Are Husbands Really That Cheap?*

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July, 2003

Abstract

The life insurance market is one of the most prominent contingent claim markets that exist and thus provides an interesting laboratory to examine agents consumption and risk sharing behavior. An examination of the 1998 Survey of Consumer Finances indicates life insurance patterns may not be consistent with patterns suggested by life-cycle models. In this paper, we investigate these apparent inconsistencies using a dynamic overlapping generation general equilibrium model. The decision making unit is the household, which is subject to mortality, demographic and idiosyncratic earnings risk. Households have access to an asset and life insurance market that allows imperfect risk

* We would like to thank participants in seminars at the 2003 Midwest Macro Meetings, 2003 Winter Econometric Society and Florida State University as well as special thanks to Fernando Alvarez, Jesus Fernández, Carlos Garriga, Stuart Low, Dave MacPherson, David Marshall, Chris Phelan, and Ned Prescott for helpful comments. We would also like to thank Charles Grassl, Curtis Knox, and Joe Travis for computational assistance and tips. Young would like to thank the Florida State University FYAP program for financial support. All errors are our errors.

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sharing. We find that the pricing scheme adopted by the industry has a significant impact on the distribution of policies, and that the pattern of life insurance holdings likely constitutes a puzzle for financial economics.

Failure of the head of a family to insure his or her life against a sudden loss of economic value through death or disability amounts to gambling with the greatest of life's values; and the gamble is a particularly mean one because, in the case of loss, the dependent family, and not the gambler must suffer the consequences.

S. Huebner and K. Black, Jr., **Life Insurance**

1 Introduction

The life insurance market is one of the most prominent contingent claim markets that exist and are readily available to households; thus it provides an interesting laboratory to examine agents' consumption and risk sharing behavior – the total size of this market in 1998 was 0.95 times annual GDP. Casual empiricism suggests that households are holding an insufficient amount of life insurance, especially in the 25 to 50 age cohort. For example, the media often mentions instances where a widow enters poverty income levels as the result of the untimely death of a spouse.[1] An examination of the 1998 Survey of Consumer Finances indicates that the participation rate for households who are wealthier and older than age 50 are higher than those in the 25 to 50 age cohort. Furthermore, households with one worker have significantly lower participation rates than two worker households. Hence, a brief look at the data seems to support the notion that households may be holding an insufficient amount of life insurance.[2]

The theoretical literature on life insurance holdings as part of a risk-sharing and lifecycle savings plan begins with Yaari (1965), who demonstrated that actuarially-fair life insurance policies increase the lifetime utility

[1] Interestingly, the life insurance industry seems to be aware of this pattern in life insurance. An advertising campaign that aired during the 2001 World Series claimed that the average widow who is under the age of 50 would use up her life insurance payment within nine months. Recently, Zick and Holden (2000) find evidence in the Survey of Income and Program Participation that widows face significant wealth declines upon the death of their spouse. See also Hurd and Wise (1989).

[2] This casual interpretation is consistent with the results in Bernheim *et.al.* (2001a) using data from the 1992 Health and Retirement Survey. Using a partial equilibrium approach to measure financial vulnerability, they find that the households with the largest vulnerability hold the least amount of life insurance. In Bernheim *et.al.* (2001b), they examine the same data that we employ, but do not use a general equilibrium model to assess it.

of a household. This investigation was extended by, among others, Fischer (1973), Pissarides (1980), Karni and Zilcha (1985), and Lewis (1989) to allow for loading factors and different family objectives.[3] Within the empirical literature, there have been a large number of motives for demanding life insurance – among them include risk sharing, bequests, taxation of estates, over-annuitization by Social Security, and funeral costs.[4] We want to focus specifically on one particular motive – life insurance is a hedging vehicle against the risk of lost income due to the death of an earner. This question will naturally focus our attention on holdings in the 25-50 age cohorts, who typically can be characterized by growing earnings and relatively low wealth. Simple economic intuition would seem to suggest that this group would hold the most life insurance, since they have the most to lose. Part of the purpose of this paper is to assess whether in fact these are the households holding the most life insurance; we then assess these patterns theoretically.

In order to assess life insurance patterns from a theoretical perspective we construct a dynamic overlapping generations model. The decision making unit is the household, which enters a period with a demographic state comprised of age, sex, marital status, and the number of children. Households face idiosyncratic uncertainty in the hourly wage they command as well as in their demographic state. To insulate themselves against these shocks, agents can accumulate interest-bearing assets and life insurance policies and supply labor to the market. A competitive life insurance industry determines the equilibrium price of the life insurance policies.

We focus on a general equilibrium model, rather than a partial equilibrium one because we believe that the pricing of policies may constitute an important piece of the puzzle and these prices are not specified exogenously; in reality, the life insurance industry is quite competitive. Therefore, we take seriously the notion that general equilibrium effects contribute to decisions. Unfortunately, our data does not contain the critical piece of information needed to investigate this question – the premium paid for a policy. In addi-

[3] Other theoretical contributions include Campbell (1980), Economides (1982), Fortune (1973, 1975), Jones-Lee (1975), and Klein (1975).

[4] Empirical papers that have studied life insurance include, but are not limited to, Davies (1981), King and Dicks-Mireaux (1982), Goldsmith (1983), Karni and Zilcha (1985), Broverman (1986), Fitzgerald (1989), Bernheim (1991), Showers and Shotick (1994), Gandolfi and Miners (1996), Walliser and Winter (1998), Brown (1999), Anderson and Nevin (2000), Hau (2000), Chen, Wong, and Lee (2001), Holtz-Eakin, Phillips, and Rosen (2001), and Japelli and Pistaferri (2003).

tion, it does not identify who the policy covers, so that the pricing data would not be perfectly informative in any case. Our general equilibrium model is calibrated to produce a wealth and earnings distribution consistent with the data and demographic shocks that match observed transition probabilities from the Central for Disease Control and the Census Bureau.

Furthermore, the specification of a fully-specified model allows to clearly state what is meant by "adequate life insurance." Although this term is used repeatedly in the literature – especially in Auerbach and Kotlikoff (1989, 1990, 1991), Bernheim *et.al* (2001a, 2001b, 2002), and Gokhale and Kotlifkoff (2003) – it is not defined carefully in terms of a calibrated general equilibrium model. As noted above, we use the model to determine what amount of life insurance would be chosen by households in a controlled environment and then compare it to the data.[5] In addition, the aforementioned authors do not determine the price of life insurance endogenously; we show that the nature of the pricing schedule used by the life insurance industry is critical for holding patterns.

The paper is organized into four major sections. In the first of these sections, we examine a cross sectional data set assembled from the 1998 Survey of Consumer Finances. This data set is used to highlight key patterns in life insurance holdings as well as to identify essential aspects that must be included in a model. We use Tobit and probit regressions to identify critical relationships between earnings, income, wealth, and life insurance participation and holdings. The second section presents the dynamic theoretical model. The third section discusses calibration issues while the fourth section discusses the results generated in the model. The paper includes a computational appendix that discusses methods employed to numerically solve the model.

2 Empirical Life Insurance Holdings

Before any modelling efforts can be undertaken, it is important to document life insurance holdings as part of a household's self insurance decision. We would like to understand how agents with different earnings, income, wealth, and demographic characteristics vary in their holding of life insurance. In

[5] Bernheim *et.al* (2001a, 2001b, 2002) have a model to guide their computations, but it uses a utility function that does not match well with the data – Leontief over consumption in each period – and thus cannot deliver reasonable theoretical predictions.

order to identify important relationships, we would prefer to have a detailed panel data set comprising of a large set of households that report such factors as age, family size, other demographic characteristics, life insurance holdings, portfolio allocations, income, and other expenditures over a long period of time. Unfortunately, such a data set does not exist. Because of our focus on life insurance, we have extracted a data set from the Federal Reserve Board's 1998 Survey of Consumer Finances (SCF). This data source, to our knowledge, best meets our need for data on household life insurance holdings, wealth holdings and diversity of demographic characteristics.[6] In addition, the SCF oversamples the wealthy and thus gives a better indication of holding patterns than the other alternatives, especially the PSID.

We will use this data to construct three different measures of life insurance. In the real world, a variety of life insurance products are available, the most common forms being term life and whole-life insurance. **Term** life insurance is a policy that exists for a fixed number of periods and promises to pay a sum, the face value, if the policyholder dies within the horizon of the policy. If death does not occur within the horizon, the policyholder receives nothing. The alternative to term life insurance is whole-life insurance. A whole-life policy continues for the entire life of an individual. This policy pays off the face value of the policy upon time of death. In contrast to term life insurance, the purchaser of a **whole-life** policy knows with certainty that a payment will be made. This payment takes the form of a life insurance payoff in the event of death and a cash payment at the termination period; the cash value can be borrowed against for current consumption. However, as we mention later, our model will be concerned with an asset that pays off whenever a spouse dies, so we must combine the two types of policies in a particular way for consistency. We add term holdings to the non-cash value of whole-life policies to determine what we refer to as **total** life insurance. It is interesting to note that if we use this measure, we find that on average households hold about 1.10 times GDP in life insurance, about half their stock of other financial wealth. If we consider only married couples (as our model will only generate a demand for life insurance for married households) this number is 0.64 times GDP.

The data set we have assembled is comprised of 4,305 households. This

[6] Given the findings in Díaz-Giménez, Quadrini, and Ríos-Rull (1997) and Budría *et.al.* (2002) that the earnings, income, and wealth distributions appears quite similar across waves, we suspect that our results would not qualitatively or quantitatively change if we considered earlier samples.

number is based on the entire sample and is the average of the five imputations per household that are reported. Population weights are used when we refer to aggregate values. Individuals are asked to report the face value of all term life insurance policies held as individual or group life insurance policies. The inclusion of group policy holdings is important because it has been documented that some households only hold life insurance in the form of benefits provided by their employer.[7] The face and cash value of holdings of whole-life insurance are also reported. As with term insurance, both individually purchased policies and group policies are reflected in the reported values. If individuals have borrowed against their whole-life policies, this value is reported. Unfortunately, the data lacks three variables that are of critical importance: the price of the policy, the distribution of coverage over family members, and whether the policy is group or individual.

We are interested in the relationship between life insurance holdings and earnings, income, and wealth levels. Earnings are defined as wages and salaries. Our measure of income includes wages and salaries, farm income, income from private practices, non-taxed investments, interest income, dividends, capital gains and losses in stock, bond and real estate transactions, and social service income sources. The measure of wealth we use is quite comprehensive. We divide wealth into financial wealth and nonfinancial wealth and then adjust for borrowing. Financial wealth includes checking and saving accounts, brokerage accounts, mutual funds in stocks and bonds, quasi-liquid retirement accounts, thrift-type plans, value of pension accounts, cash value of whole-life insurance, and trusts and managed investment accounts with equity interest. The other part of wealth is referred to as nonfinancial wealth and includes the value of vehicles, the primary residence, other residential real estate, the value of the equity of business interests, and other nonfinancial assets. From the total of financial and nonfinancial wealth, we subtract household debts. Included in household debt is the debt for housing, debt for other residential property, credit card debt, installment loans, and loans on pensions or life insurance policies.

[7] This observation does not invalidate our theoretical model which assumes households directly choose their life insurance holdings. Rather, we search for the theoretical explanation consistent with the total holdings, since presumably firms would not offer these contracts as part of total compensation if life insurance were not valued.

2.1 A First Look

In Table 1, we summarize some of the economic characteristics of our households. The average age of the adults in a household is 48.7 years and the average household size is 2.48 individuals, with average earnings, income and wealth of a household being (in 1998 dollars) $42,369, $52,295, and $283,179, respectively. We are more interested in the disparity of earnings, income and wealth in our sample. In order to gain insights on this disparity, we calculate some summary statistics based on quintiles where the first quintile represents the lowest twenty percent in the sample. We will first consider earnings. The first quintile has negative income and has the highest average age. This is explained by the fact that this quintile is dominated by retirees. As the various quintiles are examined, earnings increases. If the average earnings of a quintile is compared to average earnings, we find that the fourth quintile earns 1.15 times average income and the fifth quintile earns 3.02 average income. All the other quintiles earn less than average income. These ratios reflect the disparities in earnings and are similar to the numbers reported in Budría *et.al.* (2002). Income disparities by quintile are similar to earnings disparities over quintiles, while the greatest disparities occur in wealth. All quintiles except the fifth have wealth levels below the average wealth level over all households. The average wealth level of the fifth quintile is approximately four times the average wealth level in the economy. In other words, wealth is distributed more unevenly than earnings and income.

Table 1 also examines the relationship between income, earnings and wealth and various demographic characteristics. We find that earnings have a humped shaped pattern. The highest average income occurs in the 40-49 cohort. Income and wealth also have a humped shaped pattern. The difference is that the peak occurs later with the 50-59 cohort. In terms of family structure, married households have the highest earnings, income, and wealth. As would be expected, married households with two incomes have higher earnings, income, and wealth than a one income family. A household comprised of a single male earns approximately two-thirds of a married household. The glaring disparity appears in a household comprised of a single female. Average earning in this type of household is $14,049 which is one-third the income level of a married household.

Table 2 focuses on life insurance holdings. From the standpoint of the total population, we see that term life insurance holding exceeds whole-life insurance. We find that term policies represent 70 percent of the total amount of life insurance and roughly 60 percent of the total number of policies. In fact, if we consider aggregate total life insurance, we find that the average face value of life insurance holding is \$114,993 with the average face value of term and whole-life insurance being \$79,526 and \$35,407, respectively. The fraction of households who hold some type of life insurance is 69.2 percent.

A more interesting insight on household holding of life insurance can be gained if holdings are considered in relation to economic and demographic conditions. Life insurance is held largely by individuals who have high earnings, income, and wealth. We will focus on income initially. A clear relationship emerges – life insurance participation depends positively on income. The fraction of households in the fifth quintile who have some life insurance is 86.3 percent while only 44.6 percent of households in the first quintile hold some life insurance. This pattern also carries over to earnings and wealth. In Figure 1 we examine the relationship between life insurance participation and earnings, income, and wealth. In this figure a clear positive relationship between economic condition and participation can be seen. The type of life insurance also seems to depend on the household's economic position. Household in the lowest 40 percent of the income distribution tend to hold term life insurance as indicated by the fact that 76 percent of life insurance is term insurance. However, as income increases, more whole-life policies seem to be held – the fraction of life insurance held in term policies falls to 64 percent. Similar relationships seem to exist if income is replaced with earnings and wealth.[8]

In terms of demographics, we want examine how the face value of life insurance and the life insurance participation rate varies with age. As can be seen in Figure 2, the face value of life insurance follows a humped-shaped pattern over age. The average policy increases until age 45 peaking at approximately \$170,000 and then declines over age.[9] Simple economic intuition qualitatively agrees with these patterns. Young and rich households have a substantial amount of wealth tied up in future labor earnings that would be lost in the case of an early death. To protect against such losses, these

[8] Our data is not consistent with evidence in Di Matteo and Emery (2002), who use probate data in Ontario in 1892. They find life insurance holdings are negatively related to wealth. It seems likely that adverse selection problems were particularly severe before the widespread development of actuarial science, and that this could have some effect given the strong positive relationship between wealth and mortality.

[9] The small uptick at the end is an artifact of the polynomial used to highlight the patterns and should be ignored.

households would be the most likely households to hold large amounts of life insurance.

The life insurance participation rate tells us about coverage. The participation rate in life insurance is also humped shaped across ages with the peak participation rate occurring around age 55, or the 50-59 age cohort in Table 2. In Figure 3, we illustrate this pattern by examining total life insurance participation by age. We have fitted a second order polynomial to the data to highlight this pattern. Figure 4 examines the participation rate for different types of life insurance by age. As can be seen, the humped shape pattern also exists for each type of life insurance. The difference is that the hump occurs later with whole-life insurance. This is consistent with the fact that wealthier households, which tend to be older, seem to favor whole-life insurance. While the humped pattern is consistent with economic theory, it is surprising that households in the 30-39 and 40-49 age cohorts do not have participation rates exceeding the 50-59 age cohort. These younger cohorts are unlikely to have accumulated enough assets to self-insure over their uncertain lifetime thus making life insurance a more attractive risk hedging vehicle. Furthermore, younger households have more uncapitalized human wealth; they should be more willing to purchase life insurance as a hedge against catastrophic loss of this durable.

Another issue is life insurance participation by household type. The adult composition of a household could be a married couple, a single male, or a single female. We find that the participation rate in life insurance for married families is 68.7 percent. We also examine the behavior of two adult worker families and one adult worker families. Economic theory would seemingly suggest that it would be in the interest of the nonworking spouse to hold life insurance on the working member of the household. Thus, the expectation is that the life insurance participation rate should be higher for a one worker household; in the data, the participation rate of two worker families is slightly greater. As can be seen, the life insurance participation rate is lower for a family with one adult worker compared to a family with two adult workers. This finding is surprising and requires additional inquiry. The insurance participation rates for single male and female household are well below the rates for married households; this probably is not surprising.

In Figures 5 and 6, we examine the joint relationship between life insurance holding by age cohort and either income or wealth. Figure 5 focuses on income and Figure 6 deals with wealth. We will start by examining income. If we hold income constant at a low level, we find relatively low face value levels of life insurance with the peak around the 45-49 age cohort. For each age cohort, an increase in income translates to an increase in the face value of life insurance holdings. However, the large build up in life insurance holdings is focused on individuals who are in the highest forty percent of the income distribution and in the age cohorts between age 40 and 59. The peak life insurance holding corresponds to the highest income individuals in the 50-54 age cohort. After that peak, life insurance holdings decline with age for the top forty percent income individuals until the age cohort 65–69 when we see an increase in life insurance purchases. The increase in life insurance at this age suggests that there is a motive for life insurance that is not captured by the self-insurance motive; we discuss some possible motivations for this demand in the conclusion.

Figure 6 examines the role that wealth may play in the life insurance decision. In general, the relationships are the same as they are when income is used to measure the economic condition. One difference is that individuals in the lowest wealth group seem to purchase more life insurance at an earlier age. When income is examined, we find the peak occurs at the 45-49 age cohort for the lowest income individuals. However, when wealth is examined, two peaks occur. A large peak occurs at the 35-39 age cohort and another occurs later in the 50-54 age cohort. As wealth increases over all age cohorts, the value of life insurance increases. The largest amounts of life insurance occur for the wealthiest households who are in the 50-54 age cohort. This is the same cohort that holds the most life insurance when income is considered. Again, we find additional purchases of life insurance in the older age cohorts.

For comparison with the output of our theoretical model, we also present empirical estimates of an object we will call total life insurance holdings. In the model, agents will have access to a simple contingent claim that pays off when an adult household member dies and an uncontingent savings vehicle. Looking at the data for this object, we find that the following patterns emerge. First, total life insurance holdings are increasing and concave in earnings, income, and wealth. Second, holdings are hump-shaped over the life cycle, with the maximum holdings coming around age 45; not coincidentally, this age is close to the one at which the present value of future earnings is maximized.

2.2 A Formal Statistical Analysis

The analysis of the data suggested some important relationships. In order to determine whether the observed relationships are actually *facts,* a formal statistical analysis is required. Our observed relationships concern to two decisions - the participation decision and the holding decision. The first of these decisions relates to the decision of whether or not to purchase life insurance – a probit analysis will help in the identification of important relationships. The second decision deals with the size of life insurance holdings – a Tobit analysis is relevant for this decision. Both the probit and Tobit models employ the same set of regressors which include a constant, wealth, wealth squared, earnings, earnings squared, income, income squared, age of the household head (agehead), age of the household head squared (ageheadsq), the number of kids (kids), the education level (edhd), and dummy variables for single earner (dhone), dual earner households (dhtwo), for married households (dmarry) and for good health status (dhealth).[10] We allow wealth, earnings, or income to enter the statistical model quadratically because of the aforementioned "hump-shaped" patterns associated with these variables. The Survey of Consumer Finances purposely over samples the wealthy, and any statistical analysis must explicitly account for this bias. In our statistical analysis, individual observations are weighed by the appropriate population weight in both the probit and Tobit models.[11] In addition, a White type estimator is employed to account for heteroscedasticity

We begin with the decision to participate in the life insurance mark et. Rather than exhaustively examine all the individual coefficients and their significance which are presented in Table 3 through 6, we will focus on the results which pertain to the previously discussed observed relationships. Our preliminary examination of the data suggested that the decision to hold life insurance is positively related to earnings, income, and wealth. The results presented in Table 4 and 5 suggest that this conclusion is correct for the decision to purchase whole life or total life insurance. However, when insurance

[10]The omitted dummy variables are no earner in the household, single, and reports good health. Because income is nearly perfectly-correlated with a linear combination of earnings and wealth, we could not include it as a separate regressor. Portfolio effects are the only reasons that correlation is not exactly 1. In our theoretical model, earnings per hours and wealth will be part of the state of the world but income will not be, so we feel that this combination is the appropriate one to study.

[11]The estimation is computed using maximum likelihood with a simulated annealing search routine to minimize the chance of becoming stuck in a local optimum.

is defined as term life insurance, earnings and income are statistically significant explanatory variables while wealth is not statistically different from zero. These results appear in Table 3. This suggests that our conclusion concerning the role of wealth based on our initial examination of the data may be inaccurate. The reason that wealth is insignificant can be found in Table 6 where we allow both earnings and wealth to appear as explanatory vaiables. The important result is that when both earnings and wealth appear in the equation, the marginal effect from a change in wealth is diminished. This finding actually provides support for our notion of term insurance as a consumption-smoothing vehicle; as wealth becomes larger, this additional asset becomes less valuable.

Examination of the data suggested that earnings, income, and wealth seem to have a "hump-shaped" effect on the decision to purchase insurance. Such an effect is allowed for by the introduction of squared values of these variables. Our statistical analysis indicates that the coefficients on these variables are either not statistically different from zero or so quantitatively small when statistically different from zero as to be irrelevant. As a result, the participation rate appears to be linear in earnings, income and wealth for all insurance definitions.

The data suggested that demographics are important factors in the decision to purchase life insurance and that this relationship could be nonlinear. In Tables 3 through 5, we find the nonlinear relationship is statistically significant as both age and age squared terms are in general statistically different from zero and the age squared term has the postulated negative sign. In Table 6 where wealth, earnings and age are allowed to have nonlinear effects, we see that the nonlinear effect in age is statistically different from zero, while this is not the case for either earnings or wealth. We allowed all three of these variables to appear in the statistical model to make sure that the nonlinear effect of age was not a result of a nonlinear effect emanating from one of the economic variables. Our results suggest that age is an important factor in the life insurance decision and thus any model where agents are making life insurance purchase decisions must explicitly allow for age.

Our statistical model allows for the participation decision to differ for single and dual earning households. As can be seen in Table 3 through 5, the coefficients for both of these variables are statistically different from zero when life insurance is defined as either term or total. For whole life insurance, these two variables are less important. An obvious question is whether a one income household differs from a two income household in the decision to participate in the life insurance market. The marginal effects that are present in Tables 3 through 6 indicate that dual earner households are approximately 1.5 percent more likely to hold life insurance than single earners. We examined whether a single household's probability of participating in the life insurance market is different from the two income household for the models presented in Table 6. We formulate the hypothesis that the participation rates for these two types of households are the same. We can reject this hypothesis at the one percent significance level for whole life insurance and our total measure of life insurance. For term life insurance, we can reject the hypothesis at the ten percent significance level. This result contradicts the idea that single earner households face more labor market risk and thus should hedge more of their labor market risk. However, merely looking at the decision to participate does not tell us enough about the life insurance decision.

We also would like to know whether observed relationships on the quantity of life insurance purchased are statistically present. We employ a (weighted) Tobit model to investigate previously identified relationships. Our findings are presented in Tables 7-10. We find that earnings, income and wealth are all statistically different from zero for all three measures of insurance. The only exception is that the wealth variable is not statistically different from zero when life insurance is measured as term insurance. As argued in the analysis of the probit model, these results are consistent with the idea that term life insurance has an important consumption-smoothing role. Our analysis of the data seems to indicate that earnings, income, and wealth impact the quantity of life insurance purchased in a nonlinear manner. In contrast to the findings in the probit analysis, we find that the squared terms associated with earnings, income, or wealth enter the model with a negative, and statistically different from zero coefficient (with the exception of wealth in the term life insurance model). These results support our observation that earnings, income, or wealth have "hump-shaped" impact on the quantity of life insurance purchased.

Demographics seem to play an important role in the quantity of life insurance purchased. In fact, the relationship between age and life insurance purchases seems to be "hump-shaped." As can be seen in Tables 7-9, there is strong statistical evidence supporting the nonlinear effect of age in the decision to purchase life insurance. In Table 10, we further investigate this result by allowing for separate nonlinear effects from earnings, wealth, and age. For all three measures of life insurance we find strong statistical evidence that both earnings and wealth are nonlinearly related to the quantity of insurance purchased. The surprising result was the age and age squared are no longer statistically different from zero except when life insurance is measured by whole life insurance. This finding suggests that the humped-shaped pattern in age is largely driven by the "hump-shaped" pattern in earnings. The fact that age continues to have an impact on the quantity of whole life insurance even when earnings and wealth enter to Tobit model is important. It may be recalled that Figure 3 seems to show that households seem to shift from term life insurance to whole life insurance as they age. The statistically significant age effects are likely capturing this effect which may have something to do with the tax-preferred status of life insurance payments.

The variables that account for martial status, education level, children are all statistically different from zero with positive signs in all the statistical models presented in Tables 7 through 10.[12] The variables for single and dual families are statistically different from zero except for when life insurance is measured as whole life insurance. For the statistical models presented in Table 10, we tested that single and dual households purchase the same amount of life insurance. The chi-squared statistic for this test indicated that the null hypothesis can not be rejected for either term life insurance or total life insurance. For whole life insurance, the null hypothesis can not be rejected at the five percent level, but can be rejected at the ten percent level. Given the results from our probit analysis, the empirical results from the Tobit model is a surprising fact as we expected the single earning household to purchase more term life insurance. Our reasoning is that single earner families face significantly more risk than dual earner families. We recognize that the non-working household member can always reenter the labor market. However, since out-of-the-labor force members will not enter at the same wage level as current workers have attained due to match-specific human capital effects (learning-by-doing) and tenure effects, single earnings households should still hold more term life insurance. Without a panel we cannot assess this reasoning empirically, but it does seem to be sensible and

[12] In general, the health variable is significant, suggesting that there the notion of time horizon does affect the decision to purchase life insurance. To attempt to detect this effect, we drop the health regressor to see if age picks up the significance; if it does, then a better measure of 'expected time until death' would seem to have predictive value for life insurance holdings. However, after dropping health, the significance of age does not change.

there is evidence from the labor literature for it.[13]

3 The Model Economy

In this section, we describe our dynamic general equilibrium model. The decision making unit is the household, which may contain more than one individual. Households enter a period with a demographic state comprised of age, sex, size, and marital status; this state evolves stochastically over time. Within this environment, households make consumption-savings, labor-leisure, and portfolio decisions. In addition to the households, we have three other types of agents. Production firms rent capital and labor from households and produce a composite capital-consumption good. Insurance firms collect premium payments for life insurance policies and make payments to households. Finally, the government collects payroll taxes and makes social security payments to retirees.

3.1 The Demographic Structure

With the decision making unit being the household, the demographic structure of the model is rather complex as the household structure, the marital status of the household and the number of children have to be taken into account. The economy is inhabited by individuals who live a maximum of I periods and face mortality risk. The demographic structure of a household is a four-tuple that depends on age, the adult structure of the household, the marital status of the household, and the number of children in the household. Denote the age of an individual by $i \in \mathcal{I} = \{1, 2, ..., I\}$. Survival probabilities depend on age and sex.

The second element of the demographic variable is the adult structure of the household; we assume this variable can take on one of three values: $p \in \mathcal{P} = \{1, 2, 3\}$. If $p = 1$, then the household is made up of a single male. A value of $p = 2$ denotes a household comprising of a single female, while $p = 3$ denotes a household with a male and a female who are married.

The third element in the four-tuple is the marital status of the household. We define the marital status by $m \in \mathcal{M} = \{1, 2, 3, 4\}$. Four values are needed to account for various events that have an impact on the house. A value of

[13] See in particular Mincer and Polachek (1974), Mincer and Ofek (1982) and Albrecht *et.al.* (1999).

$m = 1$ denotes a household that is composed of a single adult, either male or female, that has never been married. If $m = 2$, then the household is comprised of a single individual that has become single due to a previous divorce. If $m = 3$, the household is a single individual that has been widowed. Finally, $m = 4$ represents a married household.[14]

The last element in the four-tuple denotes the number of children in the household. We denote this demographic state variable by $x \in \mathcal{X} = \{0, 1, 2, 3, 4\}$. This tells us that the household can have between zero and four children. We limit the number of children to four per household for computational reasons.[15] Single female households can bear children, but single male households cannot. We do not separately track the age of the children; rather, we assume that they age stochastically according to a process that leaves them in the household twenty years on average.

A household's demographic characteristics are then given by the four-tuple $\{i, p, m, x\}$. We will define a subset of demographic characteristics made up of the tuple $\{p, m, x\}$ as $\widehat{z}$; this subset evolves stochastically over time. We assume that the process for these demographic states is exogenous with transition probabilities denoted by $\pi_i\left(\widehat{z}'|\widehat{z}\right)$; note that the transition matrix is age-dependent. To avoid excessive notation, we define the age specific transition matrices so that their rows add up to the probability of being alive in the next period. In constructing the transition matrix, a number of additional assumptions had to be made. In particular, marriage and divorce create some special problems. We assume that when a divorce occurs, the household splits into two households. Economic assets are split into shares according to the sharing rule $(\rho, 1-\rho)$ where ρ is the fraction of household wealth allocated to the male. Any children are assigned to the female. If a household happens to die off (all parents die in a given period) we assume that the children disappear as well. For marriage, we only allow individuals of the same age to marry. In addition, a male with children and a female with children can only marry if the joint number of children is less than the upper bound. This set of assumptions and our demographic structure results

[14] Some gender-marital status pairs are infeasible. The only pairs that are feasible are $(p = 1, m = 1)$, $(p = 1, m = 2)$, $(p = 1, m = 3)$, $(p = 2, m = 1)$, $(p = 2, m = 2)$, $(p = 2, m = 3)$, and $(p = 3, m = 4)$.

[15] Actual data for number of children per female for 1999 indicates that the number of females with five or more children is less than 2.7 percent of females. By abstracting away from these households we are not ignoring a significant fraction of the population.

in a relatively sparse transition matrix.[16]

The computation of this transition matrix is described in the appendix. The basic demographics of the calibrated population are presented in Table 11. We find that 68 percent of the population is currently married and 32 percent is single. Of the single households, divorced households make up 14 percent of the population, widowed households make up 7 percent of the population, and households which have never been married make up 10 percent of the population. When looking at children, we find 77 percent of households live with no kids, either because they have never had children or the children are adults and have left the household. 18 percent of households contain a single child, while households with multiple children constitute about 5 percent of the population. This distribution matches nicely with the data, suggesting our calibration procedure was successful.

3.2 The Household

3.2.1 Preferences

Household utility depends on the level of household consumption, male leisure, and female leisure. We specify the household preference function as

$$E_0 \sum_{t=1}^{I} \beta^{t-1} \frac{\left[C_t^{\mu} \left(1 - h_{mt}\right)^{\chi(1-\mu)} \left(1 - h_{ft} - \iota x_t\right)^{(1-\chi)(1-\mu)}\right]^{1-\sigma} - 1}{1-\sigma}$$

where C_t denotes the level of household consumption, $(1 - h_{mt})$ represents male leisure , and $(1 - h_{ft} - \iota x_t)$ defines female leisure.[17] We require that hours worked, leisure, and consumption be nonnegative for both genders. We define household consumption as

$$C_t = \left(1_{pt} + \eta x_t\right)^{\theta} c_t$$

[16] The transition matrix for a specific age is $(p, m, x) \times (p, m, x)$. Out of this set of transition elements, only twenty-seven can be non-zero, plus the nonzero probability of transition into death.

[17] Much of the family economics literature does not give the household direct preferences, instead assuming that the decisions are the result of Nash bargaining between the adults. Our formulation is a reduced-form of this bargaining game in which utility is not separable across adults, the bargaining weights are equal to χ and $1-\chi$, and the members are constrained to enjoy the same consumption. Given that marriage and divorce are exogenous events in our economy, we do not feel that the added burden of the fixed point bargaining problem is important.

where 1_{pt} is an indicator function that takes on the value of 1 if the state variable p is either 1 or 2 or the value 2 if p is equal to 3, (*i.e.*, the married state), x_t is the state variable indicating the number of children in the family, and (θ, η) are parameters. The parameter $\theta \in (-1, 0)$ accounts for economies of scale in consumption, while the parameter η converts children into adult equivalents. Female leisure differs from male leisure; female leisure depends on hours supplied h_f as well as a leisure cost per child captured by ιx, where $\iota \in (0, 1)$. In contrast, male leisure depends solely on hours supplied h_m. The remaining parameters in the utility function are the discount factor $\beta \in (0, 1)$, the weight of household consumption in utility $\mu \in (0, 1)$, and the Arrow-Pratt coefficient of relative risk aversion $\sigma \geq 0$.

It may be the case that the elasticity of substitution between male and female leisure is not 1, as we have assumed above. For example, it is plausible to assume that there is some degree of complementarity in these two inputs to utility; however, in order to accommodate productivity growth and stationary hours worked we are restricted to keeping the elasticity of substitution between consumption and leisure equal to 1. For computational reasons we restrict this value to 1, as it leads to labor supply rules which are linear in wealth and savings.

3.2.2 Household Environment

Households live in an uncertain environment that arises from demographic factors as well as a household specific productivity shock. Each period the household receives a productivity shock $\epsilon \in \mathcal{E} = \{\epsilon_1, \epsilon_2, ..., \epsilon_E\}$.[18] In addition to the demographic state discussed above, the household begins a period with wealth $a \in \mathcal{A}$; this space will be bounded from below by the requirement that consumption be nonnegative and bounded from above by the finiteness of the individual time horizon. The state for the household is the demographic situation, the productivity shock, and the wealth position:

$$s = (a, \epsilon, p, m, x, i) .$$

Given this state, the household's sources of funds are wealth and labor earnings. Labor earnings come from the hours worked by both males and

[18] We assume the productivity shock is household specific, meaning that both the husband and wife receive the same productivity shock. This assumption is made for computational purposes.

females (if of working age) or government social security payments (if retired). Let h_i denote hours worked by the household member of gender $i \in \{f, m\}$. Each unit of labor pays $w\epsilon\upsilon_i$ to the male worker and $w\epsilon\upsilon_i\phi$ to the female; w is the aggregate wage rate, ϵ is the idiosyncratic wage factor, υ_i is the age-specific earnings parameter, and ϕ corrects for the male-female wage gap.[19] Let ϖ denote the social security payment, τ be the payroll tax rate, and 1_ϖ be an indicator of retirement. Total labor income is then given by

$$(1 - 1_\varpi)(1 - \tau) w\epsilon\upsilon_i (h_m + \phi h_f) + 1_\varpi \varpi.$$

With this level of funds, the household must consume and purchase assets. The only assets that are available are capital k and term life insurance policies l. The budget constraint for a household of age i is

$$c + k' + ql' \leq a + (1 - 1_\varpi)(1 - \tau) w\epsilon\upsilon_i (h_m + \phi h_f) + 1_\varpi \varpi \tag{1}$$

where q is the price of a life insurance policy.[20]

The next period wealth level of a household depends on the capital and life insurance choices as well the future demographic state. If the household enters the period and remains married, the future wealth level is

$$a' = (1 + r')(k' + s') \tag{2}$$

where r' is the net return of capital and s' is the accidental bequest from households who die.[21] If a divorce occurs in a household that starts the period married, the male adult in the marriage has a wealth level next period equal to

$$a' = \rho (1 + r')(k' + s') \tag{3}$$

and the female adult's next period wealth level is

$$a' = (1 - \rho)(1 + r')(k' + s') \tag{4}$$

[19] This parameter makes the apparent portfolio puzzle even more severe, since it increases the degree to which females suffer from the risk of husband mortality. If we also allow for different age-wage profiles we could increase the sensitivity of households to wage disparities.

[20] In our model, whole life insurance policies are equivalent to a portfolio of term life insurance policies and riskless capital.

[21] We employ the convention that a 'prime' on a variable denotes the value in the next period.

where $\rho \in (0, 1)$ is the sharing rule. If death of a spouse occurs, the wealth evolution equation is

$$a' = (1 + r')(k' + s') + l' \tag{5}$$

as the life insurance policy pays off. If a household enters as a single adult and becomes married, we have to merge the budget constraints of two single adult households. A marriage yields the wealth equation

$$a' = (1 + r')\left(k' + \overline{k}' + s'\right) \tag{6}$$

where $\overline{k}'$ is the average capital for single households.[22]

Both life insurance and capital holdings are restricted to be nonnegative:

$$k', l' \geq 0.$$

We do not specifically model the reasons behind our asset market restrictions. For life insurance at least, appealing to moral hazard would suffice as a negative position in life insurance is equivalent to a long position in an annuitized asset. For capital, however, this restriction is somewhat more troublesome. We do not wish to complicate the model further by incorporating debt constraints.

The timing of events is important. We assume that divorce and marriage occur before death; that is, demographic changes occur first and then survival is determined. Furthermore, our demographic state only includes the last change; for example, households who get married, then divorced, then remarried, then widowed, are considered widowed. Fortunately, there will be only a small number of such households in equilibrium, and we do not feel the added burden involved in tracking past states to be worthwhile.

3.3 Aggregate Technology

The production technology of this economy is given by a constant returns to scale Cobb-Douglas function

$$Y = K^{\alpha} N^{1-\alpha}$$

[22] We should allow $\overline{k}'$ to be age-dependent. However, computing the equilibrium of this model would be infeasible as it would involve I market-clearing conditions, one for each age. With appropriate restrictions on the transition matrices our economy satisfies a mixing condition that could justify our assumption.

where $\alpha \in (0,1)$ is capital's share of output and K and N are aggregate inputs of capital and labor, respectively. The aggregate capital stock depreciates at the rate δ each period. Our assumption of constant returns to scale allows us to normalize the number of firms to one.

Given a competitive environment, the profit maximizing behavior of the representative firm yields the usual marginal conditions. That is,

$$r = \alpha K^{\alpha-1} N^{\alpha} - \delta \tag{7}$$

$$w = (1-\alpha) K^{\alpha} N^{-\alpha}. \tag{8}$$

The aggregate inputs of capital and labor depend on the decisions of the various individuals in the economy. Let Γ denote the distribution of households over the idiosyncratic states $(a, \epsilon, p, m, x, i)$ in the current period. The aggregate labor input and capital inputs are defined as

$$N = \int_{\mathcal{A}\times\mathcal{E}} \sum_{\mathcal{P}\times\mathcal{M}\times\mathcal{X}\times\mathcal{I}} \epsilon \upsilon_i \left(h_m\left(a, \epsilon, p, m, x, i\right) + \phi h_f\left(a, \epsilon, p, m, x, i\right)\right) \Gamma\left(da, d\epsilon, p, m, x, i\right)$$

and

$$K = \int_{\mathcal{A}\times\mathcal{E}} \sum_{\mathcal{P}\times\mathcal{M}\times\mathcal{X}\times\mathcal{I}} a \Gamma\left(da, d\epsilon, p, m, x, i\right).$$

3.4 The Life Insurance Firm

We assume that the life insurance market is a perfectly competitive market. As a result, we can examine the behavior of the single firm that maximizes profits. We also know in equilibrium that the price of insurance, or the premium, will be determined by a zero profit condition. We will consider an insurance firm that offers only term life insurance; we set the term to *one* period for simplicity. The life insurance company sells policies at the price q and pays out to a household that loses a spouse. Policies have a duration of one period.[23] The price q can depend on the age and demographic characteristics of the household in general; we will restrict ourselves in this paper to study parameterized pricing schemes. An extension to investigate the properties of efficient risk-sharing in our environment is currently beyond our computational ability.

[23] We abstract from annual renewal pricing issues. Because life insurance markets are characterized by adverse selection problems which may be revealed over time, the price of renewals could differ from a first time buyer.

Life insurance only pays off if an adult household member dies; we assume that the policy covers both members. Clearly, a critical aspect in the pricing of life insurance is the expected survival rate for an individual. We will represent the probability of an age i individual surviving to age $i+1$ as $\psi_{i,p}$. The zero profit condition for a life insurance firm is

$$\int_{\mathcal{A}\times\mathcal{E}}\sum_{\mathcal{P}\times\mathcal{I}}\left(1-\psi_{i,p}\right)\frac{1}{1+r'}l'\Gamma\left(da,d\epsilon,p,m,x,i\right)=\int_{\mathcal{A}\times\mathcal{E}}\sum_{\mathcal{P}\times\mathcal{I}}ql'\Gamma\left(da,d\epsilon,p,m,x,i\right). \tag{9}$$

The right hand side of this equation measures the revenue generated from the sale of life insurance policies to households in the economy. The left hand side measures the (expected) payout in premium due to deaths at the end of the period, appropriately discounted and corrected for mortality.

4 Stationary Equilibrium

We will use a wealth-recursive equilibrium concept for our economy and restrict ourselves to stationary steady state equilibria. Let the state of the economy be denoted by $(a,\epsilon,p,m,x,i)\in\mathcal{A}\times\mathcal{E}\times\mathcal{P}\times\mathcal{M}\times\mathcal{I}$ where $\mathcal{A}\subset\mathbb{R}_+,\mathcal{E}\subset\mathbb{R}_{+,}\mathcal{P}\subset\mathbb{R}_+$, $\mathcal{X}\subset\mathbb{R}_+$and $\mathcal{M}\subset\mathbb{R}_+$. For any household, define the constraint set of an age i household $\Omega_i\left(a,\epsilon,p,m,x,i\right)\subset\mathbb{R}^5_+$ as all five-tuples (c,k',l',h_m,h_f) such that the budget constraint (1), wealth constraints (2)-(6) are satisfied as well as the following nonnegativity constraints:

$$\begin{aligned} c_i &\geq 0 \\ k_i' &\geq 0 \\ l_i' &\geq 0 \\ h_i &\geq 0. \end{aligned}$$

Let $v\left(a,\epsilon,p,m,x,i\right)$ be the value of the objective function of a household with the state vector (a,ϵ,p,m,x,i), defined recursively as

$$v\left(a,\epsilon,p,m,x,i\right)=\max_{\left(c,k',l',h_m,h_f\right)\in\Omega_i}\left\{\begin{array}{c} U\left(\left(1_p+\eta x\right)^{\theta}c,1-h_m,1-h_f-\iota x\right)+ \\ \beta E\left[v\left(a',\epsilon',p',m',x',i+1\right)\right]\end{array}\right\}$$

where E is the expectation operator conditional on the current state of the household. A unique solution to this problem is guaranteed because the objective function is continuous and strictly concave and the constraint correspondence is compact-valued and continuous.

Definition 1 *A **stationary competitive equilibrium** is a collection of value functions* $v : \mathcal{A} \times \mathcal{E} \times \mathcal{P} \times \mathcal{M} \times \mathcal{I} \to \mathbb{R}_+$ *; decision rules* $k' : \mathcal{A} \times \mathcal{E} \times \mathcal{P} \times \mathcal{M} \times \mathcal{I} \to \mathbb{R}_+$*,* $l' : \mathcal{A} \times \mathcal{E} \times \mathcal{P} \times \mathcal{M} \times \mathcal{I} \to \mathbb{R}_+$*,* $h_m : \mathcal{A} \times \mathcal{E} \times \mathcal{P} \times \mathcal{M} \times \mathcal{I} \to \mathbb{R}_+$ *, and* $h_f : \mathcal{A} \times \mathcal{E} \times \mathcal{P} \times \mathcal{M} \times \mathcal{I} \to \mathbb{R}_+$*; aggregate outcomes* $\{K, N, s\}$*; prices* $\{q, r, w\}$*; government policy variables* $\{\tau, \varpi\}$*; and an invariant distribution* $\Gamma(a, \epsilon, p, m, x, i)$ *such that*

(i) *given* $\{w, r, q\}$*, the value function* v *and decision rules* c*,* k'*,* l'*,* h_m*, and* h_f *solve the consumers problem;*

(ii) *given prices* $\{w, r\}$*, the aggregates* $\{K, N\}$ *solve the firm's profit maximization problem;*

(iii) *the price* q *is consistent with the zero-profit condition of the life insurance firm;*

(iv) *the goods market clears:*

$$f(K, N) = \int_{\mathcal{A}\times\mathcal{E}} \sum_{\mathcal{P}\times\mathcal{M}\times\mathcal{X}\times\mathcal{I}} c(a, \epsilon, p, m, x, i)\, \Gamma(da, d\epsilon, p, m, x, i) + K' - (1-\delta) K;$$

(v) *the labor market clears:*

$$N = \int_{\mathcal{A}\times\mathcal{E}} \sum_{\mathcal{P}\times\mathcal{M}\times\mathcal{X}\times\mathcal{I}} \epsilon v_i \left(h_m(a, \epsilon, p, m, x, i) + \phi h_f(a, \epsilon, p, m, x, i)\right) \Gamma(da, d\epsilon, p, m, x, i);$$

(vi) *the accidental bequest transfer* s *is equal to the aggregate wealth of households that die:*

$$\begin{aligned} s \;=\; & \int_{\mathcal{A}\times\mathcal{E}} \sum_{\mathcal{P}\times\mathcal{M}\times\mathcal{X}\times\mathcal{I}} \left(1 - \psi_{i,male}\right) k'(a, \epsilon, 1, \{1,2,3\}, x, i)\, \Gamma(da, d\epsilon, 1, \{1,2,3\}, x, i) \\ & + \int_{\mathcal{A}\times\mathcal{E}} \sum_{\mathcal{P}\times\mathcal{M}\times\mathcal{X}\times\mathcal{I}} \left(1 - \psi_{i,female}\right) k'(a, \epsilon, 2, \{1,2,3\}, x, i)\, \Gamma(da, d\epsilon, 2, \{1,2,3\}, x, i) \\ & + \int_{\mathcal{A}\times\mathcal{E}} \sum_{\mathcal{P}\times\mathcal{M}\times\mathcal{X}\times\mathcal{I}} \left(1 - \psi_{i,male}\right)\left(1 - \psi_{i,female}\right) k'(a, \epsilon, 3, 4, x, i)\, \Gamma(da, d\epsilon, 3, 4, x, i); \end{aligned}$$

(vii) *the retirement program is self-financing:*

$$\varpi = \frac{\int_{\mathcal{A}\times\mathcal{E}} \sum_{\mathcal{P}\times\mathcal{M}\times\mathcal{X}\times\mathcal{I}} \tau (1 - I_\varpi) w \epsilon v_i \begin{pmatrix} h_m(a, \epsilon, p, m, x, i) + \\ \phi h_f(a, \epsilon, p, m, x, i) \end{pmatrix} \Gamma(da, d\epsilon, p, m, x, i)}{\int_{\mathcal{A}\times\mathcal{E}} \sum_{\mathcal{P}\times\mathcal{M}\times\mathcal{X}\times\mathcal{I}} I_\varpi \Gamma(da, d\epsilon, p, m, x, i)};$$

(*viii*) *letting T be an operator which maps the set of distributions into itself, aggregation requires*

$$\Gamma'(a', \epsilon', p', m', x', i+1) = T(\Gamma)$$

and T be consistent with individual decisions.

We will restrict ourselves to equilibria which satisfy $T(\Gamma) = \Gamma$.

5 Calibration

We calibrate our model to match features in the U. S. data. Our calibration will proceed as an exercise in exactly-identified Generalized Method of Moments; we directly choose some parameters when we do not have good statistics to match from the data. As much as possible, however, we will use the equilibrium for the model to determine the appropriate values.

We select the period in our model to be one year. First we examine the preference parameters in the model. The average wealth-to-GDP ratio in the postwar period of the U.S. is about three; hence, we choose β to replicate this number. The average individual in the economy works about thirty percent of their time endowment; we use this number to set the parameter μ. From time use surveys, we note that females allocate about 2 hours per day per child for care and females conduct about 2/3 of all such care, leading us to set $\iota = 0.145$. We also select χ so as to match the ratio of the hours supplied by females to males. The 1999 Current Population Survey reports average annual hours worked for males in 1998 is 1,899 while average annual hours worked for females in the same period is 1,310. Hence, χ is chosen so that the model generates the observed ratio of 0.689. The relative wage parameter ϕ is selected to be 0.77, consistent with estimates from the 1999 CPS on the relative earnings of males and females, and we set the divorce sharing rule to $\rho = 0.5$. The other preference parameters that require specification are η , θ, and σ. We use Greenwood, Guner, and Knowles (2001) to specify the first of these parameters: $\eta = 0.3$ and $\theta = -0.5$. The last parameter, σ, is the Arrow-Pratt coefficient of relative risk aversion. Given little *a priori* consensus on the value of this parameter, we choose $\sigma = 2$, a value which is consistent with choices typically made in the business cycle literature. Choosing a relatively low value for the risk aversion parameter (at least relative to values needed to match asset market data) will bias our results against finding excess life insurance.

The technology parameters that need to be specified are determined by the functional form of the aggregate production function and the capital evolution equation. The aggregate production function is assumed to have a Cobb-Douglas form, since the share of income going to capital has been essentially constant. We specify labor's share of income, $1-\alpha$, to be consistent with the long-run share of national income in the US, implying a value of $\alpha = 0.36$. The depreciation rate is specified to match the investment/GDP ratio of 0.25, taken from the same data, yielding a value of $\delta = 0.1$.

The specification of the stochastic idiosyncratic labor productivity process is extremely important because of the implications that this choice has for the eventual distribution of wealth. Storesletten, Telmer and Yaron (2001) argue that the specification of labor income or productivity process for an individual household must allow for persistent and transitory components. Based on their empirical work, we specify $\log(\epsilon)$ to be

$$\log(\epsilon') = \omega' + \varepsilon'$$

$$\omega' = \Psi\omega + v'$$

where $\varepsilon \tilde{} N(0, \sigma_\varepsilon^2)$ is the transitory component and ω is the persistent component. The innovation term associated with this component is $v \tilde{} N(0, \sigma_v^2)$. They estimate $\Psi = 0.935$, $\sigma_\varepsilon^2 = 0.01$, and $\sigma_v^2 = 0.061$. Fernández-Villaverde and Krueger (2000) approximate the STY process with a three state Markov chain using the Tauchen (1986) methodology – this approximation yields the productivity values $\{0.5, 0.93, 1.51\}$ and the transition matrix

$$\pi = \begin{bmatrix} 0.75 & 0.24 & 0.01 \\ 0.19 & 0.62 & 0.19 \\ 0.01 & 0.24 & 0.75 \end{bmatrix}.$$

The invariant distribution associated with this transition matrix implies that an individual will be in the low or the high productivity state just under 31 percent of the time and the middle productivity state 38 percent of the time. The age-specific component of income is estimated from earnings data in the PSID. Finally, we assume that the mandatory retirement age is 65 (45 in model periods) and that agents live at most 100 years (80 model periods). The upper age limit is quite high relative to most general equilibrium studies, and given the computational burden of the model the period length is quite short. However, pricing in the life insurance industry is done relative to a male who lives 100 years; we wish to remain faithful to the reported pricing schemes and thus use these choices. Furthermore, demographic states need to be relatively persistent to generate life insurance demand, requiring a relatively-short model period.

The transition matrix for demographic states is difficult to construct. Due to the presence of history-dependence in the probabilities of marriage, divorce, mortality, and fertility, we found that we could not analytically construct this matrix. As a result, we used a Monte Carlo approach to generate the probability of transitioning between different states. In the computational appendix we detail the procedures followed to generates the transition matrix.

The last issue we must examine is the social security system. Since we are primarily concerned with the behavior of working-age households, we choose to calibrate this system to match not benefits but rather taxes. We set $\tau = 0.153$, the average social security tax rate in the postwar US, and balance the budget by adjusting the level of benefits. Our inclusion of the government transfer program has two purposes; one, it reduces the precautionary demand for assets, which in this model would implausibly increase the demand for life insurance policies in the absence of such transfers; and two, it makes the solution of the model easier as it reduces the marginal utility of poor, retired households.[24] Without income, these households can create internodal oscillations in our approximation scheme, which is based on cubic spline interpolation. The computation of the equilibrium is outlined in the appendix.

6 Findings

We now detail our results. This section will consist of three subsections. First, we will examine the equilibrium solution of the model under three insurance pricing strategies: a constant premium over all ages; an actuarially-fair premium; and two intermediate pricing strategies. We define an actuarially-fair price as where the premium is set to equal the probability that one adult in the household dies in a given period. The intermediate cases fall somewhere between the aforementioned extremes. These cases allow us to

[24] However, it does counterfactually increase the rundown of assets after retirement.

determine the sensitivity of our results as well as assess the implications of imperfect loading that we suspect occurs in the economy. In the second section, we present welfare cost computations across specifications. These calculations allow us to analyze the importance of life insurance market. In the last subsection, we examine the importance of life insurance for households with specific age and demographic characteristics.

6.1 Alternative Pricing Strategies

We first examine the results of our moment-matching calibration exercise under a constant premium (Flat Premium) over all ages. These results are presented in Table 12. As can be seen, the interest rate $r - \delta$ is around 2 percent per annum which is a reasonable value for risk-free government debt over the postwar US period. However, this value is about around half the average return to capital measured from NIPA data in McGrattan and Prescott (2003). Given that we have abstracted from default and aggregate risk, we do not find this to be a failure of the model.

More relevant for our investigation are the values for q, $\overline{k}$, and s. The life insurance premium is quite high relative to the death probability for young households – we plot the mortality rates for a household, for a male and for a female in Figure 6. The equilibrium price is 0.0605, which exceeds the mortality rate for households, males or females under (model) age 45. At this price, the young household is getting a particularly bad deal on life insurance. Because life insurance is expensive, the holding of life insurance is restricted to older households; these households pay relatively low premiums and expect to get a payout with a high probability. This is seen very clearly in upper part of Figure 7. The hump to the right, which begins around age 55, represents the holding of life insurance generated by the model under this pricing strategy. Using the axis on the right hand side, we can see that the amount of life insurance holding is small. Another way to judge the model is to compare life insurance holdings relative to GDP. According to actual data, the combined amount of life insurance – term plus the non-cash value portion of whole-life – is around 110 percent of GDP in 1998. In our model economy with a constant premium, we observe that total life insurance holdings is approximately 4 percent of GDP. The amount of capital held by singles, $\overline{k}$, is quite low; they hold about 13 percent of the total wealth in the economy, suggesting that life insurance may be critical for mitigating the effects of martial risk. Finally, the accidental bequest term is small; this term matters in this environment because it acts like free insurance and we do not want it to contaminate our results.

Within this economy, we examine certain demographic subsamples of the population. One of the main issues in the empirical literature has been the wealth of new widows. Bernheim *et.al.* (2001a,2001b) suggest that household members do not carry enough life insurance to protect themselves against a permanent and sizable drop in their consumption. In our model, we can compute the change in lifetime resources – defined as the expected future value of labor income plus government transfers plus current financial wealth – caused by the loss of a spouse at various points in the distribution. To get at this, we measure the wealth difference generated by being a widow instead of being married. The average wealth of a widow is substantially less than a married household. The average wealth of a married household is 1.82 while the average wealth of a widow is 1.29. Since very little life insurance is being purchased, the widows are not being protected from early death of their spouse.

We need to adjust the pricing mechanism so that we get premiums which are more actuarially-fair for the working age household. We will consider a pricing strategy where each household pays a premium exactly equal to the probability that an adult member will die. We will refer to this pricing strategy as perfect loading. Now cross-subsidization over ages does not occur.[25] Under this pricing policy, the model generated holdings of life insurance changes drastically from the constant premium case. Younger households purchase life insurance as the premiums are much lower than the previously examined pricing policy. In upper part of Figure 7, we plot the distribution of life insurance holdings by age. As can be seen, life insurance holding begin to occur at model age 4 and peak around model age 25. Individuals older than model age 45 do not hold life insurance. This "hump-shaped" pattern of life insurance is consistent with what we observed in actual data, although somewhat more pronounced. It is also important to note that the peak of life insurance holdings occurs before the peak in earnings. This matches with previously documented observations from the data and is consistent with the

[25] One caveat to note about our computations here is that the sampling error introduced by our Monte Carlo approach to calculating the transition matrix is no longer innocuous. Since each household will pay the premium equal to their probability of loss, small irregularities in the mortality rates generate large irregularities in life insurance holdings. Thus, we are careful to generate death probabilities which match the observed data.That is, the small dip in the death probability of males around age 30 is actually observed in the data.

idea that life insurance is a hedging vehicle for risk to the uncapitalized human wealth that younger households have in abundance. In effect, since the premium is low households "borrow" against that future income by reducing their precautionary savings, using the state-contingent payout of life insurance to protect themselves. In fact, the peak in holdings is consistent with the peak in the present value of future income.

Another way to evaluate the model is to calculate the life insurance-GDP ratio. We now observe that life insurance holdings are 95 percent of GDP. This ratio is much closer to the observed value. In our model economy, single individual households have no motivation for buying life insurance. Yet, we do observe some life insurance holdings in thr data. Since only married households would life insurance in our model economy, we also calculated the ratio of married household life insurance holdings to GDP. The actual ratio is 0.64 which is smaller than that produced by the model. Overstating the purchases of life insurance is to be expected since adverse selection problems will typically create actuarial unfairness for some members of society.

We now want to address the potential puzzle that single earner married households have a lower life insurance participation rate than do dual earner married households. We find that 72.2 percent of single earner married households have life insurance while 75.4 percent of dual earners hold life insurance. The high risk households are participating less in life insurance just as in the observed data. At first glance, it would appear that this feature is not a puzzle. However, the data shows that on average the single earner and dual earner households have roughly the same wealth, while the model does not replicate this observation. The average wealth of dual earner households is 1.70, while the average wealth of a single earner household is 0.93. Thus, part of the answer for the high life insurance participation rate that we observe ifor dual earners is the wealth effect; wealthier household participate more in the life insurance market. Since dual earner households have more wealth, we should expect a boost in their life insurance participation. Thus, we have not yet established whether the participation rate should be considered a puzzle.

Since young households are now purchasing life insurance, we should see how the wealth of widows compares with married households. We find that average wealth for widows is 1.15. This is quite a bit lower than the average wealth of married households which is 1.70. It appears that widows still suffer large wealth losses. However,when we compare working age widows with working age households, we find a different story. Widows, on average, have wealth of 2.50 versus 1.72 for married households. The widows are being protected from early death of a wage earner. However, this feature again contradicts the data, since we observe that widows havee significantly less wealth than married households. Again, this feature of the model prevents us from conclusively determining whether the participation rate constitutes a puzzle.

Having considered the extreme points in the pricing space, we now move to consider schemes which are somewhere in between these extremes. Initially, we take a simple convex combination of the two; that is, we assume that the life insurance premium for a household in state $(a, \epsilon, p, m, x, i)$ is given by

$$q(a, \epsilon, p, m, x, i) = Aq + (1 - A)\,\psi_{i,p,m,x}, \tag{10}$$

where ψ denotes the perfect loading factor and $A \in (0, 1)$. To ensure that the industry still makes zero profit, we allow q to adjust. Given the computational burden of the model, we first choose $A = 0.5$ to see if anything significant appears. In fact, we observe a collapse of purchasing very similar to the flat premium case, suggesting that the perfect loading outcome is somewhat of a knife edge solution. This feature of the model is problematic, since premiums will always be relatively unfair to the young even though they are the purchasers of insurance in the data. To examine whether this knife edge feature obtains for our economy, we solve cases close to the perfect loading outcome:

$$A \in \{0.005, 0.01, 0.02, 0.025, 0.05, 0.075\}.$$

Examining the results from these experiments, we find that the degree of loading needed to generate exactly 0.64 times GDP in life insurance holdings is $A = 0.0075$, which is a very small departure from perfectly-fair insurance. In lower part of Figure 7, we plot the distribution of life insurance holdings by age. As can be seen, life insurance holding begin to occur at model age 4 and peak around model age 20. Life insurance holdings continually decline until model age 45 (real age 65). We observe that the model suggest some additional life insurance is purchased occur around model age 50. The holding patterns of life insurance generated by the model is consistent with what we observed in actual data.

Figure 8 displays the relationship between A and $\frac{LI}{GDP}$; as the premia move away from perfect loading we find a rapid decline in $\frac{LI}{GDP}$. This feature of the model suggests strongly that purchases of life insurance do not need to be seen as irrational or even reflecting significant departures from actuarial fairness; in fact, they can be accounted for quite nicely within a realistically-calibrated model.

In brief, we find that policy holdings are dramatically different across pricing schemes; this suggests that the conclusion in Gokhale and Kotlikoff (2002) that price is not likely to be the reason that households avoid purchasing "adequate life insurance" may not be correct; our model suggests that it very well could be the entire reason.

6.2 Welfare Gains

The results in the prior section implies that the welfare gains emanating from the life insurance market may be large. In this section, we want to examine the welfare gains to households from having access to a life insurance market under the various pricing schemes. The preferred approach to calculate welfare gains is using a transitional dynamic approach. Unfortunately the immense computational burden imposed by the model keeps us from using this approach to calculate welfare gains. We examine the welfare gains by calculating the lifetime expected welfare gains associated with a newborn person who has access to the life insurance market and does not have access to the life insurance market. This gives us a measure of the importance of this specific contingent claims market.

We define the ex ante welfare of a newborn individual as:

$$W = \int_{\mathcal{E}} \sum\nolimits_{\mathcal{P}} v\left(0, \epsilon, p, 1, 0, 1\right) \pi_{\epsilon}^{inv} \pi_p. \tag{11}$$

As can be seen, the relevant value function is initialized with the age of this person being one. The initial asset position, a, is set to zero. The newborn has no children so $m = 0$. If the newborn is male, $p = 1$. A newborn female would be characterized by $p = 2$. In the above expression, π_{ϵ}^{inv} denotes the invariant distribution of ϵ and π_p is the probability matrix associated with a given gender. We compute welfare under a version of the model without operative life insurance markets, and denote this welfare value by W_0. We then compute the increase in consumption needed to make an individual in that world indifferent between that world and the one with operating life insurance policies. Given the utility function we assumed, this yields the value

$$W_1 = (1 + \lambda)^{\mu(1-\sigma)} W_0 \tag{12}$$

where W_1 is average newborn utility in an economy with life insurance markets. λ thus measures the welfare gain associated with life insurance assets.[26] We see this statistic as a quick and dirty method of determining whether life insurance is essentially redundant in our economy.

In the middle column of Table 12, we present the computed equilibrium for the inactive life insurance model; it is easy to see that the presence of this contingent claim does not change the outcome in the aggregate. The only equilibrium equation significantly affected is the capital held by single agents, and this movement is not that big. The interest rate rises slightly due to a lower capital stock. Since the equilibrium does not change much across specifications and holdings are very small, we expected very little in terms of welfare gains. Indeed, we find that newborn agents would pay only 0.25 percent of consumption to open a life insurance market priced using constant premia. When examining the actuarially-fair economy, we find that newborn agents will pay 0.55 percent of consumption to open a life insurance market. This benefit is larger than the gain from the flat premium economy; the difference comes partially from the increase in participation and partly from the fact that now young households are the purchasers. For completeness, we also compute the welfare costs for the imperfect loading case $A = 0.0075$, yielding a value of 0.33 percent.

6.3 Simulations of Death Shocks

Given the measured benefits to a household of having access to the life insurance market, we would like to have a more precise idea of what generates these benefits. In an attempt to identify these dimensions, we use our model to conduct a series of simulations that examine how a household is impacted by a death of a spouse over their remaining life cycle. We consider household who is impacted by a death of a wage earner when they hold and do not hold life insurance, paying particular attention to the impact of a death on the average paths for wealth, consumption, and hours worked.

[26] Note that, since we have incomplete markets, we cannot be sure that introducing additional assets will increase welfare. However, our prior is that it will, and in fact it does.

6.3.1 Implications of Life Insurance on Rich Households

The first set of simulations are conducted on a households with high wealth level. As a baseline, we consider a 40 year old married household with one child. Since such a household is wealthy, the (joint) labor supply is relatively low. In Figure 9, we display the average wealth path of rich households in four situations. The line **NWNOLI** represents the average wealth of a household who at age 40 is married with one child and does not hold life insurance. We assume this household remains married with one child . As can be seen, this household slowly decumulates their assets over the remainder of their life. In order to understand the impact of a death of a spouse, we assume that age 41 the male member of the household dies. The female becomes a widow and retains the child. The line labeled **WNOLI** illustrates the wealth pattern for this situation. We see that, on average, the wealth of the widowed household will be slightly less than that of the household that does not experience a death shock. In other words, this household is wealthy enough so that self insurance occurs.

The other two lines in Figure 9 illustrate the effect of introducing a life insurance market into the economy. The line **NWLI** represents the average wealth of a similar household and has access to life insurance. The introduction of life insurance brings a substantial rise in the average wealth of the household over the remaining life cycle. The line **WLI** represents the average wealth of a household who experiences a death shock at age 41 but has access to life insurance. In this case, the wealth path for the widowed household will be slightly lower than the non-widowed household.

We would like to know whether the difference in wealth paths for individuals who hold and individuals who do not hold life insurance is significant. In order to address this issue, we construct bounds around the average wealth paths. Deviations from the average paths occur because of differences in idiosyncratic wage shocks ϵ and various demographic shocks. The upper bound wealth path is a result of drawing consistently good wage shocks, not drawing any additional children, and not incurring any negative demographic events. Figure 10 displays the average wealth path (**WNOLI)** with 2 standard deviation bounds for a nonwidowed household who holds no life insurance . We see there is very little deviation in the average wealth path between age 40 and retirement. Immediately after retirement the standard deviation increases. This is due to the small chance that a retired household may still have children living in the home. Soon after retirement the bounds start to converge as the household runs down their assets and the possibility of living children vanishes. The pattern observed in Figure 10 holds for the other three cases. Because the confidence bounds are so tight around each average path, we can conclude that a (rich) widow experiences a significant drop in wealth between the ages of 41 and retirement. We also find that the introduction of a life insurance market significantly increases the average wealth of the married household whether or not they become a widow immediately.

6.3.2 Implications of Life Insurance for Poor Households

We now consider a household with a low wealth level. Such a household can no longer self-insure against the unexpected loss of a wage earner. Hence, a death in this household will likely have larger ramifications for consumption-saving and labor-leisure decisions. As a result, the availability of a life insurance market may have a larger impact on a household. We begin by considering a household at 40 with one child. The baseline case is the one with no life insurance holdings and no death of male household member. In Figure 11, we present the average wealth path for this case by **NWNOLI**. Unlike the wealthier counterpart, this household is still accumulating wealth. In fact, the peak in wealth occurs around age 62. The household who purchases life insurance has a similar wealth path, denoted as **NWLI**, with the difference being that the average path is above the household who does not buy life insurance. This difference is a result of the probability that a death could still occur to the male household member after age 41 in which case a life insurance payoff would occur. The wealth paths for a household with the stated characteristics and the male member dies at age 41 with and without a life insurance position are represented by **WNOLI** and **WLI**, respectively. Becoming a widow has major implications for the wealth paths. A widow experiences a substantial fall in average wealth over the remaining life cycle. This drop in wealth is only slightly cushioned by the introduction of the life insurance market. Without life insurance, a widow would experience a 53 percent drop in the peak wealth accumulation. With life insurance, a widow would still experience a 51 percent drop in the peak wealth accumulation. The introduction of life insurance will increase the average peak of a widow's wealth by 18 percent. There is also 14 percent increase in the peak wealth of the average non-widowed poor household. The most important aspect of life insurance is that households with life insurance experience greater average lifetime wealth. Widows will have 24 percent higher accumulated lifetime wealth if they have life insurance as compared to a widow without a life insurance.

Although we see significant changes in the average wealth of these four household types, we also want to examine the confidence bounds around these average wealth paths. In Figure 12, we present the two standard deviation bounds for the case of a widow without a position in life insurance. We see that in the upper bound situation, the widow can achieve a path approximately two times the average path. However, this individual is still poor. The more interesting path is the lower bound path for this widow. Immediately after the death shock at age 41, the widow draws down asset levels in order to achieve desired consumption levels. Some savings does occur. The peak asset level is substantially lower than the average path level and the peak occurs later in life. The household that suffers a death shock and a series of negative wage and demographic shock becomes much worse off.

We can achieve a deeper understanding of how a household is able to achieve a certain average wealth path by examining average consumption paths and average (female) labor supply paths over the remaining portion of life. Figure 13 presents the average consumption paths for the four possible cases we consider for this household. We see that, by comparing the consumption path of a household holding no life insurance that does not suffer a death shock (**CNWNOLI**) with a the consumption path of the same household but with life insurance (**CNWLI**), life insurance tends to tilt the consumption path prior to retirement. Individuals who have access and purchase life insurance have a somewhat lower consumption path. By age 55, the consumption path is higher than the path for the household without access to life insurance.[27] The consumption paths for the cases where the male member of the household dies are **CWNOLI** an **CWLI**. If no life insurance exists, we see that the remaining spouse suffers a 14 percent drop in consumption immediately after the death of their partner. More importantly, consumption never recovers and the widow remains on a lower consumption path. If life insurance is available, we see no immediate drop in consumption. Life insurance eliminates the observe initial decline in consumption and allows the widow to have a higher average consumption path. In fact

[27] After age 40, conumption decreases slightly. This is a result of the fact that the wage level choosen to generate the average paths is actual a level that is below the average wage level.

the consumption path is above the path observed for the household that has access to life insurance and does suffer a death shock.

We must also examine how the female labor supply decisions are impacted. Figure 14 displays the average hours worked by the female household member in the four cases. We initially consider the case where the household does not have access to a life insurance market. If a death to the male spouse does not occur, we see that the female household does not supply hours to the labor market. Rather, nonliesure time is being allocated to the child. We observe an increase in hours supplied to the labor market until age 65. This is a result of increasing probability that child care obligations fall (or end) and the female can take advantage of favorable labor market opportunities. If a death to male household member occurs at age 41, the female is forced to enter the labor market. Immediately after the death, the female allocates twenty percent of her time endowment to the labor market. As a result of a desire to maintain consumption levels and accumulate some assets, labor supply increases until retirement. Just prior to retirement, the female is supplying approximately thirty-six percent of the time endowment to the labor market. In contrast, the female to does not suffer a death shock is only supplying about eighteen percent of the time endowment to the labor market. We also present female labor supply decisions when the household has access to an insurance market. The female member of the household that does not suffer a death shock still supplies increasing about of time to labor market until retirement. With an insurance market, the amount the time endowment allocated to the labor market is somewhat less. If a death occurs to the spouse, we observe large increase in time allocated to the labor market. The availability of life insurance only result in a five to eight percent decline in the amount of time provided to the labor market. This is a result of the fact that this household is relatively poor and thus has a limited position in life insurance.

6.3.3 Implications of Life Insurance on Poor Households with Many Children

The final set of simulations study the a household where the likelihood of purchasing life insurance should be even higher. This is the case when a household is not able to self insure and has several children. Here, the female is at great risk if a death to the male spouse occurs given child care obligations. Hence, we want to examine average paths for a household that is relatively poor and has four children. Figure 15 displays the average wealth paths for the same four cases. If death a death to a spouse does not occur, the wealth paths are similar to what we have already observed, albeit at lower levels. The average wealth paths do change if a death to the male household member occurs. Widows without access to life insurance experience a significant drop in average wealth. If fact asset levels never recover to that asset level that existed at age 40. Widows that do have access to life insurance display a different pattern. On average, these widows experience a temporary and substantial increase in average wealth because these households buy a substantial amount of life insurance. When the death shock occurs, these household receive a huge increase in wealth. It is interesting to note that this increase in average wealth is only temporary. Because of the number of children, these widows are restricted in their ability to increase labor hours. The female labor market implications are presented in Table 16. In contrast to the results presented in Table 14, the widow increases labor supply slowly reflecting the decline in child care obligations over time. Females are required to provide a larger fraction of their time endowment when a life insurance market is not present. Over the entire life-cycle the introduction of life insurance increases average accumulated wealth by 24 percent again for non-widows and a huge 194 percent for widows.

Figure 17 displays the various average consumption path for a household with four children. The average consumption paths for these households are similar to those observed in households with one child. The main difference is that the consumption drop associated with becoming a widow without life insurance is much larger. This result can also be tied to the limited ability to increase labor hours. As before, the introduction of life insurance allows widows to have temporary high consumption, generated by the life insurance payoff which eventually converges to the average consumption of a non-widow households. Over the life-cycle, life insurance also increases the accumulated consumption of both widows and non-widows.

7 Conclusion

Our model has examined the life insurance portfolio decisions of households in a model with a reasonable amount of demographic detail. However, some aspects of the data cannot be accounted for within our framework. For example, we observe a number of small policies being held by elderly households;

frequently these policies hover around \$5000. This not so coincidentally is the same value as the average cost of funerals in the postwar US. We suspect that the introduction of a fixed cost for funerals would generate small policy holdings for agents who otherwise hold none. Second, our model cannot account for the policy holdings of single agents. Since we abstracted from the bequest motive, single households have no incentive to purchase life insurance, as it will only pay off after they die. However, single households do purchase life insurance in the data; legal requirements for divorced males can account for some of this behavior and altruism toward children could potentially account for the rest. Given that calibrating and computing a model with detailed altruistic behavior is beyond our current ability, we regretfully leave this for future work.

Another concern that we have not addressed in this paper is the possibility of bankruptcy in the life insurance industry. In our model, the law of large numbers ensures that the life insurance firm can charge exactly the right price for policies and break even in the population. In reality, many aspects of mortality are endogenous and unobservable – diet, exercise, and environmental factors combine with genetics to make mortality heterogeneous within cohorts. Firms who operate in this environment face potentially severe adverse selection problems and must also choose portfolios of assets to cover losses. This avenue would be computationally burdensome as well, but is a clear direction for research to proceed.

We have restricted our attention to the purchase of term life insurance. As noted in our data section, households switch gradually to whole life insurance as they age. Determining the factors which can account for this observation is one of our next tasks; it will require more carefully modelling of the adverse selection problem that changes the relative price of new versus renewal policies. Since we find the nature of the loading of premia matters significantly for choices in our model, extensions which derive endogenously the degree and shape of loading would seem to be critical.

Furthermore, we believe that our demographic model is of some independent interest, since it is one of few that incorporate realistic detail in terms of marriage, divorce, fertility, and mortality. We intend to exploit this model for studies involving asset prices and other forms of insurance, particularly health and durables, as well as the puzzle that consumption appears to drop permanently and significantly upon retirement.

8 Computational Appendix

This appendix details the computational strategy used to solve the model. The appendix is divided into four parts. First, we discuss the computation of the household problem; we use backward induction along the lifetime to solve for the value function. Second, we discuss the generation of the invariant distribution over wealth, productivity, demographics, and age. Third, we discuss our method for computing market clearing prices and the solution to calibration equations. Fourth, we detail our Monte Carlo method for computing the transition matrix for the demographic states.[28]

The basic algorithm is as follows:

1. Guess a value for accidental bequests s, aggregate capital held by single individuals $\overline{k}$, the life insurance premium q, the social security benefit ϖ, and the rental rate r.

2. Solve the consumer's problem and obtain the value function v and the decision rules k', l', h_m, and h_f. This step involves building a nonlinear approximation to the value function and is described in detail below.

3. Iterate on an initial distribution of idiosyncratic states until convergence. This step assumes that the distribution of a is over only a finite number of points and redistributes mass iteratively. To conserve on computational time, we calculate the invariant distribution over stochastic states and use this information to start the iterations on the distribution of wealth.

4. Check that the values for r, s, and $\overline{k}$ agree with those in step 1, the life insurance company is earning zero profit, and the government budget balances. If not, then update and return to step 1. When calibrating the model, we add to step 1 guesses for the discount factor β, the consumption weight μ, and the relative male leisure weight χ. We then check whether our guesses imply the right values for the wealth/GDP ratio, the average hours worked, and the ratio of female to male labor supply.

[28] Fortran 95 code to solve for this equilibrium is available at http://garnet.acns.fsu.edu/~eyoung/programs. This code does not implement the parallel solution method and thus is appropriate for casual users, but runtimes are extremely long.

For the model with perfectly-loaded policies, we do not need to check the profit condition of the life insurance company, since it will earn zero profit on every state. For the intermediate cases, we assume that q adjusts to clear the market.

8.1 Solving the Household Problem

We will now discuss the solution of the household's problem. Let current wealth a lie in a finite grid $A \subset \mathbb{A}$. We must solve a two-dimensional continuous portfolio problem in (k', l'); furthermore, to complicate the problem both face short-sale constraints and the price of life insurance is small, leading to some sensitivity in the portfolios. As a result, we take the approach used in Krusell and Smith (1997) and Guvenen (2001) to solve the problem. To begin, we guess that the agent holds zero life insurance. We then find the optimum level of savings in capital by solving the Kuhn-Tucker condition

$$\begin{aligned} & (1_p + \eta x)^{\theta\mu(1-\sigma)} c^{\mu(1-\sigma)} (1 - h_m)^{\chi(1-\mu)(1-\sigma)} (1 - h_f - \iota x)^{(1-\chi)(1-\mu)(1-\sigma)} \times \\ & \left(\frac{\mu}{c} \left(-1 + \frac{\partial h_m}{\partial k'} w\upsilon_i \epsilon + \frac{\partial h_f}{\partial k'} \phi w \upsilon_i \epsilon \right) - \frac{\chi (1-\mu)}{1 - h_m} \frac{\partial h_m}{\partial k'} - \frac{(1-\chi)(1-\mu)}{1 - h_f - \iota x} \frac{\partial h_f}{\partial k'} \right) \\ & + \beta E \left[v_1 (a', \epsilon', m', i+1) \right] (r + 1 - \delta) \\ \leq \; & 0 \end{aligned}$$

where h_m and h_f solve

$$\frac{\mu w \upsilon_j \epsilon}{a + w\upsilon_i \epsilon (h_m + \phi h_f) - k' - ql'} = \frac{\chi (1-\mu)}{1 - h_m}$$

$$\frac{\mu w \upsilon_i \epsilon \phi}{a + w\upsilon_i \epsilon (h_m + \phi h_f) - k' - ql'} = \frac{(1-\chi)(1-\mu)}{1 - h_f - \iota x}.$$

Next, we let life insurance holdings be slightly positive: $l' = 0.0001$. If this increase reduces lifetime utility, the agent has zero life insurance optimally. If not, we use bisection to locate the correct value for l', increasing l' whenever the gradient at the optimal value for k' is positive and decreasing it whenever the gradient is negative.

Ignoring bequests, we assume that

$$v(\cdot, \cdot, \cdot, \cdot, I + 1) = 0.$$

Then, for each $i \leq I$ and using $v(\cdot,\cdot,\cdot,\cdot,i+1)$ as the value function for the next age, we can obtain the value function for this age as the solution to

$$v\left(a,\epsilon,p,m,i\right)=u\left(C^{*},h_{m}^{*},h_{f}^{*}\right)+\beta E\left[v\left(a^{*\prime},\epsilon^{\prime},p^{\prime},m^{\prime},i+1\right)\right].$$

Cubic spline interpolation is used whenever we need to evaluate $v(\cdot)$ at points not on the grid for a.

8.2 Computing the Invariant Distribution

For the invariant distribution, the procedure outlined in Young (2002) is employed. For each idiosyncratic state and age vector (a,ϵ,p,m,i) we compute next period's wealth contingent on demographic changes. After locating $a'\left(a,\epsilon,p,m,i\right)$ in the grid using the efficient search routine **hunt.f** from Press *et.al.* (1993), we can construct the weights

$$A\left(a,\epsilon,p,m,i\right)=1-\frac{a'\left(a,\epsilon,p,m,i\right)-a_{k}}{a_{k+1}-a_{k}}$$

where

$$a'\in\left[a_{k},a_{k+1}\right].$$

Now consider a point in the current distribution

$$\Gamma^{n}\left(a,\epsilon,p,m,i\right).$$

This mass is moved to new points according to the following process. For each set $(\epsilon,p,m,i)\times(\epsilon',p',m')$ we calculate the probability of transition; denote this value by $\rho\left(\epsilon,p,m,i,\epsilon',p',m'\right)$. Mass is distributed then to the point

$$\Gamma^{n+1}\left(a_{k},\epsilon',p',m',i+1\right)$$

in the fraction

$$A\left(a,\epsilon,p,m,i\right)\rho\left(\epsilon,p,m,i,\epsilon',p',m'\right)\Gamma^{n}\left(a,\epsilon,p,m,i\right)$$

and to the point

$$\Gamma^{n+1}\left(a_{k+1},\epsilon',p',m',i+1\right)$$

in the fraction

$$(1 - A(a, \epsilon, p, m, i))\, \rho(\epsilon, p, m, i, \epsilon', p', m')\, \Gamma^n(a, \epsilon, p, m, i)\,.$$

Looping this process over each idiosyncratic state and age computes the new distribution. This process continues until the change in the distribution is negligible. Note that we can compute the weights and the brackets before iteration begins; since these values do not change we can store them and use them as needed without recomputing them at each step.

8.3 Solving for Market Clearing and Calibration

We now discuss how we solve for the equilibrium, given the solutions the value function and the invariant distribution. This algorithm takes the following form:

1. Take the fitness functions to be the sum of the squared deviations of the equilibrium conditions. We then attempt to solve

   $$\min_{\omega} \{\langle F(\omega), F(\omega)\rangle\}$$

   where ω is a vector of prices and parameters, F is the vector-valued function of equilibrium conditions, and $\langle\cdot\rangle$ is the inner product function. For the initial calibration this vector is of dimension 8:

   $$\left[r, p, \varpi, \overline{k}, s, \beta, \chi, \mu\right].$$

2. Set an initial population Ω which consists of n vectors ω. Given our strong priors on the values for certain variables, we do not choose this population at random. Rather, we concentrate our initial population in the region we expect solutions to lie.

3. Evaluate the fitness of each member of the initial population.

4. From the population, select n pairs with replacement. These vector-pairs will be candidates for breeding. The selection criterion weights each member by its fitness according to the rule

   $$1 - \frac{\langle F(\omega_j), F(\omega_j)\rangle}{\sum_{j=1}^{n} \langle F(\omega_j), F(\omega_j)\rangle}$$

   so that more fit specimens are more likely to breed.

5. From each breeding pair we generate 1 offspring according to the BLX-α crossover routine. This routine generates a child in the following fashion. Denote the parent pair by $(\omega_i^1, \omega_i^2)_{i=1}^8$. The child is then given by
$$(h_i)_{i=1}^8$$
where $h_i \sim \text{UNI}(c_{\min} - \alpha I, c_{\max} + \alpha I)$, $c_{\min} = \min\{\omega_i^1, \omega_i^2\}$, $c_{\max} = \max\{\omega_i^1, \omega_i^2\}$, and $I = c_{\max} - c_{\min}$. Our choice for α is 0.5, which was found to be the most efficient value by Herrera, Lozano, and Verdegay (1998) in their horse-race of genetic algorithms for an objective function most similar to ours.

6. We then introduce mutation in the children. With probability $\mu_G = 0.15 + \frac{0.33}{t}$, where t is the current generation number, we mutate a particular element of the child vector. This mutation involves 2 random numbers, r_1 and r_2, which are UNI$(0,1)$ and 1 random number s which is $N(0,1)$. The element, if mutated, becomes
$$h_i = \begin{cases} h_i + s\left[1 - r_2^{\left(1-\frac{t}{T}\right)^{\delta}}\right] & \text{if } r_1 > 0.5 \\ h_i - s\left[1 - r_2^{\left(1-\frac{t}{T}\right)^{\delta}}\right] & \text{if } r_1 < 0.5 \end{cases}$$
we set $\delta = 2$ following Duffy and McNelis (2001). Note that both the rate of mutation and the size shrinks as time progresses, allowing us to zero in on potential roots.

7. Evaluate the fitness of the children.

8. From each family trio, retain the most fit member. We now are left with exactly n members of the population again.

9. Compare the most fit member of the last generation, if not selected for breeding, with the least fit member of the new generation. Keep the better of the two vectors. If the most fit member of generation $t-1$ is selected for breeding this step is not executed. This step is called **elitism** and is discussed in Arifovic (1994).

10. Return to step 4 unless the population's average fit has not changed significantly across generations.

11. After convergence, we polish the equilibrium using a multidimensional Newton-Raphson routine. This routine cannot be used to calibrate the model because the equations determining the market clearing value for r and the calibration target for β do not appear to be independent.

Note that some parameter values are not permitted; for example, μ cannot be larger than one or less than zero. In these cases the fitness of a candidate is assumed to be 10^6; that is, a large penalty function is attached to impermissible combinations. These candidates will be discarded immediately and never breed.

In our implementation of the genetic algorithm and the Newton-Raphson routine, we parallelize computation by sending each separate evaluation of $F(\omega)$ to a separate processor. For the genetic algorithm, each generation requires n evaluations for the new offspring (the parents have already been computed). For the Newton-Raphson routine each step requires 6 evaluations using one-sided numerical derivatives. We could have used the Newton-Raphson routine directly, but we found that our inability to determine a reasonable starting value seriously impacted convergence.

8.4 Monte Carlo Generation of Transition Matrix

The transition matrix for the demographic states turned out to be impossible to write down analytically. The problem is that we wish to remain faithful to the Census data on mortality, marriage, divorce, and fertility. To do so requires that the transition probabilities be dependent on the path taken to a particular state; for example, it matters for mortality of women how many children they have had, not just the number that they current have, due to the inherent health risks associated with childbirth. Also, large numbers of children typically are associated with lower income families who have higher mortality rates as well. We were not able to construct the matrix analytically as a result, since any given current demographic state could have a very large number of histories associated with it. Therefore, we chose the following Monte Carlo approach.

To begin, we draw a random $UNI(0,1)$ random variable; if below 0.495 the new household is a male, if not it is a female. We then check whether the household dies, gets married, bears children, or survives unchanged, using data from the US Census and CDC to determine age and gender specific probabilities. We truncate the number of children to 4 (which leaves out less than 2.7 percent of the population), we do not allow for multiple births within 1 year, and single males cannot have children (no adoption). In cases of divorce, the children proceed with their mother, and if the last adult in the household dies, all the children living in the household die as well. Given the data and these assumptions, we then let the household age 1 year and repeat the process until death. This procedure is repeated 50 million times; the transition matrix is then estimated using the sample probabilities. Due to sampling error (even with this gigantic number of observations), some states are rarely encountered in the simulation, which leads to some irregularities in the transition matrix used in the program.[29]

We find that since the probability of death and life insurance are closely tied, it is important that the transition matrix has accurate death probabilities. To insure the correct probability of death, we normalize the transition matrix to the correct death probability. Each row of the matrix is divided by the simulated survival probability and then multiplied by the true survival probability. Each row contains the true survival probability and a smooth death probability is observed over the life cycle.

[29] Matlab code to generate this matrix is available at http://garnet.acns.fsu.edu/~eyoung/programs.

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Table 1
Summary of Household Economic Characteristics

	Sample Size	Average Age (Head)	Average HH Size	Average Earnings	Average Income	Average Wealth
Total	4,305	48.7	2.48	42,369	52,295	283,179
By Earnings						
1st Quintile	733	61.2	1.80	-344	29,594	270,170
2nd Quintile	721	47.4	2.16	8,586	25,835	126,851
3rd Quintile	689	43.7	2.37	27,657	31,254	94,636
4th Quintile	674	44.2	2.72	48,875	48,464	153,891
5th Quintile	1488	47.1	2.99	128,366	130,689	777,760
By Income						
1st Quintile	675	51.0	1.93	4,496	7,579	48,400
2nd Quintile	635	50.9	2.01	14,494	20,062	94,688
3rd Quintile	654	47.1	2.42	29,454	33,796	128,780
4th Quintile	681	46.7	2.73	48,162	54,136	206,860
5th Quintile	1660	47.9	2.96	116,584	150,870	949,219
By Wealth						
1st Quintile	715	39.5	2.29	16,944	19,175	-4,055
2nd Quintile	637	42.5	2.40	27,635	29,486	19,286
3rd Quintile	577	50.7	2.42	35,233	39,741	73,289
4th Quintile	618	54.6	2.38	42,567	50,681	177,223
5th Quintile	1758	56.4	2.55	90,255	123,562	1,164,468
By Age						
17-29	506	25.1	2.17	26,193	26,482	30,399
30-39	764	34.8	3.10	49,174	49,897	132,517
40-49	969	44.3	2.91	62,418	66,238	273,539
50-59	867	54.1	2.23	60,218	71,608	455,020
60-0ver	1199	72.3	1.69	17,764	44,073	433,590
By Family Type						
married	2578	48.7	2.41	41,426	52,788	287,991
one worker	1343	48.8	2.45	41,136	51,826	285,233
two worker	1235	48.6	2.38	41,686	53,648	290,458
single-male NM	246	43.6	1.53	28,525	37,289	183,167
single-female NM	352	52.7	1.75	14,049	26,052	127,106
single-female widow	76	51.1	1.76	13,390	24,825	123,623

Table 2

Summary of Household Life Insurance Characteristics

	Total Life Ins.	Total Term	Total Whole	Average Holdings	Average Term	Average Whole	Insurance Participation
Total (bils $)	11,785	8,154	3,630	114,993	79,526	35,407	68.7%
By Earnings							
1st Quintile	508	269	239	24,739	13,114	11,624	57.3%
2nd Quintile	603	368	234	29,304	17,922	11,382	53.5%
3rd Quintile	1,281	1,001	279	62,303	48,691	13,612	65.3%
4th Quintile	2,661	1,988	672	129,308	96,631	32,677	81.1%
5th Quintile	6,731	4,526	2,205	332,278	223,429	108,849	88.9%
By Income							
1st Quintile	541	413.9	127.4	26,314	20,121	6,193	44.6%
2nd Quintile	833	634.4	198.7	40,478	30,825	9,653	61.6%
3rd Quintile	1,463	1,073.9	389.8	71,080	52,149	18,931	77.1%
4th Quintile	2.574	1,903.3	671.3	125,011	92,415	32,596	80.9%
5th Quintile	6,372	4,129.3	2,243.5	315,368	204,345	111,023	81.9%
By Wealth							
1st Quintile	878	766.9	111.4	42,684	37,268	5,416	44.7%
2nd Quintile	1,104	875.4	229.1	53,736	42,589	11,147	53.5%
3rd Quintile	2,125	1,749.3	375.8	103,163	84,917	18,246	65.3%
4th Quintile	2,203	1,573.7	630.2	107,146	76,506	30,640	81.1%
5th Quintile	5,473	3,189.6	2,284.1	270,425	157,580	112,845	88.9%
By Age							
17-29	960	780	179	67,218	54,634	12,585	53.4%
30-39	3,226	2,414	812	151,322	113,220	38,102	68.5%
40-49	4,028	2,855	1,172	178,712	126,685	52,027	73.6%
50-59	2,384	1,487	897	139,137	86,769	52,368	76.9%
60-over	1,186	616	569	43,549	22,640	20,910	69.6%
married	7,082	4,823	2,258	114,863	78,233	36,630	68.7%
one worker	3,441	2,392	1,049	118,208	82,161	36,048	67.7%
two worker	3,640	2,431	1,209	111,870	74,718	37,152	69.5%
single-male NM	455	331	124	73,995	53,750	20,245	59.1%
single-female NM	383	292	91	35,236	26,840	8,395	58.0%
single-female widow	73	62	11	32,021	27,127	4,894	62.3%

Table 3
Probit Results On Term Life Insurance Holdings

	Economic Activity Variable					
	Wealth		Earnings		Income	
Variable	coeff	marginal	coeff	marginal	coeff	marginal
intercept	-1.4141***		-1.2235***		-1.2134***	
	(0.1556)		(0.1536)		(0.1433)	
econ	-0.0033	-0.0013	0.2162**	0.0859	0.2069***	0.0822
	(0.0040)		(0.1078)		(0.0375)	
econsq	0.0001**	0.00001	-0.0007	-0.0003	-0.0002**	-0.00009
	(0.0000)		(0.0045)		(0.0001)	
agehead	0.0206***	0.0082	0.0162***	0.0065	0.0167***	0.0067
	(0.0061)		(0.0002)		(0.0053)	
ageheadsq	-0.0001*	-0.0001	-0.0001**	-0.00004	-0.0001*	-0.00005
	(0.0001)		(0.0000)		(0.0001)	
dhone	0.3648***	0.1452	0.3187***	0.1266	0.3402***	0.1352
	(0.0414)		(0.0506)		(0.0416)	
dhtwo	0.4795***	0.1908	0.4019***	0.1597	0.4354***	0.1730
	(0.0501)		(0.0641)		(0.0492)	
dmarry	0.1427***	0.0568	0.1198	0.0476	0.1102***	0.0438
	(0.0292)		(0.2885)		(0.0340)	
kids	0.0068	0.0027	0.0016	0.0006	0.0032	0.0013
	(0.0144)		(0.0432)		(0.0143)	
edhd	0.0349***	0.0139	0.0276**	0.0109	0.0255***	0.0101
	(0.0052)		(0.0092)		(0.0054)	
dhealth	0.0562*	0.0224	0.0459***	0.0183	0.0385	0.0153
	(0.0378)		(0.1378)		(0.0392)	
# of obs	4249		4249		4249	
log likelihood	-2814.08		-2802.59		-2800.70	

Table 4

Probit Results On Whole Life Insurance Holdings

	Economic Activity Variable					
	Wealth		Earnings		Income	
Variable	coeff	marginal	coeff	marginal	coeff	marginal
intercept	-1.8012***		-1.8128***		-1.8214***	
	(0.1843)		(0.1668)		(0.1682)	
econ	0.0249***	0.0094	0.2226***	0.0832	0.1875***	0.0702
	(0.0044)		(0.0442)		(0.0429)	
econsq	-0.00001	-0.00000	-0.0013	-0.0005	0.0001	0.00005
	(0.00007)		(0.0018)		(0.0004)	
agehead	0.0211	0.0079	0.0207***	0.0077	0.0216***	0.0081
	(0.0393)		(0.0061)		(0.0064)	
ageheadsq	-0.0001	-0.00004	-0.0001**	-0.00003	-0.0001*	-0.00003
	(0.0003)		(0.00005)		(0.00006)	
dhone	-0.0317	-0.0119	-0.0828*	-0.0309	-0.0572*	-0.0214
	(0.0565)		(0.0467)		(0.0463)	
dhtwo	0.1289*	0.0484	0.0437	0.0163	0.0862*	0.0323
	(0.0754)		(0.0574)		(0.0521)	
dmarry	0.2192***	0.0823	0.2195***	0.0821	0.2127***	0.0797
	(0.0485)		(0.0329)		(0.0330)	
kids	0.0101	0.0037	0.0009	0.0003	0.0037	0.0014
	(0.0280)		(0.0154)		(0.0136)	
edhd	0.0269***	0.0101	0.0271***	0.0101	0.0259***	0.0097
	(0.0050)		(0.0053)		(0.0054)	
dhealth	0.1632***	0.0613	0.1735***	0.0649	0.1665***	0.0624
	(0.0431)		(0.0425)		(0.0405)	
# of obs	4249		4249		4249	
log likelihood	-2599.07		-2604.18		-2601.62	

Table 5
Probit Results On Total Life Insurance Holdings

	Economic Activity Variable					
	Wealth		Earnings		Income	
Variable	coeff	marginal	coeff	marginal	coeff	marginal
intercept	-1.5652***		-1.4623***		-1.3040***	
	(0.1956)		(0.1529)		(0.1367)	
econ	0.0261***	0.0097	0.4317***	0.1605	0.4729***	0.2135
	(0.0056)		(0.0865)		(0.0808)	
econsq	0.00006***	0.00002	0.0132*	0.0049	0.0139**	0.0046
	(0.00002)		(0.0076)		(0.0060)	
agehead	0.0270***	0.0100	0.0233***	0.0087	0.0194***	0.0103
	(0.0078)		(0.0053)		(0.0045)	
ageheadsq	-0.0002*	-0.0001	-0.0001*	-0.00005	-0.0001*	-0.0001
	(0.0001)		(0.0001)		(0.0001)	
dhone	0.3584***	0.1332	0.2664***	0.0990	0.3160***	0.0729
	(0.0441)		(0.0457)		(0.0419)	
dhtwo	0.5617***	0.2088	0.4035***	0.1500	0.4629***	0.1324
	(0.0559)		(0.0577)		(0.0533)	
dmarry	0.2332***	0.0867	0.2210***	0.0821	0.2093***	0.0731
	(0.0309)		(0.0369)		(0.0303)	
kids	-0.0066	-0.0024	-0.0171*	-0.0063	-0.0196*	-0.0089
	(0.0166)		(0.0150)		(0.0141)	
edhd	0.0463***	0.0158	0.0389***	0.0145	0.0336***	0.0125
	(0.0054)		(0.0058)		(0.0057)	
dhealth	0.0462*	0.0171	0.0484*	0.0179	0.0073	0.0306
	(0.0379)		(0.0375)		(0.0368)	
# of obs	4249		4249		4249	
log likelihood	-2564.06		-2426.70		-2527.03	

Table 6
Probit Results On Insurance Holdings

	Life Insurance Type					
	Term		Whole Life		Total	
Variable	coeff	marginal	coeff	marginal	coeff	marginal
intercept	-1.2753***		-1.7247***		-1.4012***	
	(0.1365)		(0.2345)		(0.1474)	
earnings	0.2753***	0.1095	0.1358***	0.0511	0.3909***	0.1441
	(0.0577)		(0.0423)		(0.0906)	
earnings sq	-0.0019	-0.0008	-0.0001	-0.0000	0.0070	2.585e-3
	(0.0023)		(0.0017)		(0.0046)	
wealth	-0.0127***	-0.0050	0.0198***	0.0074	0.0117*	4.337e-3
	(0.0039)		(0.0040)		(0.0053)	
wealth sq	0.0000**	0.0000	-0.00001	-0.0000	0.00006**	2.429e-5
	(0.0000)		(0.00000)		(0.00002)	
agehead	0.0169***	0.0067	0.0193**	0.0073	0.0223***	8.234e-3
	(0.0048)		(0.0093)		(0.0053)	
ageheadsq	-0.0001**	-0.0000	-0.0001*	-0.0000	-0.00006**	-5.181e-5
	(0.0000)		(0.0001)		(0.00002)	
dhone	0.3066***	0.1219	-0.0625*	-0.0235	-0.00014**	0.1018
	(0.0454)		(0.0465)		(0.00005)	
dhtwo	0.3803***	0.1512	0.0799*	0.0300	0.2762***	0.1550
	(0.0556)		(0.0544)		(0.0473)	
dmarry	0.1257***	0.0499	0.2096***	0.0788	0.4204***	0.0788
	(0.0286)		(0.0321)		(0.0625)	
kids	-0.0005	-0.0002	0.0050	0.0018	0.2137***	-5.609
	(0.0148)		(0.0135)		(0.0311)	
edhd	0.0296***	0.0117	0.0239***	0.0089	-0.0152	0.0135
	(0.0053)		(0.0054)		(0.0131)	
dhealth	0.0524*	0.0208	0.1623***	0.0610	0.0365***	0.0152
	(0.0411)		(0.0406)		(0.0056)	
# of obs	4249		4249		4249	
log likelihood	-2798.58		-2594.42		-2532.91	

Table 7

Tobit Results On Term Insurance Holdings

	Economic Activity Variable					
	Wealth		Earnings		Income	
Variable	coeff	marginal	coeff	marginal	coeff	marginal
intercept	-4.5619***		-3.2065***		-3.4914***	
	(0.4886)		(0.4229)		(0.3850)	
econ	0.0003	4.105e-9	1.3712***	3.209e-3	0.9657***	8.709e-4
	(0.0124)		(0.2936)		(0.2177)	
econsq	0.00001	4.057e-11	-0.0198**	-4.639e-5	-0.0043*	-3.883e-6
	(0.00002)		(0.0083)		(0.0028)	
agehead	0.0316**	3.839e-7	0.0044	1.034e-5	0.0145*	1.304e-5
	(0.0155)		(0.0147)		(0.0141)	
ageheadsq	-0.0003*	-3.144e-9	-0.00002**	-5.733e-8	-0.0001*	-1.262e-7
	(0.0002)		(0.00001)		(0.0001)	
dhone	0.9876***	1.198e-5	0.6637***	1.554e-3	0.8453***	7.624e-4
	(0.1158)		(0.1294)		(0.1011)	
dhtwo	1.2487***	1.514e-5	0.7535***	1.763e-3	1.0502***	9.471e-4
	(0.1340)		(0.1888)		(0.1353)	
dmarry	0.7251***	8.794e-6	0.5592***	1.308e-3	0.5488***	4.949e-4
	(0.0822)		(0.0731)		(0.0768)	
kids	0.1131**	1.372e-6	0.0641*	1.501e-4	0.0810**	7.309e-5
	(0.0438)		(0.0354)		(0.0353)	
edhd	0.1680***	2.038e-6	0.1170***	2.739e-4	0.1189***	1.073e-4
	(0.0159)		(0.0148)		(0.0154)	
dhealth	0.1181*	6.332e-5	0.0569	8.905e-4	0.0401	3.439e-4
	(0.0894)		(0.0867)		(0.1008)	
# of obs	4249		4249		4249	
log likelihood	13902.37		13992.28		13980.78	

For all the Probit and Tobit results *denotes significance at 10 percent level **denotes significance at 5 percent level *** denotes significance at 1 percent level.

Table 8

Tobit Results On Whole Life Insurance Holdings

	Economic Activity Variable					
	Wealth		Earnings		Income	
Variable	coeff	marginal	coeff	marginal	coeff	marginal
intercept	-4.2254***		-4.0845***		-4.3849***	
	(0.4749)		(0.4322)		(0.4797)	
econ	0.0732***	3.889e-6	0.8360***	7.977e-5	0.4807***	1.285e-5
	(0.0128)		(0.1186)		(0.0832)	
econsq	-0.0001***	-3.210e-9	-0.0163***	-1.551e-6	-0.0003***	-8.193e-9
	(0.00002)		(0.0038)		(0.0001)	
agehead	0.0463***	2.457e-6	0.0402***	3.835e-6	0.0497***	1.330e-6
	(0.0126)		(0.0127)		(0.0133)	
ageheadsq	-0.0003***	-1.579e-8	-0.0002**	-2.038e-8	-0.0003***	-8.394e-9
	(0.0001)		(0.0001)		(0.0001)	
dhone	0.0661	3.512e-6	-0.1275*	-1.217e-5	-0.0036	-9.723e-8
	(0.0946)		(0.0925)		(0.0914)	
dhtwo	0.2898**	1.539e-5	-0.0165	-1.576e-6	0.1891*	5.057e-6
	(0.1106)		(0.1109)		(0.1058)	
dmarry	0.5201***	2.763e-5	0.4986***	4.758e-5	0.5082***	1.359e-5
	(0.0744)		(0.0819)		(0.0905)	
kids	0.1062***	5.641e-6	0.0697**	6.558e-6	0.0833**	2.228e-6
	(0.0334)		(0.0323)		(0.0337)	
edhd	0.0735***	3.905e-6	0.0677***	6.462e-6	0.0732***	1.958e-6
	(0.0131)		(0.0136)		(0.0148)	
dhealth	0.3529***	2.909e-4	0.3781***	3.608e-5	0.3678***	1.869e-4
	(0.0787)		(0.0823)		(0.0793)	
# of obs	4249		4249		4249	
log likelihood	10143.32		10149.86		10134.14	

Table 9

Tobit Results On Total Life Insurance Holdings

	Economic Activity Variable					
	Wealth		Earnings		Income	
Variable	coeff	marginal	coeff	marginal	coeff	marginal
intercept	-4.4335***		-3.2212***		-3.6355***	
	(0.4675)		(0.4553)		(0.4468)	
econ	0.0952***	2.058e-6	2.0556***	4.590e-3	1.4291***	7.718e-4
	(0.0164)		(0.2706)		(0.2187)	
econsq	-0.00001*	-3.097e-10	-0.0236***	-5.284e-5	-0.0009***	-4.698e-7
	(0.00001)		(0.0078)		(0.0002)	
agehead	0.0361***	7.794e-7	0.0085	1.906e-5	0.0236*	1.275e-5
	(0.0155)		(0.0141)		(0.0146)	
ageheadsq	-0.0003***	-6.718e-9	-0.00004	-9.085e-8	-0.0002**	-1.155e-7
	(0.0001)		(0.0001)		(0.0001)	
dhone	0.9164***	1.981e-5	0.4434***	9.902e-4	0.7149***	3.861e-4
	(0.0842)		(0.1215)		(0.1022)	
dhtwo	1.2246***	2.647e-5	0.4716***	1.053e-3	0.9211***	4.975e-4
	(0.1238)		(0.1522)		(0.1535)	
dmarry	0.8355***	1.806e-5	0.6843***	1.528e-3	0.6677***	3.606e-4
	(0.1182)		(0.0880)		(0.0833)	
kids	0.1512***	3.268e-6	0.0726**	1.622e-4	0.0993**	5.365e-5
	(0.0440)		(0.0348)		(0.0338)	
edhd	0.1702***	3.680e-6	0.1248	2.787e-4	0.1276***	6.889e-5
	(0.0147)		(0.0142)		(0.0152)	
dhealth	0.1274*	1.476e-4	0.1036*	2.312e-4	0.0721	3.894e-5
	(0.0827)		(0.0766)		(0.0789)	
# of obs	4249		4249		4249	
log likelihood	18896.28		19054.09		19029.51	

Table 10

Tobit Results On Insurance Holdings

	Life Insurance Type					
	Term		Whole Life		Total	
Variable	coeff	marginal	coeff	marginal	coeff	marginal
intercept	-3.4363***		-3.7452***		-3.0670***	
	(0.3789)		(0.4262)		(0.4077)	
earnings	1.6355***	0.6492	0.6385***	0.1814	2.0211***	0.7257
	(0.2996)		(0.1246)		(0.3135)	
earnings sq	-0.0281***	-0.0112	-0.0137***	-3.894e-3	-0.0309***	-0.0111
	(0.0069)		(0.0036)		(0.0058)	
wealth	-0.0599***	-0.0238	0.0519***	0.0148	0.0231*	8.305e-3
	(0.0146)		(0.0130)		(0.0177)	
wealth sq	0.0001***	2.151e-5	-0.00004**	-1.159e-5	0.00004***	1.454e-5
	(0.00001)		(0.00002)		(0.00001)	
agehead	0.0080	3.193e-3	0.0352**	9.988e-3	0.0058	2.094e-3
	(0.0144)		(0.0128)		(0.0139)	
ageheadsq	-0.00003	-1.437e-5	-0.0002**	-5.448e-5	-0.00002	-9.173e-6
	(0.0001)		(0.0001)		(0.00013)	
dhone	0.6059***	0.2405	-0.0795	-0.0226	0.45089***	0.1619
	(0.1249)		(0.0964)		(0.1174)	
dhtwo	0.6534***	0.2594	0.0642	0.0182	0.4877**	0.1751
	(0.1807)		(0.1211)		(0.1638)	
dmarry	0.5864***	0.2328	0.4632***	0.1316	0.6665***	0.2393
	(0.0872)		(0.0793)		(0.0986)	
kids	0.0515*	0.0205	0.0793**	0.0225	0.0763**	0.0274
	(0.0370)		(0.0316)		(0.0341)	
edhd	0.1253***	0.0497	0.0566***	0.0161	0.1193***	0.0428
	(0.0152)		(0.0118)		(0.0135)	
dhealth	0.0845*	0.0335	0.3412***	0.0969	0.0891*	0.0320
	(0.0842)		(0.0812)		(0.0828)	
# of obs	4249		4249		4249	
log likelihood	-4730.89		-3365.16		-5448.93	

Table 11

Demographics of Simulated Economy

Characteristic	Percent of Population
Married	68.02
Single	31.98
Divorced	7.25
Widowed	14.49
Never Married	10.24
0 Kids	76.63
1 Kid	18.83
2 Kids	4.30
3 Kids	0.20
4 Kids	0.01

Table 12
Calibration Results

Variable	Flat Premium	Perfect Loading	No LI	Imperfect Loading
r	0.1207	0.1200	0.1075	0.1131
q	0.0605	NA	NA	0.0475
$\overline{k}$	0.2390	0.2568	0.2675	0.3014
s	0.0055	0.0055	0.0055	0.0055
ϖ	0.1674	0.1674	0.1674	0.1674
β	0.9828	0.9828	0.9828	0.9828
μ	0.2285	0.2285	0.2285	0.2285
χ	0.5750	0.5750	0.5750	0.5750

Figure 1: Household Life Insurance Participation across various Measures

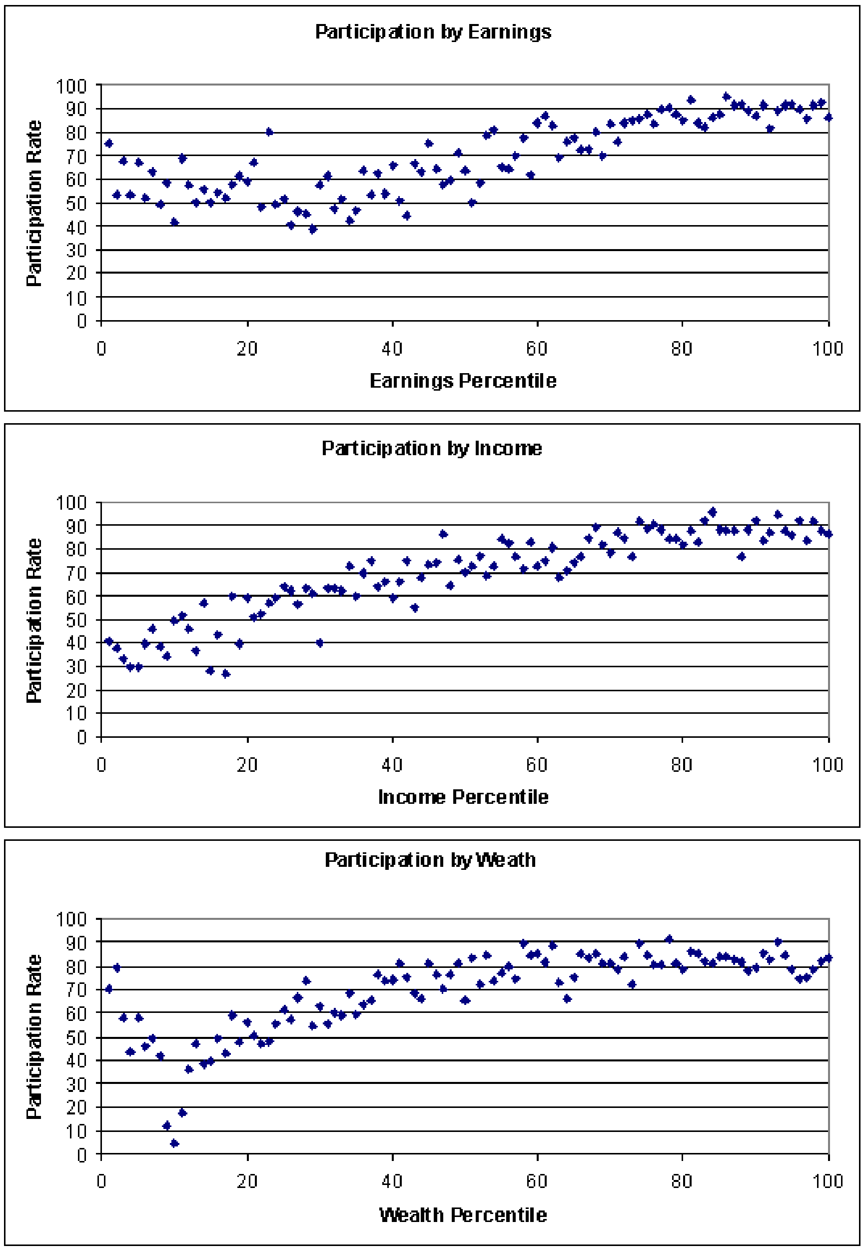


Figure 2: Average Life Insurance Holdings by Age

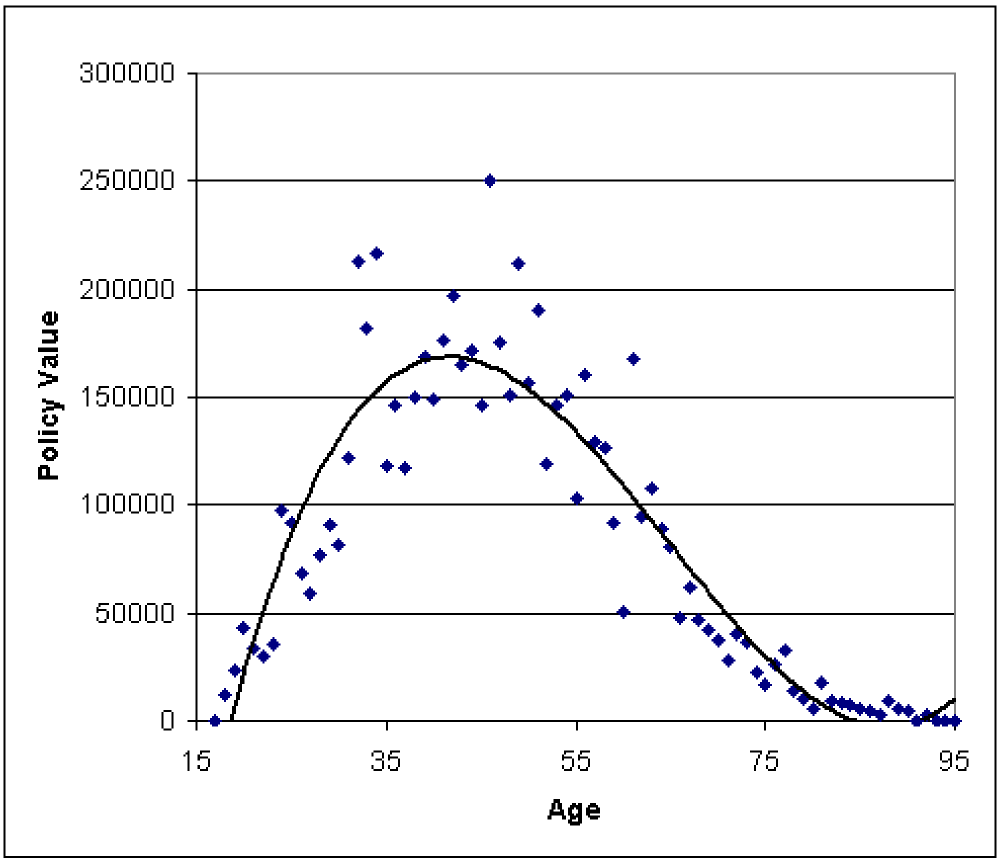


Figure 3: Life Insurance Participation By Age

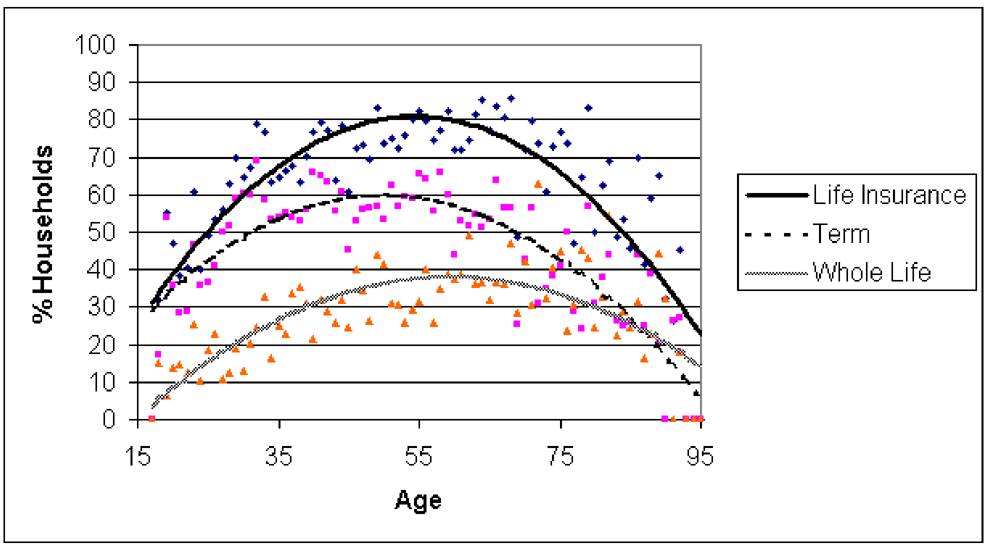


Figure 4: Life Insurance Holdings by Age and Income

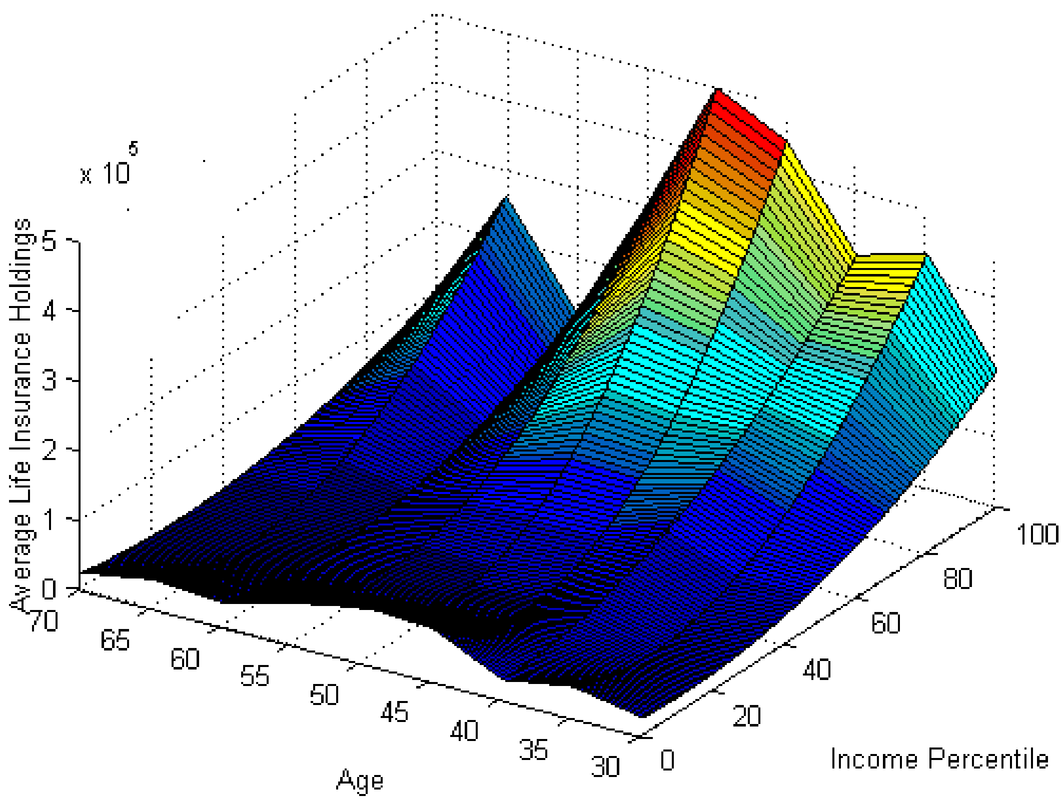
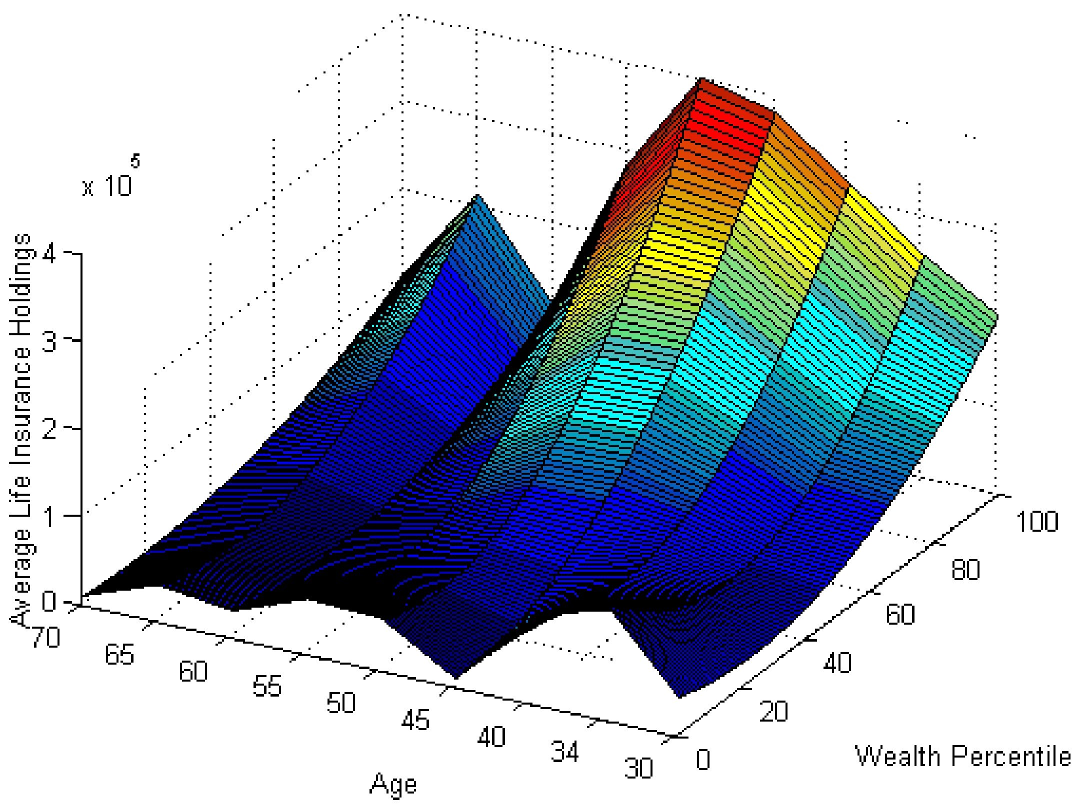


Figure 5: Life Insurance Holdings by Age and Wealth



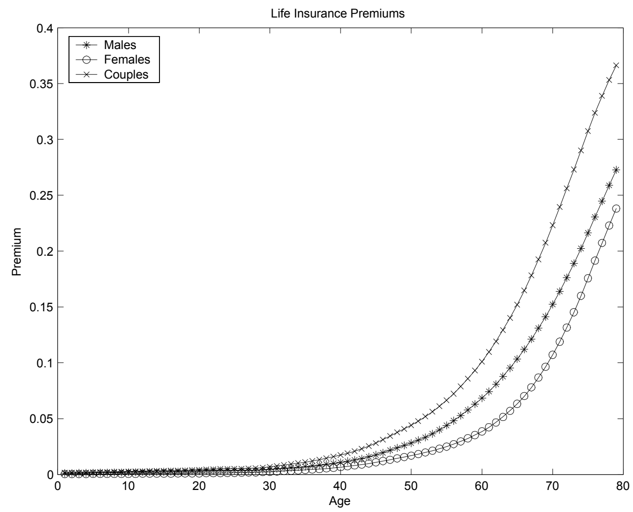
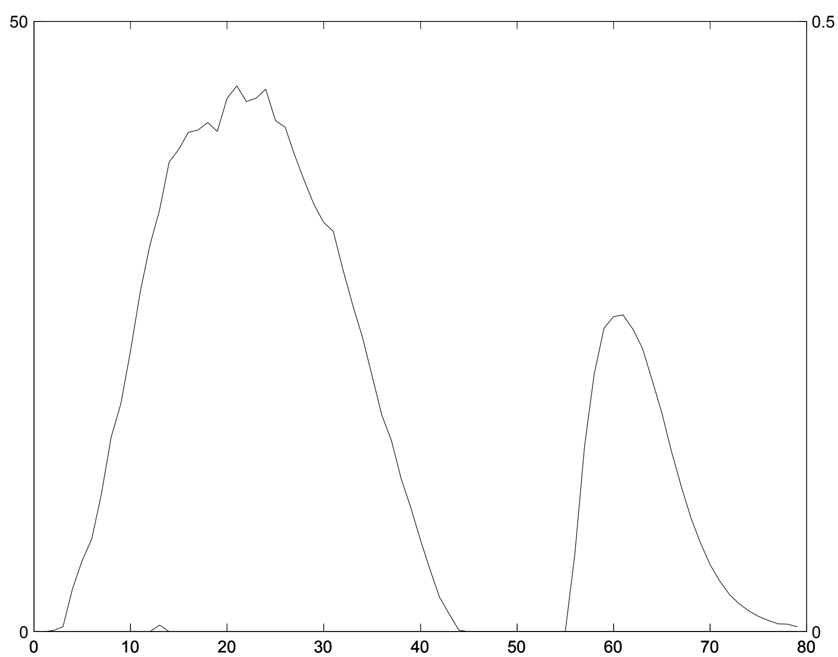


Figure 6:

Figure 7: Life Insurance Holdings



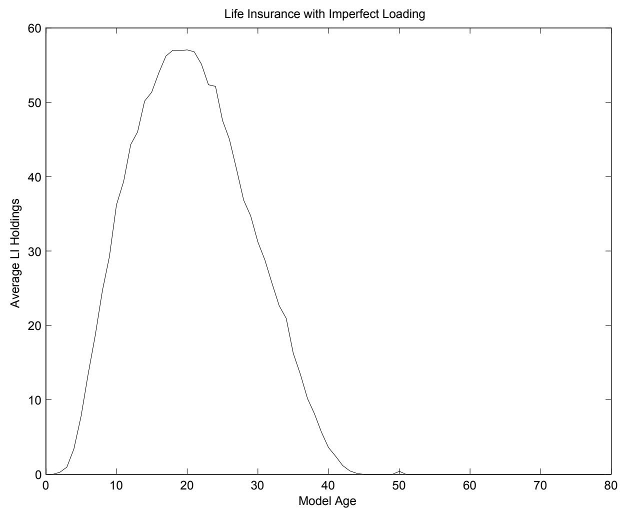


Figure 8:

Figure 9: LI holding versus Load Factors

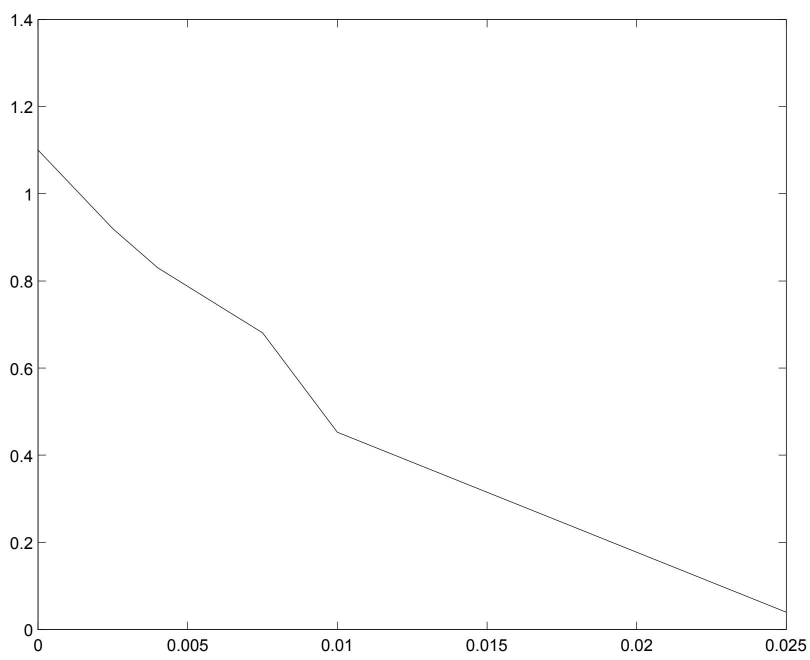


Figure 10: Wealth Path for Rich Households with One Child

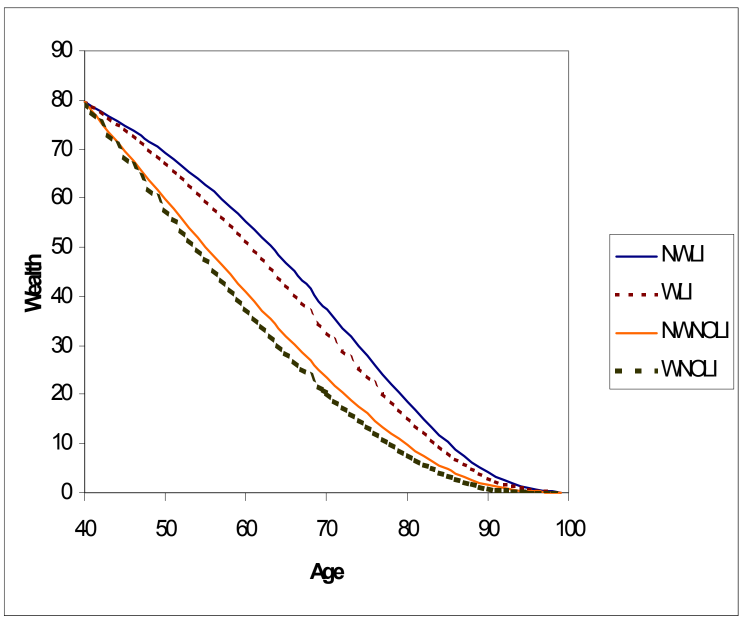


Figure 11: Average Wealth Path for Rich Households with One Child

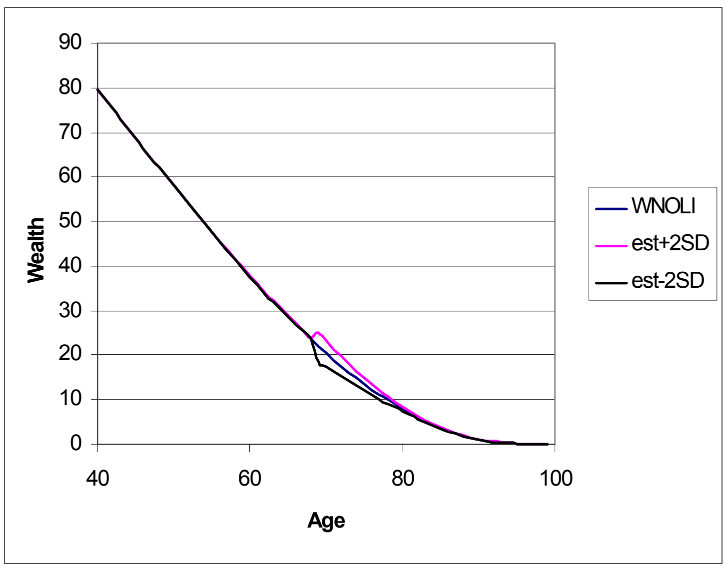


Figure 12: Wealth Path for Poor Households with One Child

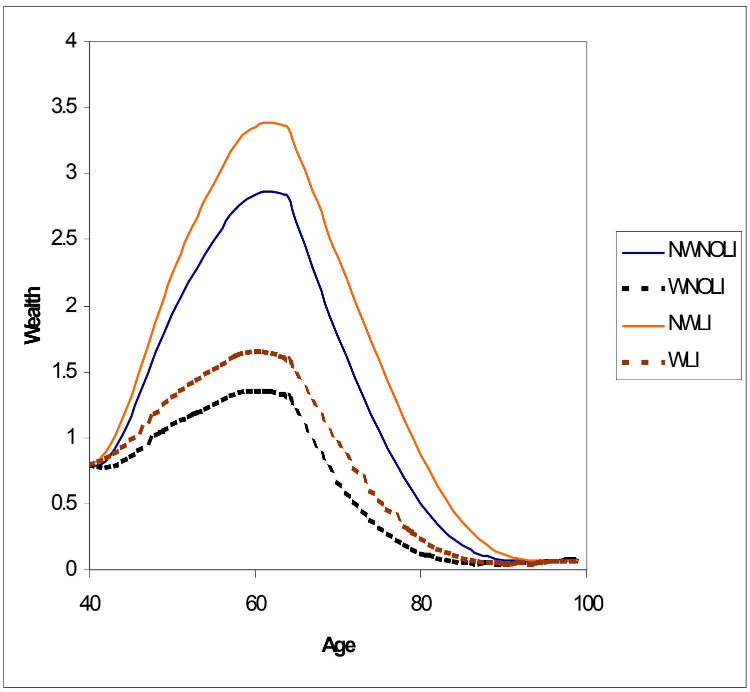


Figure 13: Average Wealth Path for Poor Widow with One Child

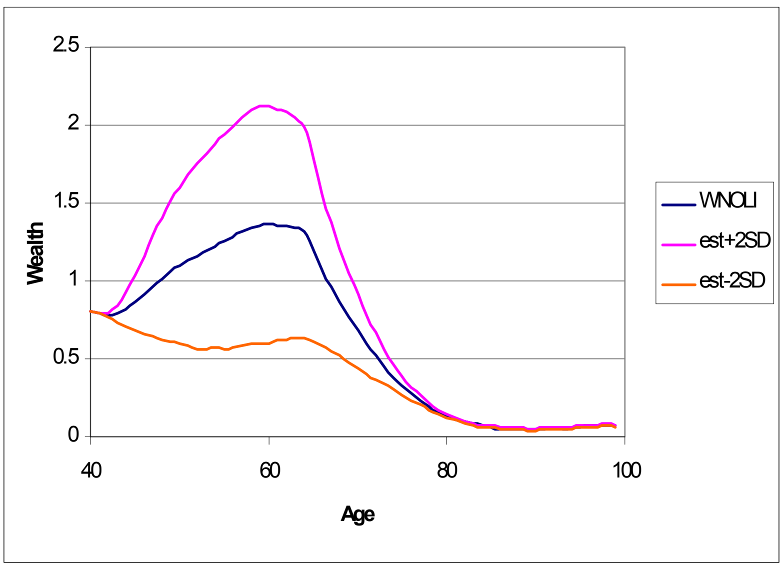


Figure 14: Consumption Path for Poor Households with One Child

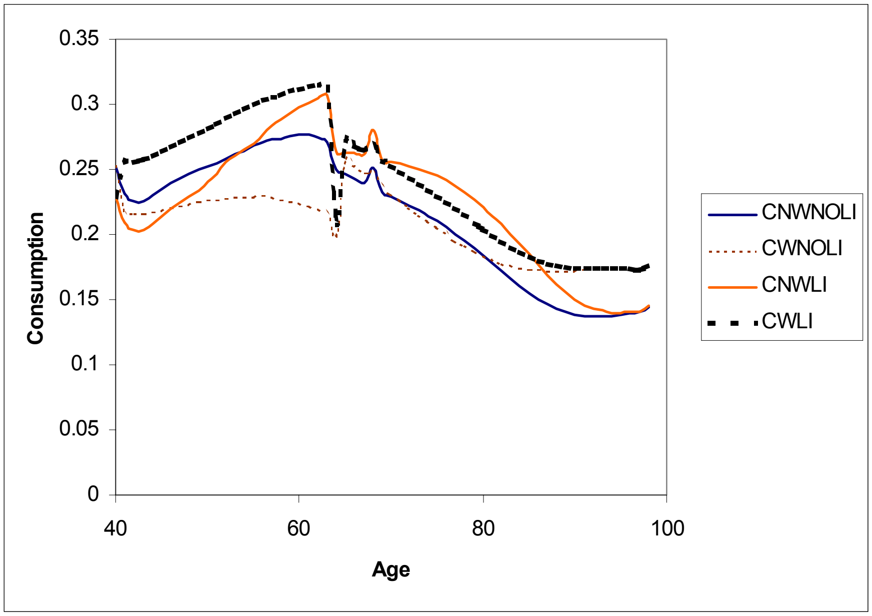


Figure 15: Female Labor Supply with One Child

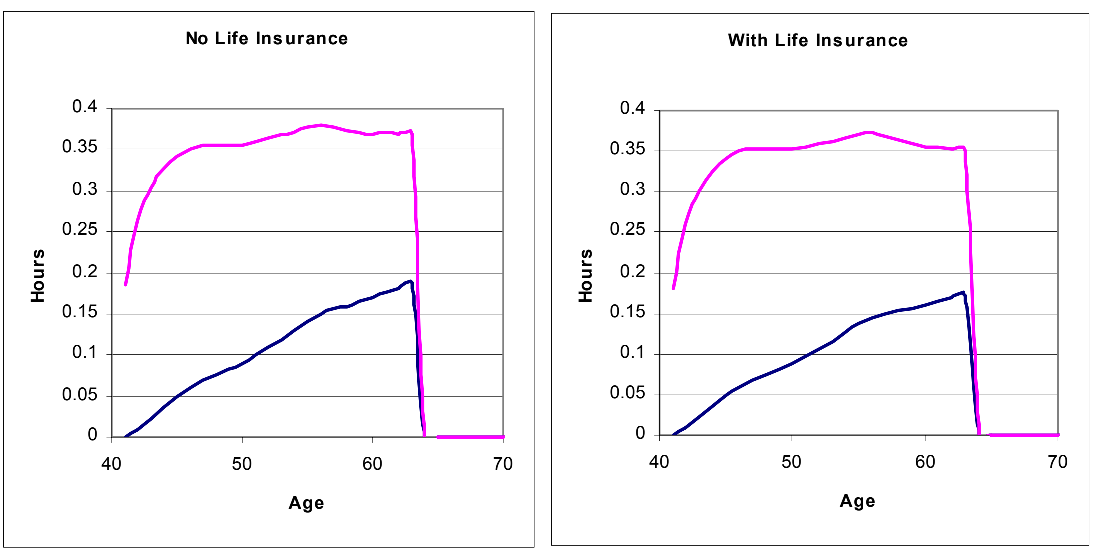


Figure 16: Wealth Path for Poor Households with Four Children

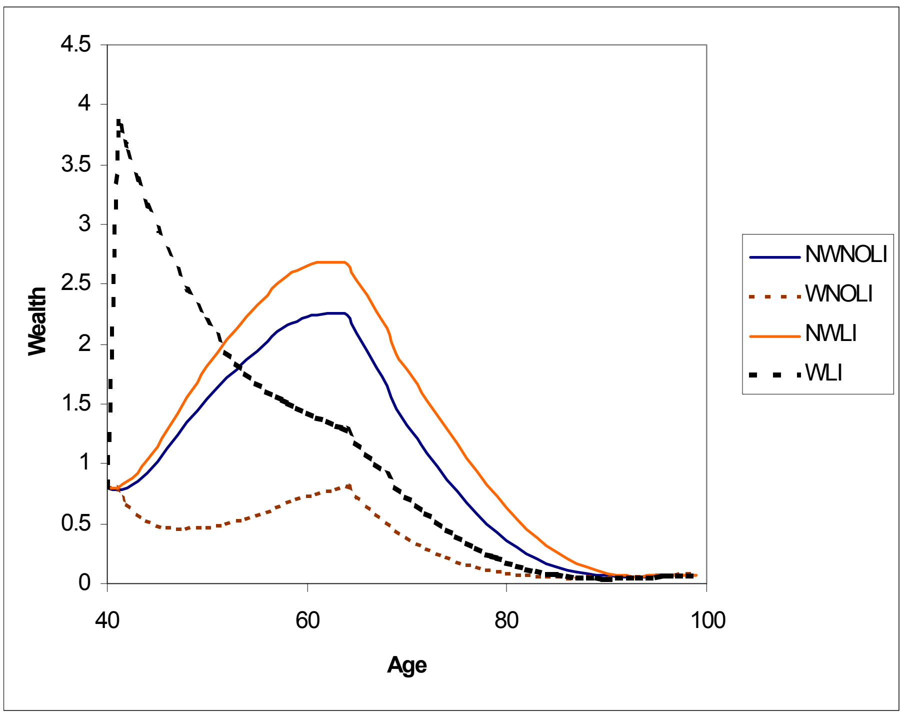


Figure 17: Female Labor Supply with Four Children

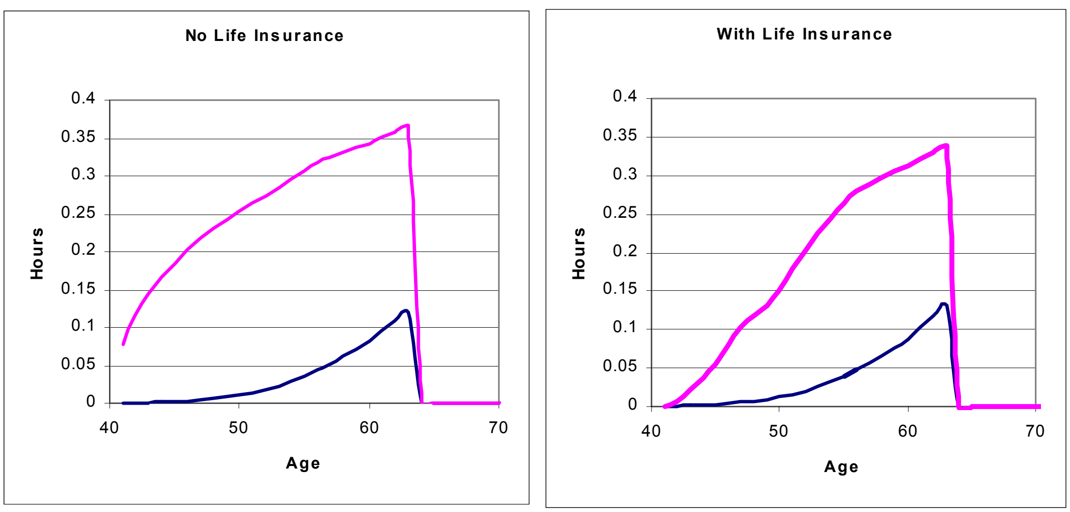


Figure 18: Consumption Path for Poor Households with 4 Children