Household's Life Insurance Demand - a Multivariate Two Part Model

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Outline

ARC 2009

Yunjie (Winnie) Sun

Objective

To understand characteristics of a household that drive life insurance demand with more sophisticated analytical techniques

- Data
  - 2004 Survey of Consumer Finance
  - Build on the work of Lin and Grace (2007) by using covariates that they developed
- Model features
  - Two part Model
    - Frequency model - Whether or not to have life insurance
    - Severity model - The amount of insurance a household demands given they decide to have life insurance
  - Multivariate Model
    - Term life insurance
    - Whole life insurance
- Important finding

  Demand of term and whole life insurance are substitutes in frequency and complements in severity.

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Motivation

- Life insurance demand literature:
  - *How much life insurance protection a household would seek given their economic and demographic structure* (see Goldsmith (1983), Burnett and Palmer (1984) and Lin and Grace (2007))
  - Tobit and OLS are widely applied.
  - Term and Whole life insurance are substitutes.
- Two part model
  - Analogous to decision making process
  - Allow for different explanatory variables for frequency and severity models respectively
- Multivariate models
  - Model two dependent variables simultaneously
  - Examine the substitutes or complements effect of term and whole life insurance

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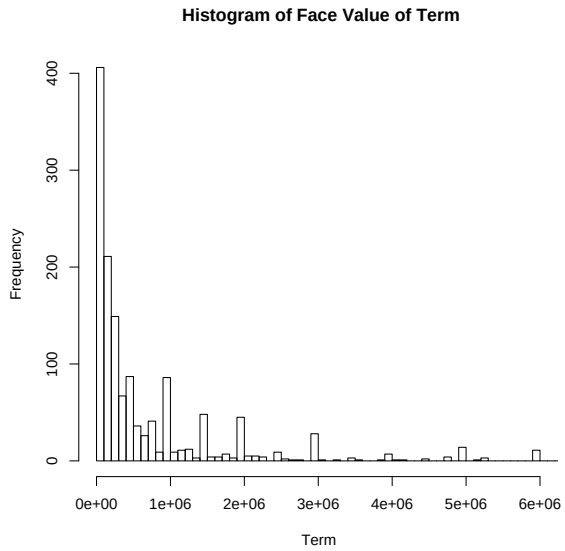
Data

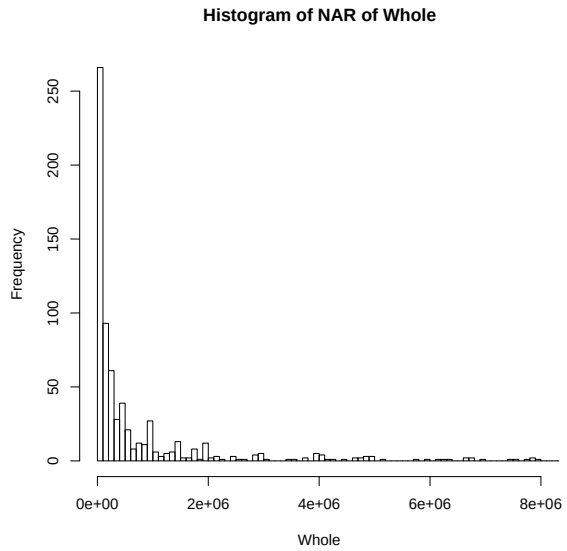
Survey of Consumer Finances (SCF) data

- A triennial survey of U.S. families conducted by the Federal Reserve
- About 4000 household level ("primary economic unit") observations during each survey period
- *A probability sample of the U.S. population*
- Extensive demographic and economic characteristics of the households as well as their behavioral aspects such as the motive to leave a bequest
- Limitations
  - Life insurance information is aggregate.
  - No information about when the life insurance was purchased.

Data

- 2150 married couples of age range from 20 to 64 (2004 SCF data)
- Dependent variable
  - Frequency Part (2150 observations)
    - Term life insurance indicator (65.86%)
    - Whole life insurance indicator (33.40%)
      *19.72% have *both* types of insurance
  - Severity Part (1710 observations—Life insurance purchasers subsample)
    - Face amount of term life insurance (Median $270,000)
    - Net Amount at Risk (NAR) of whole life insurance (Median $202,500)
      **Positively* correlated





Explanatory Variable

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- **Financial Vulnerability Index (IMPACT)**
  Measures the adverse financial impact in terms of living standard decline upon the death of one member of the household on the rest

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- Debts
- Age
- Education
- Income
- *Bequests (48.8%)*, *Obligations (58.9%)*, and Inheritance

Data description

Table 1. Summary Statistics

Variable	Minimum	25th Percentile	Median	75th Percentile	Maximum
FACETerm	0.8	100	270	1,000	150,000
NAR	0.66	60.25	202.5	900	45,000
CASHEQV	0	3	17	98	32,628
FUND	0	0	0	20	57,500
STOCK	0	0	0	50	200,000
BOND	0	0	0	1	100,000
RETIREMENT	0	0	52	272	35,000
ANNUITY	0	0	0	0	200,000
REALESTATE	0	127	350	1,294	194,380
OTHASSETS	0	15	31	66	97,203
DEBT	0	13	110	286	121,686
INHERITANCEExp	0	0	0	0	906,060
SALARY1	0	29	60	163	80,112
SALARY2	0	0	13	40	2,700
IMPACT	0	0.049	0.113	0.340	1265.02
AGE	21	39.5	47.5	54.5	64
EDUCATION1	1	12	16	17	17
EDUCATION2	0	12	15	16	17

*All the monetary variables are in thousands.

* Assets, debts, income and inheritance variables are logarithm transformed and indicator variables for zero values are added for these variables.

Two part model

- Two part model
  - $\mathbf{N}_i = (N_{i1}, N_{i2})$
    - N_{i1} — indicator for whether household i purchases term life insurance
    - N_{i1} — indicator for whether household i purchases whole life insurance
  - $\mathbf{Y}_i = (Y_{i1}, Y_{i2})$
    - Y_{i1} — the face amount of term life insurance demanded by household i
    - Y_{i2} — the net amount at risk (NAR) of whole life insurance demanded by household i
  - Decompose $(\mathbf{Y}_i)$ into frequency and severity components

$$f(\mathbf{Y}_i) = f(\mathbf{N}_i) \times f(\mathbf{Y}_i|\mathbf{N}_i).$$

- Frequency model $f(\mathbf{N}_i)$: Bivariate probit regression model
- Severity model $f(\mathbf{Y}_i|\mathbf{N}_i > 0)$: Generalized linear model with a Gaussian copulas

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Frequency model

Bivariate probit regression

- A bivariate probit regression model assumes the joint distribution of the bivariate binary choices is a standard bivariate normal distribution with a correlation coefficient ρ (see Ashford and Sowden (1970) and Meng and Schmidt (1985)).
- The log-likelihood of the ith observation is

$$\begin{aligned} l_i = \; & N_{i1}N_{i2}\ln F(\mathbf{x}_i'\beta_1, \mathbf{x}_i'\beta_2; \rho) \\ & + N_{i1}(1-N_{i2})\ln[\Phi(\mathbf{x}_i'\beta_1) - F(\mathbf{x}_i'\beta_1, \mathbf{x}_i'\beta_2; \rho)] \\ & + (1-N_{i1})N_{i2}\ln[\Phi(\mathbf{x}_i'\beta_2) - F(\mathbf{x}_i'\beta_1, \mathbf{x}_i'\beta_2; \rho)] \\ & + (1-N_{i1})(1-N_{i2})\ln[1 - \Phi(\mathbf{x}_i'\beta_1) - \Phi(\mathbf{x}_i'\beta_2) + F(\mathbf{x}_i'\beta_1, \mathbf{x}_i'\beta_2; \rho)] \end{aligned}$$

where F(·) is the cumulative distribution function of the standard bivariate normal distribution with correlation ρ.

Empirical result - Bivariate Probit Regression

	Term Insurance (1416)			Whole Insurance (718)		
Parameter	Estimate	*t*-ratio		Estimate	*t*-ratio	
Intercept	0.6669	0.7241		-0.9387	-0.9923	
Financial Vulnerability Index (IMPACT)	0.1696	2.6724	***	0.0558	0.9688	
Indicator for IMPACT $\geqslant 4$	-0.4730	-1.9327	*	-0.1623	-0.7268	
Log (1+ cash and cash equivalent)	0.0304	1.5934		0.0424	2.1641	**
Indicator for Izero cash and cash equivalent	-0.2411	-1.0359		0.2903	1.0687	
Log (1+stock)	-0.0522	-2.5445	**	-0.0369	-1.8554	
Indicator for zero stock	-0.4247	-1.8536	*	-0.4773	-2.1600	**
Log (1+ bond)	-0.0402	-2.4054	**	-0.0373	-2.3348	**
Indicator for zero bond	-0.4401	-2.6572	***	-0.5471	-3.5246	***
Log (1+ fund)	0.0309	1.2265		-0.0437	-1.7953	*
Indicator for zero fund	0.3445	1.1329		-0.6971	-2.3807	**
Log (1+ annuity)	-0.0724	-1.8533		0.0229	0.6204	
Indicator for zero annuity	-0.8718	-1.7882		0.0488	0.1072	
Log (1+ retirement)	0.0244	1.0716		-0.0319	-1.4329	
Indicator for zero retirement	-0.1217	-0.4814		-0.3881	-1.5228	
Log (1+ real estate)	-0.2092	-5.3364	***	0.0901	2.2573	**
Indicator for zero real estate	-2.5806	-5.6841	***	0.8182	1.7391	*
Log (1+ other assets)	0.0376	1.3837		0.0114	0.4211	
Indicator for zero other assets	0.3720	1.1793		-0.3394	-1.0141	
Log (1 + debt)	0.0563	2.3066	**	0.0046	0.1822	
Indicator for zero debt	0.1954	0.6560		-0.0019	-0.0059	
Average age of the couple	0.0575	2.2400	**	0.0035	0.1229	
Squared average age of the couple	-0.0006	-2.1053	**	0.0002	0.6699	
Education level of the resondent	0.0577	3.4698	***	-0.0172	-0.9852	
Education level of the spouse	0.0212	1.3865		0.0141	0.8665	
Log (1+ salary of the respondent)	0.0185	2.2804	**	0.0040	0.4896	
Log (1+ salary of the spouse)	0.0140	2.3231	**	0.0148	2.4428	**
Log (1+ sizable inheritance expected)	-0.0234	-0.6409		-0.0107	-0.2944	
Indicator for zero inheritance expected	-0.3234	-0.6867		-0.1723	-0.3676	
Indicator for the desire to leave a bequest	-0.0029	-0.0422		0.1135	1.6806	*
Indicator for foreseeable major financial obligation	0.0748	1.2013		-0.0005	-0.0082	
Rho	-0.2849	-7.6676	***			

*** Significant at 1% level
** Significant at 5% level
* Significant at 10% level

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- Financial Vulnerability Index only has impact on the frequency of term life insurance demand.

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- In general, the more assets a household has, the less likely that the household demands life insurance.

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Severity Model

- Generalized Linear Model (GLM) (see McCullagh and Nelder (1989)) Exponential family

$$f(y_i, \theta_i) = \exp\left(\frac{y_i\theta_i - b(\theta_i)}{\phi_i} + S(y_i, \phi_i)\right)$$

$$\mathrm{E}(y_i) = b'(\theta_i), \quad \mathrm{Var}(y_i) = \phi_i b''(\theta_i)$$

A link function $g(\cdot)$ links the covariates $\mathbf{x}_i$ to the response mean such that $g(b'(\theta_i)) = \mathbf{x}_i'\beta$.

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- Copulas (see Frees and Wang (2005))

$$\mathrm{C}[\mathrm{F_{i1}}(y_{i1}),\mathrm{F_{i2}}(y_{i2})]=\mathrm{F_i}(y_{i1},y_{i2})$$

  The log-likelihood of the ith household's life insurance demand given they purchase life insurance is

$$l_i=\ln f(y_{i1},\theta_{i1})+\ln f(y_{i2},\theta_{i2})+\ln c(\mathrm{F_{i1}}(y_{i1}),\mathrm{F_{i2}}(y_{i2}))$$

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- Incorporating a parametric distribution function (e.g. a Gamma distribution function with a log link function) and a parametric copula function (e.g. a Gaussian copula) to the above likelihood function, we can get an expression for the log-likelihood of the ith observation.

Empirical result - Gaussian copula with Gamma marginal distribution and log link

	Face Value of Term Insurance			NAR of Whole Insurance		
Parameter	Estimate	*t*-ratio		Estimate	*t*-ratio	
Intercept	0.6694	0.9030		0.1299	0.1178	
Financial Vulnerability Index (IMPACT)	0.1046	1.7907	*	0.2533	2.7330	***
Indicator for IMPACT $\geqslant 4$	-0.4636	-1.9698	*	-0.8145	-2.3842	**
Log (1+ cash and cash equivalent)	0.1706	8.5447	***	0.0237	0.8551	
Indicator for zero cash and cash equivalent	1.1962	3.8591	***	-1.1153	-2.0780	**
Log (1+stock)	0.0444	2.2057	**	0.0750	2.5311	**
Indicator for zero stock	0.4152	1.8819	*	1.0006	2.9940	***
Log (1+ bond)	0.0635	3.5879	***	0.0737	3.2795	***
Indicator for zero bond	0.4571	2.8738	**	0.6249	2.7952	***
Log (1+ fund)	0.0302	1.2180		0.0557	1.5422	
Indicator for zero fund	0.3965	1.3562		0.9352	2.1561	**
Log (1+ annuity)	0.0161	0.4580		0.0668	1.1762	
Indicator for zero annuity	0.2572	0.6226		0.6278	0.8866	
Log (1+ retirement)	0.0232	1.0801		0.0914	2.8581	***
Indicator for zero retirement	0.1753	0.7126		0.7532	1.9538	*
Log (1+ real estate)	0.2014	5.7790	***	0.3262	5.4281	***
Indicator for zero real estate	2.1948	5.4352	***	3.5057	4.6320	***
Log (1+ other assets)	0.1736	5.9393	***	0.1963	4.9573	***
Indicator for zero other assets	1.8250	5.2204	***	1.2862	2.3854	**
Log (1 + debt)	0.1289	5.2627	***	0.0400	0.9902	
Indicator for zero debt	1.0537	3.3861	***	0.8675	1.6730	*
Average age of the couple	0.0227	2.6742	***	0.0223	1.8322	*
Squared average age of the couple	-0.0005	-5.6999	***	-0.0006	-5.1411	***
Education level of the resondent	0.0458	2.6043	**	0.0057	0.2035	
Education level of the spouse	0.0237	1.3487		0.0560	2.0745	**
Log (1+ salary of the respondent)	0.0174	1.9938	*	0.0122	0.9756	
Log (1+ salary of the spouse)	-0.0244	-3.9509	***	-0.0280	-2.9078	***
Log (1+ sizable inheritance expected)	0.1634	4.5040	***	0.0406	0.6960	
Indicator for zero inheritance expected	1.9633	4.2608	***	0.5633	0.7446	
Indicator for the desire to leave a bequest	0.2058	3.0970	***	0.6351	5.7582	***
Indicator for foreseeable major financial obligation	0.0871	1.3906		0.1625	1.7100	*
Alpha	0.9131	28.4956	***	0.7460	30.6565	***
Rho	0.0990	1.9636	*			

*** Significant at 1% level
** Significant at 5% level
* Significant at 10% level

Empirical result - Gaussian copula with Gamma marginal distribution and log link

- The higher the financial vulnerability index, the more life insurance protection a household seeks for.

	Face Value of Term Insurance			NAR of Whole Insurance		
Parameter	Estimate	*t*-ratio		Estimate	*t*-ratio	
Intercept	0.6694	0.9030		0.1299	0.1178	
Financial Vulnerability Index	0.1046	1.7907	*	0.2533	2.7330	***

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Intercept	0.6694	0.9030		0.1299	0.1178	
Financial Vulnerability Index	0.1046	1.7907	*	0.2533	2.7330	***

- The more assets a household has, the more life insurance they demand

Log (1+ cash and cash equivalent)	0.1706	8.5447	***	0.0237	0.8551	
Indicator for zero cash	1.1962	3.8591	***	-1.1153	-2.0780	**
Log (1+stock)	0.0444	2.2057	**	0.0750	2.5311	**
Indicator for zero stock	0.4152	1.8819	*	1.0006	2.9940	***
Log (1+ bond)	0.0635	3.5879	***	0.0737	3.2795	***
Indicator for zero bond	0.4571	2.8738	**	0.6249	2.7952	***
Log (1+ fund)	0.0302	1.2180		0.0557	1.5422	
Indicator for zero fund	0.3965	1.3562		0.9352	2.1561	**
Log (1+ annuity)	0.0161	0.4580		0.0668	1.1762	
Indicator for zero annuity	0.2572	0.6226		0.6278	0.8866	
Log (1+ retirement)	0.0232	1.0801		0.0914	2.8581	***
Indicator for zero retirement	0.1753	0.7126		0.7532	1.9538	*
Log (1+ real estate)	0.2014	5.7790	***	0.3262	5.4281	***
Indicator for zero real estate	2.1948	5.4352	***	3.5057	4.6320	***
Log (1+ other assets)	0.1736	5.9393	***	0.1963	4.9573	***
Indicator for zero other assets	1.8250	5.2204	***	1.2862	2.3854	**

Empirical result - Gaussian copula with Gamma marginal distribution and log link

Parameter	Face Value of Term Insurance Estimate	*t*-ratio		NAR of Whole Insuranc Estimate	*t*-ratio
Log (1 + debt)	0.1289	5.2627	***	0.0400	0.9902
Indicator for zero debt	1.0537	3.3861	***	0.8675	1.6730
Average age of the couple	0.0227	2.6742	***	0.0223	1.8322
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Finding

The correlation between the amount of term and whole life insurance demand is positive and significant.

Empirical result - Gaussian copula with Gamma marginal distribution and log link

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Conclusion

We explore a multivariate two part framework for the household's ownership of life insurance.

- Contribution
  - Improve the understanding of a household's life insurance demand
  - Insurance company can develop marketing strategies accordingly
  - The demand of term and whole life insurance are substitutes in frequency and complements in severity

Further research

The ultimate goal of this study is to project national life insurance demand. Further research will focus on out-of-sample validation and extrapolation to the national population with the proper survey sampling method. We will also explore the demand of life insurance for single person households.

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Thanks!!