonetheless, analyses not reported in detail here show that higher order age variables and time-age interaction terms are not significant ( $p > .05$ ). In order to properly estimate the baseline survivor function, the age variable is transformed so that the baseline hazard corresponds to a 50-year-old retiree.<sup>80</sup>

In what follows, I first consider a specification (call it “M1”) with only information currently used by U.S. annuity providers i.e. age and sex. Then, the three blocks of additional prognostic factors are sequentially added to the PH model in the following order: “M2” adds the set of conventional, readily-measurable covariates; “M3” adds the block of less-conventional covariates; and finally “M4” adjusts for conventional, endogenous risk factors. In this way, any changes in the relation between the various control variables and mortality can be observed, while evaluating the fit of each specification.

### 3.3 Results: Survival Analysis

Of the sample of 9,047 HRS respondents, 6,547 survived, 1,905 died, and 595 permanently attrited by the 2008 wave. The 16-year mortality rate is 21.1%;<sup>81</sup> the attrited group is added to the denominator because it is observed that the bulk of

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<sup>79</sup> Age may interact with follow-up time; for example, a respondent who is older at enrollment may be more likely to die during follow-up (Dickman et al. 2004). If so, then the proportional hazards assumption is not appropriate for the age covariate since the hazard ratio will differ according to analysis time. In this model, the  $\text{age} \times t$  interaction term is not statistically significant, controlling for age and sex.

<sup>80</sup> I use baseline age minus 50. The origin from which the covariate is measured impacts the baseline cumulative hazard and survivor function because it changes how “all covariates equal zero” is defined. If age is unadjusted, the baseline hazard will correspond to a newborn.

<sup>81</sup> This mortality estimate (spanning Waves 1 to 9) appears reasonable given that the overall cumulative mortality for the HRS sub-sample up to Wave 7 is 15.9% (HRS 2008). The confirmed mortality rate is 22.5% (excludes the attrited group from both the nominator and denominator).

attriters had requested removal from the HRS survey in-person whilst alive.<sup>82</sup> In comparison, the 1992 lifetable mortality rate (weighted to reflect sample composition) is 23.5%. Mortality rates in the HRS sample are slightly lower than lifetable rates since HRS initially surveyed only the community-based population, which excludes long-term care facility residents. Figure 3.1 shows that 70 percent of males and 78 percent of traced females survived the entire 16 years of follow-up. Also, the men's survivor curve lies below that of the women's, indicating that mortality risks are greater for males at every age. The observation that females have a better survival experience is consistent with observed longer life expectancies for women in the population at large. The survivor functions (Kaplan–Meier curves) in the Figure are also gently sloped which suggest that the increase in mortality risk over time is gradual.<sup>83</sup> An important feature of the Kaplan–Meier curve is that it accounts for right-censoring, which occurs if a respondent withdraws from the study. The longest observation in this dataset survived 201 months (16.75 years), and was ultimately censored.

*[Figure 3.1 here]*

### ***Proportional Hazards Regressions***

Table 3.1 reports the results from fitting the Gompertz PH model for different sets of prognostic factors. The estimated hazard ratios (or odds ratios) give the partial effects of

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<sup>82</sup> The Tracker file records the detailed result of each interview attempt as of the close of the field period by wave, although the coding across waves was inconsistent. From the 2002 wave, it classifies respondents' removal from the study according to these categories: respondent requests removal in person; request through informant, request through proxy, because tracking was exhausted, or because a proxy cannot be identified. I observe that a large percentage (above 93%) had asked to be removed from the sample in-person, and only a handful of cases were lost to tracking. As a result, the extent of unaccounted deaths among the attriters in the sample is minimal.

<sup>83</sup> One reason might be that the deaths observed over the time window are of individuals who die before their life expectancies (age 79-81). The average observed death age is 66. In other words, the subjects have not reached their 'critical' years by the end of 2008.

the explanatory variables on the odds of mortality.<sup>84</sup> A hazard ratio larger than 1 indicates that an increased hazard (probability of death) is associated with the explanatory variable, and a hazard ratio less than 1 indicates that a decreased hazard is associated with the explanatory variable. Accompanying 95 percent confidence intervals are also reported. It is apparent from Table 3.1 that probability of death is significantly higher for males and older people. Specifically in Column (M1), being a male is associated with a 62% higher mortality risk ( $p < .01$ ) as compared to a female, and aging each year beyond age 50 is associated with 9% increased risk. In addition, the partial effects show that age and sex continue to be significant predictors of mortality even when more covariates are added in subsequent specifications.

*[Table 3.1 here]*

A better way to evaluate these hazard ratios is in the context of the baseline hazard function since the absolute increase in mortality risk depends on the size of baseline hazard. Figure 3.2 illustrates the hazard functions of four individuals of different attributes. The solid line is the baseline hazard depicting the hazard rates for our baseline case: a female age 50 in 1992. Her instantaneous probability of death starts low at age 50 and increases to about .0011 by the time she is age 66 (in 2008). Turning to consider the case of a male who is also age 50 in 1992, the Figure shows that his hazard function lies just slightly above the baseline hazard. This is because although he faces 1.62 times more risk than the female, the baseline hazard is small such that a 62% increase in risk does not create a large impact. In contrast, a 60-year old male has a

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<sup>84</sup> For a categorical variable, the hazard ratio compares the (mortality) hazard rate for respondents *with* the factor to the hazard rate for those *without* it. For a continuous variable, the hazard ratio represents the increase in hazard associated with a single unit of change in the explanatory variable.

hazard function that lies far above the baseline hazard. He faces about 3.84 times more the baseline case at any given point in time and has a hazard rate of .004 by the time he is age 76 (in 2008). More generally, the Figure shows closely parallel lines which support the proportionality assumption. The monotonically increasing functions are also consistent with the Gompertz parameterization.

*[Figure 3.2 here]*

Column (M2) adds race, education, whether married, prior health history, and weight – all of which are highly significant ( $p < .001$ ). Lower mortality hazards are associated with respondents who completed high school (HR=0.73; 95% CI=0.66, 0.82), or who are married (HR=0.69; 95% CI=0.62, 0.77). On the other hand, people who are nonwhite, underweight, or had chronic diseases such as lung disease, diabetes, and heart attack face higher mortality risks.<sup>85</sup> In particular, being underweight (symptomatic of an underlying disease) increases the risk of death by 2.9 times as compared to the reference normal weight group. It may appear surprising that obesity (BMI  $\geq 30$ ) is not associated with an excess risk of death. This is because the extent of obesity matters: several studies have shown statistically significant associations between all-cause mortality and BMI in severely obese groups (BMI  $\geq 35$ ), but not for the mildly obese group.<sup>86</sup> Overall,

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<sup>85</sup> Our reported hazard ratios are consistent with those in prior studies. For example, using a sample of HRS male respondents, Sloan et al. (2010) report hazard ratios of 0.945 for with high school education, 0.794 for married, 1.170 for blacks, 1.006 for baseline age, and 0.83 for foreign-born.

<sup>86</sup> Consistent with the findings here, prior studies that used HRS data did not find statistically significant differences in the mortality of overweight and mildly obese groups versus the normal weight group (Reuser et al. 2008; Mehta and Chang 2009). For example, Mehta and Chang (2009) find that respondents who are Class I obese (BMI 30-34.9) do not face excess mortality risk but those who are severely obese (Class II/III obesity with BMI  $\geq 35$ ) do. That study concluded that obesity is not a significant cause of mortality in the HRS population because there are relatively few people who are extremely obese. Applying finer classes of obesity in this present paper, I find that the ‘Class III obese’ variable has a hazard ratio above one but the effect is not significant (results not reported in detail here).

M2 has substantially better fit than M1: the Wald test statistic ( $G^2$ ) reported in the Table shows a six-fold increase and the difference is highly significant (1,287, 16 df – 191, 2 df = 1,096, 14 df,  $p < .000$ ).<sup>87</sup>

Column (M3) adds the set of less conventionally used variables, including birth region, cognitive score, and parental factors. A ten-point increase in cognitive score is associated with a 26% lower mortality hazard ( $p < .01$ ). Also significant is birth region: respondents not born in the US, or born in the West region, face 26 – 37% less mortality risk as compared to those born in the Northeast region of North America. Results also show that father's longevity is predictive of mortality; a respondent whose father survives 10 years past age 65 faces 5% lower hazard. Interestingly, a stepwise procedure (not reported in detail here) reveals that the inclusion of cognitive score is the key reason for the diminished effect of race on mortality (odds ratio falls from 1.18,  $p < .01$  to 1.14,  $p < .05$ ). This suggests that nonwhite HRS respondents are likely to have lower cognitive scores *and* to die younger.<sup>88</sup> If so, this enhances the attractiveness of cognition as pricing factor since not only is it objectively-measured, it also act as a proxy for an important demographic characteristic like race. The overall improvement in fit (Wald test statistic) is modest but statistically significant ( $p < .000$ ). In essence,

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<sup>87</sup> The test statistic is based on the chi-square test that at least one of the predictors' regression coefficients is not equal to zero in the model. It is also a measure of model fit – a larger statistic indicates better fit. In nested models, the model with more parameters will always fit at least as well as the one with fewer parameters. Whether the fuller model fits significantly better and thus preferred, can be determined by deriving the p-value of the difference between the test statistics. The Wald chi-square statistic (a variant of the likelihood-ratio chi-square) is used as it accounts for the clustering across observations for the same subject.

<sup>88</sup> This is consistent with the findings in Rodgers et al. (2003). Using the 1993 and 1998 waves of the AHEAD sample in the HRS, their regression analysis on cognitive score show that being African-American is associated with an estimated decline of about 0.49 points on the total cognitive score per year, while being Hispanic is associated with a 0.35 points decrease.

model M3 represents the complete specification with the proposed set of readily-measurable factors that can be used to price annuities, in addition to age and sex.

The set of endogenous controls are introduced in Column (M4) to test how their inclusion affects estimates of previously-controlled covariates. Results show that self-rated health and smoking are significant ( $p < .01$ ). In particular, a person who reports “poor” health faces triple the risk ( $HR=3.02$ ; 95%  $CI=2.38, 3.81$ ) of someone who reports “excellent” health. The inclusion of self-rated health also makes the race and education variables lose statistical significance.<sup>89</sup> Interestingly, pairwise correlation analyses reveal that respondents who rate their own health poorly tend to be better educated, and are white (rather than black or Hispanic). This observation concords with Dowd and Zajacova (2007) who find that individuals across SES strata differ in how they evaluate their health. In particular, lower health self-ratings are more strongly associated with mortality for adults with higher education and/or higher income. The useful takeaway here is that self-rated health is not likely to be useful as an additional pricing factor – it is subjective and its explanatory power is derived from existing SES factors. Current smoking increases hazards by 76%. While its strong independent effect on mortality enhances its usefulness as a risk-class, the need for blood tests to verify smoker status makes it less palatable than the set of readily-measurable factors already identified in Model 3.

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<sup>89</sup> A stepwise procedure (not reported in detail here) shows that the addition of self-rated health to the model has the greatest impact on existing covariates. In relation, the pairwise correlations are 0.19 (self-rated health and nonwhite) and -0.32 (self-rated health and education). Both correlations are significant at 1% level.

Table 3.1 reports the parameter  $\gamma$ , which controls the shape of the baseline hazard. The value of  $\gamma$  varies depending on the model specifications, but the key is that  $\gamma$  is a positive value indicating monotone hazard functions that increase exponentially with time.<sup>90</sup> Because it has been verified in Section 3 that the male and female hazards have the same shape, a unisex  $\gamma$  will be applied in the subsequent pricing simulations. A related issue is then whether  $\gamma$  differs significantly for the younger versus older respondents, since there is a maximum possible age gap of 12 years. To test for this age-covariates interaction, I divide the respondents into two groups: ages 50-57 (two-thirds of the sample) and ages 58-62. The number of deaths in both groups is pretty similar. Results are shown in *Appendix Table 3.2*.

Slight differences emerge: for the older group, the age covariate is not statistically significant (HR=1.04, 95% CI=0.97, 1.12,  $p>.10$ ),<sup>91</sup> and the negative effect of chronic diseases and low BMI on mortality seems less intense.<sup>92</sup> For instance, an older person with cancer faces 1.7 times the mortality risk of someone without (compared to 2.3 for a younger counterpart). One possible explanation is that at advanced ages, physical conditions become less predictive of mortality (everyone eventually becomes frail and disease-ridden), whereas mental health emerges as a more significant determinant. Although the dataset we use precludes our validating this surmise, it appears that cognitive score and years of education (proxies of mental ability)

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<sup>90</sup> This is consistent with Figure 3.2.

<sup>91</sup> The magnitude of the odds ratio, however, is similar to that for the younger group.

<sup>92</sup> Our results show that the hazard ratios for six of the eight chronic disease conditions are lower for the older group. This is consistent with results in Lee et al. (2008). Using HRS data, that study finds that as age increases, the ability of chronic conditions to predict mortality declines rapidly. Chronic conditions are stronger predictors of death for younger participants (aged 50-59 years) than for older participants.

predict mortality slightly better for the older group. But overall, there are no substantial differences in the hazard ratios or  $\gamma$  between the two age groups; thus, I proceed with the combined sample.

### ***Improved Predictive Ability from Risk-class Pricing***

One of the objectives of this paper is to explore the possible impact of pricing annuity benefits using additional risk-classes vis-à-vis existing pricing factors (age and sex). To do so, I compare the values of adjusted  $R^2$  across the four models.<sup>93</sup> Controlling only for age and sex in “M1” explain about 6.7% (SE 0.0093) of variance in mortality outcomes. In contrast, “M2” and “M3” have adjusted  $R^2$  values of 29.7% (SE 0.0139) and 30.6% (SE 0.0138) respectively. In other words, implementing the 12 to 18 additional risk-classes will allow an insurer to explain about five times more variation in mortality, suggesting that much prognostic information is carried by the additional variables.

To assess the relative contributions of individual predictors, I remove variables from “M3” one at a time – in the order that reduced  $R^2$  the least at each step. For the given sample, diabetes is the most important predictor of mortality, followed (in this order) by lung disease, heart disease, sex, age, marital status, high blood, cancer, own schooling, BMI, psychiatric condition, cognition, birth region, stroke, father’s longevity, race, mother’s education, father’s education, arthritis, and mother’s longevity. This ranking suggests that prior health history (other than arthritis) and demographic

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<sup>93</sup> The values of adjusted  $R^2$  are found at the bottom of Table 3.1. In the context of censored survival data, the adjusted  $R^2$  measures how much of the variation in outcome in a PH model is accounted for through the prognostic index ( $x\beta$ ), adjusting for the dimension of the model. See Royston (2006) for details. The Harrell’s  $C$  and Somers’  $D$  statistics for Cox PH models are not suitable for use with our weighted analysis.

variables (particularly age, sex, and marital status) are important predictors of mortality for people close to retirement. Objectively-measured variables such as BMI and cognition also rank moderately well, which lends weight to their use in annuity pricing. Race does not rank highly on this list, probably because it serves as a proxy for SES, which in this case may have been largely captured by the education variable. Parental education is ranked low, which is not surprising since the mortality of older adults may no longer be strongly associated with parental SES.

In what follows, the ten best-ranked additional risk-classes are combined with age and sex to form a “risk-class pricing” scheme.<sup>94</sup> This new model specification with a total of 12 variables has an adjusted  $R^2$  value of 29.7% (SE 0.0137). It is posited that this “risk-class pricing” scheme which is richer in information will allow insurers to derive more accurate mortality predictions than the “age-sex pricing” scheme. This paper proposes a novel approach to make this assessment by comparing age-at-death prediction intervals. To the best of my knowledge, this procedure has not been demonstrated in previous population-based studies of mortality. Studying age-at-death intervals is of interest since insurers will want to pinpoint, as accurately as possible, how long annuity payouts need to be made.

Age-at-death probability density functions are derived from post-PH regression estimates. These density functions show the relative likelihood of the individual dying at each point in time, i.e. the probability of dying before month  $k + 1$  given survival to

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<sup>94</sup> Results (not presented) show that this ranking using adjusted  $R^2$  is consistent with other variable selection methods. Stepwise and forward selection procedures both confirm that parental education, mother’s longevity, arthritis, and birth region are the least significant variables. A slight difference is that the forward selection method ranks ‘stroke’ as one of the top 12 factors in lieu of ‘own schooling’.

month  $k$ . Formally, let  $(d)$  denote the age of a retiree who purchases an individual life annuity at time 0. A discrete random variable associated with her future lifetime is  $K(d)$  where discrete time periods are measured in months.<sup>95</sup> The survival function and density function of  $K(d)$  are, respectively:

$$S(k) = \Pr[K(d) > k] = {}_k p_d, \quad d \geq 50, k = 0, 1, 2, \dots, \quad (4)$$

$$\Pr[K(d) = k] = {}_k p_d - {}_{k+1} p_d = {}_k p_d \cdot {}_1 q_{d+k}, \quad (5)$$

where  ${}_k p_d$  is the probability that  $(d)$  will attain age  $d + k$  (or so-called cumulative survival probability), and  ${}_1 q_{d+k}$  is the one-period mortality rate at age  $d + k$ . The constraint of  $d \geq 50$  is consistent with the minimum age of the given sample. The assumed terminal age that an individual can live up to is 120. Essentially, Equation (4) is the discrete-form equivalent of Equation (3). Fitted estimates of the survival function are derived for price simulations discussed in the next section. The focus here is the fitted estimates of the density function derived from Equation (5).

It is also useful to introduce the notion of a ‘risk-group’. Individuals who share a common density function are called a risk-group. In the context of annuities, a risk-group with a longer lifespan is ‘riskier’ than another. Given that the sample consists of a number of risk-groups, the objective here is to analyze how the density functions estimated under the two different annuity pricing schemes will differ, in the presence of such heterogeneity. In particular, consider four distinct risk-groups profiled as follows:

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<sup>95</sup> In actuarial terminology, this is called the curtate-future-lifetime of  $(d)$ . See Bowers (1997).

- (i) High longevity-risk: 55-year-old female, no disease history, slightly overweight, married, completed high school (HS-educated), above-average cognition.
- (ii) Average risk: 55-year-old female, no disease history, normal weight but is not married, not HS-educated, average cognition. (Note that this mortality profile is obtained by setting all 10 additional risk variables at their reference categories.)
- (iii) Low risk: 55-year-old female, history of cancer, underweight, is not married, not HS-educated, below-average cognition.
- (iv) Very low risk: 58-year-old male, overweight, has heart disease, high blood and psychiatric illness, not married, not HS-educated, below-average cognition.

Figure 3.3 plots the density functions for each risk-group. For the first three subgroups, the density curves estimated from age-sex pricing alone (dotted lines) are identical; the benchmark is the density function for an *average* 55-year old female. In contrast, estimates obtained from “risk-class pricing” (solid lines) vary significantly across the three risk-groups; the subgroup with longer longevity is expected to die later than others. Overall, this enables readers to visualize exactly how incorporating more risk-classes improves predictive power: insurers are not only able to distinguish across risk profiles, but also obtain tighter age-at-death prediction intervals (narrower distributions). In addition, the solid line functions reveal higher peaks implying that the most probable ages of death are associated with greater weight (higher probability levels).

*[Figure 3.3 here]*

The bottom-right plot in the Figure illustrates the density curves for a very low-longevity risk-group; here we characterize this as an older male with a history of several diseases. In such cases, substantial differences in mortality predictions can emerge: for instance, “risk-class pricing” predicts a most probable age-at-death at 64, whereas “age-sex pricing” yields a prediction of age 83. Having selected suitable risk-classes and demonstrated how incorporating these additional factors will lead to improved age-at-death predictions, the next step is to analyze how implementing these risk-classes affects the financial value of annuities for different demographic groups.

### **3.4 Price Simulations on a Purely Financial Basis**

This section briefly describes the actuarial valuation approach for life annuities and presents simulation results for a hypothetical cohort of 65-year-old potential annuity buyers.<sup>96</sup> It should be noted that this pool of individuals is not related in any way to the earlier sample of HRS respondents. I first simulate the annuity benefit flows accruing to a variety of risk-groups, and then simulate the annuity premiums that would be charged under different actuarially fair pricing schemes. These results are combined to obtain the money’s worth ratio for various risk-groups under alternative pricing schemes assuming no loading.

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<sup>96</sup> Earlier studies that perform annuity value simulations have similarly focused on a cohort of same-age annuitants. For instance, Brown (2003) uses a cohort of 67-year-olds. Mitchell et al. (1999) and Turra and Mitchell (2008) focus on a cohort of 65-year-olds. Age 65 is selected here because it is closer to the expected retirement age of the sample of HRS respondents (mean=63.5, SD=3.65) used in the earlier regression analyses.

### ***Benefit Flows to Annuitants***

Consider a standard, nominal, whole life annuity that pays \$1 per month as long as the annuitant is alive. The first payout starts at time  $t = 0$  when the annuity is purchased. This is the only product available to individuals in this simulation. The benefits to annuity purchasers in the same risk-group can be quantified as follows:

$$EPDV = \sum_{t=0}^{\infty} \$1 \cdot v^t \cdot {}_t p_d^{group}, \quad (6)$$

where EPDV refers to the expected present discounted value of future annuity payouts. In addition,  $v$  is the discount factor,  ${}_t p_d^{group}$  is the set of cumulative survival probabilities for a risk-group,  $d$  is the age at which the annuity is purchased, and  $t$  is time expressed in months. In actuarial terminology, the EPDV is called the actuarial present value of a life annuity and the upper bound of the summation is set to infinity by convention. Equation (6) captures the present value of the series of annuity benefits that an annuitant in a particular risk-group can expect to receive over her remaining lifetime.

Risk-groups can be defined using any combination of risk factors. For instance, a broadly-defined risk-group might be ‘age 65, females’; their set of  ${}_t p_d^{group}$  can be estimated from a PH regression that controls only for age and sex.<sup>97</sup> Another example of a risk-group would be ‘married, high-school educated, age 65, females’ – and any female with these four characteristics would be in the group (even though some would

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<sup>97</sup> Robustness checks are performed to determine if the fitted estimates of  ${}_t p_d$  are reflective of rates reported in actuarial lifetables. Results (not presented) show that the fitted cumulative survival estimates generated from the PH regression controlling only for age and sex (i.e. Model 1) are close to the survival probabilities constructed from the Social Security Administration (SSA) birth cohort tables. The 1930 and 1940 sex-specific SSA cohort tables are used since the HRS sample respondents are born 1931-1941, and are sourced from [www.ssa.gov/OACT/NOTES/as120/LifeTables\\_Tbl\\_7.html](http://www.ssa.gov/OACT/NOTES/as120/LifeTables_Tbl_7.html).

be suffering from a disease and some would not). Their set of  ${}_t p_d^{group}$  is estimated from a PH regression that controls for age, sex, education, and marital status. In the simulations that follow, a nominal annual interest rate of 6% is assumed (this rate reflects the average 30-year Treasury bond yield for the last 20 years) and I also present sensitivity analysis using an alternative value of 4%.<sup>98</sup> Further, the assumed terminal age of survival is 120.<sup>99</sup>

Table 3.2 presents the simulated expected annuity benefits (or EPDV) for a variety of risk-groups. The row in the middle shows that a 65-year-old annuity purchaser, on average, can expect to receive \$126 in annuity benefits. If the fact that females live longer than males is accounted for, then plugging sex-specific survival probabilities into Equation (6) reveals that the estimated EPDV for females is actually \$16 higher than that for males. If we further account for the education level of the annuitant, then the EPDV of high-school educated groups will be larger than that of non-high-school educated groups. The top and bottom rows of the Table draws a contrast between a very long-lived group profiled by ‘females with no high blood, married, and high-school-educated’ (EPDV \$152) and a very short-lived group profiled

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<sup>98</sup> The average 30-year Treasury bond yield from 1988 to 2010 is 6.3% (the bond was discontinued between 2003 and 2005 but re-introduced in 2006). In recent years, yields have been falling. As at end 2010, the 30-year Treasury bond yield is 4.25%. Source: Federal Reserve Statistical Release ([www.federalreserve.gov/releases/h15/data.htm](http://www.federalreserve.gov/releases/h15/data.htm)). Prior studies (e.g. Mitchell et al. 1999) have similarly used the 30-year Treasury bond yield to proxy a flat nominal term structure. The discount factor is computed using  $v = 1/(1 + i)$ , where  $i$  denotes the nominal interest rate. It is also assumed that the insurer always earns exactly this rate on the assets backing the annuity, and so any profit or loss stems solely from annuity pricing simulations and not from reinvestment risk.

<sup>99</sup> A terminal age (denoted  $w$ ) of 120 is appropriate for two reasons. First, it has been used as the limiting age in official cohort lifetables from the U.S. Social Security Administration. Second, it appears to be a reasonable choice for the sample here since the maximum death ages observed for deceased parents are 105 (father), and 110 (mother) suggesting it is plausible that HRS respondents can potentially live to 120. In Equation (6), the upper bound of the summation can thus be alternatively expressed as  $(w - d) \times 12$ .

by ‘males with high blood, unmarried, and low-educated’ (EPDV \$81). In essence, the Table reflects a spectrum of longevity profiles in a heterogeneous cohort, although one can easily imagine other forms of representative profiles.<sup>100</sup>

*[Table 3.2 here]*

### ***Premiums Charged by Insurers***

How premiums are set depends on the prevailing pricing scheme in the market. To simplify the analysis, zero-loading is assumed so the insurer is assumed to set premiums just sufficient to break-even for each benchmark group that it prices.<sup>101</sup> Table 3.3 illustrates the dollar premiums charged to the hypothetical pool of age 65 individuals under different pricing schemes for a \$1/month life annuity. In an ‘age-only’ pricing scheme, the insurer will set a price based on the average survival probabilities of 65-year-olds. All annuity buyers will be charged the same premium of \$126. Under ‘age-sex’ pricing, the insurer no longer charges a single price but now has to differentiate between the sexes. The insurer uses the average survival probabilities of 65-year-old females to derive a premium of \$134, and all female annuity purchasers (whether they are married or unmarried, with disease or without) must pay \$134. Because of their lower average survival probabilities, males are charged a lower premium of \$117.

*[Table 3.3 here]*

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<sup>100</sup> For example, ‘females with lung disease, underweight, and poor cognition’ will also fit the profile of a very short-lived group.

<sup>101</sup> Insurers typically add loadings to the insurance products they sell to cover administrative costs and to incorporate some profit margin. Such loadings are borne by the consumers.

Row 3 of the Table shows that if an ‘age-sex-education’ scheme is adopted instead, there will be a total of four distinct prices after accounting for the different permutations among the pricing factors; high-school educated females paying the highest premium of \$145. It is also important to note from this analysis that risk-groups become more narrowly-defined when the pricing scheme becomes more detailed; for example, it is not possible to compute a premium for a risk-group of 65-year old females under ‘age-sex-education’ pricing.

Risk-based pricing essentially allows insurers to price-discriminate more finely across different risk profiles. As pricing schemes incorporate more details, the schedule of possible premiums offered by an insurer grows exponentially. The Table shows that using six rating classes will result in 32 distinct prices ranging from \$82-160. If all the top 12 pricing factors are used, then there are possibly more than 4,000 distinct premiums to account for the various permutations of 65-year old annuitants. All the results in the Table assume zero-loads. Loads can be factored into the analysis, for example, by assuming that they form a fixed percentage of the premium. If loads are say 10%, then all simulated premiums simply decrease by 10%, in which case, the *relative* prices charged to different buyers are unaffected.

### ***Money’s Worth Ratios Results***

To assess the financial value of annuities accruing to different demographic groups, a metric called the “money’s worth ratio (MWR)” is employed. The MWR measures the financial value of an annuity investment to the individual, and it is simply the ratio of the EPDV over the annuity premium paid. If the MWR is less than 1, then the individual is expected to receive less back in payouts than what she paid. If she

decides to buy the annuity, she would anticipate receiving a negative expected transfer. If MWR is greater than 1, then the annuitant would anticipate receiving a positive expected transfer.

Table 3.4A presents the MWR values for different demographic groups under a variety of pricing schemes. These values are derived using the simulated EPDV and premium estimates discussed earlier. It is important to note that these are the values available to individuals *if* they should decide to buy the annuities; thus this analysis does not require the assumption that all individuals must annuitize. The key takeaway from this Table is that shorter-lived annuity purchasers will be made financially better off (and the longer-lived made worse off) when more detailed pricing schemes are implemented. This is evidenced by focusing on the ‘top’ and ‘bottom’ risk-groups in the Table which represents longer-lived and shorter-lived profiles respectively. Under age-sex pricing, the MWR for the shorter-lived group is 0.693. MWR increases substantially to 0.893 when additional factors such as education and marital status are used – this is about a 29% increase in financial value for every dollar they invest in annuities. This is because when pricing incorporates more personal characteristics, shorter-lived individuals enjoy lower premiums that reflect their high mortality attributes. In contrast, the longer-lived are charged higher premiums causing their MWR to decline. The longer-lived risk-group has a MWR of 1.204 under ‘age-only’ pricing (scheme S1) but only a MWR of 1.047 under the more detailed pricing scheme S4.

*[Table 3.4 here]*

An interesting observation is that the incremental gains achieved by the shorter-lived exceed the incremental losses experienced by the longer-lived group. Moving

progressively from scheme S2 to S4, the Table shows 13 to 15% gains in MWR for the shorter-lived. These gains are substantial as compared to the modest declines of 3 to 5% for the longer-lived. This suggests that the effect of adopting more factors in annuity pricing in a heterogeneous population of annuity purchasers is likely to be uneven; longer-lived groups will be made just slightly worse off but shorter-lived groups will be disproportionately much better off. The intuition here is that it is generally harder to increase one's survival probability than to worsen it. Hazard ratios reveal that the combined longevity advantage of being married, HS-educated, female, and without high blood, decreases the risk of death by only 50% vis-à-vis the baseline individual. Yet, having the exact opposite attributes (all else equal) increases the mortality risk of an individual by 313%.<sup>102</sup> In other words, the survival curve of the longer-lived will lie just slightly above that of the baseline individual but the survival curve of the shorter-lived will lie far below the baseline curve. This disparity in survival estimates results in the premium falling more for the shorter-lived than it rising for the longer-lived when a pricing factor is added.

In sum, the MWR analysis suggests two important reasons why more detailed pricing may help reduce adverse selection in annuity markets. First, shorter-lived groups will be induced to buy annuities. Where they may have stayed out of the annuity market previously under simpler pricing, they may now decide to annuitize given decent MWR values of 0.8 to 0.9. Moreover, as pricing schemes become progressively

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<sup>102</sup> The computations are based on the hazard ratios in Column M2, Table 3.1. Death hazards are multiplicatively proportional. Assuming all other factors are set at their reference categories, a married, HS-educated, female without high blood has a mortality risk of  $0.69*0.73*1*1=0.504$  whereas an unmarried, non-HS-educated, male who ever-had high blood has a mortality risk of  $1*1*1.92*1.63=3.13$ .

more detailed, the incremental gains in MWR (13-15%) accruing to these shorter-lived groups are substantial. Second, longer-lived groups still have an incentive to annuitize even when more detailed pricing is implemented. This is because the penalty that these groups bear through higher premiums results in only modest financial losses of about 3-5%; moreover, they can still expect to enjoy positive expected transfers from annuitization as  $MWR > 1$ . Sensitivity analysis reveals that these results remain robust under a lower interest rate assumption (see Table 3.4B).

While the MWR is a useful metric, it ignores the insurance value that individuals may derive from the elimination of longevity risk. The next section describes a utility-based model and quantifies the utility gains accruing to different demographic groups under the assumption of risk aversion. It assesses whether shorter-lived groups may obtain utility gains from more detailed pricing schemes, and if so, whether they are as substantial as the financial gains.

### **3.5 Price Simulations on a Utility-Adjusted Basis**

This section primarily builds on the work by Brown (2001, 2003) and Mitchell et al. (1999).<sup>103</sup> In particular, I adopt the approach developed in these studies to quantify the welfare gains of annuitization to an individual using a metric called the “annuity equivalent wealth (AEW)”. Unlike the MWR, the AEW is a utility-based measure of annuity valuation and it has been shown in prior studies that individuals may find an annuity to be welfare-enhancing even if  $MWR < 1$ .

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<sup>103</sup> I am especially grateful to Jeffery R. Brown and Olivia S. Mitchell for use of the code for generating utility-equivalent wealth values originating from Brown (2001).

Closest to this present paper, Brown (2003) studies the utility-adjusted value of annuitization for a cohort of 67-year-olds of heterogeneous mortality under two pricing scenarios. Mortality is differentiated using sex, education, and race.<sup>104</sup> One pricing scenario examined is unisex uniform pricing (which corresponds to age-only pricing) and the other scenario is actuarially fair pricing for each and every *separate* demographic group. This present paper aims to extend the empirical analysis on two fronts: first, I consider intermediate pricing scenarios that lie between the two markers. Thus the pricing scheme prevailing at any point in time may be more than actuarially fair for some demographic groups and less than actuarially fair for other groups.<sup>105</sup> This is perhaps a better reflection of reality since insurers are likely to adopt additional risk-classes progressively as depicted by the intermediate pricing scenarios. Second, I examine a more diverse set of demographic groups. In particular, I differentiate mortality along more demographic lines, including education, marital status, and disease condition, which serves to broaden the analysis in useful ways.<sup>106</sup> In what follows, I describe the multi-period, stochastic life-cycle model used to evaluate the insurance value of an annuity under uncertain lifetimes and simulate AEW results for the hypothetical cohort of 65-year-olds.

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<sup>104</sup> According to Brown (2003), education is selected in because it is a reasonable proxy for lifetime resources and is also a predetermined variable for most retired individuals. Race is selected because it is directly relevant to the politics of the Social Security debate in the U.S. This is consistent with the study's objective of assessing the utility implications of mandating annuitization in an environment of heterogeneous mortality.

<sup>105</sup> The pricing scheme will be actuarially fair for groups which are identified as benchmarks in that particular scheme. These benchmark groups have been identified in Table 3.3 and have MWR values of 1.000 in Table 3.4.

<sup>106</sup> Differentiating along more demographic lines increases the mortality heterogeneity between the 'top' and 'bottom' risk-groups, thus leading to a larger observed dispersion in MWR and AEW values. In addition, the choice of factors matters; selecting factors that are less correlated will create greater mortality heterogeneity between the risk-groups analyzed.

### *Analytical Framework for AEW*

At the posited retirement age of 65, the individual decides how much of her initial wealth to annuitize. The retiree is assumed to be solving an expected utility maximization problem. Formally, let  $U(C_t)$  represent the one-period utility function defined over real consumption,  ${}_t p_a$  is the probability that an individual survives to period  $t$  ( $t$  is expressed in years),  $\rho$  the time preference rate, and  $\omega$  the terminal age (assume 120). Then, assuming additive separability over time, the value function  $V_t(W_t)$  is defined as:

$$V_t(W_t) = \text{Max}_{\{C_t\}} \left[ \sum_{t=1}^{\omega-65+1} \frac{{}_t p_{65} \cdot U(C_t)}{(1 + \rho)^t} \right], \quad (7)$$

subject to the following constraints:

- (i)  $W_0$  is given,
- (ii)  $W_t \geq 0, \forall t,$  (8)
- (iii)  $W_{t+1} = (W_t - C_t + A_t)(1 + r).$

In this set of constraints,  $W_t$  is non-annuitized wealth in period  $t$ ,  $C_t$  is consumption in period  $t$ ,  $A_t$  is the annuity income she receives in period  $t$  if she had purchased an annuity, and  $r$  is the real interest rate. There is no expectation operator because the survival probabilities have been explicitly accounted for, and there are no other sources of uncertainty in this problem. In addition, as in prior studies, I assume no bequests, no loadings, and no taxes in this setup. This value function at time  $t$  is the present discounted value of expected utility evaluate along the optimal path. Knowing the optimal decision in period  $t$  allows one to find the optimal decision that maximizes the

value function in period  $t - 1$ . The problem is thus solved numerically using backward recursion from the final period, and may be expressed by the following recursive Bellman equation:

$$\text{Max}_{\{C_t\}} V_t(W_t) = \text{Max}_{\{C_t\}} U(C_t) + \frac{{}_1p_{t+1}}{(1 + \rho)} V_{t+1}(W_{t+1}), \quad (9)$$

where  ${}_1p_{t+1}$  is the one-period probability of surviving in period  $t + 1$ .

Consistent with prior studies, I apply standard methods of discretizing the wealth space, and adopt the standard assumption that individuals exhibit constant relative risk aversion (CRRA).<sup>107</sup> The CRRA utility allows the simulation results to be invariant to the level of wealth possessed by the individuals in the different demographic groups at retirement. In other words, the value of annuitization derived by each demographic group will be unaffected by the differences in wealth levels across groups. The CRRA utility structure is:

$$U(C_t) = \frac{C_t^{1-\gamma}}{1-\gamma}, \quad (10)$$

where  $\gamma$  is the coefficient of relative risk aversion. More risk-averse individuals will value annuities more highly than less risk-averse individuals. Consistent with earlier studies such as Hubbard et al. (1995), a  $\gamma$  parameter of 3 is used for the main analysis. Sensitivity analysis using an alternative value of  $\gamma = 1$  is also presented since a risk aversion of 1 corresponds to log utility, and has been found to be the average risk aversion in prior studies on consumption (e.g. Laibson et al. 1998).

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<sup>107</sup> See Turra and Mitchell (2008), Brown (2003, 2001), and Mitchell et al. (1999).

The analysis proceeds with a counterfactual exercise using two scenarios. Assume that an individual has initial financial wealth  $W^*$ . In the first scenario, individuals have full access to an annuity market where single-life, fixed-payout, nominal payout annuities are sold. Assume that the individual annuitizes all resources she has, i.e.  $W_0 = 0$ . The annual income she obtains from the annuity ( $A_t$ ) is determined by the pricing scheme used by the insurer. For the special case in which the annuity is actuarially-fair for the individual,  $A_t$  is determined by:

$$A_t = \frac{W^*}{\sum_{t=1}^{\omega-65+1} \frac{{}_t p_{65}}{(1+r)^t (1+\pi)^t}}, \quad (11)$$

where  $r$  is the real interest rate, and  $\pi$  is the inflation rate. The maximum utility  $V^*$  the individual attains in this first scenario can be found by solving the maximization problem subject to the constraints in Equation (2).

Turning to the second scenario, assume now that no annuity market is available. That is,  $W_0 = W^*$  and  $A_t = 0, \forall t$ . I solve the maximization problem again and find the amount of additional wealth,  $\Delta W$ , which must be given to the individual (in the absence of annuities) so that she can achieve the utility level  $V^*$ . Given this setup, the annuity equivalent wealth (AEW) is thus defined as:

$$AEW = \frac{W^* + \Delta W}{W^*}. \quad (12)$$

In essence, the utility-based measure of AEW is similar to the Equivalent Variation measure in applied welfare analysis. Specifically, it quantifies how much an individual's wealth needs to be multiplied by (in a scenario without annuities) in order to generate the same utility level as in the scenario where annuities are available. In a

multi-period life-cycle model with risk-averse individuals, the AEW is typically a number greater than unity since the option of annuitization is valuable. Following Brown (2003), the simulations here assume  $\rho = r = \pi = 3\%$ .<sup>108</sup> Also, simulations only focus on annuity contracts that pay fixed, nominal benefit streams.<sup>109</sup>

### ***Annuity Equivalent Wealth Results***

Annuity prices (defined here as the annual annuity income for a given premium<sup>110</sup>) are constructed by replacing the  ${}_t p_{65}$  in Equation (11) with the appropriate set of survival probabilities. For example, if annuities are priced based on age and sex only, then the annuity income for a married, or unmarried, 65-year old female is found using the average survival probabilities of 65-year old females. It is important to note that the mortality rates used as input to determine pricing are only averages and significant dispersion in mortality will exist among say, the group of 65-year old females. As such, annuities that are age-sex priced in an actuarially-fair manner for 65-year old females will be *more* than actuarially-fair for a married 65-year old female with no diseases, and *less* than actuarially-fair for an unmarried, low-cognition 65-year old female.

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<sup>108</sup> Some important parameters adopted in this present paper are different from Brown (2003), for instance, mortality inputs, age of annuitization, and limiting age. While Brown (2003) considers mortality differentiated by age, sex, race, and education, this present paper differentiates risk-groups by age, sex, education, marital status, and disease conditions. The selection of risk-classes is important since correlations among the risk-classes affect the amount of mortality heterogeneity across the various risk-groups, and in turn affect the dispersion in AEW results.

<sup>109</sup> The focus of this present paper is on the dispersion in annuity equivalent wealth ensuing across different pricing schemes, thus only one annuity type is illustrated. Readers who are interested in how the dispersion in AEW varies across annuity types can refer to Brown (2003).

<sup>110</sup> Annuity pricing can be expressed in two ways. The first is that the insurer determines the annuity premium as in the MWR analysis. This applies to a fixed-payout annuity (e.g. annuity pays \$500/month for life). The second is that the insurer determines the quantum of payout for a given premium invested. This applies when the annuitant decides to invest, say \$100,000, in an annuity. In both cases, the insurer sets the 'price' and annuitant is the price-taker.

Table 3.5 reports the annual annuity income for a \$100,000 policy under various pricing schemes. If individual-life annuities are age-sex priced, a 65-year old male will receive \$10,898 per year, while a female will receive a lower annual income of \$9,492 due to her longer life expectancy. Under pricing scheme S3, lowly-educated individuals will benefit from an increase in annuity income. In particular, the Table shows that lowly-educated males now receive \$12,344 in annual income as compared to \$10,898 under scheme S2. In contrast, better educated individuals experience a decline in annuity income. A high school-educated female now receives only \$9,036 (compare \$9,492 under S2) since her premium educational level is now factored into the annuity pricing. In the very detailed pricing scheme S4, an unmarried, lowly-educated male will receive \$5,527 more annually than a married high school-educated female for the same given annuity premium of \$100,000.

*[Table 3.5 here]*

Table 3.6A presents the annuity equivalent wealth for different demographic groups under different pricing schemes. Results show that the utility gains from annuitization are substantial for both genders under the age-sex pricing scheme used in the U.S. annuity market today. This finding is consistent with previous empirical analyses (e.g. Brown 2003; Mitchell et al. 1999). In particular, females – on average – have an AEW of 1.474, meaning that they will be indifferent between \$1 of annuitized wealth and \$1.47 of non-annuitized wealth. Compared to average females, women with longevity-enhancing attributes such as being married, or being highly-educated, enjoy even higher AEW values (1.482 to 1.495) because they have higher survival probabilities and are thus more likely to be alive to consume the annuity.

*[Table 3.6 here]*

Average males have an AEW of 1.644; this is comparable to Brown (2003)'s figure of 1.633 under age-sex pricing. The Table also shows that unmarried or lowly-educated males have lower AEW values than the average male. These risk-groups find annuities less valuable since they are less likely to survive to consume the annuity. Nonetheless, even those with very poor mortality prospects benefit from the annuitization option. For example, even the 'bottom' risk-group of unmarried, lowly-educated males with high blood disease has an AEW of 1.445.

As with the money's worth analysis, AEW results here show that shorter-lived groups find annuities more valuable as pricing becomes more detailed while longer-lived groups find annuities less valuable. The 'bottom' group experiences a 30% increase in utility moving from age-sex pricing to scheme S4 and it should be noted that these utility gains are achieved by adding just a couple of pricing factors. In contrast, the 'top' group experiences a modest 8% loss in utility but still obtains a decent AEW of about 1.4 under the detailed pricing schemes. Sensitivity analysis shows that the AEW figures are generally smaller under log utility, i.e.  $\gamma=1$  (see Table 3.6B). This is because individuals with lower degree of risk aversion value annuities less than those who are more risk-averse. Nonetheless, the finding that high-mortality-risk groups benefit the most from annuitization when annuity pricing becomes more detailed remains robust.

### 3.6 Discussion and Conclusion

Annuities provide valuable longevity insurance to individuals with uncertain lifetimes. The aging of the boomer generation in the U.S. and the global advent of individual retirement accounts will likely increase the demand for annuities. Yet in the U.S. as well as in many other developed countries, prices of most standard retail annuities do not reflect buyers' personal characteristics other than age and sex. Some impediments to annuity underwriting may be costs and thin annuity markets. It may also be that insurers think underwriting is not profitable, which would be true if mortality differentials were not substantial.<sup>111</sup> Nonetheless, the results in this paper suggest that mortality differentials are in fact substantial. Explained variation in mortality doubles from 6.7% to 12.6% just by using education and marital status, in addition to age and sex. Adjusted  $R^2$  increases further increases to 29.7% when the ten best-ranked factors are used along with age and sex. Moreover, these factors are readily-measurable and therefore not costly to collect.

A main contribution of this paper has been to show that more detailed pricing may reduce adverse selection in annuity markets. This can be attributed to two effects that occur when more pricing factors are implemented. First, shorter-lived groups may be sufficiently induced to buy annuities. Where they may have stayed out of the market previously, they may now decide to annuitize since they are able to obtain decent MWR values of 0.8 to 0.9. Adding just one or two risk factors to age-sex pricing results in

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<sup>111</sup> The *Appendix* discusses one strategy that an insurer can use to benefit economically from annuity underwriting. Assuming a unilateral deviation, an insurer can possibly make a supernormal profit margin of about 12 to 14% from a cherry-picking strategy by selling annuities only to shorter-lived groups at the age-sex price.

substantial financial gains (13-15%) for these groups. In relation, the AEW analysis shows that shorter-lived groups can attractive utility gains of about 30% when more detailed pricing is implemented. The second effect is that longer-lived groups will still be incentivized to stay in the annuity market. Although more detailed pricing schemes results in higher premiums for the longer-lived groups, they are not severely penalized. These groups experience only modest financial and utility losses of about 3 to 5%. With the shorter-lived groups entering the annuity market and longer-lived continuing to consume annuities, annuity markets are likely to grow which in turn reduces adverse selection.

Overall, these findings lend support to the movement towards risk-based annuity pricing for standard retail products, which has already begun in the U.K. and may possibly spread to other parts of the world. On the other hand, it implies that the European Union's recent elimination of the use of sex in insurance pricing – should it be extended to annuities – represents a step backwards for the ongoing efforts towards risk-classification. Reducing the number of risk-classes will bring about greater dispersion in annuity values between the shorter and longer-lived risk-groups, which has possible redistributive implications in the event that all individuals purchase annuities, for example under a mandate.<sup>112</sup> One limitation of this study is that the analysis is performed for a hypothetical cohort of 65-year-old individuals, without employing weights relevant to the HRS sample used for regression analysis. Future

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<sup>112</sup> Annuity mandates have been actively considered by policymakers as a longevity risk management tool. For example, annuitization was compulsory in U.K. defined contributions plans for many years until recently. Singapore will implement an annuitization mandate in its national provident fund by 2013 (Fong et al. 2011). Mandating life annuity purchase may be one approach to limiting adverse selection in annuity markets, provided that appropriate regulation is in place (Bateman et al. 2001).

research can extend the analysis to the nationally representative sample of HRS respondents. This will allow me to better model selection effects under various pricing schemes and also quantify the impact of more detailed pricing on adverse selection for a nationally representative mix of risk classes in the population at large.

## **Appendix: Case Analysis of a Unilateral Deviation Strategy**

This Appendix quantifies the approximate size of profits that an insurer can make when it collects more annuitant information, and uses that to earn supernormal profits through a cherry-picking strategy. To set up this case analysis, I assume a mandatory annuitization environment and everyone in the weighted HRS sample (described in Section 3.2) buys annuities. On the supply-side, assume there are only two annuity providers A and B. Since the prevailing pricing scheme in the market is ‘age-sex’ pricing, both Insurers A and B set premiums using only these two factors. Further, assume zero-loads. Suppose Insurer A is the Government with no profit motive and is willing to sell annuities to any buyer as long as the system breaks-even on average. If Insurer A serves 100% of the market, it will collect total premiums of \$3.396 billion (see Table appended). In addition, its estimated costs of payouts based on just age and sex is also \$3.396 billion. It makes no profit and breaks-even.

Now consider a unilateral deviation by Insurer B. First, Insurer B performs annuity underwriting and collects information on the top 12 factors (including education, marital status, some disease conditions etc., as outlined in Section 3.3) from all annuitants. Using a wider information set, it is able to estimate the expected costs of payouts for each individual more precisely. Insurer B then devises a cherry-picking strategy: it will only sell annuities to people whose expected cost of payout is below the age-sex price. Assuming that Insurer B gets to cherry-pick the annuitants, it will serve only 35.7% of the market. It will charge these annuitants the age-sex premium (as set by the prevailing pricing scheme) and collect \$1.207 billion. The Table appended shows Insurer B’s costs estimate is only \$1.059 billion, implying a supernormal profit margin

of about 12%. This analysis assumes a naïve market structure. Supernormal profits will not persist very long, and can be quickly competed away. Nonetheless, the figure of 12% represents a useful upper bound on the supernormal profits that can be achieved from annuity underwriting through a novel cherry-picking strategy. Since this upper bound is not too small, it suggests that annuity underwriting insurers can make abnormal profits through more detailed pricing.

	<b>High interest (6%)</b>	<b>Low interest (4%)</b>
<b><u>Insurer A</u></b>		
Number of policies sold	22,729,947	22,729,947
% of total market covered	100%	100%
Premiums collected (age-sex price)	\$3.396b	\$4.195b
Expected costs of payouts (using age & sex)	\$3.396b	\$4.195b
"Supernormal" Profit	\$0	\$0
<b><u>Insurer B</u></b>		
Number of policies sold	8,108,301	8,501,370
% of total market covered	35.7%	37.4%
Premiums collected (age-sex price)	\$1.207b	\$1.563b
Expected costs of payouts (using 12 factors)	\$1.059b	\$1.342b
"Supernormal" Profit	\$0.147b	\$0.220b
<b><i>Profit as % of revenue (Profit Margin)</i></b>	<b><i>12%</i></b>	<b><i>14%</i></b>

Source: Author.

Notes: Dollar amounts in \$billions. The sample consists of 9,047 age-eligible HRS respondents first interviewed in 1992 and baseline sampling weights are applied. Assume there are only two annuity providers A and B. The prevailing pricing scheme in the market is 'age-sex' pricing, so both A and B set premiums based only on age and sex. Insurer A only knows the annuitants' age and sex so it estimates its expected costs based only on these two factors.

**Table 3.1: Hazard Ratios for Mortality in the HRS, 1992 – 2008, Gompertz proportional hazards model (N=9,047)**

	(M1)	(M2)	(M3)	(M4)
	HR [95% CI]	HR [95% CI]	HR [95% CI]	HR [95% CI]
Age	1.09*** [1.07,1.10]	1.07*** [1.05,1.09]	1.07*** [1.05,1.08]	1.08*** [1.06,1.09]
Male	1.62*** [1.46,1.78]	1.92*** [1.72,2.13]	1.83*** [1.64,2.05]	1.69*** [1.51,1.89]
Nonwhite		1.18*** [1.05,1.33]	1.14** [1.00,1.30]	1.12* [0.98,1.27]
Schooling ≥ 12 years		0.73*** [0.66,0.82]	0.79*** [0.70,0.89]	0.94 [0.83,1.06]
Married		0.69*** [0.62,0.77]	0.70*** [0.63,0.79]	0.81*** [0.72,0.91]
<i>BMI (ref=normal weight):</i>				
Underweight		2.93*** [2.18,3.93]	2.97*** [2.18,4.03]	2.16*** [1.56,2.99]
Overweight		0.83*** [0.73,0.94]	0.83*** [0.73,0.94]	0.87** [0.77,0.98]
Obese		0.85** [0.74,0.98]	0.84** [0.73,0.97]	0.89* [0.77,1.02]
<i>Prior health history:</i>				
Ever-have Cancer (=1)		1.99*** [1.62,2.44]	1.99*** [1.62,2.44]	1.82*** [1.49,2.23]
Diabetes		2.49*** [2.18,2.84]	2.49*** [2.19,2.85]	2.18*** [1.90,2.50]
Heart disease / attack		1.63*** [1.42,1.87]	1.61*** [1.41,1.85]	1.34*** [1.16,1.54]
High blood pressure		1.40*** [1.26,1.56]	1.37*** [1.23,1.53]	1.30*** [1.16,1.45]
Chronic lung disease		2.28*** [1.93,2.69]	2.19*** [1.85,2.60]	1.62*** [1.37,1.91]
Major psychiatric condition		1.57*** [1.32,1.86]	1.54*** [1.30,1.83]	1.30*** [1.09,1.54]
Stroke		1.73*** [1.36,2.21]	1.71*** [1.34,2.19]	1.47*** [1.16,1.87]
Arthritis		1.06 [0.95,1.18]	1.05 [0.94,1.17]	0.93 [0.83,1.04]
<i>Birth region (ref = Northeast region):</i>				
Midwest region			0.90 [0.77,1.06]	0.90 [0.77,1.06]
South region			0.96 [0.83,1.12]	0.90 [0.77,1.04]
West region			0.74*** [0.58,0.93]	0.75** [0.59,0.94]
Not born in the US			0.63*** [0.50,0.80]	0.64*** [0.51,0.81]
Cognition (memory score)			0.97*** [0.96,0.99]	0.98*** [0.97,0.99]

	(M1)	(M2)	(M3)	(M4)
	HR [95% CI]	HR [95% CI]	HR [95% CI]	HR [95% CI]
Father education $\geq$ 12 years			1.08 [0.93,1.24]	1.13* [0.98,1.30]
Mother education $\geq$ 12 years			0.93 [0.81,1.07]	0.94 [0.82,1.08]
Father's Longevity			0.95*** [0.92,0.99]	0.96** [0.93,0.99]
Mother's Longevity			1.00 [0.96,1.04]	1.00 [0.97,1.04]
<i>Self-reported health (ref=excellent):</i>				
Very Good				1.27** [1.05,1.54]
Good				1.68*** [1.39,2.02]
Fair				2.29*** [1.85,2.82]
Poor				3.02*** [2.38,3.81]
Currently smoke (=1)				1.76*** [1.56,1.99]
Ever smoke (=1)				1.41*** [1.23,1.62]
Ever drink (=1)				0.94 [0.84,1.05]
<b>Gamma (<math>\gamma</math>)</b>	<b>0.0063</b>	<b>0.0076</b>	<b>0.0077</b>	<b>0.0081</b>
<b># observations</b>	<b>58,467</b>	<b>58,467</b>	<b>58,467</b>	<b>58,467</b>
<b><math>G^2</math></b>	<b>190.78</b>	<b>1,287.06</b>	<b>1,336.73</b>	<b>1,622.97</b>
<b>df</b>	<b>2</b>	<b>16</b>	<b>30</b>	<b>37</b>
<b>Adjusted <math>R^2</math></b>	<b>6.7%</b>	<b>29.7%</b>	<b>30.6%</b>	<b>36.7%</b>

Source: Author; see text.

Notes: HR = hazard ratios (\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ ), CI = 95% confidence intervals in brackets.

The sample consists of 9,047 age-eligible HRS respondents first interviewed in 1992. Analyses are weighted by base-year respondent-level weights to account for over-sampling of blacks, Hispanics, and Floridians. M2 adds conventional, predetermined covariates (race, education, whether married, and weight), M3 adds less-conventional, predetermined risk factors (birth region, cognition scores, parental factors), and M4 adds conventional, endogenous variables (self-reported health, smoking, and drinking).  $\gamma$  is the shape parameter of the baseline hazard.  $G^2$  is the Wald chi-square statistic which compares the log pseudo-likelihood of the fitted model against a null model. A model with more parameters will always have a higher statistic; whether it fits significantly better than a model with fewer parameters is determined by calculating the p-value of the *difference* in  $G^2$  between models, together with the associated degrees of freedom (df). The adjusted  $R^2$  for survival models measures how much of the variation in outcome in a Gompertz proportional hazards model is accounted for through the prognostic index ( $x\beta$ ), adjusting the dimension of the model. Flags for missing, and imputed, values for these variables are included in the analysis: birth region, father's education, mother's education ( $p < .10$ ), and parental longevity.

**Table 3.2: Benefit Flows to Annuitants** (for age 65 annuity purchasers;  $i=6\%$ )

<b>Subgroups of 65-year olds</b>	<b>Expected benefit flows</b>
<u>Top</u> : No high blood, Married, HS-educated, Females	\$152
Married, HS-educated, Females	145
HS-educated, Females	140
Females	133
65-year-olds	126
Males	117
Lowly-educated, Males	104
Not married, Lowly-educated, Males	91
<u>Bottom</u> : High blood, Not married, Lowly-educated, Males	81

Source: Author.

Notes: The benefit flows pertain to a standard, nominal, whole life, retail annuity that pays \$1/month to 65-year-old would-be annuity purchasers. Simulations are based on a nominal annual interest rate of 6% and a terminal age of 120. The risk-group of ‘No high blood, Married, HS-educated, Females’ is the longest-lived group analyzed in this Table and marked “Top”. Correspondingly, ‘High blood, Unmarried, Low-educated, Males’ is the shortest-lived group and marked “Bottom”.

**Table 3.3: Annuity Premiums Charged under Different Pricing Schemes** (for age 65 annuity purchasers;  $i=6\%$ ; zero-loads)

Different Pricing Schemes	# pricing factors	Prices (\$)		# distinct premiums
Age-only	1	Single price:	\$126	1
Age, sex	2	F: M:	\$134 117	2
Age, sex, education	3	HS-educated F: Less-educated F: HS-educated M: Less-educated M:	\$140 122 125 104	4
Age, sex, education, marital status	4	Married, HS-educated F: Unmarried, HS-educated F: Married, less-educated F: Unmarried, less-educated F: Married, HS-educated M: Unmarried, HS-educated M: Married, less-educated M: Unmarried, less-educated M:	\$145 129 129 111 128 110 109 91	8
⋮	⋮	⋮	⋮	⋮
Age, sex, education, marital status, high blood, cognition	6	⋮	\$67-153	32
⋮	⋮	⋮	⋮	⋮
All top 12 factors: Age, sex, education, marital status, high blood, cognition, diabetes, lung disease, heart disease, cancer, BMI, psychiatric.	12	⋮	\$4-161	4,096

Source: Author; see text.

Notes: Only one of these pricing schemes is adopted by the insurer at any one time. Premiums are set by the insurer and offered to 65-year-old would-be annuity purchasers. Simulations are based on a single-life, nominal, standard retail annuity with fixed \$1/month payouts, a nominal interest rate of 6%, and a terminal age of 120. The distinct number of prices in each row is obtained by multiplying the number of categories that is associated with each additional pricing factor. For example, 'sex' is associated with only two categories (male/female) but 'BMI' is associated with four categories (underweight / normal weight/ overweight/obssess). In addition, only a group of 65-year old annuitants is considered here. In other words, age is fixed. If age is allowed to vary, as it would in a random pool of annuitants, the number of distinct prices that will be larger than that indicated here.

**Table 3.4: Money's Worth Ratios for Various Risk-groups under Different Pricing Schemes (age 65 annuity purchasers)**

A: Money's Worth Ratios ( $i=6\%$ )

	Simpler Pricing		More Detailed Pricing	
	S1 Age-only	S2 Age & sex	S3 + Educ.	S4 + Marital
<u>Top</u> : No high blood, Married, High-school (HS)-educated, Females	1.204	1.133	1.081	1.047
Married, HS-educated, Females	1.150	1.082	1.032	1.000
HS-educated, Females	1.114	1.048	1.000	-
Females	1.062	1.000	-	-
65-year-olds	1.000	-	-	-
Males	0.931	1.000	-	-
Low-educated, Males	0.827	0.889	1.000	-
Unmarried, Low-educated, Males	0.722	0.775	0.873	1.000
<u>Bottom</u> : High blood, Unmarried, Low-educated, Males	0.645	0.693	0.780	0.893
<i>Decline in MWR (for Top)</i>		<b>-6%</b>	<b>-5%</b>	<b>-3%</b>
<i>Increase in MWR (for Bottom)</i>		<b>+7%</b>	<b>+13%</b>	<b>+15%</b>

B: Money's Worth Ratios ( $i=4\%$ )

	Simpler Pricing		More Detailed Pricing	
	S1 Age-only	S2 Age & sex	S3 + Educ.	S4 + Marital
<u>Top</u> : No high blood, Married, High-school (HS)-educated, Females	1.254	1.166	1.102	1.059
Married, HS-educated, Females	1.184	1.101	1.040	1.000
HS-educated, Females	1.138	1.059	1.000	-
Females	1.075	1.000	-	-
65-year-olds	1.000	-	-	-
Males	0.918	1.000	-	-
Low-educated, Males	0.801	0.872	1.000	-
Unmarried, Low-educated, Males	0.686	0.747	0.857	1.000
<u>Bottom</u> : High blood, Unmarried, Low-educated, Males	0.605	0.659	0.756	0.882
<b><i>Decline in MWR (for Top)</i></b>		<b><i>-7%</i></b>	<b><i>-6%</i></b>	<b><i>-4%</i></b>
<b><i>Increase in MWR (for Bottom)</i></b>		<b><i>+9%</i></b>	<b><i>+15%</i></b>	<b><i>+17%</i></b>

Source: Author; see text.

Notes: These calculations are the MWR values available to 65-year-old would-be annuity purchasers. The dashes indicated cases where the premium for that risk-group cannot be defined under the prevailing pricing scheme. Simulations are based on a single-life, nominal annuity with fixed \$1/month payouts, a nominal interest rate of 4% or 6%, and a terminal age of 120. S1 denotes a pricing scheme using 1 risk-class (age-only); S2 denotes a scheme using 2 risk-classes (age and sex), and so on. For example, the S4 scheme uses four pricing factors: age, sex, education, and marital status. The risk-group of 'No high blood, Married, HS-educated, Females' is the longest-lived group analyzed in this Table and marked "Top". Correspondingly, 'High blood, Unmarried, Low-educated, Males' is the shortest-lived group and marked "Bottom". Moving from left to right, the relative change in MWR for both of these groups is shown at the end of the Table.

**Table 3.5: Annual Annuity Income from \$100,000 Policy under Different Pricing Schemes** (for age 65 annuity purchasers;  $r = \pi = 3\%$ ; zero-loads)

	Simpler Pricing		More Detailed Pricing	
	S1 Age-only	S2 Age & sex	S3 + Educ.	S4 + Marital
<u>Top</u> : No high blood, Married, High-school (HS)-educated, Females	\$10,109	\$9,492	\$9,036	\$8,742
Married, HS-educated, Females	10,109	9,492	9,036	8,742
HS-educated, Females	10,109	9,492	9,036	-
Females	10,109	9,492	-	-
65-year-olds	10,109	-	-	-
Males	10,109	10,898	-	-
Low-educated, Males	10,109	10,898	12,344	-
Unmarried, Low-educated, Males	10,109	10,898	12,344	14,269
<u>Bottom</u> : High blood, Unmarried, Low-educated, Males	10,109	10,898	12,344	14,269

Source: Author; see text.

Notes: These calculations are based on a single-life, nominal, standard retail annuity that charges a lump-sum premium of \$100,000 in exchange for fixed annual payouts. Additional parameters include a real interest rate of 3%, an inflation rate of 3%, an annuitization age of 65, and a terminal age of 120. S1 denotes a pricing scheme using 1 risk-class (age-only); S2 denotes a scheme using 2 risk-classes (age and sex), and so on. For example, the S4 scheme uses four pricing factors: age, sex, education, and marital status. The dashes indicated cases where the annuity payout for that risk-group cannot be defined under the prevailing pricing scheme; for example, it is necessary to determine the educational status of the annuitant under Scheme S3 since low-educated annuitants will receive higher annuity income. The risk-group of ‘No high blood, Married, HS-educated, Females’ is the longest-lived group analyzed in this Table and marked “Top”. Correspondingly, ‘High blood, Unmarried, Low-educated, Males’ is the shortest-lived group and marked “Bottom”.

**Table 3.6: Annuity Equivalent Wealth for Various Risk-groups under Different Pricing Schemes** (age 65 annuity purchasers;  $r = \pi = 3\%$ ; zero-loads)

A: Annuity Equivalent Wealth (CRRA utility with  $\gamma=3$ )

	Simpler Pricing		More Detailed Pricing	
	S1 Age-only	S2 Age & sex	S3 + Educ.	S4 + Marital
<u>Top</u> : No high blood, Married, High-school (HS)-educated, Females	1.592	1.495	1.421	1.374
Married, HS-educated, Females	1.583	1.488	1.415	1.368
HS-educated, Females	1.577	1.482	1.411	-
Females	1.568	1.474	-	-
65-year-olds	1.552	-	-	-
Males	1.527	1.644	-	-
Low-educated, Males	1.471	1.586	1.791	-
Unmarried, Low-educated, Males	1.406	1.512	1.709	1.972
<u>Bottom</u> : High blood, Unmarried, Low-educated, Males	1.342	1.445	1.633	1.882
<i>Decline in AEW (for Top)</i>		<b>-6%</b>	<b>-5%</b>	<b>-3%</b>
<i>Increase in AEW (for Bottom)</i>		<b>+8%</b>	<b>+13%</b>	<b>+15%</b>

B: Annuity Equivalent Wealth (CRRA utility with  $\gamma=1$ )

	Simpler Pricing		More Detailed Pricing	
	S1 Age-only	S2 Age & sex	S3 + Educ.	S4 + Marital
<u>Top</u> : No high blood, Married, High-school (HS)-educated, Females	1.535	1.441	1.372	1.328
Married, HS-educated, Females	1.509	1.419	1.351	1.307
HS-educated, Females	1.492	1.402	1.336	-
Females	1.466	1.377	-	-
65-year-olds	1.429	-	-	-
Males	1.376	1.483	-	-
Low-educated, Males	1.289	1.388	1.571	-
Unmarried, Low-educated, Males	1.192	1.279	1.447	1.671
<u>Bottom</u> : High blood, Unmarried, Low-educated, Males	1.127	1.198	1.346	1.554
<b><i>Decline in AEW (for Top)</i></b>		<b><i>-6%</i></b>	<b><i>-5%</i></b>	<b><i>-3%</i></b>
<b><i>Increase in AEW (for Bottom)</i></b>		<b><i>6%</i></b>	<b><i>12%</i></b>	<b><i>15%</i></b>

Source: Author; see text.

Notes: These calculations are based on a single-life, nominal annuity that charges a lump-sum premium of \$100,000 in exchange for fixed annual payouts (as illustrated in Table 3.5). Additional parameters include a real interest rate of 3%, an inflation rate of 3%, an annuitization age of 65, and a terminal age of 120. S1 denotes a pricing scheme using 1 risk-class (age-only); S2 denotes a scheme using 2 risk-classes (age and sex), and so on. For example, scheme S4 uses four pricing factors: age, sex, education, and marital status. The dashes in the Table represent cases where annuity pricing cannot be defined for that risk-group, thus AEW is not computed for that group.

### Appendix Table 3.1: Descriptive Statistics

This Appendix provides basic descriptive statistics of the sample of 9,047 respondents in the baseline HRS cohort. Age distribution is pretty even across the range of 51 – 61; average age is 56. Approximately 79% of the respondents are white, 95% have a religion, and 90% are born in the US. Average education is about 12.1 years of schooling. About a third of the individuals are normal weight, 1.3% is underweight, and the rest are overweight or obese. In terms of parental factors, father's years of schooling is slightly lower than that of mother's years of schooling, and more respondents' mothers are alive at baseline than are their fathers.

Variable	Mean
<b>Individual demographic characteristics</b>	
Male	45.4%
Average age at interview	56.0 (3.18)
Race: nonwhite	21.2%
Married	72.7%
Born in the US	90.3%
Has religion	95.3%
<i>Place of birth (by region):</i>	
1. Northeast	17.6%
2. Midwest	25.3%
3. South	38.7%
4. West	7.9%
5. Not in the US	10.5%
<b>Socioeconomic factors</b>	
Own years of schooling	12.1 (3.20)
Father's years of schooling	8.8 (3.81)
Mother's years of schooling	9.1 (3.52)
<b>Parental longevity</b>	
Father alive	16.4%
Mother alive	42.2%
Father's age at death (if deceased)	68.0 (13.85)
Mother's age at death (if deceased)	68.5 (14.93)
Father's current age (if alive)	80.9 (5.62)
Mother's current age (if alive)	79.3 (5.85)
<b>Health &amp; Cognition</b>	
<i>BMI:</i>	
Underweight (BMI < 18.5)	1.3%

<b>Variable</b>	<b>Mean</b>
Normal weight ( $18.5 \leq \text{BMI} < 25$ )	33.6%
Overweight ( $25 \leq \text{BMI} < 30$ )	40.8%
Obese ( $30 \leq \text{BMI}$ )	24.3%
Ever-have Cancer	4.8%
Ever-have Diabetes	9.6%
Ever-have Heart condition	10.6%
Ever-have High blood pressure	34.7%
Ever-have chronic lung disease	5.3%
Ever-have major psychiatric condition	7.1%
Ever-have Stroke	2.4%
Ever-have Arthritis	34.5%
Cognition: Memory score only (scale 0 – 40)	12.8 (5.24)
<i>N</i>	9,047

Source: Author.

Notes: Percentages are shown for dichotomous variables, and means with standard deviations in parentheses are shown for continuous variables and some categorical variables (e.g. years of schooling). Statistics shown here are solely for baseline 1992 variables. The baseline cognition measure features only the memory score (based on word recall items) as the rest of the cognition test questions were not asked until wave 3. Missing values for these variables are flagged: parental education, parental longevity, birth region, BMI, and cognition scores. The birth regions are organized as follows: the Northeast Region comprises New England and Middle Atlantic divisions; the Midwest Region comprises East North and West North divisions; the South region comprises South Atlantic, East South, and West South divisions; the West region comprises Mountain and Pacific divisions.

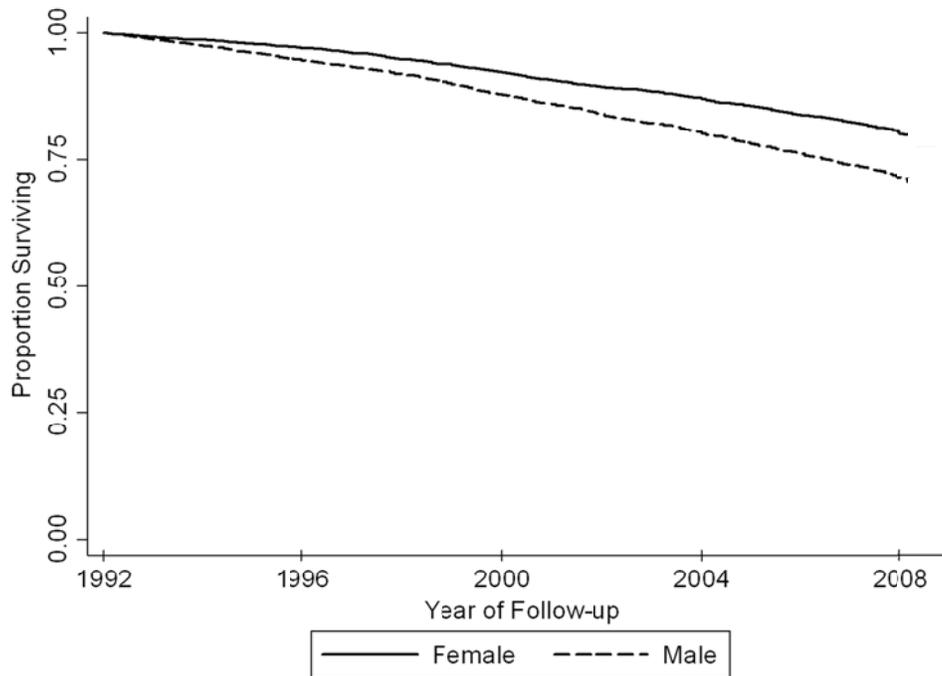
**Appendix Table 3.2: Comparing Hazard Ratios for Mortality in the HRS by Age Groups** (1992 – 2008, Gompertz proportional hazards model,  $N=9,047$ )

	(M3)	(M3) By Age Group	
	All Ages HR [95% CI]	Age 50-57 HR [95% CI]	Age 58-62 HR [95% CI]
Age	1.07 [1.05,1.08]***	1.05 [1.02,1.08]***	1.04 [0.97,1.12]
Male	1.83 [1.64,2.05]***	1.78 [1.54,2.05]***	1.89 [1.59,2.25]***
Nonwhite	1.14 [1.00,1.30]**	1.13 [0.95,1.34]	1.12 [0.91,1.37]
Own schooling $\geq$ 12 years	0.79 [0.70,0.89]***	0.81 [0.68,0.95]***	0.77 [0.64,0.93]***
Married	0.70 [0.63,0.79]***	0.71 [0.61,0.82]***	0.69 [0.58,0.83]***
<i>BMI (ref=normal weight):</i>			
Underweight	2.97 [2.18,4.03]***	3.15 [2.16,4.60]***	2.59 [1.55,4.33]***
Overweight	0.83 [0.73,0.94]***	0.82 [0.69,0.97]**	0.84 [0.70,1.02]*
Obese	0.84 [0.73,0.97]**	0.87 [0.72,1.04]	0.80 [0.64,1.01]*
<i>Prior health history:</i>			
Ever-have Cancer (=1)	1.99 [1.62,2.44]***	2.25 [1.72,2.93]***	1.72 [1.26,2.36]***
Diabetes	2.49 [2.19,2.85]***	2.61 [2.18,3.13]***	2.38 [1.95,2.90]***
Heart disease / attack	1.61 [1.41,1.85]***	1.72 [1.43,2.07]***	1.48 [1.20,1.83]***
High blood pressure	1.37 [1.23,1.53]***	1.40 [1.21,1.62]***	1.33 [1.13,1.58]***
Chronic lung disease	2.19 [1.85,2.60]***	2.01 [1.60,2.53]***	2.60 [2.03,3.33]***
Major psychiatric condition	1.54 [1.30,1.83]***	1.56 [1.25,1.95]***	1.44 [1.08,1.91]**
Stroke	1.71 [1.34,2.19]***	1.81 [1.27,2.57]***	1.61 [1.16,2.22]***
Arthritis	1.05 [0.94,1.17]	1.00 [0.87,1.16]	1.11 [0.94,1.31]
<i>Birth region (ref = Northeast):</i>			
Midwest region	0.90 [0.77,1.06]	0.84 [0.68,1.03]*	1.00 [0.78,1.27]
South region	0.96 [0.83,1.12]	0.91 [0.74,1.10]	1.06 [0.84,1.33]
West region	0.74 [0.58,0.93]***	0.66 [0.49,0.91]**	0.83 [0.59,1.18]
Not born in the US	0.63 [0.50,0.80]***	0.64 [0.47,0.86]***	0.63 [0.44,0.89]***
Cognition (memory score)	0.97 [0.96,0.99]***	0.98 [0.96,0.99]***	0.97 [0.95,0.99]***
Father education $\geq$ 12 years	1.08 [0.93,1.24]	0.97 [0.81,1.16]	1.26 [1.00,1.59]**
Mother education $\geq$ 12 years	0.93 [0.81,1.07]	0.91 [0.76,1.08]	0.96 [0.77,1.19]
Father's Longevity	0.95 [0.92,0.99]***	0.93 [0.89,0.98]***	0.99 [0.94,1.05]
Mother's Longevity	1.00 [0.96,1.04]	0.99 [0.94,1.04]	1.01 [0.96,1.07]
<b>Gamma (<math>\gamma</math>)</b>	<b>0.0077</b>	<b>0.0077</b>	<b>0.0078</b>
<b># observations</b>	<b>58,467</b>	<b>40,525</b>	<b>17,942</b>
<b>G<sup>2</sup></b>	<b>1,336.73</b>	<b>771.327</b>	<b>555.9522</b>
<b>df</b>	<b>30</b>	<b>30</b>	<b>30</b>

Source: Author; see text.

Notes: HR = hazard ratios (\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ ), CI = 95% confidence intervals in brackets. The sample consists of 9,047 age-eligible HRS respondents first interviewed in 1992. Analyses are weighted by base-year respondent-level weights to account for over-sampling of blacks, Hispanics, and Floridians.  $\gamma$  is the shape parameter of the baseline hazard.  $G^2$  is the Wald chi-square statistic which compares the log pseudo-likelihood of the fitted model against a null model. Flags for missing, and imputed, values for these variables are included in the analysis: birth region, father's education, mother's education ( $p < .10$ ), and parental longevity.

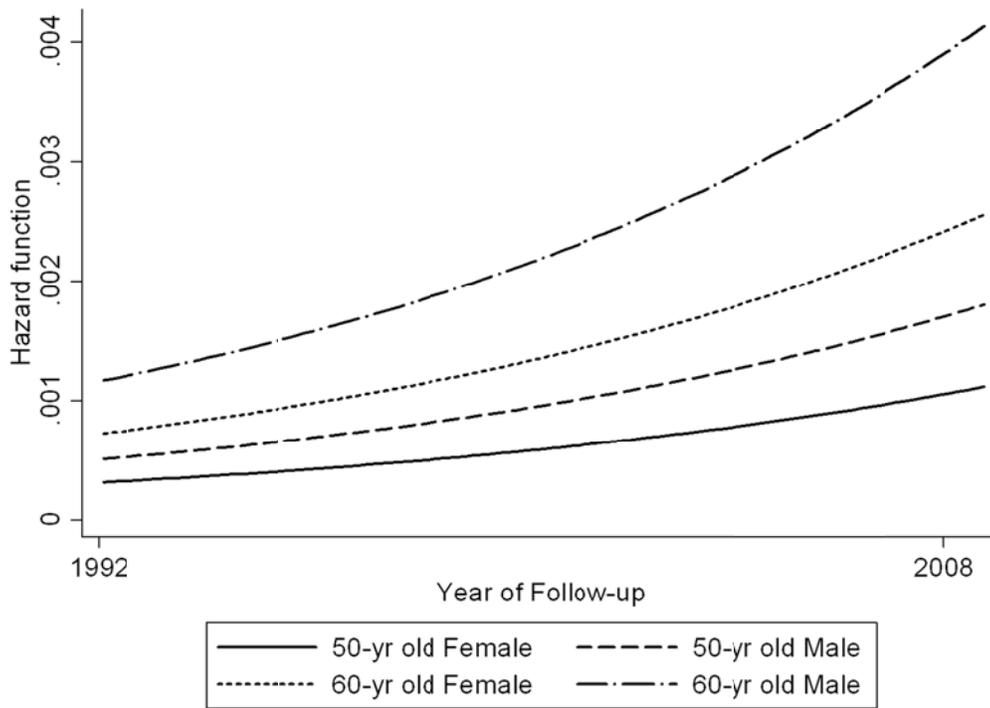
**Figure 3.1: Survival function by Sex of 50 – 62 year olds first interviewed in 1992 in the Health and Retirement Study (Kaplan-Meier estimates)**



Source: Author; see text.

Note: The sample consists of 9,047 age-eligible respondents first interviewed in 1992 in the HRS (1992-2008). At the 2008 wave cut-off, 70% of males and 78% of females are still alive. The estimates presented are un-weighted. Incorporating base-year respondent-level weights to account for over-sampling of blacks, Hispanics, and Floridians in the HRS leads to very similar results. The slight variability at the ends of the survival functions is due to a reduced effective sample at the tail caused by prior failures and censoring.

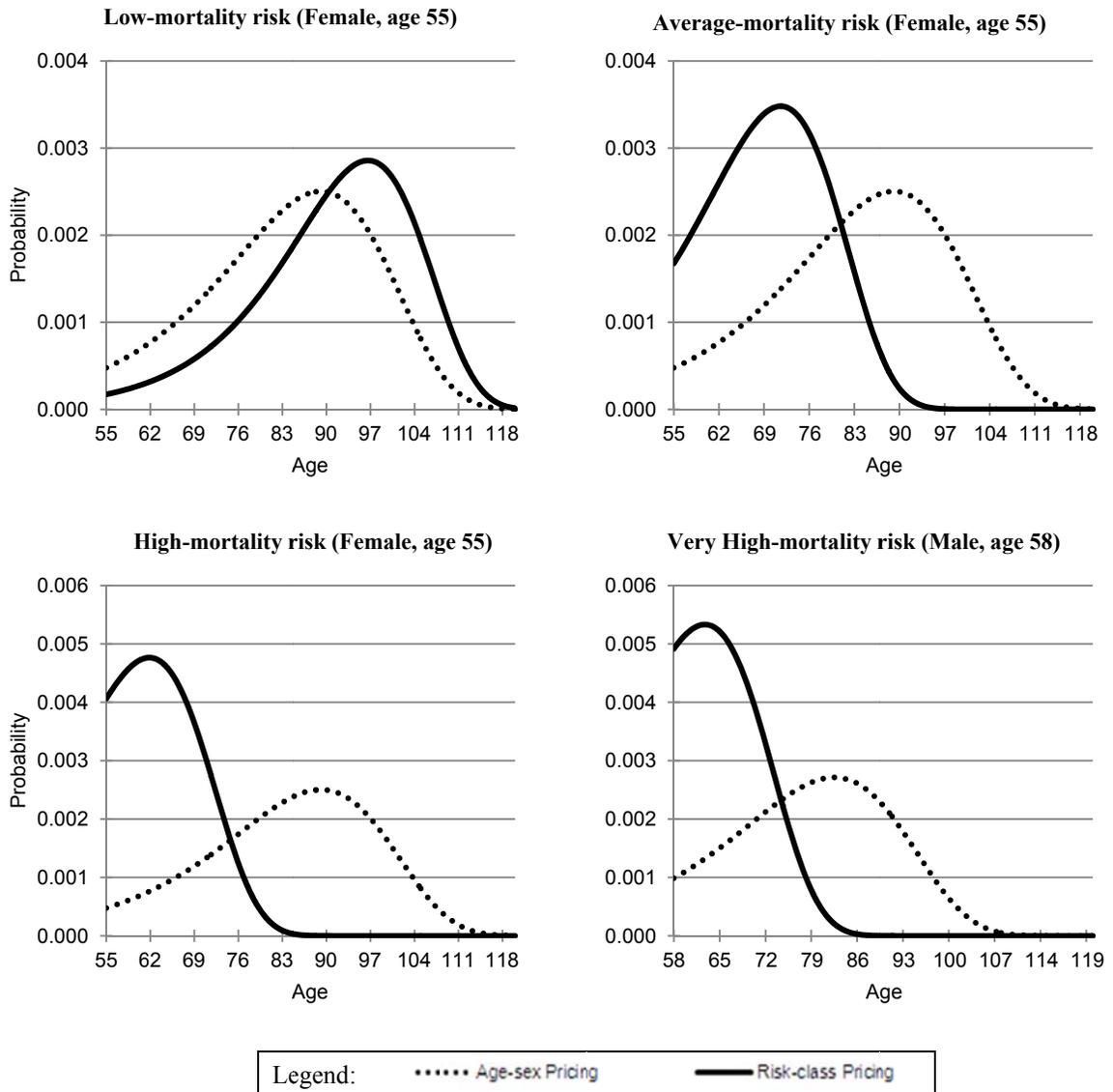
**Figure 3.2: Mortality Hazard Functions from Fitted Estimates of Gompertz PH Model 1**



Source: Author; see text.

Note: The sample consists of 9,047 age-eligible respondents first interviewed in 1992 in the HRS (1992-2008). All proportional hazards regressions include base-year respondent-level weights to account for over-sampling of blacks, Hispanics, and Floridians in the HRS.

**Figure 3.3: Density Function of the Age-at-Death random variable for Various Risk-groups**



Source: Author; see text.

Note: The graphs are based on fitted Gompertz proportional hazards regression estimates. For ‘age-sex’ pricing, only age and sex are specified in the regression. For ‘risk-class’ pricing, the following 12 controls are included: diabetes, lung disease, heart disease, sex, age, marital status, high blood, cancer, own schooling, BMI, psychiatric condition, and cognition. All regressions are weighted. The assumed terminal age is 120. The density curves show the conditional probability of death at each age. The four risk-groups are characterized in the following manner:

- High-longevity risk: age 55 female, no disease history, overweight, married, high-school (HS) educated, above-average cognition.
- Average risk: age 55 female, no disease history, normal weight but unmarried, not HS-educated, average cognition. (Note that this mortality profile is obtained by setting all 10 additional risk variables at their reference categories.)
- Low risk: age 55 female, ever-had cancer, underweight, unmarried, not HS-educated, below-average cognition.
- Very low risk: age 58 male, overweight, ever-had heart disease, high blood, and psychiatric illness, unmarried, not HS-educated, and of below-average cognition.

## Bibliography

### Chapter 1

- Arenas de Mesa, A., D. Bravo, J.R. Behrman, O.S. Mitchell, and P.E. Todd, 2008, The Chilean Pension Reform turns 25: Lessons from the Social Protection Survey, in: S. Kay and T. Sinha, eds., *Lessons from Pension Reform in the Americas*, Oxford University Press, 23-58.
- Asher, M., 1998, Investment Policies and Performance of Provident and Pension Funds in Southeast Asia, National University of Singapore, Working Paper, October.
- Asher, M., 1999, South East Asian Provident and Pension Funds: Investment Policies and Performance, National University of Singapore, Working Paper, November.
- Brown, J.R., O.S. Mitchell, and J. Poterba, 2000, The Role of Real Annuities and Indexed Bonds in an Individual Accounts Retirement Program, in: J.Y. Campbell and M. Feldstein, eds., *Risk Aspects of Investment-Based Social Security Reform*, University of Chicago Press, Chicago, 321-360.
- Central Provident Fund (CPF), 2005a, *About Us: 4<sup>th</sup> Quarter 2005*. [mycpf.cpf.gov.sg/CPF/About-Us/CPF-Stats/CPF\\_Stats2005q4.htm](http://mycpf.cpf.gov.sg/CPF/About-Us/CPF-Stats/CPF_Stats2005q4.htm), viewed 6/1/07.
- CPF, 2005b, *Handbook: CPF Investment Scheme*, CPF Board, Singapore, March.
- CPF, 2005c, *CPF Investment Scheme (CPFIS) Profits/Losses for the Financial Year Ended 30 September 2005*. [cpf.gov.sg/cpf\\_info/ie/IE\\_reportpl.pdf](http://cpf.gov.sg/cpf_info/ie/IE_reportpl.pdf), viewed 6/1/07.
- CPF, 2005d, *News Release: CPF Board Tightens CPF Investment Scheme Admission Criteria for Funds*. [mycpf.cpf.gov.sg/CPF/News/News-Release/N\\_29Dec2005.htm](http://mycpf.cpf.gov.sg/CPF/News/News-Release/N_29Dec2005.htm), viewed 6/1/07.
- CPF, 2005e, *Saving for Our Retirement: 50 Years of CPF*, CPF Board, Singapore.
- CPF, 2005f, *News Release: Speech by Prime Minister Lee Hsien Loong at the CPF Board Dinner & Dance*. [mycpf.cpf.gov.sg/CPF/News/News-Release/NR\\_25Sept2005.htm](http://mycpf.cpf.gov.sg/CPF/News/News-Release/NR_25Sept2005.htm), viewed 6/1/07.
- CPF, 2006a, *News Release: Lower Charges on New CPF Investments in Funds under CPF Investment Scheme to Benefit Members*. [mycpf.cpf.gov.sg/CPF/News/News-Release/N\\_28December2006.htm](http://mycpf.cpf.gov.sg/CPF/News/News-Release/N_28December2006.htm), viewed 6/1/07.
- CPF, 2006b, *Quantitative Performance Analysis UT Q2 2006*, Standard & Poor's Fund Services, Asia, August.
- Chen, R., K.A. Wong, and M.Y. Chiang, 1997, Singaporean's Knowledge and Attitudes toward the Central Provident Fund, *Singapore Management Review*, 19(2): 1-16.
- Chen R., and K.A. Wong, 1998, The Adequacy of the CPF Account for Retirement Benefits in Singapore, *Singapore International Insurance and Actuarial Journal*, 2: 121-138.

- Choi, J.J., D. Laibson, and B.C. Madrian, 2005, Why Does the Law of One Price Fail? An Experiment on Index Mutual Funds, National Bureau of Economic Research, Working Paper.
- Clark, R.L., 1999, Ageing Policies in East Asia, presented at a Conference on Perspectives on Public Policy in the 21<sup>st</sup> Century, National University of Singapore, Singapore, September.
- Doyle, S., O.S. Mitchell, and J. Piggott, 2004, Annuity Values in Defined Contribution Retirement Systems: Australia and Singapore Compared, *Australian Economic Review*, 37(4): 402-416.
- Fong, W.M., 2002, On the Cost of Adverse Selection in Individual Annuity Markets: Evidence from Singapore, *Journal of Risk and Insurance*, 69(2): 193-207.
- Investment Company Institute (ICI), 2006, *Investment Company Factbook 2006*. [www.icifactbook.org/06\\_fb\\_sec5.html#trends](http://www.icifactbook.org/06_fb_sec5.html#trends), viewed 6/1/07.
- Investment Management Authority of Singapore (IMAS), 2005, Guidelines for the Disclosure of Expense Ratios. [www.imas.org.sg/downloads/imas](http://www.imas.org.sg/downloads/imas), viewed 6/1/07.
- Low, L., and T.C. Aw, 1997, *Housing a Healthy, Educated, and Wealthy Nation through the CPF*, The Institute of Policy Studies, Times Academic Press, Singapore.
- Low, L., and T.C. Aw, 2004, *Social Insecurity in the New Millennium: The Central Provident Fund*, Times Academic Press, Singapore.
- Lusardi, A., and O.S. Mitchell, 2007, Financial Literacy and Retirement Preparedness. Evidence and Implications for Financial Education, *Business Economics*, January: 35-44.
- McCarthy, D., O.S. Mitchell, and J. Piggott, 2002, Asset Rich and Cash Poor in Singapore? Retirement Provision in a National Defined Contribution Pension Fund, *Journal of Pension Finance and Economics*, 1(3): 197-222.
- Mitchell, O.S., 1998, Administrative Costs of Public and Private Pension Plans, in: M. Feldstein, ed., *Privatizing Social Security*, University of Chicago Press for NBER, Chicago, 403-456.
- Mitchell, O.S., G. Mottola, S. Utkus, and T. Yamaguchi, 2005, The Inattentive Participant: Trading Behavior in 401(k) Plans, PRC Working Paper, The Wharton School.
- Mitchell, O.S., G. Mottola, S. Utkus, and T. Yamaguchi, 2006, Winners and Losers: 401(k) Trading and Portfolio Performance, PRC Working Paper, The Wharton School.
- Singapore Department of Statistics (SDOS), 2006, *Statistics: Demography (Themes)*. [singstat.gov.sg/stats/themes/people/demo.html](http://singstat.gov.sg/stats/themes/people/demo.html), viewed 6/1/07.

## Chapter 2

- Abel, A.B., 1986, Capital Accumulation and Uncertain Lifetimes with Adverse Selection, *Econometrica*, 54: 1079 - 1098.
- Avanzi, B., and S. Purcal, 2009, Forced Savings and Annuitization with Cross-Subsidies: A Mutation of the Beast, Working Paper, University of New South Wales. <http://ssrn.com/abstract=1466386>.
- Babbel, D., and C. Merrill, 2007, Rational Decumulation, Working Paper, Wharton Financial Institutions Center, May.
- Blake, D., A.J. Cairns, and K. Dowd, 2003, Pensionmetrics 2: Stochastic Pension Plan Design during the Distribution Phase, *Insurance: Mathematics and Economics*, 33(1): 29–47.
- Boardman, T., 2006, Annuitization Lessons from the UK: Money-Back Annuities and Other Developments, *Journal of Risk and Insurance*, 73: 633-646.
- Bowers, N., H. Gerber, J. Hickman, D. Jones, and C. Nesbitt, 1997, *Actuarial Mathematics*, Society of Actuaries, Schaumburg, IL.
- Brown, J., 2003, Redistribution and Insurance: Mandatory Annuitization with Mortality Heterogeneity, *Journal of Risk and Insurance*, 70: 17-41.
- Brown, J., O.S. Mitchell, J. Poterba, and M. Warshawsky, 2001, *The Role of Annuity Markets in Financing Retirement*, MIT Press, Cambridge, MA.
- Bütler, M., and F. Teppa, 2007, The Choice between an Annuity and a Lump Sum: Results from Swiss Pension Funds, *Journal of Public Economics*, 91: 1944-1966.
- Central Provident Fund Board (CPF), 2007, *CPF Minimum Sum Scheme: Table of Monthly Payment Rates for the Minimum Sum Of \$99,600 placed with a Participating Insurance Company*, July. [mycpf.cpf.gov.sg/NR/rdonlyres/883DD6D3-D1EC-48DD-8B09-811C0D24ECE\\_8/0/AnnuityComparison.pdf](http://mycpf.cpf.gov.sg/NR/rdonlyres/883DD6D3-D1EC-48DD-8B09-811C0D24ECE_8/0/AnnuityComparison.pdf), viewed 3/20/08.
- CPF, 2008, *Report by the National Longevity Insurance Committee (NLIC)*, February. [mycpf.cpf.gov.sg/Members/Gen-Info/CPF\\_LIFE/NLIC.htm](http://mycpf.cpf.gov.sg/Members/Gen-Info/CPF_LIFE/NLIC.htm), viewed 12/31/09.
- CPF, 2009a, *CPF Trends: Changing Age Structure of CPF Members*, October. <http://mycpf.cpf.gov.sg/CPF/About-Us/CPF+Trends.htm>, viewed 12/31/09.
- CPF, 2009b, *CPF Trends: Minimum Sum Scheme*, June. <http://mycpf.cpf.gov.sg/CPF/About-Us/CPF+Trends.htm>, viewed 12/31/09.
- CPF, 2009c, *CPF Withdrawal Calculator*, Central Provident Fund Board. [cpf.gov.sg/cpf\\_trans/ssl/financial\\_model/wdl\\_assumption.asp](http://cpf.gov.sg/cpf_trans/ssl/financial_model/wdl_assumption.asp), viewed 12/31/09.
- CPF, 2009d, *CPF LIFE Information Booklets*, September. [mycpf.cpf.gov.sg/Members/Gen-Info/CPF\\_LIFE/CPF\\_LIFE.htm](http://mycpf.cpf.gov.sg/Members/Gen-Info/CPF_LIFE/CPF_LIFE.htm), viewed 11/15/09.

- CPF, 2009e, *CPF LIFE Payout Estimator*, Central Provident Fund Board, [cpf.gov.sg/cpf\\_trans/ssl/financial\\_model/lifecal/index.html](http://cpf.gov.sg/cpf_trans/ssl/financial_model/lifecal/index.html), viewed 6/15/09 and 9/19/2009.
- CPF, 2009f, *Frequently Asked Questions on CPF LIFE*, Central Provident Fund Board, [mycpf.cpf.gov.sg/Members/Gen-Info/CPF\\_LIFE/CPF\\_LIFE.htm](http://mycpf.cpf.gov.sg/Members/Gen-Info/CPF_LIFE/CPF_LIFE.htm), viewed 12/31/09.
- CPF, 2010, *CPF LIFE*, Central Provident Fund Board, [mycpf.cpf.gov.sg/Members/Gen-Info/CPF\\_LIFE](http://mycpf.cpf.gov.sg/Members/Gen-Info/CPF_LIFE), viewed 5/11/10.
- Doyle, S., O.S. Mitchell, and J. Piggott, 2004, Annuity Values in Defined Contribution Retirement Systems: Australia and Singapore Compared, *Australian Economic Review*, 37: 402-416.
- Emms, P., and S. Haberman, 2008, Income Drawdown Schemes for a Defined-Contribution Pension Plan, *Journal of Risk and Insurance*, 75: 739-761.
- Finkelstein, A., and J. Poterba, 2002, Selection Effects in the United Kingdom Individual Annuities Market, *Economic Journal*, 112: 28-50.
- Finkelstein, A., and J. Poterba, 2004, Adverse Selection in Insurance Markets: Policyholder Evidence from the U.K. Annuity Market, *Journal of Political Economy*, 112: 183-208.
- Fong, J.HY., O.S. Mitchell, and B.SK. Koh, 2010, Longevity Risk and Annuities in Singapore, in: R. Clark and O.S. Mitchell, eds., *Reorienting Retirement Risk Management*, Oxford University Press, 156-176.
- Fong, W.M., 2002, On the Cost of Adverse Selection in Individual Annuity Markets: Evidence from Singapore, *Journal of Risk and Insurance*, 69(2): 193-207.
- Gale, W.G., J.M. Iwry, D.C. John, and L. Walker, 2008, Increasing Annuitization in 401(k) Plans with Automatic Trial Income, Working Paper, Brookings Institution, Washington D.C.
- Heritage.org., 2010. *Singapore: Economic Freedom Score*, [heritage.org/index/pdf/2010/countries/singapore.pdf](http://heritage.org/index/pdf/2010/countries/singapore.pdf), viewed 5/31/10.
- Horneff, W.J., R.H. Maurer, and M.Z. Stamos, 2008, Optimal Gradual Annuitization: Quantifying the Costs of Switching to Annuities, *Journal of Risk and Insurance*, 75: 1019-1038.
- Mitchell, O.S., J. Poterba, M. Warshawsky, and J. Brown, 1999, New Evidence on the Money's Worth of Individual Annuities, *American Economic Review*, 89: 1299-1318.
- Mitchell, O.S. and J. Ruiz, 2010, Pension Payments in Chile: Past, Present, and Future Prospects, in: O.S. Mitchell, J. Piggott, and N. Takayama, eds., *Revisiting Retirement Payouts: Market Developments and Policy Issues*, Oxford University Press, *Forthcoming*.

- Monetary Authority of Singapore (MAS), 2008a, *Insurance (Valuation and Capital) Regulations 2004*. [mas.gov.sg/resource/legislation\\_guidelines/insurance/sublegislation/Insurance%20\(Valuation%20and%20Capital\)%20Regs%202004.pdf](http://mas.gov.sg/resource/legislation_guidelines/insurance/sublegislation/Insurance%20(Valuation%20and%20Capital)%20Regs%202004.pdf), viewed 12/31/09.
- MAS, 2008b, *Statistics Room: Daily SGS prices*. [mas.gov.sg/data\\_room/index.html](http://mas.gov.sg/data_room/index.html), viewed 12/31/09.
- MAS, 2007, *Insurance Statistics: Individual Life Insurance: New Policies Issued Of Singapore Insurance Funds during the year ended 31 Dec 2007 and Policies In Force of Singapore Insurance Funds as at 31 Dec 2007*. [mas.gov.sg/data\\_room/insurance\\_stat/2007/Insurance\\_Statistics\\_2007.html](http://mas.gov.sg/data_room/insurance_stat/2007/Insurance_Statistics_2007.html), viewed 12/31/09.
- Murthi, M., J.M. Orszag, and P.R. Orszag, 2000, Annuity Margins in the UK, OECD paper. [oe.cd.org/dataoecd/30/61/2402277.pdf](http://oe.cd.org/dataoecd/30/61/2402277.pdf).
- NTUC Income, 2009, *Annuity Plans*. [income.com.sg/insurance/annuity](http://income.com.sg/insurance/annuity), viewed 3/16/09.
- Singapore Department of Statistics (SDOS), 2008a, *Statistics: Demography (Themes)*. [singstat.gov.sg/stats/themes/people/demo.html](http://singstat.gov.sg/stats/themes/people/demo.html), viewed 3/16/09.
- SDOS, 2008b, *Complete Life Tables for 2006 – 2007 for the Singapore Resident Population*, Information Paper, May.
- Singapore Prime Minister's Office (SPMO), 2007, *Transcript of Prime Minister Lee Hsien Loong's National Day Rally English Speech: City of Possibilities; Home for All*, August.
- Thorburn, C., R. Rocha, and M. Morales, 2005, An Analysis of Money's Worth Ratios in Chile, *Journal of Pension Economics and Finance*, 6: 287-312.

### Chapter 3

- Abel, A., and M. Warshawsky, 1988, Specification of the Joy of Giving: Insights from Altruism, *Review of Economics and Statistics*, 70(1): 145–149.
- Banking Times, 2008, *NU Increases Risk Factors in Annuity Pricing*, June 17. [www.bankingtimes.co.uk/17062008-nu-increases-risk-factors-in-annuity-pricing/](http://www.bankingtimes.co.uk/17062008-nu-increases-risk-factors-in-annuity-pricing/), viewed on 10/31/2010.
- Bateman, H., G. Kingston, and J.R. Piggott, 2001, *Forced Saving: Mandating Private Retirement Incomes*, Cambridge University Press.
- Batty M., A. Tripathi, A. Kroll, C. Wu, D. Moore, C. Stehno, L. Lau, J. Guszcz, and M. Katcher, 2010, *Predictive Modeling for Life Insurance*, Deloitte Consulting LLP, April.
- Bestwire, 2010, *Towers Watson Finds Growth in U.K. Enhanced Annuity Market*, September 9. <http://insurancenewsnet.com/article.aspx?id=224602&type=annuity>, viewed on 10/31/2010.

- Bongaarts J., and G. Feeney, 2002, How Long Do We Live?, *Population And Development Review*, 28(1): 13–29.
- Bowers, N., H. Gerber, J. Hickman, D. Jones, and C. Nesbitt, 1997, *Actuarial Mathematics*, Society of Actuaries, Schaumburg, IL.
- Brown, J.R., 2003, Redistribution and Insurance: Mandatory Annuitization with Mortality Heterogeneity, *Journal of Risk and Insurance*, 70: 17-41.
- Brown, J.R., 2002, Differential Mortality and the Value of Individual Account Retirement Annuities, in: M. Feldstein and J. Liebman, eds., *The Distributional Aspects of Social Security and Social Security Reform*, University of Chicago Press for NBER, Chicago, 401-446.
- Brown, J.R., 2001, Private Pensions, Mortality Risk, and the Decision to Annuitize, *Journal of Public Economics*, 82(1): 29–62.
- Brown, R.L., and P. Scahill, 2010, Issues in the Issuance of Enhanced Annuities, Social and Economic Dimensions of an Aging Population Program: Research Paper No. 265, McMaster University.
- Brown, R.L., and J. McDaid, 2003, Factors Affecting Retirement Mortality, *North American Actuarial Journal*, 7(2): 24–43.
- Cawley, J., and T. Philipson, 1999, An Empirical Examination of Information Barriers to Trade in Insurance, *American Economic Review*, 89 (4): 827-846.
- Chiappori, P. and B. Salanie, 2000, Testing for Asymmetric Information in Insurance Markets, *Journal of Political Economy*, 108(1): 56-78.
- Cleves M., R. Gutierrez, W. Gould, and Y. Marchenko, 2010, *An Introduction to Survival Analysis using Stata*, 3<sup>rd</sup> edition, Stata Press, College Station, TX.
- Cox, D.R., and E.J. Snell, 1968, A General Definition of Residuals, *Journal of the Royal Statistical Society B*, 30: 248–275.
- Deary, I.J., 2008, Why do Intelligent People Live Longer?, *Nature*, 456: 175-176.
- Deaton, A., and C. Paxson, 2001, Mortality, Education, Income and Inequality among American Cohorts, in: D. Wise, ed., *Themes in the Economics of Aging*, University of Chicago Press, Chicago, IL.
- Dickman, P.W., A. Sloggett, M. Hills, and T. Hakulinen, 2004, Regression Models for Relative Survival, *Statistics in Medicine*, 23: 51–64
- Dowd, J.B., and A. Zajacova, 2007, Does the Predictive Power of Self-Rated Health for Subsequent Mortality Risk Vary by Socioeconomic Status in the U.S.?, *International Journal of Epidemiology*, 36(6):1214-21.
- Dupre M.E., A.N. Beck, and S.O. Meadows, 2009, Marital Trajectories and Mortality among US Adults, *American Journal of Epidemiology*, 170(5): 546–555.
- Finkelstein, A., and J. Poterba, 2002, Selection Effects in the United Kingdom Individual Annuities Market, *Economic Journal*, 112: 28-50.

- Fisher, G.G., H. Hassan, W.L. Rodgers, and D.R. Weir, 2009, *Health and Retirement Study Imputation of Cognitive Functioning Measures: 1992 – 2006*, HRS User Guides, University of Michigan, September.
- Fong, J.HY., O.S. Mitchell, and B.SK. Koh, 2011, Longevity Risk Management in Singapore's National Pension System, *Journal of Risk and Insurance*, *Forthcoming*.
- Glymour, M., T. DeFries, I. Kawachi, and M. Avendano, 2008, Spousal Smoking and Incidence of First Stroke, *American Journal of Preventive Medicine*, 35(3): 245-248.
- Gompertz, B., 1825, On the Nature of the Function Expressive of the Law of Mortality, *Philosophical Transactions*, 27: 513–585.
- Hauser, R.M., and A. Palloni, 2010, Why Intelligent People Live Longer, CDE Working Paper, No. 2010-04.
- Herzog, A. R., and R.B. Wallace, 1997, Measures of Cognitive Functioning in the AHEAD Study, *Journals of Gerontology: Psychological Sciences and Social Sciences*, 52B (Special Issue): 37–48.
- Health and Retirement Study (HRS) Tracker, 2009, *Data Description and Usage: HRS Tracker 2008 (v1.0)*, HRS User Guides, University of Michigan, December.
- HRS, 2008, *Sample Sizes and Response Rates (2002 and beyond)*, HRS Survey Design Documents, University of Michigan, Fall.
- Hubbard, R.G., J. Skinner, and S.P. Zeldes, 1995, Precautionary Saving and Social Insurance, *Journal of Political Economy*, 103(2):360-399.
- Hurd, M., and K. McGarry, 2002, The Predictive Validity of Subjective Probabilities of Survival, *Economic Journal*, 112(482): 966-985.
- Idler, E.L., and R.J. Angel, 1990, Self-Rated Health and Mortality in the NHANES-1 Epidemiologic Follow-up Study, *American Journal of Public Health*, 80(4): 446-452.
- Idler, E.L., and Y. Benyamini, 1997, Self-Rated Health and Mortality: A Review of Twenty-Seven Community Studies, *Journal of Health and Social Behavior*, 38(1): 21-37.
- Juster, F.T., and R. Suzman, 1995, An Overview of the Health and Retirement Study, *Journal of Human Resources*, 30(5): S7–S56.
- Kitagawa, E.M., and P.M. Hauser, 1973, *Differential Mortality in the United States: A Study in Socioeconomic Epidemiology*, Harvard University Press, Cambridge, MA.
- Knox, D.M., 2000, The Australian Annuity Market, World Bank Policy Research Working Paper No. 2495, November.
- Kotlikoff, L.J., and A. Spivak, 1981, The Family as an Incomplete Annuities Market, *Journal of Political Economy*, 89(2): 372–391.

- Laibson, D., A. Repetto, and J. Tobacman, 1998, Self-Control and Saving for Retirement, *Brookings Papers on Economic Activity*, 1: 91-172.
- Lee, S.J., A.S Go, K. Lindquist, D. Bertenthal, and K.E. Covinsky, 2008, Chronic Conditions and Mortality among the Oldest Old, *American Journal of Public Health*, 98(7): 1209-14.
- Mackenzie, G.A, 2006, *Annuity Markets and Pension Reform*, Cambridge University Press, Cambridge.
- McCarthy, D., and O.S. Mitchell, 2010, International Adverse Selection in Life Insurance and Annuities, in: S. Tuljapurkar, N. Ogawa, and A. Gauthier, eds. *Ageing in Advanced Industrial States: Riding the Age Waves*, Springer: 119-135.
- Mehta, N.K., and V.W. Chang, 2009, Mortality Attributable to Obesity among Middle-Aged Adults in the United States, *Demography*, 46(4): 851-872.
- Mehta, K.M., K. Yaffe, K. Langa, L. Sands, M. Whooley, and K. Covinsky, 2003, Additive Effects of Cognitive Function and Depressive Symptoms on Mortality in Older Community Living Adults, *The Journals of Gerontology: Medical Sciences*, 58A(5): M461-467.
- Mitchell, O.S., J. Poterba, M. Warshawsky, and J.R. Brown, 1999, New Evidence on the Money's Worth of Individual Annuities, *American Economic Review*, 89(5): 1299-1318.
- Orth, B.J., 2008, Approaches for Promoting Voluntary Annuitization, Monograph, presented at the 2008 Retirement 20/20 Conference.
- Preston, S.H., P. Heuveline, and M. Guillot, 2001, *Demography: Measuring and Modeling Population Processes*, Blackwell, Malden, MA.
- Preston, S.H., I.T. Elo, I. Rosenwaike, and M. Hill, 1996, African-American Mortality at Older Ages: Results of a Matching Study, *Demography*, 33(2): 193-209.
- RAND Corporation, 2010, *RAND HRS Data Documentation: Version J*, Rand Center for the Study of Aging, June.
- Reuser, M., L. Bonneux, and F. Willekens, 2008, The Burden of Mortality of Obesity at Middle and Old Age is Small. A Life Table Analysis of the US Health and Retirement Survey, *European Journal of Epidemiology*, 23(9): 601-7.
- Rodgers, W.L., M.B. Ofstedal, and A.R. Herzog, 2003, Trends in Scores on Tests of Cognitive Ability in the elderly US Population, 1993 – 2000, *The Journal of Gerontology: Social Sciences*, 58B(6): S338-S346.
- Royston, P., 2006, Explained Variation for Survival Models, *The Stata Journal*, 6(1): 83-96.
- Rusconi, R., 2008, National Annuity Markets: Features and Implications, OECD Working Papers on Insurance and Private Pensions, No. 24, OECD publishing.

- Siegel, M.J., E.H. Bradley, and S.V. Kasl, 2003, Self-rated Life Expectancy as a Predictor of Mortality: Evidence from the HRS and AHEAD surveys, *Gerontology*, 49(4): 265-271.
- Sloan, F.A., P. Ayyagari, M. Salm, and D. Grossman, 2010, The Longevity Gap Between Black and White Men in the United States at the Beginning and End of the 20<sup>th</sup> Century, *American Journal of Public Health*, 100(2): 357-363.
- Society of Actuaries (SOA), 2010, Obesity and its Relation to Mortality and Morbidity Costs, *SOA Research Projects series (Life Insurance)*, December.
- SOA, 1983, The Bragg Smoker and Non-Smoker Mortality Tables and Health Insurance Report, *The Actuary*, October, 17(8): 5.
- Sorlie, P., E. Rogot, R. Anderson, N.J. Johnson, and E. Backlund, 1992, Black-White Mortality Differences by Family Income, *The Lancet*, 340: 346-350.
- Stewart, F., 2007, Policy Issues for Developing Annuities Markets, OECD Working Papers on Insurance and Private Pensions, No. 2, OECD Publishing.
- The Investors Chronicle, 2008, *How to Get the Best Annuity*, December 31.
- Turra, C., and O.S. Mitchell, 2008, The Impact of Health Status and Out-of-Pocket Medical Expenditures on Annuity Valuation, in: J. Ameriks and O.S. Mitchell, eds., *Recalibrating Retirement Spending and Saving*, Oxford University Press, Oxford, UK, 227-250.
- U.S. Supreme Court, 1988, Florida v. Long, 487 U.S. 223, June 22. <http://supreme.justia.com/us/487/223/>, viewed on 10/31/2010.
- Wall Street Journal (WSJ.com), 2011, EU Insurance Ruling: More Pain for Women?, Commentary, March 1. <http://blogs.wsj.com/source/2011/03/01/eu-insurance-ruling-more-pain-for-women/>, viewed on 3/30/2011.