CHANGES IN RETIREMENT ADEQUACY, 1995-2004:

ACCOUNTING FOR RETIREMENT STAGES

Dissertation

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By

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ABSTRACT

Previous retirement adequacy studies have ignored retirement income stages in their research models. Studies that ignore retirement income stages result in biased estimations of retirement adequacy. In this study, retirement income stage is first being analyzed theoretically and then empirically. The effect of having retirement income stages on retirement adequacy is tested through two-sample t-tests and logistic regressions according to the theory of consumer psychology and bounded rationality.. In addition, the life cycle saving hypothesis and modern portfolio theories are used to project asset accumulation and distribution during retirement.. Retirement adequacy is measured by Palmer's (1992, 1994) required retirement ratio concept with adjustments according to Maslow's hierarchy-need theory. A retirement income stage is defined as a period in which the income source number is constant. Whenever the retirement income source number changes, one new stage is created. The income stage starts with planned retirement age and ends at the expected age of death of the individual or the couple. The maximum stage number for a married household is eight, based on the stage drivers of Social Security retirement benefit, Defined Benefit pension, and part-time job wage. The retirement adequacy indicator fluctuates across the retirement stages, while the method of previous studies concludes that retirement adequacy is constant across retirement life.

The more stages a household has, the greater the difference of retirement adequacy between this new methodology and traditional methodology, i.e., ignoring stages.

A replacement rate serves as an indicator of economic measurement, in which the numerator includes retirement income, such as Social Security benefits, Defined Benefit pensions, part-time job wages, and annuity distribution, while the denominator includes only pre-retirement income. Normal income is used as a proxy of pre-retirement income, and therefore, it is also used to calculate the Social Security benefit and the Defined Benefit pension. The benchmark replacement ratio is calculated according to the income distribution from the Consumer Expenditure Survey 2005.

The median replacement ratio ranges from 47.8% to 109.8% across categories and new stages and from 47.8% to 186.1% when stage partition is ignored. The corresponding adequacy proportion based on the replacement ratio of retirement adequacy proportions ranges from 33.6% to 83.0% across categories and new stages, but ignoring stage partition, the proportion ranges from 33.6% to 74.6%. The percentage interval of adequacy proportion for non-stage partition is sufficiently larger than that of stage partition method.

The overall adequacy proportion of new stage 1 ranges from 45.9% to 59.8%, while the adequacy proportion of new stage 2 ranges from 48.4% to 61.2%. It shows that the overall adequacy taking stages into account increased each survey period from 1995 to 2004. The combined stage adequacy proportion ranges from 47.2% to 60.5%. When ignoring stage partition, the adequacy proportion ranges from 58.0% to 61.7%. Compared these two methods, the adequacy proportion difference is about 11.7% in 1995, 8.4% in 1998, 3.8% in 2001, and 1.2% in 2004.

Three categories are used to segment the sample to see whether households have more than one stage and whether they have enough retirement assets. Category 1 indicates that households have two new stages and enough retirement assets; while category 2 indicates two new stages but not enough retirement assets. Category 3 indicates only one new stage. The descriptive results, it shows that households with only one stage of retirement had much lower adequacy because of having fewer sources of retirement income, typically only a Social Security pension. Furthermore, the descriptive result shows that households with more than one stage of retirement, who were projected to accumulate enough retirement assets to even out spending across retirement stages, had a very high rate of retirement adequacy, 83% in 2004.

Using two-sample t-test and stage partition method, the adequacy proportion of 1998 is significantly less than that of 2001. In addition, the adequacy proportion of 2001 is significantly less than that of 2004. Nevertheless, when ignoring stages, only adequacy proportion of 2001 is significantly less than that of 2004.

Using logistic regression and stage partition method, households in 2004 are significantly more likely to have adequate retirement than those in 2001. However, when ignoring stage, households in 2004 are significantly less likely to have adequate retirement.

Tested by two-sample t-test with RII technique and logistic regression with RII technique, the replacement ratio when ignoring stage partition is much more than that of using stage partition, since the method of ignoring stage recognizes all retirement incomes at planned retirement age, while the stage partition method recognizes retirement income at the actual ages. The stage partition method provides more insight of the fluctuation of retirement adequacy across years. This method has more consistent results between t-test and logistic regression, since this method has more robust estimation of retirement adequacy.

Those having defined contributions and benefit pensions are more likely to have retirement adequacy. Those with the expectation of inheritance are also more likely to have retirement adequacy as well.

In the multivariate analysis, the planned retirement age is positively correlated to the likelihood of having an adequate retirement. Furthermore, controlling for retirement age and other factors, households with more stages are more likely to have an adequate retirement. The demographic variables are not all consistently significant across those logistic models, but they do play a role as control variables.

Dedicated to my wife, Jui-Min Chang

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FIELDS OF STUDY

Major Field: Human Ecology (Family Resource Management)

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CHAPTER 1

INTRODUCTION

1.1 Motivation and Justification

The first baby boomers will reach 62 in 2008 (Butrica, Iams & Smith, 2003), and retirement benefits withdrawn from Social Security will dramatically increase. If the Social Security policy doesn't change, it is projected that the Social Security Old Age, Survivors and Disability Insurance (OASDI) Trust Fund will be exhausted by 2041 (Butrica et al., 2003) and baby boomers will not receive their expected retirement benefits. Although defined benefit pension plans provide guaranteed retirement income, increasingly employers have switched retirement plans to defined contribution pension plans, such as 401Ks and IRAs. Just over half of workers with private employers had access to a defined contribution plan in 2006 (U. S. Department of Labor, 2006). How to prepare for an affordable retirement is an important contemporary issue for Americans.

Beyond the increasing responsibility of managing retirement accounts, other important reasons for retirement planning are described as follows. Due to improvements in medical care, life expectancy has increased (Kim, 2002). Extended life expectancy requires more financial resources for retirement. However, based on a previous study by Yuh, Hanna, and Montalto (1998), only about 52% of households with a worker aged 35 to 70 in the United States had enough savings for an adequate retirement. The discrepancy between how much potential retirees should save and how much they do save suggests that the measurement of retirement adequacy can lead to a better understanding of what it means to have an adequate retirement income.

Over the last decade, retirement adequacy has been an important issue for researchers. A large body of literature on retirement adequacy has been published in journals. These studies have explored the development of retirement adequacy by analyzing adequacy indicators, such as replacement ratio, prescribed savings rate, and the ratio of retirement wealth to needs. However, there is still no consensus on an appropriate measurement of retirement adequacy. The literature review in Chapter 3 is designed to answer the question of what has been done in retirement needs, retirement income, asset allocation, financial asset contribution, rate of return, retirement ages and retirement income stage.

1.2 Purpose of This Study

The main purpose of this study is to explore how many retirement income stages households have and to analyze the effect of taking stages into account on retirement adequacy. Although the life cycle saving hypothesis proposes that people are rational enough to predict permanent income, the real situation might not be true, since most studies (Yuh, Hanna & Montalto, 1998; Moore & Mitchell, 1997; Mitchell& Moore, 1998) project that people are not financially prepared for an adequate retirement. This inadequacy challenges the proposition of life cycle saving hypothesis. The bounded rationality of behavior economics is used to serve a foundation why people act irrationally. Retirement income stages form a more complex income projection and therefore households with multiple stages may be more likely to fail to accumulate enough assets for retirement.

The second purpose of this study is to evaluate measurements of retirement adequacy in terms of financial aspects. Previous studies have developed several different kinds of retirement adequacy indicators, such as required replacement ratio (Palmer, 1992, 1994), prescribed saving rate (Moore & Mitchell, 1997; Mitchell & Moore, 1998), ratio of retirement needs to retirement assets (Yuh, Hanna & Montalto, 1998) and financial failure rate (Ameriks, 2000, 2001). Those indicators make different kinds of assumptions about retirement adequacy. This study argues that the version of Palmer's method, i.e., the required replacement ratio, best measures retirement adequacy in terms of the relative status of households before and after retirement.

The third purpose of this study is to have a more objective measurement of retirement needs. In the replacement ratio method, a retirement need is measured by the relative pre-retirement living standard. However, Palmer's method is not enough to explain why the extreme high income or low income households should replicate the pre-retirement living standard and is defined as adequate financially. Therefore, no global specific required replacement ratio is applicable to each household, but instead, an income based retirement need is assessed. Maslow's hierarchy need theory demonstrates why different income households should have different required replacement ratio with respect to the categories of unavoidable and avoidable consumption.

The fourth purpose of this study is to simulate retirement asset accumulation at the planned retirement age. In this section, many empirical assumptions are made to articulate the retirement asset simulation. Historic inflation-adjusted returns for different investment categories are applied to each household's investment balances and contributions to project the accumulation of investment assets by retirement.
Without the classification and diversification concept of investment vehicles, e.g. large stock, small stock, government bonds, and corporate bonds, it is difficult to project the accumulated retirement assets.

The fifth purpose of this study is to observe the change of retirement adequacy across years. This retirement adequacy trend will enlighten some implications and contribution to political policy. Although the dataset used in this study is a cross sectional dataset, the projection of retirement adequacy is not impaired by this dataset. The purpose of this study is not to observe how people behave from pre-retirement to post-retirement, but to have a forward projection of retirement adequacy, such that policy can be shaped by a better understanding of retirement adequacy.

The final purpose of this study is to test hypotheses through two-sample t-test and multivariate statistical analyses. The two-sample t-test will test the hypotheses without controlling for the effects of other variables, for instance, are households with more stages less likely to have retirement adequacy? The multivariate statistical analyses will test the hypotheses with controls for other variables. Logistic regression is used, since it provides the likelihood of having retirement adequacy for each independent variable. More justifications of the statistical methods and sample selection are found in the methodology section.

1.3 Organization of the Dissertation

This dissertation is organized into seven chapters:

Chapter I describes the motivation and justification of a study of retirement adequacy. It outlines the scope and discussion of this dissertation with respect to retirement adequacy.

Chapter II discusses the four theoretical frameworks used in this dissertation: the life cycle saving hypothesis, bounded rationality, Maslow's hierarchy of needs and modern portfolio theory.

Chapter III presents a summary of the empirical assumptions necessary to simulate projections of retirement adequacy. Factors, such as retirement needs, retirement income, asset allocation, contribution, rate of return, planned retirement age, life expectancy and retirement income stages are discussed in this chapter.

Chapter IV discusses the characteristics of the Survey of Consumer Finance (SCF) dataset and sample selection. Several techniques, including weighting and multiple imputation are discussed as well in this section.The strength and weakness of using SCF are evaluated in this section.

Chapter V demonstrates the statistical techniques used in this dissertation. Logistic regression is an appropriate multivariate statistical technique to analyze dichotomous dependent variables such as retirement adequacy indicators. The two-sample t-test is used to measure the magnitude of means difference.

Chapter VI presents the descriptive statistical results of income stage distribution, retirement adequacy proportion, the discrepancy of stage partition in retirement adequacy, results of the two-sample t-test, and results of logistic regression.

Chapter VII discusses research conclusions, the implications for public policy, and suggestions for future research.

CHAPTER 2

THEORETICAL FRAMEWORK

2.1 Life Cycle Saving Hypothesis and Forward Looking Theory

A number of different consumption theories have been developed over the decades. The most widely accepted are the permanent-income theory developed by Milton Friedman and the life cycle model developed by Ando and Modigliani (1963). Those theories differ from the Keynesian consumption function in that they measure income by total resources rather than by current income. These two theories are closely related, and together they have served as a foundation for most of the rational expectations research on consumption in macroeconomics in recent years. Both the permanent income theory and the life cycle saving hypothesis are forward looking theory, which assume that households set their consumption based on expectations of future income. A forward looking theory assumes that consumers look ahead to their likely future disposable income, which depends on their future earnings from working, their future income from wealth they have accumulated, and how high taxes will be in the future. Based on their current income and expected future disposable income, consumers decide how much to consume this year after taking into account their likely consumption in future incomes. They expect their incomes to vary over their lifetimes, but they recognize less variation in their consumption patterns over time. Therefore, they need to shift resources from periods of high income to periods of low income in order to provide for consumption (Bryant, 1990).

The permanent income hypothesis illuminates the differences between permanent income, which a household expects to be long lasting, and transitory income, which a household expects to disappear shortly. The life cycle saving hypothesis assumes that a household looks ahead over its entire lifetime. Both the permanent-income and the life cycle hypotheses emphasize that the reason for saving and borrowing is to even out consumption, despite variation in one's income over time. (Bryant, 1990; Hall & Papell, 2005).

Ando and Modigliani (1963) proposed the life cycle saving hypothesis, in which they assumed the utility function is a function of consumption in current and future periods. The individual is then assumed to maximize their utility subject to the sum of current and discounted future earnings over a lifetime and their current net worth. The life cycle hypothesis implies a consumption smoothing pattern in that the consumption amount will remain relatively stable despite changes in the current income.

The equation in Figure 2.1 simplifies the life cycle model into a two-period model. In this model, a household will maximize the lifetime utility subjected to the inter-temporal budget constraint. The budget constraint includes income and the profits from saving.

$$TU = U[C_1] + U[C_2]/(1+\rho) \qquad (2.1)$$

,where

TU : denotes total lifetime utility

C_1 : denotes year 1 consumption

C_2 : denotes year 2 consumption

ρ : denotes the personal discount rate or time preference rate

People with higher discount rates are more likely to increase their current consumption since the discounted utility of the second period is lower than the utility of the first period (Hanna, Fan & Chang, 1995; Engen, Gale & Uccello, 1999).

2.1.1 Personal Discount Rate (Time Preference)

The personal discount rate reflects an individual's attitude toward consumption both now and in the future. A high discount rate means that a person is more present-oriented and prefers to consume more currently than in the future. High-discount-rate people perceive future consumption as being worth less than their current consumption. The personal discount rate is subjective and varied individually. Individuals can anticipate that they will not be able to enjoy retirement due to poor health for instance, and then may decide to consume more currently than in retirement. This thinking results in less saving for retirement. The discount rate (time preference) might also be based on perceived life expectancy. People who expect to live longer might have a lower discount rate and will consume less currently but more in the future.

Hanna, Fan and Chang (1995) listed the probability of death, change in family composition, or other factors as reasons for time preference. They assumed the discount factor $1/(1+\rho)$ to be equal to the probability of surviving from year n to n+1. Therefore a young consumer should value next year's consumption almost as highly as this year's consumption, but will place a low utility value on consumption 50 years into the future because the cumulative effect of discounting for the risk of death is huge. The probability of death is based on mortality tables for all Americans (U.S. Center for Health Statistics, 1986). The probability of death increases as the respondent ages; in other words, the discount factor decreases as the respondent ages.

It is difficult to measure the personal discount rate. To determine the personal discount rate Barsky, Juster, Kimball and Shapiro (1997) used a hypothetical question asking the respondents to choose a preferred consumption profile. Engen, Gale and Uccello (1999) provided theoretical reasons for choosing the discount rate. They set the time preference rate equal to the real average after-tax return rate as a natural benchmark. It implies that, controlling for elasticity, consumption would be constant, since the personal discount rate is equal to the average after-tax return rate. They chose 3% and 0% as time preference rates to calculate a household's optimal consumption level. Although 3% is lower than previous empirical studies, Engen et al. (1999) argued that 3% is equal to the after-tax interest rate and is therefore a reasonable time preference rate. The reason to set 0% as the time preference is because setting the time preference at 3% would make the marginal utility at age 25 almost six times that at age 85. A zero time preference rate assumes that households are extremely patient.

The approaches of estimating personal discount rates between Hanna et al. (1995) and Engen et al. (1999) are quite different. Hanna et al. (1995) assumed that the discount rate is based on observable factors, the risk of death by age and changes in household size. Engen et al.'s (1999) method of deriving the discount rate is arbitrary, and does imply constant consumption for a household. The Barsky et. al. method is based on hypothetical questions presented to a small group of older respondents.

2.1.2 Elasticity of Marginal Utility

The most common utility function used in analyses of inter-temporal choices is the constant elasticity function:

$$U[C_i] = (C_i^{1+\varepsilon})/(1+\varepsilon) \qquad \{\text{for } \varepsilon \neq -1\} \qquad (2.2a)$$
$$U[C_i] = Ln(C_i) \qquad \{\text{for } \varepsilon = -1\} \qquad (2.2b)$$

, where ε is elasticity of marginal utility with respect to consumption (White, 1978; Skinner, 1985). The constant elasticity utility functions shown above are also widely used (Hanna et al., 1995; Engen et al., 1999; Scholz et al. 2004), especially in a static model with uncertainty (Hanna, Gutter & Fisher 2003), under which the utility function is called a constant relative risk aversion (CRRA) function. . To clarify the usage of these functions, Hanna et al. (2003) concluded that for the two-period inter-temporal model, the utility is compared between two periods; for the two-state of the world uncertainty, the utility is compared between two states.

The parameter ε shows the indifference curves between consumption in any two years (Skinner, 1985; Engen et al., 1999). This parameter is important since it is crucial to the optimal consumption and saving level, when controlling real interest rates and personal time preference. The study of Yuh (1998) has been critiqued by Hanna et al. (2002) because of the assumption of constant consumption both before retirement and after retirement without controlling real interest rate and personal discount rate. Hanna, et al. (2002) noted that for low growth of income pattern, a higher value of - ε lead to a more constant saving pattern, but for lower value of -ε, optimal annual saving is initially high but then decreases before retirement. Hanna, Gutter and Fan (2001) asked respondents about the acceptable percentage of loss if the pension could be doubled to determine the relative risk aversion level. Hanna, Gutter, and Fisher (2003) used a sample of 252 undergraduate students to arrive at an empirical estimate of both the relative risk aversion factor and the elasticity of marginal utility. They found that the mean value of relative risk aversion was 5.9 and the mean value of elasticity of marginal utility was 5.0. This result conformed to similar mathematical properties between the constant relative risk aversion function and the constant elasticity utility function. Their study also pointed out that the higher the value of -ε, the lower the initial percent of income saved out of period 1 income.

$$C_1 = I - S \qquad (2.3)$$

$$C_2 = I(1+g) + S(1+r) \qquad (2.4)$$

, where

I : denotes year 1 income

S : denotes saving in year 1

g: denotes growth rate in income

r: denotes real interest rate

The interest rates that households face depend on what kind of investment the households have and whether they borrow. Households that invest conservatively, e.g., in bonds or CDs, have lower interest rates. In contrast, households with more aggressive investments have higher interest rates.

From (2.1), (2.2a), (2.3) and (2.4), the growth of consumption from year 1 to year 2 can be derived as the follow:

$$(\frac{C_2}{C_1})=[\frac{(1+r)}{(1+\rho)}]^{-\frac{1}{\varepsilon}} \qquad (2.5)$$

The general form of equation 2.5 can be shown as equation 2.6, so it maximizes lifetime utility under certain conditions:

$$(\frac{C_{n+1}}{C_n})=[\frac{(1+r)}{(1+\rho)}]^{-\frac{1}{\varepsilon}} \qquad (2.6)$$

In equation 2.6, the optimal consumption depends on r, ρ and ε. If ρ is equal to 0 and ε is equal to -1, the optimal consumption should increase by the real interest rate each year. For a particular value of ε, the optimal consumption depends on r and ρ solely. If r is greater than ρ, the consumption will steadily increase. If r is equal to ρ, the consumption holds constant across time. If r is less than ρ, the consumption will decrease steadily. In addition, Hanna et al. (1995) found that the optimal growth rate $[\frac{(1+r)}{(1+\rho)}]^{-\frac{1}{\varepsilon}}$-1 is approximated to be $g_c \approx (r-\rho)/(-\varepsilon)$, where g_c is the optimal growth rate of consumption between two periods.

Equations 2.3 and 2.4 are the simplified inter-temporal budget constraint. Yuh (1998) presented a lifetime budget constraint as follows:

$$\sum_{t=0}^{T} C_t/(1+r)^t = A_0 + \sum_{t=0}^{T} E_t/(1+r)^t \equiv A_0 + Y_0 \qquad (2.7)$$

, where

A_0 : denotes initial asset

E_t : denotes the earnings of period t

Y_0 : denotes the discounted value of lifetime earnings

Another extension of the standard life cycle model, the augmented life cycle model is addressed by Scholz, Seshadri, and Khitatrakun (2004). Scholz et al. created this model to calculate the optimal wealth at retirement based on an optimal consumption level. They then compared optimal wealth with actual wealth to determine retirement adequacy. Similar to Engen et al. (1999), the probabilities of living and family size are adjusted in this model. The innovation of the Scholz et al. (2004) study is the differentiation of the life cycle into 3 categories: before retirement, retirement, and after retirement. They then set up different utility functions and budget constraints and assumed that households will have less mortality risk and out-of-pocket medical expenses before retirement. In the retirement category, they assumed that the last earnings of a household's working life would determine the amount of defined benefit pension after retirement. They also separated Social Security benefits and defined benefit pensions from regular earnings. In addition, they set up a more realistic function of taxes dependent on earnings, Social Security benefits and defined benefit pensions, assets, the year, and the number of people in the household.

Their model implied that there is a borrowing constraint and assumed that individuals cannot die with debt (Scholz et al., 2004, p 9). They assumed that individuals will pay off debt even if they have no earnings.

2.1.3 Conclusion

In summary, to analyze consumer behavior within the life cycle savings hypothesis, three main factors need to be considered: a personal discount rate (time preference), the elasticity of marginal utility, and a real interest rate. The elasticity of marginal utility reflects the attitude of the consumer toward consumptions and savings. The time preference parameter reflects the probability of death or health. The real interest rate is usually assumed at a certain level and is usually larger than the personal discount rate. From equation 2.6, the consumption growth rate is supposed to increase if r is greater than ρ and fixed $-1/\varepsilon$ at a certain level.

The influence of the income growth rate is less in the analysis of consumption growth. However, the basic assumption of the optimal life cycle model is that people are forward looking and are rational enough to project their income pattern. Once they determine their lifetime income, the role of r, ρ and $-1/\varepsilon$ are plugged in, and then the optimal consumption level is determined. Therefore, the influence of income growth is overall but not period by period. In addition, the income growth rate is related to an important issue in empirical research, the age of the sample selection. The study of Hanna et al. (2002) concluded that individuals with lower $-\varepsilon$ are more likely to have a higher consumption growth rate and the consumption variation starts from a very young age, e.g., 20.

For the representative purpose of the aggregate sample, Hanna et al. (2002) included these young households in the sample to represent more realistic consumption. However, including those young households might result in an inaccurate projection of permanent income. Young households are usually unstable since young consumers are more likely to return to school or get married. Therefore, the income projection might not be accurate (Yuh, 1998). There is a trade-off between representative and accurate projection.

From the above discussion, the parameter measurement is improved and refined (Engen et al., 1999; Scholz et al., 2004). Although the life cycle savings model does not describe consumer behavior well at the household levels or at the aggregate level, it is the only rigorous model designed to provide a prescriptive answer to the question of how much a consumer should save (Hanna et al., 1995).

2.2 Consumer Psychology

2.2.1 Bounded Rationality

Behavioral economics grew out of a critique of standard economic assumptions (Fundenberg, 2006; Pesendorfer, 2006). Behavioral economics is a collection of "biases" or violations of assumptions in standard economics. In this section, behavior economics serve as a theoretical basis of the retirement income stage empirical testing. Although the life cycle saving hypothesis assumes that people are rational enough to predict their permanent income, without more detailed assumptions like income source numbers, it is difficult to verify this theory by empirical test. When people facing a complex cognitive burden, are they still able to make a rational decision? Although generally speaking, judgments and choices are intuitive, skilled, unproblematic, and reasonably successful (Klein, 1998), Tvershy and Kahneman (1986) have shown that the complexity of framing effects results in consumer mistakes. The reasoning process is impaired by the complexity of situation, and therefore, people tend to have bounded rationality when making decisions. Bounded rationality refers to the way that people use the exogenous rule of thumb to derive consequences for their actions (Fundenberg, 2006). In behavioral economics, people are more likely to use heuristics methods like the "rule of thumb" to make decisions (Fundenberg, 2006). When using the rule of thumb, people might not take into account some important information and are more likely to make irrational decisions.

Income stage management is equivalent to cash flow management. A precisely predicted income cash flow can ensure that individuals reach their financial goals.

Previous literature concluded that those with the same lifetime income but with stable income cash flow are more likely to have higher utility than those with unstable income cash flow. The reason of having more utility is because the stable income cash flow is easier to predict and such that it is easier for people to set their financial goal. Another reason of having higher utility is because people with stable income are less likely to spend more than income. People with more stages are equivalent to have non-stable income cash flow; thus, it is relatively difficult to smooth spending. This explains why people are not rational enough to predict their permanent income and cannot smooth spending. In consumer psychology, the prediction of permanent income with respect to retirement income, e.g., defined benefit pension, and defined contribution pension, is more likely to result in bounded rationality. This bounded rationality makes people omit the pension income recognition time and only heuristically perceive the amount of retirement income.

2.3 Maslow's Hierarchy of Needs

When measuring retirement needs in terms of a certain replacement level, it is difficult to find a one-size-fits-all replacement ratio. A particular replacement ratio like 80% might not objectively represent the retirement needs for the extreme low income household. Xaio and Noring (1994) concluded that consumer finance needs to follow a hierarchy pattern and have a priority of meeting needs. People will fulfill lower needs first and then move to fulfill higher needs. In addition, Xiao and Noring (1994) found that when families have limited resources, they seek to meet lower level needs first, such as needs for survival and security. This finding coincides with the traditional demand theory of normal goods and luxury goods. When family financial resources increase and lower level financial needs are met, households will expand to higher level needs. Therefore, according to Maslow's theory, a universal benchmark replacement ratio across different income households is unsuitable. The life cycle saving hypothesis provides a theoretical framework for how individuals can replicate pre-retirement living standards, while Maslow's hierarchy of needs provides an absolute measurement of living standards.

2.3.1 Needs Priority

Maslow's (1954) hierarchical theory proposed that human needs are hierarchical. The priority of needs is: physiological needs, safety needs, love/belonging needs, esteem needs and self-actualization needs. When the lower level of needs are met, individuals move to an upper level of needs, and so on until the highest level of needs are met. The first level of needs is physiological and includes the need to breathe, sleep, regulate homeostasis, eat, dispose of bodily wastes and engage in sexual activity. The second priority of needs, safety needs, include security of health and employment, physiological security, family security and safety from violence, delinquency, and aggressions. After people fulfill the first two levels of needs, they require the third needs: love, belonging and social needs. This need includes friendship, sexual intimacy, and having a supportive and communicative family.

The fourth needs are the esteem needs. Esteem needs are self-respect, being respected and respecting others. Esteem needs reflect how individuals need be recognized among their social peers and need to contribute themselves to gain self value.

Esteem needs have two levels: lower level and higher level. The lower level of esteem includes components such as fame, respect and glory, while the higher level of esteem includes confidence, competence and achievement. People with lower level esteem needs usually require respect from others, while people with higher level esteem needs only require personal success and confidence irrespective of other individuals. The final need in Maslow's theoretical framework is self-actualization, which describes how individuals have the need to make the best of themselves in accomplishing tasks. Those who are self-actualized are usually more creative, more interested in solving problems, have a more positive attitude toward the realities of the world, and a greater appreciation for life.

2.3.2 Test of Maslow's Hierarchy of Needs Theory

Xiao and Noring (1994) used the 1986 Survey of Consumer Finances to test the major motives for saving. They agued that life cycle saving hypothesis and permanent income hypothesis represent only one motive for saving, namely, the retirement and bequest motive respectively. Also, the behavior life cycle hypothesis fails to explain why consumers have different motives for saving (Xiao & Noring, 1994). A more appropriate theoretical framework that explains different motive for saving is Maslow's hierarchy of needs theory. Applying Maslow's framework and using the 1986 Survey of Consumer Finances, Xiao and Noring (1994) concluded that households with low income and low paper assets or real assets are more likely to save for lower level of needs, i.e., daily purchasing. As the income increases, households save more for retirement.

Hagerty (1999) tested Maslow's hierarchy of needs in terms of quality of life by using a new dataset including annual quality of life for 88 countries from 1960 to 1994.

Hagerty (1999) concluded that the testing results agreed with Maslow's hierarchy of needs theory. The dataset has physiological needs indicators including daily calories available per person and GDP per person. They defined daily calories as the caloric equivalent of all food in the country over a year, after accounting for imports and exports, subtracting food used for seed or for animal feed. Security needs indicators included safety from war, safety from murder, and high life expectancy.

In this study, the hypothesis of need fulfillment sequence was tested following Maslow's sequence. Hagerty (1999) used the international dataset to track the time series of need fulfillment and found that the sequence of need fulfillments is as follows: GDP per person, safety from war, calories per person, life expectancy, divorce, secondary education, female working participation, tertiary education, safety from homicide, infant mortality, and democracy. Hagerty found that the correlation test between the empirical sequence and Maslow's hierarchy of needs is significant (p-value < 0.02) and concludes that Maslow's hierarchy needs theory is supported.

2.3.3 Justification of Needs Categories

The studies of Xiao and Noring (1994) and Hagerty (1999) show that needs have unavoidable priority. Therefore, extreme low income households spend more than they earn. When setting up the benchmark required replacement ratio, the true spending, i.e., total spending minus contributions to pension and retirement, is set up as the numerator. This method is consistent with Palmer's (1992, 1994) method. Although this method might include some spendings beyond the basic need or necessity, for instance entertainment, it is hard to justify which spending should be taken off from the aggregate data. In addition, the retirees are more likely to spend on travel, reading, and other miscellaneous costs. Thus, the numerator includes all spending except for contribution to pension and retirement accounts.

2.4 Modern Portfolio Theory

According to the life cycle saving model, consumption growth rate depends on the elasticity of marginal utility, real interest rate and personal discount rate. The real interest rate depends on what kind of investment vehicles households have. Having a high return investment vehicle implies that the household will have higher future consumption, because the effects of interest compounding accumulates future wealth. Alternatively, a higher return investment allows the households to save less but be able to maintain the constant consumption level. Another reason that asset allocation is important is that retirement pensions, such as the 401(k), allow households to self-direct the composition of their retirement account. In general, a higher return investment accompanies higher risk. To decide what kind of investments households should have, they must trade off between return rate and risk. The decision to hold a large number of risky assets is usually referred to as the personal risk attitude.

Some studies refer to the personal risk attitude as risk aversion or risk tolerance (Hanna & Chen, 1997). Modern portfolio theory explains that based on certain risk aversion levels, the individual is able to decide the optimal allocation between risk-free assets and risky assets. The optimal allocation means that under this allocation of assets the utility is maximized (Bodie et al. 2002). The utility function used by Bodie et al. (2002) is as follows:

$$U = E(r) - .005A\sigma^2 \qquad (2.9)$$

, where A is the risk aversion factor, .005 is the scale factor, and σ^2 is the variance of the complete portfolio. The higher the value of A the higher level of risk aversion. The utility function in this case is different from the constant relative risk aversion utility function in life cycle saving model, because the expected utility of a gamble depends on the probability distribution of the outcomes. However, in some circumstances the expected utility of a gamble will only depend on the mean and variance summary statistics of the distribution. The most common example of this is a mean-variance utility function (Varian, 1992 p. 189).

The utility function used by Bodie et al. (2002) is a quadratic form of the utility function. According to Varian (1992) the quadratic utility function has some undesirable properties in that it is a decreasing function with wealth in some ranges and it exhibits increasing absolute risk aversion. Compared to this absolute risk averse function the constant relative risk averse function in the life cycle saving hypothesis section is a more plausible measurement in the simulation of retirement adequacy. The constant relative risk averse function reveals the risk aversion level in the simulation.

2.4.1 Decision Rule of Investment in Risky and Risk Less Assets

The asset allocation of a household can be represented by the capital asset line (CAL), which indicates the risk free rate (intercept) and the reward to variability ratio (slope). The reward to variability ratio represents the additional return by taking one unit of additional risk. Through the CAL, the proportion of the household's risky assets indicates the standard deviation of the complete portfolio (σ_C). The following equation shows how CAL is calculated:

$$E(r_C) = r_f + y[E(r_p) - r_f] \qquad (2.10)$$

, where $E(r_C)$ is the expected return of the complete portfolio, r_f is risk-free return, y is the proportion of risky portfolio to the complete portfolio which can be substituted by σ_C / σ_P, and $[E(r_p) - r_f]$ is the excess of risky portfolio return over risk-free return, usually called risk premium. If we substitute σ_C / σ_P into y, we can see the reward to variability ratio as $[E(r_p) - r_f] / \sigma_P$. The risk of the complete portfolio is the product of the proportion of the risky portfolio and the standard deviation of the risky portfolio.

To determine the optimal proportion of the risky portfolio in the complete portfolio, substitute equation 2.9 with equation 2.10 and replace $y^2\sigma_p^2$ with σ^2 and then derive the utility function with respect to y. Thus, the following equation can be derived:

$$y^* = \frac{E(r_p) - r_f}{.01A\sigma_p^2} \qquad (2.11)$$

, where y^* is the optimal proportion of the risky portfolio in the complete portfolio. With this percentage of risky portfolio, the individual's utility is maximized.

Although the percentage of the risky portfolio has be determined, what kind and what percentage of the investment vehicles still need to be determined in the risky portfolio. According to the 2006 Investment Company Fact Book issued by the Investment Company Institute (ICI), there were 8,454 mutual funds (including funds that invest in other funds), 6,019 unit investment trusts, 634 closed-end funds, and 201 exchange-traded funds at the end of 2006. (http://www.icifactbook.org/06_fb_sec1.html).

Choosing investments is critical for the individual. First, how many investment vehicles should be included? In general, diversification can hedge the nonsystematic risk (or firm-specific risk). According to Statman (1987), the portfolio variance falls as the number of securities increases, but it cannot be reduced to zero. Here, Statman (1987) pointed out that portfolio risk includes nonsystematic risk and systematic risk (or market risk). The nonsystematic risk can be reduced to zero by diversification. However, diversification cannot reduce systematic risk. The theory of reducing nonsystematic risk is that diversification can reduce the portfolio variance. The portfolio's standard deviation contains not only the standard deviation of individual stocks but also the covariance among individual stocks. Equation 2.12 shows the portfolio variance:

$$\sigma_p^2 = W_a^2\sigma_a^2 + W_b^2\sigma_b^2 + 2W_aW_bCov(r_{a,}r_b) = W_a^2\sigma_a^2 + W_b^2\sigma_b^2 + 2W_aW_b\sigma_a\sigma_b\rho_{\text{ab}} \qquad (2.12)$$

, where ρ_{ab} is the correlation coefficient between security A and security B. When ρ_{ab} is equal to -1, the portfolio variance is minimum. When the security in the portfolio increases, the major variance is from the covariance term. The individual security variance becomes less important relatively. Including more negatively correlated securities can reduce risk.

In general the more securities included in a portfolio the better. Traditional wisdom states that high profit accompanies high risk. However, higher return securities with the same risk do exist. In contrast, lower risk securities with the same return also exist.

2.4.2 Mean-Variance Selection Rule

The return and risk dilemma was solved by Harry Markowitz in 1952 with the famous Mean-Variance portfolio selection model by diversification rule. Based on this selection model, the efficient portfolio includes the highest expected return at any risk level. Alternatively, the efficient portfolio includes the lowest risk portfolio at any targeted expected return (Bodie et al., 2002; Lai & Hanna, 2004). For example, portfolio A dominates portfolio B if and only if it satisfies both equation 2.13 and 2.14. In the mean-variance model, the efficient frontier is introduced. The efficient frontier is a locus of the candidate portfolio which satisfies the mean-variance selection based on equation 2.13 and 2.14.

$$E(r_A) \geq E(r_B) \quad (2.13)$$

$$\sigma_A \leq \sigma_B \quad (2.14)$$

To sum up, in equation 2.11, the calculation is based on the assumed constant risk premium $[E(r_p) - r_f]/\sigma_p$. Once the mean-variance selection rule is applied, the higher risk premium, and hence the slope of CAL increases. The tangent point of CAL and efficient frontier indicates the optimal risk portfolio in which the percentage of each security is specified. In contrast, the tangent point of the indifference curve and CAL indicates the optimal complete portfolio where the percentage of risk-free assets and risky assets are specified.

So far, the risky portfolio is just part of a total market portfolio. If the risky portfolio is substituted by the market portfolio, called an aggregate world-wide portfolio, the CAL is called capital market line (CML), the best attainable CAL. Under the theory of the capital asset pricing model (CAPM), there are assumptions that all investors are rational mean-variance optimizers. The important result of CAPM shows that the individual risk premium is proportional to the risk premium of the market portfolio by the beta coefficient. Equation 2.15 shows the result:

$$E(r_i) - r_f = \frac{Cov(r_i, r_m)}{\sigma_m^2}[E(r_m) - r_f] = \beta_i[E(r_m - r_f)] \qquad (2.15)$$

The CAPM implies that as individuals intend to optimize their personal portfolios they each arrive at the same portfolio with the weight on each asset equal to that of the market portfolio (Bodie et al., 2002). The assumption of CAPM that all investors use identical mean-variance selection rules applied to the same universe of securities for the same time horizon and use the same input list (security list) leads to an identical risky portfolio. Therefore, the tangent point of CML and the market portfolio efficient frontier specifies the optimal portfolio allocation. Another important conclusion of CAPM is that the market index portfolio usually outperforms individual stocks. The market index portfolio (mutual fund) provides the passive investment strategy that allows investors not to spend time doing analysis.

CHAPTER 3

LITERATURE REVIEW AND MODEL DEVELOPMENT

The studies discussed below are related to the definition of adequacy indicators. Each study discussed below has a unique approach to define retirement adequacy. Palmer's (1992, 1994) research is essential in retirement; since he addressed a most cited estimate of retirement needs/spending determined by income minus saving. The study of Moore and Mitchell (1997) used a prescribed savings rate as an indicator of retirement income adequacy. Yuh, Montalto, and Hanna (1998) used the assets to needs ratio to define retirement adequacy. Ameriks (2000, 2001) used financial failure rate with the financial plan programming approach to define retirement adequacy. Scholz, Seshadri, and Khitatrakun (2004) compared the actual net worth with optimal net worth to define retirement adequacy. All of these studies used secondary data sets to compare their empirical results against the prescribed standard.

3.1 Retirement Adequacy Indicator

To determine retirement adequacy, some studies, such as Palmer (1992) and Palmer (1994) focused on required replacement ratio, while others, such as Moore and Mitchell (1997), Mitchell and Moore (1998), focused on the prescribed saving rate. The required replacement ratio assumes pre-retirement spending is a proxy of post-retirement spending, and the post-retirement income should be able to maintain post-retirement spending. The prescribed savings rate is a specific saving rate under which the household can maintain a pre-retirement living standard when they retire. Moore and Mitchell's approach is to determine the prescribed rate of saving to meet the required replacement ratio as determined by Palmer. Their approaches are discussed in the following paragraphs.

Palmer (1992, 1994) suggested that the required replacement ratio (post-retirement income divided by pre-retirement income) can serve as an indicator of retirement adequacy. Palmer used two models to establish the replacement ratio. He used an income statement method to estimate the spending by subtracting savings from income. Then, he calculated the required replacement ratio. In the numerator of required replacement ratio of the first model, taxes and savings are subtracted from pre-retirement income to compute a pre-retirement spending level. The denominator is pre-retirement gross income. To make the model more realistic, Palmer adjusted work-related expenses and age-related expenses from the numerator, since the work- related expenses will not happen in retirement, and age related-expenses, e.g. medical expenses, might increase in retirement. Palmer used the 1988 and 1991 Consumer Expenditure Survey dataset to calculate the required replacement ratio across income levels and found that the replacement ratio reduced with pre-retirement income. One of the major missing assumptions in Palmer's study is the lack of consideration given to the potential income generated from accumulated assets. Specifically, he ignored the interest-compounding effect, hence, he could not accurately project retirement adequacy. In addition, Palmer failed to recognize the impact of life expectancy.

To improve Palmer's model weakness, Moore and Mitchell (1997), and Mitchell and Moore (1998) utilized the 1992 Health and Retirement Study (HRS) dataset to project retirement wealth at age 62 and 65 by compounding savings. The model they built determines the prescribed saving rate and replacement rate simultaneously with an iterative simulation until both saving equation and replacement equation hold. Moore and Mitchell's model is more complete than Palmer's. The model they built determines the prescribed savings rate based on Palmer's required replacement ratio. A household with a particular income can find a corresponding required replacement ratio in Palmer's approach. Under the corresponding required replacement ratio, Moore and Mitchell were able to find a prescribed savings rate. To determine the prescribed savings, they utilized market average returns drawn from the Ibbotson 1996 year book to project wealth at the point of retirement. Retirement wealth included: net financial wealth (including non-residential assets and business), net housing wealth, pension, and Social Security. On the saving side, Moore and Mitchell (1997) found that only about 33% of all households in the Consumer Expenditure Survey reach the prescribed savings rate. They also compared the prescribed savings rates with Bernheim's work in 1994, and found Bernheim's target savings rate was twice as large as their prescribed savings rate for the same age group. The key reason for this discrepancy was Bernheim’s omission of household wealth in his formulas.

However, a couple of issues are not taken into account in their research. First, the retirement age is simply assumed to be 62 or 65, but in real life, workers retire at different ages. Second, the iterative method of determining a prescribed saving rate and a required replacement ratio simultaneously is not appropriate for a prescriptive study. Such a method allows those who currently save less to have higher required replacement ratios because the retirement need is estimated by subtracting savings from pre-retirement income. The negative correlation between the savings rate and the replacement rate shown in Moore and Mitchell (1997) is not a plausible measurement of retirement adequacy.

To make a sound retirement wealth projection and plausible measurement of retirement adequacy, Yuh, Montalto, and Hanna (1998) and Yuh, Hanna, and Montalto (1998) used the 1995 SCF dataset to project retirement wealth and retirement needs. They defined retirement adequacy as when individuals are able to retire at their planned retirement age and can maintain their pre-retirement consumption level. The difference between the Moore and Mitchell (1997) piece and both Yuh, Montalto, et al. and Yuh, Hanna, et al. is that the latter authors’ comparison of accumulated retirement wealth and retirement needs at the planned retirement age. Neither Yuh, Montalto et al. nor Yuh, Hanna, et al. estimated retirement needs through the income statement method, i.e., Palmer (1992, 1994) and Moore and Mitchell’s approach. Instead, they estimated retirement needs from current spending using the Consumer Expenditure Survey (CES).

This approach avoids the weakness of biased estimation in retirement needs, i.e., Palmer's method, by deriving the retirement needs from the endogenous variable, saving.

To project retirement wealth, the current asset portfolio is compounded based on historical return from the Ibbotson Yearbook, and a lognormal projection model is utilized (Yuh, Montalto & Hanna, 1998). Individual investment components such as stocks and bonds are projected separately based on historical return. Retirement needs are assumed to be identical to the pre-retirement consumption level, i.e., pre-retirement consumption is a proxy of retirement needs. The pre-retirement consumption information is attained from the 1994 Consumer Expenditure Survey. Yuh, Montalo, et al.'s (1998) study concluded that only 52% of households are on track for adequate retirement.

Although Yuh, Montalto and Hanna (1998) and Yuh, Hanna and Montalto (1998) have a more plausible estimation of retirement needs, the argument of unchanged spending from pre-retirement to post-retirement is still questionable. Palmer (1992, 1994), Moore and Mitchell (1997), Mitchell and Moore (1998), Yuh, Montalto, and Hanna (1998), and Yuh, Hanna, and Montalto (1998) all assumed that retirement spending should be 100% of pre-retirement spending. Although Palmer (1994) has a slight adjustment for the age-related and work-related expense in his second model, the basic idea is to assume 100% retirement spending. They all assumed the individuals in each study should be forward looking such that they could maintain a constant level of consumption. However, a substantial amount of research, such as Hamermesh (1984), Hurd and Rohwedder (2003), Bernheim, Skinner and Weinberg (2001), and Steinberg and Lucas (2004) conclude that there is a reduction in spending from pre-retirement to post-retirement based on their empirical results.

Another indicator of retirement adequacy beyond the replacement rate, the prescribed savings rate and the net worth/needs ratio, is the failure rate of financial assets (i.e., running out of financial assets). Ameriks (2000) used the 1992 and 1995 SCF dataset and financial planning software to project the failure rate of financial assets, and found about 48.5% fail at any time, 15% fail before retirement, and 33.5% fail after retirement. The overall failure rate dropped from 48.5% in 1995 to 44.5% in 1998. For 1998, 13.3% fail before retirement and 31.3% fail after retirement. Because SCF does not ask the respondents about current or future living expenses,

the estimate is based on the assumption that living expenses make up the balance of current income after the respondents had paid all taxes, made any savings contributions, and paid housing expenses and debt obligations.

The major innovation of Amerik's approach was to calculate the financial status dynamically from working life to retirement life by comparing the accumulated financial assets and spending. The financial assets increased when there was surplus from the year before or because of compounding interest, but reduced when withdrawn. This model is more realistic. On the spending side, Ameriks assumed that the living expenses would increase along with the rate of inflation, 3%, and would then decline by 20% at the point of retirement. Although the model is more realistic, the assumed percentage of spending is not persuasive.

Beyond the financial planning software method, Scholz et al. (2004) proposed an augmented model of life cycle saving hypothesis, which is based on the dynamic optimal programming method. They constructed this model to find the optimal net worth in retirement by using the HRS dataset waves 1-4, in which households were assumed to maximize their utility and were subject to restricted resources. They then compared the optimal net worth with the real net worth from the HRS, and found that about 80% of American households reach this optimal new worth level, and were defined as well-prepared for retirement. This model included three sub-models for working households, households at retirement age, and retired households. Earnings and living expenses were adjusted based on their working/retirement status. The assumption of assets is similar to Amerik's that assets increase by income but decrease by withdrawals for living expenses. The ending balance is calculated each year across the working life.

3.2 Summary of Other Issues

3.2.1 Retirement Needs

Bernheim, Skinner and Weinberg (2001) found that consumption drops by an average of 14% at retirement. Hurd and Rohwedder (2003) also concluded that non-retired singles' spending declined about 17% between 1992 and 2000.

Among couples, the reduction average was about 12% between 1992 and 2000. Butrica, Goldwyn and Johnson (2005) concluded that the spending percentage of income increased with age. For example, non-married adults aged 75 and older spent 96% of after-tax income, compared with 86% for those aged 65 to 74. The median level of expenditures declined by 21% between the youngest and oldest age groups, whereas the median value of income before taxes declined by 49%.

However, in most adequacy studies, retirement needs were assumed to be the same as pre-retirement consumption. Moore and Mitchell (1997), Mitchell and Moore, (1998), Yuh, Montalto, and Hanna (1998) and Yuh, Hanna and Montalto (1998), assumed that retirement needs strictly resembled pre-retirement needs. Therefore, the assumption of retirement needs in the retirement adequacy deserves more attention. Ameriks (2000, 2001) assumed living expenses would increase at the inflation rate of 3% and living expenses would decline by 20% at the point of retirement and a further 20% when one member of a couple died. Scholz, et al. (2004) used the per capita consumption in the utility function. The per capita consumption in working life is the household consumption adjusted by the number of adults and the number of children. The utility function of retirement life only includes the number of adults adjustment (i.e., two), but has no adjustment for the number of children in the household. Moreover, the medical expenses are included in the retirement consumption. It is difficult to tell whether Scholz et al. (2004) assume an increase or a decrease in consumption at retirement. From the above, we can see that there is no consensus in the assumption of consumption level at retirement.

The seminal pieces in this discipline assume that consumption remains constant after retirement, although Palmer (1992, 1994) suggested work related and age related spending adjustments in his model. Scholz et al. (2004) are somewhat different from those of other studies. The objective was to maximize utility and the optimal consumption simultaneously. Therefore, they determined consumption first and then determined savings. However, Palmer (1992, 1994), Moore and Mitchell (1997), and Mitchell and Moore (1998) determined savings first, and then determined consumption.

Yuh, Hanna, and Montalto (1998) and Yuh, Montalto and Hanna (1998) determined consumption and saving separately, but still assumed that the consumption levels remains constant. Ameriks (2000, 2001) assumed a specific consumption level and then determined savings.

So far, the retirement needs are discussed relatively to the pre-retirement needs; however, for some extreme cases, e.g. extreme low income households, maintaining a pre-retirement living standard does not guarantee the retirees a good objective living quality. The retirement needs should be adjusted for the extreme cases. Maslow's hierarchy needs theory provides a guideline about how the retirement needs should be met orderly. In the theory section, we have discussed the context of Maslow's hierarchy needs theory; however, so far, no literature of retirement adequacy ever uses this theory as a foundation of estimating retirement needs.

3.2.2 Retirement Income

The projection of Social Security retirement benefits is very complicated, since it requires all of a person's wage history, marital status, birth date, and other related information. The Social Security projection requires the average indexed monthly earnings (AIME) during the 35 years in which the applicant earned the most (Dalton, 2004). Then, the Social Security Administration applies a formula to these earnings and arrives at a basic benefit, which is referred to as the primary insurance amount (PIA). The PIA determines the amount that applicant will receive at his or her full retirement age, but the dollar amount of the benefit depends on the year in which the worker retires. The PIA is indexed to the consumer price index (CPI) annually. Therefore, all wage history is required. However, this would require a longitudinal dataset for 35 years. Moore and Mitchell (1997) and Mitchell and Moore (1998) used Social Security Administration supplied earning files, which covered the taxable maximum earning ceilings from 1951 to 1991, to calculate the AIME. Yuh, Hanna and Montalto (1998) and Yuh, Montalto and Hanna (1998) used normal income as the proxy of AIME to project Social Security and adjust the normal income by CPI. Ameriks (2000, 2001) assumed the real salary growth rate as 5% for ages 25 to 35, and 1% for ages 36 to 50 to project Social Security. Palmer's (1992, 1994) model did not demonstrate how Social Security was calculated, but just subtracted the contribution of Social Security (FICA) to determine spending. Scholz et al. (2004) classified respondents for nine different scenarios, corresponding to the Social Security Administration's low, intermediate, and high long-term projections for interest rates, wage growth rates, and inflation rates.

The assumption of Yuh, Hanna and Montalto (1998) and Yuh, Montalto and Hanna (1998) is not accurate, but acceptable as long as the normal income is a good proxy of AIME. Amerik's (2000, 2001) assumption does not have a persuasive reasoning for specifying 5% and 1% salary increments. Scholz's (2004) projection seems to be based on the current salary, but no more detail is provided. The projection of Social Security benefits by Moore and Mitchell (1997) and Mitchell and Moore (1998) appear to be more accurate.

The projection of defined benefit and defined contribution pension requires more assumption as well. Yuh, Hanna and Montalto (1998), Yuh, Montalto and Hanna (1998), and Ameriks (2000, 2001) used information provided by SCF about the expectation of the amount to be received in a defined pension. Scholz et al. (2004) used the "Pension Present Value Database" that Bob Peticolas and Tom Steinmeier made available on the HRS World Wide Web Site to calculate the value of defined benefit /contribution pensions. Palmer (1992, 1994) did not project defined benefit/contribution pensions. Moore and Mitchell (1997) and Mitchell and Moore (1998) used the software developed at the Institute for Social Research at the University of Michigan to calculate a defined benefit/contribution pensions. This software uses information collected from employers of HRS participants to calculate benefit streams based on workers' salary and service.

The studies with SCF used the self-reported expectation of a defined benefit/contribution amounts. However, the self-reported pension amount might not be accurate. Others with HRS use the additional dataset to calculate the defined benefit/contribution pension. However, there is no clue as to how exactly the amount is calculated exactly in the additional dataset. The linkage between HRS and other datasets is only salaries and service years. Neither SCF nor HRS has an accurate estimate of the pension amount. The projection of defined benefit/contribution pensions requires a more detailed assumptions such as the employee's wage, job tenure/ service years, current age/date of birth, planned retirement age/ actual retirement age, marital status, and life expectancy.

3.2.3 Retirement Asset Allocation

Financial assets and non-financial assets are two major categories of household net worth. Financial assets include non-retirement account financial assets, e.g., checking, saving, stock, mutual funds, and retirement account financial assets, such as 401Ks and IRAs. The definition of non-retirement-account financial assets varies across different studies. Most studies include checking and savings accounts, CDs, stocks, bonds, and mutual funds in non-retirement-account financial assets, although the articles do not specify the details of the financial assets (Palmer, 1992, 1994; Moore & Mitchell, 1997; Mitchell & Moore, 1998, Yuh, Montalto & Hanna, 1998; Yuh, Hanna & Montalto, 1998; Ameriks, 2000, 2001; Scholz, Seshadri, & Khitatrakun, 2004).

Housing is the major asset in most households. Engen et al. (1999) had a deeper discussion about whether to include home equity in retirement assets. They found the reasons for excluding home equity: some surveys suggest that people do not like to move when they are old; others indicate that people do not want to consume home equity to finance retirement; and some evidence suggests that younger elderly households in the 1970s chose not to reduce housing equity.

In previous studies, Moore and Mitchell (1997), Mitchell and Moore (1998), Yuh, Hanna and Montalto (1998), Yuh, Montalto and Hanna (1998) and Scholz et al. (2004), included housing wealth in retirement assets. Palmer (1992, 1994) subtracted the mortgage payment as saving from income to determine the spending. Ameriks (2000, 2001) assumes that upon retirement of the last individual in the household, individuals would "trade down" and purchase a new residence worth 75% of the original home. All remaining mortgage payments, if any, are translated at the point of trade down into a new loan.

Non-financial assets such as non-residential real estate and business are not commonly agreed upon to be included in retirement assets. Moore and Mitchell (1997), Mitchell and Moore (1998), Yuh, Hanna and Montalto (1998) and Yuh, Montalto and Hanna (1998), and Scholz et al. (2004) include non-residential real estate or business in retirement assets. Ameriks (2000, 2001) does not consider any other non-financial assets.

3.2.4 Contribution to Financial Assets

Financial assets are commonly projected to grow based on current balances and assuming that current contributions remain constant in real terms. (Moore & Mitchell, 1997, Mitchell & Moore 1998; Yuh, Hanna & Montalto, 1998; Yuh, Montalto & Hanna, 1998). Those studies projected the financial assets by compounding the return rate but ignored the possibility of additional contribution or reduced contribution. It is understandable that Moore and Mitchell (1997), and Yuh, Hanna and Montalto (1998) and Yuh, Montalto and Hanna (1998) assumed constant contribution, because they assume constant consumption and income. Individuals might sell out their financial assets due to job loss, or increase their contribution due to income increases. To take into account the additional contribution, a savings projection in working life must be determined first. This task requires a lot of assumptions about income, spending, and taxes (Ameriks, 2000, 2001). The financial software method assumed the real salary growth of 5% a year from age 25 to 35, and then 1 % per year while age 36 to 50, then it remains constant after age 50. Ameriks also assumed that living expenses increased at the rate of inflation, i.e., 3% annual rate. Furthermore, the living expenses were assumed to decline by 20% at the point of retirement and by a further 20% when one member of a couple died. Scholz et al. (2004) determined the contribution by determine consumption first. Scholz's method is similar to Ameriks' method. Although Amerik's method can determine the projected assets precisely, those assumptions still need to be examined. So far, most researchers of retirement assets projection or simulation still assume the assets hold constant from their current status.

3.2.5 Rate of Return

In this section, rate of return is related to how non-financial assets, financial assets, and pension values appreciate. First, how the return rate influences non-financial assets will be discussed. For non-financial assets such as non-residential real estate and business, it is difficult to assign a globally accepted return rate. However, it is necessary to assume a return rate, if the study needs to project the retirement assets. Yuh, Hanna and Montalto (1998) and Yuh, Montalto and Hanna (1998) used the inflation-adjusted geometric mean annual composite real estate returns from 1947 to 1982 estimated by Ibbotson. For business, the return rate is assumed to be equivalent to the return rate of small stocks. Moore and Mitchell (1997), Mitchell and Moore (1998), Ameriks (2000,2001) and Scholz et al. (2004) assumed that home, other assets, and real estate remain in constant real terms and applied a 10 year straight line depreciation rate to the vehicle. Palmer (1992, 1994) did not assume the return rate of non-financial assets.

For financial assets, the return rate is easier to estimate, since most of them have a public market. The public transaction offers the return rate. For example, Yuh, Hanna and Montalto (1998) and Yuh, Montalto and Hanna (1998) used the inflation-adjusted geometric mean of annual returns for large stocks, long-term corporate bonds, Treasury

Bills, and small stocks, respectively, for the period 1926 to 1998. However, there are still a number of studies that make a uniform assumption of the return applicable to each category of asset. For example, Scholz et al. (2004) assumed an annualized 4% real rate of return. Ameriks (2000, 2001) assumed that the return rate corresponds to risk tolerance, e.g., 10%, if households were willing to take substantial risk, 9% if households were willing to take above-average risk, 7.5% for average risk, and 6% for taking no risk. Palmer (1992) and Palmer (1994) did not use a return rate. Moore and Mitchell (1997) and Mitchell and Moore (1998) made a very comprehensive assumption of the return rate: 0.5% for checking account, saving account, CDs and T-bill; 2.3% for corporate bonds; 7.2% for stocks and business.

3.2.6 Planned or Actual Retirement Age

To discuss the assumption of retirement age, we must first separate the sample into "currently not retired" and "currently retired". For those currently not retired, Yuh, Hanna and Montalto (1998), Yuh, Montalto and Hanna (1998), Ameriks (2000, 2001) and Scholz et al. (2004) assumed workers would retire at the planned retirement age. Ameriks (2000, 2001) imputed the full retirement age to the planned retirement age, if the planned retirement age was not attainable, and ended up with 32.7 % imputed. For the currently retired population, Scholz et al. (2004) used actual retirement age. Yuh, Hanna and Montalto (1998), Yuh, Montalto and Hanna (1998) and Ameriks (2000, 2001) did not have currently retired sample. Palmer (1992, 1994) assumed only one wage earner in the household and would retire at age 65. Moore and Mitchell (1997), Mitchell and Moore (1998) did not separate samples into retired or non-retired, but simply assumed that all wage earners retired at age 62 or 65.

At age 62 retirees are eligible for Social Security benefits, and at age 65, older retirees have been eligible for unreduced benefits, , so naturally these are the most common retirement ages. This assumption overestimates retirement adequacy, since some workers will retire before ages 62 or 65. The delayed retirement age would allow them to have more time and more income to accumulate retirement assets or be eligible to take Social Security retirement benefits. Yuh, Hanna and Montalto (1998) and Yuh, Montalto and Hanna (1998) concluded that planned retirement age was positively correlated to retirement adequacy; hence, early retirement might induce insufficient retirement asset accumulation. Therefore, the uniform assumption of retirement age of Palmer and Moore and Mitchell in the aggregate data might not be plausible. The empirical results of retirement adequacy might not be representative.

3.2.7 Life Expectancy

The studies comparing the present value of retirement income with the present value of retirement needs should have a plausible assumption of life expectancy, since life expectancy would be the period of discounting retirement income to calculate the amount needed at retirement. Yuh, Hanna and Montalto (1998) and Yuh, Montalto and Hanna (1998) used the actuarial annuity table published by the IRS to determine life expectancy. Ameriks (2000, 2001) estimated the life expectancy by the financial planning software based on the respondent's health status. He added ten years to the life expectancy estimate because the financial planning software generally underestimated life expectancy. Moore and Mitchell (1997) and Mitchell and Moore (1998) estimated the life expectancy by using the forecasted life expectancy variable from HRS. Scholz, et al. (2004) assumed that individuals face a probability of death at each remaining year of life in the stochastic model. The probability of death is incorporated to calculate expected utility. In the other direction, Palmer (1992, 1994) did not specify the life expectancy, because their retirement adequacy measurement did not discount retirement income to the retirement age.

3.2.8 Retirement Income Stages

Quite a few studies have discussed retirement stages, although none have taken retirement stages into account in projecting retirement adequacy of current workers. DeVaney (1993) used a financial ratio as a retirement adequacy indicator, but concluded that different retirement stages might have different results of retirement adequacy. The stage that DeVaney mentioned is life cycle stage, e.g., youth, middle age, elder. DeVaney's remark gives us an idea of financial status variation across life cycle stages. Everett and Anthony (2002) addressed a concept about the retirement stage. They classified retirement life into three stages: Early retirement stage (actual retirement to age 70 ½), Middle retirement (ages 70 ½ to 85 ½) and Late retirement (ages 85 ½ to 95 ½). The stage classification standard is based on the critical age, 70 ½. Tax rules require individuals to start taking distributions from many of their tax-deferred funds and start paying taxes on them at age 70 ½. Furthermore, Social Security has critical ages at 62 and 65. Therefore, we can see that retirement income is fluctuating across retirement life, i.e., income occurs at specific critical ages.

3.2.9 Empirical Studies of Retirement Adequacy

Table 3.1 shows the summary of retirement adequacy indicators, empirical results, and datasets. The gradual development of the retirement adequacy indicator has become more complete and reaches a more realistic measurement. Based on Palmer's method of retirement needs estimation, Moore and Mitchell (1997) concluded that about 33% of households do not reach the prescribed savings rate, Yuh, Montalto, and Hanna (1998) concluded that about 52% would not have enough assets for retirement. Ameriks (2000, 2001) concluded that about 48.5% and 44.5% of households do not have enough financial asset accumulation. Scholz et al. (2004) concluded that about 20% do not reach the optimal net worth. Those studies have different results showing the proportion of inadequate retirement raging from 20% to 52%.

The assumptions of retirement income, retirement needs, retirement asset allocation, contribution to financial assets, return rate, life expectancy, and retirement age are documented. Those assumptions are critical to the retirement study with simulation methodology, since the results of a prescriptive standard depend greatly on the assumptions. However, few studies discussed retirement stage.

Author	Adequacy Proportion	Dataset
Moore and Mitchell (1997)	31% of households do not need to save more, based on retirement at 62; 40% do not need to save more based on retirement at 65. The median couple household would have to save an additional 16% of income for retirement at 62, or an additional 8% of income for retirement at 65.	1992 HRS
Yuh, Hanna, and Montalto (1998); Yuh, Montalto, and Hanna (1998)	Retirement adequacy under mean projection of accumulated assets is 52%; and 42% under pessimistic projection.	1995 SCF
Ameriks (2000, 2001)	The overall adequacy rate rose from 51.5% in 1995 to 55.5% in 1998. For 1995, 85% adequate before retirement and 66.5% adequate after retirement. For 1998, 86.7% and 68.7% adequate respectively.	1992, 1995 SCF for 2000 study 1995, 1998 SCF for 2001 study
Butrica, Iams, & Smith (2003)	65% of current retirees, 56% of near retirees, 55% of early boomers, and 56% of late boomers will replace 75% or more of their lifetime earnings.	1990-1999 MINT
Scholz et al. (2004)	About 80% of American households reached this optimal net worth level, and are defined as well prepared for retirement	1992, 1994, 1996, 1998, 2002, 2004 HRS

Table 3. 1 Retirement Adequacy Indicator and Dataset

3.3 Summary of the Empirical Assumptions

This literature review demonstrates the history of the study of retirement adequacy. Indicators such as required replacement ratio, prescribed savings rates, retirement assets to needs ratio, and financial failure rates are demonstrated in the literature. Most of the adequacy indicators are static rather than dynamic. Static measurements only provide the adequacy status at certain points. The fluctuation of household retirement income reveals that a single adequacy indicator cannot represent the household financial status. Income stage classification in the replacement rate might be one of the solutions, since it both gives a more accurate measurement of retirement adequacy and is dynamic. How to categorize the retirement income stage becomes an important issue. No study has used a retirement stage classification for evaluating retirement adequacy.

The main challenge of determining retirement adequacy is to have a plausible measurement of retirement needs. Palmer's method of determining retirement needs is not persuasive since those who save more currently might desire to spend more in the future. The income statement method does not objectively represent current spending, and hence might not accurately represent retirement spending.

The retirement needs/spending assumption is not consistent across these five studies. The assumption of retirement needs/spending directly influences the results of retirement adequacy; therefore, more attention should be paid to examine the retirement needs/spending. The retirement income generally includes Social Security and a defined benefit pension plan. Although some studies used an additional dataset to project retirement income, the projection is based on criteria, such as age and salary from the original dataset.

The studies also show no consensus about whether or not to include the house as a retirement asset. Housing equity accounts for the majority of accumulated assets and thus its inclusion does substantially influence the result of retirement adequacy.

The contribution to financial assets is either assumed constant (Moore & Mitchell, 1997, 1998; Yuh et al., 1998a, 1998b) or dependent on the surplus of the prior year (Ameriks, 2000, 2001; Scholz et al., 2004). The underlying assumption of constant contribution is that households have surplus and are willing to contribute the same amount. The approach of Ameriks (2000, 2001) and Scholz et al. (2004) assumes that income and consumption change every year, such that the contribution depends on the prior year's surplus.

The assumption of the return rate is diversified. Studies with more comprehensive assumptions, such as Moore and Mitchell (1997, 1998) and Yuh et al., 1998a, 1998b) contained more accurate projections of retirement adequacy. Ameriks (2000, 2001) incorporated the return rate with risk tolerance and assumed a series of return rates, but did not provide evidence for such an assumption. In addition, the high risk tolerance does not necessarily have a causal relationship with a high return rate, whereas the return rate is more likely determined by the asset type. The universal return rate of Scholz et al. (2004) is not plausible.

The self-reported life expectancy from the HRS (Moore & Mitchell, 1997, 1998) is unconvincing. The health determined life expectancy of Ameriks (2000, 2001) is more plausible, but the estimation is not explained. Scholz et al. (2004) also used health-determined life expectancy with a stochastic probability model. The probability of death is used to calculate the expectation of utility. Yuh, Hanna and Montalto (1998a, 1998b) used the actuarial annuity table published by the IRS to determine life expectancy. The approach of Scholz et al. (2004) and Yuh, Hanna, et al. (1998a, 1998b) seems more objective for the aggregate data.

Although researchers do not reach consensus, it is still justifiable to assess which study makes a more plausible assumption. More attention should be given to income stage partition, retirement needs/ spending estimates, and life expectancy. In addition, the personal discount rate assumptions and elasticity of utility functions are not well discussed in these literatures. An accurate projection of retirement adequacy indicators can reveal to U.S. households what they still need to do to improve their retirement saving.

3.4 Definition of Retirement Income Stages

Although DeVaney (1993) and Everett and Anthony (2002) addressed the concept of stages; how to split stages across the life cycle or retirement is still a technical problem. The critical eligibility age for each type of pension may differ by the pension type. Using age-determined stage classification might not disclose the accurate financial status. In contrast, the income-determined stage could disclose a more accurate financial status. The income-determined stage method is more objective and more understandable. However, so far, no study projecting retirement adequacy of workers has ever discussed the income-determined stage method.

I will define a retirement income stage as a period in which the real income remains constant. In practice, some events might cause small income changes, for example, changes in income tax rules. Therefore, to have a more meaningful and technically feasible definition, only projected changes in the number of income sources are considered. Thus, the income stage is formally defined as a period in which the projected number of income sources is constant. Whenever the projected number of income sources changes, one new stage is created. The income stage starts with the planned retirement age and ends when the individual dies. The maximum stage number for a married household is eight, based on the stage drivers of Social Security retirement benefit, Defined Benefit pension, and part-time job wage.

The retirement adequacy indicator fluctuates across the retirement stages, while the method of previous studies concludes that retirement adequacy is constant across retirement life. The more stages a household have the greater the difference of retirement adequacy between this new methodology and traditional methodology, i.e., ignoring stages.

3.5 Calculation of Retirement Adequacy Indicator

Equation 2.6 shows that the future consumption increment depends on real return, personal discount rate, and the risk aversion factor. Since it is difficult to estimate the personal discount rate and risk aversion factor in the Survey of Consumer Finance, the assumption of equal denominator and numerator is made in the equation and thus the goal is to maintain post-retirement consumption at the same level as pre-retirement consumption. This assumption is also made by Engen et. al. (1999) and Scholz et. al. (2004).

During working life, asset accumulation includes two parts, i.e. the current contribution of investment and future contribution of investment. The investment vehicles includes all kinds of financial assets, such as CDs, savings, stocks, bonds, mutual funds, 401Ks and IRAs. Annual contribution is assumed constant (Moore & Mitchell, 1997, 1998; Yuh et al. 1998a, 1998b) based on the assumption of constant consumption and constant income with inflation adjustments only. Therefore, the annual contribution is assumed constant as well. According modern portfolio theory, the return rate varies with risk so that high risk investment vehicles accompany high return. For example, small stock is presumed to have a higher return. Previous studies used to assume a certain level of return fit for all different investment vehicles; however, this is not plausible. In this study, the arithmetic means of the return rate is estimated according the investment categories, such as large stock, small stock, corporate bonds, government bonds, and real estate, for equation 3.1.In general, large capital stock is the stock with more than 2 billion capital and small capital stock is the stock with less than 2 billion capital. Applying Capital Asset Pricing Model (CAPM), the expected return rate is equal to the risk free rate plus the product of beta and risk premium. Those return rates can be obtained from the financial institute, such as Ibbotson Investment Company.

Equation 3.2 shows assets accumulation during work life with current contribution. In this model, we assume households will use the entire accumulated asset to purchase a fixed income annuity at the planned retirement age. The fixed income generated from an annuity in retirement life is demonstrated in equation 3.4. The life expectancy is defined as the a length between planned retirement age and death (Yuh, et al., 1998) Other retirement incomes, such as Social Security, Defined Benefit Pension and part-time jobs highly depend on pre-retirement income (Scholz et. al., 2004) and are demonstrated in equation 3.5. The Social Security retirement benefit is calculated through average indexed monthly earnings (AIME) during the 35 years in which the applicant earned the most (Dalton, 2004). Then, the Social Security Administration applies a formula to these earnings and arrives at a basic benefit, which is referred to as the primary insurance amount (PIA). Similarly, the defined benefit pension and part-time job wage calculation depends on the past salary history as well.

$$A_R = C_S * \frac{[(1+r)^{R-S+1} - (1+r)]}{r} \tag{3.1}$$

$$A_R^{'} = A_S^{'} * (1+r)^{R-S} \tag{3.2}$$

$$P_R = A_R + A_R^{'} \tag{3.3}$$

$$I_t = \frac{P_R}{1 + \frac{[1 - \frac{1}{(1+r)^{D-R-1}}]}{r}} \quad \text{t} \in \{R,...,D\} \tag{3.4}$$

$$I_t^{'} = SS(\sum_{j=S}^{R-1} I_j) + DB(\sum_{j=S}^{R-1} I_j) + PT(\sum_{j=S}^{R-1} I_j) \quad \text{j} \in \{S,...,R-1\}\text{ , t} \in \{R,...,D\} \tag{3.5}$$

$$\begin{aligned} I_K^{'} = 0 \text{ or } & SS(\sum_{j=S}^{R-1} I_j) \text{ or } DB(\sum_{j=S}^{R-1} I_j) \text{ or } PT(\sum_{j=S}^{R-1} I_j) \text{ or } SS(\sum_{j=S}^{R-1} I_j) + DB(\sum_{j=S}^{R-1} I_j) \text{ or} \\ & \text{DB}(\sum_{j=S}^{R-1} I_j) + PT(\sum_{j=S}^{R-1} I_j) \text{ or } SS(\sum_{j=S}^{R-1} I_j) + PT(\sum_{j=S}^{R-1} I_j) \\ & \text{or } SS(\sum_{j=S}^{R-1} I_j) + DB(\sum_{j=S}^{R-1} I_j) + PT(\sum_{j=S}^{R-1} I_j) \quad \text{K} \in \{1,2,3,4,5,6,7,8\} \end{aligned} \tag{3.6}$$

$$REPL_t = \frac{(I_t + I_t^{'})}{I_j} \quad \text{j} \in \{S,...,R-1\}\text{ , t} \in \{R,...,D\} \tag{3.7}$$

$$REPL_K = (\frac{I_t + I_K^{'}}{I_j}) \quad \text{j} \in \{S,...,R-1\}\text{ , t} \in \{R,...,D\}, \text{K} \in \{1,2,3,4,5,6,7,8\} \tag{3.8}$$

$$\text{ADQ}_t\text{=1 if } REPL_t = \frac{(I_t + I_t^{'})}{I_j} \geq \text{BREPL} \tag{3.9}$$

$$\text{ADQ}_t = 0 \text{ if } REPL_t = \frac{(I_t + I_t^{'})}{I_j} < \text{BREPL} \tag{3.10}$$

$$\text{ADQ}_k = 1 \text{ if } REPL_k = \frac{(I_t + I_K^{'})}{I_j} \geq \text{BREPL} \tag{3.11}$$

$$\text{ADQ}_k = 0 \text{ if } REPL_k = \frac{(I_t + I_K^{'})}{I_j} < \text{BREPL} \tag{3.12}$$

where

A: denotes assets accumulated from annual contribution.

C: denotes contribution constantly through working life.

$A^{'}$: denotes assets accumulated from current contribution.

R: denotes planned retirement age.

S: denotes current age.

D: denotes death age.

r: denotes real return according the investment categories, such as small stock, large stock, corporate bond, government bond, and real estate.

P: denotes annuity premium purchased.

I_t : denotes retirement income from annuity distribution

$I_t^{'}$: denotes retirement income from Social Security, Defined Benefit pension, and part-time job

$I_K^{'}$: denotes stage retirement income either from Social Security, or Defined Benefit pension, or part-time job.

$REPL_t$: denotes replacement ratio when stage partitions are ignored

$REPL_K$: denotes replacement ratio with stage partition

BREPL : denotes benchmark replacement ratio derived from Consumer Expenditure Survey based on Maslow's hierarchy needs theory

ADQ: denotes retirement adequacy indicator, a dichotomous variable.

In equation 3.6, Social Security, defined benefit pensions, and part-time jobs are no longer assumed to happen in the same age like in equation 3.5. Since retirement incomes fluctuate across retirement stages even though some households may have all their retirement income sources at the same time, other households have fluctuating real income, and perhaps even periods with zero income. For a married household, the maximum stage number this household has would be 8, if husband and wife retire in different years, and other retirement incomes such as defined benefit pension and part-time job wage happen at different year. As discussed in the literature review, no previous study has taken income stages into account, and therefore ignores the time effect of retirement income. Equation 3.5 has a higher retirement income since it assumes all the retirement incomes happen at planned retirement age, while equation 3.6 computes retirement income at the exact age.

The replacement rates with stage partition and ignoring stage partition are presented in equation 3.7 and 3.8. The replacement rate ignoring stage partition is equal to the annuity distribution and sum of the retirement income divided by the pre-retirement income. In contrast, the replacement rate with stage partition is equal to the annuity distribution and stage retirement income divided by pre-retirement income. The replacement rate with stage partitions and without stage partitions will be different.

According to Palmer (1992, 1994), the required replacement ratio is a proxy of retirement needs as long as the retirement income can cover needs. However, Palmer failed to discuss the extreme high income and extreme low income cases. Maintaining a pre-retirement living standard just provides a relatively adequate retirement. Maslow's hierarchy of needs depict the objective living standards through the classification of needs, e.g., physiological needs, safety needs, love/belonging needs, esteem needs and self-actualization needs.

In equations 3.9 to 3.12 the empirical tests compare the projected replacement rate and the benchmark replacement rate. The adequacy indicator is a dichotomous variable with value 0 and 1. When the projected replacement rate exceeds the benchmark replacement rate, the indicator is equal to 1; otherwise, the indicator equals 0.

3.6 Testable Hypotheses

Based on the theoretical frameworks, literature review and empirical results of previous sections, the following hypotheses are proposed.

Hypothesis 1a: Holding other thing constant, households who have multiple stages are more likely to overestimate retirement adequacy. This hypothesis suggests that households who have multiple stages will simply assume all retirement incomes recognized at the planned retirement age which results in an over-estimation of retirement adequacy due to the time value of money and bounded rationality. Under this over-estimation, they will save less than usual, and result in less accumulated retirement assets. Therefore, households with multiple stages are less likely to have an adequate retirement.

The bounded rationality of consumer psychology proposes that individuals make irrational decisions when encountering complex situations like multiple stages. They are therefore more likely to miss information and make mistakes (Fundenberg, 2006). Those households without multiple retirement stage are more likely to over-estimate retirement adequacy.

Hypothesis 1b: Holding other things constant, the retirement adequacy measurements, i.e., replacement ratio is significantly different across retirement income stages.

Under bounded rationality theory, people think all retirement incomes happen at the same time point. This myopic thinking might lead them to decide to retire earlier, and therefore have a period without income. This period created another stage. Therefore, it is highly possible to have different retirement adequacy across stages. In practice, those retirement incomes happen at different times. Therefore, retirement incomes are different across stages. This study will provide more convincing evidence for the necessity of stage partitioning.

Hypothesis 2a: Holding other things constant, retirement adequacy does not change from 1995 to 1998.

According to Plous's (1993) proposition, consumer behavior is strongly influenced by recent events, and therefore the behavior of contributions will adjust according to the market performance. When the stock market performance changes, individuals might treat the market raise as a permanent phenomenon, i.e., according to Plous's proposition, so they reduce the contribution to retirement account. For example, when the stock market goes up, contributions to the stock investments decrease. The high returns between 1995 and 1998 lead to reduced contributions to individual stocks and mutual funds because investors are myopic and believe that high returns will continue. If stock performance does compensate for the reduction of contribution, the future value of the portfolio will either increase or decrease depending on the net effect of the contribution and stock market performance.

Another scenario is that the individuals are smart enough to know it is a temporary market raise, so do not change the contribution to the retirement account. Under this scenario, the effect toward retirement adequacy is only related to the stock performance. The other scenario under bounded rationality is that individuals do not even sense the market performance has been changed; therefore, do not have any adjustment or adjust slowly. Again, the effect toward retirement adequacy is only related to stock performance. Since all the scenarios might happen, it seems plausible to hypothesize that the positive and negative effects of stock market are canceled out each other. Therefore, it is plausible to hypothesize that retirement adequacy does not change from 1995 to 1998.

Hypothesis 2b: Holding other things constant, the retirement adequacy of households does not change from 1998 to 2001.

From the Yahoo Finance website, the Dow Jones Industrial Average index was at 93% of its previous peak, and the S&P 500 was at 83% of its previous peak on May 1,

2001. However, for most of the first eight months of 2001, the level of the S&P 500 was above the corresponding period in 1998. Also, income was higher in 2000 than in 1997. Therefore, retirement adequacy depends on the net effect of contribution and stock market performance.

Hypothesis 2c: Holding other things constant, the retirement adequacy of households does not change from 2001 to 2004.

From the Yahoo Finance website, the Dow Jones Industrial Average closed at about 10911.94 on May 1, 2001, while it closed at about 10188.45 on May 3, 2004 (http://finance.yahoo.com). The S&P 500 also shows an decreasing trend by having a close price at 1183.50 on April 9, 2001 and a close price at 1098.7 on May 3, 2004. The index chart of Dow Jones Industrial Average showed a decrease in the middle of 2003 but an increase after that. The indices were around the same level in both 2001 and 2004. According to bounded rationality theory, contributions will remain constant. Therefore, it is plausible to assume that retirement adequacy did not change in this period.

Hypothesis 3a*:* Holding other things constant, households with Defined Benefit pension plans are more likely to have retirement adequacy.

The Defined Benefit pension is a rule-of-thumb for retirement income replacement. It is relatively easy to manage for employees. Therefore, according to bounded rationality theory, households with defined benefit pension plans are more likely to have retirement adequacy.

Hypothesis 3b: Holding other things constant, households with Defined Contribution pension plans are more likely to have retirement adequacy.

The defined contribution pension, a self directed pension plan, is a good retirement plan to control retirement saving. It helps the household to practice the task of planning ahead for the retirement saving.

Hypothesis 4: Holding other things constant, households with expectations of inheritance are less likely to have retirement adequacy.

The expectation of inheritance influences retirement adequacy, since this expectation influences current behavior. In addition, the expectation variables also serve as control variables in the multivariate analysis since those expectation variables might plausibly influence the dependent variable. The household expecting to receive inheritance will reduce their household savings, since they presume permanent income to be much higher than current income. They will consume more than their current income. Therefore, controlling every other thing; individuals with the expectation of inheritance are less likely to have adequate retirement.

Hypothesis	Behavioral model (Bounded Rationality)	Rational forward planning life cycle model
H1a	Retirement adequacy lower for those with multiple stages, controlling for resources	No difference in retirement adequacy between those with and without multiple stages, controlling for resources
H1b	Significant differences in retirement adequacy between stages	No difference in retirement adequacy for different stages
H2a	No significant difference, myopic consumers might adjust contributions	Retirement adequacy in 1998 is better than 1995, because rational consumers will not adjust contributions
H2b	No significant difference, myopic consumers might adjust contributions	Retirement adequacy in 2001 is better than 1998, because rational consumers will not adjust contributions
H2c	No significant difference, myopic consumers might adjust contributions	Retirement adequacy in 2004 is about the same as 2001, because stock market is about the same.
H3a	Yes, if households follow rules of thumb	No, if households with DB plan rationally plan to have lower retirement contributions
H3b	Yes, DC plan provides control, otherwise irrational households would not practice self-control	No --- would otherwise contribute enough to achieve retirement adequacy
H4	No, myopic households will not be influenced by inheritance expectation	Yes, because the measure of retirement adequacy does not take into account the possible inheritance. A rational household will save less today because of the expected inheritance.

Table 3. 2 Summary of Hypotheses Based on Behavior Model and Rational Forward Planning Life Cycle Model

Table 3.2 summarizes the theoretical frameworks for the hypotheses. In the first hypothesis, the behavior model reasoning is that people are bounded rational under a complicated situation, i.e., multiple stages, and can only apply a simple rule of thumb to make decision. Based on this model, people are more likely to mistakenly treat the time point of retirement income when facing a complicated situation. In contrast, the rational life cycle model always assumes people are rational enough to plan, and will therefore not make a mistake even when facing a complicated situation.

In second hypothesis, the rational life cycle saving model is the theoretical framework of testing the hypotheses, under which, people are assumed to keep a constant contribution to their retirement accounts and benefit from the stock market performance. On the other hand, the behavior model presumes people will change their contribution amount according to stock performance. Changes in retirement adequacy mainly depend on the net effect of contribution and stock market performance.

In the third hypothesis, again, the two models assume people behave in opposite ways. The behavior model presumes that people will maintain a constant contribution since those pension plans help self control, whereas the life cycle model suggests people will reduce contribution to match lifetime income and lifetime needs. Furthermore, in the fourth hypothesis, the behavior model does not assume people's behavior is influenced by the expectation of inheritance, while the life cycle model assumes that people will save less, resulting in less retirement adequacy.

The above hypotheses include some of the independent variables of the logistic regression model. Demographic variables, such as age, gender, education, marital status, and race are not formally tested, since there is no hypothesis that correlates them with the retirement adequacy indicator. In addition, according to the theoretical discussion and empirical results in the literature discussed above, those variables are likely to be related to retirement adequacy, and therefore are included in the multivariate analyses as control variables.

CHAPTER 4

DATA AND SAMPLE

4.1 Data and Sample Selection

The SCF is a triennial cross-section dataset sponsored by the Board of Governors of the Federal Reserve System in cooperation with the Statistics of Income Division of the Internal Revenue Service. Data for the 2001 SCF were collected by the National Opinion Rersearch Center (NORC) (Kennickell, 2003). The purpose of the SCF is to provide comprehensive and detailed information on financial characteristics as well as demographic characteristics and expectations/attitudes characteristics of U.S. households.

The SCF is a dual frame sample design. One frame is selected from a standard multi-stage area-probability design and the other is selected from the statistical records (e.g., the individual tax file) derived from the tax data by the Statistics of Income Division of the Internal Revenue Service (Kennickell, 2003). The second sample was designed to disproportionately select families that were likely to be relatively wealthy (Kennickell, 2003).

In this dissertation, the 1995, 1998, 2001, and 2004 Survey of Consumer Finance (SCF) datasets are used to test the empirical result. The sample selection rule is to select those households currently working and with a head-of-household ages 35 to 70. Total sample size is 19,252. Since this study is to project future retirement adequacy, the sample only includes those households with either a head or spouse currently working. Respondents who are younger than 35, might change jobs, or marital status, therefore, the sample includes only those over 35. In addition, the 70 ½ mandatory Social Security withdrawal age makes us select those under 70.

Furthermore, since SCF tends to sample more wealthy households we used variable weight to adjust the sampling weight. The Federal Reserve Bank provides the weight adjustment macro, so we used it to adjust the sampling weight. Repeat Imputation Inference (RII), the technique of handling missing data and precise inferring and testing, will also be discussed in this chapter. More detailed discussions of the dataset, the sample, and the strengths and weaknesses of using SCF will be discussed in this chapter.

4.2 Weight

The SCF sample is not an equal-probability design; therefore, weights play a critical role in interpreting the survey data. The main data set contains the final non-response-adjusted sampling weights. These weights are intended to compensate for unequal probabilities of selection in the original design and for unit non-response (failure to obtain an interview) (Kennickell, 2003). Therefore, it is necessary to weight descriptive analyses to make the results representative of U.S. households (Lindamood, Hanna & Bi, 2007). However, in the multivariate analysis of Lindamood et al.'s study, the analysis result with the weighted method and the un-weighted method have similar but not identical results. The better criteria for running weighted multivariate analysis is when the weights are endogenous and suspect for hypothesis testing (Deaton 1997).

4.3 Multiple Imputation and RII Technique

The problem of missing values due to non-response rate has been critical in data analysis and survey sampling. If the missing values happen randomly, deleting them does not hurt the parameter estimate significantly, since the missing values proportionally represent the population. However, if the missing values are not random, i.e., related to the estimated parameters, it will result in a biased estimation. For example, if the wealthy households skip the questions related to their financial situation, deleting them might result in a lower mean value of household financial situation. To solve this problem, the most commonly used technique is imputation.

The SCF data has five complete data sets called "implicates" as a result of multiple imputation to handle missing data (Rubin, 1987; Montalto et al., 2000). This study uses repeated-imputation inference (RII) techniques to combine the five different data sets to make valid inferences (Rubin, 1987; Montalto et al., 2000; Montalto & Sung, 1996). The statistical inference and test task can be accomplished by the RII technique. Compared to traditional statistical inference and tests, the RII technique remedies the weakness of a missing value, since these five implicates have their own distributions. The key is to use all the five implicates simultaneously instead of using individual implicates separately; otherwise, it might result in a biased estimate (Lindamood, Hanna & Bi, 2007). The total variance rises due to the corresponding imputation. The total variance includes “between” implicate variance and “within” implicate variance. Once we determine the sample mean, total variance, and degree of freedom, we can execute the inference and test through T statistics.

4.3.1 RII for T-TEST

The RII technique is commonly used for regression analysis, such as ordinary least square regression and logistic regression. However, it is not commonly used for a means test, such as t-test. The study of Montalto and Sung (1996) has a one sample t-test with the point estimates of mean and variance. The point estimate of mean is the average value of five implicates. The point estimate of variance is the sum of “between” implicate variance and “within” implicate variance. Compared to non-RII method, the RII method has greater standard error; thus, has a smaller T statistics. The reduction of T statistics reduces the likelihood of rejecting null hypothesis. Using this method does not influence the type I and type II error, since those errors are predetermined in the maximum likelihood estimation; whereas, the test statistics are affected as mentioned above.
The T test statistic is as follows:

$$t = \frac{\overline{Q_m} - Q_o}{\sqrt{T_m}} \qquad (4.1)$$

where

$\overline{Q_m}$: denotes the point estimate of mean value

Q_o : denotes the tested parameter value

T_m : denotes the total variance of point estimate

However, from equation 4.1, it is difficult to perform the two-sample t-test; since the total variance in the two-sample t-test is different from that of the one-sample t-test. Equation 4.2 shows how the total variance is conducted in the two-sample t-test. When we assume these two samples have constant variance, the pooled sample variance is as follows:

$$T_{mp} = \frac{(n_1 - 1)T_{m1} + (n_2 - 1)T_{m2}}{(n_1 - 1) + (n_2 - 1)} \qquad (4.2)$$

where

T_{m1} : denotes best point estimate of variance of first sample

T_{m2} : denotes best point estimate of variance of second sample, which is calculated based on method of Montalto and Sung (1996).

n_1 : denotes sample size of first sample

n_2 : denotes sample size of second sample.

Moreover, the degree of freedom is different from the one sample t-test. The degree of freedom of two-sample t-test is as follows:

$$\text{d.f.} = \frac{[(T_{m1}/n_1) + (T_{m2}/n_2)]^2}{\frac{(T_{m1}/n_1)^2}{n_1 - 1} + \frac{(T_{m2}/n_2)^2}{n_2 - 1}} \qquad (4.4)$$

Because the best point estimates of pooled variance and degree of freedom is calculated in equation 4.3 and 4.4, it is possible to use those estimates to set up a two-sample t-test statistic. It is as follows:

$$t=\frac{(\overline{Q_{m1}}-\overline{Q_{m2}})-(Q_{o1}-Q_{o1})}{\sqrt{T_{mp}}\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} \tag{4.3}$$

However, if the variances of sample distribution are not equal, the variance and degree of freedom are changed. Also, the pooled variance is no longer suitable for this test statistic, but the combination of individual variance is used. The degree of freedom is as follows:

$$\text{d.f.}=[(\frac{T_{m1}}{n_1}+\frac{T_{m2}}{n_2})^2]/[(\frac{T_{m1}}{n_1})^2/n_1+(\frac{T_{m2}}{n_2})^2/n_2] \tag{4.5}$$

Then, the test statistic is as follows:

$$t=\frac{(\overline{Q_{m1}}-\overline{Q_{m2}})-(Q_{o1}-Q_{o1})}{\sqrt{\frac{T_{m1}}{n_1}+\frac{T_{m2}}{n_2}}} \tag{4.6}$$

Appendix A and B present the corresponding SAS code for the two-sample t-test with constant variance assumption and non-constant variance assumption.

4.4 Strength of the SCF in Testing the Hypotheses

The strength of the SCF dataset is that it contains very detailed financial information, such as CDs, bonds, insurance, stocks, and mutual funds. When testing the hypotheses, defined benefit pension and defined contribution pension are required independent variables. The SCF data set includes all contributions, withdrawal amounts, and withdrawal age information of these pensions. The second strength of the SCF dataset is that it provides a good estimate of pre-retirement income, such as normal income. Normal income can be used to calculate Social Security and defined benefit pensions. In addition, the normal income can be used to calculate the retirement adequacy indicator, i.e., the replacement ratio.

The third strength of using SCF is that the Federal Reserve Bulletin Board provides sufficient technical support. It includes the complete asset and liability macros, which can be easily applied to the data analysis. CPI adjustment and risk tolerance are also provided.

4.5 Weakness of the SCF in Testing the Hypotheses

As discussed above, the SCF does not provide a measurement of Social Security. Social Security constitutes a major portion of retirement income. Due to the shortage of Social Security information, some authors used the additional dataset, the Social Security Administration supplied earning profile, to calculate Social Security (Moore & Mitchell, 1997, 1998; Scholz et al., 2004). Although part of the information is provided by the Social Security Administration, the calculation of Social Security benefits is not described explicitly in these studies. Other more detailed information about Social Security calculations can be obtained from the Social Security Bulletin, Annual Statistical Supplement. Based on the earning profiles and planned retirement ages, the amount of PIA and delayed retirement credit are calculated.

Secondly, we hypothesized that retirement adequacy will decrease from 1995 to 1998, increase from 1998 to 2001, and remain constant from 2001 to 2004. As we discussed above, the stock market price index is not provided in the SCF. Instead, the SCF asks respondents how they feel about economic trends. The question asked by the SCF is more subjective. The objective measurement of economic trends is expressed in the stock market price index. The price index can be obtained through many financial websites such as Yahoo Finance and Morning Star.

Another weakness of the SCF is that it does not ask for respondents' current or future expenses (Ameriks, 2000). The method of Yuh et al. (1998a, 1998b) and Moore and Mitchell (1997, 1998) requires an accurate estimate of retirement needs. Their estimation of retirement needs is based on multivariate analysis using the Consumer Expenditure Survey. However, this estimation still depends on whether the model fit well, which requires a full disclosure of methodology.

Life expectancy is based on the subjective expectation of the respondent. The SCF just asks respondents how old they expect to live. Americks (2000, 2001) used the health situation to project life expectancy. Yuh et al. (1998a, 1998b) used the IRS-published actuarial annuity table. There is evidence that life expectancy is correlated to current age. Using the actuarial annuity table, we can construct a regression model with life expectancy as a dependent variable and current age as an independent variable to predict the life expectancy.

Return rates of financial and non-financial assets are not provided either. Return rates are critical when we calculate accumulated assets. It is difficult to accurately predict the return rates. Monte Carlo bootstrap simulation and lognormal projection are commonly used to predict return rates. The lognormal projection of return rates is attainable from Ibbotson Associates. The geometric mean and standard deviation in lognormal projection provides a more objective estimate of return rates.

The testability of part-time job wages are partly attainable. The SCF data set asks respondents whether they will work part-time right after they retire. However, the SCF data set does not provide a variable to record part-time job wages. One solution to this problem is to estimate part-time job wage based on full-time job wage. The Bureau of Labor Statistics provides the aggregate levels of part-time job wages (from Table 1 and Table 5 of BLS.), which shows the evidence that part-time wages are roughly 1/3 of full-time wages.

4.6 Inflation Effect

The public SCF dataset uses the normal price for valuing the assets, liabilities, income and expense. This inflation effect is adjusted by the applying price index adjustment macro, which is provided by Federal Reserve Board. In the SAS code of calculating assets and liabilities, the variable CPILAG is applied to adjust the value of old survey data to current survey data. For example, the house value in 1998 is adjusted to the equivalent value in 2004, because 2004 is the last survey dataset in this study. For income and expense items, the variable CPIADJ is used to adjust the value of income or expense to the value of current survey year. After those adjustments, the assets, liabilities, income and expense values of different survey have a fair comparison basis.

4.7 Conclusion

Benefited from the detailed information of income, assets, and liabilities in the SCF dataset, the replacement ratio is easy to calculate. However, some additional information is still needed. For example, the Social Security Administration supplied earning profile is needed to calculate the Social Security retirement benefit. Also, the IRS actuarial table is needed to calculate life expectancy. Moreover, the rate of return estimation can be obtained from Ibbotson Yearbook. In addition, the part-time job wage estimation can be obtained from Bureau of Labor Statistics. Although the SCF dataset has these limitations, the SCF dataset is still most appropriate dataset to test the hypotheses.

CHAPTER 5

METHODOLOGY

5.1 Statistical Methods

5.1.1 Two-Sample T-Test

The method of two-sample t-test is commonly used in comparing two sample means difference. Two-sample t-test is classified to two independent sample test and two paired sample test. The two-independent sample test requires the selected samples are independent, while the paired sample test requires selected samples to be correlated and most commonly used in panel data to compare the treatment effect. In this study, the dataset is a cross section dataset; therefore, the two-independent sample test is utilized. The difference between independent sample test and paired sample test is the standard error for the T test statistics. The standard error of independent sample test is a combination of standard error of each sample, whereas the paired standard error is just a single set standard error of the distribution of means difference (Ramsey and Schafer, 2002).

Constant variance is one of the two-independent sample test assumptions. This assumption requires the variance of each sample to be constant, and therefore be able to calculate the pooled standard deviation with the unbiased estimate of variance. However, when this assumption is violated, the standard deviation must be a combination of each individual stand deviation. Moreover, the degree of freedom is different between these two scenarios, i.e., constant variance and non-constant variance. The degree of freedom under constant variance assumption is equal to the combination of total sample size minus two, i.e., $n_1 + n_2 - 1$; in contrast, the non-constant variance scenario has degree of freedom as $[(\frac{\delta_1}{n_1} + \frac{\delta_2}{n_2})^2]/[\frac{(\frac{\delta_1}{n_1})^2}{n_1} + \frac{(\frac{\delta_1}{n_1})^2}{n_1}]$. Both scenarios are commonly used in a statistical package for benchmark.

5.1.2 Logistic Regression

Since our dependent variable, the retirement adequacy indicator which is defined by replacement rate exceeding required replacement ratio, is dichotomous, logistic regression would be a good approach for multivariate analysis. The logistic regression model has a linear form for the logit of this probability,

$$\text{logit}[\pi(x)] = \log(\frac{\pi(x)}{1-\pi(x)}) = \alpha + \beta(x) \text{ , where } \beta \text{ is a vector of } \beta_1, \beta_2, \beta_3, ..., \beta_p$$

Based on this logistic regression, we can see how strong the association is between the independent and dependent variables. Logistic regression is a special case of the generalized linear model (GLM). In the logistic model, we set dummy variable for each independent variable, i.e., 1 for success, and 0 or fail. For example, we set dummy variables as 1 for married couple, but 0 for non-married couple.

Odds for $x_1 = 1$: $\frac{\pi(x_1 = 1)}{1-\pi(x_1 = 1)} = e^{(\alpha+\beta_1 + \textit{controlled} \text{ independent varaibles})}$

Odds for $x_1 = 0$: $\frac{\pi(x_1 = 0)}{1-\pi(x_1 = 0)} = e^{(\alpha + \textit{controlled} \text{ independent varaibles})}$

Odds ratio between $x_1 = 1$ and $x_1 = 0$: Odds ratio= $\frac{\pi(x_1 = 1)/(1-\pi(x_1 = 1))}{\pi(x_1 = 0)/(1-\pi(x_1 = 0))} = e^{\beta_1}$

Note that the intercept and the controlled independent variables are canceled out when calculating the odds ratio. Whenever the odds ratio exceeds one, we can conclude that married couples are more likely to have adequate retirement than non-married couples.

Reference Group

When the independent variable has more than two levels, we can set one of the levels as the reference group. For example, we want to compare the retirement adequacy among 1995, 1998, 2001 and 2004. We set $x_1 = 1$ when the year is 1998, otherwise $x_1 = 0$; and $x_2 = 1$ when year is 2001, otherwise $x_2 = 0$; and $x_3 = 1$ when year is 2004, otherwise $x_3 = 0$. So the model is: $\text{logit}[\pi(x)] = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3$. Note that we do not set an independent variable for the year 1995, since we chose it as the reference group. When we compare year 2001 and year 1995, the odds and odds ratios are as follows:

Odds for $x_2 = 1$: $\frac{\pi(x_2 = 1)}{1 - \pi(x_2 = 1)} = e^{(\alpha + \beta_1 * 0 + \beta_2 + \beta_3 * 0)} = e^{(\alpha + \beta_2)}$

Odds for $x_2 = 0$: $\frac{\pi(x_2 = 0)}{1 - \pi(x_2 = 0)} = e^{(\alpha + \beta_1 * 0 + \beta_2 * 0 + \beta_3 * 0)} = e^{\alpha}$

Odds ratio between $x_2 = 1$ and $x_2 = 0$: Odds ratio= $\frac{\pi(x_2 = 1) / (1 - \pi(x_2 = 1))}{\pi(x_2 = 0) / (1 - \pi(x_2 = 0))} = e^{\beta_2}$

Note that one can argue that $x_1 = 1$ or $x_3 = 1$ in the second odds, because when year is not equal to 2001, it is possible that year is 1998 or 2004. But the logistic regression will control the value of x_1 and x_3, i.e., set them equal to zero, such that we can compare the odds between 2001 and 1995. That is why we have 1995 as our reference group. This concept can be applied to the variables with more than two levels, and then set one of the levels as the reference group.

5.1.2.1 Dependent Variables in Logistic Regression

The replacement ratio is defined as post-retirement income divided by pre-retirement income. Post retirement income includes a withdrawal from accumulated retirement assets and disposable retirement income. The accumulated retirement assets include non-retirement account financial assets, such as CD, bonds, stocks, and mutual fund, retirement-account financial assets, such as 401k and IRA, non-financial assets, such as non-residential real estate, and owned business. The disposable retirement income includes Social Security, defined benefit pension, and part-time job wage. In this study, the withdrawal from accumulated retirement assets is treated as buying a fixed income annuity with annual constant payment. Pre-retirement income is presumed equal to normal retirement income.

Non-Retirement Account Financial Assets

The non-retirement account financial assets are classified to cash equivalents, bonds and stocks to calculate the time value of money. The following equation shows how it is calculated.

$$FVNRF=\sum_{i=1}^{3} CBNRF_S^i * cpiadj * (1+r^i)^{R-S} \qquad (5.1)$$

where

FVNRF: denotes future value of non-retirement account financial assets

CBNRF: denotes current balance of non-retirement account financial assets

i=1: denotes cash equivalent assets

i=2: denotes individual stocks or stocks split from mutual funds

i=3: denotes individual bonds or bonds split from mutual funds

cpiadj: denotes consumer price index adjustment

r^i : return rate corresponding to the investment vehicles

R: planned retirement age

S: current age

Equation 5.1 shows that the future value of non-retirement account financial asset is equal to the product of current balance of investments compounding return rate and consumer index adjustment. In addition, the SCF dataset has a question asking what percentage the individual stock counts in the mutual fund; therefore, the individual stock can be separated from mutual fund. After combining all stocks, the pooled stocks are compounded by the return rate during the working life, i.e., between current age and planned retirement age.

The cash equivalent asset is defined as a high liquidity asset, such as checking, saving, CD, money market account, and call accounts at a brokerage. Stock return rate and bond return rate are presumed to be equivalent to large stock return rate and corporate bond return rate, provided by Ibbotson, respectively for the conservative purpose. Bond return rate is presumed to be equivalent to the average T-Bill rate. Those are conservative assumptions. Future contribution of non-retirement account financial is not constant and the SCF dataset does not provide this information; so it is not included in this equation.

Retirement-Account Financial Assets

The major difference between non-retirement account financial assets and retirement account financial assets is that most retirement-account financial assets have fixed amount contribution and regularly contributed. Hence, the contribution is included in equation 5.2. Another difference is that the investment subject of retirement-account financial asset includes real estate. Therefore, equation 5.2 includes the individual real estate split from 401K or IRA.

$$FVRF=\sum_{i=1}^{4} CBRF_S^i*cpiadj*(1+r^i)^{R-S} + \sum_{i=1}^{4} C_S^i*cpiadj *[(1+r^i)^{R-S+1}-\frac{1+r^i}{r^i}] \quad (5.2)$$

where

FVRF: denotes future value of retirement –account financial assets

CBRF: denotes current balance of retirement-account financial assets

i=1: denotes cash equivalent assets split from mutual funds, 401K and IRA

i=2: denotes stocks split from mutual funds, 401K and IRA

i=3: denotes bonds split from mutual funds, 401K and IRA

i=4: denotes real estates split from mutual funds, 401k and IRA

C_S^i: denotes the contribution of the corresponding investment vehicle

As discussed in the literature review section, a large number of the studies assume the annual contribution to retirement assets remain constant, because the income and consumption level do not fluctuate across working life. Therefore, the annual contribution in this study is assumed to be constant in the study as well.

Non-Financial Assets

The SCF dataset has variables recording the values of other residential assets and non-residential assets separated from the major residential assets. Those assets are either time shares, vacation houses, or the real estates for investment purposes. The return rate of owned business is presumed to be equivalent to small stock return rate, since most of the owned business is small capital business.

$$FVNF= \sum_{i=1}^{3} CBNF_S^i*cpiadj*(1+r^i)^{R-S} \quad (5.3)$$

where

FVNF: denotes future value of non-financial assets

CBNF: denotes non-financial assets

i=1: denotes non-residential real estates

i=2: denotes owned business

i=3: denotes other residential real estates

The accumulated retirement assets at planned retirement age is equal to the sum of FVNRF, FVRF, and FVNF as discussed above. The withdrawal of accumulated retirement assets is assumed to be a fixed amount withdrawal during retirement life.

Social Security

Another piece of retirement income is the disposable income, such as Social Security, defined benefit pension, and part-time job wage. The calculation of Social Security is complicated, since it involves salary history, marital status, and planned retirement age. In this study, the salary history is replaced by the normal income before retirement. Marital status and planned retirement age are provided by the SCF dataset. In addition, the calculation of early retirement penalty and deferred retirement credit is need as well. The following equation shows how the Social Security retirement benefit is calculated:

$$\mathrm{SS}(\sum_{\mathrm{i=S}}^{\mathrm{R}} \mathrm{I_i}) = f(\sum_{\mathrm{i=S}}^{\mathrm{R}} \mathrm{I_i}) * (1 - re_R) * (1 + cr_R) \qquad (5.4)$$

where

re_R: denotes the reduction percentage of early retirement

cr_R : denotes the credit percentage of deferred retirement

In equation 5.4, the Social Security retirement benefit is not differentiated for the marital status. However, for a legally married couple, the spouse with a lower average earnings record would be eligible to receive a benefit equal to 50% of the pension of the higher paid spouse.

Defined Benefit Pension

The SCF dataset have variables recording the expected age of taking defined benefit pension, payment, and the frequency of payment. In this study, the amount of defined benefit pension is defined as the product of payment and frequency of payment. In addition, the SCF has three different defined benefit pension variables for respondent and spouse respectively. The following equation shows how defined benefit pension is calculated:

$$\mathrm{DB}=\sum_{i=1}^{6}\sum_{j=1}^{31}\mathrm{PMT}_{ij} * FREQ_{ij} \tag{5.5}$$

where

DB: denotes the total defined benefit pension benefit that a household has

PMT: denotes the benefit payment

FREQ: denotes the frequency of payment

i=1-6: denotes three defined benefit pension for respondent and spouse

j=1: denotes daily payment

j=2: denotes weekly payment

j=3: denotes bi-weekly payment

j=4: denotes monthly payment

j=5: denotes quarterly payment

j=6 denotes annual payment

j=11: denotes semi-annual payment

j=12: denotes bi-moth payment

j=14: denotes payment by job

j=31: denotes semi-month payment

Part-Time Job Wage

The SCF dataset has variables recording the whether the respondent will have part-time job and the planned age of stopping part-time job. However, it does not provide the wage variable, thus, based on the publication of Bureau of Labor Statistics, the part-time job wage is assumed to be one third of the full time job wage.

Benchmark Replacement Ratio

From above discussion, the retirement income equals to the sum of annuity withdrawal, Social Security, defined benefit pension, and part-time job wage. The actual replacement ratio is equal to retirement income divided by pre-retirement income.
The benchmark replacement ratio is derived from the proxy of retirement needs, which is attained from the 2005 Consumer Expenditure Survey (CES), divided by income (U. S. Department of Labor, 2005).

Table 5.1 represents the summary of benchmark replacement ratio across income categories.

Income Category	1	2	3	4	5	6
Income Range	Less than $10,000	$10,000 to $14,999	$15,000 to $19,999	$20,000 to $29,999	$30,000 to $39,999	$40,000 to $49,999
Benchmark Replacement Ratio	2.53	1.49	1.27	1.07	0.90	0.82
Income Category	7	8	9	10	11	12
Income Range	$50,000 to $69,999	$70,000 to $79,999	$80,000 to $99,999	$100,000 to $119,999	$120,000 to $149,999	$150,000 and more
Required Replacement Ratio	0.74	0.68	0.64	0.62	0.58	0.28

Table 5. 1 Summary of Benchmark Replacement Ratio

The dependent variable of logistic regression is a dichotomous variable with value equal to 1, when the replacement ratio is greater than the benchmark replacement ratio; otherwise, it is equal to 0. Households with benchmark replacement ratio greater than 1 are those with lower current income correspondingly, and are possible to have higher income in the future. However, if the lower income persist for a long time, and become permanent income, then the benchmark replacement ratio might not be correct.

The logit is a log function of odds, i.e., the probability of having retirement adequacy divided by the probability of not having retirement adequacy. Therefore, the likelihood of having retirement adequacy can be calculated by simple mathematics manipulation of the estimated coefficients as discussed in section 5.1.2.

5.1.2.2 Independent Variables in Logistic Regression

Independent variables such as demographic variables, economic status variables, and financial attitude variables are incorporated in those retirement adequacy studies. In general, the demographic variables include age, education, race, and marital status. In multivariate analysis it is more useful to know what kind of individual is more likely to have an adequate retirement. Therefore, the demographic variables are important for the multivariate analysis.

Current Age

The independent variable current age is the age of head-of-household using the following 4 categories: 35-44, 45-54, 55-64, and 65-70. Four dummy variables are set up for each category, and Table 5.1 demonstrates the settings of the dummy variables. The sample selection rules require selecting those households with a head between 35 and 70. The 10-year segment of ages represents generations. For example, the category 35-44 represents youth, the category 45-54 represents early mid-age, 55-64 represents late mid-age, and 65-70 represents elders. In addition, both the Current Population Survey and the Consumer Expenditure Survey use 10 year to segment in their categories. In logistic regression, age 35-44 is set as the reference group.

Planned Retirement Age

Social Security plays a critical role determining retirement income so the planned retirement age should be classified according to Social Security’s critical ages. In this multivariate analysis planned retirement ages are classified as retired before 62, retired between 62 and full retirement age, and retired after full retirement age, since the legal age of Social Security retirement benefit is age 62, and the full retirement age varies with birth year. The full retirement age for those born before 1943 is age 65, and the full retirement extends to age 66 for those born between 1943 and 1960, and age 67 for those born after 1960. Three dummy variables are set up for these three categories.

Education

Four categories of education variables are classified in the multivariate analysis: less than high school, high school, some college, and bachelor degree. According to the Consumer Expenditure Survey, some college and associate degree counts about 24.7%, high school graduate counts about 20.3%, less than high school counts about 12.1%, and bachelor and master counts about 21%. Therefore, the education variables are as follows: less than high school, high school, some college, and more than or equal to a bachelor's degree with four dummy variables. The reference group has less than a high school education.

Race and Ethnicity

In the 1995 Survey of Consumer Finance (SCF) dataset race identification is categorized into: Native American/Eskimo/Aleut, Asian or Pacific Islander, Hispanic, Black or African-American, and White or Other. In the 1998, 2001, 2004 SCF dataset, race identification is categorized into: White (Includes Middle Eastern and Arab), Black/African-American, Hispanic/Latino, Asian, American Indian/Alaska Native,

Native Hawaiian/Pacific Islander or Other. However, the SCF just reports four categories: White, Black, Hispanic, Asian and other race in the public dataset (Lindamood, Hanna, & Bi, 2007). Therefore, "Other" in the public dataset corresponds to Asian, Native American/Eskimo/Aleut, Pacific Islander, Native Hawaiian and other races. In this dissertation, the race variable is categorized according to the public report of SCF and includes its four categories of race classification. Again, a dummy variable is set for each race and White is set as a reference group.

Marital Status

Yuh et al. (1998) classified marital status into just 3 categories: married, unmarried male and unmarried female. This classification might not capture important differences, because unmarried households include divorced, separated, and widowed heads-of-household. In addition, a partner household is not clearly defined in that study. Furthermore, the sample unit in the Survey of Consumer Finance is the household unit so it would not be feasible to test the gender effect toward retirement adequacy. Legally married households are eligible for more Social Security retirement benefits so it is necessary to clearly define marital status. In this dissertation, 5 categories of marital status are specified: married, separate or divorced, widowed, partners, and never married.

Normal Income

In the tables published for the Consumer Expenditure Survey, income categories are segmented by $5,000 but this segmentation is not appropriate in multivariate analysis. Too-detailed categories will reduce the degree of freedom of random effect in multivariate analysis. The Current Population Survey divides the population to five equal income quintiles but this categorization is less meaningful. Alternatively, the income variable could be set as a continuous variable, if the interest is to know the likelihood of adequate retirement according to per dollar increment of income. In this dissertation, the interest is to know whether high income households are more likely to have adequate retirement, so income categories are limited to poor, low income, mid income, high income, and very wealthy. Households with income below $10,000 are defined as poor, households with income between $10,001 and $24,999 are defined as low income, households with income between $25,000 and $49,999 are defined as mid income, households with income between $50,000 and $99,999 are defined as high income, and households with income above $100,000 are defined as very wealthy. Five dummy variables are set up, and households with income below $10,000 are set as the reference group according to the hypothesis.

Defined Benefit Pension

When one of the household members has a defined benefit pension this household is defined as a benefit pension household. The value of the dummy variable equals one when the household has defined benefit pension.

Defined Contribution Pension

When one of the household members has a defined contribution pension this household is defined as a contribution pension household. The value of dummy variable equals to one, when the household has defined contribution pension.

Spending Behavior

When household spending exceeds household income, the value of dummy variable is equal to 1, otherwise it is equal to 0. There is no spending level variable in the SCF dataset, but there is a variable that asks the respondent to state whether the household spends more than, about the same as, or less than their income.

Part-Time Job

The SCF dataset has a variable asking the following question.

Do you/Does [he/she]) expect to work part-time after that?

In addition, the SCF dataset has another variable recording the part-time job stop age. The value of the dummy variable is equal to 1 when either the respondent's or their spouse's stop age is greater than zero.

Risk Tolerance

Risk tolerance is classified into 4 categories: take no risk, take average risk, take above average risk, and take substantial risk. Four corresponding dummy variables are set up. The reference group of this variable takes no risk.

Survey Year

Four survey years and corresponding dummy variables are used in the merged dataset. The research interest is to test the changes of retirement adequacy across years. The year effect is mainly tested by the two-sample T test with the Repeated Imputation Inference (RII) technology. In logistic regression, the retirement adequacy of 1998 is compared to the reference year 1995. In another logistic regression, the retirement adequacy of year 2001 is compared to reference year 1998. Finally, the adequacy of year 2004 is compared to reference year 2001. Those comparisons are in three different logistic regression models, since logistic regression can only have one reference year each time. To be consistent with the t-test these logistic regression models use the RII technique as well. The testing result from t-test is comparable to that of logistic regression, even though t-test does not control other variables.

Expectation to Inheritance

The SCF dataset has the following question about the expectation of pension.

> Do you or your (spouse/partner) expect to receive a substantial inheritance or transfer of assets in the future?
> 1. *YES
> 5. *NO

The value of dummy variable equals 1, when the respondent answer yes, otherwise the dummy variable equals to 0.

Expectation of Health

The SCF dataset has this variable recording the expectation of health.

> Would you say your health is excellent, good, fair, or poor?
> Would you say your (spouse/partner)'s health in general is excellent, good, fair, or poor?
> 1. *Excellent
> 2. *Good
> 3. *Fair
> 4. *Poor
> 0. Inap. (/no spouse)

Since both head of household and spouse have expectation variables the calculation of this dummy variable is complicated. For married and partner households when the sum of answers is less than or equal to 4, the dummy variable of good health is equal to 1; otherwise, it is equal to 0. For single, separated or divorced households, when the answer is less than or equal to 2, the dummy variable is equal to 1; otherwise, it is equal to 0.

Independent Variable	Coding in SAS
Age 35-44 (Reference Variable)	Not coded
Age 45-54	1 or 0
Age 55-64	1 or 0
Age 65-70	1 or 0
Less than High School (Reference Variable)	Not coded
High School	1 or 0
Some College	1 or 0
Bachelor Degree	1 or 0
Married (Reference Variable)	Not coded
Partner	1 or 0
Separated or Divorced	1 or 0
Widow	1 or 0
Never Married	1 or 0
White (Reference Variable)	Not coded
Black	1 or 0
Hispanic	1 or 0
Asian or Others	1 or 0

Continued

Table 5. 2 Independent Variable Coding in Logistic Regression

Table 5.2 Continued

Independent Variable	Coding in SAS
Household Income less than 10,000 (Poor) (Reference Variable)	Not coded
Between 10,001 and 24,999 (Low Income)	1 or 0
Between 25,000 and 49,999 (Mid Income)	1 or 0
Between $50,000 and $99,999 (High Income)	1 or 0
Between $100,000 and over (Very Wealthy)	1 or 0
Have DC plan	1 or 0
Have DB plan	1 or 0
Planned retirement age before 62 (Reference Variable)	Not coded
62<=retire age<full retirement age	1 or 0
Retire age>=full retirement age	1 or 0
Deficit (Spend more than income)	1 or 0
Take no risk (Reference Variable)	Not coded
Take average risk	1 or 0
Take above average risk	1 or 0
Take substantial risk	1 or 0
Year 1995 (Reference Variable)	Not coded
Year 1998	1 or 0
Year 2001	1 or 0
Year 2004	1 or 0
Have Part Time Job	1 or 0
Spouse Retires Later	1 or 0
Expectation of Inheritance	1 or 0
Expectation of Enough Pension	1 or 0
Expectation of Good Health	1 or 0

In table 5.2, the SAS coding of the independent variables is demonstrated. The reference variable is not coded, i.e., not put in the logistic regression, since the zero values of all the other independent variables represent the effect of reference variable.

5.1.3 Compare and Contrast between T-Test and Logistic Regression

5.1.3.1 Model Assumption

The two-sample t-test assumes the compared variables with normal distribution and constant variance. Independence of variables is as well assumed in t-test. Logistic regression does not assume linear correlation between the independent variable and the dependent variable (Agresti, 1996). It does not require normally distributed variables, and does not assume constant variance of independent variables, but assumes independence of independent variables (Agresti, 1996). Generally speaking, logistic regression has less stringent requirements, and therefore it is an advantage of logistic regression.

5.1.3.2 Result Explanation

The result explanation of the t-test is straightforward. The test result shows a p-value indicating whether all the means are equal. Under a chosen specific significance level, whether the null hypothesis is accepted or not can be decided. In addition, the individual confidence interval indicates whether the means are different in the comparison.

The result explanation of logistic regression is somewhat more complicated than the t-test. For example, the test of year effect in retirement adequacy much be performed in three different models, i.e., have 1995, 1998, and 2001 as reference year in three different models. The logistic regression model only takes one reference year each time. In addition, the logit explanation is not as straight forward as the T-Test. In contrast, the advantage of logistic regression is the ability to control other variables so that correlation between the independent and dependent variables can be distinguished.

CHAPTER 6

RESULTS

6.1 Descriptive Statistics

6.1.1 Sample Characteristics

Table 6.1 shows selected characteristics of the sample, based on weighted tabulations. About 44% of the heads-of-household are between 35 and 44, and about 38% are between 45 and 54. Having a high school diploma (30.84%) and a college diploma (43.36%) are two main education levels in this merged dataset. About 62% of respondents are currently married, while about 20% of respondents are separated or divorced. Only 9% of respondents have never married. About 39% of respondents have a normal income between $50,000 and $99,999. Because the sample selection rule stipulates inclusion of those household currently working, this normal income seems a little higher than other studies. Whites account for 77% of the sample, and Blacks account for about 14% of the sample. Whites are still the majority of the sample.

About 30% of the households have defined contribution pension plans, while only about 25% of the households have defined benefit pension plans. Planned retirement ages are between the critical ages 62 and 65, because individuals at age 62 are eligible to receive Social Security retirement benefits, and age 65 is the earliest full retirement age. Almost half (48%) of the households would like to retire between age 62 and 65, while about 37% of respondents would like to retire before age 62. More than half (60%) of the households have listed retirement as one of their saving goals. About 70% of households are willing to take average or more risk in their investments, while only 30% of households take no risk. Only about 12% of the households say they spend more than their income. About 67% of the households have more than one planned retirement stage. About 26% of households plan to work part-time after retirement. The majority (83.57%) of the sample does not expect an inheritance. About 82% of the sample expects to have good health.

Variables		%
Age of head	Between 35 and 44	43.47
	Between 45 and 54	37.99
	Between 55 and 64	17.41
	Between 65 and over	1.13
Education of head	Less than high school	7.59
	High school graduate	30.84
	Some college	18.22
	College or more	43.36
Marital Status	Married	62.41
	Partner	5.43
	Separated or Divorced	19.76
	Widow or widower	2.92
	Never married	9.48
Income	Less than $10,000	0.67
	Between $10,000 and $24,999	8.23
	Between $25,000 and $49,999	28.57
	Between $50,000 and $99,999	39.09
	Between $100,000 and over	23.43
Race/Ethic	White	76.83
	Black	12.43
	Hispanic	6.60
	Asian and others	4.14
Household defined contribution pension plan		
	Yes	29.47
	No	70.53
Household defined benefit pension plan		
	Yes	25.46
	No	74.54

Continued

Table 6. 1 Sample Characteristics of Households

Table 6.1 Continued

Variables		%
Head's Planned retirement age	retire age <**62**	37.45
	62<=retire age<=**65**	48.37
	Retire age>**65**	14.18
Has retirement as saving purpose	Yes	60.14
	No	39.86
Risk Tolerance	Take no risk	29.71
	Take average risk	44.34
	Take above average risk	21.39
	Take substantial risk	4.56
Spending behavior (Spending is larger or equal to income)	Yes	12.35
	No	87.65
Household has more than one stage	Yes	66.63
	No	33.37
Household have part-time job after retirement	Yes	25.76
	No	74.24
Household expectation inheritance	Yes	16.43
	No	83.57
Household expect to have good health	Yes	81.67
	No	18.83

Note: Total sample size is 19,252.

Table 6.2 presents the financial characteristics of households when calculating the retirement adequacy indicator. Non-retirement-account financial assets, retirement-account financial assets, and non-financial assets are components of the retirement asset current balance. The non-retirement-account financial assets include CD's, checking accounts, savings accounts, stocks, bonds and mutual funds. Retirement-account financial assets include defined contribution pensions and 401ks and other related retirement plans. Non-financial assets include businesses and non-residential real estate. In the merged dataset, households on average have about $100,000 non-retirement-account financial assets, about $37,000 in retirement-account financial assets, and about $112,000 in non-financial assets respectively. In addition, about most households (about 96%) have non-retirement-account financial assets, while only about one third of the sample has retirement-account financial assets and non-financial assets. It shows that more than half of U.S. households do not have an official retirement plan. The mean annul contribution to the retirement plan is about $3,300 and only one third of the households have this contribution. The mean and median expected Social Security retirement benefit for heads-of-household is around $14,000, whereas, the mean and median expected Social Security retirement benefit for spouses is around $9,000 and $7,000 respectively. The percentages for both head and spouse are 100%, because the assumption is that everyone is covered by the Social Security program.

Only about 21% of heads of household have defined benefit pension and only about 7% of spouses have defined benefit pension. The mean value of the expected defined benefit pension is about $7,000 and $1,000 respectively. About 35% heads-of-household plan to have part-time jobs after retirement with a mean wage of $21,000; however, only about 19% of spouses plan to have part-time jobs with mean wage $5,000. In the methodology section the part-time job wage is presumed to be one third of the full-time job wage. This information is attained from Bureau of Labor Statistics (U. S. Department of Labor, 2005). In addition, the mean and median value of years until planned retirement age is 15 years.

	Mean ($)	Median ($)	Percentage of Amount > 0
Non-Retirement-Account Financial Assets	100,633	13,060	96.32%
Retirement-Account Financial Assets	36,584	-	39.22%
Non-Financial Assets	111,653	-	29.03%
Contribution	3,302	-	29.54%
Expected Social Security of Head	14,134	13,638	100.00%
Expected Social Security of Souse	8,577	6,818	100.00%
Expected Defined Benefit Pension of Head	7,301	-	21.34%
Expected Defined Benefit Pension of Spouse	1,485	-	7.43%
Expected Part-Time Job Wage of Head	20,756	14,310	35.44%
Expected Part-Time Job Wage of Spouse	5,072	-	18.56%
Years until Retirement based on Head's Planned Retirement Age	15	15	99.54%

Table 6. 2 Financial Characteristics of Households

6.2 Stage Counting

6.2.1 Stage Frequency of Each Household

About 66% of households have two stages or less, so about 34% of households have more than two stages. Quite few households (3.43%) have 5 stages or 6 stages. Having less than two stages might result from the high percentage of instances where both head and spouse retire at the same time. Quite few households (about 25%) have defined benefit pension plans and part-time jobs (26%). That is, quite few households have retirement stage drivers: different planned retirement age, defined benefit pensions, and part-time jobs.

stages	Percentage	Cumulative Percentage
1	36.83	36.83
2	28.90	65.73
3	19.88	85.61
4	10.95	96.57
5	3.04	99.61
6	0.39	100

Table 6. 3 Stage Frequency

6.2.2 Length of Retirement Stages

Table 6.4 shows the median length of household stages by the total number of stages. The median length of New Stage 1 is the sum of the lengths of the first N-1 old stages. The length of New Stage 2 is the difference between remaining life expectancy and the length of New Stage 1. The total length of New Stage 1 and New Stage 2 is equal to the remaining life expectancy at retirement. The followed simple example demonstrates how the length of New Stage 1 and New Stage 2 are combined from the old stages. For example, a household has 3 stages. The length of Stage 1 is 3 years, Stage 2 is 4 years and life expectancy is 30 years.

First Old Stage 1 and Old Stage 2 are combined to New Stage 1. The Old Stage 3 is New Stage 2. Therefore the length of New Stage 1 is 7 years (3+4 years). The length of New Stage 2 is 23 years (30-7years).

Median Period Length subgroup by stages							Median New Stage Length		First Retirement Age
	p1	p2	p3	p4	p5	p6	newN1	newN2	
1 stage	23.21						23.21		65
2 stages	6	16.24					6	16.24	64
3 stages	7	2	16.56				10	16.56	58
4 stages	6	3	2	16.88			13	16.88	55
5 stages	6	2	3	2	15.10		14	15.10	55
6 stages	7	2	1	2	2	12.68	14	12.68	55

Note: This table is a summary of aggregate data result.

Table 6. 4 Median Period Length of Old Stage and New Stage

The first retirement age is defined as head's age when the first retirement happens. First retirement is calculated by comparing head's planned retirement age and spouse's planned retirement age. Additionally, the spouse's planned retirement age is converted to the head's current age, so that both head and spouse's planned retirement age can be compared in terms of head's age. The earlier the age of first retirement, the more likely they are to have multiple stages as shown in Table 6.4. For example, households with 4 stages have a median first retirement age of 55, compared to the median first retirement age of 65 for households with only one stage. Generally speaking, if the first retirement age is before 62 there will be more than one retirement stage because the household will have to wait until the head turns 62 to start receiving the Social Security pension.

The last stage length decreases as the households have more stages. For example, households with 2 stages have a last stage length of 16.24 years, while households with 6 stages have last stage length of 12.68 years. The reason for this phenomenon is because first N-1 stages already counts part of the life expectancy, so that the last stage length decreases.

Another interesting finding is that the length of the first stage is generally longer than that of the middle stages. Households with 2 stages have a first retirement age of 64, suggesting that the first stage is not generated retirement at the Social Security legal age of 62. It is likely generated by having a defined benefit pension and a part-time job. In contrast, households with more than 2 stages have a first retirement age before age 62 and it is likely that the first stage results from retirement before the Social Security legal age of 62. This can be verified by adding the length of first stage to the first retirement age which results in an age close to 62. For example, in households with 4 stages, the length of first stage is 6 years, and the first retirement age is 55. Therefore the sum of 6 and 55 is 61, which is very close to Social Security legal age 62. Since the first stage usually happens before age 62, and middle stages usually happen between 62 and 65, the length of the first stage is generally greater than that of middle stages.

The last interesting finding is the length of the middle stages. The length of middle stage is around 1 to 3 years. This result verifies the assumption that the middle stage occurs between the ages of 62 and 65. Therefore, the length of middle stages is less likely to be greater than 4 years. However, full retirement age is extended to 67 for the younger generation so that the length of middle stages is still likely to increase.

6.2.3 Household Category by Retirement Stage

In Table 6.5, each survey year's dataset is classified into three categories. The purpose of segmenting the sample to three categories is to control the highly correlated variable, i.e., disposable income or annuity. Under different categories, the retirement adequacy is sufficiently different. The first category includes households with two New Stages and with projected retirement assets high enough to allow for equal spending in New Stage 1 income and New Stage 2. The second category includes households with two New Stages but lacking sufficient projected retirement assets to have equal spending in the two stages. The third category includes households with only one stage.

	1995	1998	2001	2004
	Percent	Percent	Percent	Percent
Category1	25.76%	37.26%	34.75%	37.99%
Category2	37.32%	28.27%	29.69%	34.38%
Category3	36.92%	34.47%	35.55%	27.63%

Table 6. 5 Stage and income category

Category 1: Households have two New Stages. New stage 1 spending and New Stage 2 spending *can* be equalized by accumulated retirement assets.
Category 2: Households have two New Stages. New stage 1 spending and New Stage 2 spending *cannot* be equalized by accumulated retirement assets.
Category 3: Households have only one stage.

The distribution of these three categories looks like uniform distribution across survey years. However, there still a trend across years. Category 1 increases from year 1995 to year 2004, while category 3 decreases from year 1995 to year 2004. This means some households move from category 3 to category 1 as time goes by. It also means more households are having more than 1 stage and have enough retirement assets to even out the retirement spending.

Case	Percent	Cumulative Percent
1	49.38	49.38
2	46.82	96.20
3	3.80	100

Table 6. 6 Case of head and spouse labor participation

Case 1: Only head is working.
Case 2: Both head and spouse are working.
Case 3: Only spouse is working.

About 96% of households have the head working. In 49% of the sample only the head currently works, whereas in 47% of the sample both the head and spouse work. The partition of labor participation is meaningful because it demonstrates the spouse labor participation rate. The spouse labor participation rate is an indicator of stage generating since the spouse's planned retirement age is a driver of stage. From Table 6.6, in more than 50% households, the spouse is currently working.

6.3 Retirement Adequacy Indicator

6.3.1 Replacement Ratio

The median replacement ratio ranges from 47.83% to 109.76% across categories and new stages. If stage partitions are ignored, the replacement ratio ranges from 47.83% to 186.08%. It is as expected that replacement ratio ignoring stage partition is much higher than that with stage partition, because the method lacking stage partition recognizes all retirement income at planned retirement age. In contrast, the method with stage partition recognizes retirement income when income really occurs. The overestimation of replacement ratio is severe in category 1. Comparing the replacement ratio in category 1 between stage partitions and ignoring the stage partition, the average overestimation of replacement is around 70%.

	1995	1995	1998	1998	2001	2001	2004	2004
With Stage Partition	New Stage 1	New Stage 2	New Stage 1	New Stage 2	New Stage 1	New Stage 2	New Stage 1	New Stage 2
Category1	91.18%	91.18%	94.91%	94.91%	99.57%	99.57%	109.76%	109.76%
Category2	69.62%	67.96%	70.98%	68.81%	77.56%	76.69%	76.64%	76.99%
Category3	56.99%	NA	47.83%	NA	63.00%	NA	65.34%	NA
No Stage Partition	1995		1998		2001		2004	
Category1	155.01%		172.77%		169.80%		186.08%	
Category2	137.17%		136.22%		153.28%		149.45%	
Category3	56.99%		47.83%		63.00%		65.34%	

Table 6. 7 Median Replacement Ratios

With stage partition, the replacement ratio of category 1 steadily increased from 1995 to 2004. The replacement ratio of new stage 1 of category 2 steadily increased from 1995 to 2001, but dropped slightly in 2004, whereas, the replacement ratio new stage 2 steadily increased from 1995 to 2004. In Category 3 the replacement ratio dropped from 1995 to 1998 then increased after 1998.Furthermore, within the same year, the replacement ratio is highest in category 1 and lowest in category 3. This is likely because individuals in category 3 are those with just only one new stage and therefore are less likely to have defined benefit pensions and part-time jobs. The households in category 1 have two new stages and have enough accumulated assets to even out the spending for both stages. Therefore category 1 has the highest replacement ratio. In general, in category 2 the replacement ratio of new stage 1 is greater than that of new stage 2. It is because households in category 2 are more likely to stop part-time jobs in new stage 1 and therefore have a higher replacement income in new stage 1.

If stage partitions are ignored, the year trend of replacement ratios is not apparent. For category 1, the replacement ratio increased in 1998, but reduced in 2001, and increased again in 2004. For category 2, the year trend of replacement ratio is exactly opposite from that of category 1. For category 3, the replacement ratio dropped in 1998, but increased in 2001, and increased again in 2004. More tests are needed to analyze these changes of retirement adequacy across years. Category 1 has the highest replacement ratio, category 2 is in between, and category 3 has lowest replacement ratio.

	1995	1995	1998	1998	2001	2001	2004	2004
With Stage Partition	New Stage 1	New Stage 2	New Stage 1	New Stage 2	New Stage 1	New Stage 2	New Stage 1	New Stage 2
Category1	138.86%	138.86%	113.78%	113.83%	120.97%	121.11%	125.76%	125.76%
Category2	77.62%	78.07%	77.00%	75.90%	83.47%	85.67%	80.23%	89.91%
Category3	94.26%	NA	83.59%	NA	89.81%	NA	85.15%	NA
No Stage Partition	1995		1998		2001		2004	
Category1	266.35%		200.35%		212.42%		215.36%	
Category2	160.64%		172.97%		184.14%		189.53%	
Category3	94.26%		83.59%		89.81%		85.15%	

Table 6. 8 Mean Replacement Ratios

Table 6.8 presents the summary of mean replacement ratio across categories and stages. The mean replacement ratio ranges from 75.9% to 138.86% across categories and new stages. If the stage partitions are ignored, the replacement ratio ranges from 83.59% to 266.35%. The overestimation of replacement ratio is severe in category 1.The replacement ratio in category 1 under the method of stage partition is about 80% higher than that of ignoring stage partition.

With stage partition, the replacement ratio of category 1 dropped from 1995 to 1998 but increased in 2001 and 2004. The mean replacement ratio of new stage 1 in category 2 increased in 1998 and 2001, but dropped in 2004. The mean replacement ratio of new stage 2 in category 2 dropped in 1998, but increased in 2001 and 2004. The pattern of category 3 is the same as the pattern of new stage 1 in category 2.

Households in category 1 have two new stages and have enough accumulated assets to even out the spending for both stages. Therefore, category 1 households have the highest replacement ratio.

If the stage partition is ignored, for category 1, the replacement ratio decreased from 1995 to 1998, but increased in 2001 and 2004. For category 2, the replacement ratio steadily increased from 1995 to 2004. For category 3, the replacement ratio dropped in 1998 , increased in 2001, but dropped again in 2004. More tests are needed to analyze the changes of retirement adequacy across years. In summary, category 1 has the highest replacement ratio, category 2 is in between, and category 3 has the lowest replacement ratio.

	1995	1995	1998	1998	2001	2001	2004	2004
With Stage Partition	New Stage 1	New Stage 2	New Stage 1	New Stage 2	New Stage 1	New Stage 2	New Stage 1	New Stage 2
Category1	72.57%	72.57%	74.03%	74.03%	80.83%	80.83%	83.02%	83.02 %
Category2	36.86%	43.35%	34.91%	38.84%	48.38%	49.30%	48.49%	52.39 %
Category3	36.54%	NA	33.58%	NA	41.17%	NA	42.02%	NA
No Stage Partition	1995		1998		2001		2004	
Category1	74.64%		69.92%		71.49%		68.73%	
Category2	69.95%		71.98%		72.62%		69.82%	
Category3	36.54%		33.58%		41.17%		42.02%	

Table 6. 9 Mean Retirement Adequacy Proportion (Compared to Benchmark Replacement Ratio)

The mean retirement adequacy proportion ranges from 33.58% to 83.02% across categories and new stages. Ignoring stage partition, the proportion ranges from 33.58% to 74.64%. It is as expected that the retirement adequacy proportion ignoring stage partition is higher than that with stage partition because the median and mean replacement ratio of ignoring stage partition is higher.

For category 1, the adequacy proportion steadily increased across years. The retirement adequacy proportion of new stage 1 and new stage 2 dropped from 1995 to 1998 but increased in 2001 and 2004 for categories 2 and 3. Within the same year, the adequacy proportion is highest in category 1, but is lowest in category 3. Categories 3 is those with just one new stage and are therefore less likely to have defined benefit pensions and part-time jobs. The households in category 1 have two new stages and have enough accumulated assets to even out spending for both stages. Therefore category 1 has the highest adequacy proportion. The trend of adequacy proportion is similar to the placement ratio.

Ignoring stage partition, the retirement adequacy proportion of category 1 decreased in 1998, increased in 2001, but decreased in 2004. For category 2, the retirement adequacy proportion increased in 1998 and 2001, but decreased in 2004. For category 3, the adequacy proportion dropped in 1998 but increased in 2001 and 2004.

The across categories combined results are presented in Table 6.10. The new stage 1 adequacy proportion is weighted by the category percentage presented in Table 6.5. New stage 2 adequacy proportion is weighted by the category percentage as well. The average adequacy proportion of new stage 1 and new stage 2 is weighted by 50% of each new stage.

Under the stage partition method, the average adequacy proportion steadily increased from 1995 to 2004. Ignoring the stage partition, the adequacy proportion does not change sufficiently across years. The reason why the stage partition has more apparent trend might be due to stage driver, such as define benefit pension and defined contribution pension, are more time sensitive. Therefore, the adequacy proportion in the particular stage has obvious time trend.

	1995	1998	2001	2004
Stage 1	45.9%	49.0%	57.1%	59.8%
Stage 2	48.4%	50.1%	57.3%	61.2%
Average of S1 & S2	47.2%	49.6%	57.2%	60.5%
Non-stage partition	58.9%	58.0%	61.0%	61.7%
Difference	11.7%	8.4%	3.8%	1.2%

Table 6. 10 Retirement Adequacy Difference between Stage Partition Method and Non-Stage Partition Method

6.4 RII T-Test

6.4.1 RII T-Test for Year Effect

Table 6.11 shows the t-test results of adequacy proportion mean difference under the RII technique. The RII t-test is to calculate the test statistics by using the total variance instead of only using within implicate variance, since total variance includes between implicate variance and within implicate variance. Therefore, the variance under RII is larger than that of not using RII, and test statistics is smaller. Using a smaller test statistics is less likely to reject the null hypothesis; in other words, it is less likely to accept alternative hypothesis. Since the SCF dataset uses multiple implications, use of the RII method gives a more accurate result for hypothesis testing.

	Replacement Ratio Adequacy Proportion-With Stage	
	Means Difference	P-Value
1995-1998	-1.85%	0.0833
1998-2001	-6.93%	<.0001
2001-2004	-3.95%	<.0001
	Replacement Ratio Adequacy Proportion-Ignoring Stage	
	Means Difference	P-Value
1995-1998	0.90%	0.4209
1998-2001	-3.00%	0.0032
2001-2004	-0.70%	0.4801

Table 6. 11 RII T-Test of Year Effect

These means tests are based on combined category and combined stages, i.e. the summary product of individual retirement income and length of stage. When taking stage partitions into account, the first pair comparison, i.e. 1995-1998, presents the result that adequacy proportion of 1995 is somewhat significantly lower than that of 1998 in terms of replacement ratio. The second comparison, i.e. 1998-2001 indicates that adequacy proportion in terms of replacement ratio of 1998 is significantly lower than that of 2001 again. The third comparison, i.e., 2001-2004 shows that adequacy proportion in terms of replacement ratio of 2001 is significantly lower than that of 2004 again.

If stages are ignored, the results are somewhat different from prior discussions. The positive means difference suggests that the adequacy proportion decreased from 1995 to 1998. This result is opposite to that of taking stage into account. The second pair comparison of 1998 vs. 2001 is the same as that using stage partition. The third comparison 2001-2004 shows that adequacy proportion of 2001 is not significantly lower than that of 2004.

6.4.2 RII T-Test for Non-Stage, New Stage 1 and New Stage 2

Table 6.12 presents the results of RII t-test for the comparison between non-stage method and stage partition method in terms of replacement ratio. The first test result based on replacement ratio shows that adequacy proportion under non-stage method is significantly greater than that of new stage 1.

	Replacement Ratio Adequacy Proportion	
	Means Difference	P-Value
Non-Stage vs. New Stage 1	6.53%	<.0001
Non-Stage vs. New Stage 2	18.12%	<.0001
New Stage 1 vs. New Stage 2	11.59%	<.0001

Table 6. 12 RII T-Test for Non Stage, New Stage 1 and New Stage 2

In the second comparison, i.e. non-stage and new stage 2, the adequacy proportion under non-stage method is significantly greater than that of new stage 2. In the third comparison, the result shows that adequacy proportion of news stage 1 is significantly greater than that of new stage 2.

Table 6.12 shows that the adequacy proportion difference between non-stage and stage2 is greater than that between non-stage and stage1. In addition, the magnitude of adequacy proportion difference between stage 1 and stage 2 is in between the difference of non-stage and stage1 and the difference of non-stage and stage2.

6.4.3 RII T-Test for Having Defined Contribution Pension and Defined Benefit Pension

Households with a defined benefit (DB) plan are more likely to have retirement adequacy in terms of replacement ratio. The adequacy proportion ranges from 64.77% to 68.05% for households with defined contribution (DC) plans. In contrast, households with DB plans are likely to have retirement adequacy proportion ranging from 65.40% to 74.93%. Table 6.13 shows the comparison of the retirement adequacy proportion between having and not having defined contribution/benefit pension in terms of replacement ratio with the stage partition differentiation. When taking stages into account, the retirement adequacy proportion of households with defined contribution pension is about 20% higher than that of households without defined contribution pension. On the other hand, the retirement adequacy proportion of households with defined benefit pension is about 28% higher than that of households without defined benefit pension. Even if stage partitions are ignored, the retirement adequacy proportion of households with defined contribution pension is about still 7% higher than that of households without defined contribution pension. The retirement adequacy proportion of households with defined benefit pension is also about 7% higher than that of households without defined benefit pension.

Based on the RII t-tests, households with defined contribution pension or defined benefit pension have significantly higher retirement adequacy than those without those pension plans. In addition, compared to the households taking stage into account, households ignoring the stage effect have lower difference of adequacy proportion. Furthermore, the means difference under having defined benefit pension is higher that that under having defined contribution pension.

	Have Plan	No Plan	P-value for RII t-test of difference between those with plan and without plan
Defined Contribution Plan			
With stage partition	68.05%	48.46%	< 0.0001
Ignoring stage partition	64.77%	58.08%	< 0.0001
Defined Benefit Plan			
With stage partition	74.93%	47.16%	< 0.0001
Ignoring stage partition	65.40%	58.23%	< 0.0001

Table 6. 13 RII T-Test of Retirement Adequacy for Having DC and Having DB Plans

Table 6.14 shows comparison of the retirement adequacy proportion between having and not having inheritance in terms of replacement ratio with the stage partition differentiation. When taking stages into account, the retirement adequacy proportion of households with expectation of having inheritance is about 12% higher than that of households without expectation of having inheritance. Even though ignoring the stage partition, the retirement adequacy proportion of households with expectation of inheritance is about 3% higher than that of households without expectation of inheritance.

6.4.4 RII T-Test for Expectation of Having Inheritance

	Have expectation of inheritance	Not have expectation of inheritance	P-value for RII t-test of difference between those with plan and without plan
With stage partition	63.95%	52.32%	< 0.0001
Ignoring stage partition	62.36%	59.61%	< 0.0001

Table 6. 14 RII T-Test of Retirement Adequacy for Having Inheritance Expectation

The retirement adequacy proportion of households with expectation of inheritance is higher than that of households without expectation of inheritance across two adequacy indictors. In addition, from Table 6.14, the test shows a consistent result that the expectation of inheritance has a higher adequacy proportion than not having an expectation of inheritance.

Table 6.14 shows the mean percentage of retirement adequacy in each scenario. The adequacy proportion in terms of replacement ratio ranges from 62.36% to 63.95% for households with an expectation of inheritance.

6.5 Multivariate Analysis Using Repeated Imputation Inference Technique (RII)

6.5.1 Two Logistic Regression Models with RII Technique

The multivariate analyses are logits for the combined datasets from 1995, 1998, 2001, and 2004. Independent variables include demographic variables, financial characteristics variables, and financial decision/attitude variables. Dependent variables are dichotomous variables with a value equal to 1 when the replacement ratio is greater than the benchmark replacement ratio. Two models are conducted in the multivariate analysis. Model A has a dependent variable measured by the replacement ratio counting stages. Model B also has a dependent variable measured by the replacement ratio but ignoring stage partitions. Table 6.15 presents the logit results for the replacement ratio with stage partition. The dependent variable is a dichotomous variable with a value of 1 when the replacement ratio is greater than benchmark replacement ratio. The replacement rate is measured on a merged stage basis, since the logit results would only differ slightly between new stage 1 and new stage 2. The merged replacement ratio is calculated as the sum of the first stage retirement income times the length of the first stage and the second stage retirement income times the length of the second stage, then the sum is divided by the sum of lengths of the two stages.

Repeated Imputation Inference technique is used for this logistic regression model. The model coefficients are estimated by averaging the coefficient of each individual implicate of the SCF dataset.

The odds ratio is equal to the exponential function of coefficient, and therefore the odds of having an adequate retirement increases when the coefficient is positive. In other words, the odds ratio is greater than one when the coefficient is positive.

For Model A (Table 6.15), Households with head ages 45 to 54 are significantly more likely than those between 35 and 44 to have retirement adequacy, while other age ranges are not significant. The education of head is not significantly correlated to the likelihood of having an adequate retirement. Separated, divorced, and widowed households are significantly less likely to have an adequate retirement than married households. White households are more likely than Asian and other ethnicities to have an adequate retirement. Income independent variables do not have a huge impact on the probability of having an adequate retirement except in the highest income category. Having a defined benefit pension and a defined contribution pension is positively correlated to the likelihood of adequate retirement. This result is consistent with Yuh et al. (1998). Also, planning to retire later is more likely to result in an adequate retirement. Households that spend more than their income are less likely to have an adequate retirement. Taking a greater level of risk increases the likelihood of having an adequate retirement. Compared to 1995, households in 2001 and 2004 are more likely to have an adequate retirement. This result is consistent with the two-sample t-test of year 1995 to year 2004 in Table 6.11. Households with more than one stage are more likely to have an adequate retirement. The expectation of good health has a positive effect in having an adequate retirement. The 88.5% concordance shows that a high percentage of variation is represented in this logistic model. In addition, the extremely small p-value concludes that the logistic model does fit.

Model A	Estimate	P-Value	Odds Ratio
Intercept	-2.5606	0.0018	
Age of Head: reference category: age between 35 and 44			
Age 45-54	0.3139	0.0057	1.37
Age 55-64	0.0117	0.9418	1.01
Age 65-70	0.2731	0.6151	1.31
Education of head: reference category: less than high school			
High School	0.1946	0.3468	1.21
Some College	-0.0346	0.8778	0.97
Bachelor Degree	0.2796	0.2052	1.32
Marital status: reference category: married			
Partner	0.1981	0.3790	1.22
Separated or Divorced	-1.6803	<0.0001	0.19
Widow	-1.1787	0.0002	0.31
Never Married	-1.1804	<.0001	0.31
Race: reference category: White			
Black	-0.3321	0.0554	0.72
Hispanic	-0.1912	0.3691	0.83
Asian or Others	-0.5032	0.0475	0.60

Continued

Table 6. 15 RII Logistic Regressions of Adequacy (Replacement Ratio with Stage Partition)

Table 6.15 Continued

Model A	Estimate	P-Value	Odds Ratio
Household income: reference category : less than 10,000			
Between 10,000 and 24,999	-0.7186	0.3415	0.49
Between 25,000 and 49,999	-0.4088	0.5831	0.66
Between \$50,000 and \$99,999	0.3507	0.6463	1.42
Between \$100,000 and over	2.3422	0.0036	10.40
Have DC plan	0.5507	<.0001	1.73
Have DB plan	1.3739	<.0001	3.95
Planned retirement age: reference category : before 62			
62<=retire age<=65	0.8392	<.0001	2.31
Retire age>65	1.9591	<.0001	7.09
Deficit (Spend more than income)	-0.3556	<.0001	0.70
Risk tolerance: reference category: Take no risk			
Take average risk	0.4706	0.0006	1.60
Take above average risk	0.8691	<.0001	2.38
Take substantial risk	1.0018	0.0001	2.72
Year: reference category:1995			
1998	0.0239	0.8675	1.02
2001	0.2810	0.0386	1.32
2004	0.5650	<.0001	1.76
Household has more than one stage	1.0155	<.0001	2.76
Have part-time job	-0.1705	0.2275	0.84
Expectation of inheritance	0.0926	0.5010	1.10
Expectation of good health	0.4970	0.0009	1.64
Concordance	88.5		
Model Fit Test (Beta not equal zero)	<.0001		

Note: The concordance and model fit tests are based on the averaging of the five implicates, not on the RII results.
P-value ≤ .05, ** P-value ≤ .01, *** P-value ≤ .001

For Model B (Table 6.16), under the method of not using stage partition, households with a head ages 55 to 64 are more likely than those between the ages of 35 and 44 to have retirement adequacy. The education demographic variables are not significantly correlated to the likelihood of having an adequate retirement. Individuals who are separated, divorced, or never married are less likely than married individuals to have an adequate retirement. Compared to Whites, Blacks and Hispanics are less likely to have an adequate retirement, while Asians are about having the same level of likelihood. Income independent variables do not have a huge impact in the probability of having an adequate retirement. Households with income greater than $100,000 are more likely to have an adequate retirement than those with incomes less than $10,000. Having a defined benefit pension or a defined contribution pension is less likely to have an adequate retirement. Also, individuals planning to retire later are more likely to have an adequate retirement. Taking average, above average, and substantial risk is positively correlated to the likelihood of an adequate retirement. The 68.1% concordance shows that a substantial percentage of variation is represented by this logistic model. In addition, the extremely small p-value concludes that the logistic model does fit.

Model B	Estimate	P-Value	Odds Ratio
Intercept	-2.3481	<.0001	
Age of Head: reference category: age between 35 and 44			
Age 45-54	0.0727	0.4269	1.0754
Age 55-64	0.4807	0.0004	1.6173
Age 65-70	0.2127	0.5901	1.2371
Education of head: reference category: less than high school			
High School	0.0173	0.9314	1.0175
Some College	0.0814	0.6883	1.0848
Bachelor Degree	0.1512	0.4719	1.1633
Marital status: reference category: married			
Partner	0.0560	0.8049	1.0576
Separated or Divorced	-0.5342	<.0001	1.7062
Widow	0.5043	0.0566	1.6558
Never Married	-0.8756	<.0001	2.4003
Race: reference category: White			
Black	-0.3650	0.0109	0.6941
Hispanic	-0.2165	0.2876	0.8052
Asian or Others	0.0537	0.8003	1.0552

Continued

Table 6. 16 RII Logistic Regressions of Adequacy (Replacement Ratio ignoring stage Partition)

Table 6.16 Continued

Model B	Estimate	P-Value	Odds Ratio
Household income: reference category : less than 10,000			
Between 10,000 and 24,999	0.3160	0.5870	1.3717
Between 25,000 and 49,999	0.7938	0.1603	2.2118
Between $50,000 and $99,999	0.9330	0.0972	2.5427
Between $100,000 and over	1.7823	0.002	5.9440
Have DC plan	-0.0305	0.0748	0.9698
Have DB plan	-0.2854	0.0044	0.7516
Planned retirement age: reference category : before 62			
62<=retire age<=65	1.0696	<.0001	2.9144
Retire age>65	2.0208	<.0001	7.5446
Deficit (Spend more than income)	0.0068	0.9584	1.0068
Risk tolerance: reference category: Take no risk			
Take average risk	0.1663	0.0072	1.1809
Take above average risk	0.2631	0.0007	1.3009
Take substantial risk	0.3363	0.0120	1.3997
Year: reference category:1995			
1998	-0.0984	0.4016	0.9062
2001	0.0675	0.5486	1.0698
2004	0.1614	0.1349	0.8509
Have part-time job	-1.3810	<.0001	0.2513
Expectation of inheritance	-0.1076	0.3204	0.8979
Expectation of good health	0.0261	0.8129	1.0264
Concordance	68.1		
Model Fit Test (Beta not equal zero)	<.0001		

Note: The concordance and model fit tests are based on the averaging of the five implicates, not on the RII results.
P-value ≤ .05, ** P-value ≤ .01, *** P-value ≤ .001

6.5.2 Year Effect

Table 6.17 summarizes logits of the year effect by changing the reference year in each regression. For example, in the regression model 1998 vs. 2001, the reference year is 1998, while in model 2001 vs. 2004, the reference year is 2001. All the other independent variables are the same across these three models. In addition, in each year comparison the two scenarios are set up using the following: a replacement ratio with stage counting, a replacement ratio while ignoring stages. Therefore, the logistic regressions are executed 6 times. In the 1995 vs. 1998 regression, the stage-partition method shows that the likelihood of having adequate retirement in 1998 is higher than that in year 1995; whereas, ignoring stage has different result. However, the p-values are not small enough so the results are insignificant.

In the 1998 vs. 2001 regression model, both methods shows the same results concluding that the likelihood of having adequate retirement in 2001 is higher than that in year 1998. That means households in year 2001 were more likely to have retirement adequacy than those in 1998 when controlling for other variables. However, again, the p-values are not smaller enough.

In the 2001 vs. 2004 regression model, the stage partition method and non-stage partition method have different results. When using stage partition method, the likelihood of having adequate retirement in 2004 is significantly higher than that in year 2001. However, when ignoring the stage partition, likelihood of having adequate retirement in 2004 is lower than that in 2001.

		1995 vs. 1998	1998 vs. 2001	2001 vs. 2004
Replacement Ratio-With Stage	Estimate	0.0239	0.3089	0.3199
	P-Value	0.8675	0.3652	0.0070
Replacement Ratio-Ignoring Stage	Estimate	-0.0984	0.1660	-0.2289
	P-Value	0.4017	0.1425	0.0312

Table 6. 17 RII Logistic Regression for Year Comparison

A complete summary of two-sample t-test and logistic regression results is presented in Table 6.18. Most testing results of t-test and logistic regression are corresponding across year comparisons and scenarios, except for the 01 vs. 04 comparison. In 01 vs. 04 comparison, the t-test shows that adequacy proportion increases from 2001 to 2004, while the logit shows that the likelihood of adequate retirement decreases from 2001 to 2004. The t-test result of 98 vs. 01 shows that the adequacy proportion of 2001 is significantly greater than that of 1998. However, when controlling other variables, the likelihood testing becomes insignificant.

The consistent results in terms of replacement ratio are: t-tests of 95 vs. 98, 98 vs. 01, and 01 vs. 04 are consistent between the stage partition method and non-stage partition method. The logistic regression results of 95 vs. 98 and 98 vs. 01 are consistent between the stage partition method and non-stage partition method.

From above discussions, the hypothesis 2a is fully supported, since all the test results show non-significant difference. Hypothesis 2b is also somewhat supported, since 2 out of 4 test results showing non-significant difference as well. Hypothesis 2c is not supported, since all the test results show significant difference.

		Two-Sample T-Test	
Period	Hypothesis	Replacement Ratio-With Stage	Replacement Ratio-Ignoring Stage
95 vs.98	No change	NS	NS
98 vs.01	No change	I	I
01 vs.04	No change	I	I
		Changes controlling for other variables (Logits)	
Period	Hypothesis	Replacement Ratio-With Stage	Replacement Ratio-Ignoring Stage
95 vs.98	No change	NS	NS
98 vs.01	No change	NS	NS
01 vs.04	No change	I	D

Table 6. 18 Summary of Year Effect for T-Test and Logistic Regression

I = Increase significantly at 0.05 level using two-sample t-test.
D = Decrease significantly at 0.05 level using two-sample t-test.
NS = No significantly difference at 0.05 level using two-sample t-test

6.5.3 Stage Effect

In this section, the stage effect is tested mainly by two-sample t-test, but not by logistic regression, since the stage effect is used to split different models for logistic models. Using t-test, the adequacy proportion of ignoring stage in terms of replacement ratio is not significantly greater than that of new stage 1. However, the ignoring stage method has higher adequacy proportion than new stage 2. Using logistic regression, the likelihood of ignoring stage is significantly higher than that of stage partition method.

In the second comparison, i.e., new stage 1 vs. new stage 2, the t-test result shows that adequacy proportion of new stage 1 is significantly different from that of new stage 2.

From above discussion, the hypothesis 1a is fully supported, since 2 out of 3 tests have the same results as hypothesis. Hypothesis 1b is fully supported, since the t-test result shows that adequacy proportion of new stage 1 and new stage 2 are significantly different.

		Two-Sample T-Test	
	Comparison	Hypothesis	Replacement Ratio
H1a	Ignoring Stage vs. New Stage 1	Increase	NS
H1a	Ignoring Stage vs. New Stage 2	Increase	I
H1b	New Stage 1 vs. New Stage 2	Significantly Different	S
		Hypothesis	Logistic Regression (Model A)
H1a	Ignoring Stage vs. Multiple Stages	Increase	I

Table 6. 19 Summary of Stage Effect for T-Test

I = Increase significantly at 0.05 level using two-sample t-test.
NS = No significantly difference at 0.05 level using two-sample t-test
S=Significant differently at 0.05 level using two-sample t-test

The stage-more-than-one independent variable is put in model A to test whether more stages are more likely to have an adequate retirement. Model A is the model that uses replacement ratio as indicator and takes stage into account. In Model A, the households with more than one stage are significantly more likely to have retirement adequacy. Compared to households with only one stage, those with more than one stage are most likely couples retiring in different year, or having defined benefit pension, or having part-time job. This test concludes that households with those characteristics are more likely to have retirement adequacy.

6.5.4 Pension Effect

The t-test and logistic regression model have somewhat consistent testing results of whether having pension plans will influence the likelihood of retirement adequacy proportion. The t-test shows identical results between the stage partition method and non-stage partition method. However, the logistic regression shows that having the defined contribution and defined benefit pension will reduce the likelihood of adequate retirement when ignoring the stage partition. When counting the stage partition, having a defined benefit pension or defined contribution pension will increase the likelihood of adequate retirement.

		Two Sample T-Test	
Period	Hypothesis	Replacement Ratio-With Stage	Replacement Ratio-Ignoring Stage
DC vs. No DC	Increase	I	I
DB vs. No DB	Increase	I	I
		Changes controlling for other variables (Logits)	
Period	Hypothesis	Replacement Ratio-With Stage	Replacement Ratio-Ignoring Stage
DC vs. No DC	Increase	I	D
DB vs. No DB	Increase	I	D

Table 6. 20 Summary of Pension Effect for T-Test and Logistic Regression

I = Increase significantly at 0.05 level using two-sample t-test.
D = Decrease significantly at 0.05 level using two-sample t-test.

6.5.5 Inheritance Effect

Table 6.21 have a summary of testing results with whether having expectation of inheritance will influence the retirement adequacy. The two-sample t-test has very different results from logistic regression for the effect of expecting an inheritance. Under t-test, households with expectation of inheritance are significantly more likely to have an adequate retirement. In the logistic regression, the test results are not significant. From above discussion, the hypothesis H4 is not supported.

		Two-Sample T-Test	
Period	Hypothesis	Replacement Ratio-With Stage	Replacement Ratio-Ignoring Stage
Inheritance vs. No Inheritance	Decrease	I	I
		Changes controlling for other variables (Logits)	
Period	Hypothesis	Replacement Ratio-With Stage	Replacement Ratio-Ignoring Stage
Inheritance vs. No Inheritance	Decrease	NS	NS

Table 6. 21 Summary of Inheritance Effect for T-Test and Logistic Regression

I = Increase significant at 0.05 level using two-sample t-test.
NS = No significant difference at 0.05 level using two-sample t-test

6.5.6 Demographic Factor

One out of the two models shows that households with a head ages 45 to 54 are more likely than those ages 35 and 44 to have retirement adequacy, perhaps due to the fact that younger individuals are only beginning to accumulate retirement assets. The education level of the head does not have a consistent result toward the likelihood of have an adequate retirement in those four models. However, the positive coefficients indicate that individuals having more education are more likely to have an adequate retirement. The marital demographic variables do not have consistent testing results for the likelihood of adequate retirement. There is only a weak correlation between ethnic groups and retirement adequacy, but the negative coefficients of Blacks, Hispanics, and Asian indicate a negative impact toward retirement adequacy.

6.5.7 Financial Characteristic Factor

The correlation between household income and retirement adequacy is weak. Even though higher income households should be able to accumulate more retirement assets than lower income households, they may decide not to accumulate retirement assets proportionally to income, since taxes and savings count for a higher proportion of their gross income. In section 6.5.4, households with defined benefit pensions and with defined contribution pensions are more likely to have retirement adequacy than similar households without such plans. This result is consistent with the study of Yuh et al. (1998).

6.5.8 Financial Decision/Attitude Factor

Planned retirement age is an important factor related to retirement adequacy. All the coefficients of the planned retirement age are very significant for each logit. Households planning to retire after age 61 are more likely to have retirement adequacy than similar households planning to retire before 62. This result is consistent with the study of Yuh et al. (1998). In addition, the later planned retirement ages have a greater positive coefficient of likelihood of retirement adequacy. Households with later planned retirement ages have more time of in pre-retirement life, so they can have more time and income to accumulate retirement assets.

Spending behavior is significant in the model A. For model A, individuals with a deficit are less likely to have an adequate retirement. In addition, households spending more than their income will have less accumulated retirement assets.

Households willing to take average or above average risk are more likely to have retirement adequacy under the replacement ratio model. The correlation between the magnitude of taking risk and the likelihood of adequate retirement is strong and monotone.

CHAPTER 7

CONCLUSION AND IMPLICATIONS

7.1 Conclusion

7.1.1 Conclusion from Descriptive Statistics

The main focus of this study is the effect of retirement stages on retirement adequacy. About 63% of households have more than one stage, and 37% of households have one stage. One person households planning to retire at 62 or later and not planning to work part-time during retirement are likely to have only one stage, as are couples planning to retire in the same calendar year with both age 62 or older.

The planned first retirement age is negatively correlated to the number of stages, i.e., when the first retirement age is earlier, this household has more stages. When the first retirement age is before 62, there will be more than one retirement stage because the household will have to wait until the head turns 62 to start receiving the Social Security retirement benefit. In addition, the length of last stage is the longest, since it is the period between the age of income leveling off and the age of death. Furthermore, the last stage length decreases as the households have more stages.

The household categories defined in section 6.2 present a trend that category 1 increases from year 1995 to year 2004, but category 3 decreases from year 1995 to year 2004. This means that households in 2004 are more likely than those in 1995 to have more than one stage and also more likely to have accumulated enough retirement assets to be able to smooth consumption between stages.

About 29% of the households have a defined contribution pension and about 25% of the households have a defined benefit pension. It shows that quite a few households participate in employer-sponsored retirement plans. A large number of households (about 48%) plan to retire between the ages of 62 and 65. About 70% of households are willing to take financial risks. Only about 26% of households plan to have a part-time job after retirement.

On average, the current balance of retirement assets is about $249,000, assuming non-retirement account financial assets and non-financial assets will be used for retirement purposes. The mean annul contribution to the retirement plan is about $3,300 and only one third of the households have that contribution. Moreover, the mean and median expected Social Security retirement benefit of head-of-household is around $14,000, whereas, the mean and median expected Social Security retirement benefit of spouses is around $9,000 and $7,000 respectively. In addition, the mean value of expected defined benefit pension is about $7,000 and $1,000 respectively. The mean annual part-time job wage of the head-of-household is around $21,000; however, the mean annual part-time job wage of spouses is only around $5,000.

The median replacement ratio ranges from 47.8% to 109.8% across categories and new stages and from 47.8% to 186.1% when stage partition is ignored. The corresponding adequacy proportion based on the replacement ratio of retirement adequacy proportions ranges from 33.6% to 83.0% across categories and new stages, but ignoring stage partition, the proportion ranges from 33.6% to 74.6%. The percentage interval of adequacy proportion for non-stage partition is sufficiently larger than that of stage partition method.

The overall adequacy proportion of new stage 1 ranges from 45.9% to 59.8%, while the adequacy proportion of new stage 2 ranges from 48.4% to 61.2%. It shows that the overall adequacy taking stages into account increased each survey period from 1995 to 2004. The combined stage adequacy proportion ranges from 47.2% to 60.5%. When ignoring stage partition, the adequacy proportion ranges from 58.0% to 61.7%. Compared these two methods, the adequacy proportion difference is about 11.7% in 1995, 8.4% in 1998, 3.8% in 2001, and 1.2% in 2004.

7.1.2 Conclusion from T-Test with RII Technique

The replacement ratio ignoring stage is much greater than when stage partition is used, since the ignoring stage method recognizes all retirement income at the planned retirement age, while the stage partition method recognizes retirement income at the actual age. Hypothesis 1a is fully supported by using the two-sample t-test with the RII technique. The hypothesis 1b of different adequacy proportions between new stage 1 and new stage 2 is fully supported by using the two-sample t-test. Therefore, it is concluded that households ignoring stage are more likely to overestimate retirement adequacy, and retirement adequacy is significantly different in different stages.

The test of year-effect is more complicated than other testing, since it involves more pair comparisons and more scenarios. In the second hypothesis, retirement adequacy is hypothesized not to change because of the net effect of reducing contribution and better stock performance. After performing the t-test, hypothesis 2a is fully supported since all the test results are not significant. Hypothesis 2b is not supported; since the tests results show that adequacy proportion significantly increase. Hypothesis 2c is not supported either, since all the test results shows that adequacy proportions significantly increase as well.

For the third hypothesis, test result concludes that individuals having defined contribution or defined benefit pensions are more likely to have retirement adequacy; that is, the hypothesis 3a and 3b are supported.

In the fourth hypothesis, households with an expectation of inheritance are hypothesized to be less likely to have retirement adequacy; however, the t-test shows the opposite results. Hypothesis 4 is not supported.

7.1.3 Conclusion from Logistic Regression with RII Technique

The hypothesis 1a of different adequacy proportions between new stage 1 and new stage 2 is fully supported by using logistic regression. The "stage more than one" independent variable is significant in model A. The hypothesis 1b is not applicable in logistic regression, since the retirement stage is used to segment the population.

In the second hypothesis, testing results of the logistic regression between stage partition method and non-stage partition are consistent in some magnitude, except for the 01 vs. 04 comparison. From Table 6.20, the hypothesis 2a and 2b are fully supported, while hypothesis 2c is not supported.

In third hypothesis, the multivariate test does not have consistent results between stage partition method and non-stage partition method.

In the fourth hypothesis, the multivariate test results shows non-significant difference of retirement adequacy between having and not having expectation of inheritance. Therefore, hypothesis 4 is not supported.

In the multivariate analysis, the demographic variables are not all consistently significant across these two models, but play a role as control variables. The age effect is not obvious or consistent. In addition, the education of the head-of-household does not have a consistent effect. However, the positive coefficients indicate that an individual having more education is more likely to have an adequate retirement. Married households are more likely to have adequate retirements than other household types, such as partners, separated, divorced, widow, and never married. Moreover, in Model A (Table 6.15) Whites are more likely to have adequate retirement than those identifying themselves as a group other than Black or Hispanics, and Whites are somewhat more likely to have retirement adequacy than Blacks, though the difference is significant at only the 0.055 level.

In the multivariate analysis, financial behavior variable plays a critical role. The planned retirement age is positively correlated to the likelihood of having adequate retirement; households with later retirement ages are more likely to have retirement adequacy. Other behavior variables, such as having a running deficit, taking risks, and the expectation of good health are not consistently significant across the four models.

7.2 Implications

7.2.1 Implications for Educators and Researchers

Future research should focus on the components of retirement income stages. In this study, only three stage drivers are demonstrated: the Social Security retirement benefit, defined benefit pensions, and part-time job wages. In practice, more stage drivers, such as public assistance, food stamps, profit sharing plans, and inheritance, during retirement could be examined. How to allocate those income cash flows and financial goals across the timeline of retirement is critical when the financial planners consider retirement planning.

On the retirement needs side, more attention should be paid to the definition and scope of retirement needs. The purpose of using different definitions of retirement needs is to have an absolute and relative basis for justifying retirement adequacy. According

Maslow's hierarchy of needs, the retirement adequacy indicator provides an absolute basis of economic measurement. When using pre-retirement needs on the other hand, retirement adequacy provides a relative basis of economic measurement. Previous literature does not have a detailed discussion of retirement needs. However, it is necessary for government policy to plan a social welfare program an in terms of absolute economic measurement, since the welfare program is designed to help those who are really in need. A financial planner's perspective is somewhat different from the government's perspective regarding retirement needs. Future research should distinguish the retirement needs differences for different purposes.

7.2.2 Implications for Financial Planners

The implication for financial planners is to consider retirement income stages when analyzing retirement adequacy. Retirement income stages represent multiple income cash flows. A household with more retirement income stages would have more income cash flows. Income cash flow management is critical in retirement planning with respect to financial goals fulfillment. To meet financial goals, households can either use credit loans or income stage management to articulate income cash flow. Compared to costly credit loans, retirement income stage management would be a less costly method to meet financial goals by planning ahead.

Retirement income stage deserves more attention from financial planners since it enhances the financial fulfillment possibility and reduces the cost of borrowing. Due to the complexity of cash flow management, some households might fail to forecast the timing and amount of future cash flow, and then be forced to borrow to finance their goals. However, if the household plans for cash flow management, it can reduce the cost of borrowing.

An important responsibility of financial planners is to educate individuals to plan the financial goal in advance and try to match their financial goals with the retirement income cash flows. Another responsibility of financial planners is to suggest individuals how to allocate their assets to gain benefit and hedge risk according to their life cycle phase, since the retirement plan has been switched from defined benefit pension to defined contribution pension. Moreover, the financial planners should encourage the individuals participating in employer provided pension plan or stick to a prescribed saving rate for retirement preparation.

7.2.3 Implications for Government Policy

The tax deferred contribution regulation will influence the individual’s saving behavior (Moore & Mitchell, 1997). An important task of government is to encourage individuals to increase their contributions to tax deferred retirement accounts. Government policy should focus on the encouragement the early preparation for retirement with more tax deferment. In addition, under the Social Security Reform act, the distribution of retirement benefit should provide variety distribution methods, such that the benefits can finance their financial goals. The extended withdrawal of retirement account will benefit the retirees the power of interest compounding.

APENDIX A

SAS Code for Two-Sample T-Test with Constant Variance Assumption

```
data [new data name];
set [old data name];
if year=1995 then repl_adq95=repl_adq;  /*assign the adequacy indicator across years*/
if year=1998 then repl_adq98=repl_adq;
if year=2001 then repl_adq01=repl_adq;
if year=2004 then repl_adq04=repl_adq;
X1=repl_adq95;
X2=repl_adq98;
X3=repl_adq01;
X4=repl_adq04;
run;

PROC SORT DATA=[new data name];  /* Sort by 5 implicates */
BY IMPLic;

PROC UNIVARIATE DATA=[new data name]VARDEF=WDF;
  VAR X1 X2 X3 X4;
  WEIGHT nwgt;
  BY IMPLIC;
  OUTPUT OUT=RII MEAN=QX1 QX2 QX3 QX4
         STD=UX1 UX2 UX3 UX4  /*  Export covariance matrix  */
         N=NX1 NX2 NX3 NX4 ;
PROC PRINT DATA=RII;

*RII TECHNIQUE FOR A SCALAR;
PROC IML;
  RESET AUTONAME;
  USE RII VAR{QX1 QX2 QX3 QX4 }; READ ALL INTO QI;
  USE RII VAR{UX1 UX2 UX3 UX4 }; READ ALL INTO UI;
  USE RII VAR{NX1 NX2 NX3 NX4 }; READ ALL INTO NI;
  MM= NROW(QI); JMAT = J(MM,1);
  NN= NCOL(QI); NAMES={X1 X2 X3 X4 };
```

```
*AVERAGE OF THE FIVE POINT ESTIMATES OF THE MEAN (Eq. 1);
 QMBAR=QI(|+,|)/MM;
 QMBAR12=(QI[+,1]-QI[+,2])/MM;
 QMBAR13=(QI[+,1]-QI[+,3])/MM;
 QMBAR14=(QI[+,1]-QI[+,4])/MM;
 QMBAR23=(QI[+,2]-QI[+,3])/MM;
 QMBAR24=(QI[+,2]-QI[+,4])/MM;
 QMBAR34=(QI[+,3]-QI[+,4])/MM;

*VARIANCE OF THE MEAN (SQUARE OF THE STANDARD ERROR);
 UI=UI#UI;

*AVERAGE WITHIN IMPUTATION VARIANCE (Eq. 2);
 UMBAR1=UI[+,1]/MM;
 UMBAR2=UI[+,2]/MM;
 UMBAR3=UI[+,3]/MM;
 UMBAR4=UI[+,4]/MM;

*INTERMEDIATE STEPS FOR CALCULATING BETWEEN IMPUTATION
VARIANCE;
 QMBARX=QMBAR@JMAT;
 QDIF = QI-QMBARX;
 QDIFSQ = QDIF#QDIF;

*BETWEEN IMPUTATION VARIANCE (Eq. 3);
 BM1 = QDIFSQ[+,1]/(MM-1);
 BM2 = QDIFSQ[+,2]/(MM-1);
 BM3 = QDIFSQ[+,3]/(MM-1);
 BM4 = QDIFSQ[+,4]/(MM-1);

*RII TOTAL VARIANCE OF THE MEAN (Eq. 4);
TM1 = UMBAR1+(1+1/MM)*BM1;
TM2 = UMBAR2+(1+1/MM)*BM2;
TM3 = UMBAR3+(1+1/MM)*BM3;
TM4 = UMBAR4+(1+1/MM)*BM4;

*Pooled standard deviation;
SP12=SQRT(((NI[+,1]-1)*TM1+(NI[+,2]-1)*TM2)/(NI[+,1]+NI[+,2]-2));
SP13=SQRT(((NI[+,1]-1)*TM1+(NI[+,3]-1)*TM3)/(NI[+,1]+NI[+,3]-2));
SP14=SQRT(((NI[+,1]-1)*TM1+(NI[+,4]-1)*TM4)/(NI[+,1]+NI[+,4]-2));
SP23=SQRT(((NI[+,2]-1)*TM2+(NI[+,3]-1)*TM3)/(NI[+,2]+NI[+,3]-2));
SP24=SQRT(((NI[+,2]-1)*TM2+(NI[+,4]-1)*TM4)/(NI[+,2]+NI[+,4]-2));
SP34=SQRT(((NI[+,3]-1)*TM3+(NI[+,4]-1)*TM4)/(NI[+,3]+NI[+,4]-2));
```

```
*Pooled standard error;
SE12=SP12*SQRT(1/NI[+,1]+1/NI[+,2]);
SE13=SP13*SQRT(1/NI[+,1]+1/NI[+,3]);
SE14=SP14*SQRT(1/NI[+,1]+1/NI[+,4]);
SE23=SP23*SQRT(1/NI[+,2]+1/NI[+,3]);
SE24=SP24*SQRT(1/NI[+,2]+1/NI[+,4]);
SE34=SP34*SQRT(1/NI[+,3]+1/NI[+,4]);

*T statistic;
T12=QMBAR12/SE12;
T13=QMBAR13/SE13;
T14=QMBAR14/SE14;
T23=QMBAR23/SE23;
T24=QMBAR24/SE24;
T34=QMBAR34/SE34;

*Degree of Freedom;
DF12=NI[+,1]+NI[+,2]-2;
DF13=NI[+,1]+NI[+,3]-2;
DF14=NI[+,1]+NI[+,4]-2;
DF23=NI[+,2]+NI[+,3]-2;
DF24=NI[+,2]+NI[+,4]-2;
DF34=NI[+,3]+NI[+,4]-2;

*P-value;
P12=PROBT(T12,DF12)*2;
if P12>1 then P12=(1-PROBT(T12,DF12))*2;

P13=PROBT(T13,DF13)*2;
if P13>1 then P13=(1-PROBT(T13,DF13))*2;

P14=PROBT(T14,DF14)*2;
if P14>1 then P14=(1-PROBT(T14,DF14))*2;

P23=PROBT(T23,DF23)*2;
if P23>1 then P23=(1-PROBT(T23,DF23))*2;

P24=PROBT(T24,DF24)*2;
if P24>1 then P24=(1-PROBT(T24,DF24))*2;

P34=PROBT(T34,DF34)*2;
if P34>1 then P34=(1-PROBT(T34,DF34))*2;
```

```
*COMMANDS TO PRINT RESULTS;
PRINT SE12 SE13 SE14 SE23 SE24 SE34;
PRINT T12 T13 T14 T23 T24 T34;
PRINT DF12 DF13 DF14 DF23 DF24 DF34 ;
PRINT QMBAR12 QMBAR13 QMBAR14 QMBAR23 QMBAR24 QMBAR34;
PRINT P12 P13 P14  P23 p24 P34;  run;
```

APPENDIX B

SAS Code for Two-Sample T-Test with Non-Constant Variance Assumption

```
data [new data name];

set [old data name];
if year=1995 then repl_adq95=repl_adq;  /*assign the adequacy indicator across years*/
if year=1998 then repl_adq98=repl_adq;
if year=2001 then repl_adq01=repl_adq;
if year=2004 then repl_adq04=repl_adq;
X1=repl_adq95;
X2=repl_adq98;
X3=repl_adq01;
X4=repl_adq04;
run;

PROC SORT DATA=[new data name];
BY IMPLIC;     /* Sort by 5 implicates */

PROC UNIVARIATE DATA=[new data name] VARDEF=WDF;
  VAR X1 X2 X3 X4;
  WEIGHT nwgt;
  BY IMPlic;
  OUTPUT OUT=RII MEAN=QX1 QX2 QX3 QX4
              STD=UX1 UX2 UX3 UX4    /*  Export covariance matrix  */
              N=NX1 NX2 NX3 NX4 ;

PROC PRINT DATA=RII;

*RII TECHNIQUE FOR A SCALAR;
PROC IML;
  RESET AUTONAME;
  USE RII VAR{QX1 QX2 QX3 QX4 }; READ ALL INTO QI;
  USE RII VAR{UX1 UX2 UX3 UX4 }; READ ALL INTO UI;
  USE RII VAR{NX1 NX2 NX3 NX4 }; READ ALL INTO NI;
```

```
 MM= NROW(QI); JMAT = J(MM,1);
 NN= NCOL(QI); NAMES={X1 X2 X3 X4 };

*AVERAGE OF THE FIVE POINT ESTIMATES OF THE MEAN (Eq. 1);
 QMBAR=QI(|+,|)/MM;
 QMBAR12=(QI[+,1]-QI[+,2])/MM;
 QMBAR13=(QI[+,1]-QI[+,3])/MM;
 QMBAR14=(QI[+,1]-QI[+,4])/MM;
 QMBAR23=(QI[+,2]-QI[+,3])/MM;
 QMBAR24=(QI[+,2]-QI[+,4])/MM;
 QMBAR34=(QI[+,3]-QI[+,4])/MM;

*VARIANCE OF THE MEAN (SQUARE OF THE STANDARD ERROR);
 UI=UI#UI;

*AVERAGE WITHIN IMPUTATION VARIANCE (Eq. 2);
 UMBAR1=UI[+,1]/MM;
 UMBAR2=UI[+,2]/MM;
 UMBAR3=UI[+,3]/MM;
 UMBAR4=UI[+,4]/MM;

*INTERMEDIATE STEPS FOR CALCULATING BETWEEN IMPUTATION
VARIANCE;
 QMBARX=QMBAR@JMAT;
 QDIF = QI-QMBARX;
 QDIFSQ = QDIF#QDIF;

*BETWEEN IMPUTATION VARIANCE (Eq. 3);
 BM1 = QDIFSQ[+,1]/(MM-1);
 BM2 = QDIFSQ[+,2]/(MM-1);
 BM3 = QDIFSQ[+,3]/(MM-1);
 BM4 = QDIFSQ[+,4]/(MM-1);

*RII TOTAL VARIANCE OF THE MEAN (Eq. 4);
TM1 = UMBAR1+(1+1/MM)*BM1;
TM2 = UMBAR2+(1+1/MM)*BM2;
TM3 = UMBAR3+(1+1/MM)*BM3;
TM4 = UMBAR4+(1+1/MM)*BM4;

*Estimate of standard deviation, based on assumption of diff population var ;
SE12=SQRT(TM1/NI[+,1]+TM2/NI[+,2]);
SE13=SQRT(TM1/NI[+,1]+TM3/NI[+,3]);
SE14=SQRT(TM1/NI[+,1]+TM4/NI[+,4]);
SE23=SQRT(TM2/NI[+,2]+TM3/NI[+,3]);
SE24=SQRT(TM2/NI[+,2]+TM4/NI[+,4]);
SE34=SQRT(TM3/NI[+,3]+TM4/NI[+,4]);
```

```
*T statistic;
T12=QMBAR12/SE12;
T13=QMBAR13/SE13;
T14=QMBAR14/SE14;
T23=QMBAR23/SE23;
T24=QMBAR24/SE24;
T34=QMBAR34/SE34;

*Degree of Freedom;
DF12=((TM1/NI[+,1]+TM2/NI[+,2])##2)/((TM1/NI[+,1])##2/NI[+,1]+(TM2/NI[+,2])##
2/NI[+,2]);
DF13=((TM1/NI[+,1]+TM3/NI[+,3])##2)/((TM1/NI[+,1])##2/NI[+,1]+(TM3/NI[+,3])##
2/NI[+,3]);
DF14=((TM1/NI[+,1]+TM4/NI[+,4])##2)/((TM1/NI[+,1])##2/NI[+,1]+(TM4/NI[+,4])##
2/NI[+,4]);
DF23=((TM2/NI[+,2]+TM3/NI[+,3])##2)/((TM2/NI[+,2])##2/NI[+,2]+(TM3/NI[+,3])##
2/NI[+,3]);
DF24=((TM2/NI[+,2]+TM4/NI[+,4])##2)/((TM2/NI[+,2])##2/NI[+,2]+(TM4/NI[+,4])##
2/NI[+,4]);
DF34=((TM3/NI[+,3]+TM4/NI[+,4])##2)/((TM3/NI[+,3])##2/NI[+,3]+(TM4/NI[+,4])##
2/NI[+,4]);

*P-value;
P12=PROBT(T12,DF12)*2;
if P12>1 then P12=(1-PROBT(T12,DF12))*2;

P13=PROBT(T13,DF13)*2;
if P13>1 then P13=(1-PROBT(T13,DF13))*2;

P14=PROBT(T14,DF14)*2;
if P14>1 then P14=(1-PROBT(T14,DF14))*2;

P23=PROBT(T23,DF23)*2;
if P23>1 then P23=(1-PROBT(T23,DF23))*2;

P24=PROBT(T24,DF24)*2;
if P24>1 then P24=(1-PROBT(T24,DF24))*2;

P34=PROBT(T34,DF34)*2;
if P34>1 then P34=(1-PROBT(T34,DF34))*2;
```

```
*COMMANDS TO PRINT RESULTS;
PRINT SE12 SE13 SE14 SE23 SE24 SE34;
PRINT T12 T13 T14 T23 T24 T34;
PRINT DF12 DF13 DF14 DF23 DF24 DF34 ;
PRINT QMBAR12 QMBAR13 QMBAR14 QMBAR23 QMBAR24 QMBAR34;
PRINT P12 P13 P14  P23 p24 P34;
run;
```

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