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HOUSEHOLD FINANCE:
EDUCATION, PERMANENT INCOME AND PORTFOLIO CHOICE

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ABSTRACT

This paper studies household financial choices: why are these decisions dependent on the education level of the household? A life cycle model is constructed to understand a rich set of facts about decisions of households with different levels of education attainment regarding stock market participation, the stock share in wealth, the stock adjustment rate and wealth-income ratio. Model parameters, including preferences, the cost of stock market participation and portfolio adjustment costs, are estimated to match the financial decisions of different education groups. Based on the estimated model, education matters through two channels: the mean of income and the discount factor.

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Household Finance: Education, Permanent Income and Portfolio Choice*

Russell Cooper† and Guozhong Zhu‡

December 24, 2013

Abstract

This paper studies household financial choices: why are these decisions dependent on the education level of the household? A life cycle model is constructed to understand a rich set of facts about decisions of households with different levels of education attainment regarding stock market participation, the stock share in wealth, the stock adjustment rate and wealth-income ratio. Model parameters, including preferences, the cost of stock market participation and portfolio adjustment costs, are estimated to match the financial decisions of different education groups. Based on the estimated model, education matters through two channels: the mean of income and the discount factor.

1 Motivation

It is common for studies of household financial decisions to condition on education. Asset market participation decisions, adjustment rates, savings rates and portfolio choice are frequently linked to education attainment.

For example, Campbell (2006) presents evidence on the determinants of public equity market participation and portfolio composition. His regressions indicate that both income and education have a significant influence on household financial choices. This evidence, and other comparable studies such as Vissing-Jorgensen (2002), support the view that education is empirically relevant for household financial decisions.

But what is the underlying impact of education on financial decisions? Are different household decisions a consequence of education specific observables such as income processes and mortality rates, and/or unobservable heterogeneities that are correlated with education, such as risk aversion and cognitive abilities? Addressing these questions is the point of this paper.

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The analysis is built upon empirical evidence that links education to household financial choices, including asset market participation, the share of risky assets in household portfolios, the frequency of portfolio adjustment and wealth to income ratios. While many studies have focused on one or more of these components of household financial decisions, one contribution of the paper is to understand these choices jointly.[1] This is important not just as means of generating a more complete picture of these choices but in allowing us to identify the sources of these differences. For example, a household considering asset market participation will recognize the subsequent cost of portfolio adjustment which is evidenced by the low stock adjustment rates. The factors, such as attitudes towards risk, that determine the share of assets in a household portfolio will also influence wealth accumulation and the stock market participation decision of the household. Another example is that, with fixed portfolio adjustment cost, higher wealth levels may lead to a higher stock share as wealthy households bear a lower cost (per unit) of adjustment. This stock share decision interacts with the participation decision, creating identification problems when participation is not modeled explicitly.

Our approach to determining the dependence of financial choices on education starts with the specification and estimation of a life cycle model of household financial choices. Regression analysis as in Campbell (2006) reveals how household finance depends on education and income in a static way. Our framework allows us to study the dynamic effects of education-related traits. For example, the model shows the important role of permanent income over life cycle, rather than realized income at a point of time. The life cycle framework, rather than the infinitely lived agent model, is needed to examine the affects of post-retirement income and stochastic medical expenses on financial decisions, both pre- and post-retirement.

The estimation is an integral part of the analysis. Without estimating a model we would not be able to decompose the channels of influence between education and household financial decisions. Further, we would be unable to determine the affects of education on the parameters of household preferences and adjustment costs without estimating the parameters. The estimation uses a simulated method of moments approach, where the moments reflect the key household financial decisions by education group. These moments are selected to identify key parameters.

More specifically, the analysis puts households into four education (attainment) groups.[2] From the Survey of Consumer Finance (SCF), average stock market participation rate and financial wealth to income ratio increase sharply with education attainment. Stock share also increases with education status, but not as sharply. From the Panel Study of Income Dynamics (PSID), stock (portfolio) adjustment rates are higher for more educated households.

[1]For example, Hubbard, Skinner, and Zeldes (1995) study why more educated households save more. Alan (2006) studies participation patterns only using a model with a single asset. Vissing-Jorgensen (2002) and Gomes and Michaelides (2005) study both participation and stock share. Achury, Hubar, and Koulovatianos (2012) and Wachter and Yogo (2010) study the relation between education/wealth and stock share in wealth. Cocco, Gomes, and Maenhout (2005) studies portfolio shares over the life cycle, highlighting how the components of labor income influence this choice. Other studies focus on portfolio adjustment rates, such as Bonaparte, Cooper, and Zhu (2012) and Calvet, Campbell, and Sodini (2009), without focusing on participation rates.

[2]To be clear, the model does not explain education. Rather it looks at the household financial choices given education.

Parameter estimates come from using the structural model to match the averages of stock market participation rates, stock shares in wealth, stock adjustment rates and wealth-income ratios of the four education groups, pre- and post-retirement. These moments are very informative about costs and risk preferences. By matching these observations, we estimate adjustment costs of stock market along with preference parameters. In addition, by allowing heterogeneities in preferences and costs across education groups, the estimation results enable us to study the roles played by risk aversion, patience and other unobservables .

The recent literature provides insights that costs associated with stock market participation, eg. Alan (2006), Gomes and Michaelides (2005), and costs of financial transactions, eg. Bonaparte, Cooper, and Zhu (2012), are important. Consistent with the empirical evidence in Vissing-Jorgensen (2002), we consider two types of portfolio adjustment costs: an entry cost and a transaction cost, both are fixed rather than proportional. In the presence of these costs, our model is able to match the data moments of participation, adjustment rate, portfolio share and wealth-income ratio. Further, our structural estimation allows us the test to what extent these costs are education specific.

In the absence of costs, predictions based on common representations of risk preferences tend to contradict the data. For example, standard household portfolio models typically predict that every household should participate in the stock market, and that the share of stock in total financial wealth should be high, e.g. Heaton and Lucas (1997) and Merton (1971). As another example, constant absolute risk aversion preference predict that a household's optimal investment in risky asset is roughly a fixed amount independent of total wealth, which implies that the more educated should have lower share of stock in financial wealth.

As pointed out by Campbell (2006), a fundamental issue that confronts the household finance literature is how to specify the household utility function. We carry out the estimation using three specifications: constant absolute risk aversion (CARA), constant relative risk aversion (CRRA) and recursive utility (EZW) taken from Epstein and Zin (1989) and Weil (1990). Our estimation results indicate that recursive utility brings the simulated and data moments closer together than do the CARA and CRRA representations. Apart from understanding the link between education and financial choices, the finding in support of the recursive utility specification in an estimated model is of independent interest. This result, based on estimating the competing models, complements existing simulation based exercises that have documented the contribution of this specification of utility.

A critical input into household optimization problem is the education specific stochastic processes for income, medical expense and mortality. Education impacts both the permanent and transitory components of labor income. Based on the PSID, more educated households have higher levels of deterministic income before retirement, lower income replacement ratios, and less income risks. According to data from the Health and Retirement Study (HRS), after retirement, the more educated have higher out-of-pocket medical expenses relative to their income, and are subject to lower mortality risks.

In answer to the central question of our paper, the main observable factor that links household financial decisions to education is the dependence of the **mean level of income** on education.[3] Other factors, such

[3] In her empirical analysis, Vissing-Jorgensen (2002) highlights the importance of mean and risk effects of nonfinancial income.

as income volatility and differences in medical expenses as well as mortality do not play a large role in explaining the variation of household financial decisions across education groups.

We also allow preferences, the stock market entry cost and the portfolio adjustment cost to differ across education groups. **Point estimates consistently show that the discount factor differs across education groups: high education households discount the future much less than low education households.** There is also limited evidence that high education households are faced with a lower entry cost, but slightly higher adjustment cost. Other differences in parameters are not significant and have little power in explaining household finance differences across education groups.

2 Data Facts

We present two types of data facts. The first are the processes characterizing exogenous income during working years, out-of-pocket medical expenses during retirement and mortality risks faced by households. These processes, taken as exogenous, determine the extent to which households accumulate precautionary savings balances and how they structure their portfolios.[4]

The second set of facts concerns household financial choices: asset market participation, stock share in portfolios, the frequency of adjustment and wealth-income ratio. These dimensions of household financial choices reflect both the aforementioned processes that households face as well as the costs of participation and adjustment. These facts become the moments to match in the estimation of household preference parameters and adjustment costs. As with the exogenous processes, we study household financial decisions both pre- and post-retirement.

Consistent with the motivation of the paper, the income, mortality rates and medical expense processes as well as the moments summarizing household choices are presented by education group. A key point of the paper is to go beyond these education dependent observable facts to understand why education matters.

2.1 Income Heterogeneity

Households are broken into four groups by (highest) education attainment of the household head. Specifically they have years of schooling less than 12 years, equal to 12 years, over 12 but less than or equal to 16 years, and over 16 year respectively. For each group, income, defined as the sum of labor income and transfers, is decomposed into deterministic and stochastic components. The sample period is 1989-2007. The Appendix provides detailed information on sample selection criteria and the decomposition method.

In this paper we study their relative importance in a structural model. Wachter and Yogo (2010) relate the rise of stock share with education attainment to luxury goods assumption, underlying which is higher income of the more educated. Similarly, Achury, Hubar, and Koulovatianos (2012) link income level to stock share through subsistence consumption.

[4]Endogenous income as a result of flexible labor supply will lead to more risk taking of working households, which is shown in Bodie and Samuelson (1992) and Gomes and Viceira (2008). Regarding medical expenses, DeNardi, French, and Jones (2010) compare the results on wealth accumulation from models with exogenous and endogenous medical expense and find little difference.

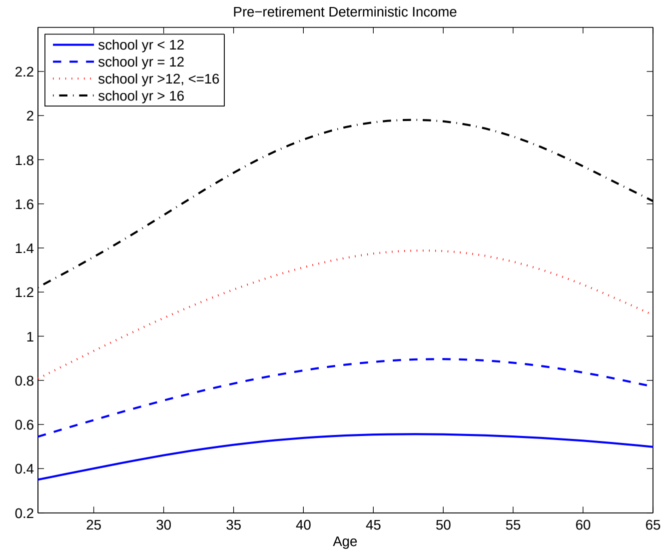

Figure 1: Pre-retirement Deterministic Income

This figure shows the average profiles of pre-retirement income by education attainment. Income profiles are normalized so that the average income of the pooled households is one.

Figure 1 presents the profiles of deterministic income of the four education groups.[5] Differences in the mean of the paths illustrate gains to education. The hump-shape of lifetime income is considerably more pronounced for higher education households.

These differences in mean income by education group will play a prominent role in our analysis. They will account for a large amount of the differences in household financial decisions by education group.

Let $\tilde{y}_{i,t}$ denote the stochastic component of income for household i in period t. We decompose it into transitory and persistent shocks.

$$\tilde{y}_{i,t} = z_{i,t} + \epsilon_{i,t}$$
$$z_{i,t} = \rho z_{i,t-1} + \eta_{i,t} \quad (1)$$

where $\epsilon_{i,t}$ and $\eta_{i,t}$ are independent zero-mean random shocks, with variance σ_ϵ^2 and σ_η^2 respectively. The shock $\eta_{i,t}$ is persistent, with persistence parameter of ρ. The Appendix provides additional details on this decomposition and the estimation of this stochastic income processes.

The stochastic properties of income for different groups are presented in Table 1. The rows denote the education attainment of the household head. Households with more educated heads are exposed to smaller transitory income shocks. The persistence and size of persistent income shocks are about the same across education groups, except that the most educated group appears to have less persistent but larger shocks.[6]

[5]A very similar figure appears in Cocco, Gomes, and Maenhout (2005) though for a different sample period.

[6]Some other papers in the literature also find the less educated are exposed to larger transitory income shocks. Examples

Table 1: Stochastic Processes of Income

	Income		
years of schooling	σ_ϵ^2	σ_η^2	ρ
<12	0.107	0.017	0.963
	(0.017)	(0.004)	(0.007)
12	0.071	0.016	0.952
	(0.007)	(0.002)	(0.004)
>12, ≤ 16	0.067	0.018	0.960
	(0.007)	(0.004)	(0.006)
>16	0.020	0.037	0.935
	(0.008)	(0.007)	(0.009)

This table reports the variances and persistence parameters of income shocks estimated from PSID for four education groups. Standard errors are presented in parentheses.

There are also differences across education groups post-retirement. The deterministic component of post-retirement income is a proportion of the pre-retirement permanent income, defined as the product of deterministic income and accumulated persistent shocks ($z_{i,t}$). To estimate this income replacement ratio for each education group, we take a sample of households from PSID who have valid information on income both before and after retirement. Pre-retirement permanent income is approximated by the within education group average of reported income. Table 2 shows that the income replacement ratio decreases with education attainment.

Table 2: Income Replacement Ratio

Years of Schooling	<12	=12	>12, ≤16	>16	all
Replacement Ratio	0.744	0.625	0.537	0.513	0.605
	(0.06)	(0.03)	(0.03)	(0.02)	(0.02)
Number of Obs.	480	679	637	324	2201

This table reports the income replacement ratios estimated from PSID for four education groups. Standard errors are presented in parentheses.

Though post-retirement income is assumed to be non-stochastic, retired households are subject to medical

include Guvenen (2009) (Table 1) and Hubbard, Skinner, and Zeldes (1994) (Appendix A.4). The t-statistics reported in Hubbard, Skinner, and Zeldes (1994) imply that these parameters are imprecisely estimated. One the other hand, Carroll and Samwick (1997) (Table 1) offer very precise estimates, but find a non-monotone relation between education attainment and size of income shocks.

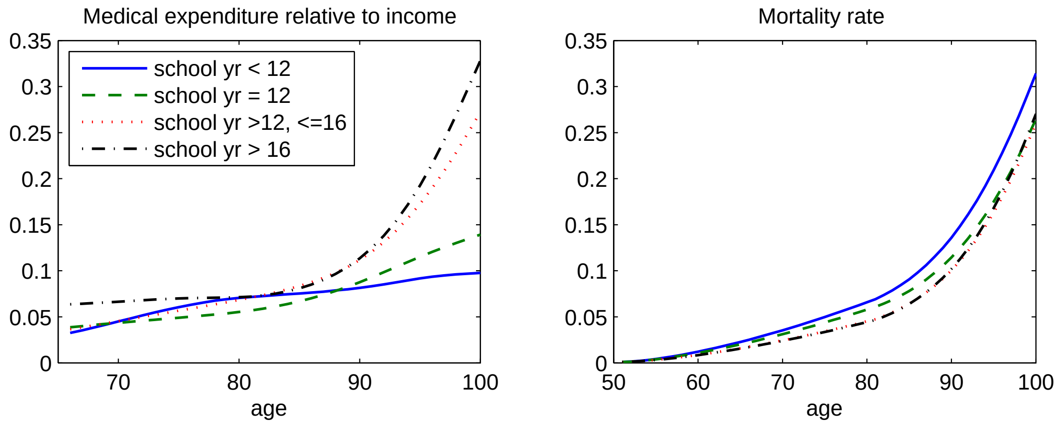

Figure 2: Post-Retirement Medical Expenditure and Mortality

The left panel shows the average profiles of post-retirement out-of-pocket medical expenses relative to post-retirement income by education group. The right panel is the estimated mortality rates conditional on survival.

expenditure shocks. Since out-of-pocket medical expense is stochastic, the post-retirement income after medical expense is stochastic as well.

The estimation of out-of-pocket medical expenses is based on data from French and Jones (2004). The paper shows that the logarithm of stochastic component of out-of-pocket medical expenses can be well represented by an $AR(1)$ process plus a pure transitory shock. We assume the stochastic process of medical expenses to be the same across education groups, and take the estimates directly from French and Jones (2004). We estimate the ratio of out-of-pocket medical expenses to post-retirement income for each education group. Details about data sources, definitions and the stochastic process for medical expenses are given in the Appendix.

The left panel of Figure 2 shows average out-of-pocket medical expense relative to post-retirement income by education group. Post-retirement income by education attainment is constructed from individual post-retirement income, which is measured as the retiree's average income over all periods during which he or she is observed in the data from Heath and Retirement Study. From this figure, medical expense relative to income increases sharply with age. The most-educated group has higher expense, but the other groups are faced with very similar medical expenses relative to income.

The right panel of Figure 2 shows mortally risk as a function of age by education group. Consistent with the literature, see for example Lleras-Muney (2005) and Starr-McCluer (1996), mortality and health are correlated with education.

In the estimation of the model, these education specific income, medical expense and mortality processes are exogenous inputs. Moreover, the variance of income innovations varies by education class, and is also taken as exogenous inputs. As noted above, we restrict the variability of medical expenses post-retirement to be the same across education groups.

2.2 Patterns of Household Finance

Table 3 reports the averages of participation rate, stock share, adjustment rate and median wealth-income ratio by year of schooling. The Appendix provides details on data sources and calculations of these moments.

A household is a participant in asset markets if it either directly or indirectly owns stocks according to our sample from the SCF. The share of stocks in total wealth is for stockholders only, defined as the ratio of stock holdings to total wealth which is the sum of stock and bond holdings. We also consider a measure of wealth where housing is included.[7] The wealth income ratio is defined as the median of the ratios of all the households in the same education group. It is also presented both with and without the inclusion of net housing equity in wealth.

Adjustment refers to the actual purchase or sale of stocks by the stockholders. This is measured bi-annually. This adjustment rate includes changes in IRA-holdings. Automatic reinvestments are not considered as adjustments. Notice that our definition of stock adjustment is narrow in the sense that it is for stockholders in the previous survey only. New entrants are not included in the calculation.

There are a couple of key features to note from Table 3. Participation rates and wealth-income ratios increase sharply with education attainment. The stock share and the adjustment rate increase as well, though not as much. The rise of median wealth-income ratio with education attainment is consistent with the finding that richer households save more, as in Dynan, Skinner, and Zeldes (2004).

The incentives for asset accumulation reflected in the wealth to income ratio are created by income risks, low income replacement ratio, post-retirement medical expense risks and a bequest motive. The discount factor, risk aversion, and the value of bequests will determine the response to income patterns.

The costs of asset market participation as well as the costs of portfolio adjustment are relevant for understanding the frequency of adjustment, the participation decisions and the portfolio shares. A unique feature of our study is the presence of both of these costs. Having moments on participation as well as adjustment rates will allow us to identify them. As with the savings decision, household preferences also influence adjustment and participation choices.

In the estimation, these data averages are informative moments for the estimation of household parameters. These moments have some life cycle dimensions as we study both pre- and post retirement behavior.

The Wealth/Income ratio is less precisely estimated than other moments. As a consequence, the weighting matrix will put less weight on matching these moments compared to others.

[7] Here we do not consider the demand for money. See Aoki, Michaelides, and Nikolov (2012) for recent work integrating money demand into portfolio choice.

Table 3: Participation, Composition and Adjustment by Education

	Pre-retirement				Post-retirement			
	Years of Schooling				Years of Schooling			
	<12	=12	>12,≤ 16	>16	<12	=12	>12,≤ 16	>16
Stock Share	0.523	0.539	0.562	0.602	0.451	0.495	0.568	0.599
	(0.02)	(0.008)	(0.004)	(0.005)	(0.021)	(0.014)	(0.009)	(0.011)
Participation	0.173	0.322	0.560	0.814	0.221	0.451	0.734	0.851
	(0.01)	(0.007)	(0.006)	(0.006)	(0.013)	(0.014)	(0.012)	(0.012)
Adjust. Rate	0.560	0.563	0.615	0.701	0.397	0.417	0.558	0.646
	(0.02)	(0.02)	(0.011)	(0.014)	(0.03)	(0.034)	(0.03)	(0.035)
Wealth/Income	0.077	0.148	0.451	1.787	0.638	1.563	4.292	5.828
	(0.005)	(0.005)	(0.017)	(0.071)	(0.187)	(0.249)	(0.437)	(0.671)
With Home Equity								
Stock Share	0.261	0.361	0.353	0.425	0.262	0.296	0.418	0.448
	(0.025)	(0.063)	(0.007)	(0.032)	(0.029)	(0.022)	(0.013)	(0.015)
Wealth/Income	0.441	0.789	1.503	3.573	4.015	5.204	7.773	8.880
	(0.063)	(0.031)	(0.040)	(0.098)	(0.447)	(0.572)	(0.472)	(0.881)

This table reports the averages of participation rates, stock shares, stock adjustment rates and median wealth-income ratios by education attainment. The "With Home Equity" block includes housing in wealth and reports the correspondingly changed stock shares and wealth-income ratios.

3 Model

To infer parameters from these moments requires an optimization model at the household level. Both the participation and adjustment decisions are discrete while the portfolio share is a continuous choice variable. We embed these discrete and continuous decisions into a life cycle framework.

3.1 Dynamic Optimization Problem

A household makes consumption, saving and financial choices during its working and retirement period. The retirement age, $T^r = 65$, is exogenous in our analysis. A household starts to work at age 26 and earns stochastic income, characterized in Table 1 and Figure 1. At $t = T^r$ the household's income process switches to a stable retirement income according to Table 2, supplemented by stochastic medical costs. The household is faced with a death probability which is age- and education-specific, shown in the right panel of Figure 2. The death probability equals one at age $T + 1$ for each education group, so that the maximum life span is T which we assume to be 100 when computing the model.

Confronting the riskiness of income while working is a main motive for household finance choices. During retirement, the household faces stochastic medical expenses. As described above, following DeNardi, French, and Jones (2010), these medical expenses are treated as variations in household disposable income and thus are a source of risk during retirement.

The state of a household of age t in education group e is its current labor income y_t^e, its medical expenditure m_t^e, its current holdings of stocks, denoted A^s, and bonds, denoted A^b, and the return on assets R. Income and medical expenditures are superscripted by education attainment, e. These exogenous difference across education groups will lead to endogenous difference in saving and financial choices. Let $\Omega = (y_t^e, m_t^e, R, A)$ represent the current state, with $A = (A^b, A^s)$ being a vector of endogenous state variables. Notice that R is time (age) invariant and independent of education attainment. In addition, we assume shocks to stock return is independent of income shocks and medical expense shocks.

A household currently not participating in the stock market has the choice in period (at age) t to remain outside of that market or to pay an entry cost for the right to trade stocks. That discrete choice is represented as:

$$w_{e,t}(\Omega) = \max\{w_{e,t}^n(\Omega), w_{e,t}^p(\Omega)\} \tag{2}$$

for all Ω. Here $w_{e,t}(\Omega)$ is the maximum of the values of participating, $w_{e,t}^p(\Omega)$, and not participating, $w_{e,t}^n(\Omega)$. The value functions are subscripted by education attainment and age because of the finite-horizon nature of the optimization problem.

If the household chooses to remain outside of asset markets, the household can engage in consumption smoothing through its bond account and re-optimize in the following period. The value of that problem is given by:

$$w_{e,t}^n(\Omega) = \max_{A^{b\prime} \geq \underline{A}^b} u(c) + \beta E_{y_{t+1}^e, m_{t+1}^e | y_t^e, m_t^e} \left\{ \nu_{t+1}^e w_{e,t+1}(\Omega') + (1 - \nu_{t+1}^e) B(R^b A^{b\prime}) \right\} \tag{3}$$

for all Ω. Here β is the discount factor, $1 - \nu_{t+1}^e$ is the death probability, as indicated in the right panel of Figure 2. $B(b')$ is the value of leaving a bequest of size b' and is explained in detail below. Consumption is given by

$$c = y_t^e + TR - m_t^e + R^b A^b - A^{b\prime}. \tag{4}$$

Here TR is the transfer from the government from various social insurance programs. Following Hubbard, Skinner, and Zeldes (1995) and DeNardi, French, and Jones (2010), we assume the following functional form for this transfer

$$TR = \max\{0, \underline{c}_t - (y_t^e + R^b A^b - m_t^e)\} \tag{5}$$

where $\underline{c}_t$ is the consumption floor, the minimum level of consumption guaranteed by the government. In order to be eligible for the transfer, a household's means of living net of medical expenditure, $y_t^e + R^b A^b - m_t^e$, must be less than the floor. Therefore the transfer function captures asset-based, means-tested social programs such as Medicaid, food stamps and Temporary Assistance for Needy Families. This support program has implications for precautionary savings, particularly by low wealth households. The consumption floor is estimated for both the pre-retirement, $\underline{c}$ and post-retirement period, $\kappa\underline{c}$.

In this problem, there is a lower bound on bond holdings, $\underline{A}^b$. We assume $\underline{A}^b = 0$ so that the household is not allowed to borrow. The household is not allowed to own stocks as it is a non-participant in the stock market. Hence in (3), $A^s = A^{s\prime} = 0$ is imposed.

If a household chooses to participate in the stock market, then it incurs an entry cost of Γ and becomes a participant with future value of $v_{e,t+1}(\Omega)$. This switch in status happens instantly and the household is in a position to make portfolio adjustment decisions. The value of participating is given by:

$$w^p_{e,t}(\Omega) = \max_{A^{b\prime} \geq \underline{A}^b, A^{s\prime} \geq 0} u(c) + \beta E_{y^e_{t+1}, m^e_{t+1}, R^{s\prime} | y^e_t, m^e_t, R^s} \left\{ \nu^e_{t+1} v_{e,t+1}(\Omega') + (1 - \nu^e_{t+1}) B(R^b A^{b'} + R^{s'} A^{s'}) \right\}$$

$s.t.$

$$c = y^e_t + TR - m^e_t + R^b A^b - A^{b\prime} - A^{s\prime} - \Gamma \tag{6}$$

$$TR = \max\{0, \underline{c}_t - (y^e_t + R^b A^b - m^e_t)\}. \tag{7}$$

Here the bequest value is a function of total wealth, including the liquidated value of stocks. The household chooses a bequest portfolio without knowing the stock return that will determine the full value of the inheritance.

The entry cost Γ does not differ across across education groups in the basic model, although it is a smaller proportion of deterministic income for less educated households. Γ captures not just financial cost, but also mental cost and time cost associated with learning and information searching. These non-financial costs are likely to depend on cognitive ability and financial literacy of the households, therefore in section 5 heterogeneous entry costs are estimated.

A participant in asset markets has a discrete choice between adjusting, not adjusting its stock account or exiting asset markets. This choice is represented as:

$$v_{e,t}(\Omega) = \max\{v^a_{e,t}(\Omega), v^n_{e,t}(\Omega), v^x_{e,t}(\Omega)\} \tag{8}$$

for all Ω.

If the household adjusts, it is able to adjust both its stock and bond accounts. The household solves:

$$v^a_{e,t}(\Omega) = \max_{A^{b\prime} \geq \underline{A}^b, A^{s\prime} \geq 0} u(c) + \beta E_{y^e_{t+1}, m^e_{t+1}, R^{s\prime} | y^e_t, m^e_t, R^s} \left\{ \nu^e_{t+1} v_{e,t+1}(\Omega') + (1 - \nu^e_{t+1}) B(R^b A^{b'} + R^{s'} A^{s'}) \right\}$$

$s.t.$

$$c = y^e_t + TR - m^e_t + \sum_{i=b,s} R^i A^i - \sum_{i=b,s} A^{i'} - F \tag{9}$$

$$TR = \max\{0, \underline{c}_t - (y^e_t + \sum_{i=b,s} R^i A^i - m^e_t)\}. \tag{10}$$

In this problem, there is again a lower bound to bond holdings which we assume is the same as that for non-participants. The household is not allowed to sell stocks short. The transfer function in (10) is the same as (5) for non-participants, except that the means of living now includes wealth from stock holdings.

The F in budget constraint (9) is the cost of adjusting stock account. It is assumed to be independent of education attainment, age and income. It is possible to include an additional adjustment cost proportional to income as in Bonaparte, Cooper, and Zhu (2012), as well as flow costs of asset market participation, as discussed in Vissing-Jorgensen (2002). For matching the moments that are the focus of this study, this fixed adjustment cost along with the participation cost are sufficient.[8] As we shall see, the cost of adjustment induces exit from stock participation. In addition, these costs are important for the forward-looking household's choice to participate in asset markets.

The adjustment cost should be interpreted as a comprehensive measure of commission, time cost of adjustment and cost of information search. Much of these costs are not directly observable, but are closely related to the observed infrequent adjustment of stock account. By matching the adjustment rates of different education groups, both pre- and post-retirement, we obtain quite precise estimates of the fixed cost. As with the entry, heterogeneous adjustment costs are considered in section 5.

A household that participates in asset markets but chooses not to adjust its stock portfolio is able to freely adjust its bond portfolio. The value of no-adjustment is given by:

$$v^n_{e,t}(\Omega) = \max_{A^{b\prime} \geq \underline{A}^b} u(c) + \beta E_{y^e_{t+1}, m^e_{t+1}, R^{s\prime}|y^e_t, m^e_t, R^s} \left\{ \nu^e_{t+1} v_{e,t+1}(\Omega') + (1-\nu^e_{t+1}) B(R^b A^{b'} + R^{s'} A^{s'}) \right\}$$

s.t

$$c = y^e_t + TR - m^e_t + R^b A^b - A^{b\prime} \quad (11)$$

$$A^{s\prime} = R^s A^s \quad (12)$$

$$TR = \max\{0, \underline{c}_t - (y^e_t + \textstyle\sum_{i=b,s} R^i A^i - m^e_t)\} \quad (13)$$

where $A^{s\prime} = R^s A^s$ since the return on stocks is (costlessly) reinvested into the stock account.

Finally, a household may choose to exit the stock market. This choice is particularly pertinent for agents late in life. The value of exit is given by:

$$v^x_{e,t}(\Omega) = \max_{A^{b\prime} \geq \underline{A}^b} u(c) + \beta E_{y^e_{t+1}, m^e_{t+1}|y^e_t, m^e_t} \left\{ \nu^e_{t+1} w_{e,t+1}(\Omega') + (1-\nu^e_{t+1}) B(R^b A^{b'}) \right\} \quad (14)$$

s.t.

$$c = y^e_t + TR - m^e_t + \textstyle\sum_{i=b,s} R^i A^i - A^{b\prime} \quad (15)$$

$$TR = \max\{0, \underline{c}_t - (y^e_t + \textstyle\sum_{i=b,s} R^i A^i - m^e_t)\}. \quad (16)$$

This dynamic discrete choice problem allows us to capture the pertinent choices of market participation and portfolio adjustment. One of the interesting tensions, explored in Bonaparte, Cooper, and Zhu (2012), in the household's problem is how to respond to income shocks. For small fluctuations in income, adjustment in the bond account will be adequate for consumption smoothing. For large fluctuations in income, the household will need to adjust its stock and bond holdings jointly, thus incurring that adjustment cost. The riskiness of income influences the portfolio choice: all else the same, a riskier income process implies a more liquid (a lower stock to bond ratio) portfolio.

[8] See Gomes and Michaelides (2005) and Alan (2006), among others, for models with participation costs alone.

There is also a richness in the participation decision. By participating in stock markets, household can take advantage of a higher average return. But that higher return comes at two costs: stocks are riskier and are more expensive to trade.

Differences between pre- and post-retirement come into play in a couple of ways. First, entry into asset markets is a type of investment and thus the gains to participation will depend on the horizon of the household, along with the discount factor. Second, the income process changes over the life cycle.

Finally, there is the exit decision from asset markets. Since retirement income is lower on average than that during working life, participation ought to fall during retirement. Further, due to the presence of large medical expenditure shocks during retirement (modeled as large income shocks), a household may be induced to liquidate stock holdings in low income states and then exit from asset markets.

3.2 Preferences

Three types of preferences are considered. Estimating preference parameters beyond the traditional CRRA specification is one of the contributions of this paper.

The first is the commonly used CRRA preference (power utility), with

$$u(c) = \frac{\gamma}{1-\gamma} c^{1-\gamma}. \tag{17}$$

The second one is CARA preference (exponential utility), with

$$u(c) = -e^{-\gamma c}. \tag{18}$$

As is well understood from Merton (1971) and the related literature, these two preference structures impose certain properties on portfolio shares when markets are complete. Under CRRA the portfolio share of the risky asset is constant. Under CARA, the amount invested in the risky asset is constant so that its share is lower in larger portfolios. Neither of restrictions imposed by these two extremes fit the data well though both are used for convenience in theoretical and some empirical exercises. Further, we have incomplete markets: household's bear some risk due to idiosyncratic shocks.

Finally, the EZW representation of preferences, taken from Epstein and Zin (1989) and Weil (1990), is give by

$$V_{e,t} = \left\{ (1-\beta)c^{1-1/\theta} + \beta \left[\nu^e_{t+1} [E_t V^{1-\gamma}_{e,t+1}]^{\frac{1-1/\theta}{1-\gamma}} + (1-\nu^e_{t+1}) E_t [B(R^b A^{b'} + R^{s'} A^{s'})^{1-\gamma}]^{\frac{1-1/\theta}{1-\gamma}} \right] \right\}^{\frac{1-\gamma}{1-1/\theta}}, \tag{19}$$

where $V_{e,t}$ is a state-dependent value of the optimization problem. For stock market participants, $V_{e,t} = v_{e,t}(\Omega)$, while for non-participants, $V_{e,t} = w_{e,t}(\Omega)$. This is a generalization of the CRRA structure. It allows more flexibility by distinguishing risk aversion (γ) from the elasticity of intertemporal substitution (θ). Bhamra and Uppal (2006) discuss the portfolio implications of this preference structure. Among other things, they point out that in the face of stochastic returns, the portfolio choice depends jointly on the elasticity of substitution and the degree of risk aversion, i.e. the parameters (θ, γ). As in Weil (1990), non-interest income is deterministic in their analysis. Relatively few quantitative studies of household portfolio choice, Gomes and Michaelides (2005) being a prime exception, use this specification of preferences in a fully stochastic environment.[9]

3.3 Terminal Value

Denote wealth, and hence the bequest of an agent, at death by Z. The utility flow from a bequest, in the case of CRRA preferences, is:

$$B(Z) = L\frac{(\phi + Z)^{1-\gamma}}{1-\gamma}. \quad (20)$$

The parameters L and ϕ determine the utility flow from bequest. L measures the strength of the bequest motive.[10] Ihe inclusion of ϕ allows bequest to be a luxury goods. When $\phi > 0$, the optimal choice may involve a zero bequest for low income/wealth households. ϕ could also be interpreted as a proxy for the expected income of beneficiaries. Financial choices, such as asset allocation, are responsive to both parameters. For other preference specifications other than the CRRA, the specification in (20) changes accordingly.

3.4 Education Choice

The human capital decision is made prior to the portfolio choices. Suppose that the net cost of education is given by the random variable ψ which is distributed across the population. Differences in the cost of education could reflect heterogeneity in ability, in the socioeconomic status of parents, in school quality, etc. Given a draw of ψ, households will optimally choose the amount of education. Having made this decision, education only matters for household financial choices through the processes for income, mortality and medical expenses. It is precisely these effects of educational choice that we capture through the mapping of education specific processes to household financial choices in our initial estimation.

There could be heterogeneities across households that are not directly observable but underlie their education choices. Some of them would have no effect on household saving and portfolio choice. For example, households may differ in the disutility of time spent studying relative to leisure, as in Keane and Wolpin (2001).

Other factors, such as the discount factor, could explain the education choice. Further, education itself could influence parameters such as participation costs and adjustment costs, which is studied in the literature of financial literacy.[11] Moreover, factors such as cognitive ability which help to determine the education

[9] Gomes and Michaelides (2005) provide simulation results for a variety of parameterizations, illustrating the sensitivity of participation and portfolio shares to risk aversion and the intertemporal elasticity of substitution. Cocco, Gomes, and Maenhout (2005) consider EZW preferences in their simulations and study the sensitivity of portfolio shares to the EIS. In contrast to our paper, there is no estimation in either paper.

[10] This structure also appears in, *inter alia*, Gomes and Michaelides (2005), DeNardi, French, and Jones (2010) and Cagetti (2003).

[11] See, for example, Lusardi (2008)

choice, may also matter for household financial decisions. These possibilities are explored when parameters of preferences and entry/adjustment costs are allowed to vary by education type.[12]

4 Quantitative Analysis

The quantitative analysis of the model revolves around estimating the parameters of the household optimization problem as well as adjustment costs to match key moments from the data. To do so, the various representations in section 3.2 are studied.

The initial set of estimates focuses on the effects of education specific processes that are directly observable in the data. The goal is to understand the relative importance of these observable factors. Section 5.2 broadens the analysis to allow parameter differences as well, which sheds light on to what extent unobservable heterogeneity accounts for differences in household finance.

4.1 Approach

The estimation of income processes, stock return process, out-of-pocket medical expenditure and mortality rate is presented in the Appendix. Preference parameters are estimated by simulated method of moments. The vector of parameters $\Theta \equiv (\beta, \gamma, \Gamma, F, L, \phi, \underline{c}, \kappa, \theta)$, solve the following problem:

$$\pounds = min_{\Theta}(M^s(\Theta) - M^d)W(M^s(\Theta) - M^d)' \quad (21)$$

where W is a weighting matrix, discussed in the Appendix.

In Θ, there are a set of preference parameters: β is the discount factor, γ is the curvature (risk aversion) of the utility function and θ is the elasticity of inter-temporal substitution for the EZW specification. There are two parameters for the bequest function, (L, ϕ). There are two adjustment costs: Γ to participate in the stock market and F, the fixed trading cost. Finally, $\underline{c}$ is the consumption floor pre-retirement and $\kappa\underline{c}$ is the post-retirement floor.

The data moments, M^d, are those reported in Table 3. The simulated moments, $M^s(\Theta)$, are calculated from the simulated data set created by solving the household optimization problem specified in equations (2) to (20) given the parameter vector Θ and a representation of utility. The moments from the simulated data are calculated in the same way as the moments from the actual data.

The initial distribution of assets is important for the moments generated by the solution of the model. For example, a household may never participate in the stock market if it is not a participant initially, but may stay in the stock market until the end of life if it is in the market initially. This is because participation status itself has value due to the entry cost. Hence the mean level of participation, a key moment, will depend on initial conditions.

[12] Bringing together the education choice, say as in Keane and Wolpin (2001), along with the complex financial decisions modeled in this paper would be of interest and could place further restrictions on parameters.

We estimate the initial distribution of households on the product space of stock and bond holdings from the Survey of Consumer Finance.[13] Using this initial condition, we simulate the paths of consumption, stockholding and bond holding for a large number of households to create a simulated panel given a vector of parameters. The moments in (21) are calculated from this panel and the objective function is evaluated for a given value of Θ.

4.2 Results

In the basic model we restrict the households to have the same preferences and asset market costs. The estimation results are reported in Tables 4 and 5. The results for the three leading preference specifications, CRRA, CARA and EZW, are shown in the top rows. The last two rows, labeled EZW(I) and housing, are explained below.

Table 4 shows the parameter estimates as well as the fit. Under each of the parameter estimate is the standard error. As indicated by the last column of the table, the fit of the EZW specification is better than either of the alternatives. Hereafter, the EZW specification is termed the **baseline model**.[14]

Table 4: Basic Estimation Results

	β	γ	Γ	F	L	ϕ	$\underline{c}$	κ	θ	£
CRRA	0.574	7.272	0.024	0.019	6.316	1.490	0.300	0.102		391.33
	(0.003)	(0.042)	(0.0001)	(0.0003)	(2.325)	(0.035)	(0.003)	(0.001)		
CARA	0.584	11.241	0.028	0.015	4.273	0.223	0.138	0.182		107.63
	(0.003)	(0.070)	(0.001)	(0.00005)	(0.196)	(0.007)	(0.390)	(0.967)		
EZW	0.731	12.175	0.014	0.001	3.275	0.487	0.212	0.902	0.968	85.37
	(0.001)	(0.066)	(0.0002)	(0.00002)	(0.103)	(0.013)	(0.004)	(0.143)	(0.014)	
EZW(I)	0.905	3.859	0.019	0.016	1.445	4.211	0.204	0.172	0.988	0.073
	(0.010)	(0.290)	(0.001)	(0.001)	(0.891)	(1.080)	(0.018)	(0.731)	(0.038)	
Housing	0.851	9.359	0.023	0.001	5.915	0.442	0.223	0.483	0.844	69.47
	(0.001)	(0.070)	(0.0007)	(0.00003)	(0.558)	(0.024)	(0.006)	(0.693)	(0.006)	

This table reports the estimated parameter values and fits (distance between model and data moments computed from (21)) for the CRRA, CARA and EZW preferences. The "housing" case is estimated using the moments with housing equity reported in Table 3. The inverse of variances is used as weighting matrix, except in the case of EZW(I) where the identity matrix is used.

Regarding the parameter estimates, for the baseline model, the discount factor is estimated at 0.731, below conventional estimates, and the estimated risk aversion is 12.175. For the EZW specification, θ controls the elasticity of inter temporal substitution and is nearly unity. The estimated γ is much larger than $\frac{1}{\theta}$ so the time separable CRRA model is rejected.

[13] Section 8.2.3 in the Appendix provides some statistics from this initial distribution.

[14] While the difference in the fit between the EZW and CARA specifications is not significant at the 5% level, the EZW specification is treated as the baseline model. For our further results, we discuss robustness to the CARA case in the Appendix.

For comparison, the baseline calibration of Gomes and Michaelides (2005) assumes: $\beta = 0.96, \gamma = 5, \theta = 0.2, \Gamma = 0.025$. Binsbergen, Fernandez-Villaverde, Koijen, and Ramirez (2012) estimate a DSGE model with EZW preference based on the term structure of interest rate. The estimated γ ranges from 41-85 and the EIS ranges from 1.30-2.01, implying even larger risk aversion and inter-temporal substitution. By matching the medians of wealth distribution, Cagetti (2003) estimates a β around 0.98 for college educated while his estimated discount factor is between 0.85 and 0.90 for high school education and below. His estimated risk aversion ranges from 4.3 for high school graduates to 2.4 for those not finishing high school.[15]

The participation cost, Γ, and adjustment cost, F, are both significant. The values reported are fractions of the average pre-retirement income of all households. Thus the entry cost is about 1.4% of average disposable income or about \$700 in 2010 dollar. The adjustment cost is much smaller, only 0.1%, or about \$50. In comparison, Vissing-Jorgensen (2002) finds a per period (rather than one time) participation cost of about \$50 in 2000 price based on a simple framework of certainty equivalent return to a portfolio. Bonaparte, Cooper, and Zhu (2012) use a CRRA preference and estimate fixed trading costs of about \$900 though in that model there is no participation cost.

The estimated parameters for the bequest motive are both significant. This is important as bequests are a relevant factor in the savings decision. In contrast, DeNardi, French, and Jones (2010) report an insignificant bequest motive for their estimated model with CRRA preferences. Our estimate of L is significantly different from zero for the CRRA case as well, though it is not estimated very precisely.

The consumption floor is about 21% of income. Given the estimate of κ, the floor is 10% lower during retirement years. Here these parameters are fractions of overall mean income and thus are the same across education groups. Consequently, the floor is much closer to the mean income of the low education group compared to others.

In simulated data using the estimated parameters, about 10% of households in the low education group hit the consumption floor pre-retirement. In the post-retirement period, almost 50% of these households hit the consumption floor in response to adverse medical shocks. Though the other education groups do not hit the floor pre-retirement, 17% of the second group and 14% of the next to highest group hit the floor during retirement. Even the highest education group is supported through the floor in about 3.5% of the observations.[16]

The CRRA and CARA models have considerably lower discount factors and lower estimates of risk aversion. In comparison, Alan (2006) uses a CRRA representation and estimates parameters to match the coefficients of a reduced form regression of participation on age and lagged participation. She estimates $\beta = 0.92$ and $\gamma = 1.6$.

The CRRA model has larger adjustment costs than the EZW specification and a larger point estimate of bequest motive (though it is imprecisely estimated) . For the CRRA model, the consumption floor is higher

[15] In section 5 we allow heterogeneous preferences/costs and find the most educated households have significantly higher β, but about the same γ compared with the least educated group.

[16] These rates are much lower under CARA preferences.

pre-retirement but lower post-retirement. The CARA model estimates higher risk aversion than the CRRA model and also sizable adjustment costs, compared to EZW. It is noteworthy that the consumption floor is not significant for CARA preferences.

Table 5 presents the data moments and those produced by simulating the models at the estimated parameter values. The EZW specification, as well as the others, succeeds in generating a stock share of around 60%, though the model misses the share of the most educated group during retirement. Given the mean differential in return between safe and risky assets of of 4.3 percentage points, researchers often struggle to match the stock share. In this analysis, the presence of the stock trading costs implies that the liquid asset has more value and thus motivates the holding of bonds.

Participation increases by education group in the data. And, for each education group, the participation rate is higher post-retirement. The EZW model, as well as the other specifications capture this pattern. But the predicted participation rate is much lower than in the data for the CRRA model.

The adjustment rate is also increasing by education in the data but is lower post-retirement for each education group. This pattern is also captured by the models. Here though the CARA representation does not match the data as well as the EZW model.

The median wealth to income ratio rises considerably with both education and retirement status. None of the models do a good job in matching these levels. The CARA model comes closest, particularly for the highest education group. This means that the models are not quite generating as much savings as in the data. Relative to the parameters, this could reflect a relatively low discount factor, as seems to be the case, and/or a low degree of risk aversion so that the precautionary savings motive is attenuated.

As noted earlier, the median wealth to income ratio moments are not as precisely estimated as other moments. Consequently, they are down-weighted in the estimation. It is interesting to see the parameter estimates under an alternative. The row denoted EZW (I) in Tables 4 and 5 present estimates and moments for the EZW case where the weighting matrix, W, in (21) is the identity matrix.[17] This weighting matrix also produces consistent estimates, though it is not as efficient in large samples.

The estimates with this alternative weighting scheme are quite different from the baseline. The estimated $\beta = 0.905$ is much closer to conventional estimates and the risk aversion estimate is much lower than the baseline. The estimated portfolio adjust cost is an order of magnitude larger. A higher adjustment cost is needed to balance the higher discounted gains from adjustment once β is larger.

From Table 5, with the higher discount factor, the model has a much higher median wealth to income ratio and matches the data more closely except for the low education groups, pre-retirement. But, for these parameters, the stock share is much higher than in the data as is the participation rate for low education groups.

The analysis that follows will use the baseline estimates rather than those from the identity matrix. In this way we are closer to matching the portfolio and participation decisions of the household, which are of

[17] With $W = I$ in (21), the EZW model again outperformed the other preference specifications.

Table 5: Moments: Participation, Composition and Adjustment by Education

	Pre-Retirement				Post-Retirement			
School	<12	=12	>12 <=16	>16	<12	=12	>12 <=16	>16
	Stock Share							
Data	0.523	0.539	0.562	0.602	0.451	0.495	0.568	0.599
CRRA	0.599	0.615	0.654	0.712	0.701	0.830	0.787	0.816
CARA	0.693	0.696	0.619	0.587	0.517	0.752	0.662	0.632
EZW	0.466	0.575	0.613	0.644	0.485	0.457	0.542	0.445
EZW(I)	0.860	0.862	0.899	0.922	0.924	0.930	0.913	0.885
Housing(data)	0.261	0.361	0.353	0.425	0.262	0.296	0.418	0.448
Housing(model)	0.275	0.355	0.379	0.407	0.141	0.145	0.148	0.153
	Participation							
Data	0.173	0.322	0.560	0.814	0.221	0.451	0.734	0.851
CRRA	0.295	0.501	0.664	0.710	0.103	0.087	0.328	0.539
CARA	0.154	0.274	0.571	0.777	0.035	0.168	0.456	0.769
EZW	0.150	0.319	0.610	0.693	0.103	0.272	0.570	0.722
EZW(I)	0.346	0.504	0.650	0.751	0.280	0.628	0.794	0.911
Housing(model)	0.162	0.346	0.608	0.759	0.148	0.379	0.716	0.880
	Adjustment Rate							
Data	0.560	0.563	0.615	0.701	0.397	0.417	0.558	0.646
CRRA	0.271	0.218	0.339	0.337	0.213	0.242	0.441	0.544
CARA	0.379	0.444	0.600	0.703	0.273	0.490	0.729	0.827
EZW	0.456	0.536	0.646	0.679	0.333	0.284	0.385	0.418
EZW(I)	0.313	0.308	0.438	0.505	0.596	0.515	0.563	0.547
Housing(model)	0.534	0.496	0.576	0.604	0.782	0.762	0.747	0.753
	Median W-I ratio							
Data	0.077	0.148	0.451	1.787	0.638	1.563	4.292	5.828
CRRA	0.221	0.422	0.571	0.750	0.239	0.059	0.238	0.446
CARA	0.105	0.263	0.717	2.051	0.008	0.207	0.505	2.804
EZW	0.093	0.278	0.387	0.428	0.012	0.229	0.384	0.559
EZW(I)	0.235	0.513	0.929	1.437	0.045	1.713	4.134	5.843
Housing(data)	0.441	0.789	1.503	3.573	4.015	5.204	7.773	8.880
Housing(model)	0.749	0.991	1.251	1.516	2.450	2.886	3.160	3.285

This table reports the averages of participation rates, stock shares and stock adjustment rates and median wealth-income ratios both in the real data and in the simulated data from the CRRA, CARA and EZW models. The inverse of variances is used as weighting matrix, except in the case of EZW(I) where the identity matrix is used. In the rows labeled “Housing”, housing equity is included in the measure of wealth, which affects the calculation of stock share and wealth to income ratio, but not participation rate and adjustment rate.

interest as well as the savings rate.[18]

5 Why Does Education Matter?

The above estimated parameters use education specific moments of financial choices without allowing parameters to differ by education attainment. The model includes differences across the education groups in the labor income process, mortality rates and medical expenses. Given these estimates, we return to a central question of the paper: **what factors determine the different choices made by the disparate education groups?**

The analysis is in part motivated by the results of Campbell (2006) which indicated a role for both realized income and education in household choices. As our analysis allows the processes for income, mortality and medical expenses to differ across education groups, even if two households have the same income realization, then may make different choices if they come from different education groups. In addition, we emphasize it is permanent income, rather than realized income, that matters most for household finance. As this section develops, we introduce differences in parameters as well.

Section 5.1, focuses on the differences in household financial decisions that stem from the driving processes for income, mortality and medical expenses. Section 5.2 introduces differences in preferences and adjustment costs across education groups.

We report two principal findings. **First, the education specific mean level of income is a main source of differences in household financial decisions.** Differences in the shapes of income over working years, mortality rates and medical expenses are far less important. **Second, the analysis uncovers significant differences in parameters as well, largely in the discount factors.**

5.1 Mortality, Income and Medical Expenses

Tables 6 presents simulation results for alternative specification of income and medical expenses. These are simulation results using the baseline parameters for alternative specifications. There is no re-estimation.

Each row of the table has a different treatment of mortality, income and medical expenses across education groups. In the baseline model, all of these processes differ across education groups. The "Same Mortality" treatment forces all education groups to have the same mortality rate. The "Same Medical Exp." treatment forces all education groups to have the same average expense relative to post-retirement income. The "Same Stochastic Inc." treatment assumes that all education groups have the same variances of their income process. The "Same Determ. Inc." treatment forces all education groups to have the same mean income profile.[19]

[18]The estimates from either matrix are consistent. Those using the original weighting matrix is close to the one that produces efficient estimates. But of course, the small sample properties may differ.

[19]The experiment of giving the high education group the initial average wealth of the low education group is partly captured by this experiment as both entail a change in the discounted present value of lifetime income.

Table 6: Household Finance and Exogenous Processes: Baseline Specification

School	Pre-Retirement <12	Pre-Retirement =12	Pre-Retirement >12 <=16	Pre-Retirement >16	Post-Retirement <12	Post-Retirement =12	Post-Retirement >12 <=16	Post-Retirement >16	Fit
	Stock Share								
Baseline	0.466	0.575	0.613	0.644	0.485	0.457	0.542	0.445	85.37
Same Mortality	0.466	0.571	0.599	0.629	0.485	0.412	0.405	0.337	98.69
Same Medical Exp.	0.466	0.575	0.613	0.645	0.485	0.448	0.539	0.472	83.83
Same Stochastic Inc.	0.466	0.558	0.613	0.646	0.485	0.452	0.535	0.448	93.89
Same Determ. Inc.	0.466	0.481	0.433	0.388	0.485	0.514	0.581	0.606	1035.20
Same Timing of Inc.	0.466	0.588	0.623	0.644	0.485	0.457	0.542	0.445	92.37
	Participation								
Baseline	0.150	0.318	0.610	0.693	0.103	0.272	0.570	0.722	
Same Mortality	0.150	0.318	0.612	0.695	0.103	0.283	0.630	0.741	
Same Medical Exp.	0.150	0.319	0.610	0.693	0.103	0.275	0.570	0.723	
Same Stochastic Inc.	0.150	0.317	0.616	0.663	0.103	0.278	0.558	0.704	
Same Determ. Inc.	0.150	0.061	0.127	0.138	0.103	0.034	0.046	0.065	
Same Timing of Inc.	0.150	0.296	0.564	0.661	0.103	0.272	0.568	0.722	
	Adjustment Rate								
Baseline	0.456	0.536	0.647	0.679	0.333	0.284	0.384	0.418	
Same Mortality	0.456	0.539	0.643	0.682	0.333	0.312	0.376	0.512	
Same Medical Exp.	0.456	0.534	0.647	0.678	0.333	0.282	0.378	0.414	
Same Stochastic Inc.	0.456	0.523	0.653	0.669	0.333	0.285	0.391	0.414	
Same Determ. Inc.	0.456	0.336	0.365	0.348	0.333	0.282	0.329	0.355	
Same Timing of Inc.	0.456	0.552	0.659	0.683	0.333	0.284	0.386	0.418	
	Wealth-Income Ratio								
Baseline	0.093	0.280	0.393	0.435	0.012	0.228	0.372	0.546	
Same Mortality	0.093	0.282	0.409	0.456	0.012	0.248	0.614	0.822	
Same Medical Exp.	0.093	0.278	0.387	0.424	0.012	0.233	0.384	0.512	
Same Stochastic Inc.	0.093	0.275	0.383	0.402	0.012	0.235	0.382	0.542	
Same Determ. Inc.	0.093	0.099	0.074	0.172	0.012	0.012	0.000	0.008	
Same Timing of Inc.	0.093	0.276	0.384	0.426	0.012	0.229	0.384	0.559	

This table reports the model moments from counter-factual exogenous processes. "Same Determ. Inc." case imposes the same deterministic income of the least educated group to the remaining three. Other cases are similarly defined. The simulations are based upon the baseline estimates from the EZW preferences. Fit is computed from (21) for the various cases.

Finally, the "Same Timing of Inc." treatment gives all households the same shape of life cycle income profile but allows the means to differ by education.

For each of these treatments, the process for the lowest education group is used as the common element of the process. This choice of using the profile of the lowest education group is simply a normalization to provide a basis of comparison.

As this table makes very clear, the difference in deterministic income is the major factor explaining the diverse financial decisions across education groups. If all education groups shared the same (low education) income profile, the pre-retirement household finance moments are uniformly reduced. While differences across education groups remain, the high education group looks very much like the low education group. For example, the wealth-income ratio, pre-retirement, is still predicted to be larger for high compared to low education households (0.172 vs. 0.093), but this difference is much less than in the baseline. Differences between other groups are also very much muted.

This treatment also impacts post-retirement decisions, in part because the deterministic post-retirement income is lower. In particular, the wealth-income ratio is lower for all education groups (except the lowest by construction) post-retirement.

Requiring all agents to have the same income profile as the low education group has two components: (i) the mean level of income and (ii) the shape of the profile over the life cycle. As is evident from Figure 1, the low education households have both a lower mean income and a profile that is relatively flat. As is clear from the last row of the table, the effect of the shape of income profile on household financial choice is quite small. Hence we conclude that mean income differences by education are key for observed differences in household financial decisions.

Forcing all agents to have the same mortality has a small affect on pre-retirement and a larger impact on post-retirement financial decisions. For a high education household, the increase in the mortality rate (to the level of the low education household) induces a lower stock share and a slightly higher participation rate. It also increases the wealth-income ratio. This is because bequest is a luxury good given our estimates of the bequest function, which causes higher income households to leave much larger bequest.

Overall, we conclude that differences in mean income matter most for observed differences in household financial choices. Formally, this is made clear from the last column of Table 6, which shows how well the model fits the moments under the alternative processes. The fit in the "Same Det Inc." experiment is over 10 times worse than the baseline. This difference is statistically significant.

The influence of mean income comes, in part, from the participation and adjustment costs. Both of these costs, Γ and F, are independent of income.[20] Thus higher income groups face lower costs of participation and adjustment relative to their income and thus financial wealth. Consequently the high average income (high education) groups are more likely to enter the stock market, and adjust portfolios more frequently to buffer income shocks.

[20] To be clear, the estimates of Γ and F are reported as fractions of the average income of the pooled households. but the costs are simply constants in the household problem for all education groups.

The consumption floor comes into play for the low education group much more than the higher education groups. This has an added affect of lowering the wealth to income ratio for the low education group.

5.2 Parameter Differences

The baseline model estimated identical parameters for all education groups. Yet one could argue that the discount factor, adjustment costs and other parameters could differ by education or the factors that influenced that choice.[21] All else the same, more patient people will go to school. And more educated people might face lower adjustment costs. In addition, differences in risk aversion might underlie the differential finance choices across education groups.

Table 7: Results of Estimation with Heterogenous Preferences/Costs

β_1	γ_1	θ_1	Γ_1	F_1	L	ϕ	$\underline{c}$	κ
0.747	13.88	0.659	0.0157	0.0013	0.259	1.592	0.262	0.406
(0.016)	(0.837)	(0.038)	(0.0057)	(0.00013)	(0.056)	(0.262)	(0.027)	(0.320)
β_4	γ_4	θ_4	Γ_4	F_4				
0.849	13.89	0.683	0.0125	0.0017				
(0.012)	(0.535)	(0.133)	(0.0018)	(0.00011)				
$p = 0.00$	$p = 0.537$	$p = 0.432$	$p = 0.293$	$p = 0.058$				

This table reports estimated parameters from the model with two education groups and heterogeneous preferences/costs. In parenthesis are standard errors. In the last row we report p value (one-tail) for the difference between preferences/costs of the two education groups.

To make the analysis more tractable, we look at parameter differences between the lowest and highest groups groups only.[22] The estimates are obtained by SMM using the same set of moments described earlier.

Tables 7 report parameter estimates for the EZW preferences allowing parameters to vary across the two education groups. For this re-estimation, parameters for the low education group is denoted by subscript 1 and high education groups by subscript 4. The estimation focuses on the parameters that are likely to explain differences in household financial decisions between these two extreme education groups. This includes the discount factor (β), risk aversion (γ), the participation cost (Γ), the adjustment cost (F) and the intertemporal elasticity of substitution (θ). In the last column of the table, we repot one-tail p-value for the difference of parameters between the two education groups.

The results in Table 7 are quite clear. There is substantial variation in the estimate of the discount factor across education groups. The point estimate of $\beta_1 = 0.747$ for low education groups is economically and statistically different from the estimate of $\beta_4 = 0.849$ for the high education group. The point estimate of the

[21] Haliassos and Michaelides (2003) assumes heterogeneity in risk aversion and argue that stock market participants may be more risk averse than non-participants. Gomes and Michaelides (2005) and Cagetti (2003) also have heterogeneous groups. Keane and Wolpin (2001) do not allow the discount factor to vary across individuals except for marital status.

[22] The Appendix presents estimated in which a single parameter was allowed to vary across each of the four education groups.

participation cost is slightly higher for the less educated group compared to the more educated group, but the difference is not statistically significant. The estimate of adjustment costs is lower for the less educated group with p-value equal to 0.058. Therefore we have some weak evidence that the less educated households are subject to lower adjustment cost, possibly due to their lower opportunity cost of time.

5.3 Income Differences or Parameter Heterogeneity?

We argued earlier that a main difference across households of different education groups was due to the higher levels of income by the higher education group. Given our estimation of a higher discount factor, and other parameter differences, for high education households, it is natural to ask two questions: (i) whether income differences remain key; (ii) how important the parameter heterogeneity is.

We conduct similar counterfactual experiments as in Section 5.1. Table 8 reports results from imposing the low education group income process to the high education group. The "Full Model" row shows the moments obtained from the estimates reported in Table 7 as well as the value of $\mathcal{L}$ from (21), termed fit in the table.

The first section, "Processes", studies how differences in mortality, medical expenses and income processes impact the household financial choices for the high education group. As in the previous decomposition, the processes for the low education group are imposed on the high education group. Consequently, the moments of the low education group do not change. Consistent with the findings reported in Table 6, replacing the deterministic income of the high education group with that of the low education group has a very large effect on the fit. Other variations hardly matter at all.

For the middle part of the table, one of the parameter estimates for the low education group is used in the high education agent's problem. All other parameters are held fixed. So, in the row labeled "Same β", both education groups use $\beta = 0.747$. The measure of fit is computed from (21) using the simulated moments for the high education group created from this alternative discount factor.

From this exercise, it is clear that the moments are very sensitive to differences in β across the education groups. The fit is considerably worse when the heterogeneity in β is eliminated. The same experiment with other parameters generates small changes in the fit. This is consistent with the reported coefficients and their standard errors in Table 7.

The bottom part of the table is similar but instead of using the low education parameter in the high education group's optimization problem, the roles are reversed. So, in the row labeled "Same β" in the bottom part of the table, both education groups use $\beta = 0.849$. The results do not change: the fit worsens considerably when both groups have the same discount factor. Other parameters differences are not important.

Table 8: Determinants of Household Finance

	Education	Pre-Retirement				Post-Retirement				
		share	part.	adj.	W/I	share	part.	adj.	W/I	Fit
		Imposing Observable Process of Low Education Group to High								
Full Model	high	0.600	0.848	0.691	1.536	0.602	0.885	0.652	1.455	18.84
Same Determ. Inc.	high	0.555	0.393	0.557	0.106	0.773	0.376	0.577	0.285	454.81
Same Mortality	high	0.594	0.850	0.691	1.558	0.509	0.903	0.638	1.798	23.56
Same Medical Exp.	high	0.600	0.848	0.691	1.536	0.602	0.885	0.652	1.455	18.85
Same Stochastic Inc.	high	0.626	0.936	0.733	1.538	0.648	0.929	0.626	1.332	45.21
Same Timing of Inc.	high	0.597	0.855	0.695	1.553	0.563	0.904	0.651	1.670	20.71
		Imposing Parameter of Low Education Group to High								
Full Model	high	0.600	0.848	0.691	1.536	0.602	0.885	0.652	1.455	18.84
Same β	high	0.582	0.758	0.540	0.601	0.936	0.334	0.689	0.082	231.57
Same γ	high	0.600	0.848	0.691	1.536	0.602	0.885	0.652	1.455	18.85
Same θ	high	0.597	0.851	0.695	1.579	0.586	0.896	0.654	1.556	18.98
Same Γ	high	0.599	0.847	0.691	1.536	0.601	0.881	0.653	1.455	18.94
Same F	high	0.605	0.850	0.765	1.531	0.608	0.891	0.713	1.446	18.86
		Imposing Parameter of High Education Group to Low								
Full Model	low	0.496	0.221	0.445	0.054	0.413	0.033	0.274	0.0002	18.84
Same β	low	0.641	0.401	0.659	0.309	0.795	0.364	0.614	0.1422	189.88
Same γ	low	0.501	0.197	0.575	0.076	0.476	0.041	0.303	0.0002	18.91
Same θ	low	0.503	0.191	0.562	0.053	0.477	0.037	0.297	0.0002	20.56
Same Γ	low	0.512	0.230	0.571	0.076	0.474	0.043	0.303	0.0002	20.24
Same F	low	0.489	0.194	0.451	0.077	0.432	0.035	0.285	0.0002	21.71

This table reports the results of counter-factual experiments that show the relative importance of various determinants of household finance. The rows labeled "Full Model" reports simulated moments from the model with full difference in exogenous processes and heterogeneities in parameters. Other rows show results that impose restriction either on exogenous processes or parameter heterogeneities. Fit is computed from (21) for the various cases.

6 Robustness: Housing as Wealth

The results on the role of education and the policy experiments have ignored housing. This section of the paper introduce housing and re-addresses to the key question: why does education matter for household financial choices?

We introduce housing into the model both as a consumption good and as an asset. Returning to the household choice problem, let c represent the consumption flow of the household. As in Cagetti (2003), consumption is a composite of normal goods and services (x) as well as the service flow from housing (h). Assume a Cobb-Douglas function, $c = x^{\alpha} h^{1-\alpha}$, so that a constant fraction of expenditures is on housing services. Following the standard literature, we assume $\alpha = 0.25$.

The return of housing as an asset has two components: price appreciation and (imputed) rental return. Various evidence show that long-run price appreciation is low and rental return is the major component.[23] Since housing rent is relative stable over time, the housing return resembles bonds.

With housing treated as an safe asset, the return to bonds needs to be re-calibrated. First, we take housing return to be 5% per annum. As noted before, the majority of housing return comes from rental income. Campbell, Davis, Gallin, and Martin (2009) show that rent-price ratio for the US residential market is about 0.05 on average, but appears to decline since the end of 1990s. Next, from SCF data, on average housing wealth takes up 69.5% of total wealth. Therefore the return of composite bond-housing asset is $69.5\% \times 5\% + (1 - 69.5\%) \times 2\% = 4.08\%$.

Two sets of moments are re-calculated from SCF data with housing equity included – stock share in total wealth and wealth-income ratio. These new moments are reported in the lower block of Table 3. Not surprisingly, shares are much lower and wealth-income ratios are much higher than without housing.

The bottom rows of Tables 4 and 5 show the parameter estimates and moments for the model with housing, using EZW preferences and these revised moments of stock share and the wealth-income ratio. Comparing these results to the baseline in Table 4, there a number of important differences. The inclusion of housing leads to a larger estimated β and a smaller estimated γ, the degree of risk aversion. The larger estimate of β accommodates the higher wealth to income ratios with housing equity included. The estimated consumption floor post-retirement, κ, is not significantly different from zero and the estimated participation cost, Γ, is larger.

Looking at the simulated data, the fraction of households hitting the consumption floor is much lower once housing is in the model. For the low education post-retirement group, only 12% of the observations are at the consumption floor, compared to the nearly 50% prediction for the model without housing.

Table 9 reports estimates allowing parameters to differ across the high and low education groups. This table is similar to Table 7 except that housing is added. As indicated by the p-values, the only significant difference at 5% level is the discount factors. Again, the high education group is more patient. The p-value

[23]For example, during 1987-2011, the Case-Shiller index at national level increased at an average rate of 0.285% per annum after inflation adjustment.

Table 9: Results of Estimation with Heterogenous Preferences/Costs, With Housing

β_1	γ_1	θ_1	Γ_1	F_1	L	ϕ	$\underline{c}$	κ
0.855	8.868	0.738	0.0262	0.0025	0.191	1.335	0.215	0.561
(0.004)	(0.392)	(0.044)	(0.00514)	(0.00039)	(0.1)	(0.336)	(0.013)	(0.885)
β_4	γ_4	θ_4	Γ_4	F_4				
0.886	9.195	0.711	0.0144	0.0021				
(0.005)	(0.534)	(0.121)	(0.0057)	(0.00028)				
p=0.00	p=0.311	p=0.417	p=0.061	p=0.214				

This table reports estimated parameters from the model with two education groups and heterogeneous preferences/costs. Housing equity is treated as part of riskless assets, which leads to lower stock share and higher wealth to income ratio. In parenthesis are standard errors. In the last row we report p value (one-tail) for the difference between preferences/costs of the two education groups.

for the difference of entry costs is 0.061, therefore entry cost appears to be lower for the more educated group, which reflects either the higher cognitive ability or better financial literacy of this group.

Returning to the question of why education matters, Table 10 reports the same decompositions of differences across education groups. Once again, the main differences across groups comes from differences in the deterministic income levels. There are also differences in fit created by forcing both groups to have the same stochastic discount factor. But these effects are smaller in the model with housing than in the case without housing reported in Table 10. Note that this model does not fit as well as the baseline model with parameter differences.

7 Conclusions

This paper studied household financial decisions for different education groups. Patterns of household finance, including participation in asset markets, portfolio shares, stock adjustment rates and wealth to income ratios, differ across education groups. These patterns are studied jointly in this paper.

Based on this rich set of patterns, we ran an estimation horse race between three common utility functions: constant relative risk aversion, constant absolute risk aversion and recursive utility. The recursive utility representation of household preferences fits the data best.

The main contribution of the paper is to estimate a structural model that maps education-related differences to household finance decisions. This mapping goes through a dynamic choice model in which households face uncertainty in income and returns and make costly decisions regarding savings, asset market participation as well as portfolio adjustment.

Among the observable education-specific factors, the important difference across households is their mean income. Highly educated households have the highest mean income and this translates into a higher rate

Table 10: Determinants of Household Finance: With Housing Wealth

	Education	Pre-Retirement				Post-Retirement				
		share	part.	adj.	W/I	share	part.	adj.	W/I	Fit
		Imposing Observable Process of Low Education Group to High								
Full Model	high	0.453	0.838	0.669	2.111	0.241	0.943	0.784	4.353	38.98
Same Determ. Inc.	high	0.295	0.485	0.673	1.288	0.280	0.644	0.772	2.064	237.61
Same Mortality	high	0.447	0.842	0.670	2.168	0.220	0.978	0.784	4.780	44.80
Same Medical Exp.	high	0.455	0.837	0.668	2.092	0.247	0.943	0.781	4.307	39.66
Same Stochastic Inc.	high	0.495	0.852	0.667	1.866	0.276	0.988	0.725	3.830	47.49
Same Timing of Inc.	high	0.451	0.851	0.676	2.125	0.238	0.976	0.789	4.772	44.22
		Imposing Parameter of Low Education Group to High								
Full Model	high	0.453	0.838	0.669	2.111	0.241	0.943	0.784	4.353	38.98
Same β	high	0.461	0.775	0.577	1.231	0.394	0.815	0.614	1.573	55.40
Same γ	high	0.472	0.838	0.663	2.079	0.253	0.948	0.785	4.329	39.87
Same θ	high	0.455	0.836	0.658	2.054	0.243	0.937	0.777	4.248	40.42
Same Γ	high	0.439	0.814	0.654	2.108	0.238	0.935	0.789	4.354	39.11
Same F	high	0.448	0.836	0.616	2.111	0.239	0.938	0.758	4.359	41.21
		Imposing Parameter of High Education Group to Low								
Full Model	low	0.306	0.168	0.547	0.450	0.394	0.208	0.445	0.102	38.98
Same β	low	0.330	0.302	0.581	0.867	0.253	0.440	0.782	1.815	75.82
Same γ	low	0.270	0.153	0.499	0.466	0.361	0.207	0.477	0.111	40.26
Same θ	low	0.306	0.184	0.545	0.468	0.381	0.226	0.501	0.114	40.30
Same Γ	low	0.343	0.262	0.508	0.467	0.414	0.245	0.431	0.107	46.46
Same F	low	0.308	0.176	0.592	0.452	0.391	0.221	0.508	0.104	40.69

This table reports the results of counter-factual experiments that show the relative importance of various determinants of household finance. The rows labeled "Full Model" reports simulated moments from the model with full difference in exogenous processes and heterogeneities in parameters. Other rows show results that impose restriction either on exogenous processes or parameter heterogeneities. Fit is computed from (21) for the various cases.

of asset market participation, higher stock share in wealth and a higher wealth to income ratio. Other observables, including income uncertainty, mortality and medical expenses, have little power in explaining different household finance patterns across education groups. Among the unobservable heterogeneities, we consistently find that the highest education group discounts the future much less than the lowest education group.

There are a couple of areas for further research based upon our findings. First, while housing is considered as a robustness check, the potential costs associated with adjustments in the stock of housing are not included. This is partly due to tractability problems from having too large of a state space. Adding housing with its own adjustment costs to an optimization problem with costs of stock adjustment would be of considerable interest.

Second, the model focuses only crudely on the life cycle: looking at behavior pre and post-retirement. The model can be used to fit age-dependent moments, thus matching the life cycle profiles of each of the financial decisions by education group. Matching these additional features of the data is left to future work.

Finally, the model is estimated using moments aggregated across households. It would be of interest to complement this exercise using moments created from individual decisions. For example, using data that include household choices of adjustment, participation as well as relevant state variables, one could create moments from estimating an approximate decision rule and then use these moments in a SMM exercise to estimate structural parameters.

8 Appendix

8.1 Exogenous Processes

Income process before retirement We estimate household's income processes from PSID during the period of 1989-2009, corresponding to the time periods from which we construct household finance moments.[24] Compared with most of the relevant studies, we include more recent waves of the survey. Household income is defined as the sum of labor income of both spouse and transfers, adjusted for inflation based on CPI, so that income is in 1998 dollar before being re-scaled.

From PSID, we extract a balanced panel of 1245 households. Households with the following traits are excluded:(i) in low-income (SEO) subsample (ii) with invalid information on age, education, and race of head (iii) younger than 30 or older than 65 in 2009, the last wave of survey (iv) zero income in any year (iv) income growth below 1/20 or over 20 in any year.

To estimate the deterministic income profile and stochastic processes of income, we break the data into four education groups. For each education group, data from various years are pooled together. Then the logarithm of income is regressed on age dummies, year dummies and dummies for race.

The education-specific deterministic income profile comes from the coefficients of age dummies, re-scaled

[24] The survey has been bi-annual since 1997.

so that average income equals education-specific average income. Then we pool the income profiles of the four education groups together, re-scaled the data again, so that the mean income of the four groups equals one. The profiles in Figure 1 are the smoothed versions. We use a Hodrick-Prescott filter with smoothing parameter of 400.

It should be noted that the deterministic income profiles are a mixture of age effect and cohort effect. In the dummy regression, year effect is specifically controlled for. Due to the well-known identification problem among year effect, cohort effect and age effect, we are unable to control for cohort effect once year effect is in the regression.

The residuals from the regression, denoted $y_{i,t}$ are assumed to be income shocks that follows the stochastic process in equation(1) To estimate ρ, σ_{ϵ}^2 and σ_{η}^2, we employ the standard minimum distance method, matching the variance-covariance of $\{y_{i,t}\}$ from the econometrics model with that in the data. For details about moments construction and estimation method, see Guvenen (2009).

Income replacement ratio by education attainment Recent waves of PSID survey (2005, 2007, 2009) provide quite detailed information about the after-retirement income of respondents. We select households whose heads are retirees in 2005, or 2007, or 2009, and calculate their income replacement ratios. Then we average over households in the same education group to obtain the mean values. When selecting retirees, we include all the households with valid information on pre-retirement income, post-retirement income, year of retirement and education attainments of the heads. Households whose calculated income replacement ratio is above 20 are excluded. The total number of observations is 2201.

Take a retiree in 2009 as an example, we first calculate the after-retirement income, denote Y_i^r. Then we trace the labor income of this household before retirement based on the reported year of retirement. Ten observations of pre-retirement labor income are used with the mean denoted Y_i^b. Then the replacement ratio of this i^{th} household is $\frac{Y_i^r}{Y_i^b}$. If one or more of the 10 observations of income is zero, then we excludes them and calculate Y_i^b from the remaining.

Our definitions of Y_i^r is consistent with our model setup. Unlikely the conventional definition, we exclude income from defined contribution accounts (e.g.,IRAs) and other accounts of financial assets. The reason is, we treat such accounts as either stocks or bonds in the model, as well as in the calculations of life cycle patterns from the data. Therefore our definition of post-retirement income is narrower than, for example, Smith (2003). Specifically, our Y_i^r includes (i) non-veteran pension (ii) veteran pension (iii) social security income (iv) supplemental income from social security (v) alimony.

Medical Expenses Information on medical expenses is based on University of Michigan Heath and Retirement Study (HRS). This is a longitudinal panel study that surveys a representative sample of more than 26,000 Americans over the age of 50 every two years. Supported by the National Institute on Aging and the Social Security Administration. Out-of-pocket medical expenditure is defined as the sum of what the household spends on insurance premia, drug costs, and costs for hospital, nursing home care, doctor visits, dental visits, and outpatient care. The waves of survey used in this paper are: 1996, 1998, 2000, 2002, 2004, 2006 and 2008.

We assume the same stochastic process for each education group, and take the persistence and variances of shocks directly from French and Jones (2004). The variance of transitory shocks is large with $\sigma^2_{\epsilon_M} = 0.442$. The variance of the persistent shocks is $\sigma^2_{\eta_M} = 0.0503$ with serial correlation of $\rho_M = 0.922$. Deterministic out-of-pocket medical expenditure differ significantly cross education groups.

For our model we need the ratio of out-of-pocket expenditure over post-retirement income. To estimate the profiles of this ratio, we take the data used in French and Jones (2004). Education attainment information is not available from the online data of French and Jones (2004), so we obtain it from HRS website (`http://hrsonline.isr.umich.edu/`) and merge it with other variables by matching household identities. From the matched data we delete respondents whose ratio is not positive or greater than 10. Totally there are 11866 respondents. For each education group, we regress the ratio on age dummies, and take the coefficients of age dummies as the age profile. The profile is then re-scaled so that the mean ratio equals mean value in the data. Since the data from French and Jones (2004) contain only respondents aged 70 or older, we extrapolate the profile between age 66-69 using spline method.[25]

Mortality Rate Mortality rate of each education group is estimated based on the data and method in DeNardi, French, and Jones (2006).[26]. The data is augmented with education attainment information from HRS via matching household identities. Minimum age in the data is 69. For each education group, we obtain the profile of mortality rate from age 50-68 through extrapolation.

Asset Returns The return process for stocks is taken from Robert Shiller's online data of $S\&P500$ for the period 1947-2007. The return is defined as the sum of annual dividend return and capital gain, deflated by CPI. The estimated mean and standard deviation of annual stock return are 6.33% and 15.5% respectively. The return on bonds is assumed to be non-stochastic and is set at 2% annually.

8.2 Moments

8.2.1 Participation, Stock Share and Wealth-income Ratio

We obtain household level stock market participation, stock share in financial wealth for stockholders and median wealth-income ratio from seven waves of Survey of Consumer Finances: 1989, 1992, 1995, 1998, 2001, 2004 and 2007.[27] From each wave of survey, data with one of the following traits are excluded: (i) not

[25] The profiles in Figure 2 is the smoothed profiles using Hodrick-Prescott filter with smoothing parameter being 400.

[26] We are grateful to Eric French for sharing the data and stata code with us.

[27] We also obtain the two profiles from PSID data introduced below. The resulting profiles have very similar shape as in SCF, but of different scales. For example, the mean stock market participant rate for working households is 47.6% in PSID, but it is 59.2% in SCF. For working households, the mean stock share is 44.2% in PSID, but 70.3% in SCF. The major reason for such differences should come from different sampling strategy. In addition to a standard multistage area-probability design, which leads to a representative sample, SCF selects a second sample based on tax data from the Statistics of Income Division of the

Table 11: Basic Statistics of SCF Data

Survey year	1989	1992	1995	1998	2001	2004	2007
Sample Size	1393	2457	3632	3728	3966	4011	3923
Mean Age	56.6	43.1	49.5	49.5	49.7	50.3	51.0
Mean Participation Rate	0.501	0.496	0.500	0.548	0.564	0.559	0.575
Median W/Y	1.391	0.350	0.337	0.479	0.683	0.555	0.602
Mean Stock Share (Participants)	0.379	0.501	0.543	0.627	0.606	0.578	0.581

having valid information on asset holding, non-asset income, age of head, and education attainment of head; (ii) stock holding being negative; (iii) bond holding being non-positive; (iv) house heads being younger than 25 or older than 85. Table 11 presents the basic information on data from the SCF.

We define stock as the sum of three categories (i) publicly trade stock (including those with brokerage account, employment related stock and foreign stock) (ii) mutual fund and trust or managed investment account that are investment in equity market (iii) IRA and annuity. Part of IRA and annuity may not be invested in equity, but we include them in our definition of stocks because these assets are costly to adjust, which is consistent with our model definition of stock. We define bonds as the sum of assets in two broad categories: (i) checking account, savings account, CDs, bond market account and whole insurance (ii) mutual fund and trust or managed investment account that are investment in bond markets or CDs.

To bring assets in mutual fund and trust or managed investment account into our definition of stock and bond, we follow Gomes and Michaelides (2005). Specifically, based on the answer of respondents to survey question "how is [this money] invested?", if most of the asset is in stocks, then it is included in our definition of stock. If most of the asset is in bonds or money market or CDs, it is included in our definition of bond. If the investment is reported as a combination or mixed or diversified, then half of that asset is included in stock and the other half in bond. For other answer to the survey, we assume the asset is non-financial.[28]

Our definition of stock and bond covers the majority of financial assets held by US households. We define stock market participants as those who own have positive stockholding by our definition. For the participants, we define stock share in financial wealth as $\frac{stock}{stock+bond}$. Both stockholding and bondholding are adjusted to 1998 dollar based on CPI urban series.

To compute median-income ratio, we define income as total family income minus asset income reported in SCF. The following are included as asset income: income from non-taxable investments such as municipal bonds, income from dividends, income from stock, bond and real estate and other interest income.

Internal Revenue Service, which leads to a representative sample of approximately 1,500 high-wealth households. Consequently, SCF has a larger sample of wealthier households.

[28]Other ways of investment include life insurance, fixed contract, annuities, tangible assets other than real estate, intangible assets, business investments and others.

Table 12: Basic Statistics of PSID Data Used to Estimate Adjustment Rates

Survey Year	2001	2003	2005	2007
Sample Size	2496	2541	2473	2518
Mean Age	47.4	47.8	48.5	48.8
Mean Adj. Rate	0.639	0.574	0.577	0.581

8.2.2 Adjustment Rate

We obtain stock adjustment rate of stockholders from four waves of Panel Study of Income Dynamics: 2001, 2003, 2005, 2007. Starting from 1997, PSID survey includes a set of questions regarding households' wealth status and its dynamics since last survey. These questions enable us to estimate adjustment rate for each education group. Stockholders are defined in a similar way as with SCF data. Stock is defined as the sum of "non-IRA stock (variables ER15007 ER19203 ER22568 ER26549 ER37567)" and "IRA/annuity (variables ER15014 ER19210 ER22590 ER26571 ER37589)". Since we are obtaining stock adjustment information for stockholders, households with zero stockholings are dropped from the sample. Low income families (SEO subsample), as well as those with invalid information on stockholding and stock adjustment are also dropped. Finally, in each wave of survey we drop households whose heads are either younger than 20 or older than 80. Basic statistics about the data are presented in Table 12.

PSID asks a set of questions about the changes in stock account. For non-IRA stocks, it asks the following questions:

(i) "[Since January of last survey], did you (or anyone in your family) buy any shares of stock in publicly held corporations, mutual funds, or investment trusts, including any automatic reinvestments–not including any IRAs?"

(ii) "Did you (or anyone in your family) also sell any such assets?"

(iii)"Did you buy more or sell more–that is, on balance, did you put money into stocks, mutual funds, or investment trusts, take money out of them, or put about as much in as you took out?"

For IRA and annuity, the following questions are asked:

(i) "[Since January of last survey], did you (or your family) put aside money in any private annuities or IRAs?"

(ii) "did you (or anyone in your family) cash in any part of a pension, private annuity, or IRA?"

We define household level adjustment as a binary variable. The variable is assigned "1" if a household reported to have bought or sold shares in non-IRA stock, or have put aside money in or cash in private annuities or IRAs. It should be noted that our definition is the"net adjustment", in the sense that it excludes the adjustment of individual stocks within the stock portfolio, whether it is done by the household or mutual fund manager.

8.2.3 Initial Distribution

As noted earlier, the quantitative analysis requires an initial distribution of asset holdings. Table 13 summarizes the initial asset allocation by education group. Both average stock and bond holdings are positively correlated with the level of education attainment. The initial participation rate and stock shares are also higher for the high education group.

Table 13: Initial Asset Allocation By Education

Schooling	Stock (1998 $)	Bond (1998 $)	Stock/Income	Bond/Income	Participation	Stock Share (participants)
	Means					
<12	81.37	1951.39	0.003	0.091	0.032	0.425
=12	776.71	3334.41	0.035	0.160	0.137	0.493
>12 & <16	3941.72	6459.67	0.169	0.301	0.299	0.498
>16	6118.96	8812.79	0.269	0.421	0.399	0.538
	Standard Deviations					
<12	658.42	4966.91	0.025	0.225		
=12	3836.69	8058.36	0.174	0.404		
>12 & <16	13824.92	13099.07	0.581	0.633		
>16	15894.16	12402.11	0.668	0.557		

This table reports the initial holdings of stock and bonds by education group. Within education group means and standard deviations are calculated from the pooled data of seven waves of SCF survey (1989, 1992, 1995, 1998, 2001, 2004, 2007). CPI is used to adjust asset levels to 1998 dollar.

8.2.4 Weighting Matrix

In the basic model, we use the inverse of the variances of the moments as the weighting matrix. This is a diagonal matrix. The usual variance-covariance matrix is not used for two reasons. First, the moments are from two data sets: PSID and SCF, so it is not possible to calculate covariances of moments from different sources. Second, stock shares from SCF are based on a small sample containing only stockholders, while participation rates and wealth-income ratios are based on a larger sample including non-participants. Therefore one can only have covariances of moments for stockholders only, weighting matrix from which may not be more informative than diagonal matrix for our estimation.

8.3 Sensitivity of Moments to Parameters

To illustrate identification, we pick the best fitting model and see how the moments respond to parameter variations. This is shown in Table 14. For example, from the block labeled "β", variations in this parameter

Table 14: Elasticity of Moments with Respect to Parameters

		Pre-Retirement				Post-Retirement			
	School	<12	=12	>12 <=16	>16	<12	=12	>12 <=16	>16
β	share	-0.391	-0.090	3.856	1.638	-3.274	-4.638	-1.294	-7.372
	part.	15.530	3.546	6.236	3.740	23.131	11.216	22.570	3.579
	adj.	2.072	1.985	2.107	0.610	9.741	2.269	-2.692	3.403
	W/I	18.074	5.841	6.863	6.147	96.997	13.492	37.168	14.425
γ	share	-1.747	-1.450	-2.457	-1.051	-0.378	-1.451	-1.625	-1.125
	part.	-3.819	0.109	-0.905	-0.034	-14.43	-1.084	-0.521	0.041
	adj.	0.773	-1.539	-1.274	-0.111	-1.992	1.376	0.650	-0.618
	W/I	0.089	1.220	1.123	0.602	-0.393	0.582	0.076	0.367
Γ	share	-0.099	-0.038	-0.785	-0.060	0.350	0.000	-0.190	-0.003
	part.	-2.660	-0.095	-1.089	-0.161	-7.269	0.000	-0.182	-0.010
	adj.	-0.112	-0.116	-0.455	-0.019	-0.283	-0.001	-0.131	0.009
	W/I	-0.122	0.003	-0.211	-0.001	0.000	0.000	-0.278	0.000
F	share	-0.068	-0.120	-0.435	-0.044	0.014	0.200	-0.185	-0.044
	part.	-0.047	-0.056	-0.019	-0.015	-0.613	-0.168	-0.120	-0.100
	adj.	-0.399	-0.831	-0.958	-0.451	-1.084	-1.084	-0.772	-0.685
	W/I	0.009	-0.025	-0.027	-0.068	-0.846	0.073	-0.155	0.072
L	share	-0.143	-0.056	-0.040	-0.074	-0.160	-0.941	-0.803	-0.623
	part.	-0.008	0.070	0.000	-0.041	-0.246	0.337	0.891	0.133
	adj.	0.045	0.219	-0.008	0.044	-1.401	0.706	-0.386	-0.528
	W/I	0.015	0.027	0.091	0.130	7.234	1.038	1.722	0.988
ϕ	share	-0.007	-0.001	0.066	0.021	0.383	0.853	0.477	0.434
	part.	0.375	0.152	-0.004	-0.007	2.332	0.202	0.038	-0.147
	adj.	-0.020	-0.081	-0.077	0.154	-0.056	-1.629	0.114	0.316
	W/I	-4.142	-0.014	-0.100	-0.083	-39.47	-2.517	-1.350	-0.621
$\underline{c}$	share	0.222	0.004	-0.004	0.000	-0.051	0.016	-0.019	0.009
	part.	-0.592	0.000	0.001	0.000	0.906	-0.014	0.040	-0.003
	adj.	-2.062	0.046	0.037	-0.001	-0.443	-0.170	0.080	-0.212
	W/I	-6.636	-0.001	-0.014	0.000	-21.53	0.001	0.030	0.026
κ	share	0.017	0.004	-0.004	0.000	-0.106	0.016	-0.019	0.009
	part.	-0.001	0.000	0.001	0.000	-0.013	-0.014	0.040	-0.003
	adj.	0.189	0.046	0.037	-0.001	-0.310	-0.170	0.080	-0.212
	W/I	0.009	-0.001	-0.014	0.000	-8.226	0.001	0.030	0.026
θ	share	-0.322	0.245	-0.378	0.107	0.687	-0.873	-0.295	-0.260
	part.	-1.609	-0.084	-0.572	-0.216	0.477	0.469	0.393	0.034
	adj.	0.348	-0.186	-0.622	-0.439	-2.159	2.505	-0.301	0.009
	W/I	-5.730	-0.924	-0.703	-0.726	-10.61	0.514	0.941	0.731

has large effects on the participation and wealth to income ratio moments. Not surprisingly, variations in Γ have the biggest affect on the participation decision. Variations in the adjustment cost have a smaller impact on participation but influence the adjustment rates.

8.4 Parameter Differences: Further Results

Section 5.2 presented estimation results allowing a subset of parameters to vary between low and high education groups. Here we present additional results allowing parameters to vary individually across the four education groups.

As before, the estimates are obtained by SMM using the same set of moments described earlier. The results use the recursive preference representation.

Table 15 and 16 show the estimation results allowing one parameter, indicated at the start of the row, to vary across the education classes. So, for example, the β row of Table 15 shows all the parameters estimated when β is allowed to vary across the education groups. Hence, there are four point estimates reported for β. In this case, the estimate of β is 0.783 for the low education group and 0.810 for the high education group.

Table 16 presents the moments for these exercises as well as measures of fit and F-tests. From Table 4, the fit of the baseline model was 85.37 which is larger than the fit values reported in Table 16. The improved fit is not surprising given that there are additional parameters. The largest improvement comes from allowing the participation cost, Γ to vary across education groups. **Yet, as indicated by the p-values, the improved fit of these models is not significant at conventional levels**.

Table 15: Estimation with Heterogenous Preferences/Costs: One Heterogeneity

Hetero β	β_1	γ	Γ	F	L	ϕ	$\underline{c}$	κ	θ	β_2	β_3	β_4
	0.783	13.683	0.0166	0.00091	2.957	0.904	0.300	0.768	0.989	0.754	0.7746	0.8104
	(0.003)	(0.074)	(0.0008)	(0.00002)	(0.113)	(0.015)	(0.002)	(0.055)	(0.012)	(0.002)	(0.0020)	(0.0017)
Hetero γ	β	γ_1	Γ	F	L	ϕ	$\underline{c}$	κ	θ	γ_2	γ_3	γ_4
	0.732	11.095	0.0138	0.00094	3.312	0.496	0.206	0.920	0.953	11.49	12.47	12.15
	(0.001)	(0.168)	(0.0003)	(0.00002)	(0.081)	(0.011)	(0.002)	(0.159)	(0.009)	(0.071)	(0.073)	(0.090)
Hetero θ	β	γ	Γ	F	L	ϕ	$\underline{c}$	κ	θ_1	θ_2	θ_3	θ_4
	0.736	12.294	0.0155	0.00087	3.265	0.559	0.230	0.678	0.955	0.976	0.8900	0.7803
	(0.001)	(0.070)	(0.0007)	(0.00002)	(0.093)	(0.014)	(0.006)	(0.097)	(0.022)	(0.020)	(0.0140)	(0.0329)
Hetero Γ	β	γ	Γ_1	F	L	ϕ	$\underline{c}$	κ	θ	Γ_2	Γ_3	Γ_4
	0.736	12.289	0.0141	0.00084	3.274	0.545	0.228	0.876	0.968	0.015	0.0176	0.0093
	(0.001)	(0.061)	(0.0009)	(0.00002)	(0.062)	(0.011)	(0.005)	(0.079)	(0.010)	(0.0022)	(0.00051)	(0.00069)
Hetero F	β	γ	Γ	F_1	L	ϕ	$\underline{c}$	κ	θ	F_2	F_3	F_4
	0.731	12.098	0.0147	0.00067	3.366	0.492	0.216	0.939	0.948	0.00094	0.0011	0.00078
	(0.001)	(0.065)	(0.0005)	(0.00003)	(0.118)	(0.010)	(0.003)	(0.134)	(0.010)	(0.00005)	(0.00004)	(0.00004)

This table reports estimated parameters from the model with single heterogeneity in preferences or costs. In parenthesis are standard errors.

Table 16: Moments from Model with Heterogenous Preferences/Costs: One Heterogeneity

	Pre-Retirement				Post-Retirement						
School	<12	=12	>12 ≤16	>16	<12	=12	>12 ≤16	>16	Fit	F-stat	p-value
					Stock Share						
data	0.523	0.539	0.562	0.602	0.451	0.495	0.568	0.599			
Hetero β	0.559	0.628	0.605	0.658	0.551	0.502	0.526	0.447	78.46	1.080	0.43
Hetero γ	0.582	0.536	0.576	0.596	0.535	0.600	0.568	0.336	72.44	1.178	0.36
hetero Γ	0.500	0.577	0.590	0.674	0.497	0.488	0.548	0.456	71.84	1.188	0.35
Hetero F	0.485	0.581	0.613	0.652	0.465	0.463	0.538	0.449	83.45	1.023	0.48
Hetero θ	0.461	0.563	0.610	0.641	0.517	0.475	0.548	0.436	84.10	1.015	0.49
					Participation						
data	0.173	0.322	0.560	0.814	0.221	0.451	0.734	0.851			
Hetero β	0.188	0.327	0.622	0.710	0.157	0.303	0.583	0.727			
Hetero γ	0.131	0.268	0.676	0.804	0.185	0.252	0.717	0.878			
hetero Γ	0.169	0.322	0.572	0.755	0.133	0.303	0.591	0.747			
Hetero F	0.161	0.318	0.606	0.696	0.133	0.279	0.564	0.730			
Hetero θ	0.159	0.324	0.628	0.712	0.115	0.290	0.615	0.731			
					Adjustment Rate						
data	0.560	0.563	0.615	0.701	0.397	0.417	0.558	0.646			
Hetero β	0.489	0.596	0.671	0.709	0.357	0.315	0.406	0.443			
Hetero γ	0.552	0.599	0.685	0.717	0.318	0.321	0.435	0.671			
hetero Γ	0.517	0.631	0.693	0.742	0.391	0.339	0.441	0.494			
Hetero F	0.605	0.580	0.638	0.759	0.457	0.297	0.369	0.501			
Hetero θ	0.509	0.589	0.674	0.704	0.352	0.308	0.407	0.445			
					Median W-I ratio						
data	0.077	0.148	0.451	1.787	0.638	1.563	4.292	5.828			
Hetero β	0.100	0.261	0.406	0.439	0.008	0.221	0.392	0.558			
Hetero γ	0.000	0.237	0.568	0.911	0.000	0.026	0.515	1.720			
hetero Γ	0.051	0.288	0.396	0.451	0.008	0.214	0.379	0.570			
Hetero F	0.088	0.282	0.393	0.436	0.008	0.229	0.382	0.555			
Hetero θ	0.098	0.298	0.417	0.462	0.011	0.205	0.387	0.580			

This table presents the moments from the model with one heterogeneity in preference or costs. Given that the fits follows Chi-square distribution under the null, with degree of freedom being 32-9=23 in the baseline model, and 32-12=20 in the model with heterogeneity, their ratio follows a F-distribution with degree of freedom (20,23). The p-value is defined as the probability $(F(20, 23) > ratio)$.

8.5 Robustness: CARA

The parameter estimates and moments for the CARA model are reported in Tables 4 and 5. Table 17 reports estimates allowing the parameters to differ between the low and high education groups assuming CARA utility. Using these estimates, Table 18 reports the decompositions along the lines of Table 8.

Table 17: Results of Estimation with Heterogenous Preferences/Costs, CARA Utility

β_1	γ_1	Γ_1	F_1	L	ϕ	$\underline{c}$	κ
0.570	12.431	0.0488	0.0110	3.008	0.588	0.186	0.350
(0.016)	(0.795)	(0.0105)	(0.0011)	(1.742)	(0.074)	(0.015)	(1.947)
β_4	γ_4	Γ_4	F_4				
0.612	11.335	0.0131	0.0154				
(0.012)	(0.144)	(0.0049)	(0.0011)				
p=0.02	p=0.09	p=0.01	p=0.02				

This table reports estimated parameters from the CARA model with two education groups and heterogeneous preferences/costs. In parenthesis are standard errors. In the last row we report p value (one-tail) for the difference between preferences/costs of the two education groups.

Clearly the conclusion from the EZW case is robust to CARA preferences. The main differences across household financial decisions comes from the mean income profile and the discount factor. For the CARA case there is also some evidence of differences in other parameters. The high education group, besides being more patient, is less risk averse and faces a lower cost of participating in asset markets. Also, the cost of adjusting is slightly higher for the high education group.

Table 18: Determinants of Household Finance: CARA Utility

	Education	Pre-Retirement				Post-Retirement				
		share	part.	adj.	W/I	share	part.	adj.	W/I	Fit
		Imposing Observable Process of Low Education Group to High								
Full Model	high	0.599	0.824	0.683	2.335	0.635	0.781	0.843	3.607	28.04
Same Determ. Inc.	high	0.684	0.255	0.235	0.077	0.766	0.067	0.286	0.008	927.43
Same Mortality	high	0.597	0.824	0.684	2.334	0.632	0.773	0.847	3.558	28.63
Same Medical Exp.	high	0.598	0.823	0.684	2.328	0.625	0.771	0.859	3.524	28.75
Same Stochastic Inc.	high	0.589	0.844	0.681	2.079	0.655	0.718	0.813	2.318	34.49
Same Timing of Inc.	high	0.602	0.836	0.707	2.521	0.641	0.812	0.847	4.795	29.77
		Imposing Parameter of Low Education Group to High								
Full Model	high	0.599	0.824	0.683	2.335	0.635	0.781	0.843	3.607	28.04
Same β	high	0.578	0.810	0.675	2.010	0.632	0.719	0.855	2.522	33.27
Same γ	high	0.591	0.837	0.709	2.701	0.630	0.822	0.851	4.920	33.23
Same Γ	high	0.598	0.771	0.698	2.336	0.637	0.769	0.863	3.774	31.91
Same F	high	0.618	0.829	0.745	2.365	0.643	0.794	0.888	3.794	30.42
		Imposing Parameter of High Education Group to Low								
Full Model	low	0.707	0.172	0.512	0.088	0.508	0.042	0.453	0.0001	28.04
Same β	low	0.723	0.191	0.545	0.149	0.642	0.063	0.621	0.0002	45.97
Same γ	low	0.722	0.139	0.486	0.029	0.457	0.025	0.359	0.0001	36.92
Same Γ	low	0.629	0.336	0.350	0.094	0.761	0.055	0.374	0.0002	78.86
Same F	low	0.677	0.155	0.401	0.087	0.481	0.034	0.357	0.0001	30.85

This table reports the results of counter-factual experiments that show the relative importance of various determinants of household finance. The rows labeled "Full Model" reports simulated moments from the model with full difference in exogenous processes and heterogeneities in parameters. Other rows show results that impose restriction either on exogenous processes or parameter heterogeneities. Fit is computed from (21) for the various cases.

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