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ABSTRACT

Essays on Household Finance

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This thesis comprises three essays addressing theory and evidence on the household response to tax-favored saving incentive schemes, with a particular emphasis on household risk taking. The US tax code and related regulatory institutions offer a variety of incentives to encourage US households to save and participate in risky investment schemes such as defined contribution (DC) accounts and employer-sponsored stock compensation schemes. In exchange for tax incentives, employers and employees are subject to a variety of regulatory restrictions when they participate in the plans affecting the choices available to employees. These incentives and restrictions provide a natural setting to theorize about and study the economic behavior of households.

The first essay summarizes the theory and evidence on the effect of DC retirement accounts on household wealth accumulation and portfolio choices. The emphasis of this chapter is on documenting the empirical successes and failures of standard economic model of lifetime household portfolio choice, in which precautionary savings motives tradeoff against retirement savings motives to produce sharp predictions about DC account choices. The second essay evaluates the welfare loss to an employee participating in a DC plan where the employer provides matching contributions to an employee's DC account using the employer's stock instead of an unrestricted investment in diversified mutual funds. Calibration of the model to plausible lifetime savings and portfolio choices demonstrates that long dated holding requirements should lead employees to privately discount their holding by as much as 70% of its

value. The thirds essay develops a simple analytic framework that provides closed form expressions for the cost of holding undiversified single stock positions over an interval of time. The cost increases with an increase in: risk aversion; holding horizon; the idiosyncratic risk of the stock; and the association between the idiosyncratic risk of the stock and the employee's human capital.

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DEDICATION

I dedicate this thesis to my wife, Samantha, for her love, patience

and encouragement over many years.

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CHAPTER 1: INTRODUCTION

This thesis comprises three essays addressing theory and evidence on the household response to tax-favored saving incentive schemes. The US tax code and related regulatory institutions offer a variety of incentives to encourage US households to save and participate in risky investment schemes such as defined contribution (DC) accounts and employer-sponsored stock compensation schemes. In exchange for tax incentives, employers and employees are subject to a variety of regulatory restrictions when they participate in the plans affecting the available of employees. These incentives and restrictions provide a natural setting to theorize about and study the economic behavior of households.

Chapter 2 summarizes the theory and evidence on the effect of DC retirement accounts on household wealth accumulation and portfolio choices. From an economic perspective, noteworthy features of DC accounts are the voluntary nature of participation, that investment risk is borne by the participant and that owning an account necessitates a trade-off between favorable taxation treatment and account illiquidity. Employer-sponsored accounts are particularly interesting due to the additional incentive for participants to contribute due to employer matching, non-discrimination rules and restrictions on contributions, withdrawals and investments. Variation in features across plans allows researchers to estimate the effect of plan features on household behavior.

The theoretical foundation for studying household decisions in the presence of DC accounts is the classic precautionary life-cycle models of household saving behavior (in the spirit of Deaton (1991) and Carroll (1992)) extended to include DC accounts and portfolio choices. This model provides a benchmark for understanding observed household behavior and assessing the behavioral response to various provisions of DC accounts. A large literature provides support for the variation in precautionary motives across households as a determinant of household saving (see Browning and Crossley (2000)). Chapter 2 discusses the theoretical and empirical support for the notion that precautionary motives should also affect DC retirement account choices. Households that do not have an adequate buffer stock of liquid wealth are, in theory and in practice, less likely to contribute to their retirement accounts. On the other hand, household choices regarding their DC accounts are sometimes difficult to reconcile with the assumption that agents are forward looking in life-cycle models since many households appear to shun making active saving choices and stick with plan “defaults”. DC plan portfolio choices are subject to unaccountable variation across households and many household fail to hold their most heavily taxed assets inside their retirement accounts and hence, forego a lower tax burden. Moreover, many households appear willing to hold large concentrated positions of their employer’s stock in their retirement account, eschewing the classic finance notion of diversification.

Chapter 3 of the thesis evaluates the welfare loss to an employee participating in a DC plan in which the employer provides matching contributions to each employee’s DC account using the employer’s stock instead of an unrestricted investment in diversified mutual funds. This is a surprisingly common practice among large US corporations. The welfare cost is estimated from a calibrated precautionary life-cycle model that incorporates portfolio choices, retirement accounts and restrictions on sale of stock. In the model, employees are risk averse, so that they would not voluntarily hold an undiversified portfolio if a diversified alternative is available. Calibrating the model to produce plausible levels of lifetime wealth accumulation and portfolio choices produces a large efficiency cost for an employer to match in stock instead of a diversified alternative if there are long dated restrictions on the sale of the stock and other things being equal. For instance, a young employee would willingly accept a matching contribution in a diversified alternative that is only 60% of the typical match in stock if they cannot sell the stock until near retirement. Correlation between job prospects and stock price performance exacerbate the estimated cost, but the effect is modest even under extreme assumptions. Calibration of the model also reveals that matching in stock should mildly deter employees from contributing to their retirement accounts.

Finally, chapter 4 develops a simple analytic framework that provides closed form expressions for the cost of holding undiversified single stock positions over an interval of time. In the framework, an investor with power utility exogenously holds a fraction of his wealth in a single undiversified asset and the remainder of his wealth in human capital, the risk free asset and a diversified asset. With assets that obey geometric Brownian motion and an allowance for jump states to capture unemployment (a shock to human capital) and bankruptcy (a shock to the undiversified asset) closed form expressions for the private value of one dollars worth of the undiversified asset are obtained. The private value decreases with an increase in: risk aversion; holding horizon; the idiosyncratic risk of the stock; and the association between the idiosyncratic risk of the stock and the employee's human capital. The chapter concludes by demonstrating application of the framework to valuing stylized versions of empirically observed stock compensation plans where investors cannot sell their acquired stock until a minimum period has elapsed.

CHAPTER 2: DEFINED CONTRIBUTION ACCOUNTS AND LIFE-CYCLE SAVING

2.1 INTRODUCTION

The past 20 years has witnessed spectacular growth in household ownership of tax-favored defined contribution (DC) retirement savings accounts both in the US and abroad. DC plans include individual plans sponsored by financial institutions, such as Individual Retirement Accounts (IRAs), and employer-sponsored plans. The Investment Company Institute (2003) estimates that the total value of assets held in retirement plans stood at US $10.2 trillion in 2002.[1] The share of DC plans, including IRAs, employer-sponsored DCs and federal government DCs, has grown from 35% in 1990 to about 45% in 2002. Over the same period, the value of defined benefit plan (DB) plans, both government and privately sponsored, has shrunk from 52% to 44% in 2002. (The remaining share is attributable to annuities.) Over 28% of aggregate DC assets are attributable to the DC plans of local, state and federal governments. The share of retirement assets in DC plans is likely to increase as employers continue to switch their employees from DB to DC plans and more employees experience a lifetime of participation in them.

The continuing growth in DC participation and assets will reduce the reliance on traditional forms of retirement income including social security and private DB pensions. However, to the extent that DC assets substitute for other sources of retirement income, there is

[1] The Investment Company Institute defines the retirement market to include IRAs, annuities and employer-sponsored DB and DC plans. The employer-sponsored plans includes both public and private companies as well as government organizations retirement plans.

an increased onus on employees to make adequate saving and investment decisions in these plans. In most DC plans, employees must decide whether to participate, choose a contribution level and make an investment allocation. Individual financial circumstances and the trade-off between saving in taxable accounts, tax preferred DC accounts or other investment vehicles complicate these decisions.

This chapter reviews the theory and US evidence on individual saving and portfolio choice decisions in the presence of DC retirement accounts. In contrast with other reviews of DC accounts (such as Choi, Laibson and Madrian (2004) and Munnel and Sunden (2004)) this chapter explicitly evaluates the evidence against conventional economic models of life-cycle saving. Section 2 describes the life-cycle framework that motivates the remainder of the chapter, addresses the role of retirement saving among other saving motives and describes a canonical model of saving over the life-cycle with DC accounts.

DC plans have many institutional peculiarities that can affect life-cycle saving decisions and can be captured in a life-cycle model (an extensive review of employer-sponsored DC plans is contained in Appendix A). Both IRA and 401(k) accounts allow participants to earn compound rates of return on their balances free from annual taxation. To prevent tax avoidance and discourage pre-retirement use of DC accounts the tax code limits annual contribution limits, and places restrictions and penalties on withdrawals. In employer-sponsored plans, employer often match employee contributions or make additional contributions to participant accounts and allow participants to make loans from accounts.

The effect of these and other features of DC plans are discussed in section 3 and 4 of this chapter. Section 3 explores DC plan participation and contribution rates in light of the broader patterns of household wealth accumulation and DC plan features. Observed behavior is loosely consistent with the predictions of a precautionary life-cycle model, but clearly many household display signs of inattentiveness or ignorance by failing to utilize DC plans even when it would provide a risk free increase in wealth. The evidence on portfolio choices described in section 4 is more challenging. DC accounts have fostered household participation in the equity market but many DC participants fail to utilize the full tax advantages of their accounts by placing heavily taxed assets inside their retirement accounts and hold poorly diversified portfolios that include heavy investments in the stock of their employer.

2.2 LIFE-CYCLE SAVING IN A DEFINED CONTRIBUTION WORLD

2.2.1 The Life-Cycle Framework and Saving

Browning and Lusardi (1996) identify retirement as just one of many motives to save and note that the retirement saving motive complements other motives to save. The most pertinent example of complimentary motives is the use of accumulated wealth to provide consumption in retirement or emergency consumption in unexpected contingencies. This dual purpose of saving means it is not possible to disentangle retirement from other forms of saving and that it is not meaningful to talk about a minimum standard of wealth at retirement since consumption in retirement trades off against consumption at other times. Defined contribution retirement accounts diminish, but do not eliminate, these complementarities by creating strong incentives for participants to contribute to their account and limiting or penalizing the use of contributed funds for any purpose other than retirement.

The conventional approach to studying individual saving decisions is the life-cycle framework. According to Browning and Crossley (2001), the life-cycle framework

> *provides a guide to thinking about the modeling of many life-cycle choices – such as consumption, saving, education, human capital, marriage, fertility and labor supply – while taking account of uncertainty in a rigorous way… In its most general formulation, the life-cycle framework simply asserts that agents make sequential decisions to achieve a coherent (and "stable") goal using currently available information as best they can.* [p. 3]

In their view, this definition rules out agents making choices governed by strict rules of thumb or psychological influences. However, the definition does admit quasi-rational explanations for choices such as mental accounting costs, habit formation and non-expected utility variations of rational decision making under uncertainty. Browning and Crossley argue strongly for adopting the framework to construct models that form the testable hypothesis of empirical work because it admits a rich class of models that are empirically distinguishable and falsifiable.

A common characteristic of all life-cycle models in the framework is the concept of smoothing. Unlike the classic life-cycle model of Modigliani and Brumberg (1954), smoothing does not necessarily require that agents smooth their consumption through time and across uncertain states of the world. Instead, agents make choices that smooth out the marginal utility they gain from consumption of goods, services and leisure subject to constraints imposed by a limited budget, and any incentives, barriers or restrictions caused by institutional or informational frictions. Personal taste, frictions and other limits on choice may dictate a consumption stream that has significant volatility over time.[2] In life-cycle models, purely financial assets serve the purpose of delivering consumption through time and across states of the world, but ownership does not confer direct utility. Venti and Wise (1992) provide arguments that households may obtain non-pecuniary benefits from financial assets if they help to resolve mental accounting, commitment and information problems.

In the context of the life-cycle framework and at the most superficial level, defined contribution retirement accounts are an institutional friction that distorts the saving incentives of individuals. Offering individuals a choice between saving in conventional liquid but taxable form versus saving in illiquid but tax preferred retirement accounts creates a tension between saving for the long and short run. Imrohoroglu, Imrohoroglu and Joines (1998) point out that this tension is trivial without uncertainty and market frictions. Uncertainty about future income or expenditure prevents an agent from precisely planning the allocation of saving across retirement and pre-retirement needs. Market frictions prevent agents from engaging in tax arbitrage by saving exclusively in retirement accounts (to the extent possible) and funding short term consumption needs by borrowing. The precautionary saving model of Deaton (1991) and Carroll

[2] Browning and Crossley (2001) give the example that consumption expenditure is higher in December than any other month in the year for most households, a by-product of holiday institutions and possible complementarities between leisure time and the consumption of goods and services.

(1992) contains both of these elements and is a useful starting point for thinking about the determinants of saving.

2.2.2 Precautionary Saving

In the precautionary saving model, a long-lived agent saves previously earned income in a risk free account to reduce variation in consumption caused by uninsurable exogenous income shocks. The strength of the precautionary model is that utility maximizing behavior can rationalize the empirical observation that lifetime consumption is volatile and tends to track income over time.[3] The interaction of personal preferences, the rate of return on saving and exogenously determined uncertain lifetime income determine an individual's consumption and saving rate at any moment in time. Income uncertainty and the assumed inability to borrow against future income, motivates an agent to accumulate a buffer stock of wealth to smooth consumption during income shocks.[4] If the agent is impatient, she will accumulate the buffer stock slowly, so her consumption tends to track her income fluctuations, at least while she is young. The target buffer stock is not necessarily a stationary dollar amount and can fluctuate with future expectations of the level and variability income.

The empirical content of the precautionary saving model is the relation between saving (and, hence, consumption and wealth), the level of income and income shocks. The savings

[3] Zeldes (1989) provides evidence on the superiority of precautionary saving models over traditional certainty equivalent life-cycle models.

[4] Carroll (2004) provides general conditions under which the precautionary model gives rise to a target level of buffer stock wealth relative to income. When the wealth-income ratio is below the target the agent saves and when the ratio is above the target the agent draws down wealth.

response to income shocks depends on whether the shocks are transitory (for example, unpredictable variation in working hours due to seasonal fluctuations in demand) or permanent (for example, the uncertain component of an annual pay rise). In particular, the model predicts agents will consume a greater percentage of a permanent than transitory income increases. The evidence in support of the precautionary model is mixed. Gourinchas and Parker (2002) show the model does a good job of fitting the life-cycle consumption profiles that they estimate from consumption expenditure and income data for various occupational cohorts. On the other hand, direct evidence of the link between shocks to income and its impact on the level of precautionary wealth held is more tenuous. Carroll, Dynan and Krane (2003) point out the inherent difficulties in assessing labor income uncertainty from survey data since observed income variation was not necessarily a source of uncertainty for the economic actor (they give the example of a college professor who chooses to work in the summertime every second year experiencing predictable income variation). Thus, they focus their attention on uncertainty arising from unemployment as opposed to fluctuations in wage levels. Their results suggest an increase in the probability of unemployment by one percentage point leads to an additional 3 months worth of income in precautionary saving for median income households.[5] In another approach, Lusardi (1998) finds there is a link between self-reported measures of income uncertainty and precautionary wealth. Overall, the evidence suggests there is at least some link between income uncertainty and precautionary wealth, but the effect is not strong and cannot explain the accumulation choices of

[5] For low income households, precautionary saving changes imperceptibly with changes in unemployment probability, Carrol et al (1999) attribute this to social insurance programs that provide little incentive for low income households to save for emergencies.

wealthy households.

The extension of precautionary life-cycle models to obtain predictions about retirement saving during working life is straightforward in the absence of retirement accounts and portfolio choices.[6] In the simplest case, consider an agent who on average experiences the empirically observed hump shaped lifetime income profile: income rises through middle age then levels off or declines gradually with a pronounced drop at retirement. In order to smooth lifetime utility from consumption, an impatient agent will now accumulate wealth for retirement and for precautionary purposes. For a sufficiently impatient agent, Cagetti (2003) shows that the retirement motive becomes increasingly important with age. The agent still has a target buffer stock of wealth relative to permanent income as in the standard precautionary model, but the target now rises with age. Because agents care about life-cycle consumption stream, there is no static target level of retirement wealth. Shocks to income and wealth over an agent's lifetime may dictate that a small or large accumulated retirement wealth is optimal. Precautionary saving motives will also cause wealth at retirement to be unpredictable and depend on the individuals past history of income shocks. More complex life-cycle models may incorporate uncertainty about the timing of retirement and an agent's lifespan, make the retirement choice endogenous and incorporate bequest motives.[7] These considerations may increase or decrease the motive to save for retirement, but do not change the core predictions that the motive to save for retirement

[6] Life-cycle saving decisions post retirement are beyond the scope of this paper.

[7] See, for example, Engen, Gale and Uccello (1999) for a detailed discussion of these issues and their implications for lifetime wealth accumulation and saving.

grows stronger with age or that wealth at retirement varies across otherwise similar individuals depending on their lifetime income experience.

2.2.3 A Canonical Model of Life-Cycle Saving with DC accounts

Sections 3 and 4 of this chapter discuss the extent to which evidence on DC retirement account participation, contributions, portfolio choices and overall wealth accumulation can be rationalized in the life-cycle framework and specific life-cycle models. A canonical model is analyzed by Amromin (2003), Gomes, Michaelides, Polkovnichenko (2004) and Chapter 3 of this thesis. This model extends the model of precautionary saving with exogenous retirement by adding a tax-preferred DC retirement account and risky assets to the choice set of the individual or household.[8]

In the canonical model, income and gains on assets held outside of retirement accounts are taxed periodically providing an incentive to shelter assets inside retirement accounts.[9] As Imrohoroglu et al (1998) point out, borrowing frictions and retirement account illiquidity are necessary model ingredients to prevent saving in the DC account from dominating taxable saving. Retirement account liquidity can take the form of outright restrictions on withdrawals or penalized withdrawal. The precautionary motive to save and the illiquidity of the retirement account typically ensures an individual will rationally accumulate at least a small buffer stock of

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[8] Imrohoroglu et al (1998) and Love (2006) also study precautionary models in the presence of DC accounts but without risky assets.

[9] Matching contributions also provide an incentive to contribute to a retirement account and are included in the model presented in chapter 3 as well as the models of Gomes et al (2004) and Love (2005). The issues are discussed in more detail in section 3 of this chapter.

liquid taxable wealth. Contributing to a retirement account and accumulating a buffer stock of liquid wealth are two elements of a balancing act to smooth out lifetime wealth. Section 3 discusses the evidence on DC account contributions, participation and wealth accumulation in light of this basic model.

Investment risk is a distinguishing characteristic of DC accounts from traditional pension plans. Explicitly incorporating risky assets that households can hold in taxable or tax preferred accounts in the canonical model provides a number of testable implications concerning risk taking, wealth accumulation and tax efficiency of portfolio choice. Risky assets that offer a risk premium give individuals an incentive to exchange a smooth consumption stream for a consumption stream with higher average level but greater volatility. The desirability of risky assets depends on individual risk aversion and the magnitude of uninsurable income shocks. Differential taxation of different asset classes may favor holding highly taxed assets in DC accounts, but precautionary motives can partially offset this, creating a small demand for safe but highly taxed assets. Section 4 contains a more detailed discussion of these predictions and the relevant evidence including the widespread participant investment in the stock of the stock of the sponsoring employer.

2.2.4 Limits to the Empirical Content of the Canonical Model

The canonical model predicts associations between the composition of household wealth, DC account participation, contributions, asset allocation, tax rates and plan specific factors. These predictions form the basis for the empirical exploration in sections 3 and 4. The model also provides a normative framework to analyze the cost of observed empirical departures from optimal allocations. Unlike the broader empirical literature on saving, this chapter does not explore the link between DC accounts and total household consumption or saving. Datasets that have good information about retirement accounts (including the Health and Retirement Survey, the Survey of Consumer Finances and retirement plan administrative records) have much poorer information about consumption and saving. The discussion in this chapter also focuses on the working life predictions of the canonical model rather than post-retirement consumption and saving decisions.

The model abstracts from a variety of real world considerations. It does not incorporate the dynamics household demographics and its impact on short versus long term saving motives. The model includes no other illiquid assets besides retirement vehicles such as real estate, businesses and motor vehicles that require down-payment saving and costly financing. Similarly, transaction costs incurred in trading financial assets also diminish their liquidity but are not included in the model. Emergency expenditures for medical procedures and other uninsured risks are another motive for precautionary saving that are explicitly discussed. Finally, in addition to assuming utility maximization, risk-aversion and impatience there is an implicit assumption that employee's are well informed about their income risks, retirement plans and entitlements, and the risk and rewards of different asset classes.

A final disclaimer is in order before turning to the evidence on DC accounts. In all life-cycle models, a high degree of subjective impatience is necessary to produce the low levels of lifetime wealth accumulation observed in household data.[10] The high degree of impatience also

[10] Laibson, Repetto and Tobacman (2005) and Engen et al (1999) discuss the issues involved in determining an appropriate subjective discount rate, but generally confirm that it must be 3 percent at a minimum to

helps to rationalize the failure of many households to participate in or make large contributions to DC accounts. However, as Bernheim, Skinner and Weinberg (2001) note, accommodating low saving rates in a model by simply assuming a high subjective discount rate does not answer the question of whether households save adequately. This chapter does not address the question of saving adequacy, but rather looks for consistency between DC account decision making and broader wealth accumulation and portfolio choices.

2.3 PARTICIPATION AND CONTRIBUTIONS

2.3.1 The Evolving Defined Contribution System

Tax-favored DC accounts that give participants discretion over contributions and investments have a relatively short history in the US, which limit the inferences that can be drawn from the historical record about long dated saving decisions. Congress enacted Individual Retirement Accounts (IRAs) in 1974 and employer-sponsored 401(k) accounts in 1985. The popularity of IRAs as a savings vehicle has waxed and waned as policymakers have varied contribution limits and eligibility in an attempt to stimulate saving (especially by low-income households) but minimize tax avoidance. 401(k) plans have proved much more popular. More generous contribution limits than IRAs coupled with non-discrimination rules designed to ensure universal employee coverage have lead to enormous growth in participants and assets held. DC plans offer employees greater transparency, control and portability of retirement wealth than

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be consistent with observed household decision making (in models with higher yielding risky assets, it must be significantly higher). Laibson et al conclude that dynamically inconsistent hyperbolic subjective discount rates are better able to capture many features of life-cycle saving.

traditional DB plans, which may in part explain the shift away from the latter.[11] The ability to roll funds from employer-sponsored DC accounts into IRAs and retain tax favored status has also led the growth in employer-sponsored plans to spill over into IRAs.

The impact of DC accounts on total household wealth is difficult to assess. Superficially, the tax advantage of retirement accounts should raise the effective rate of return on household saving and hence, increase the motivation to save at the margin (matching contributions should have a similar effect). However, Engen, Gale and Schulz (1996) have long argued against a significant aggregate impact of tax-favored accounts after accounting for the cost of providing the tax subsidy because those who most benefit from tax-favored accounts exhaust the contribution limit and, hence, it is the after tax rate of return that determines their marginal incentive to save. Venti and Wise (1996) and Hubbard and Skinner (1996), respectively, offer strongly and mildly dissenting arguments based on financial market frictions and sub-optimal behavior (some of this behavioral evidence is addressed in section 3.4). Borrowing constraints, as in the canonical model of DC saving, are one such friction that could lead constrained agents to contribute less than the contribution limit. Engen and Gale (2000) argue that difficulty in controlling for the heterogeneity in the taste for saving can lead to an overstatement of the effects of 401(k) plans on wealth. Correcting for this they report modest increases in new saving for those with access for 401(k) plans, an effect that is concentrated among lower income households.

[11] Also note DB-like pension payments can be replicated in DC plans using Guaranteed Investment Contracts and annuities.

Rather than address the broader question of whether household wealth increased following the introduction of tax-favored DC accounts, this sub-section focuses on the changing composition of household wealth following their introduction and the determinants of participation in and contributions to DC accounts. Some of the empirical work discussed in later chapters of this section use administrative data from which it is not possible to observe the entirety of household wealth and circumstances. Sub-section 2.3.3 provides the bigger picture that is missing from these studies using household wealth data from the Survey of Consumer Finances.

2.3.2 Data Description

The Federal Reserve Board's Survey of Consumer Finances is the definitive source of information on aggregate household wealth in the US. Each survey year the Board interviews approximately 4,000 households with wealthy households over-sampled to improve estimates of aggregate US wealth. All statistics from the SCF reported in the tables of this chapter were computed using the accompanying survey weights, unless noted in the table. The sample is restricted to households: with business ownership less than 10% of their total assets; with non-financial incomes between $10,000 and $400,000 (in real 1989 dollars), where the head of household is aged no more than 70; where neither household head or spouse is retired; and at least one partner is employed. This sub-sample accounts for approximately 50% of the households surveyed. All variables used correspond to the aggregate variables compiled by Aizcorbe, Kennickell and Moore (2003) or to variables constructed from individual survey response variables.

The analysis on changing wealth composition reported in section 2.3.3 uses definitions of household wealth components in both dollar and income relative terms, as well as statistics on ownership of different types of account and demographic factors for 1989 and 2001. Non-financial income as defined in Gomes, Michaelides and Polkovnichenko (2004) is used to scale household wealth levels because in life-cycle models with permanent income shocks, agents target a precautionary buffer stock of wealth relative to income. Income also determines individual tax burdens, and in 401(k) plans, employer imposed contribution limits and matching limits. The definition of total household assets and debt is the same as that used by Aizcorbe, Kennickel and Moore (2003) and notably excludes accumulated DB pension wealth. Retirement wealth is the value of all household DC retirement accounts including employer-sponsored accounts (401(k) and others), IRAs and Keogh accounts presented at their pre-tax reported values. Liquid wealth is the difference between household financial assets (as per Aizcorbe et al) and DC retirement wealth.[12]

2.3.3 Changing Wealth Composition

Table 1 reports the changing composition and distribution of wealth between 1989 (closely following the introduction of 401(k) accounts) and 2001. Gale and Pence (2006) attribute much of the change in household wealth over this period to changing demographics. Aggregate shifts in the number of two partner households and workforce participation are two factors reported in tables 1 and 2. Theoretically, it is difficult to argue the direction of

[12] For the most part, this includes checking accounts, money market accounts and directly owned stocks, bonds and mutual funds. The SAS programming language source code used to construct the sample, variables and the tabulations of statistical results is available from the author.

demographic changes on total household wealth. In the sample represented in the table, average and all percentiles of household wealth increased in real dollar terms, but shrank in income relative terms (due to the more rapid growth in incomes). Wealth became increasingly financial over the period with liquid and retirement wealth rising disproportionately. The increased value of retirement account wealth is attributable to both rising participation and longer average enrollment times in DC plans (see table 2).

Survey Year	1989				2001			
Statistic	Mean	Q1	Median	Q3	Mean	Q1	Median	Q3
Dollar Amounts								
Non-financial Income	39044	20000	30000	49000	56048	25000	44000	73000
Assets	224657	26566	114797	248727	299419	27650	131690	310200
Debt	43856	2753	17894	62766	58825	2800	28000	90000
Net Assets	180802	12113	69373	191190	240593	12000	72600	230200
Liquid Assets	52784	1445	7708	28906	87091	1400	8690	44500
DC Retirement Assets	21753	0	0	13765	50500	0	3200	37600
Employer DC Assets	12236	0	0	1376	25147	0	0	13000
IRA or Keogh Assets	9517	0	0	4129	25353	0	0	5000
Relative to Income								
Assets	5.36	1.11	3.35	6.26	5.19	0.86	2.78	5.25
Liquid Assets	1.15	0.06	0.23	0.78	1.56	0.04	0.19	0.81
DC Retirement Assets	0.68	0.00	0.00	0.46	1.12	0.00	0.09	0.79
Employer DC Plan Assets	0.25	0.00	0.00	0.05	0.31	0.00	0.00	0.23
IRA or Keogh Assets	0.21	0.00	0.00	0.09	0.40	0.00	0.00	0.08
Plan ownership and demographics (% of population)								
Owns DB plan	54				38			
Owns IRA plan	30				32			
Owns employer DC plan	32				44			
Owns any DC plan	50				59			
Spouse	68				64			
One partner not working	56				44			

Table 1: Summary Statistics on Household Wealth Between 1989 and 2001
Computed from the Survey of Consumer Finances (1989, 2001) using survey weights. Sample and variable construction details are described in sub-section 2.3.2. Q1 and Q3 refer to first and third quartiles, respectively, of the corresponding variable.

The median, first quartile and third quartiles reported in table 1 reveal significant cross-sectional disparity in not just aggregate but also components of household wealth. There is a tendency for households that are wealthier or that have higher incomes to have more of all types of assets. However, even accounting for incomes and demographic factors, there is considerable heterogeneity in aggregate, liquid and retirement wealth. Bernheim, Skinner and Weinberg (2001) and Engen, Gale and Uccello (1999) offer, contrasting views on the interpretation of this heterogeneity and whether it is consistent with the predictions of life-cycle model. One thing is very clear from table 1: despite the introduction of DC accounts more than 20 years ago, more than half of the sample carried a negligible balance as recently as 2001. This is more than coincidentally related to the small levels of net worth (less than $100,000) carried by the majority of US households.

Table 2 reports the changing composition of wealth and retirement account ownership statistics partitioned by cohorts based on the age of the household head. That is, the table tracks households as they age. Of course, a more careful cohort analysis would use longitudinal data, but the table is sufficiently suggestive of broad trends. Consistent with simple precautionary life-cycle models, average household incomes grew most rapidly for younger cohorts whereas assets relative to income grew most strongly for older households (suggesting a retirement motive that grows stronger with age). The averages hide considerable heterogeneity and are heavily skewed by the small number of wealthy households (even though the richest were typically filtered by the income and business asset exclusions).

As can be seen in table 2, participation in DC accounts grew for all cohorts, although growth was greatest for younger cohorts. Participation in employer-sponsored accounts significantly diminished for the oldest cohort probably because they became eligible for penalty free distributions during the intervening years. Wealth in DC accounts also grew strongly for each cohort, but so did liquid wealth. Thus, there is only weak evidence of the life-cycle prediction that households should tilt away from liquid wealth toward DC accounts as they age. The large liquid wealth holdings of the oldest cohort may reflect cash outs from retirement plans although it is odd that older households would hold so much wealth outside of retirement accounts given they are eligible for penalty-free distributions.

Head of Household Age	26-35	38-47	36-45	48-57	46-55	58-67
Survey Year	1989	2001	1989	2001	1989	2001
Mean Dollar Values						
Non-Financial Income	34,143	62,664	45,214	67,278	49,064	54,129
Total Assets	115,413	256,123	213,276	395,023	319,121	565,138
Relative to Non-Financial Income						
Total Assets	3.05	3.70	4.28	5.51	6.29	11.58
Liquid Wealth	0.68	0.78	0.60	1.41	1.03	4.01
Retirement Wealth	0.16	0.74	0.43	1.35	1.08	3.33
Employer-sponsored Accounts	0.08	0.40	0.23	0.42	0.55	0.50
IRA/Keogh Accounts	0.04	0.17	0.10	0.47	0.27	1.42
Plan ownership and demographics (% unless noted)						
Owns DB plan	39	35	58	50	67	60
Owns IRA plan	20	30	27	41	41	47
Owns employer DC plan	34	54	41	48	37	26
Owns any DC plan	43	65	56	66	58	59
Avg time in emp plan (yrs)*	4.4	9.9	5.7	13.1	8.8	14.3
Spouse	68	65	68	65	71	68
One partner not working	52	38	46	42	53	71

Table 2: Comparison of Age Based Cohorts of Households Between 1989 and 2001
Computed from the Survey of Consumer Finances (1989, 2001) using survey weights. Sample and variable construction details are described in sub-section 2.3.2.
* conditional on ownership of at least one employer-sponsored DC plan

2.3.4 Participation in 401(k) Plans

The bulk of the empirical literature on retirement saving with DC accounts concentrates on two margins of retirement wealth accumulation: the participation decision and the contribution decision. Researchers usually define participation as actively contributing to a particular DC account at a given point in time (see, for example, Springstead and Wilson (2000) and Munnel, Sunden and Taylor (2000)). The contribution decision refers to the dollar amount (or percentage of compensation) an employee voluntarily contributes to their account at a particular point in time. These two decisions are not strictly separable since deciding not to participate is equivalent to choosing a contribution rate of zero. The distinction does serve a useful purpose, however, since many researchers view participation as first-order in importance. Furthermore, the participation decision is the margin most likely to be affected by investor ignorance.

Many researchers, including Munnell and Sunden (2004), Choi, Laibson, Madrian and Metrick (2002a) and Huberman, Iyengar and Jiang (2003) have documented what they consider to be surprisingly low rates of participation in DC plans and question whether individuals understand the value of participation (particularly, the value of tax incentives and matching contributions) and adequately plan for retirement. On the other hand, the canonical life-cycle model of DC saving, in which participation has no direct cost, predicts individuals will not always participate due to liquidity concerns. Even where participation may be optimal, the benefits may be so small that the welfare loss of deferred participation or complete failure to participate is also small.

Springstead and Wilson (2000) examine the level and determinants of participation rates in 401(k) plans, the Federal Employee's Thrift Saving Plan (very similar to a 401(k) plan) and IRAs. Using data sourced from the Department of Labor, they report participation rates for 1993 of 67%, 79% and 8%. This rate of active participation in IRAs is only just over one-third the rate of household ownership of IRAs (approximately 23% in the 1992 Survey of Consumer Finances) because individuals may not elect to contribute in every year and employees can rollover accumulated DC balances in employer plans into IRAs after job separation. Likely factors in the low participation rate for IRA accounts are the availability of superior employer-sponsored 401(k) accounts and lack of sufficient tax incentives. Employer-sponsored accounts are much more popular in part because employers encourage participation by matching employee contributions, by sometimes automatically enrolling employees and by providing 401(k) plan education seminars.[13] These employer actions are a response to non-discrimination rules of employer-sponsored plans that are designed to ensure lower paid employees participate sufficiently in them. Employer-sponsored accounts may also be simply more visible to employees than IRA accounts.

The recorded rate of participation in DC accounts varies by data source, but has generally increased over time.[14] Focusing on employer-sponsored accounts, statistics from the Current Population Survey suggest a participation rate as low as 57% in 1988, but this increased to 65%

[13] There is little evidence of the relative importance of pecuniary versus other factors in explaining why 401(k) plans are much more popular than IRA plans. Duflo, Gale, Liebman and Orszag (2004) report the results of a field experiment where selected low-income households were offered matching contributions if they participated in an IRA account. For households offered a 50c match, the participation rate was 17 percent, whereas only 3 percent of households participated when they were offered the account without a matching contribution. It is difficult to predict whether participation rates observed in this one-time experiment would be the same in a situation in which IRA accounts contributions were always matched.

[14] It is likely that evidence from survey data overstates the participation rate because non-participant households are likely to fail to report the availability of an account.

by the next survey in 1993. By the late 90s, participation stabilized to around 75-80% and has hovered in that range ever since (based on various sources including Profit Sharing Council of America (1999-2005), Munnel and Sunden (2004)).

Munnel, Sunden and Taylor (2000) report that participation rates rise with income, age, education and job tenure. They find that the most important determinant is the individual's self-reported planning horizon, which could be loosely interpreted as inversely related to a household's subjective discount rate in life-cycle models. Engelhardt and Kumar (2003) jointly study variation in participation and contributions of employees in 401(k) plans, and estimate that participation rates strongly respond to matching contributions (strengthening earlier findings of Choi, Madrian, Laibson, Metrick (2002) and Kusko, Poterba and Wilcox (1994)). Hungerford (1999) finds the availability of plan loans and withdrawals also makes an employee more likely to participate. Each of these factors is consistent with a broadly conceived model of life-cycle DC saving. However, even among well-educated, high-income employees in secure employment, a significant number fail to participate in their accounts. For instance, approximately 10% of households in the top income quartile fail to contribute to their retirement accounts.

Households may opt out of participating in their retirement accounts for many reasons. Not all are inconsistent with life-cycle models of saving. Firstly, households often have access to more than one employer-sponsored account as well as IRA accounts. For example, the rate of non-participation in a household's primary employer-sponsored 401(k) account was approximately 20% in the 2001 Survey of Consumer Finances. However, of that 20%

approximately half of them contributed to another employer-sponsored DC account, had an IRA account or a DB pension.[15] Focusing on non-participation in any one account may understate the utilization of tax-favored accounts. Even with quite strict contribution limits, one account is sufficient to accumulate a significant level of wealth at retirement.

More importantly, retirement accounts are just one of many savings vehicles. Tax benefits and matching contributions of employer-sponsored DC accounts may be attractive, but taxable investments such as money market funds offer a liquidity advantage and durable good investments such as housing offer consumption benefits. Such tradeoffs can be analyzed formally in a life-cycle model. In the canonical DC saving model with taxable liquid investments as the only alternative to DC saving, participation in a DC account is always optimal for an agent sufficiently close to retirement. However, calibration of the model (as described in chapter 3) reveals that the lifetime welfare cost of never participating in a typical employer-sponsored account can be surprisingly small. For low-income workers facing a 15% marginal tax rate and a 75% income replacement rate in retirement the lifetime cost is less than 0.5% of per annum consumption (assuming they otherwise save optimally over their lifetime). For households with high incomes (facing a 35% marginal tax rate and 50% replacement rate) the cost is significantly higher, approximately 4% of annual consumption, although empirically this group is much more likely to participate. Without matching, the cost of failing to participate in a DC plan for even

[15] Munnel et al (2000) report a similar finding, although Huberman, Iyengar and Jiang (2003) report conflicting evidence that after controlling for characteristics of 401(k) plans ownership of a DB plan has no effect on participation rates.

high-income employees is less than 1% of consumption per annum.[16] Imposing vesting conditions on matching contributions also reduces the value of participation and discourages participation by low tenure employees.

In calibrating the canonical model, the agent's degree of subjective impatience is the key factor driving the low lifetime costs of non-participation. A high degree of impatience is necessary to produce the low levels of lifetime wealth accumulation observed in household data, as discussed in section 2.4. An impatient borrowing constrained agent would be willing to give up a great deal of future consumption for more immediate consumption, but observed retirement account incentives do little to offset this impatience. The failure of many households to participate thus appears to be symptomatic of their failure to save more generally.

Focusing on the lifetime cost of failing to participate can be misleading. In the canonical model, the value of participation rises with age. For employees aged over 59½, participation in an employer plan with generous matching contributions should dominate other forms of saving since penalty free withdrawals are available. Choi, Laibson and Madrian (2005) study administrative records for seven 401(k) plans that offered a generous match to employees. Among those employees eligible for penalty free withdrawals, they report a surprisingly low rate of participation of 38%. However, they find the average cost of failing to take advantage of plan matching contributions is only 1.3% of annual salary, or $250. The relatively low level of

[16] This helps to explain the low rates of participation in IRA accounts. Without the matching contribution, employer-sponsored DC plans are almost identical to an IRA account, except for the higher contribution limits of the former.

matching available in some of the plans in the sample appears to drive the low cost.[17] For a subset of employees, however, the costs of sub-optimal participation are larger ($1,200 per annum). Choi et al (2005) report that factors driving non-participation among this subset of employees are financial illiteracy and procrastination, discussed in more detail in section 3.4.

In summary, the evidence on participation rates appears largely consistent with life-cycle models. Lower rates of participation are observed among the young and especially those with lower incomes. This suggests that the failure to participate largely stems from the inability or failure to save at all. Tax and matching incentives do appear to encourage participation in retirement accounts consistent with the life-cycle models. The most problematic observation is the failure of many older employees to take a risk-free increase in compensation by participating in accounts with generous matching and unrestricted withdrawals.

2.3.5 Incentives to Contribute: Taxes and Matching versus Liquidity

In the canonical model, penalties and constraints on withdrawals trade off against the tax and any matching incentives of DC accounts to ensure households have a demand for both DC wealth and taxable liquid assets. The tax advantage of DC accounts largely arises from the right to accumulate compound investment income without periodic taxation (the dollar benefit grows geometrically over time). Deferring income tax on the contributed funds may also be beneficial to an employee expecting to face a lower marginal tax rate in retirement.[18] In most employer-sponsored DC plans, employers match a fraction of employees' contributions up to some

[17] According to the Profit Sharing Council of America (2005), in the average large 401(k) plan, the employer matches approximately 3% of compensation. Given that degree of matching, the 1.3% annual cost that Choi et al find for their sample of employee's exhibiting sub-optimal behavior is surprisingly small.

threshold of compensation. The Profit Sharing Council of America's annual survey for 2002 reported the most common matching contribution is 50 cents per dollar contributed by the employee for each dollar the employee contributes up to 6 percent of compensation.[19] The other side of the trade-off is the restriction on accessing the account prior to retirement. Under current US tax law, the IRS levies a penalty of 10% on withdrawals made by individuals under 59½ on top of regular income taxes.[20] In employer-sponsored DC plans, withdrawals are typically only allowed following separation, death, disability or during demonstrated financial hardship. Plans may also limit the frequency of withdrawals.

Three factors could render the 10% penalty insufficient to prevent DC accounts from dominating taxable savings during an employee's working life (before the age of 59½). First, under progressive income tax rates and with uninsurable income shocks as the primary motive for precautionary saving, the drop in marginal tax rate accompanying an income shock may lower the income tax due on withdrawn retirement funds by more than the penalty amount. But not all shocks lower taxable income. For example, unpredictable medical expenses and other

[18] Conversely, so-called Roth IRA and Roth 401(k) accounts allow employees to pay the income tax on the contributed funds up-front, which may be valuable for those households expecting higher marginal tax rates in retirement.

[19] The survey found that over 90% of plans offered employer contributions, although not all contributions were matching contributions. Many plans offered fixed contributions as a percentage of employee compensation or a combination of fixed and matching contributions.

[20] There are many exceptions to the penalty for IRAs and employer-sponsored accounts. These include death, disability, certain medical expenses, and in the case of IRA accounts, first home purchase and education expenses.

emergency expenses do not lower taxable income or marginal tax rates, yet may necessitate an account withdrawal unless an individual has sufficient access to credit or non-retirement liquid wealth.

Second, the marginal benefit of employer matching contributions may be more than sufficient to offset the penalty, allowing the employee to churn money through his account to take advantage of the match.[21] Many employers discourage such behavior by preventing withdrawals of matched funds until a minimum period has elapsed or ceasing to make matching contributions in the year following a withdrawal. Unvested employer contributions are subject to forfeiture if the participant separates from the employer and cannot be accessed in-service until vested.

Third, instead of taking a penalized withdrawal, most 401(k) participants can take a penalty free loan that they could use to fund unanticipated emergency expenditures (the loan must be repaid with interest, but the interest is credited to the borrower's account). There are some limits on the attractiveness of such loans. Loans are limited to the lower of 50% of the account balance or $50,000. The loan must be repaid in a timely manner (usually 5 years, except for first home purchase) otherwise it is treated as a withdrawal and the 10% penalty is assessed. Separation from the employer also requires automatic repayment to avoid the withdrawal penalty.

[21] For instance, suppose an employee faces a 35% marginal income tax rate and receives a 50c employer match. The employee could contribute $1, immediately withdraw the $1.50 contributed and receive marginal net income of $0.825. The alternative is to forgo the match and receive a lesser $0.65 as after tax income.

Most employer-sponsored DC plans offer loans and allow in-service hardship withdrawals, and many households take advantage of them. The 2002 survey by the Profit-Sharing Council of America revealed that 87% of 401(k) plans allowed hardship withdrawals and 86% of plans offered loans. Holden and VanDerhei (2005) report that 19% of participants in a 401(k) plan administrative database have an outstanding loan (although the outstanding loan balances represent on 2 percent of DC plan assets in aggregate according to the Profit Sharing Council of America). Amromin and Smith (2003) use a panel of individual tax filings to study the determinants of early withdrawals. They estimate that approximately 5 to 6 percent of employer-sponsored DC plan participants make an early withdrawal in any year.[22] Furthermore, the likelihood of withdrawal increases by 3 to 10 percent for individuals that experience job loss, income shocks, divorce or purchase a new home.

Are these loan and withdrawal provisions sufficiently generous to eliminate the need for households to maintain taxable liquid savings for precautionary purposes? In some cases, the answer may be yes, especially when an employee receives generous matching contributions with few restrictions on withdrawal. Otherwise, an employee may find it optimal to maintain a lower DC account contribution rate in order to accumulate a buffer stock of taxable liquid wealth. Obviously, this stock of liquid wealth will become less important as an employee nears the age when penalty-free withdrawals are available. This relationship between the stock of precautionary liquid wealth and contribution rates is a central prediction of the canonical model. No previous empirical work has documented the validity of this prediction.

[22] Amromin and Smith don't cleanly observe withdrawals since the tax filings do not distinguish rollovers, such as from a 401(k) to an IRA, from withdrawals to meet expenses.

In addition to the stock of liquid wealth, the canonical model predicts that many other factors affect the rate that households contribute to their DC accounts including: the availability of plan features such as matching, loans and in-service withdrawals; limits on contributions, be they statutory or plan specific; income factors such as income shocks, future income needs (especially retirement income needs); the availability of other pension assets; marginal tax rates; personal tastes such as tolerance for risk and impatience. Other factors that may be relevant but are beyond the scope of this section are the availability of other illiquid assets (such as housing) and the availability of risky investment alternatives within and outside DC accounts (discussed in section 4). Empirically, previous researchers have found that most of the factors driving participation also determine the level or rate of contributions. The factors with the most theoretically ambiguous impact on contributions are matching contributions and the role of other assets.

VanDerhei and Copeland (2001) conducted a comprehensive analysis of contribution behavior of individual plan participants using a very detailed subset of the EBRI/ICI 401k database.[23] Average contribution rates in the sample are around 7% of salary (supporting previous findings in a study by Clark, Goodfellow, Scheiber and Warwick (2000)) with only a minor difference between males and females. Contribution rates appear to vary markedly with salary, and to a lesser extent with age. Except for the highest income ranges, contribution rates

[23] The sample comprises information on the 401(k) holdings of 160,000 individuals from over 30,000 plans. The EBRI/ICI 401k database has very detailed information on plans, including precise employer matching formulas. It also has a certain amount of demographic information, including gender, age and salary of the individual. Unfortunately, actual wealth holdings of individuals outside of their 401(k) accounts cannot be observed.

tend to increase with salary. Presumably the lower contribution rate of high income workers is due to the statutory dollar limit on contributions. For low income workers, contribution rates appear to increase with age, whereas age seems to be less of a factor in contribution rates for higher income employees (again, this could be due to contribution limits).[24] While this evidence generally supports a simple life-cycle theory, one should note that the demographic and plan characteristics available to VanDerhei and Copeland appear to explain less than 3% of the total variation in contribution rates across individuals.

Another factor in the 401(k) participation and contribution decisions is the availability of the funds before retirement. Employees in their early working years may have very little incentive to tie up their wages in a saving plan that cannot be easily accessed until they retire and consequently will contribute less to their accounts, or delay participation altogether. Holden and VanDerhei (2001) and Munnnell, Sunden and Taylor (2000) estimate that the presence of a loan provision in a plan generates an additional contribution of up to 1% of salary.[25]

In an influential study Kusko, Poterba and Wilcox (1994) examined contribution rates in a large 401(k) plan with two main findings. The first is that contributions tend to cluster at "corners" of the 401(k) contribution opportunity set, such as the limit of the employer match and the statutory limit on 401(k) contributions. This finding has been supported in the comprehensive EBRI/ICI 401(k) database by VanDerhei and Yakoboski (1996) and VanDerhei and Copeland

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[24] These participant characteristics are consistent with evidence found in previous studies. See Munnell, Sunden and Taylor (2000).

[25] The former make their inferences from the EBRI/ICI 401(k) database and the latter use data from the Survey of Consumer Finances.

(2001). While clustering at such kinks in the intertemporal budget constraint is consistent with economic theory, it could also relate to behavioral rules of thumb, such as taking the matching threshold as a psychological cue (this is addressed further in section 3.4).

The second, more controversial finding of Kusko et al (1994) is that both contribution levels and participation rates are relatively insensitive to employer matching contributions. The 401(k) data set used in the Kusko et al study was unique because the employer had changed the matching rate several times in the plan's history enabling them to observe the response of participation and contribution rates to changes in the employer match within the same firm. Previous research indicated a positive relationship between participation and matching but mixed results for contribution levels and matching. However, this research relied on cross-sectional data on plans, from which it is difficult to disentangle firm effects from matching effects.[26] Unfortunately, the Kusko et al dataset comes only from a single firm and thus is hardly generalizable to the population of 401(k) plans.

VanDerhei and Copeland (2001), Choi, Madrian, Laibson and Metrick (2002a) and Engelhardt and Kumar (2003) study the impact of the employer match on individual contribution decisions. The two key aspects of employer matching are the rate at which the employer matches each dollar contributed by the employee and the threshold or range of income over which the match is available. In many previous studies one or both of these variables are imperfectly observed, which could make findings of correlation between matching and contributions

[26] See for example Papke (1995), Papke and Poterba (1995), Engelhardt and Kumar (2003), Huberman, Iyengar and Jiang (2002), Munnell, Sunden and Taylor (2000), Clark and Scheiber (1998), and Even and Macpherson (2003).

spurious.[27] For example, a plan that increases its matching percentage and simultaneously reduces the matching threshold (or vice versa) creates conflicting incentives for participants. Thus increasing the matching percentage may be observed to reduce contribution rates, but only because this was accompanied by a reduction in the matching threshold.

Choi et al (2002a) and Engelhardt and Kumar (2003) analyze the response of participation rates and contributions to the matching rate and threshold changes in terms of income and substitution effects. The income effect of an employer match may reduce the need for a participant to save because the employer is subsidizing their saving, whereas the substitution effect of an employer match lowers the relative price of future consumption and thus increases the incentive to contribute. Whether substitution or income effects dominate depends on where the employees initial contribution levels lie in relation to the original and new threshold.[28] Decomposing the contribution decision in this way, Choi et al (2002a) and Engelhardt and Kumar (2003) find that participation and contributions respond positively to increases in both match rates and thresholds. Choi et al (2002a) emphasize that the response to employer matching contributions is also tenure specific, with new enrollees responding much more to changes in the employer match. VanDerhei and Copeland (2001) adopt a related

[27] Kusko et al (1998), Papke (1995) and Clark and Scheiber (1998)

[28] The finding that participant contribution levels tend to cluster at kinks in the opportunity set such as at the match threshold is particularly relevant to this point. For those clustering at the original match threshold a minute increase in match threshold has a pure substitution effect, so contribution rates should increase. On the other hand for those clustering at the statutory limit for contributions (and above the match threshold) an increase in the match threshold will have pure income effect, tending to reduce contributions.

methodology using Probit analysis on the more comprehensive EBRI/ICI database and confirm these results for contributions. However, the estimates from all three of these studies are potentially biased by the fact that they ignore the participant's portfolio outside of the 401(k) and are furthermore completely silent about whether total household saving (as opposed to the 401(k) contribution component of saving) is increased by the presence of an employer match.

Household access to more than one retirement account may also affect contributions to any particular account. Munnel, Sunden and Taylor (2000) find contribution levels in one plan are weakly negatively related to the size of the balance of other retirement plans.[29] In contrast, Huberman, Iyengar and Jiang (2003) analyzed detailed pension administration data of approximately 800,000 participating and non-participating employees in 647 401(k) plans and found that contribution levels are actually higher at firms that also offer a DB plan. The Huberman et al findings support the notion that employees with access to additional pension assets at their firm are more motivated to save or more informed about the benefits of retirement saving.[30]

Statistical analysis of the Survey of Consumer Finances confirms that most of the factors discussed in this section are jointly and individually significant in determining contribution rates.

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[29] This is supported in earlier studies on participation rates by Andrews (1992), Papke (1995), Bernheim and Garrett (2003) and on contribution levels Cunningham and Engelhardt (2002). Clark and Scheiber (1998) and Clark, Goodfellow, Scheiber and Warwick (2000) report similar findings to Munnell, Sunden and Taylor (2000) using administrative 401(k) plan data.

[30] Ippolito (2000) theorizes that employees with a taste for saving match with firms that offer saving incentives.

Table 3 reports the co-efficient estimates on relevant variables from several regression model specifications relating contribution rates in employer-sponsored DC plans to household and plan characteristics. The sample of households is the same as that reported in sub-section 2.2.1. The dependent variable in each regression, the contribution rate, is the sum of all dollar contributions to employer-sponsored DC plans divided by total household non-financial income. Panel I reports OLS regression results, which are likely affected by truncation bias since a large number of households with access to 401(k) accounts do not contribute (i.e. their contribution rate clusters at zero). Panel II reports Tobit type I regression results from a standard threshold-crossing model of contributions. The Tobit regressions account for the truncation bias and as a result considerably strengthen estimates.[31] Results are also stronger for 2001 survey year than the pooled sample of all survey years or any individual earlier year suggesting a growing awareness of DC plan features. Overall explanatory power of the regressions is modest, but stronger than reported in VanDerhei and Copeland (2001).

Each regression includes dummy variables for whether the plan: has employer matching contributions; allows in-service withdrawals; and allows loans. All of these factors have a statistically and economically significant on contributions rates. Reporting bias may be playing a role in the strength of the plan related coefficient estimates, since those households most familiar with their plans are most likely to both report affirmatively and contribute (see section 3.4 for more discussion of household ignorance). A self-reported categorical variable for risk aversion is strongly statistically significant with the expected sign based on the logic that those who are

[31] The contribution rate is likely to be both left (due to the zero lower bound) and right censored (due to the statutory upper bound) but only left censoring is taken into account

most risk averse will prefer to hold more liquid assets for emergencies. However, the self-reported planning horizon (a proxy for subjective impatience) has little significance after controlling for wealth and income. The length of enrollment in a household's oldest plan also explains little of contribution choices after controlling for the age of the household head.

I: OLS regression coefficient estimates				
	All yrs (1)	All yrs (2)	2001 (1)	2001 (2)
Has half year of income in liquid wealth?	0.0063	-	0.0115	-
Truncated liquid wealth to income	-	0.0047	-	0.0093
Retirement wealth to income	0.0018	0.0017	0.0023	0.0023
Can borrow?	0.0109	0.0110	0.0134	0.0135
Can withdraw in-service?	0.0135	0.0135	0.0150	0.0147
Employer Matches?	0.0247	0.0247	0.0249	0.0253
Time in plan (yrs)	0.0002*	0.0002*	0.0001*	0.0002*
Self-reported planning horizon	0.0015*	0.0014*	0.0010*	0.0009*
Self-reported risk preference	-0.0057	-0.0056	-0.0063	-0.0060
R-squared	**0.2202**	**0.2236**	**0.2369**	**0.2390**
II: Tobit regression coefficient estimates				
	All yrs (1)	All yrs (2)	2001 (1)	2001 (2)
Has half year of income in liquid wealth?	0.0081	-	0.0161	-
Truncated liquid wealth to income	-	0.0060	-	0.0123
Retirement wealth to income	0.0017	0.0016	0.0019*	0.0019*
Can borrow?	0.0226	0.0228	0.0293	0.0296
Can withdraw in-service?	0.0215	0.0215	0.0216	0.0211
Employer Matches?	0.0580	0.0581	0.0564	0.0568
Time in plan (yrs)	0.0006*	0.0006*	0.0005*	0.0005
Self-reported planning horizon	0.0024*	0.0024*	0.0014*	0.0013*
Self-reported risk aversion	-0.0088	-0.0087	-0.0100	-0.0096

Table 3: Determinants of Contribution Rate for Households with Access to 401(k) Plans
The table contains regression coefficient estimates in models with the household DC contribution rate (dollar contributions divided by household non-financial income) as the dependent variable. All regressions include additional controls for household income, total wealth and age. Computed from the Survey of Consumer Finances (1989, 1992, 1995, 1998 and 2001). Columns 2 and 3 contain the regression parameter estimates for the two model specifications of precautionary liquid wealth when the sample is pooled, whereas columns 4 and 5 contain the estimates for 2001 only. Sample and variable construction details are described in sub-section 2.3.2.
* Statistically insignificant at the 5% level

From the perspective of the canonical model of life-cycle saving with DC accounts, the most important addition to the list of empirically important factors is ownership of a minimal balance of liquid wealth.[32] The precautionary saving motive and illiquidity of DC accounts suggests that any household that does not own a stock of liquid wealth should contribute less to their DC accounts in order to build one. Two definitions of this minimal level of precautionary wealth are included in the regressions. The first is a dummy variable on whether the household has at least half a year of income in liquid wealth (reported in the columns labeled (1) in table 3). The second is liquid wealth relative to income truncated right at two times labor income. Both definitions yield strongly significant results with the expected sign. Using the second definition and the Tobit regression estimates for the 2001 sample, other things equal, each year of income held as liquid wealth (up to 2 years of income) increases contribution rates by 1.2 percentage points. It is difficult to argue that minimal liquid wealth simply proxies for a taste for saving because other factors related to a taste for saving, including household income, total wealth, income, retirement account wealth and self-reported planning horizon have already been controlled for. Even more compelling (but not reported in table 3) interacting the dummy for minimal liquid wealth with a dummy for age of the household head, reveals that the minimal liquid wealth is only economically and statistically significant for those households with the head aged under 59 (i.e. those households more likely to face the 10% early withdrawal penalty).

[32] When liquid wealth relative to income is included without adjustment it actually has a negative estimated impact on the rate of DC contributions. This may be because households with large balances of liquid wealth have a particular attachment to those assets for tax or other reasons. This raises the question of whether such assets are truly “liquid”. The canonical model is silent about such issues.

2.3.6 DC Account Anomalies and the Life-Cycle Framework

The most challenging evidence for life-cycle models comes from longitudinal analysis of 401(k) plan administrative data, allowing researchers to observe behavior of individual participants over time. The first academic study to find anomalous behavior in administrative data was the above mentioned Kusko et al (1998). As noted in section 2.3.3, they reported a tendency for participants to set their contribution rate equal to the employer's matching threshold (whenever the threshold was below the statutory dollar limit on contributions). Choi et al (2002a) confirmed this finding in a set of plans that adopted or changed matching policy over several years. They suggest that in addition to offering a direct financial incentive to contribute, the match threshold is a psychological anchor point for participants. Choi et al found this effect was strongest among new plan enrollees implying that the match threshold that prevails at time of enrollment determines contribution rates for many years to come.

Another puzzle relates to the importance of plan enrollment protocols (see Madrian and Shea (2001), Choi, Laibson, Madrian and Metrick (2002b) and Choi, Laibson and Madrian (2004a)). Whether a plan automatically enrolls employees, requires employees to make a decision about enrollment or, by default, does not enroll employees leads to very different wealth accumulation outcomes. In the case of automatic enrollment and non-enrollment, the research consistently finds that employees tend to avoid making active decisions and simply stick with the choice that is made for them by default. When called to make an active decision, employees are more likely to participate than under an automatic non-enrollment protocol. Enrollment protocols also affect contribution rates since plans that offer automatic enrollment will often choose a default rate of contribution. This default is also highly potent as it often takes many years before employees deviate from the default. The research does not address how much of this inaction is caused by employees who are close to indifference between participation and non-participation or its overall welfare cost.

The importance of anchor points and enrollment protocols to employees may be symptomatic of investor ignorance. For example, the benefit of tax-free compounding in DC plans is often poorly understood. Starr-McCluer and Sunden (1999) examined retirement plan knowledge by comparing respondent data on DB and DC pensions in the 1989 Survey of Consumer Finances (SCF) with linked pension provider records. Respondents with DC plans were more likely to correctly identify their plan than DB plan participants, reversing an earlier finding from Mitchell's (1988) examination the 1983 SCF. Growth in DC plans between 1983 and 1989 probably contributed to this result. Starr-McCluer and Sunden found that many DC plan participants failed to recognize the availability of in-service withdrawals (69%), plan loans (36%) or distinguish employer from employee contributions (26%). In contrast, knowledge of DB plan features such as vesting and portability were higher. Given the growth in DC plans, and 401(k) accounts in particular, it is likely the knowledge of DC accounts is now as good as or better than knowledge DB plans. It is an open question as to how much ignorance drives the matching and enrollment protocol observations. Gustman and Steinmeier (2001) conduct a similar study to Starr-McCluer and Sunden using linked data from respondents in the Health and Retirement Survey, Social Security Administration records and a plan sponsor survey.

Puzzlingly, they find little relationship between knowledge of accounts and planned or actual wealth accumulation behavior.

Behavioral theorists, notably Benartzi and Thaler (2001), have proposed various plan designs that take advantage of employees' proclivity to procrastinate on DC account decisions. For example, Benartzi and Thaler have advocated "contribution rate elevators", in which participants' contribution rates are set very low upon enrollment but raised in subsequent years. Automatic protocols of this kind need to take into account factors such as the value of matching contributions, vesting considerations or liquidity concerns of participants. The merits of such benign paternalism are discussed in Thaler and Sunstein (2003).

2.4 PORTFOLIO CHOICE

2.4.1 Investment in Risky Assets and Heterogeneity

As table 1 attests, the rapid growth in DC plans has coincided with growth in the ownership of financial assets more generally. Financial innovation, deregulations and the improvement in administrative support technologies have allowed ordinary households unprecedented access to a broad spectrum of risky investments. Greater access to financial assets facilitates increased risk sharing across sectors of the economy, allows heavier investment in risky but profitable ventures and offers households a greater opportunity to share in aggregate economic growth. Table 4 reports a breakdown of the aggregate value of real and financial asset classes held by US households in 2001 (from the Survey of Consumer Finances). Financial assets comprised of short term interest and non-interest bearing deposits and securities (cash), longer term bonds and stock were just under half the estimated value of household assets.

Although moderate in aggregate share, economists often treat ownership of equities, the largest class of speculative asset, as a barometer of risk sharing in an economy. Table 5 contains a break down of the proportion of households owning equity by investment vehicle from 1989 through 2001, a period of rapid growth in equity ownership. As the table shows, ownership of equities via DC retirement accounts and mutual funds became increasingly important. Poterba (2001) notes that it is difficult to isolate a root cause for the broadening of equity ownership but he cites changes associated with the risk and return of corporate stock, changes in investor risk-aversion and innovation driving down the cost of owning equities. The currents behind the regulatory shift toward favorable treatment of DC plans over DB plans may also be associated with these changes.

Asset Class	*Percent*
Cash	24.4
Bonds	7.6
Stocks	15.8
Subtotal Financial Assets	47.8
Housing	41.3
Other Real Estate	4.8
Private Businesses	4.2
Other	1.9
Total	100.

Table 4: The Composition of Household Wealth by Asset Class
Tabulations are from the 2001 SCF, and based on survey weights. (source: Heaton, Lucas, Curcuru and Moore (2004))

Year	*Directly Owns Mutual Fund*	*Only Owns Equity in DC Plan*	*Only Owns Direct Equity*	*Owns Equity*
1992	8.4	14.9	11.1	36.7
1995	11.3	17.6	10.5	40.4
1998	15.2	20.2	10.4	48.9
2001	16.7	21.2	9.8	51.9

Table 5: How Stocks are Held (% of population)
Tabulations are from the SCF, various years, and based on survey weights. (source: Heaton, Lucas, Curcuru and Moore (2004))

Curcuru, Heaton, Lucas and Moore (2004) review the puzzlingly high degree of heterogeneity in asset ownership across households. Conventional portfolio choice models (including those built upon a life-cycle framework by authors including Cocco, Gomes and Maenhout (2001), Viceira (2001), Campbell and Viceira (2002, Ch 7) and Gomes and Michaelides (2003)) have a great deal of difficulty in rationalizing these choices even when accounting for diversity in preferences and circumstances (including demographics, wealth, incomes and illiquid assets). Curcuru et al note two chief puzzles: the failure of approximately half the US population to hold equities despite the seemingly low direct cost of access and the historically high level of reward relative to risk; and the high frequency of observing households with poorly diversified financial asset holdings. Both of these puzzles go to the very heart of modern thinking about portfolio choices, and hence, the way portfolio choices are incorporated into life-cycle models.[33]

Table 6 reports a breakdown of mean and median asset ownership shares by age and net worth based on the 2001 Survey of Consumer Finances.

[33] Cocco, Gomes and Maenhout (2001), Viceira (2001), Campbell and Viceira (2002, Ch 7) and Gomes and Michaelides (2003) develop finite horizon portfolio choice models with precautionary saving motives. The first two of these use constant relative risk averse (CRRA) utility in a two asset model with uninsurable labor income risk, and focus on the evolution of the optimal portfolio policy as the individual nears retirement age. A hump shaped income profile with a permanent drop in income at retirement leads to a large accumulation of financial wealth and is sufficient to generate a declining equity portfolio share as the agent ages. However, early in life, expected income growth is sufficiently high and retirement is sufficiently distant that the only motive to save is to smooth out income shocks (the buffer stock motive) and the portfolio is allocated exclusively to equities (because income is not sufficiently risky or sufficiently correlated with equity).

Age	*<35*	*35-44*	*45-54*	*55-64*	*65-74*	*75+*
			$10K < Net Worth < $100K			
Stocks	16.2 / 5.8	16.2 / 3.7	11.2 / 0.9	9.2 / 0.0	0.6 / 0.0	1.7 / 0.0
Bonds	7.0 / 0.3	8.3 / 0.6	7.8 / 0.0	5.2 / 0.0	4.2 / 0.0	4.9 / 0.0
Cash	12.9 / 3.2	9.2 / 3.1	9.8 / 3.1	9.6 / 2.0	15.8 / 4.8	29.8 / 9.1
Personal Home	52.4 / 70.9	57.6 / 72.3	64.6 / 81.4	68.6 / 85.1	72.7 / 89.2	60.1 / 85.1
Other Real Estate	3.7 / 0.0	4.5 / 0.0	3.2 / 0.0	3.4 / 0.0	4.5 / 0.0	2.2 / 0.0
Business	2.9 / 0.0	2.4 / 0.0	1.9 / 0.0	2.8 / 0.0	1.2 / 0.0	0.0 / 0.0
Income ($1,000)	51.6 / 50.0	52.4 / 46.0	46.4 / 42.0	32.3 / 29.0	25.6 / 20.0	19.8 / 15.0
			$100K < Net Worth < $1M			
Stocks	19.7 / 12.1	21.2 / 15.9	21.4 / 15.7	21.2 / 15.0	16.8 / 3.1	13.3 / 0.0
Bonds	3.4 / 0.3	6.8 / 1.0	7.1 / 1.8	8.6 / 0.7	7.5 / 0.0	5.5 / 0.0
Cash	7.8 / 3.4	6.2 / 3.2	8.2 / 3.6	8.7 / 3.4	16.5 / 9.1	21.1 / 12.0
Personal Home	50.4 / 51.6	51.1 / 51.6	47.9 / 45.6	48.0 / 44.1	47.7 / 46.5	52.1 / 51.0
Other Real Estate	5.8 / 0.0	5.7 / 0.0	6.5 / 0.0	7.2 / 0.0	6.3 / 0.0	5.8 / 0.0
Business	10.7 / 0.0	7.4 / 0.0	6.8 / 0.0	4.9 / 0.0	3.4 / 0.0	0.7 / 0.0
Income ($1,000)	84.5 / 78.0	93.3 / 77.0	87.2 / 75.0	64.9 / 58.0	47.0 / 37.0	34.3 / 28.0
			Net Worth > $1M			
Stocks	20.4 / 6.1	23.8 / 20.2	29.4 / 23.1	33.9 / 33.4	31.5 / 30.1	37.3 / 37.8
Bonds	9.0 / 0.1	5.0 / 0.5	8.5 / 3.3	12.3 / 4.7	11.4 / 5.9	18.0 / 12.1
Cash	4.2 / 1.3	4.9 / 2.1	5.6 / 2.3	6.1 / 2.4	9.9 / 3.6	7.0 / 3.8
Personal Home	10.6 / 4.3	24.7 / 22.7	22.9 / 19.1	17.7 / 16.1	16.5 / 16.0	20.1 / 17.6
Other Real Estate	6.4 / 0.0	8.3 / 0.7	11.5 / 1.8	12.6 / 2.6	18.2 / 8.7	9.3 / 0.8
Business	41.7 / 28.6	31.9 / 27.3	19.8 / 3.2	14.8 / 0.0	11.2 / 0.0	7.1 / 0.0
Income ($1,000)	317.5 / 130.0	413.6 / 235.0	443.2 / 200.0	365.6 / 168.0	222.5 / 120.0	144.4 / 97.0

Table 6: Shares of Financial Assets by Age and Net Worth (Mean / Median)
Tabulations are from the 2001 SCF, and based on survey weights. (source: Heaton, Lucas, Curcuru and Moore (2004))

2.4.2 Investment Choices in DC plans

Holden and VanDerhei (2003) provide estimates for the year 2002 of aggregate 401(k) asset allocation using the EBRI/ICI 401(k) database.[34] The breakdown of asset allocation across

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[34] Holden and VanDerhei have published annual reports for the Investment Company Institute detailing asset allocation, plan balances and related 401(k) activity for each iteration of the EBRI/ICI 401(k) database since

all plans in their database is 45% to equity funds (including mutual funds and brokerage accounts), 23% to bond and money market funds, 16% to guaranteed investment contracts (GICs) and 16% to stock of the employer. Empirical evidence of the latter is addressed comprehensively in the next subsection. However, there is a great deal of cross-sectional variation in these allocations across both plans and individuals.

The overwhelming majority of employer-sponsored DC plans (and, by default, all IRA plans) allow participants to allocate their balances among a variety of investment alternatives including brokerage accounts, guaranteed investment contracts, stock and bond mutual funds, and curiously, investments in employer securities. Participants in plans that allow investment choice are more likely to participate and make larger contributions than participants in plans that do not (see Papke (2003)). In contrast, Iyengar and Jiang (2003) find that offering too many investment options appears to confuse participants as participation and contribution rates are lower than in plans with fewer options. Benartzi and Thaler (2002) report that many participants would rather leave investment allocation decisions in the hands of a professional manager.[35]

Choi et al (2004) argue that plan design can have a big impact on participant portfolio choices. They note that, on average, in plans with investment choice participants generally choose to invest a greater share of their account balance in equities than a plan that does not offer investment choice would choose on their behalf. For plans with investment choice, inertia is just

1999 (covering data for 1998).

[35] In the 2002 survey of the Profit Sharing Council of America, approximately 10% of plans offered a professionally managed investment option. Life-cycle funds, where balanced portfolios of stocks and bonds are rebalanced by age, are also becoming increasingly common as an investment option.

as relevant to asset allocation as it is to participation and contribution decisions. The default investment allocation (typically a low risk money market fund) of a plan with automatic enrollment will often become the long-term investment of inattentive or procrastination-prone employees. Most plans do not automatically rebalance participant accounts so volatile assets can easily dominate an account of an inattentive participant over time.

2.4.3 Tax efficiency

The composition of portfolios inside and outside of retirement accounts has attracted significant attention in the finance literature. Early work focused on the differential tax treatment of different types of assets.[36] In particular, equities and other speculative assets attract favorable capital gains treatment in comparison with traditional income producing assets.[37] This suggests that an arbitrage opportunity for households is to substitute speculative assets held in retirement accounts for income producing assets held outside. This would lead to a risk free increase in lifetime wealth.

Taken literally, the tax efficiency argument suggests households should not hold heavily taxed assets outside of retirement accounts unless they have exhausted the capacity to hold such assets in tax deferred DC accounts. Empirically, however, households massively deviate from this prediction (see Bergstresser and Poterba (2004)). Amromin (2003a, 2003b) finds that precautionary saving motives can help explain these departures for households with modest holdings of bonds. Amromin (2003a) calibrates a version of the canonical model with risky and

[36] See Black (1980) and Tepper (1981). For more recent developments see Huang (2000), Shoven and Sialm (2001), and Dammon, Spatt and Zhang (2004).

[37] As of 2003, dividend income paid on US equities also receives favorable tax treatment.

risk free assets that have differential taxation and finds that a modest holding of the more heavily taxed risk free asset outside of the retirement account is optimal for a liquidity constrained agent. Amromin (2003b) finds empirical support for precautionary bond holdings. Households that own several multiples of a years income worth of bonds outside of their retirement account and a comparable value of equities inside, especially those on high incomes, give up substantial tax benefits with that choice. Calibrating a life-cycle model to account for such failure could reveal the likely magnitude of those benefits.

There may also be information and transactions cost motives for households to hold equities in retirement accounts. An Investment Company Institute survey found that 48% of households gained their first access to equities via their DC account.

2.4.4 Employer Stock

Mitchell and Utkus (2003) provide a review of the evidence on the extent of employer stock holdings in 401(k) defined contribution plans.[38] Estimates from the 1998 US Department of Labor data suggest that company stock investments comprised roughly 16% of all plan assets.[39] Not all 401(k) plans offer company stock as an investment option, but among plans that do offer company stock estimates from administrative data suggest that approximately 30% of balances are invested in company stock. The number of plans offering company stock as a 401(k) investment option is only 3% of all plans however these are usually large public companies

[38] This evidence is consistent with additional surveys from the Profit Sharing/401(k) council, SEC Forrm 11-K filings and Insitute of Management and Adminstration reviewed in Purcell (2002).

[39] This may not be representative of other time periods, since 1998 was close to the end of a very long bull run of the US stock market.

covering a very large number of employees. Plans offering company stock as a 401(k) option are estimated to cover 42% of all plan participants and 59% of all plan assets. Mitchell and Utkus also report a great deal of diversity in the concentration of employer stock holding across plans. From EBRI/ICI database estimates, approximately 23 million participants were covered by plans offering company stock. Of these, roughly half of the plans held less than 20% of balances in company stock and more than 25% of plans held more than 60% of plan balances in company stock.

The widespread ownership and sheer magnitude of employer stock holdings by 401(k) participants is puzzling. The fundamental lesson of modern portfolio theory is that diversification matters. It is easy to show that a risk-averse agent in a life-cycle model is always better off with a suitably leveraged position in a diversified portfolio of risky assets than with a concentrated position in any single asset. Thus for a life-cycle model to account for large holdings by an individual in a single company stock requires either non-standard behavioral assumptions or some additional incentive or requirement to hold that single stock. Diversification is a fundamental principle of modern financial theory and sits at the core of asset pricing models, capital budgeting techniques and is the basis for ignoring firm specific risk in assessing company cost of capital.

The cost of holding arbitrary positions in employer securities due to unrewarded risk-taking are explored in Meulbroek (2002) and, more extensively using an expected utility based framework, in chapter 4 of this thesis. It is easy to demonstrate that an employee with a large fraction of wealth invested in his employer's stock takes so much unrewarded risk that it is equivalent to giving up 3% per annum of its value with certainty. Firm-specific human capital exacerbates this cost (see chapter 4).

Despite attempts at investor education and the negative publicity following the many corporate collapses at the turn of the century, ownership of employer stock in 401(k) plans persists. In part, this observation is simply part of a broader willingness for households to concentrate investments in single assets even when diversified alternatives are available (see Curcuru et al (2004) for a discussion). However, employer-sponsored plan regulation also plays a role. Diversification is a guiding principle in the fiduciary duty of plan administrators. Retirement plan regulations, however, allow a plan's administrator to escape his duty to diversify by giving participants investment choice with sufficient diversified investment alternatives even if some alternatives are not well-diversified. Employer contributions to DC accounts are also exempt from diversification requirements for employer contributions invested in employer stock. Employer Stock Ownership Plans (ESOPs), a type of retirement vehicle that invests exclusively in employer securities, are commonly used to invest employer contributed balances and provide the benefit of corporate deductibility of dividends.

Chapter 3 estimates the welfare cost of restricted stock matching contributions from a calibrated life-cycle model with 401(k) accounts, a variant of the canonical model with restricted risky assets and employer matching contributions. The risk-averse employee would not voluntarily hold company stock, so it is only with sales restriction that matched stock imposes a cost. Lifetime consumption costs associated with undiversifiable employer stock matching contributions are small for an impatient employee that makes optimal saving and portfolio choice decisions. In contrast, the marginal value for a match in employer stock in comparison with a diversified match is can be very low.

Empirical evidence appears to contradict the idea that employees are averse to bearing idiosyncratic risk (see for example Bernartzi (2001), Purcell (2002), Brown Liang and Weisbenner (2004), Choi, Laibson, Madrian and Metrich (2004) and Huberman and Sengmueller (2004)). The voluntary holdings of employer stock appear to outweigh the restricted employer contributions by a factor of two (see Chapter 3). Employees at firms that match with stock are more likely to voluntarily purchase and hold it when conventional theory would predict they should be attempting to short the stock. Likewise, employees at firms with better past stock price performance are also likely to make new purchases of stock despite the general academic acceptance that past stock price performance lacks predictive content. Ignorance is also likely to play a strong role in employee decision making. Utkus and Waggoner (2003) surveyed a large number of 401(k) participants and found that the majority failed to identify their employers stock as more risky than a diversified equity fund.[40]

Other explanations the presence of company stock in 401(k) plans are less convincing. The incentive aligning arguments used to justify executive stock compensation seem less appropriate for employee stock compensation. The majority of employee ownership is voluntary and there is a very weak connection between the performance of individual employees and a

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[40] Boyle, Uppal and Wang (2003) speculate that employees' willingness to hold their employer's stock instead of a diversified equity fund may be a by product of an aversion to ambiguity. Another possibility is that individual's favor the positive skewness of individual stock holdings that offer virtually unlimited upside versus a limited liability downside .

firm's stock price. Tax arguments such as the deductibility of dividends paid on stock held in ESOP plans may help explain employer matching, but Brown et al (2004) find only weak evidence that this is the case (many firms fail to use ESOP plans for their matching contributions).

2.5 CONCLUSION

As Browning and Crossley (2001) note, the life-cycle framework provides a coherent framework to study lifetime saving decisions. The canonical model of life-cycle saving with DC accounts presented in section 2 helps frame the research on DC accounts. Many features of the data are broadly consistent with the predictions of the model. In particular, precautionary savings motives appear to affect household participation, contribution and asset allocation decisions.

Researchers have found several notable departures from the predictions of the canonical model and forward looking models of household behavior more generally. Many households fail to participate in a DC plan even when it would lead to a risk free increase in household wealth (a welfare loss of approximately 3% of annual income). Plan design parameters, such as the threshold of employer matching contributions and plan enrollment protocols can have long lasting effects on DC account accumulation and asset allocation due to inattentiveness and inertia among many participants. Even wealthy households fail to fully capitalize on the tax advantages of DC accounts by holding heavily taxed assets outside instead of inside their DC accounts. A surprisingly large number of 401(k) plan participants maintain significant holdings of their employer's stock in their 401(k) account, which ultimately leads to significantly more volatile lifetime consumption without a compensating increase in the expected level of lifetime consumption.

The discussion largely skirted around the issues of whether DC accounts increase household saving or had an impact on the adequacy of household saving. To establish the impact of DC accounts on household saving requires a careful evaluation of whether DC accounts alter marginal incentives to save and how much they crowd out other forms of saving (both public and private). The canonical model suggests that the households that are most likely to increase their net saving with access to DC accounts are poorer and younger households (i.e. those more likely to be income constrained). Assessing the adequacy of saving is more difficult because adequacy is subjective. Inconsistencies in decision making, such as participants defaulting into arbitrary DC account contribution rates and asset allocations that have a material impact on lifetime consumption, are at least an indication of inadequate household planning. Whether benign paternalism as endorsed by Thaler and Sunstein (2003) in plan design or increased investor education can improve household welfare remains a topic for further debate.

CHAPTER 3: EVALUATING EMPLOYER STOCK CONTRIBUTIONS IN 401(K) PLANS

3.1 INTRODUCTION

Since the 1980s there has been a marked increase in participation in equity markets by US households. More and more commonly household equity investments are held indirectly inside a defined contribution retirement plan, particularly employer-sponsored plans such as 401(k) plans offered by private employers. A significant portion of retirement plan equity investment is invested in low-cost diversified equity mutual funds, but it is also surprisingly common to see large and persistent direct investment by individual plans in the equity of the sponsoring firm.

As of 2003, as much as $500 billion (or 10 percent) of aggregate defined contribution asset value was directly attributable to the stock of the private employer sponsoring each plan.[1] Focusing on defined contribution plans that actually invest in the sponsor's stock that share increases to a whopping 29 percent of plan assets.[2] This subset of plans is small in number, but because they are typically large corporations they account for 42 percent of participants and 59 percent of assets in 401(k) plans. [3] In terms of coverage and dollar amount, these levels of employee investment in the equity of their employer are unprecedented.

[1] Source: Investment Company Institute (ICI) and Profit Sharing Council of America (PSCA).

[2] Source: ICI and Employee Benefits Research Institure (EBRI) 401(k) plan database

[3] Source: ICI/EBRI 401(k) plan database.

Conventional financial wisdom is very clear about investing in individual stocks. While capital market theory suggests there should be compensation for bearing risk, investors should not expect to be rewarded for the diversifiable risk of individual stocks because it can be so cheaply avoided by holding portfolios of less than perfectly correlated stocks.[4] In the case of investing in an employer's stock, the diversifiable risk is likely to be related to an employees job prospects compounding the negative effects of a bad investment outcome with job loss or a pay cut. That employee's appear to ignore such simple logic and voluntarily purchase their company's stock at market price in their 401(k) retirement plans is widely documented.[5] There is also little dispute that such holdings are difficult to rationalize without resorting to behavioral bias or employee ignorance.

Not all employee holdings of company stock are voluntary. Employees usually have discretion over the amounts they contribute to their 401(k) account, but retirement regulation allows an employer to also contribute to employee accounts and control how those contributions are invested. Frequently, employers match some fraction of an employees own contribution to their 401(k) account with an investment in company stock that must be held for a specified period of time. Hedging away the idiosyncratic risk of such a long dated exposure would be

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[4] To the extent that an individual has private information about an individual stock this may not be true. It seems very unlikely that the large number individual employees could legally obtain sufficient valuable information about their company to inform their trading.

[5] See Chapter 2, Benartzi (2001), Mitchell and Utkus (2003), Choi, Laibson, Madrian and Metrick (2003b) and Utkus and Waggoner (2003).

prohibitively expensive. Thus even the most rational devotee of diversification will be faced with savings choices that necessitate holding the stock of their employer.

The purpose of this chapter is to model the effect of employer stock contributions on the decisions and welfare of such a rational employee in the context of their lifetime retirement saving. This motivates the development and calibration of a life-cycle model incorporating many institutionally relevant features of 401(k) retirement accounts. The model provides quantitative estimates of employee welfare under alternative employer contribution formulas where the proceeds are invested in restricted stock or a diversified stock fund. Estimates of the private value that an employee should place on his employer's stock can be inferred from the welfare estimates. No attempt is made to explain the decision of many employees to voluntarily invest in their company's stock.

The predictions of the model are just as relevant to corporate executives and financiers as they are to employees and policy makers. In modern corporate finance, a valid representation of the value of the firm is the sum of the value of claims on its assets. Where claims are not market traded, a model is necessary to arrive at their value. In the case of a corporate policy that makes employees shareholders through their retirement accounts the market price of the stock is not appropriate because risk-averse employees cannot readily trade away their exposure to the idiosyncratic risk of the stock. A model that measures the cost of bearing idiosyncratic risk in retirement accounts is required. The relevant model to value the employees' stock claim is a model of employee lifetime saving and portfolio choice behavior.

The model is the stylized representation of the myriad savings choices facing a representative employee at a firm offering a 401(k) account. Each period the employee makes consumption, saving, retirement account contribution and portfolio choices in the presence of exogenous uninsurable income risk and illiquid retirement accounts to maximize lifetime utility from periodic consumption. The employee may accumulate wealth by holding assets both inside and outside of retirement accounts. As shown in the buffer stock saving models of Deaton (1991) and Carroll (1992) uninsurable income shocks and borrowing constraints motivate small but positive rates of saving observed among young employees and so are incorporated in the model. However, in addition to income shocks, life-cycle income patterns are an important determinant of retirement saving and hence are key to the issue of risk in retirement accounts.[6] The tradeoff between maintaining a reasonable level of consumption in retirement and smoothing consumption against uninsurable income shocks earlier in life motivate holding assets on a taxable basis and in a less liquid but tax favored employer-sponsored retirement account.[7] As an employee ages, they should hold more assets in their retirement account than outside of it.[8]

[6] Life-cycle portfolio choice models with exogenous income risk have been considered previously in Cocco et al (1999), Viceira (2001) and Gomes and Michaelides (2003). Models with uninsurable expenditure shocks would equally rationalize a precautionary demand for liquid assets and is modeled similarly (for instance, Palumbo (1999) models uninsurable health expenditure shocks of retirees).

[7] The employee is assumed to be ineligible for any other form of defined contribution retirement account, such as IRA plans. Entitlements to defined benefit plan or social security entitlements are approximated through

[8] This is consistent with the life-cycle model of Gomes, Michaelides and Polkovnichenko (2004) with portfolio choice and retirement accounts and equilibrium life-cycle models of Love (2004) and Joines, Imrohoroglu and Imrohoroglu (1998) incorporating retirement accounts without portfolio choice.

Employees are modeled as impatient and risk averse in their preference over lifetime consumption. Impatience dictates a low willingness to trade present consumption for future consumption and is required to keep saving rates at the moderate levels observed in data. Risk aversion indicates a preference for smooth rather than volatile lifetime consumption. With a sufficiently high level of risk aversion an employee will not invest exclusively in risky assets, trade away from a position involving unrewarded idiosyncratic risk if possible and maintain a precautionary demand for taxable assets even if investing in retirement accounts is vastly more profitable in the long term. On the other hand, as shown by Tepper (1981), Black (1980) and Dammon, Spatt and Zhang (2004) simple tax arguments are more important than risk aversion in determining the optimal asset mix across retirement and taxable accounts. [9] More heavily taxed assets (i.e. bonds) should be first held inside the tax favored retirement account. Conversely, equities (including the employer's stock) should be first held outside of a retirement account.

Employer stock is introduced into the model via employer contributions to the 401(k) account.[10] For purposes of the chapter, the employer contributions are treated as a separate account where balances diversify gradually into the pool of employee contributions and become available for withdrawal.[11] The employer periodically makes either a fixed contribution as a percentage of employee income or a matching contribution, a fixed fraction of the employee's

[9] In life-cycle models, Amromin (2002) and Gomes et al (2004) find that income shocks can motivate a modest holding of bonds outside of a retirement account.

[10] The effect of employer stock on employee decision making is similar to saving and portfolio choices in models with background risk previously studied in the context of income, housing and entrepreneurial businesses (see Curcuru et al (2004) for a review).

contribution to their 401(k) account. The employer decides whether account balances are invested in company stock or invested in a diversified equity alternative and the rate at which they become diversifiable. The presence of employer contributions affects an employee's incentive to contribute to their retirement account.

In the model, an employee is always worse off receiving employer contributions invested in company stock rather than in a diversified equity fund because it makes their consumption stream more volatile.[12] A contribution in employer stock rather than a diversified alternative makes the retirement account less attractive and tends to reduce the optimal discretionary investment in diversified equity. The primary determinants of the welfare loss, and hence private value, associated with the employer's stock are its degree of idiosyncratic risk, how correlated it is with the employee's income shocks, the length of time it must be held, the overall attractiveness of the retirement account it is held in and the employee's degree of risk aversion and impatience. While many model parameters are directly observable, employee preference parameters are chosen so as to achieve sensible levels of life time wealth accumulation and portfolio choice.

The main objective of this chapter is to compare lifetime welfare for otherwise identical employees where one receives a company stock contribution and the other receives a diversified

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[11] This is a slight deviation from the reality of employer contributions, since even after employer contributions are diversified they will not usually be available for withdrawal unless the employee separates from the employer.

[12] This follows from risk aversion and the assumption that the distribution of the company stock return is a mean preserving spread of the return to a diversified fund (i.e. idiosyncratic risk does not command a risk premium)

employer contribution. Based on benchmark parameters, an employee should be willing to give up 0.8% of annual consumption to receive diversified matching contributions instead of company stock when the latter cannot be diversified until near retirement. For the case where employees can diversify completely after 5 years of receiving a contribution, the compensating consumption change drops to 0.1% per annum. Despite these relatively modest costs in lifetime consumption terms, the average private value a young employee should attach to a marginal employer contribution in company stock is very low: only 16c per dollar when diversification is restricted until near retirement and 86c per dollar when diversification is allowed after 5 years.[13]

Labor income shocks have both a direct and indirect impact on the welfare cost of employer stock contributions. Indirectly, an employee's overall preference for taking financial risk, including employer stock holding, is lower when the employee is more likely to experience large uninsurable income shocks. The direct impact is caused by the association between income shocks and employer stock returns. For a sufficiently risk-averse agent, a large income loss such as an unemployment spell that is associated with company bankruptcy could have a large welfare impact even if this occurs with small probability. In the model calibration these shocks are incorporated but have a modest impact on welfare. Going from a calibration where unemployment spells are independent of firm bankruptcy to one where they are related increase the welfare cost in consumption terms of employer stock matches by falls from 0.8% to 0.4% per annum (assuming sales of company stock are restricted until near retirement).

[13] For the case of an employee near retirement marginal values are much higher: xx and yy in the case of near retirement diversification and 5 year diversification respectively.

Whatever benefits a firm believes it obtains by relying on this internal source of capital must be considered in light of its diversification cost to employees. Efficient compensation should trade off the employer benefits associated with company stock against the costs that must be borne by employees. The model can be used to make plausible estimates of the cost of employer stock contributions versus contributions invested in a diversified fund. For cases where stock sales are restricted until retirement, on average an employee would value lifetime employer stock contributions at only 40 to 60 percent of a lifetime employer contribution invested in a diversified fund. Where stock sales are restricted for only 5 years, the average equivalent diversified contribution is 80 to 90 percent of a given lifetime employer stock contribution.

The remainder of the chapter proceeds as follows. Section 2 describes the relevant stylized facts that are used to calibrate the model. Section 3 outlines the model and the calibration parameters. Section 4 discusses the calibration results including the welfare implications of employer stock and the effects of plan rules on welfare and portfolio choice. Section 5 concludes with a summary of the main results of this chapter and directions for future research.

3.2 THE INCIDENCE OF EMPLOYER STOCK MATCHING

Figure 1 depicts the distribution of 401(k) participant's employer stock holdings for a large sample of 401(k) plans as reported in Holden and VanDerhei (2004). This data is constructed from participant 401(k) balances at firms where the employer's stock is either an investment option or directly contributed by the employer. The inferences that can be drawn from Figure 1 are limited. While more than 50% of employees held at least 10% of their 401(k) balance in employer stock, it is unclear what proportion of this is contributed directly by the employer. In aggregate, it can be inferred from VanDerhei (2002a, 2002b) that approximately one-third of the value of all employer stock holdings are employer contributed. This leaves a significant quantity of stockholding by a large number of employees that cannot be explained by conventional portfolio choice theory. Brown et al (2004), Benartzi (2001), Choi et al (2003b), Utkus and Waggoner (2003) find that voluntary holdings of company stock are associated with positive past stock performance and whether or not the firm provides matching contributions suggesting behavioral explanations.

Employer contributions of company stock are very frequently accompanied by sales restrictions. In a survey of 375 plan sponsors, VanDerhei (2002b) reports that 87% of firms imposed minimum holding periods. There are few restrictions in the tax code or Employee Retirement Income Security Act on the stringency of the sales restrictions imposed by employers except that the employee is always entitled to the vested portion of their stock upon separation or retirement from the firm.[14] Despite this, many companies impose less severe restrictions such as

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[14] The employer has discretion over how their contributions to 401(k) plans are invested, and company stock is excluded from the diversification rule governing these plans. A common approach to managing employer contributions of company stock is to use an Employer Stock Ownership Plan (ESOP). ESOPs are a type of retirement plan specifically designed to invest in the employer securities. The only constraint on sales restrictions in ESOPs is a statutory obligation for the employer to give employees aged 50 with at least 10 years of service the right to diversify 25% of their company stock holding immediately and another 25% 5 years later. These plans were particularly popular during the merger wave of the 1980s because they allowed firms to avoid hostile takeovers by placing themselves in the hands of employees. ESOPs can also provide a valuable dividend deduction to the firm that is not available in the case of externally raised equity. See Appendix A for more details.

3 or 5 year holding requirements from the date of the contribution. Alternatively, companies could impose restrictions based on tenure, so that all contributions received beyond a tenure limit become immediately diversifiable.[15]

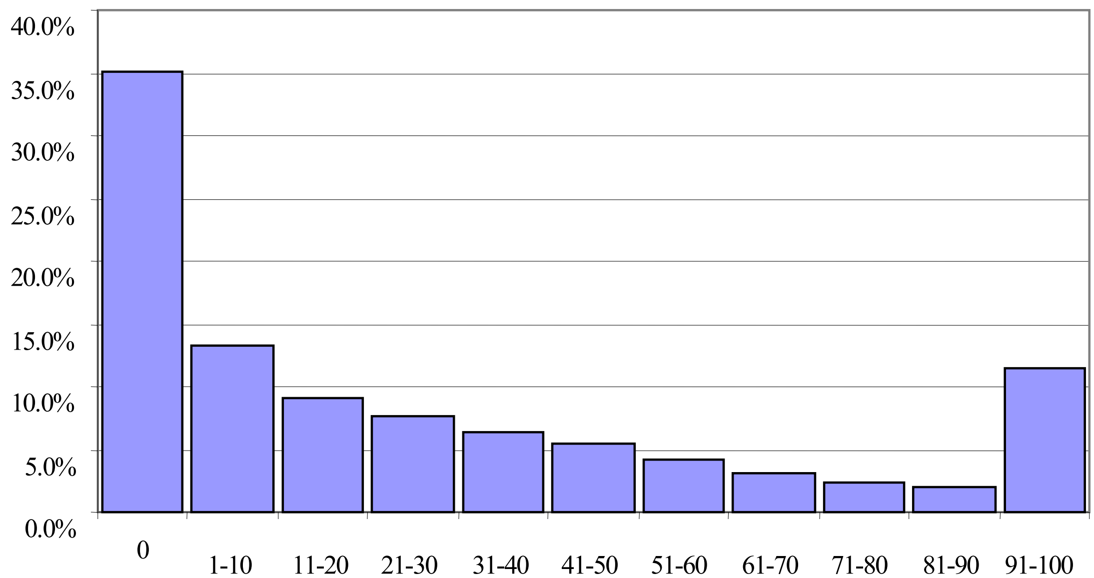

Figure 1: Participant Holdings of Company Stock in 401(k) Plans
This figure shows the distribution of 401(k) participants holdings in employer stock across a large sample of participants enrolled in a 401(k) in which employer stock is an investment option. The horizontal axis bins the portfolio shares of employer stock (including both voluntary and required holdings) into deciles. The vertical axis reports the percentage of employees holding a particular share. For example, over 35 percent of participants held did not hold any of their employer's stock in their plan whereas a approximately 12 percent held over 90% of their 401(k) balance in their employer's stock. (Source: Holden and VanDerhei (2004))

The type and magnitude of employer contributions are also important factors in welfare. Most commonly, employers will match an employee's contribution up to a certain percentage of

[15] For instance, sales restriction can be associated with the vesting of employer contributions. If an employee terminates service prior to vesting (a period of time as long as five years) they forfeit all of their unvested employer contributions. Vesting of employer contributions and tenure based sales restrictions are not studied explicitly in this paper.

salary. Alternatively, some employers offer a fixed contribution as a percentage of employee salary instead of or in addition to a matching contribution. Table 7 reports the prevalence of these types of matching contributions. In plans that offer matching, employers typically match 50 to 100 percent of an employee's contribution up to some limiting employee contribution (6% of salary on average).[16]

Match Type	*All Plans (%)*	*Large Plans (%)*
Match Plus Other Contributions	67.3	63.4
Safe Harbor Match	5.2	10.7
Fixed Contributions Only	17.8	13.4
No Contributions	5.4	3.6
Other	4.3	8.9

Table 7: Type of Employer Contributions Offered in 401(k) Plans
The table reports survey responses on matching policy in use by plans responding to the 2004 Annual Survey of the Profit Sharing Council of America (PSCA). Plans report providing either matching contributions, matching contributions according to statutory formula (Safe Harvor), fixed contributions, no contributions or other. Percentages in the second column represent the percentage of plan reporting a given matching type out of all plans surveyed. Percentages in the third column are the corresponding percentages when the sample is restricted to large plans (for plans with more than 100,000 participants) (Source: PSCA 2004 Annual Survey)

The IRS has designated two types of safe harbor contributions based on a minimal level of matching or fixed contributions. Plans that offer the safe harbor contribution to all eligible employees are deemed to automatically meet anti-discrimination tests. Otherwise, plans that do not offer safe harbor contributions must ensure adequate participation and contributions by lower paid employees relative to higher paid employees. Implementation of the safe harbor contributions is uncommon. As a result more than 50% of large plans report restricting the

[16] Source: PSCA Annual Survey of Profit Sharing Plans (2004).

maximum level of employee contributions or returning excess contributions of highly compensated employees.[17] In practice, this could limit some employee's contributions to less than 10% of salary even though the statutory limit on contributions may be higher than this.

A rational view of employee risk taking considers the risk of individual assets in the context of the employee's total wealth. The premise that idiosyncratic risk is not rewarded in financial markets is based on this notion. Employer stock contributions are likely to form only a minor source of an employee's lifetime consumption since they are just one source of financial wealth. Moreover, financial assets complement an employee's human capital stock by allowing them to smooth consumption from the fruits of labor over time. Income shocks and lifetime income trends are important determinants of wealth accumulation.

With a view to placing retirement plans assets in the context of household wealth, table 8 below reports averages for components of household wealth by age for a sub-sample of working US households that participate in a 401(k) or similar employer-sponsored retirement plan from the Federal Reserve Board's Survey of Consumer Finances (SCF). Defined contribution retirement plan balances account for a surprisingly modest share of household wealth even for households near retirement. There are many reasons for this low share that suggests defined contribution retirement balances may become a more important component of household wealth in the future. Firstly, many households hold the majority of their wealth in housing, also an illiquid asset that may make holding other illiquid assets such as retirement accounts less attractive. Furthermore, discretionary retirement savings is only required to the extent that a

[17] Source: PSCA Annual Survey of Profit Sharing Plans (2004).

household needs additional wealth in retirement. Social security and participation in employer-sponsored defined benefit plans can reduce these needs substantially. It is only since the late 1980s that employers have switched from offering employees defined benefit plans in favor of 401(k) defined contribution plans. No worker has experienced a lifetime of working participation in a 401(k) plan and the rate of coverage has yet to stabilize (this can be observed, but is not reported, in the change in households holding retirement assets between the 1989 and 2001 waves of the SCF). Finally, there is widely documented ignorance and naivety among households regarding retirement plans and retirement saving that may contribute to the failure of many households to accumulate balances, although knowledge may improve with time.[18]

	Age					
Mean Dollar Values	Under 35	35-44	45-54	55-59	60-64	65+
Non-Financial Income	47,317	60,969	70,793	64,307	60,949	67,873
Total Assets	128,575	239,520	387,357	426,759	522,394	544,578
Net Assets	72,458	160,404	309,022	363,167	472,764	498,766
Liquid Wealth	27,140	45,895	97,750	113,658	160,221	168,400
Retirement Wealth	15,752	43,942	88,744	95,100	130,755	138,335
Employer-sponsored Accounts	12,371	34,921	61,056	64,435	74,906	75,383
Private Accounts	3,382	9,021	27,689	30,665	55,850	62,952
Relative to Non-Financial Income						
Total Assets	2.53	3.87	5.16	6.19	8.31	7.80
Net Assets	1.38	2.52	4.02	5.10	7.46	7.12
Liquid Wealth	0.33	0.77	1.38	1.74	2.67	3.01
Retirement Wealth	0.52	0.68	1.21	1.40	2.15	2.26
Employer-sponsored Accounts	0.22	0.51	0.75	0.93	1.27	0.93
Private Accounts	0.06	0.13	0.32	0.41	0.70	1.04
Other						
DB plans ownership (%)	25	40	51	54	53	57
Enrollment in 401(k) (yrs)	2.87	7.10	10.55	10.95	11.38	9.68

Table 8: Composition of Household Wealth by Age of Household Head
This table reports asset ownership values in dollar terms and relative to income for employees at different ages. The sample is restricted to households reporting eligibility to enroll in at least one employer-sponsored defined contribution plan. All reported figures are calculated from constant 1989 dollars values averaged across all eligible households surveyed between 1989 and 2001 using the Survey's imputation weights. Source: Survey of Consumer Finances (1989, 1992, 1995, 1998, 2001). Description of the data and construction of variables is contained in subsection 2.3.2.

[18] For instance, see Choi et al (2003a, 2004a, 2004b).

For the purposes of the model, retirement wealth and liquid wealth are the only forms of wealth considered. The model abstracts from the ownership decision and risks of illiquid assets such as the family home. Preference parameters in the model are chosen to produce plausible levels of wealth accumulation, although retirement shares of wealth are generally higher in the calibrated model than observed in table 8, partly for reasons discussed above. Under representative calibrations, company stock will comprise as much as one-half of an employees retirement account balance via employer matching contributions.

3.3 THE MODEL

3.3.1 Overview

The model is designed to capture the essential elements of the saving and portfolio choice decisions faced by an employee at a firm offering a 401(k) retirement plan. The retirement plan allows participants choose their contribution rates and investment allocation. In addition, the employee receives employer contributions invested in either the stock of the employer or some diversified alternative. This model builds on a significant body of previous theoretical work in the dynamic portfolio choice literature. Connections to this literature are discussed in the results section, but see Curcuru et al (2005) for a survey.

A precautionary life-cycle model is well suited to studying 401(k) plan provision, rules and choices made by plan participants because it captures the tradeoff between tying up assets in pension plans that accumulate on a tax deferred basis versus holding money in a more liquid but taxable form. The model also formalizes the liquidity concerns of employees facing exogenous income and asset return shocks. A dynamic analysis enables measurement of well-being over an employee's entire life-cycle rather than merely focusing on retirement outcomes, a hallmark of the many previous analyses of employer stock in retirement plans.[19] The life-cycle approach also has the advantage of formally capturing the interaction of employer stock with labor income risks and other portfolio choices. While this is not a model of equilibrium employee retirement compensation, the model is informative about optimal compensation by predicting rational employee choices and welfare under alternative retirement benefit structures.

3.3.2 Lifetime Assumptions and Preferences

The employee lives a known finite life of T periods, and at period $T^* < T$ the employee retires. In each period t and in every possible state of the world the employee selects a level of consumption (c_t), a retirement account contribution (s_t) and asset allocations in the liquid and retirement accounts (denoted by the vectors $\mathbf{x}_{Lt}$ and $\mathbf{x}_{Rt}$ respectively).[20] The choices are made subject to a variety of budgetary restrictions, evolution of wealth equations, exogenous processes for asset returns and labor income. Formally the time consistent Epstein-Zin preferences are defined by the recursion:

$$U_t = \left[c_t^{1-\rho} + \beta \left(E_t U_{t+1}^{1-\alpha} \right)^{\frac{1-\rho}{1-\alpha}} \right]^{\frac{1}{1-\rho}} \tag{1}$$

With utility at the terminal date, T, given by

[19] Examples of non-life-cycle welfare analyses of stock-based compensation include Meulbroek (2002), Poterba (2003), and in the context of executive compensation, Hall and Murphy (2003).

[20] All dollar denominated or percentage return variables are to be interpreted as real (rather than nominal) quantities.

$$U_T = c_T \tag{2}$$

E_t is the expectations operator conditional on information available at time t and earlier (all variables dated t and earlier are in the employee's information set at time t). The subjective discount factor β is strictly between 0 and 1, implying that employees prefer to consume earlier than later. The coefficients α and ρ are the coefficients of relative risk aversion and the reciprocal of the elasticity of intertemporal substitution respectively.

3.3.3 Budget Constraints and Wealth Transitions

The employee has three accounts, namely a liquid wealth account (L), a discretionary retirement account (R) and an employer matching account (E). Wealth held in liquid and discretionary retirement accounts is invested in a portfolio of assets. The matching account is invested in a single asset, either the stock of the company or a well-diversified stock fund. Total wealth in each account is tracked with a state variable, denoted respectively by Z_{Lt}, Z_{Rt} and Z_{Et}. All forms of wealth can be used to provide for consumption at some stage during an employee's life, but only liquid wealth is freely accessible at any time.

Given a level of liquid wealth the employee may spend it on consumption, c_t, invest it in liquid assets on a taxable basis, the value of the holding in each asset represented by the vector $\mathbf{x}_{Lt}$, or transfer an amount $g_t(s_t)$ into the retirement account (where the retirement account balance is increased by s_t).[21] Withdrawals from the account are accommodated by a negative level of s_t

[21] Note that s_t is interpreted as the amount that is added to the retirement account. That is, it is the pre tax value of the contribution plus any unrestricted employer match. It's defined in this way because the match is a function of the pre tax contribution not the after tax contribution

and correspondingly a negative level of g. Contributions to the retirement account may be accompanied by employer contributions (described shortly). The liquid wealth budget constraint summarizing liquid account activity is

$$Z_{Lt} = c_t + \mathbf{x}_{Lt}'\mathbf{1} + g_t(s_t) \tag{3}$$

The function g_t is a piecewise linear function representing withdrawal and contribution incentives (defining the rate at which a given dollar of liquid wealth is transformed into retirement account wealth). Note that $s_t>0$ implies a retirement account contribution and $s_t<0$ implies a withdrawal. [22] The function g_t is defined and explained in relation to institutional retirement account incentives shortly.

Liquid wealth in the next period comes from the gross after tax return, $\mathbf{R}_{Lt+1}$, on the prior periods allocation to liquid assets, $\mathbf{x}_{Lt}$, plus any after tax return on investment plus after tax labor income in that period (l_{t+1}). This is summarized in the evolution of liquid wealth constraint,

$$Z_{Lt+1} = \mathbf{x}_{Lt}'\mathbf{R}_{Lt+1} + l_{t+1} \tag{4}$$

Both $\mathbf{R}_{Lt+1}$ and l_{t+1} are stochastic random variables from the perspective of time t and earlier and are resolved in period t+1.The retirement wealth budget constraint requires that

[22] Defining withdrawals and contributions in a single variable, s_t, means that an agent cannot simultaneously deposit and withdraw funds from their account. This is consistent with empirical observation and prevents employees from exploiting the positive incentives such as the employer match associated with new contributions to their retirement account. That is, an agent who would prefer to consume than save would still find it profitable to invest cash in their retirement account and be awarded the employer match and then immediately withdraw the deposited funds and consume them.

existing retirement wealth (Z_{Rt}) plus any contributions (s_t) must be assigned to an asset class (the vector $\mathbf{x}_{Rt}$ represents dollar of wealth allocated to each class of asset available)

$$Z_{Rt} + s_t = \mathbf{x}_{Rt}'\mathbf{1} \tag{5}$$

Retirement wealth at the start of the next period (t+1) is given by the value of retirement assets at time t plus any before tax return (since retirement investments are not taxed periodically as per liquid assets). A further source of retirement wealth comes from the diversified fraction, d_{t+1}, of any period t+1 balance in the employer contribution account, $[Z_{Et} + m_t(s_t)]R^e_{t+1}$. Thus the evolution of retirement wealth constraint is given by

$$Z_{Rt+1} = \mathbf{x}_{Rt}'\mathbf{R}_{t+1} + d_{t+1}[Z_{Et} + m_t(s_t)]R^e_{t+1} \tag{6}$$

The employer contribution account holds a single asset and for the purposes of the chapter, this asset is either the employer's stock or a well-diversified stock fund. Since there is a single asset in the account no budget constraint is explicitly required. Wealth in the account evolves according to

$$Z_{Et+1} = (1 - d_{t+1})[Z_{Et} + m_t(s_t)]\,R^e_{t+1} \tag{7}$$

At the end of each period t, the value of the employer contribution account derives from any undiversified balance Z_{Et} and any new contributions to the account. Employer matching contributions, $m_t(s_t)$, are increasing in employee's contribution to their retirement account. The employee does not directly contribute to this account.[23] At the start of the next period, this ending

[23] The employee cannot be prevented from selling company stock in a participant directed retirement plan, so a direct employee contribution to a restricted account does not make sense.

balance from period t will grow by the gross pre-tax rate of return on the employers stock R^e_{t+1} and fraction d_{t+1} will be diversified into the retirement account. To retain numerical tractability diversified matching funds are assumed to transfer to the discretionary retirement account, and hence become available for withdrawal.

Short-selling constraints are imposed on all assets in liquid and retirement accounts, i.e.

$$x^i_{jt} \geq 0 \ \forall \ i \in \{f, m, e\}, j \in \{C, R\}, 0 \leq t \leq T \tag{8}$$

At all dates prior to the retirement date T^*, withdrawals from the retirement account must not exceed the sum of a fraction of the retirement account and a fraction of the restricted employer stock account.

$$s_t \geq -q_R W_{Rt} - q_E W_{Et} \tag{9}$$

Finally g_t is defined as

$$g_t(s) = \begin{cases} s(1-p)(1-\tau_t), & s < 0, t < T^* \\ s(1-\tau_t) & \bar{s}_t > s \geq 0, t < T^* \\ \infty & s \geq \bar{s}_t, t < T^* \\ s(1-\tau_t) & s < 0, t = T^* \\ 0, & s < 0, t > T^* \\ s, & s \geq 0, t \geq T^* \end{cases} \tag{10}$$

The first three lines of the definition of g_t correspond to pre-retirement contributions and withdrawals. For $s_t<0$ each \$1 withdrawn from the retirement account provides $(1\text{-}p)(1\text{-}\tau_t)$ units of cash wealth, where p is the marginal penalty on each dollar withdrawn from the retirement account. That is, each dollar withdrawn is subject to tax at the employee's marginal rate and a penalty rate for early withdrawal. On the other hand, for s_t positive but less than the contribution limit $\overline{s}_t$, each dollar contributed to the retirement account only costs (1-τ_t) dollars because contributions are made from pre-tax labor income.[24] Beyond the contribution limit, each dollar contributed to the retirement account is infinitely expensive, preventing further contributions to the retirement account beyond the limit.[25]

The fourth line of the definition of g_t corresponds to withdrawals at retirement. At retirement, withdrawals from the retirement account are taxed but not penalized so each dollar withdrawn provides (1-τ_t) in cash wealth.[26] After the retirement date, the retirement account is no longer available to the employee, thus the conditions for $T > T^*$ are merely technical to ensure there is no incentive to maintain or contribute funds to the retirement account. The tax rate is specified to be time varying to allow for a lower tax rate at retirement.

The matching account is available to the employee up until the retirement date T^* when the balance is transferred to the freely allocable retirement account, which is in turn taxed and delivered as liquid wealth. The employer uses the rule in equation (11) to contributing to the employer stock account. The matching function *m* defines matching activity up to the employer

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[24] To minimize notation, it is assumed that the employer match is provided up to the statutory contribution limit. This assumption is easily relaxed to allow for lower levels of employer matching contributions, or a match that declines with the contribution rate.

[25] While there is no specific restriction in the model to ensure that contributions are made only from labor income as opposed to all liquid wealth, such a constraint would very rarely bind in practice, in part because of the cap on contributions.

[26] It would be simple to incorporate a tax rate at retirement that is different from the tax rate paid during working years.

imposed limit $\bar{\bar{s}}_t$, where typically $\bar{\bar{s}}_t \leq \bar{s}_t$. The employer matches the fixed dollar amount m_{0t} and a variable quantity of m_1 per dollar of employee contributions.[27] The matching function is written

$$m(s_t) = \begin{cases} 0, & s_t < 0, t < T^* \\ m_{0t} + m_E s_t & \bar{\bar{s}}_t > s_t \geq 0, t < T^* \\ m_{0t} + m_E \bar{\bar{s}}_t & s_t \geq \bar{\bar{s}}_t, t < T^* \\ 0 & t \geq T^* \end{cases} \tag{11}$$

3.3.4 Labor Income and Asset Prices

Both labor income and asset prices follow exogenous stochastic processes. Labor income is assumed to have a non-stochastic component and a multiplicative shock component that is independent and identically distributed through time. Thus l_t is written

$$l_t = \theta_t L_t \tag{12}$$

where L_t is the trend component and θ_t is the stochastic component. This specification of labor income can embed an unemployed state, in which θ_t is close to zero with positive probability. The trend component of income can accommodate a hump shaped life-cycle income profile as observed in data: low income while young steadily increasing through middle age then decreasing as working activity winds down leading up to and during retirement.

Due to the homogeneity of preferences in consumption levels, permanent income shocks can be accommodated without adding a state variable. In this case all level dependant constraints must be expressed as a percentage of permanent income rather than real dollar amounts.[28] All level variables are reinterpreted from real dollar amounts to levels relative to permanent income,

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[27] Normally the fixed component would be a percentage of salary, but this has negligible impact on the calibration results.

and all asset returns must be scaled by the stochastic growth rate of permanent income. Euler equations and the value function describing optimal choices also change slightly.

Asset prices are assumed to follow an exogenous arbitrage free process and generate time independent rates of return. There are only three asset classes in the model, a one period risk free asset, a diversified risky asset and the stock of the employer. The risky assets classes can be positively or negatively correlated with each other and also with the labor income shock (whether transitory or permanent).

3.3.5 Value Function

The multiperiod optimization problem in equations (1)-(11) can be solved by backward induction. Starting at period T, the employee is retired with an accumulated balance of liquid wealth (and no other forms of wealth) and a single remaining period to consume. Trivially, the employee will optimally consume all of this wealth because of the monotonicity of the period utility function. The accumulated liquid wealth completely characterizes the value function of the employee's problem,

$$V_T\left(\left\{Z_{jT}\right\}_j\right) = Z_{LT} \tag{13}$$

Note that the value function is written as a function of all three forms of wealth. This is because in earlier periods $t < T$, the trio of wealth levels is necessary and sufficient to

[28] Obviously this would mean changing the upper bound on 401(k) matches from a fixed real dollar amount to a percentage of permanent income. This is not unreasonable if the relevant limit is an employer imposed limit on matching rather than the statutory dollar amount.

characterize the state of the employee's problem. Thus for $t < T$, the value function can is a function of the state variables,

$$V_t\left(\left\{Z_{jt}\right\}_j\right) = \max_{\left\{c_t, s_t, \{\mathbf{x}_{jt}\}_j \in \Gamma_t\left(\left\{Z_{jt+1}\right\}_j\right)\right\}} \left[c_t^{1-\rho} + \beta \left(E_t V_{t+1}^{1-\alpha} \left(\left\{ Z_{kt+1}\left(c_t, s_t, \{\mathbf{x}_{jt}\}_j\right)\right\}_k \right)\right)^{\frac{1-\rho}{1-\alpha}} \right]^{1/(1-\rho)} \quad (14)$$

Γ_t is the set of constraints (3), (5), (8) and (9). Note that the transition equations (4), (6) and (7) define the period t+1 state variables (Z_{jt+1}) over all possible random states of nature given the current state (Z_{jt}) and the choice variables c_t, s_t, $\mathbf{x}_{Lt}$, $\mathbf{x}_{Rt}$.

An extension of the method in Carroll (2005) provides a reliable procedure to compute the quantitative implications of the model. The value function and its derivatives are computed recursively, beginning at the last period of the problem, using a finite element method at each period t to discretize the state space over the permissible range of $\{Z_{jt}\}_j$. Solving for the optimal policy in period t involves a non-linear optimization over the choice variables at every element of the state space. The Euler conditions for the optimal choices at period t depend on the derivatives of the value function from period $t + 1$ so a non-linear interpolation approach is used to compute the period t expectation of the marginal value of the problem at period $t + 1$.

3.4 CALIBRATION PARAMETERS

The model is solved computationally for a variety of specifications of parameters. The model spans 50 years of a representative employee's life, 25 prior to retirement (in five-year age intervals from ages 35 to 60) and 25 after retirement (ages 65 to 90). Throughout it is assumed the employee makes decisions at 5 year intervals (results using annual periods are quantitatively similar).

3.4.1 Preferences

Following Gomes and Michaelides (2003) and Cocco et al (2004) the benchmark preference parameters are 5 for the coefficient of relative risk aversion and 0.3 for the elasticity of intertemporal substitution. As there are no bequest motives or explict modeling of death events, a constant subjective discount factor of 0.6 is required to keep wealth accumulation at the low levels observed in the SCF for "average" employed households (equivalent to an annual rate of subjective rate of impatience of approximately 10%). This is consistent the life-cycle models of Deaton (1991) and Carroll (1992).

3.4.2 Asset Returns and Labor Income

The risk free rate of return before personal taxes is assumed to be constant over time at 2% p.a. (10.4% per 5 years). Returns to diversified equity are assumed to obey a time independent lognormal distribution with an expected return of 6.5% p.a. and standard deviation of 18% p.a. (corresponding to 33.8% and 51.8% respectively over the 5 year interval). The gross return on the employers stock pays the gross diversified equity return multiplied by a idiosyncratic risk term. The idiosyncratic risk is calibrated so that the employer stock return has the same expected value as diversified equity and a standard deviation of 45% per annum. The idiosyncratic risk factor has no correlation with the diversified equity return and the range of return outcomes includes a "bankruptcy" state when the stock pays a -100% net return.

The exogenous after tax income path is assumed to increase at a rate of 2% per annum, but levels off at age 55 and remains flat until the exogenous retirement age of 65. At retirement, income drops to a fraction of its pre-retirement value (referred to as the income replacement rate) but is still subject to the transitory and permanent income shocks. The model is calibrated separately for low and high income employees, which entails different income replacement rates in retirement and different marginal tax rates across the two groups. For benchmark calibrations, the income replacement rate is taken to be 75% of net income for low income employees and 50% of net income for high income employees.[29] Marginal tax rates are discussed shortly.

Transitory income shocks have an annual standard deviation of 20% per annum around the trend level (corresponding to a standard deviation of 47% over a 5 year period), consistent with Carroll (1992) and Cocco et al (2001). Transitory income shocks are correlated with the return on the employers stock through the bankruptcy event. That is, it is assumed that the bankruptcy event is always associated with unemployment, and has a 1% per annum probability in the benchmark case. This is reasonable for unemployment rates but overstates firm bankruptcy risks substantially. However, high bankruptcy rates have surprisingly minor welfare implications even for very risk-averse employees (consistent with closed form results on bankruptcy shocks presented in chapter 4).

The permanent component of income evolves according to a time independent process with a standard deviation of 10% p.a. (or 22.6% per 5 years) again consistent with Carroll (1992) and Cocco et al. (2001). For simplicity, permanent income shocks are independent of the transitory shocks, the diversified equity return, and the idiosyncratic risk of the employers stock. Closed form results in chapter 4 suggest that interaction between returns to human capital and

[29] This gives average replacement rates that are slightly higher than the social security replacement rates estimated by Munnell and Soto (2005). The additional increment is intended to account for ownership of defined benefit plans.

company has important welfare consequences, alternative specifications with correlated permanent income shocks and company stock idiosyncratic returns are also considered.

3.4.3 Tax Rates

The model is calibrated to two types of employees, low and high income, although most of the analysis focuses on the high income case. It is assumed a low income employee always pays a low tax rate of 15% per annum on labor income and taxable bond returns and a 10% tax rate on taxable equity returns, the lower rate reflecting more favorable capital gains tax treatment. For high income employees the labor income and taxable bond tax rate is 35% per annum and for taxable equities it is 25% per annum. No attempt is made to model the employee's movements between tax brackets as their incomes rise or fall through time. No adjustment to tax rates is made for the compounding effect on taxes that would be paid on an investment held over 5 years and this will slightly understate tax payments on taxable investment returns.

Rather than model rollovers of retirement account balances into tax-favored annuities at retirement or retain the tax favored retirement accounts into retirement years, it is simply assumed that retirees are granted a reduced tax rate on rollovers. The rollover tax rate is set at 10% for low income employees and 25% for high income employees.

3.4.4 Retirement Plan Characteristics

The emphasis of this analysis concerns employer contributions, so the model is calibrated to a variety of employer contribution rules with the contribution invested in either the employers stock or the diversified equity fund. The benchmark employer contribution is either a 50c match in the diversified asset or company stock per dollar contributed by the employee. This match is provided for all employer contributions up until the 6% contribution limit. Alternative cases when the employer provides fixed contributions, higher or lower matching rates are also considered.

Employee contributions to plans are limited to no more than 6% of the employee's pre tax trend income level. For most employees, this limit is significantly lower than the statutory limit of $14,000, however many plans impose more stringent limits than the statutory limit due to non-discrimination rules. Plan withdrawals are allowed from the discretionary retirement account but not the matching account, although matching account balances will gradually transfer to the discretionary retirement account depending on the diversification schedule (a concession to the complexity of the problem). Withdrawals are charged a penalty of 50% of the funds withdrawn in addition to any taxes that must be paid. This penalty is unrealistically high, but ensures the employee's problem has a unique solution under very generous matching scenarios. A more realistic level of 15% is also reported in the analysis but results are only modestly affected.[30] The benchmark rate of matching is 50c per dollar contributed by the employee and matches are invested in either a company stock fund or a diversified equity fund. Diversification of matching contributions also plays an important role so a wide range is considered: from 100% diversification of the previous period's company stock balance at one

[30] The statutory level is 10% but an extra 5% is included to account for administrative or opportunity costs (e.g. time delays) involved in making a withdrawal. Hardship withdrawals are not considered, but would in principle make a retirement account more attractive because it allows penalty free withdrawals when an employee needs funds the most.

extreme to diversification only at retirement at the other extreme. The benchmark diversification rate is where the employee can diversify 25% of the account balance at age 55 and another 25% at age 60 (closely matching the regulatory rules for diversification of company stock in ESOP plans).

3.5 COMPUTATIONAL RESULTS

This section is broken into two parts. The first reports optimal employee savings and portfolio choice behavior in the model under the benchmark parameter specifications. This includes an exploration of the sensitivity of employee decisions to variation in the parameter values, especially retirement plan specific parameters. The second half of the section is devoted to measuring the inefficiency of investing employer contributions in the employer's stock.

3.5.1 Optimal Choices

As discussed in the calibration section, preference parameters were set in an attempt to generate the low levels of average household wealth and conservative portfolio choices observed in data such as the Survey of Consumer Finances. The averages in the data mask considerable heterogeneity and while it is possible to generate variation in optimal wealth and portfolio choices through preference heterogeneity alone it is nonetheless interesting to explore how individual choices in the model are affected by plausible heterogeneity in observable exogenous factors.[31]

Table 9: Simulated Average Wealth in Liquid and Retirement Accounts by Age

[31] Bernheim, Skinner and Weinberg (2001) find little evidence to support variation in preferences of conventional life-cycle models as an explanatory of observed wealth dispersion among US households.

	Account	Age 35-39	40-44	45-49	50-54	55-59	60-64
(1) Benchmark Diversified Match	Liq	1.45	1.94	2.29	2.53	2.72	2.80
	Ret	0.39	1.05	1.92	3.00	4.21	6.12
(2) Low Salary	Liq	1.59	2.19	2.68	3.16	3.72	4.43
	Ret	0.03	0.32	0.73	1.21	1.72	2.48
(3) Transitory Income Shocks only	Liq	1.06	1.28	1.43	1.52	1.67	1.76
	Ret	0.06	0.16	0.51	1.05	1.75	2.81
(4) No Retirement Accounts	Liq	1.62	2.42	3.26	4.17	5.21	6.56
	Ret	-	-	-	-	-	-
(5) No Contribution Limit	Liq	1.52	1.99	2.24	2.25	1.75	0.00
	Ret	0.18	0.84	1.95	3.65	6.50	12.54
(6) Low Penalty	Liq	1.16	1.63	1.93	2.14	2.30	2.27
	Ret	1.07	1.79	2.79	3.91	5.16	7.22
(7) No Withdrawal Limit	Liq	1.40	1.88	2.23	2.46	2.64	2.69
	Ret	0.50	1.19	2.08	3.17	4.40	6.34
(8) Low Penalty, No Withdrawal Limit	Liq	1.09	1.37	1.67	1.87	2.02	2.05
	Ret	1.16	2.23	3.20	4.31	5.55	7.51
(9) No Employer Contributions	Liq	1.51	2.04	2.49	2.91	3.41	4.02
	Ret	0.18	0.60	1.15	1.82	2.52	3.59
(10) $1 Match	Liq	1.39	1.84	2.14	2.27	2.26	1.98
	Ret	0.68	1.59	2.78	4.24	5.90	8.41
(11) Fixed Employer Contribution	Liq	1.55	2.06	2.47	2.80	3.17	3.50
	Ret	0.23	0.72	1.39	2.21	3.16	4.65
(12) Match in Employer's Stock	Liq	1.54	2.05	2.47	2.80	3.14	3.48
	Ret	0.18	0.80	1.62	2.69	3.91	5.83

This tables reports the average levels of optimally accumulated wealth in the two retirement accounts (the employee's account and the employer's matching account) and liquid account at each age grouping under various model parameterizations, which are numbered in the rows. Calibration parameters are described in section 3.4. Alternative model parameterizations deviate from the benchmark case as follows: (2) Low Salary case 10% marginal tax rate and 75% income replacement rate at retirement; (3) The volatility of the permanent income shock component of labor income is set to zero; (4) The employee saves only liquid wealth; (5) The employee may make unlimited contributions to the retirement account (although the matching contribution is still limited to a fixed fraction of income); (6) The penalty on withdrawals from the employee's discretionary account is set at 15% instead of 50%; (7) Employee's may withdraw the entire balance from their discretionary account instead of the 30% limit; (8) Combines (6) and (7); (9) The employer does not make any matching contributions over the entire employee's life; (10) The employer contributes $1 to the matching account for each $1 contributed by the employee to his discretionary account (instead of the 50 cent match in the base case).; (11) The employer makes a fixed contribution of 3% of the employee's labor income irrespective of the employee's own contribution; and (12) The employer contributes 50 cents in stock for each $1 contributed by the employee (as opposed to a diversified equity match as in all other calibrations in this table).

Table 9 displays simulated average levels of liquid and retirement wealth relative to labor income for an employee at different ages under the benchmark model and various deviations from the benchmark model. Each set of simulations is based on the employee starting at age thirty with liquid wealth equal to one year of initial salary and no accumulated retirement wealth. Accumulated retirement wealth is the sum of discretionary employee contributions and fixed or matching employer contributions. Wealth overall follows the familiar pattern observed in typical precautionary life-cycle models (for instance, see Carrol (1997), Carroll and Samwick (1997) and Cagetti (2003)) where the younger employee holds wealth as insurance against income shocks, but then increases this buffer stock to produce sufficient wealth for consumption in retirement. Naturally, liquid wealth is better suited to meeting precautionary needs than wealth in a retirement account hence the employee holds most wealth in the liquid account when young then gradually accumulates wealth in the retirement account with age. Precautionary saving is driven by borrowing constraints and uninsurable income shocks. For younger employees, transitory shocks tend to increase precautionary saving without increasing retirement saving, whereas permanent income shocks induce both precautionary and retirement saving (this can be seen comparing model results with and without permanent income shocks in lines 1 and 3 respectively of table 9).

As discussed in section 3.2, average retirement account balances for older employees are significantly higher in the model simulations than observed among current 401(k) participants observed in table 8. Gomes, Michaelides and Polkovnichenko (2004) account for average 401(k) enrollment times in their simulations of a very similar model to this one and more closely match

SCF wealth accumulation statistics as a result.[32] Here the objective is not to explain the past but to project costs associated with future employer stock holdings for lifetime 401(k) participants.

In the model, contribution limits are the primary determinant of the composition of wealth at retirement. In the period prior to retirement, provided there is an employer match or a tax benefit to holding assets in the retirement account, an employee should hold as much wealth as possible in their retirement account. Indeed, in the absence of contribution limits, the employee would optimally hold all of their wealth in the retirement account (see line (5) of table 9). This is not true in early periods of the employee's working life since withdrawal limits and penalties on retirement accounts prevent assets held in the retirement account dominating liquid assets on a rate of return basis as in the final working period.

Comparison of lines (1) and (2) of table 9 reveals an employee's salary level is also an important determinant of lifetime retirement account utilization since it determines their marginal tax rate and social security entitlements. The higher the tax rate paid by the employee, the greater the incentive to take advantage of tax deferral offered by the retirement account. On the other hand, the larger the social security payment an employee expects to receive the less necessary retirement saving becomes reducing the share of wealth held in the retirement account. The low salary case illustrates a quite dramatic change in the wealth composition from the focal high income calibration.

Retirement account composition is also determined by the trade off between tax and employer contribution incentives on one hand and retirement account illiquidity on the other.

[32] They also note a distinct gap in wealth accumulation between those who own equity outside of their retirement account and those who do not.

The marginal dollar contribution to the retirement account reduces either current consumption or liquid wealth. This diverted dollar offers the incremental advantage of tax free compounding, effectively raising the periodic rate of return on investment compared with the liquid account. Employer contributions that match the part of an employee's contribution also raise the effective investment return, but at a periodic rate that diminishes with the holding horizon since the match is paid regardless of investment horizon.

The fact that tax and matching incentives lower the price of future consumption relative to current consumptions implies a substitution effect, but these incentives also have an income effect because they endow the employee with additional future wealth. If consumption in each different state and period is a normal good then a strictly positive endowment of future wealth should lead to less retirement account saving in order to consume more today. This is most clearly observed for the case of non-matching fixed employer contributions since, to a first order approximation, these contributions have only an income effect (compare lines (9) and (11) of table 9). While an employee accumulates more wealth in the retirement account with a fixed employer contribution than with no employer contribution at all, what is not shown is that voluntary employee contributions are actually lower on average.

Any measure of the net impact of these savings incentives must account for their costs. As has been noted by Gale and Scholz (1994), tax favored retirement accounts do not necessarily raise savings rates net of the cost of providing the subsidy and in aggregate could have no net saving impact at all. In a frictionless investing environment, an unconstrained employee could make the maximum tax preferred retirement contribution by reducing current taxable assets or borrowing and this would leave marginal saving incentives unchanged. Net of the cost of providing tax subsidized saving to each employee there would be no impact on net saving. Similar logic applies to the provision of contributions by the employer. Thus, to obtain a non-trivial employee response to these incentives in a life-cycle model necessitates borrowing constraints and uninsurable income shocks.

The other side of the trade off between holding retirement and liquid assets is liquidity. This takes the form of both withdrawal penalties and constraints on retirement account wealth. To guarantee numerical stability, the benchmark parameterizations assume an unrealistic 50% penalty (in addition to income taxes) and limits withdrawals to 30% of the discretionary retirement account balance. Employer contributions cannot be withdrawn until retirement in all parameterizations in table 9. Parameterization with less restrictive liquidity restrictions are displayed on lines (6) through (8) of the table. Reassuringly, these alternatives have only a modest effect on lifetime accumulation.

The discussion of income and substitution effects is relevant to the issue of employer stock holding. The income and substitution effects of tax are affected by the uncertainty of investment outcomes. Thus whether an employer makes contributions in company stock versus a diversified fund should have different impacts on optimal retirement account contributions. As reported in table 9, for the benchmark parameters the employee's optimal response to matching in employer stock is to reduce retirement account accumulation (compare line (12) with line (1)), but other calibrations may show the opposite.

Empirically, it appears that there are large departures from even the simplest wealth composition and retirement account utilization predictions of the model. For instance, Choi, Laibson and Madrian (2005) report the failure of individuals eligible for penalty free withdrawals from their 401(k) accounts to take full advantage of employer matching contributions. In contrast with the active decision that is assumed at every period, Choi et al (2003a, 2004a and 2004b) report evidence that many individuals accept plan default contribution levels and fail to deviate from their initial contribution selections for long periods of time. Such passivity could lead to large departures from the optimal composition of liquid and retirement wealth, although some of these departures would have small welfare costs (see Chapter 2 for more discussion of this point).

Turning now to portfolio choice, table 10 reports the portfolio choices (specifically the risk-free share in each account) in the liquid wealth and the retirement account under alternative model calibrations. Note that the reported portfolio shares in the retirement account are the discretionary shares and do not include the employer contributed amounts that are invested in either the diversified asset or the employer's stock. The combination of a high level of risk aversion under Epstein-Zin utility, a low equity risk premium and large permanent income shocks leads to quite conservative portfolio choices consistent with average household risk-free shares observed in the Survey of Consumer Finances. Of course, the model cannot rationalize the significant voluntary holdings of the employer's stock observed in more detailed 401(k) plan administrative data such as that reported in Holden and VanDerhei (2003).

With Epstein-Zin utility and in the presence of the assumed large income shocks simulated portfolio choices are sensitive to risk aversion (as shown in the table) and the assumed level of the expected equity premium (not shown). The income drop off at retirement necessitates a rising risk-free share in total wealth to maintain acceptable consumption volatility in retirement. As the share of financial wealth grows relative to human capital, the employee becomes less willing to take financial risks such as investing in equities that would create large consumption volatility in retirement. This is consistent with lifetime portfolio choice results in Campbell and Viceira (2001), Gomes and Michaelides (2003) and Gomes, Michaelides and Polkovnichenko (2004).

The lifetime averages suggest that the employee maintains risk free holdings in the liquid and retirement accounts simultaneously. The averages, however, hide the tax specialization of asset holdings that almost always occurs. That is, where possible the employee will hold the risk free asset in the retirement account if it is held at all, since in the liquid account the risk free asset is assumed to be taxed at a higher rate than equities, reflecting the preferential tax treatment of risky assets.

Despite the fact that Amromin (2002) shows it is theoretically possible to see an employee voluntarily hold tax inefficient portfolios due to uninsurable income risks, it is rarely observed in the numerical calibrations. In reality tax inefficient portfolio choices are a common occurrence in household data as reported by Amromin (2002), Dammon, Spatt and Zhang (2004) and Bergstresser and Poterba (2004). The most challenging aspect is that consumption smoothing models predict equities should be the asset of choice in the liquid account for younger households, but instead a surprisingly large number hold bonds or money market funds in their liquid taxable accounts and equities in their retirement accounts. Gomes, Michaelides and Polkovnichenko (2004) interpret the observed magnitude of equity holdings in 401(k) accounts as an efficient shortcut to otherwise costly participation in equity markets, making tax efficiency a secondary concern. Alternatively, bond holdings in the liquid account may reflect liquidity concerns not captured in models based on income shocks.

	Age					
	35-39	*40-44*	*45-49*	*50-54*	*55-59*	*60-64*
Liquid Portfolio Risk Free Share						
Stock vs. Diversified Match						
Benchmark (Diversified)	0%	8%	19%	25%	37%	59%
Company Stock	0%	8%	17%	16%	24%	40%
Size of Match						
No Match	0%	5%	10%	11%	19%	28%
1 Dollar Company Stock Match	0%	8%	19%	18%	26%	45%
1 Dollar Diversified Match	0%	8%	19%	32%	53%	81%
Relative Risk Aversion						
2	0%	0%	0%	0%	0%	0%
10	34%	57%	70%	81%	92%	97%
Discretionary Retirement Portfolio Risk Free Share						
Stock vs. Diversified Match						
Benchmark (Diversified)	0%	16%	32%	60%	83%	96%
Company Stock	0%	8%	22%	54%	76%	91%
Size of Match						
No Match	0%	14%	34%	59%	77%	89%
1 Dollar Company Stock Match	0%	6%	17%	51%	76%	92%
1 Dollar Diversified Match	0%	23%	41%	64%	87%	99%
Relative Risk Aversion						
2	0%	0%	0%	0%	0%	2%
10	100%	93%	94%	98%	100%	100%

Table 10: Average Simulated Risk-Free Shares in the Liquid and Retirement Accounts by Age
This table reports the average risk free share held in the liquid and discretionary retirement accounts by age simulating from initial conditions under alternative model specifications. Calibration parameters are described in section 3.4.

The most surprising simulation result is that risk free asset holdings are lower on average in both retirement and taxable savings accounts when the employer match is invested in company stock than when invested in the diversified asset. So while matching in company stock offering a return that is a mean preserving spread of the diversified asset return makes the employee unambiguously worse off in utility terms, the optimal response often involves increasing the discretionary holding of the diversified asset and lowering the investment in the risk free asset. Gollier (2001, Ch 9) provides conditions on expected utility functions where the imposition of an uncorrelated background risk would lead to a more conservative portfolio choice. It is easy to demonstrate that utility functions exhibiting constant relative risk aversion satisfies these conditions and hence adding a background risk will increase discretionary holdings of the risk free asset. However, these results do not extend to the present case of determining the impact on risk free asset holdings of switching from a diversified match to a match in company stock that amounts to adding uncorrelated noise to a correlated background risk.

Many commentators on the issue of employer stock held in retirement accounts have focused on the distribution of wealth at retirement or compare utility over terminal wealth with and without employer stock (see for instance VanDerhei (2002), Poterba (2003), Brown et al (2004)). These analyses ignore the life-cycle smoothing motivations of employees and their ability to alter retirement account contributions and asset allocation in response to employer contributions in company stock. As a result, the model predicts significantly less incremental volatility in wealth at retirement arising from employer contributions of company stock than these other studies. Table 11 reports the dispersion of wealth and various company plan designs with and without employer stock contributions. The employer’s stock has only a modest impact on the dispersion of retirement wealth outcomes even with the strong restrictions on early withdrawal of employer stock balances assumed in these calibrations. The presence of the employer's stock makes the distribution of wealth slightly more right skewed with the left tail only marginally more dispersed (as evidenced by the percentiles of simulated liquid wealth at retirement).

	Percentiles								*Std*
	0.01	*0.05*	*0.1*	*0.5*	*0.9*	*0.95*	*0.99*	*Avg*	*Dev*
Benchmark 50c Diversified Match	0.71	1.45	2.02	4.8	9.26	10.8	14.9	5.32	2.99
50c Employer Stock Match	0.65	1.44	2.05	4.91	9.6	11.3	15.3	5.47	3.11
1 Dollar Diversified Match	0.71	1.5	2.07	4.91	9.53	11.2	15.4	5.46	3.1
1 Dollar Employer Stock Match	0.63	1.38	2.01	4.82	9.42	11.1	15.1	5.36	3.05
Fixed 3% Contribution Diversified	0.76	1.61	2.24	5.26	10.3	12.3	16.7	5.9	3.37
Fixed 3% Contribution Employer Stock	0.71	1.57	2.19	5.28	10.8	13.2	21.7	6.88	15.3

Table 11: Simulated Wealth Holdings at Retirement
This table reports the percentiles, average and standard deviation of wealth relative to income in the year of retirement simulating from initial conditions. Calibration parameters are described in section 3.4.

3.5.2 The Inefficiency of Company Stock Matching

The remainder of this section reports estimates of the inefficiency of employer stock contributions relative to diversified contributions from the employer. Reported results are focused around the case of an employee subject to the high salary calibration of the retirement income drop off and tax rates (the low salary case leads to uniformly lower efficiency estimates because the tax favored account is utilized far less).

Three alternative measures of the inefficiency of employer contributions invested in the employer's stock instead of a diversified fund are considered. The first is the percentage of annual consumption an employee would exchange for having employer contributions invested in a diversified fund instead of the employer's stock. The second, more compelling measure, computes the welfare equivalent size of a contribution an employer could pay if it was invested in a diversified fund instead of in the employer's stock. The third measure compares the marginal value of a dollar of employer contributions with the marginal value of a dollar of employee contributions. This final measure has considerable variation by age and circumstance of the employee and allows the cost of mandatory retirement account employer stock investments to be decomposed into an amount related to tying up funds in illiquid form (the employer contribution account) and an amount related to holding an undiversified instead of diversified asset.

Under Epstein-Zin preferences it is easy to show that the life time percentage annual consumption difference, x, between any two regimes, for instance, diversified matching (D) and company stock matching (S) satisfies

$$x = 1 - \frac{V_0^S\left(Z_{L0}, Z_{R0}, Z_{E0}\right)}{V_0^D\left(Z_{L0}, Z_{R0}, Z_{E0}\right)} \qquad (15)$$

Table 12 presents the annual consumption a rational employee would willingly give up to receive a well-diversified match instead of a company stock match. The annual consumption cost is modest at 0.8% for the case of a 50c match and 1.4% for the case of a 1 dollar match that cannot be diversified to retirement.[33] This is surprising given the large magnitude of income shocks and strong association between bankruptcy and unemployment. The magnitude of the annual consumption equivalent depends on the level of the employee's subjective impatience, the degree of risk aversion, the volatility of the idiosyncratic risk of the employers stock (and its

[33] Despite concentrating more retirement wealth in the employer's stock, doubling the match less than doubles the consumption cost because the employee can reduce retirement account contributions and reduce risk taking.

association with labor income shocks) and how long the employee is compelled to hold the employer contributed stock.

The degree of subjective impatience is the primary determinant of wealth accumulation, especially for consumption in retirement. When impatience is very high, a young employee is unwilling to exchange present consumption for retirement consumption, even if the price of retirement consumption is lowered by generous retirement plan incentives. In lifetime consumption terms an impatient employee will only slightly differentiate between retirement contributions invested in stock or a diversified fund because the employee places so little value on the retirement consumption that these contributions generate.

Risk aversion and the excess volatility of the company stock over the diversified risky asset also have a comparable detrimental impact on welfare. Doubling the degree of relative risk aversion is similar in welfare terms to doubling the idiosyncratic volatility of the employer stock (this is consistent with closed form results presented in chapter 4). Obviously there are no welfare implications for a rational employee if they are not compelled to hold company stock as the optimal employee response is to always sell the stock immediately. Thus, the length of the lock up period, or alternatively the rate at which the stock can be diversified plays as important a role in welfare costs as the other factors. A firm that imposes less stringent diversification rules on employer stock held in the matching account imposes fewer welfare costs, but this may run counter to the intention of the employer providing stock in the first place.

From a plan design perspective, a very natural measure of the cost of company stock to an employee is the magnitude of the diversified match that is welfare equivalent to a given the match in the employer's stock. Table 13 shows the equivalent diversified match for a variety of employer's stock match levels under different stock volatilities and rates of matching account diversification. The benchmark parameterization with medium volatility and statutory diversification shows that the employer could pay a diversified match only 43% to 60% of the company stock match and leave the rational employee indifferent. Thus despite the quite modest welfare cost of company stock matching in consumption terms, the cost to the employer is significant. This is because the employer bears most of the cost late in an employee's career, but consumption at this time is heavily discounted by the impatient employee.

Subjective Discount Rate	*10% p.a.*									*5% p.a.*		
Relative Risk Aversion	*2*			*5*			*10*			*5*		
Stock Volatility	*L*	*M*	*H*	*L*	*M*	*H*	*L*	*M*	*H*	*L*	*M*	*H*
50c Match – Diversify at Retirement	0.1	0.2	0.4	0.6	0.8	1.0	1.7	1.8	2.0	1.6	2.0	2.4
- Statutory Diversification	0.1	0.2	0.3	0.5	0.6	0.9	1.5	1.7	2.0	1.3	1.6	2.2
- Diversify 10% per 5 years	0.1	0.1	0.2	0.3	0.4	0.7	1.0	1.2	1.5	0.7	1.0	1.5
- Diversify 25% per 5 years	0.0	0.1	0.1	0.2	0.3	0.4	0.6	0.8	1.1	0.4	0.6	1.0
- Diversify 100% per 5 years	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.4	0.7	0.1	0.2	0.4
$1 Match – Diversify at Retirement	0.3	0.5	0.7	1.2	1.4	1.8	2.7	2.9	3.2	3.1	3.6	4.4
- Statutory Diversification	0.2	0.3	0.6	0.9	1.2	1.6	2.4	2.7	3.2	2.6	3.2	4.0
- Diversify 10% per 5 years	0.2	0.3	0.5	0.7	0.9	1.3	1.7	2.0	2.6	1.6	2.1	2.9
- Diversify 25% per 5 years	0.1	0.2	0.3	0.4	0.6	0.9	1.2	1.5	2.1	0.9	1.3	2.1
- Diversify 100% per 5 years	0.0	0.1	0.2	0.3	0.3	0.6	0.7	1.0	1.5	0.0	0.2	0.7
3% Fixed Contribution – Diversify at Retirement	0.2	0.3	0.5	0.5	0.6	0.8	0.6	0.7	0.8	0.5	0.6	0.8
- Statutory Diversification	0.1	0.2	0.4	0.4	0.5	0.7	0.5	0.6	0.7	0.4	0.5	0.7
- Diversify 10% per 5 years	0.1	0.2	0.4	0.4	0.5	0.7	0.5	0.6	0.7	0.4	0.5	0.7
- Diversify 25% per 5 years	0.1	0.2	0.3	0.3	0.4	0.6	0.4	0.5	0.6	0.3	0.4	0.6
- Diversify 100% per 5 years	0.0	0.1	0.1	0.1	0.2	0.3	0.2	0.3	0.4	0.1	0.1	0.3

Table 12: Consumption Measure of Efficiency Loss from Employer Stock Match
Percentage of additional annual consumption required to make an employee receiving matching contributions invested in a diversified fund indifferent to having those matching contributions invested in the employer's stock instead. Calibration parameters are described in section 3.4.

The interaction of the age of the employee and the diversification schedule plays an important role in determining the value of company stock. If the employer is very liberal with the restrictions on diversifying company stock, the lifetime welfare cost is small even for high levels of risk aversion or low levels of subjective impatience as table 12 confirms. At the other extreme the employer can restrict diversification until near the employee's retirement and impose significant costs on the employee. In the latter case, the employee's value for company stock becomes much more age dependent because it is the time to retirement that determines the accessibility of the company stock.

A consideration in measuring the inefficiency of company stock contributions is that the marginal dollar contributed will always be worth less than the average value of the total contribution. In some instances, the marginal value is the more relevant measure of inefficiency. The marginal value can be defined in a variety of ways, but here it is the amount of discretionary retirement wealth required to compensate for a small reduction in employer contribution account.[34] This is derived from partial derivatives of the value function

$$dV_t\left(Z_{Lt},Z_{Rt},Z_{Mt}\right) = \frac{\partial V_t\left(Z_{Lt},Z_{Rt},Z_{Et}\right)}{\partial Z_{Et}}\left(-dZ_{Et}\right) + \frac{\partial V_t\left(Z_{Lt},Z_{Rt},Z_{Et}\right)}{\partial Z_{Rt}}dZ_{Rt} \qquad (16)$$

The objective is to find the dZ_{Rt} per unit of $-dZ_{Et}$ such that $dV_t = 0$, i.e.

$$\left.\frac{dZ_{Rt}}{dZ_{Et}}\right|_{U=\bar{U}} = \frac{\partial V_t}{\partial Z_{Et}} \Big/ \frac{\partial V_t}{\partial Z_{Et}} \qquad (17)$$

[34] The value of the employee contribution account could also be measured relative to liquid wealth

Stock Match (cents per $1 employee contribution)		*10*	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*	*100*
Equivalent Match in Cash											
Low Stock Volatility	Diversify at Retirement	6	11	16	20	24	27	31	34	37	40
	Statutory Diversification	7	13	19	24	30	35	40	44	49	53
	10% per 5 years	8	15	23	30	36	43	49	56	62	68
	25% per 5 years	9	17	26	34	42	50	58	66	74	81
	100% per 5 years	9	19	28	37	46	55	64	73	81	90
Medium Stock Volatility	Diversify at Retirement	5	9	12	16	19	21	24	27	29	31
	Statutory Diversification	6	11	16	20	25	29	33	36	40	43
	10% per 5 years	7	14	20	26	32	38	43	48	54	59
	25% per 5 years	8	16	24	32	39	46	53	60	67	74
	100% per 5 years	9	18	27	36	44	53	62	70	78	86
High Stock Volatility	Diversify at Retirement	3	5	7	9	10	12	13	14	15	17
	Statutory Diversification	4	7	11	13	16	18	21	23	25	27
	10% per 5 years	6	11	16	20	24	28	32	35	39	42
	25% per 5 years	7	14	21	27	32	38	43	48	53	58
	100% per 5 years	9	18	26	33	40	47	55	62	69	76

Table 13: Diversified Match Equivalent to a Match in Restricted Employer's Stock
Equivalent diversifiable match to a given employer stock match for an employee receiving stock contributions to her matching account over her entire life under various model parameterizations. Calibration parameters are described in section 3.4.

The marginal value of the employer contribution account is reported in table 14 for various plan parameters assuming the employer makes matching contributions (results for fixed contributions are similar). The reported values are the average marginal values based on life-cycle simulations from initial conditions. The inefficiency associated with employer contributions arise from the incremental illiquidity of the employer contribution account and the investment of that account in the employers stock, an unrewarded risk. These two factors are decomposed by reporting separate results for matching contributions that are diversified, so that the private value reflects only the incremental illiquidity of the employer contribution account over the discretionary retirement account. Table 14 suggests that the effect of incremental illiquidity alone is quite modest relative to the inefficiency of investing contributions in the employers stock. For the benchmark calibration, an employee receiving a 50c match in stock with diversification allowed only at retirement places a marginal value on an incremental dollar in the matching account of only 16 cents worth of discretionary retirement wealth when young, rising to 65 cents in the 5 years prior to retirement. For a $1 match in stock the marginal value is even lower, ranging from 10 cents when young to 52 cents just prior to retirement. For more liberal diversification opportunities, the value of the matching account is much higher and more constant through time.[35] Intuitively, the greater the volatility of the stock the lower the value of the matching account (doubling the degree of risk aversion has a similar impact to so it is not reported).

[35] The marginal value of the matching account under liberal diversification opportunities is overstated slightly due to the simplifying assumption that the matching account funds are transferred to the discretionary account when they become diversifiable making them available for withdrawals prior to retirement. In reality, matched funds from the employer even once diversified cannot be withdrawn prior to retirement unless the employee changes jobs.

Match Size	50c Match						$1 Match					
Age	35-39	40-44	45-49	50-54	55-59	60-64	35-39	40-44	45-49	50-54	55-59	60-64
Diversified Match												
Retirement	0.91	0.92	0.94	0.96	0.97	0.98	0.78	0.78	0.83	0.88	0.91	0.94
Statutory	0.94	0.95	0.97	0.99	0.99	0.99	0.85	0.86	0.91	0.95	0.96	0.98
10% per 5 years	0.98	0.98	0.99	0.99	0.99	0.99	0.93	0.93	0.95	0.97	0.98	0.99
25% per 5 years	0.99	0.99	0.99	0.99	0.99	0.99	0.97	0.96	0.97	0.99	0.99	0.99
100% per 5 years	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	1.00	1.00
Match in Stock (Low Volatility)												
Retirement	0.24	0.26	0.30	0.38	0.51	0.70	0.15	0.17	0.20	0.26	0.38	0.58
Statutory	0.38	0.41	0.47	0.58	0.64	0.77	0.30	0.32	0.37	0.47	0.52	0.66
10% per 5 years	0.66	0.63	0.62	0.62	0.67	0.79	0.58	0.56	0.53	0.52	0.56	0.69
25% per 5 years	0.81	0.80	0.78	0.77	0.79	0.86	0.76	0.74	0.72	0.70	0.71	0.79
100% per 5 years	0.90	0.91	0.91	0.90	0.90	0.92	0.86	0.89	0.88	0.87	0.87	0.89
Match in Stock (Medium Volatility)												
Retirement	0.16	0.18	0.21	0.29	0.42	0.65	0.10	0.11	0.14	0.20	0.31	0.52
Statutory	0.27	0.30	0.37	0.48	0.54	0.70	0.21	0.23	0.28	0.39	0.43	0.58
10% per 5 years	0.58	0.55	0.52	0.52	0.57	0.72	0.50	0.47	0.44	0.43	0.46	0.61
25% per 5 years	0.75	0.73	0.70	0.69	0.70	0.78	0.68	0.66	0.63	0.60	0.60	0.69
100% per 5 years	0.86	0.88	0.87	0.86	0.85	0.87	0.81	0.84	0.83	0.81	0.80	0.82
Match in Stock (High Volatility)												
Retirement	0.05	0.07	0.09	0.14	0.25	0.54	0.03	0.04	0.06	0.09	0.18	0.40
Statutory	0.11	0.15	0.21	0.33	0.37	0.57	0.08	0.11	0.15	0.25	0.28	0.43
10% per 5 years	0.43	0.41	0.38	0.37	0.39	0.59	0.36	0.34	0.31	0.29	0.31	0.45
25% per 5 years	0.62	0.60	0.56	0.53	0.52	0.64	0.52	0.49	0.47	0.43	0.42	0.51
100% per 5 years	0.77	0.79	0.77	0.75	0.74	0.74	0.69	0.71	0.68	0.65	0.63	0.63

Table 14: Marginal Value of One Dollar in the Matching Account Relative to 1 Dollar in the Discretionary Account
Each column of reported values reflect the employee's marginal valuation for a 50c or $1 match to the matching account at age-specific average levels of wealth relative to income. Each row of the table reports the marginal value for a given type of match (Diversified Equity or Employer's Stock) and a given diversification rule (at Retirement, according to the maximum allowed under Statutory rules, 10% of balances each 5 years, 25% of balance each 5 years and 100% of balance each 5 years). Calibration parameters are described in section 3.4.

3.5.3 Human Capital and Company Stock

To this point it has been assumed that there is a fixed association between the company stock return and the transitory innovations to the employee's labor income process via the bankruptcy and unemployment event. Specifically there is a 1% p.a. chance that the employee will suffer an unemployment spell coinciding with bankruptcy of the employer, but there is no link between permanent income shocks and stock performance. Table 15 reports the marginal valuation of matched employer stock relative to $1 of retirement account wealth across three alternative assumptions about the association between human capital and employer stock. The first assumption is that there is no link between firm bankruptcy and unemployment but overall volatilities of company stock returns and income shocks are maintained. While this actually lowers lifetime consumption cost of receiving a company stock match instead of a diversified match, the marginal value of the stock actually drops because the employee actually contributes more to their retirement account and as a result accumulates more stock in the employer contribution account.[36] The second alternative increases the annual probability of simultaneous bankruptcy and unemployment to 2% per annum. Surprising, this leads to a negligible reduction in lifetime welfare and lowers the marginal private value of company stock contributions only slightly.[37] The third assumption is that on top of the 1% disaster state, permanent income shocks are correlated with the idiosyncratic component of stock returns, but again maintaining overall volatilities. This would be especially true in skilled industries where employees have firm specific human capital (or receive labor compensation related to firm performance). With a correlation of 0.5 this leads to quite a large reduction in the marginal private value of company

[36] If the risk of bankruptcy is not associated with an unemployment spell for the focal case the lifetime consumption cost an employee would willingly pay to receive diversified instead of employer stock matches falls from .7% to .4% for a 50c match and from 1.4% to 1.1% for a $1 match assuming stock cannot be diversified until retirement.

[37] Welfare is similarly insensitive to a 4% probability of the disaster state. More severe welfare consequences associated with this type of disastrous shock can only occur if the income shock during unemployment is much larger than the 60% drop assumed.

stock contributions, and actually has a larger negative welfare impact under more generous diversification rules.[38] All of these alternatives are large departures from the benchmark association between asset returns and income shocks yet yield very small changes in lifetime welfare measured in consumption terms.

	50c Match						*$1 Match*					
Age	*35-39*	*40-44*	*45-49*	*50-54*	*55-59*	*60-64*	*35-39*	*40-44*	*45-49*	*50-54*	*55-59*	*60-64*
Diversify at Retirement												
Benchmark	0.16	0.18	0.21	0.29	0.42	0.65	0.10	0.11	0.14	0.20	0.31	0.52
No Association	0.08	0.10	0.12	0.17	0.27	0.56	0.04	0.06	0.08	0.11	0.20	0.41
2% bankruptcy	0.09	0.12	0.16	0.23	0.37	0.62	0.05	0.07	0.10	0.15	0.27	0.50
0.5 Correlation	0.03	0.05	0.08	0.16	0.29	0.54	0.02	0.03	0.06	0.12	0.23	0.46
Diversify after 5 years												
Benchmark	0.86	0.88	0.87	0.86	0.85	0.87	0.81	0.84	0.83	0.81	0.80	0.82
No Association	0.83	0.84	0.82	0.80	0.78	0.76	0.74	0.76	0.73	0.70	0.67	0.66
2% bankruptcy	0.85	0.79	0.79	0.80	0.79	0.82	0.85	0.79	0.75	0.73	0.72	0.75
0.5 Correlation	0.58	0.55	0.59	0.60	0.63	0.68	0.57	0.53	0.57	0.58	0.59	0.64

Table 15: Marginal Value of the Matching Account Under Alternative Human Capital and Bankruptcy Assumptions
The table captures the employee's marginal value of $1 of company stock in the matching account relative to $1 in the discretionary account measure at average levels of wealth to income under alternative assumptions about the correlation between company stock returns and employee labor income. Calibration parameters are described in section 3.4.

3.6 CONCLUSION

The preceding analysis reveals that from the perspective of maximizing lifetime employee welfare compensating employees with retirement account contributions invested in company stock is highly inefficient, particularly when it is accompanied by long dated holding requirements. For realistic parameter values a rational risk-averse employee would willingly accept a diversified matching contribution that is 40 to 50 percent of a given match in the

[38] Annual consumption equivalent to receiving stock instead of diversified employer contributions rise by 0.2% when diversification is restricted until retirement, but rise by 0.5% when diversification is allowed after 5 years.

company's stock when such holdings must be maintained until retirement. For the marginal dollar of stock contributed to the account, the value is even lower. For instance, with a plan that matches employee contributions dollar for dollar with company stock, the marginal value of the restricted stock for an age 30 employee is only 16 cents worth of completely discretionary retirement wealth. On the other hand a firm that provides much more liberal diversification opportunities significantly reduces the inefficiency of stock compensation. A 5 year holding requirement increases the welfare equivalent diversified matching contribution to 85 to 90 percent of the matching in company stock.

The foundation of the analysis is the assumptions that (i) employees should be unwilling to take unrewarded risks and (ii) that employer stock holding is an unrewarded risk because it is dominated from a risk-return perspective by a more diversified investment in equities. These assumptions ensure the lifetime welfare costs in consumption terms estimated from the benchmark model calibrations are small (1% p.a. or less) because an employee typically avoids excessive consumption volatility concentrations as a result of holding company stock by selling it whenever possible or by adjusting discretionary portfolio choices and retirement account contributions. However, the extraordinary level of voluntary company stock holdings (and the corresponding failure to sell them) observed among a large subset of US households is a significant challenge to the first assumption if the second assumption is true. It is very difficult to motivate voluntary company stock holdings from a purely investment perspective, and it is likely that the answer lies with employee loyalty, ignorance about the nature of stock returns and inertia when it comes to selling existing holdings of stock. It is clear that by holding their company's stock employees expose themselves to additional unrewarded variation in lifetime consumption.

It is also puzzling that a firm would consider compensating employees with company stock using a broad based compensation mechanism when there is at least some subset of employees aware that company stock is a poor investment from a risk taking perspective. Perhaps many firms view company stock as a cheap form of compensation because stock can be issued directly to employees without draining a firm's cash reserves, an argument that relies on the notion that raising external finance is costly. In the case of firms that use ESOP accounts to hold matching contributions in company stock, there is also a tax motivation to match with company stock because the dividends paid on stock held by employees in the ESOP is an allowable deduction for the firm, whereas dividends paid on stock held by outsiders is not. Alternatively, a firm may believe that more productive employees have a higher marginal valuation for the company's stock. In this case, stock compensation effectively discriminates in favor of these employees and may discourage less productive employees from joining or remaining with the firm. Such an explanation is problematic because the marginal valuation of an employee also depends on factors unrelated or even negatively related to productivity such as how much stock the employee already holds, the age or tenure of the employee (when diversification is age or tenure based) and ignorance about the risk of stock. In sum, it would hard to justify these benefits relative to the welfare loss due to diversification considerations under long dated holding periods. Even if short dated holding periods can be justified it remains questionable that retirement accounts are the appropriate vehicle for company stock ownership as opposed to other tax favored employee ownership vehicles.

A variety of other factors not explicitly considered in this chapter would have an impact on the evaluation of employer contributions invested in company stock. The model does not allow for endogenous labor separation or retirement timing decisions that would reduce welfare costs associated with large concentrations of company stock.[39] The model also excludes other forms of illiquid assets such as real estate and businesses. The family home in particular is an important asset to many households. Homeownership will tend to crowd out other assets and so is likely reduce the share of consumption derived from company stock, but homeownership has its own financial risks that may make additional financial risk taking less desirable. Another simplifying assumption is that retirement plans are static over the lifetime of the employee, whereas in reality the employer has discretion to change plan parameters over time and each time an employee moves from one job to another they are entitled to sell their company stock stake and will typically enroll in a new plan. To the extent that employees experience enrollment in retirement plans without being compelled to hold company stock, the lifetime welfare loss will be reduced. Finally, vesting rules are applied in a large number of private plans leading to forfeiture of some or all of the employer contributions received by an employee who separates the firm before certain tenure requirement are met (this minimum period can be as long as 5 years under current regulations). This will make retirement accounts less attractive to all

[39] For instance, an employee that separates or retires from their firm has the right to sell their holding of company stock provided they are vested. Delaying retirement would also lower the financial cost associated with poor performance of the company stock.

employees yet to meet the tenure requirements irrespective of whether the firm compels the employer contribution to be invested in company stock.

While this chapter has focused on welfare associated with company stock holdings in retirement accounts, straightforward variations of the basic model structure would allow for a more general analysis of retirement plan design and optimal retirement plan choices. Choi et al (2004a) report inertia and procrastination among employees enrolled in 401(k) plans. The life-cycle model can shed light on how costly such decisions are in terms of lifetime consumption. The model predicts that optimal retirement plan participation and contribution levels are associated with observable employee characteristics such as age, income risks and the relative levels of retirement to liquid wealth as well as plan designs such as the employer contribution formulas. Including vesting rules would also add a tenure dimension to an employee's retirement plan decisions. From the firms perspective, in addition to deciding on employer contributions a firm must make decisions about plan liquidity (such as allowing loans and withdrawals), vesting rules, investment options and enrollment rules subject to meeting the non-discrimination provisions of tax qualified retirement plan.

CHAPTER 4: THE PRIVATE VALUE OF CONSTRAINED INVESTMENTS IN STOCK COMPENSATION PLANS

4.1 INTRODUCTION

Many US corporations offer broad based stock compensation plans to their employees. As of 2005, The National Center for Employee Ownership estimates there were over 20,000 such plans covering approximately 30 million employees. A conservative estimate of the market value of stock entitlements in these plans is $600 billion.[1] While this is a modest share of the aggregate value of the $15 trillion US stock market, for many employees the stock acquired in these plans is a significant share of their financial assets. The most popular types of plans are: Employee Stock Purchase Plans where employees have the option to purchase stock at a discount; Employee Stock Ownership Plans a tax favored retirement vehicle invested primarily in employer securities; Employee Stock Option Plans where employee receive the valuable right to purchase stock in the future; and Restricted Stock Bonus Plans where employees receive stock grants that cannot be sold for a period of time. Many of these plans receive favorable tax or accounting treatment.

Unfortunately, giving or selling stock to employees promotes inefficient risk taking. Maintaining a large exposure to any individual company stock necessitates bearing diversifiable firm specific risk that, if financial markets are functioning efficiently, is on average not rewarded. An employer's stock is even more risky if wage or employment shocks are associated

[1] This figure excludes stock held exclusively in executive compensation schemes.

with poor stock performance. Consequently, employees should privately value their stock entitlement in these plans below market value. Unless an employee is provided with additional compensation for deferring sale of stock it should be sold as soon as possible.

Employee or employer decisions about stock compensation should correctly recognize the risk of holding employer stock. However, survey evidence and observed behavior suggests that employees are largely ignorant of this risk.[2] Even when employees do recognize that holding individual stocks is risky, there may be a tendency to ignore the impact of other sources of wealth due to mental accounting or framing issues.[3] This suggests a need for a simple analytical framework for valuing stock entitlements in stock compensation plans.

This chapter derives relatively simple closed form expressions for the private value an employee should attach to exogenously determined entitlements in stock compensation plans.[4] Unlike Meulbroek (2002) who combines the capital asset pricing model with a simple leverage argument to establish an appropriate discount factor to apply to a given market value of company stock, the private value is derived in this chapter from a simple welfare based comparison of future wealth under competing constrained and diversified portfolios. This approach has the

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[2] For example, in a survey of employees Utkus and Waggonner (2003) document ignorance of the risk of stock held in retirement plans.

[3] See Thaler (1999) for a discussion of the evidence and implications of mental accounting for portfolio choices.

[4] Strictly speaking, the methodology only applies to valuation of stock rather than stock options. Stock options have dynamically changing risk making valuation more challenging.

advantage of incorporating individual employee risk aversion and specific risk factors such as human capital into the valuation.

Intuitively, the private value decreases with an increase in any of four key factors: the degree of employee risk aversion, the length of the holding period, the share of wealth invested in the stock and the magnitude of diversifiable firm specific risk. In addition, factoring in plausible bankruptcy risk associated with a shock to human capital (such as job loss) or, more generally, correlation between wages and stock specific performance lowers the private value of the stock. The effect of plausible bankruptcy risk is surprisingly modest, even for highly risk-averse employees. For standard levels of risk aversion, a 25% share of financial wealth invested in stock and plausible structural parameters the holding period dependant private value varies between \$0.965 for a one-year holding period and \$0.701 cents per dollar for a 10-year holding period (approximately corresponding to a 1.4% penalty to the annual rate of return on the stock).

The risk of employee stock compensation plans has been studied previously, but usually in the context of specific plan structures. Kahl, Liu and Longstaff (2003) study the private value of stock granted in restricted stock plans incorporating income risks, saving and portfolio choice. Endogenous saving and portfolio choices can help to offset the welfare cost of holding stock. Similarly, rational participation in Employer Stock Ownership Plans is considered in chapter 3 in the context of lifetime retirement saving. Engelhardt and Madrian (2004) look at the value of employee stock purchase plans to employers and employees. They weigh up the tax benefits of providing and participating in stock purchase plans, but purely from a tax arbitrage perspective. In particular, they ignore the incentive for employees to defer sale of stock held in these plans and how this trades off against the risk of holding stock. Degeorge, Jenter, Tufano and Moel (2004) examine a French stock purchase plan where stock purchased at a discount could not be sold for several years. They demonstrate the effect of risk on optimal investment in the plan, but point out that failure to participate in such plans appears to be more a function of ignorance than risk aversion. The effect of firm specific risk on the value of executive and employee stock options is analyzed in Meulbroek (2001). There is also a growing awareness of the importance of the trade off between executive risk aversion and incentives in the voluminous literature on executive compensation (see for example Hallock (1998), Aggarwal and Samwick (1999), Hall and Murphy (2002)).

The remainder of the chapter proceeds as follows. Section 2 derives the basic closed form for the private value of acquired stock in the case that employee's future wealth is comprised of just two assets: the employer stock and a diversified mutual fund. Section 3 relaxes the portfolio rebalancing assumption critical to obtaining the closed form results. This has a large impact on an employee's private value for company stock when risk aversion is high or holding periods are long. Section 4 demonstrates that adding a risk free asset and assuming it is optimally combined with the diversified fund as part of a discretionary portfolio has no effect on the private value of the exogenous stock entitlement. Section 5 derives the closed form for the private value in the presence of non-tradable risky human capital, which is treated as a third asset with randomly fluctuating value. Even a low level of correlation between human capital and firm specific stock risk can have a significant effect on the private value of the stock. Section 6 incorporates bankruptcy risk with simultaneous shocks to stock price and human capital and considers two applications. Section 7 concludes.

4.2 UTILITY BASED FRAMEWORK FOR ASSESSING THE PRIVATE VALUE OF STOCK COMPENSATION

This section outlines the utility based approach for valuing the exposure to idiosyncratic risk of constrained undiversified positions to a single security. The mathematical treatment of this section simplifies the stochastic calculus required to generate the results. More detailed derivations of the results of this and subsequent sections are contained in appendix C.

Assume the employee invests initial wealth W in a portfolio until some terminal date T. The portfolio comprises a position in two assets: a single stock (S) and an "efficiently diversified" risky asset (D). The prices of these assets are assumed to obey logarithmic Brownian motion. The gross rate of return on each asset over a discrete period of time satisfies

$$1 + r_D = R_D \tag{18}$$

$$1 + r_S = R_D Z_S \tag{19}$$

where

$$\ln R_D \sim N\left(\mu - \sigma_D^2 / 2, \sigma_D^2\right) \tag{20}$$

$$\ln Z_S \sim N\left(-\sigma_S^2 / 2, \sigma_S^2\right) \tag{21}$$

$$R_D, Z_S \text{ independent}$$

These assumptions are consistent with efficient pricing of individual stocks relative to diversified portfolios in the Capital Asset Pricing Model. Asset S has total variation of return equal to $\sigma_D^2 + \sigma_S^2$, comprising non-diversifiable risk equal to the total risk of asset D and diversifiable risk. Only non-diversifiable risk is rewarded in equilibrium, so asset S earns the same rate of return as asset D, namely μ per period. These assumptions exclude the possibility that an employee has inside information about his employer's stock or that employee ownership affects the productivity, and hence, profitability of the company.

Under the assumptions in through , combining S in a portfolio with D will increase the portfolio risk relative to investment in D alone without increasing its expected return. Thus, for any investor with risk-averse expected utility function defined over terminal wealth, it is easy to demonstrate that the optimal investment in S is zero.[5] Any constrained holding of S imposes a welfare cost on the investor. A tractable analytic measure of employee welfare is most easily established for the case of an iso-elastic utility function, $U(W_T)$, defined over portfolio wealth, W_T, at some future date T:

$$U\left(W_T\right) = \left[E_0\left(W_T^{1-\gamma}\right)\right]^{\frac{1}{1-\gamma}} \tag{22}$$

Where γ is the coefficient of relative risk aversion, E_0 is the expectations operator conditioned on prices and wealth at time 0. Combining the iso-elastic utility assumption with asset prices that obey Geometric Brownian motion with fixed mean and variance implies fixed portfolio shares are optimal regardless of the level of initial wealth or investment horizon.[6]

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[5] This follows from the concavity of an expected utility function and the (log) second order stochastic dominance of asset D over asset S. Kroll and Levy (1980), Gollier (2001) and Samuelson (1967) also demonstrate related results on the value of diversification.

Suppose investments in the two assets are held in constant proportion and continuously rebalanced over time. Portfolio wealth at any point in time is log-normally distributed (see appendix C)

$$\ln W_t \sim N\left\{\mu_{W,t}, \sigma^2_{W,t}\right\} \tag{23}$$

where

$$\mu_{W,t} = \ln W + \mu t - \left[\sigma^2_D + w\sigma^2_S\right] t/2 \tag{24}$$

$$\sigma_{W,t} = \left[\sigma^2_D + w\sigma^2_S\right] t \tag{25}$$

A standard result for moments of powers of a lognormal variable allows $U(W_T)$ to be written as

$$U(W_T) = \exp\left[\mu_W + \frac{1}{2}(1-\gamma)\sigma^2_W\right] \tag{26}$$

Substituting for the mean and variance of $\ln W_t$ gives a final expression for the utility function. This is referred to as the value function (V) and takes as arguments the employees initial wealth (W) and the share (w) invested in the single stock

$$V(W,w) = W\exp\left\{\mu T - \frac{\gamma T}{2}\left(\sigma^2_D + w^2\sigma^2_S\right)\right\} \tag{27}$$

A simple metric for comparing a constrained position in the single stock with a completely diversified portfolio is the fraction of initial wealth an employee would willingly take

[6] See Merton (1968) for the classic treatment with time separable utility over consumption and Campbell and Viceira (2002) for the case of utility defined over terminal wealth.

in exchange for replacing a position w in the single security with the diversified asset. Given the value function $V(W,w)$, we seek

$$V(W,w) = V\left(xW,0\right) \tag{28}$$

The solution for x is simply expressed as

$$x = \exp\left(- \frac{T\gamma\, w^2\sigma_S^2}{2} \right) \tag{29}$$

The welfare equivalent, x, is bounded between zero and one, decreasing in risk aversion, the portfolio share of the stock, the idiosyncratic risk of the stock and the length of the time the stock must be held. The amount the investor would give up to avoid the position in S is $1 - x$ and can be larger than its initial investment share w, implying the investor would be willing to give up more than the current market value of the single stock to avoid it. This result follows from the portfolio rebalancing assumption. If the stock performs poorly relative to the diversified asset then more of it will be purchased under the rebalancing assumption, subjecting more wealth to the idiosyncratic risk of the stock than the initial investment in it (the impact of rebalancing is discussed in the next section).

In the context of a rebalanced portfolio, a natural measure of welfare is the constant return premium, k, required to welfare compensate the holding of the single stock. In this case, k should satisfy

$$W \exp\left\{ \mu T + wkT - \frac{\gamma T}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right) \right\} = W \exp\left\{ \mu T - \frac{\gamma T}{2}\sigma_D^2 \right\} \tag{30}$$

Where the expression on the left hand side is the value function when the investor holds fraction w in S but earns an excess return of k per period in compensation for holding it and the expression on the right hand side is the value function when the employee is well diversified. Solving for k

$$k = \frac{\gamma w \sigma_S^2}{2} \tag{31}$$

This can be used to generate a private value for \$1 worth of stock over any given holding period. A one dollar investment in the single stock would have expected value exp[μT] in T periods time. Given the employees required premium, k, in addition to its market rate of return μ, the appropriately discounted value of this expected future promise is:

$$Q \equiv \exp\left[\mu T - (\mu + k)T\right] = \exp\left[-\frac{\gamma w \sigma_S^2 T}{2}\right] \tag{32}$$

Q can be interpreted as the private discount factor, or private value, an investor should apply to constrained holdings of the single stock. Like x, Q is bounded between 0 and 1, decreasing in risk aversion, the portfolio share of the stock, the idiosyncratic risk of the stock and the length of the time the stock must be held. Meulbroek (2002) derives a similar expression for the private value using Merton's (1971) continuous time CAPM. While Meulbroek's estimate does not explicitly depend on employee risk aversion, the level of risk aversion is implied by the assumed market risk premium and optimal investment share between risk free and diversified risky assets in the absence of constrained single stock holding (see appendix D for more detail).

Table 16 below reports estimates of the private value in comparison with Meulbroek's estimate for a variety of empirically plausible parameters.

The private value responds identically to a proportional increase to any of: risk aversion, holding period, the variance of the idiosyncratic component of the stock return and the portfolio share of the stock. Private values vary a great deal over a plausible range of parameters. Thus, the appropriate value may be both individual and context specific.

		Preference Based Private Value			*Meulbroek's Equivalent*		
w	*T*	$\gamma = 10$	$\gamma = 5$	$\gamma = 2.5$	$\gamma = 10$	$\gamma = 5$	$\gamma = 2.5$
1	20	0.000	0.000	0.014	0.000	0.000	0.002
1	10	0.000	0.014	0.119	0.000	0.002	0.048
1	5	0.014	0.119	0.346	0.002	0.048	0.219
1	2.5	0.119	0.346	0.588	0.048	0.219	0.468
0.5	20	0.000	0.014	0.119	0.000	0.002	0.048
0.5	10	0.014	0.119	0.346	0.002	0.048	0.219
0.5	5	0.119	0.346	0.588	0.048	0.219	0.468
0.5	2.5	0.346	0.588	0.767	0.219	0.468	0.684
0.25	20	0.014	0.119	0.346	0.002	0.048	0.219
0.25	10	0.119	0.346	0.588	0.048	0.219	0.468
0.25	5	0.346	0.588	0.767	0.219	0.468	0.684
0.25	2.5	0.588	0.767	0.876	0.468	0.684	0.827
0.1	20	0.183	0.427	0.654	0.088	0.297	0.545
0.1	10	0.427	0.654	0.809	0.297	0.545	0.738
0.1	5	0.654	0.809	0.899	0.545	0.738	0.859
0.1	2.5	0.809	0.899	0.948	0.738	0.859	0.927

Table 16: Private Value of Constrained Position in Single Security
Reported private per dollar of market value for various parameters. Idiosyncratic stock volatility is $\sigma_S = 0.41$. Q is calculated from the preference based valuation in equation (32) and Meulbroek's CAPM based method is derived in Appendix D.

4.3 PRIVATE VALUE WITHOUT REBALANCING

The rebalancing assumption made in section 2 is useful because it allows closed form calculation of the welfare cost and private value of employer stock. Of course, this assumption requires the market value of the single stock and diversified assets remain in constant proportion over the horizon. If the value of the single stock declines in value relative to the diversified asset then more of the single stock is purchased with proceeds from selling a corresponding market value of the diversified asset (the opposite happens if the single stock's value increases relatively). Thus rebalancing imposes an additional welfare cost on the employee, which should lower the private value of the stock grant. To assess the size of this incremental cost, consider an employee facing a fixed and non-rebalanced investment of their portfolio in the single stock.

As in section 2, assume that at time 0, fraction w of initial wealth, W, is invested in the single stock and fraction $1 - w$ in the diversified asset. Subsequent to the initial investment being made, the portfolio composition fluctuates according to the changes of relative value of the individual assets. Wealth at any instant in time is now the sum of two lognormally distributed random variables. The employee's value function is again the expected utility over terminal wealth, W_T

$$V(W,w) = E_0 U(W_T) = WE\left\{\left[(1-w)(R_D)^T + w(R_D Z_S)^T\right]^{1-\gamma}\right\}^{\frac{1}{1-\gamma}} \tag{33}$$

Where R_D and Z_S are defined as in equations (18) to (19). Factoring out terms involving R_D and using the independence of R_D and Z_S

$$V(W,w) = WE\left\{R_D^{\,T(1-\gamma)}\right\}^{\frac{1}{1-\gamma}} E\left\{\left[(1-w) + w(Z_S)^T\right]^{1-\gamma}\right\}^{\frac{1}{1-\gamma}} \tag{34}$$

Using the well known result for moments of log-normal random variables reduces the first expectation to a simpler expression

$$V(W,w) = W\exp\left(T\mu - \gamma T\sigma_D^2/2\right)E\left\{\left[\left(1-w\right)+w\left(Z_S\right)^T\right]^{1-\gamma}\right\}^{\frac{1}{1-\gamma}} \tag{35}$$

Unfortunately there is no simple closed form reduction for the second expectation, but it can be computed numerically in a straightforward manner. The welfare equivalent fraction of wealth x_{NR} satisfies

$$x_{NR} = E\left\{\left[\left(1-w\right)+w\left(Z_S\right)^T\right]^{1-\gamma}\right\}^{\frac{1}{1-\gamma}} \tag{36}$$

An expression for *k*, and hence *Q*, cannot be derived analogously to equation (32) since *k* is time varying in the continuously rebalanced context due to the changing portfolio composition over time. Instead, the private value of the initial investment in the stock can be arrived at more directly. The employee would willingly accept a diversified portfolio worth xW to avoid holding position w in the employers stock. Subtracting from this the market value of the diversified position in the original portfolio $(1 - w)W$ gives the private value the employee attributes to the stock. Dividing by the market value wW yields the private value of the stock per dollar of market value

$$Q = [x - (1 - w)] / w \tag{37}$$

Table 17 compares the private value of stock under the non-rebalanced and rebalanced cases for a variety of parameters.[7] The rebalanced welfare equivalent consistently overstates the welfare loss of the non-rebalanced case and there can be considerable disparity between the two. The difference is small for low levels of risk aversion and short holding periods, so approximating the private value of the non-rebalanced case with the simpler to calculate private

[7] Changing variance of the idiosyncratic stock return is equivalent to changing T.

value of the rebalanced case may be reasonable in some contexts. The difference is also small for any set of parameters where w is close to zero or one, although these cases are less interesting.

w	T	$\gamma = 10$ Non-Rebal.	$\gamma = 10$ Rebal.	$\gamma = 5$ Non-Rebal.	$\gamma = 5$ Rebal.	$\gamma = 2.5$ Non-Rebal.	$\gamma = 2.5$ Rebal.
1	20	0.000	0.000	0.000	0.000	0.014	0.014
1	10	0.000	0.000	0.014	0.014	0.119	0.119
1	5	0.014	0.014	0.119	0.119	0.345	0.345
1	2.5	0.119	0.119	0.345	0.345	0.588	0.588
0.5	20	0.130	0.000	0.196	0.014	0.294	0.119
0.5	10	0.234	0.014	0.340	0.119	0.478	0.346
0.5	5	0.366	0.119	0.506	0.346	0.652	0.588
0.5	2.5	0.520	0.346	0.666	0.588	0.790	0.767
0.25	20	0.220	0.014	0.312	0.120	0.428	0.346
0.25	10	0.368	0.120	0.492	0.346	0.628	0.589
0.25	5	0.532	0.346	0.664	0.589	0.780	0.768
0.25	2.5	0.680	0.589	0.796	0.768	0.880	0.874
0.1	20	0.350	0.183	0.460	0.425	0.580	0.651
0.1	10	0.540	0.425	0.660	0.651	0.770	0.809
0.1	5	0.700	0.651	0.810	0.809	0.880	0.895
0.1	2.5	0.830	0.809	0.900	0.895	0.940	0.951

Table 17: Private Value with Rebalanced versus Non-Rebalanced Investment in Company Stock
Private value of non-rebalanced (equation 32*)* versus continuously rebalanced investment in company stock (equation 36). Note: $\sigma_D = 0.412$

4.4 PRIVATE VALUE AND OPTIMAL EMPLOYEE LEVERAGE

Intuitively, including a risk free asset in the employee's choice set could allow the employee to offset some of the welfare cost associated with the exposure to the single stock by investing his discretionary portfolio more conservatively. Assume the mean return of both the single stock and the diversified asset is μ per unit of time (as in section 4.2) and the return on the risk free asset is r, with $\mu > r$. Over the horizon, the single stock is held in constant proportion w, the risk free asset in proportion w_F and the diversified asset in proportion $1 - w - w_F$. This gives a value function for the employee depending on arguments W, w and w_F

$$V(W, w, w_F) = W \exp\left\{\left[\, w_F r + \left(1 - w_F\right) \mu \,\right] T - \frac{\gamma T}{2}\left[\left(1 - w_F\right)^2 \sigma_D^2 + w^2 \sigma_S^2\right]\right\} \qquad (38)$$

Assuming a leverage choice (i.e. the portfolio mix between the risk free and diversified assets) is chosen to maximize the welfare of the employee taking as given the fixed investment share in the individual stock of w over the investment horizon then the optimal risk free share w_F is

$$w_F = 1 - \frac{\mu - r}{\gamma \sigma_D^2} \qquad (39)$$

As the exogenous share invested in the single stock increases, the risk free share is unchanged (this result is specific to iso-elastic utility). Thus the presence of the single stock merely serves to crowd out diversified equity holdings. The employee does not overcompensate for the risk of the exposure to the single stock by holding more of the risk free as one might intuit (although as a percentage of the discretionary portfolio the risk free share rises). This is related to more general results on the effects of uncorrelated background risks on risk taking (see Gollier (2001)). The new value function under the optimal leverage choice can be expressed as

$$V(W, w) = \ln W + \left(r + \frac{\left(\mu - r\right)^2}{2\gamma \sigma_D^2} \right) T - \frac{\gamma\, w^2 \sigma_S^2 T}{2} \qquad (40)$$

The measures of the welfare cost and private value of the single stock, x and Q respectively, derived in the previous section also hold here. Optimal leverage has no impact on the welfare cost of the single stock provided the diversified asset is defined such that its variance of return is equal to the variance of the systematic component of the return on the single stock. This result is also true in the presence of human capital as modeled in sections 4.5 and 4.6.

4.5 PRIVATE VALUE AND HUMAN CAPITAL

Only a naïve employee would ignore other sources of wealth when making portfolio choices. Likewise, any evaluation of employee welfare should consider an employee's total wealth. Empirically, labor income, or human capital, is the largest source of wealth for most employees. In the context of any discussion of diversification, income is relevant because it is volatile, it is very difficult to insure or trade against and income shocks may be associated with shocks to the single stock (particularly when the latter is the common stock of the employer).

In the interest of retaining closed form tractability, human capital is treated as a third asset offering a return with known mean, variance and correlations with the other assets and comprises a fixed share of an employee's total wealth. The value of human capital is defined as the present value of the future income stream (i.e. the income stream discounted by an appropriate risk adjusted rate).[8] The simplest case to derive closed form results for is where the employee's total wealth (including human capital) is a continuously rebalanced portfolio of the three assets held in fixed proportions and each asset obeys geometric Brownian motion. Denote human capital by H and assume it pays a periodic return with expected value normalized to 0 and variance σ_H^2.[9] The correlation between the single stock return and the human capital return is ρ_{HS}. The correlation between the diversified asset return and the human capital return is assumed

[8] Given the assumed non-tradability of future income it may not be meaningful to talk about its present value. However, all that is desired is some proxy of the value for future labor income that could be used to offset (or interact with) the risk from holding company stock.

[9] This implies the human capital has a continuously compounded return with mean zero and variance $(\sigma_H)^2$. Welfare results do not depend on the mean zero assumption.

to be zero.[10] The diversified asset and single stock returns have the same distributional properties as in the two asset case. The share of human capital in total wealth is w_H, the share of the single stock is $w_H\, w$ and the share of the diversified asset is $w_H\,(1-w)$. Here, w is interpreted as the share of the employee's *financial* portfolio held in the single stock. The value function in this case depends on three arguments (W, w and w_H)

$$V(W,w,w_H) = \ln W_0 + (1-w_H)\mu T - \frac{\gamma T}{2}\begin{bmatrix} w_H^2\sigma_H^2 + (1-w_H)^2\left[\sigma_D^2 + w^2\sigma_S^2\right] \\ +2w_H\left(1-w_H\right)w\sigma_H\sigma_S\rho_{HS} \end{bmatrix} \quad (41)$$

The welfare equivalent wealth share and private value are respectively

$$x_H = \exp\left\{-\frac{\gamma T}{2}\left[(1-w_H)^2 w^2\sigma_S^2 + 2w_H\left(1-w_H\right)w\sigma_H\sigma_S\rho_{HS}\right]\right\} \quad (42)$$

$$Q_H = \left(x_H\right)^{\frac{1}{w(1-w_H)}} = \exp\left\{-\frac{\gamma T}{2}\left[(1-w_H)w\sigma_S^2 + 2\left(1-w_H\right)\sigma_H\sigma_S\rho_{HS}\right]\right\} \quad (43)$$

Here H is used to denote the case with human capital. This reduces to the two asset case when $w_H = 0$. Table 18 provides values of Q for varying levels of γ, w, w_H and ρ_{HS}. The level of σ_H is assumed to be 0.1 consistent with permanent income shocks used in household portfolio choice models such as Gomes and Michaelides (2003). The share of financial wealth is varied

[10] However, there is evidence that in aggregate returns to human capital are correlated with returns to the stock market, especially over long horizons (see Baxter and Jermann (1997)). Benzoni, Collin-Defresne and Goldstein (2006) show that aggregate level correlation can still matter for decision making at the individual level, if human capital and stock market are cointegrated. These are second order concerns when it comes to determining the impact of bearing idiosyncratic risk. Provided any correlation between the stock market and labor income is also present in the systematic risk of the single security, the private value of a constrained holding will be unaffected.

between 0.5 and 0.85 to capture the human capital share of employees at different stages of the life-cycle (older employees tend to have a larger share of outside assets).

It is assumed ρ_{HS} is never negative, but if it was then inclusion of the single stock in the financial portfolio could actually be welfare improving because it hedges human capital risk. If returns to human capital and the single stock are uncorrelated, the private value of the single stock increases with the share of human capital, w_H. A modest increase in the correlation can have a quite dramatic impact on the private value. In practice human capital and company stock correlation is unlikely to be strong. For instance, Davis and Willen (2000) find only mild evidence of association between labor income and stock price performance at the industry level. It would be difficult to justify a correlation of more than 0.2. Surprisingly, this modest level of correlation has a large impact on the private value even when the stock comprises a small share of the financial portfolio and risk aversion is modest.

$w_H = 0.5$												
	γ= 2.5				γ= 5				γ= 10			
	W				w				w			
ρ	0.1	0.25	0.5	1	0.1	0.25	0.5	1	0.1	0.25	0.5	1
0	0.899	0.767	0.588	0.345	0.808	0.588	0.345	0.119	0.654	0.345	0.119	0.014
0.05	0.865	0.738	0.565	0.332	0.748	0.544	0.320	0.110	0.560	0.296	0.102	0.012
0.1	0.832	0.710	0.544	0.320	0.693	0.503	0.296	0.102	0.480	0.253	0.088	0.010
0.2	0.770	0.657	0.503	0.296	0.593	0.431	0.253	0.088	0.352	0.186	0.064	0.008
0.5	0.611	0.521	0.399	0.235	0.373	0.271	0.159	0.055	0.139	0.074	0.025	0.003
0.75	0.503	0.429	0.329	0.193	0.253	0.184	0.108	0.037	0.064	0.034	0.012	0.001
1	0.415	0.354	0.271	0.159	0.172	0.125	0.074	0.025	0.030	0.016	0.005	0.001
$w_H = 0.7$												
	γ= 2.5				γ= 5				γ= 10			
	w				w				w			
ρ	0.1	0.25	0.5	1	0.1	0.25	0.5	1	0.1	0.25	0.5	1
0	0.938	0.853	0.727	0.528	0.880	0.727	0.528	0.279	0.775	0.528	0.279	0.078
0.05	0.889	0.808	0.689	0.501	0.790	0.652	0.474	0.251	0.624	0.426	0.225	0.063
0.1	0.842	0.765	0.652	0.474	0.709	0.585	0.426	0.225	0.502	0.343	0.181	0.051
0.2	0.756	0.687	0.585	0.426	0.571	0.471	0.343	0.181	0.326	0.222	0.117	0.033
0.5	0.546	0.496	0.423	0.308	0.298	0.246	0.179	0.095	0.089	0.061	0.032	0.009
0.75	0.417	0.379	0.323	0.235	0.174	0.143	0.104	0.055	0.030	0.021	0.011	0.003
1	0.318	0.289	0.246	0.179	0.101	0.083	0.061	0.032	0.010	0.007	0.004	0.001
$w_H = 0.85$												
	γ= 2.5				γ= 5				γ= 10			
	w				w				w			
ρ	0.1	0.25	0.5	1	0.1	0.25	0.5	1	0.1	0.25	0.5	1
0	0.969	0.923	0.853	0.727	0.938	0.853	0.727	0.528	0.880	0.727	0.528	0.279
0.05	0.907	0.865	0.798	0.681	0.823	0.748	0.637	0.463	0.677	0.559	0.406	0.215
0.1	0.849	0.810	0.748	0.637	0.721	0.655	0.559	0.406	0.520	0.430	0.312	0.165
0.2	0.745	0.710	0.655	0.559	0.555	0.504	0.430	0.312	0.308	0.254	0.185	0.098
0.5	0.502	0.479	0.442	0.377	0.252	0.229	0.195	0.142	0.063	0.052	0.038	0.020
0.75	0.361	0.344	0.318	0.271	0.131	0.119	0.101	0.074	0.017	0.014	0.010	0.005
1	0.260	0.248	0.229	0.195	0.068	0.061	0.052	0.038	0.005	0.004	0.003	0.001

Table 18: Private Value with Human Capital
Private value of \$1 worth of the single stock when the investor also has non-traded human capital (computed from equation 43).
Assumptions: $\sigma_S = 0.41$, $\sigma_H = 0.15$, $T = 10$, $w_H = 0.7$

Finally, consider giving the employee an opportunity to leverage his risky financial portfolio, holding constant the human capital share of total wealth and assuming the correlation between human capital and the idiosyncratic component of the employer stock return is zero. In this case, the optimal risk free share of financial wealth, w_F, satisfies

$$1 - w_F = \frac{\mu - r_F}{\gamma \sigma_D^2 \left(1 - w_H\right)} \tag{44}$$

where $\mu - r_F$ is the equity market risk premium. This equation is useful for calibrating an appropriate level of risk aversion because it captures the essential elements of a representative employee's portfolio choice problem (ignoring real estate holdings). Taking an expected annual equity risk market premium of at least 5%, an equity market volatility of no more than 20%, a human capital share of wealth of no less than 2/3 and a non-negative optimal risk free share requires a risk aversion parameter of at least 5. This is the baseline level of risk aversion used in the final section of the chapter.

4.6 PRIVATE VALUE, HUMAN CAPITAL AND BANKRUPTCY

The assumption that all assets obey diffusive processes rules out the interesting case of firm bankruptcy causing large shocks to the price of the employers stock and the employee's human capital. Intuitively, large but improbable shocks to wealth should impose greater welfare costs for risk-averse employees than the diffusive shocks considered to this point because they deepen the left tail of the wealth distribution where the employee's marginal utility is high. This section incorporates the risk of bankruptcy into the private value of the employee's constrained holding of stock and is the most general statement of the private value derived in this chapter.

As in section 5, the share of human capital in total wealth is w_H, the share of the single stock is $w_H\, w$ and the share of the diversified asset is $w_H\, (1 - w)$. Here, w is interpreted as the share of the employee's *financial* portfolio held in the single stock. Each of the assets has the diffusive properties assumed in section 5. In addition with fixed intensity q, a bankruptcy state occurs causing the price of the stock to drop to zero and human capital is reduced to fraction θ of its value. Thus after bankruptcy occurs, the employee's total wealth is worth fraction $\left[\theta\, w_H + (1-w_H)(1-w)\right]$ of its pre-bankruptcy value. In order to retain tractability it is assumed the effect of this shock is not propagated until the end of the stock holding horizon.[11] Thus, the diffusive component of the individual stock continues to affect wealth even after the bankruptcy shock occurs.

Even with these additional assumptions, the value function can still be expressed in closed form

$$V(W,w,w_H) = W\left(\begin{array}{l}\exp\left[(1-\gamma)T\left(\mu(1-w_H) - \dfrac{\gamma}{2}\left[\begin{array}{l} w_H^2\sigma_H^2 + (1-w_H)^2\left(\sigma_M^2 + w^2\sigma_S^2\right) \\ +2(1-w_H)w_H w\sigma_H\sigma_S\rho_{SH}\end{array}\right]\right)\right] \\ \times\ \left\{y + (1-y)\exp\left[(1-\gamma)\left[w_H(1-\theta) + (1-w_H)w\right]qT - qT\right]\right\}\end{array}\right)^{\frac{1}{1-\gamma}} \tag{45}$$

with

$$y = \frac{\left[\theta\, w_H + (1-w_H)(1-w)\right]^{1-\gamma}}{1-(1-\gamma)\left[w_H(1-\theta) + (1-w_H)w\right]} \tag{46}$$

The diversified equivalent fraction of wealth to a position w in the single stock in this case is

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[11] This is equivalent to assuming that after the bankruptcy shock, the investor's remaining wealth is rebalanced in the same proportions as before the shock into the diversified asset, human capital and a new employer's stock that does not have bankruptcy risk.

$$x_{BH} = \exp\left\{ -\frac{\gamma T}{2}\left[(1-w_H)^2 w^2\sigma_S^2 + 2w_H(1-w_H)w\sigma_H\sigma_S\rho_{HS} \right] \right\}$$
$$\times \left\{ \frac{y + (1-y)\exp\left[(1-\gamma)\left[w_H(1-\theta) + (1-w_H)w \right] qT - qT \right]}{y(0) + (1-y(0))\exp\left[(1-\gamma)\left[w_H(1-\theta) \right] qT - qT \right]} \right\}^{\frac{1}{1-\gamma}} \tag{47}$$

Where $y(0)$ is y evaluated with $w = 0$. The welfare cost decomposes into a diffusive component (identical to equation 42) and a bankruptcy component. The idiosyncratic risk discount factor satisfies

$$Q_{BH} = \left(x_{BH} \right)^{\frac{1}{w(1-w_H)}} \tag{48}$$

To gain an appreciation for the impact of discrete shocks versus diffusive shocks, consider the case without human capital (i.e. $w_H = 0$). In this two asset case, the expressions for x and Q simplify to

$$x_B = \exp\left[-\frac{\gamma}{2} w^2\sigma_S^2 T \right]\left[y + (1-y)\exp\left[(1-\gamma)wqT - qT \right] \right]^{\frac{1}{1-\gamma}} \tag{49}$$

and

$$Q_B = \left(x_B \right)^{\frac{1}{w}} \tag{50}$$

As in the general three asset case, both x and Q can be decomposed into a diffusive component (identical to equations 42 and 43 respectively) and an additional component capturing the effect of bankruptcy risk. The bankruptcy term is strictly less than one so including bankruptcy risk reduces the private value. However, including bankruptcy increases total stock volatility. Accounting for this additional source of volatility by adjusting down the diffusive component of idiosyncratic risk (σ_S) to keep the total single stock volatility constant across the two cases isolates the impact of a discrete shock from more general variation in stock price. Over a discrete interval of time the total variance of the single stock return (including bankruptcy risk) satisfies

$$\exp(2\mu)\left\{\exp\left(q+\sigma_D^2+\sigma_S^2\right)-1\right\} \tag{51}$$

The variance in the purely diffusive case is the above expression with $q = 0$. The appropriate downward adjustment is simply $\sigma_S^2 - q$. Table 19 compares the private value estimates for a variety of parameters across the purely diffusive and diffusion with bankruptcy cases. Increasing the probability of bankruptcy reduces the private value of the stock even after adjustment to maintain total stock risk. However, the incremental effect of bankruptcy is miniscule whenever the portfolio share of the single stock is small, the risk of bankruptcy is low or the degree of risk-aversion is low.

$\gamma = 5$							
	q						
w	0.000	0.001	0.002	0.005	0.010	0.020	0.050
0.95	0.018	0.018	0.003	0.002	0.002	0.002	0.004
0.5	0.119	0.119	0.114	0.109	0.100	0.093	0.107
0.25	0.345	0.345	0.344	0.342	0.338	0.333	0.345
0.1	0.654	0.654	0.653	0.653	0.652	0.651	0.664
$\gamma = 10$							
	q						
w	0.000	0.001	0.002	0.005	0.010	0.020	0.050
0.95	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.5	0.014	0.010	0.009	0.008	0.008	0.009	0.018
0.25	0.119	0.116	0.113	0.107	0.103	0.102	0.128
0.1	0.427	0.426	0.425	0.423	0.420	0.419	0.440

Table 19: Private Value of Company Stock with Bankruptcy Risk
Reported private values contrast cost under varying intensities of bankruptcy including the purely diffusive case (q = 0). All values are calculated from equation (50) with firm specific idiosyncratic volatility of 0.42 and the holding horizon of 10 years.

While bankruptcy risk has only a minor impact on private value in the two asset case, it could have much more significant effects in the three asset case if bankruptcy also causes large shocks to human capital. On the other hand, introducing human capital also reduces the share of the single stock in total wealth. The net quantitative effect of introducing human capital with correlated unemployment and bankruptcy shocks isn't obvious. Table 20 below presents estimates of the discount factor assuming a coefficient of risk aversion of 5 (discussed in the previous section), a holding period of 10 years, a wealth share of human capital equal to 0.7, firm specific stock volatility of 0.41 and human capital volatility of 0.1. Three structural parameters control the interaction between human capital and company stock: correlation between human capital and firm specific return (ρ_{HS}), the magnitude of the human capital shock in bankruptcy (1 – θ), the intensity of bankruptcy (q). These are set at baseline levels of 0, 0.1 and 0.005 respectively and varied one at a time. For each variation, the private value is reported for the levels financial share of the employers stock between 0.1 and 1.

Even at the baseline values there is significant variation in the private value of company stock from variation in risk aversion and the financial share of the stock. High levels of risk aversion also make the private value more sensitive to the variation in human capital interaction factors. On the other hand, for lower levels of risk aversion, the private value is considerably less sensitive to plausible variation in any one of the human capital interaction factors. Combining all three effects would have a large impact: For instance raising the bankruptcy probability to 1%, shocks to human capital above 20% (i.e. θ below 0.8) and firm specific risk and income correlation of 0.1 lowers the private value by 20 to 40 percent depending on the share of stock in the financial portfolio. Of course, the plausibility of risks factors of this magnitude is unlikely for most employees.

Although not reported in the tables, private values are also sensitive to human capital share of wealth and the holding period. Around the baseline values the private value always rises with the human capital share of wealth despite the interaction between human capital and wealth. Private value always declines with the investment horizon, although this can be converted to a roughly constant per annum excess return premium

$$-(\log Q) / T \tag{52}$$

There are numerous applications of the valuation framework to specific decision making contexts. In restricted stock bonus plans, many employees face forfeiture of stock if they change employers and cannot sell their stock holding for several years. The impact of these restrictions could be simulated in the framework by assuming a high "bankruptcy" probability corresponding to job loss and stock forfeiture. Consider a young employee with a 25% financial share (w) invested in company stock for 3 years and an 85% human capital share of wealth (w_H). Because job change is so frequent for young employees but usually not disastrous, assume an annual unemployment intensity of q = 0.1 and associated human capital shock of 5% (i.e. θ = 0.95). With other parameters standard, the employee's private value for each dollar of stock held is \$0.64. In other words, other things equal a young employee should be willing to give up \$0.36 per dollar of stock owned for the right to sell the stock immediately. Considering that there is a greater than 30% chance of forfeiture due to job loss over the 3 year period, the large magnitude is not particularly surprising.

Fixed Parameters		Variable Parameters	Range	Baseline
w_H	0.7	ρ_{HS}	0 – 1	0.0
σ_S	0.412	θ	.05 – 1	0.9
σ_H	0.1	q	0 - 0.05	0.005
γ	5	w	{.1, .25, .5, 1}	n/a
		T	{1, 10}	n/a

Values of Q:

T=1											
Varying q	0.000	0.001	0.002	0.005*	0.010	0.015	0.020	0.025	0.030	0.050	0.100
w = 0.1	0.987	0.987	0.986	0.985	0.982	0.979	0.977	0.974	0.971	0.961	0.938
w = 0.25	0.969	0.968	0.967	0.965	0.961	0.958	0.954	0.950	0.947	0.933	0.902
w = 0.5	0.938	0.937	0.936	0.932	0.927	0.921	0.915	0.910	0.905	0.884	0.839
w = 1	0.880	0.878	0.875	0.867	0.854	0.841	0.829	0.818	0.807	0.768	0.692
Varying θ	1.00	0.90*	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10	0.05
w=0.1	0.987	0.985	0.981	0.975	0.965	0.946	0.913	0.848	0.723	0.501	0.357
w = 0.25	0.968	0.965	0.961	0.953	0.941	0.919	0.878	0.797	0.644	0.393	0.250
w = 0.5	0.936	0.932	0.927	0.917	0.900	0.868	0.806	0.686	0.474	0.207	0.102
w = 1	0.873	0.867	0.855	0.834	0.793	0.711	0.557	0.323	0.108	0.012	0.001
Varying ρ_{HS}	0.00*	0.05	0.10	0.15	0.20	0.30	0.40	0.50	0.60	0.80	1.00
w = 0.1	0.985	0.978	0.970	0.964	0.957	0.943	0.929	0.916	0.903	0.877	0.852
w = 0.25	0.965	0.958	0.951	0.944	0.937	0.924	0.911	0.898	0.885	0.860	0.835
w = 0.5	0.932	0.926	0.919	0.912	0.906	0.893	0.880	0.868	0.855	0.831	0.807
w = 1	0.867	0.861	0.854	0.848	0.842	0.830	0.818	0.807	0.795	0.772	0.750
T = 10											
Varying q	0.000	0.001	0.002	0.005*	0.010	0.015	0.020	0.025	0.030	0.050	0.100
w = 0.1	0.880	0.876	0.871	0.857	0.836	0.817	0.800	0.785	0.771	0.727	0.668
w = 0.25	0.727	0.722	0.716	0.701	0.678	0.657	0.639	0.623	0.609	0.566	0.512
w = 0.5	0.529	0.523	0.516	0.499	0.473	0.452	0.434	0.419	0.406	0.370	0.330
w = 1	0.280	0.271	0.264	0.244	0.220	0.203	0.190	0.180	0.172	0.153	0.137
Varying θ	1.00	0.90*	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10	0.05
w = 0.1	0.877	0.857	0.827	0.783	0.717	0.623	0.498	0.351	0.209	0.102	0.066
w = 0.25	0.720	0.701	0.673	0.631	0.569	0.483	0.371	0.249	0.139	0.063	0.039
w = 0.5	0.516	0.499	0.472	0.434	0.378	0.304	0.217	0.132	0.066	0.026	0.014
w = 1	0.260	0.244	0.221	0.188	0.147	0.102	0.060	0.029	0.010	0.001	0.000
Varying ρ_{HS}	0.00*	0.05	0.10	0.15	0.20	0.30	0.40	0.50	0.60	0.80	1.00
w = 0.1	0.857	0.797	0.742	0.690	0.642	0.556	0.481	0.417	0.361	0.270	0.203
w = 0.25	0.701	0.652	0.607	0.565	0.525	0.455	0.394	0.341	0.295	0.221	0.166
w = 0.5	0.499	0.464	0.432	0.402	0.374	0.323	0.280	0.242	0.210	0.157	0.118
w = 1	0.244	0.227	0.211	0.197	0.183	0.158	0.137	0.119	0.103	0.077	0.058

Table 20: Private Value of Company Stock with Human Capital and Bankruptcy Risks
The table reports private value per dollar of compensation held by an employee endowed with human capital for various parameter levels, facing diffusive risks and firm bankruptcy shocks calculated from equation (48) with parameters as above.

In employer stock ownership plans (ESOPs) corporations are entitled to take a tax deduction for any dividends paid on stock held in the plan.[12] This deduction is not available on equity owned by outside investors. For each year stock is held in the ESOP a profitable corporation paying a steady 3% dividend yield would accumulate annual tax savings approximately equal to 1% of the value of stock held.[13] This 1% saving must trade off against the inefficient risk exposure employees face from holding company stock in these plans.[14] Using the baseline parameters from table 20, the 1% p.a. benefit from dividend deductibility, if passed on to the employee, would support an employer stock share (w) of only 6%. This share is approximately stable regardless of investment horizon.

4.7 CONCLUSION

This chapter has established a very simple framework to evaluate the risk of company stock in employee compensation plans expressed as a simple adjustment to the market price of a constrained holding of company stock. Five key factors determine the appropriate adjustment: the degree of employee risk aversion; the share of the stock position in total wealth; the length of the holding period; the volatility of the idiosyncratic component of the employer's stock return and the association between the employer's stock return and income shocks. For plausible

[12] ESOP plans also have the same tax qualified status as defined contribution plans where contributions are made on a pre-tax basis and accumulate tax free until withdrawn. However, the only incremental tax benefit from investing plan balances in company stock instead of a diversified portfolio is the corporate deductibility of dividends (see Appendix A for more detail).

[13] This assumes a marginal corporate tax rate of 35%.

[14] The risk of forfeiture of unvested ESOP holdings is ignored.

parameters, variation in the stock-wage association has the least effect on private value. Two applications were considered in section 4.6 to illustrate the magnitude of costs in plausible stock compensation scenarios. While these applications abstract from real world complexity, they do give a sense that bearing idiosyncratic risk should be a first order concern in stock compensation decision making.

APPENDIX A: INSTITUTIONAL OVERVIEW OF 401(K) RETIREMENT ACCOUNTS[1]

Qualified Plans

The two primary sources of legislation governing 401(k) plans are the 1978 Internal Revenue Code (the Code) and the 1974 Employee Retirement Income Security Act (ERISA), the former administered by the Internal Revenue Service, the latter by the Department of Labor. The Code defines a qualified retirement plan by the conditions it must meet to qualify for tax-advantaged status.[2] ERISA covers certain non-tax aspects such as participation, disclosure, and fiduciary responsibility in employer-sponsored plans. Certain securities laws are also relevant if an employer-sponsored plan holds employer securities.

Qualified plans can be either Defined Contribution (DC) or Defined Benefit (DB) plans, distinguished by the method used to allocate individual employee entitlements.[3] In DB plans, entitlements are defined in terms of the benefit each employee will receive upon retirement. The plan administrator calculates each employee's benefit using a formula typically tied to tenure and the final years of salary. To finance these benefits, the employer must make compulsory annual contributions to the plan. All DB plans must meet minimum funding rules, as defined in the Code, to ensure the plan has sufficient assets to pay future benefits.

[1] More detailed accounts of the institutional detail can be found in Beam and McFadden (2001) and Rosenbloom (2001)

[2] Section 401(a) of the Code defines a qualified plan.

[3] These are defined in sections 414(i) and (j) of the Code.

In a DC plan, each employee has an account in the plan with a balance reflecting past contributions and any investment income earned or accrued. In some DC plans, investment risk is borne by the plan and individual balances accrue at a fixed rate. If this is the case, the plan is also subject to minimum funding rules because of the risk that plan assets will be insufficient to cover future allocated balances. The Code refers to plans whose participants do bear investment risk as profit sharing plans. By definition, past contributions and investment income fully fund a profit sharing plan and, hence, minimum funding rules do not apply.

A 401(k) plan is a profit sharing plan that allows both employer contributions and elective employee deferrals. Section 401(k) of the Code allows employers to offer employees the right to defer salary into the plan on a pre-tax basis. An employer can link their contributions to an employee's elective deferrals (referred to hereafter as matching contributions) or a flat percentage of compensation (a flat dollar contribution or profit sharing contribution). Employer contributions are distinct from the employee's contribution and subject to different rules and limits.

The rules for a 401(k) plan to meet qualified plan status are largely consistent with other profit sharing DC plans (with a few exceptions). Beam and McFadden (2001, Ch 18) arrange the qualified plan rules into six broad categories: (1) eligibility and coverage; (2) non-discrimination and top heavy rules; (3) funding and fiduciary requirements; (4) vesting requirements; (5) limitations on benefits and contributions; and (6) restrictions on payouts.[4] These groups of rules are interrelated in that the way a plan meets one set of rules may narrow the requirements for

[4] This categorization was can be found in Beam and McFadden (Ch 18).

other rules. The Economic Growth and Tax Relief Reconciliation Act of 2001 (EGTRRA) temporarily amended many of the rules and limits in the Code and the discussion reflects these amendments.

Eligibility and Coverage: Any private employer can sponsor a 401(k) plan. A qualifying plan can define its eligibility over a group of participants, such as all employees in a division, all part-time workers or all full-time workers. However, to qualify the plan cannot exclude any employee within the group with at least one year of service and aged 21 or above. In addition, coverage tests in the Code ensure that the participation rate or benefits as a percentage of salary do not disproportionately favor highly compensated employees (HCEs).[5] The coverage test can be a substantial hurdle in a 401(k) plan because the contributions are voluntary and lower paid employees are likely to contribute at a lower rate than HCEs (if they contribute at all).

Non-Discrimination and Top Heavy Rules: In addition to the coverage tests, there are specific section 401(k) anti-discrimination rules, called Actual Deferral Percentage (ADP) tests. Essentially, the percentage of salary deferred by highly compensated employees (HCEs) must not exceed the percentage of salary deferred by all other employees by more than a certain amount.[6] More recently, the Code was amended to include "safeharbor" provisions that deem a plan to have met the ADP tests if an employer makes a minimal level of matching or profit

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[5] IRC section 410

[6] The two tests are: (1) the average ADP of HCEs cannot exceed the average ADP of other eligible employees times 1.25; and (2) the average ADP of HCEs cannot exceeds the lesser of the average ADP of other eligible employees (a) times 2 or (b) plus 2 percent. Only one of these tests needs to be satisfied.

sharing contributions.[7] In addition to the anti-discrimination rules there are also rules that apply to plans that are considered top heavy in any plan year. Top heavy rules penalize “key” employees and bestow advantages upon non-key employees for that plan year (defined in section 416 of the Code).

Funding and Fiduciary Requirements: The funding and fiduciary elements of qualified plans are extensive. For the most part all 401(k) plans are fully funded in cash from the employer, representing employees’ salary deferrals and employer contributions. Employer contributions may help to encourage adequate participation by younger and lower paid workers in order for the plan to meet non-discrimination rules, even in plans that do not adopt the safeharbor provisions.

The plan fiduciary is trustee for the plan and its assets. The fiduciary can be an individual, committee, or corporate entity and is responsible for overseeing the administration of the plan and investment of the plan’s funds. Administration includes processing of benefits, receipt of contributions, record keeping, reporting and disclosure. The Employee Retirement Income Security Act (ERISA) defines the fiduciary duties although they differ only marginally

[7] Under section 401(k)(12) an employer is deemed to meet the ADP test by either providing a minimum profit sharing or matching contribution. The minimum profit sharing contribution is 3 percent of salary to each eligible employee. The minimum matching contributions is at least 100 percent of the first 3 percent of compensation that an employee defers and at least 50 percent for the next 2 percent of compensation deferred. The matching contribution can be more generous than this, but the incremental matching rate must not increase with the deferral rate.

from the duties of a typical trustee.[8] A plan administrator may delegate their fiduciary duties. For example, a plan may outsource record keeping or investment management tasks, thereby reducing aspects of their own fiduciary duty. In addition, some parties, including the employer, can become a fiduciary of a plan by their actions. Historically, the remedies for participants against breaches of fiduciary duty by the plan administrator or delegates have been minimal.

The specific fiduciary duties identified in ERISA include the exclusive purpose rule, the prudent man rule and the diversification rule. The exclusive purpose rule requires that the fiduciary operate the plan for the sole benefit of plan participants (and not the employer).[9] The prudent man rule requires that the plan administrator act as any prudent individual would in an enterprise with like character and aims.[10] Perhaps the most relevant of the three is the diversification rule, requiring adequate diversification of plan assets to minimize the risk of large losses. A crucial exception to the rule is that a plan may invest in employer securities without limit.[11]

Because a 401(k) plan is a defined contribution plan, each participant must have an individual account invested at the discretion of the plan administrator. All profit sharing plans

[8] ERISA section 404

[9] Surprisingly, and in contrast with the intent of anti discrimination and top-heavy rules, the exclusive purpose rule does not prevent key employees of a corporation from acting as plan administrator.

[10] The Department of Labor interpretation of prudence with respect to investment decisions includes due consideration of diversification, the ability to meet current and future cash flow requirements of the plan in light of liquidity of and current and future return on the investments

[11] This is only true for profit sharing plans. Legislation introduced in 1997 prevents a pension plan from holding more than 10 percent of plan assets in employer owned securities.

can offer participant's the right to direct their investments.[12] This relieves the fiduciary duty of the plan administrator with regard to the investment choice of the participant, although they do have a duty to ensure the adequacy of the investment choices on the menu. Unsurprisingly, investment choice is a common feature of 401(k) plans.

Vesting Requirements: In the context of a DC plan, vesting refers to transferring ownership of an account balance from the plan to an employee. An employee is entitled to the full value of their account only when 100 percent vested. Any unvested portion of a participant's account is subject to forfeiture to the plan trust if the employee leaves the employer. Section 411 of the Code defines minimum vesting standards. In a 401(k) plan, employee contributions are 100 percent vested at all times although the employer contributions may not be. For employer contributions, an employer may impose no more than a 5-year cliff or 3- to 7-year gradual vesting schedule.[13] Vesting schedules may improve employee retention by giving employees an incentive to stay on with the employer. On the other hand, unvested matching contributions may deter employees from making salary deferrals to a plan in industries with high employee turnover, which could make meeting non-discrimination tests more difficult.[14]

[12] ERISA section 404(c)

[13] Under cliff vesting, an employee becomes 100 percent vested in their account balance no more than 5 years of "qualified" service. Under gradual vesting, an employee must be 20 percent vested after 3 years of service and an additional 20 percent vested for each additional year of service (fully vesting in the 7th year). EGTRRA provisions have reduced allowable vesting periods on matching contributions in 401(k) plans to 3 years under cliff vesting and 6 years under gradual vesting.

[14] Note that participant balances are 100 percent vested in plans that adopt the safeharbor matching contribution.

Limitations on Benefits and Contributions: Section 415 of the Code places percentage limits and annually indexed dollar limits on employer and employee contributions. The sum of employee and employer contributions across all of an employees DC retirement accounts cannot exceed the lesser of $44,000 per participant (as of 2006) or 100 percent of each employee's compensation per year.[15] As of 2006, employee salary deferrals are restricted to the lesser of $15,000 or 100 percent of compensation per year, although a plan may allow additional after-tax contributions by employees.[16] In order to retain qualified state, the employer typically distributes contributions in excess of these limits to employees as taxable compensation. A plan may impose more stringent limits than the statutory amounts and this is common among plans that fail the non-discrimination tests. Unlike DB plans, the code does not limit the size of the benefit paid to each participant.

Restrictions on Payouts: An employee or his beneficiaries can withdraw some or all of his balance from a 401(k) plan under are variety of conditions including: upon reaching age 59½; terminating employment; death or permanent disability; plan termination or financial hardship.[17] Withdrawal of employer contributions is subject to slightly looser rules but remain at the

[15] Prior to EGTRRA, the percentage limit was 25 instead of 100 percent. Furthermore, an employer cannot take a deduction for contributions made to all qualified plans exceeding 25 percent of total compensation in any plan year (the limit was 15 percent prior to enactment of EGTRRA).

[16] Under EGTRRA, employees aged 50 or over are also entitled to make "catch up" contributions of up to $5,000 in 2006. Plans are not required to offer catch up contributions.

[17] In addition to the limitations on taking early payouts, there are also minimum distribution requirements to prevent abuse of the tax-sheltered status of a qualified plan. In particular, participants who retire or are aged 70½ or over must take a distribution from the plan irrespective of their employment status.

discretion of the plan sponsor. Withdrawals while still in-service are relatively uncommon outside of financial hardship and again at the discretion of the plan. In order to make a hardship withdrawal a plan participant will usually have to show evidence of a genuine financial hardship. While there is no obligation for a 401(k) plan to offer hardship distributions, they may make the plan more attractive to lower compensated employees whose participation is required to meet non-discrimination tests. The IRS levies a 10 percent penalty tax on in-service distributions, distribution following employment termination prior to age 55 and hardship distributions.[18]

An alternative to offering hardship withdrawals is for a plan to offer loans against account balances up to the lesser of $50,000 or 50 percent of the account balance for a term of up to 5 years.[19] Participants do not earn investment income on the borrowed balance, but the plan credits each participant's account with any interest paid on their loan. From the perspective of an employee, the economic differences between a loan and a withdrawal may be minor. The IRS only levies a 10 percent penalty on a loan if an employee fails to repay, whereas few pre-retirement withdrawals escape the penalty. The IRS levies personal taxes and any penalty in the year of a hardship withdrawal, whereas an employee pays taxes on loans indirectly over time as an employee repays their loan with after tax salary deductions. In the year of a hardship withdrawal, a plan may restrict a participant from making any further contributions for up to 6

[18] Section 72(t) of the Code covers plan penalties. There are also several classes of exemption from penalties for financial hardship including withdrawals taken to finance first home purchase and education.

[19] Section 72(p) of the Code covers hardship withdrawals for qualified and non-qualified plans. Where a plan allows loans, they must be available on a non-discriminatory basis.

months, whereas the employer may choose to stop making matching contributions to a participant who has a loan balance outstanding over the entire term of the loan.

Tax Treatment of Qualified Plans

Like most other forms of employee compensation, contributions to the 401(k) account within the prescribed limits are exempt from most state and federal taxation at the corporate level and personal level.[20] However, the employer must withhold taxes for Social Security, Medicare and Unemployment Insurance on employee but not employer contributions.[21] Both employee and employer contributed balances accumulate tax free until withdrawn as a taxable distribution. Personal taxes are levied upon the distribution of a participant's plan balance, except when the balance is rolled over into a new tax qualified retirement plan (such as an Individual Retirement Account or another employer-sponsored DC plan) pension or annuity, ensuring taxes are only levied when the money leaves a retirement vehicle.

Employer Securities in Qualified Plans

A unique aspect of employer-sponsored plans is the discretion for employers to invest employer contributed plan balances in company securities, especially common stock. An employer can also offer company securities as one of the investment options in a plan that offers investment choice. As mentioned earlier, there is no fiduciary duty for a plan administrator to

[20] In Roth 401(k) plans (allowed under EGTRRA from 2006 onwards) the IRS taxes employee contributions as regular income, but investment income and distributions are exempt from tax. A Roth 401(k) offers more favorable tax treatment for employees expecting higher income tax rates at retirement.

[21] These taxes are significant and can add up to over 15 percent of payroll.

diversify plan investments in employer stock.[22] The plan administrator can acquire securities on a listed exchange or pay fair value for freshly issued securities.

An Employee Stock Ownership Plan (ESOP) is a commonly used vehicle to hold employer securities. Like a 401(k) plan, an ESOP is another type of profit sharing plan and, thus, subject to many of the same regulatory requirements. Unlike 401(k) plans, ESOP plans do not allow salary deferrals. The employer makes all contributions and invests them almost exclusively in employer securities. Historically, companies have used ESOPs as a merger defense by placing its equity in friendly employee hands.[23] In some corporate restructures, employees have taken long-term equity stakes in an ESOP in exchange for lower wages. ESOPs have remained a popular retirement vehicle partly due to favorable taxation treatment relative to other qualified plans and because the ESOP can borrow money to fund the acquisition of stock.

Taxation of ESOPs is much the same as for 401(k) and other profit sharing plans. There are no taxes on contributions made by the employer and employee until distribution. One difference is that dividends paid on shares in the ESOP are a tax deduction to the employer.[24] Dividends paid on employee held stock are not deductible in a regular 401(k) plan.

[22] Section 404(c) of ERISA defines the requirements that a plan must meet with respect to investment choice for the fiduciary duty over investment choice to be relieved. A part of this section dictates requirements on employer stock as an investment option to ensure that employee buying, selling and voting are free of employer influence. Section 404(c) relief from fiduciary duty over investment choices made by participants applies only to the portion of any balance that can be directed by the participant to a diversified set of assets, so the plan administrator and delegates retain their fiduciary duty with respect to those balances that cannot be directed. Of course, in the case of employer stock, there is no duty to diversify in any event.

[23] The ESOP trustee retains voting control of each participant's allocation of shares.

ESOPs have a diversification requirement that is unique among qualified plans (covered by code section 401(a)(28)(B)). Once an employee has attained age 55 and at least 10 years of service, the employee may elect to diversify some of their ESOP account balance into cash or a menu of diversified investment options.[25] If an employer also offers a 401(k) plan, an employee can instead diversify his ESOP account balance into the investment options of the 401(k) plan with the benefit of reducing administrative costs.

Many large listed companies offer an ESOP in conjunction with a 401(k) plan. Under a typical arrangement, the employer matches an employee's 401(k) salary deferral with an allocation of stock to the employee's ESOP account.[26]

401(k) Plans and Individual Retirement Accounts

For the purposes of retirement saving, an individual retirement account (IRA) is a close substitute for 401(k) and other employer-sponsored DC plans. Like a 401(k) plan, employees contribute pre-tax salary to an IRA, earn investment income tax free and pay tax only at distribution.[27] Early withdrawals from the plan are subject to the same 10 percent IRS penalty imposed on early distributions from 401(k) plans.

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[24] A company can set up a separate class of shares for the ESOP offering a high level of dividends per share to take advantage of this tax deduction.

[25] An employee may, over a period of 5 years, elect to diversify up to 25 percent of their ESOP shares once they have attained age 55 and 10 years of service with the employer. Once they reach the 6th year of attainment, they have an opportunity to diversify up to 50 percent of their allocated shares (including shares previously diversified). Any remaining balance is preserved until the employee retires or leaves the firm.

[26] Mathews (2004) describes a variety of legal structures combining 401(k) and ESOP.

There are, however, many differences between IRA and 401(k) plans. Most importantly, 401(k) plans are employer-sponsored and as a result subject to much stricter regulation and non-discriminatory provisions. Since financial institutions sponsor personal IRA plans and participation is open to the investing public, the strict rules and regulations of employer-sponsored qualified plans such as non-discrimination in eligibility, coverage and participation do not apply. Some of the primary differences between 401(k) and IRA plans are as follows:

1. IRA plans are not subject to non-discrimination tests.
2. All individuals are eligible to participate in an IRA if they do not participate in an employer-sponsored plan or their income is less than annually published limits. In contrast, employees are only eligible to participate in a 401(k) plan if the employer chooses to offer one and provided they meet any minimum service requirement stipulated by the employer.
3. There are no matching or profit sharing contributions in an IRA.
4. The $5,000 contribution limit to IRA plans is much lower than the $15,000 salary deferral limit of 401(k) plans.
5. Participants in IRAs can readily transfer balances between financial institutions and across investments. Participants in 401(k) plans may have more limited investment options or no investment choice at all.
6. Withdrawals from IRAs are allowed at any time (but subject to the 10% penalty), but are more restricted in 401(k) plans. Unlike 401(k) plans, participants cannot take a loan from an IRA plan.

[27] There are also Roth IRA plans that allow employees to contribute after tax salary and take tax-exempt distributions (much like Roth 401(k) plans). Roth IRAs pre-date Roth 401(k) plans.

7. An employee can transfer his 401(k) balance into an IRA upon termination of employment. An employee can transfer an IRA balance into a 401(k) plan only if allowed by the 401(k) plan.

APPENDIX B: PROPERTIES OF THE MODEL IN CHAPTER 3

Strict concavity of the utility function and convexity of the constraint set over the admissible choice variables are sufficient conditions to ensure a unique maximum to the employee's decision problem exists. Unfortunately, the constraint set is not necessarily convex for all interesting parameter cases. Specifically, whenever the size of the employer matching contribution is large relative to the withdrawal penalty there may occasionally be two solutions to the problem for a given state. In one solution, the employee invests a positive amount in their 401(k) account (i.e. $s_t>0$) and in the other the employee withdraws from the account (i.e. $s_t<0$). A sufficient condition to ensure a unique solution to the problem is $(1+m_j) < 1/(1-p)$, where m_j is the marginal matching contribution rate under stock or cash matching. Even without this assumption, if the stochastic variables are defined as continuous random variables, then the set of states for which there are multiple solutions has measure zero, and it is harmless (in terms of the reported transition paths) to simply assume the employee chooses the solution with $s_t>0$. On the other hand, the first order conditions used to compute the optimal transitions numerically will have multiple solutions over a positive measure of the state space. This requires a comparison of the value function across the candidate solutions at every state to isolate the value maximizing policy.

First order conditions for the optimal program can be reduced to conditions governing the choices of $\mathbf{x}_{Lt}$ and $\mathbf{x}_{Rt}$ (c_t and s_t are pinned down by state variables, $\mathbf{x}_{Lt}$, $\mathbf{x}_{Rt}$ and the budget constraints 3 and). For the case of time additive separable utility and for each asset j held in the liquid account, the first order conditions satisfy

$$E_t\left\{\beta \frac{u'(c_{t+1})}{u'(c_t)} R^j_{Lt+1}\right\} \leq 1 \forall\ j \in \{f,m,e\}, t = 1,\ldots,T \tag{53}$$

This is the standard Euler condition for portfolio choice in a time separable frictionless trading setting with short sales constraints. On the other hand for each asset j held in the retirement account, optimal choices under time additive separable utility satisfy

$$E_t\left\{\beta \frac{\lambda_{Rt+1}}{\lambda_{Rt}} R^j_{Rt+1}\right\} \leq 1 \forall\ j \in \{f,m,e\}, t = 1,\ldots,T^* - 1 \tag{54}$$

Where λ_{Rt} is interpreted as the marginal utility of retirement account wealth and following from the envelope condition satisfies

$$\lambda_{Rt} = \frac{\partial V_t(Z_{Lt}, Z_{Rt}, Z_{Et})}{\partial Z_{Lt}}\ t = 1,\ldots,T^* - 1 \tag{55}$$

The first order condition retains the intuitively appealing property that all assets held in positive quantity in the retirement account balance the marginal utility of retirement account wealth between the current and next period. Utility from retirement wealth arises from the consumption it provides. Retirement account wealth most effectively delivers consumption in retirement and can only be used for consumption prior to retirement at a penalty. The marginal value of retirement wealth is pinned down to some fraction of the marginal utility of period t consumption whenever the agent makes an interior contribution or withdrawal from the retirement account. In particular, at retirement (date T^*), the marginal utility of retirement wealth trivially satisfies the following condition regardless of the state

$$\lambda_{RT^*} = u'(c_{T^*})(1 - \tau_R) \tag{56}$$

That is, each dollar of retirement wealth delivers (1-τ_R) units of consumption at the retirement date (reflecting taxation of the account balance at rollover).[1] Prior to retirement, whenever the employee makes an interior contribution or withdrawal to the retirement account in period *t*, the marginal utility of retirement wealth in that period will be equalized to the marginal utility of period *t* consumption. In the case of a withdrawal from the account

$$\lambda_{Rt} = u'(c_t)(1 - p)(1 - \tau_t), \quad t = 1,...,T^* - 1 \tag{57}$$

In other words the employee is willing to withdraw money from their retirement account up to the point where the marginal value of foregone future consumption equals the value it could provide in consumption at *t* after adjusting for tax and the early withdrawal penalty. For the case of a contribution in period *t*, the employer stock match introduces a complexity

$$\lambda_{Rt} + \lambda_{Et} m'_t(s_t) = u'(c_t)(1 - \tau_t), \quad t = 1,...,T^* - 1 \tag{58}$$

Where λ_{Et} reflects the marginal utility of employer contribution account wealth and satisfies $\lambda_{Et} = \alpha\lambda_{Rt}$ in any state where fraction α of the matching contribution becomes diversifiable, but will otherwise take a value much less than λ_{Rt}.[2] If the employer contribution account is always diversifiable with a fixed match of fraction *m* this reduces to

$$\lambda_{Rt}(1 + m) = u'(c_t)(1 - \tau_t) \; t = 1,...,T^* - 1 \tag{59}$$

[1] Keep in mind that the retirement wealth can be used to deliver consumption beyond (not just at) the retirement date, but this value is implicitly captured through the optimal liquid asset choice, and hence dynamics of the post retirement marginal utility of wealth governed by equation (53).

[2] In general, its dynamics are governed by an equation analogous to 58.

Here the employee is willing to reduce period *t* consumption to make a contribution to the retirement account up to the point where the marginal utility of the lost consumption is equal to the utility of future consumption that the contribution can provide (which incorporates a marginal reduction in tax payable at *t* since contributions are made on a pre tax basis and the marginal value of the employer matching contribution).

The analysis shows that the employee values assets that are capable of providing wealth in states where consumption is low (i.e. when the marginal utility of consumption is high). Assets which are risky or held in illiquid forms will be undesirable if they cannot adequately deliver wealth to states where wealth (and hence consumption) is low. This is particularly true of the highly illiquid and risky stock of the employer, which can only deliver deferred consumption and may fail to deliver in low consumption states.

APPENDIX C: DERIVATION OF RESULTS IN CHAPTER 4

Following Campbell and Viceira (2001, Ch. 2) consider an investor with wealth at time 0, W, whose preferences are defined over lotteries of wealth at time T, W_T, and represented by the expected utility function

$$U(W_T) = E_0\left(W_T^{1-\gamma}\right)^{\frac{1}{1-\gamma}} \tag{60}$$

Individual assets, i, have prices, $P_i(t)$, that obey Geometric Brownian motion

$$\frac{dP_i}{P_i} = \mu_i dt + \sigma_i dZ_i \tag{61}$$

Portfolio returns on wealth assuming continuously rebalanced asset shares w_i are defined by

$$\frac{dW}{W} = \sum_{i=1}^{n} w_i \frac{dP_i}{P_i} \tag{62}$$

From Ito's Lemma, we can express

$$d\ln W = \frac{dW}{W} - \frac{1}{2}\left(\frac{dW}{W}\right)^2 \tag{63}$$

$$\left[\begin{array}{l}\text{incidentally} \\ d\ln P_i = \dfrac{dP_i}{P_i} - \dfrac{1}{2}\left(\dfrac{dP_i}{P_i}\right)^2\end{array}\right] \tag{64}$$

Substituting the definition of the portfolio return into gives

$$d\ln W = \sum_{i=1}^{n} w_i \frac{dP_i}{P_i} - \frac{1}{2}\left(\sum_{i=1}^{n} w_i \frac{dP_i}{P_i}\right)^2 \tag{65}$$

Using the definition of the price increments and again applying Ito's Lemma

$$d\ln W = \sum_{i=1}^{n} w_i\left(\mu_i dt + \sigma_i dZ_i\right) - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \sigma_i \sigma_j \rho_{ij} dt \tag{66}$$

The stochastic integral of the above is

$$\ln W(t) - \ln W(0) = \int_{s=0}^{t} d\ln W(s) = \sum_{i=1}^{n} w_i\left(\mu_i t + \sigma_i Z_i(t)\right) - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \sigma_i \sigma_j \rho_{ij} t \tag{67}$$

where $Z_i(t)$ is normally distributed with variance *t*. This provides the following expression for wealth

$$W(t) = W(0)\exp\left[\sum_{i=1}^{n} w_i\left(\mu_i t - \sigma_i Z_i(t)\right) - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \sigma_i \sigma_j \rho_{ij} t\right] \tag{68}$$

Thus W(t) has a lognormal distribution with mean and variance parameters

$$\mu_W = \ln W(0) + \sum_{i=1}^{n} w_i \mu_i t - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \sigma_i \sigma_j \rho_{ij} t \tag{69}$$

$$\sigma_W^2 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \sigma_i \sigma_j \rho_{ij} t \tag{70}$$

The objective function is a power of a log normal random variable, W_T. Thus,

$$U(W_T) = E\left(W_T^{1-\gamma}\right)^{\frac{1}{1-\gamma}} = \exp\left[\mu_W + \frac{1}{2}(1-\gamma)\sigma_W^2\right] \tag{71}$$

Substituting (69) and (70) into (71) gives

$$U(W_T) = W_0 \exp\left\{\sum_{i=1}^{n} w_i \mu_i T - \frac{\gamma}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \sigma_i \sigma_j \rho_{ij} T\right\} \tag{72}$$

Optimizing over w, gives the standard mean variance portfolio choice solution.

Two Asset Special Case under Mean Preserving Spread

Consider suboptimal choices in the case of two assets, D and S with

$$\frac{dP_M}{P_M} = \mu\, dt + \sigma_D dZ_D \tag{73}$$

$$\frac{dP_S}{P_S} = \mu\, dt + \sigma_D dZ_D + \sigma_S dZ_S \tag{74}$$

with Brownian motion processes Z_D and Z_S uncorrelated. Asset M represents a diversified market portfolio and Asset S a single security. Both assets pay the same expected rate of return, μ, but asset S has additional idiosyncratic risk conveyed by the diffusion σ_S.

$$U(W_T) = W_0 \exp\left\{ \mu T - \frac{\gamma T}{2} \left(\begin{array}{l} w^2 \left(\sigma_D^2 + \sigma_S^2\right) \\ + (1-w)^2 \sigma_D^2 + 2w(1-w)\sigma_D^2 \end{array} \right) \right\} \tag{75}$$

This simplifies to

$$U\left(W_T\right) = W_0 \exp\left\{ \mu T - \frac{\gamma T}{2}\left(\sigma_M^2 + w^2 \sigma_S^2\right) \right\} \tag{76}$$

Certainty Equivalents

To compare the welfare cost of a position $w_0>0$ in the undiversified asset versus a completely diversified position one can define the equivalent percentage of initial wealth (1 – x) that an investor would be willing to pay to avoid the position as

$$x \quad s.t. \quad U(W_T; W_0, w_0) = U(W_T; W_0 x, 0) \tag{77}$$

Using (76) a closed form solution for x is

$$x = \exp\left(- \frac{T\gamma\, w_0^2 \sigma_S^2}{2} \right) \tag{78}$$

$$0 < x < 1$$

The private value, Q, is derived in the body of the chapter.

Human Capital

Consider the case of three assets, D, S and H each following a diffusion process. As before, assets D and S are the diversified asset and single stock respectively. Asset H represents human capital and is assumed to have Brownian increments that are independent of asset D, but correlated with asset S (specifically, the increments dZ_D and dZ_H are correlated). H has Brownian increments with mean 0 (for simplicity) and volatility σ_H. Investment shares in all assets are fixed with human capital comprising share w_H total wealth. Fraction w of remaining wealth is held in the single stock and fraction $1 - w$ in the diversified asset. Therefore, the share of the single stock out of total wealth is $w_S = w(1-w_H)$ and the share of the diversified asset out of total wealth is $w_D = (1-w)(1-w_H)$.

The utility expression for the investor with a fixed investment horizon and constant utility shares in the multi-asset case is

$$U(W_T) = W_0 \exp\left\{ \sum_{i=1}^{n} w_i \mu_i T - \frac{\gamma}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \sigma_i \sigma_j \rho_{ij} T \right\} \tag{79}$$

For this specific case it reduces to

$$U(W_T) = W_0 \exp\left\{ (1 - w_H)\mu T - \frac{\gamma T}{2}\left[\begin{array}{l} w_H^2 \sigma_H^2 + (1 - w_H)^2 \left[\sigma_D^2 + w^2 \sigma_S^2 \right] \\ + 2 w_H (1 - w_H) w \sigma_H \sigma_S \rho_{HS} \end{array} \right] \right\} \qquad (80)$$

An employee would give up fraction 1 – x of initial wealth in order to have his entire investment portfolio invested in the diversified asset where x satisfies

$$x = \exp\left\{ -\frac{\gamma T}{2}\left[(1 - w_H)^2 w^2 \sigma_S^2 + 2 w_H (1 - w_H) w \sigma_H \sigma_S \rho_{HS} \right] \right\} \qquad (81)$$

ρ_{HS} is the correlation between the human capital increments and the idiosyncratic risk component of the stock.

Results with Bankruptcy

As before, the employee's wealth is held in a portfolio of the assets S and D, where S and D are defined as in equations (73) and (74). D retains the property of stochastic dominance over S. In addition, it is assumed that holdings of asset S are subject to a random bankruptcy state that occurs at random time t^*. The bankruptcy time t^* is a draw from an exponential distribution with arrival intensity q. When bankruptcy occurs all wealth held in S is forfeited. As a result wealth is discontinuous at t^* with

$$W^+(t^*) = (1 - w) W^-(t^*) \qquad (82)$$

Where subscripts + and – denote right and left hand limits respectively.

Prior to t^* wealth evolves according to

$$\frac{dW}{W} = (1 - w)\frac{dP_D}{P_D} + w\left[\frac{dP_S + q dt}{P_S} \right] \qquad (83)$$

After t^* wealth evolves according to:

$$\frac{dW}{W} = \left(1 - w\right)\frac{dP_D}{P_D} + w\frac{dP_S}{P_S} \tag{84}$$

If t^* does not arise prior to T the latter expression may never prevail. The difference between the two expressions involves $q\ dt$ to compensate for the bankruptcy risk present prior to t^*.[1]

Now our objective function is an expectation of a function of Brownian motion processes and an orthogonal Poisson process

$$\begin{aligned} U(W_T) &= \left\{ E\left(W_T^{1-\gamma}\right)\right\}^{\frac{1}{1-\gamma}} = \left\{ E_{t^*}E_{W_T|t^*}\left(W_T^{1-\gamma}\right)\right\}^{\frac{1}{1-\gamma}} \\ &= \left\{ \int_{t^*=0}^{T} E_{W_T|t^*\leq T}\left(\left(W_T\right)^{1-\gamma}\right) q\exp(-qt^*)dt^* + E_{W_T|t^*>T}\left(W_T^{1-\gamma}\right)\exp\left[-qT\right]\right\}^{\frac{1}{1-\gamma}} \end{aligned} \tag{85}$$

Conditional on a jump at time $t^*<T$, the expected value of terminal wealth is given by

$$\begin{aligned} E_{W_T|t^*\leq T}\left(W_T^{1-\gamma}\right) = W_0^{1-\gamma} &\exp\left\{ t^*(1-\gamma)\left[\mu + wq - \frac{\gamma}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right)\right]\right\} \\ &\times (1-w)^{1-\gamma}\exp\left\{\left(T - t^*\right)(1-\gamma)\left(\mu - \frac{\gamma}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right)\right)\right\} \end{aligned} \tag{86}$$

Conditional on no jump prior to T, the expected value of terminal wealth is given by

$$E_{W_T|t^*\leq T}\left(W_T^{1-\gamma}\right) = W_0^{1-\gamma}\exp\left\{T(1-\gamma)\left[\mu + wq - \frac{\gamma}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right)\right]\right\} \tag{87}$$

Substituting into gives

[1] In the market equilibrium context the equivalent rate of return earned on the bankruptcy prone single stock and the diversified asset implies that bankruptcy risk is diversifiable.

$$\left(\frac{U}{W_0}\right)^{1-\gamma} = \int_{t=0}^{T} \exp\left[\left(1-\gamma\right)\left\{\mu - \frac{\gamma}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right) + wq\right\}t\right]\left(1-w\right)^{1-\gamma}$$
$$\times \exp\left[\left(1-\gamma\right)\left\{\mu - \frac{\gamma}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right)\right\}(T-t)\right]q\exp(-qt)dt \tag{88}$$
$$+ \exp\left[\left(1-\gamma\right)\left\{\mu - \frac{\gamma}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right) + wq\right\}T\right]\exp\left[-qT\right]$$

Simplifying

$$\left(\frac{U}{W_0}\right)^{1-\gamma} = \exp\left[\left(1-\gamma\right)\left(\mu - \frac{\gamma}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right)\right)T\right]\left(1-w\right)^{1-\gamma} q\int_{t=0}^{T}\exp\left[\left(1-\gamma\right)wqt - qt\right]dt$$
$$+ \exp\left[(1-\gamma)\left(\mu - \frac{\gamma}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right) + wq\right)T - qT\right] \tag{89}$$

Integrating

$$\left(\frac{U}{W_0}\right)^{1-\gamma} = \exp\left[\left(1-\gamma\right)\left(\mu T - \frac{\gamma}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right)T\right)\right]$$
$$\times \frac{\left(1-w\right)^{1-\gamma} q}{q - \left(1-\gamma\right)wq}\left\{1 - \exp\left[\left(1-\gamma\right)wqT - qT\right]\right\} \tag{90}$$
$$+ \exp\left[(1-\gamma)\left(\mu - \frac{\gamma}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right) + wq\right)T - qT\right]$$

Simplifying and collecting terms gives the final expression for the utility function

$$U\left(W_0, w\right) = W_0\exp\left[\mu T - \frac{\gamma}{2}\left(\sigma_D^2 + w^2\sigma_S^2\right)T\right]\left(y + \left(1-y\right)\exp\left[(1-\gamma)wqT - qT\right]\right)^{\frac{1}{1-\gamma}} \tag{91}$$

With

$$y = \frac{\left(1-w\right)^{1-\gamma}}{1-\left(1-\gamma\right)w} \tag{92}$$

Now find

$$x \quad s.t. \quad U(W_T; W_0, w_0) = U(W_T; W_0 x, 0) \tag{93}$$

The solution is

$$x = \exp\left[-\frac{\gamma}{2}w^2\sigma_S^2 T\right]\left[y + (1-y)\exp[(1-\gamma)wqT - qT]\right]^{\frac{1}{1-\gamma}} \tag{94}$$

Human Capital and Bankruptcy

Instead of modeling a direct correlation between the Brownian increments of the idiosyncratic risk component of the stock and the employee's human capital, an alternative is to model a bankruptcy event accompanied by a shock to human capital. As before, bankruptcy occurs with intensity q per period and when it occurs the single stock's investment value falls to zero and human capital is reduced to fraction θ of its value. As in the diffusion case, the share of human capital out of total wealth is denoted w_H, the share of the single stock is $w_S = w(1-w_H)$ and the share of the diversified asset is $w_D = (1-w)(1-w_H)$. Wealth before and after the bankruptcy event at t^* are related by

$$W^+(t^*) = \left[\theta\, w_H + (1-w_H)(1-w)\right]W^-\left(t^*\right) \tag{95}$$

Where subscripts + and – denote right and left hand limits respectively. Prior to t^* wealth evolves according to

$$\frac{dW}{W} = w_H\left[\frac{dP_H + (1-\theta)\,qP_H dt}{P_H}\right] + (1-w_H)(1-w)\frac{dP_D}{P_D} + (1-w_H)\,w\left[\frac{dP_S + qP_S dt}{P_S}\right] \tag{96}$$

After t^* wealth evolves according to

$$\frac{dW}{W} = w_H\frac{dP_H}{P_H} + (1-w_H)(1-w)\frac{dP_D}{P_D} + (1-w_H)\,w\frac{dP_S}{P_S} \tag{97}$$

The jump event associated with bankruptcy is uncorrelated with the diffusive components so terminal utility can be written as

$$
\begin{aligned}
U(W_T) &= \left\{ E\left(W_T^{1-\gamma}\right)\right\}^{\frac{1}{1-\gamma}} = \left\{ E_{t^*} E_{W_T|t^*}\left(W_T^{1-\gamma}\right)\right\}^{\frac{1}{1-\gamma}} \\
&= \left\{ \int_{t^*=0}^{T} E_{W_T|t^*\le T}\left(\left(W_T\right)^{1-\gamma}\right) q\exp(-qt^*)dt^* + E_{W_T|t^*>T}\left(W_T^{1-\gamma}\right)\exp\left[-qT\right]\right\}^{\frac{1}{1-\gamma}}
\end{aligned} \tag{98}
$$

Conditional on a jump at time $t^*<T$, the expected value of terminal wealth raised to power $1-\gamma$ is given by

$$
\begin{aligned}
E_{W_T|t^*\le T}\left(W_T^{1-\gamma}\right) &= W_0^{1-\gamma}\exp\left\{ t^*(1-\gamma)\left[\begin{array}{l} \mu\left(1-w_H\right) + \left[w_H\left(1-\theta\right) + \left(1-w_H\right)w\right]q \\ -\dfrac{\gamma}{2}\left[\begin{array}{l} w_H^2\sigma_H^2 + \left(1-w_H\right)^2\left(\sigma_M^2 + w^2\sigma_S^2\right) \\ +2(1-w_H)w_H w\sigma_H\sigma_S\rho_{SH} \end{array}\right] \end{array}\right]\right\} \\
&\times \left[\theta w_H + (1-w_H)(1-w)\right]^{1-\gamma} \\
&\times \exp\left\{ \left(T-t^*\right)(1-\gamma)\left(\mu\left(1-w_H\right) - \frac{\gamma}{2}\left[\begin{array}{l} w_H^2\sigma_H^2 + \left(1-w_H\right)^2\left(\sigma_M^2 + w^2\sigma_S^2\right) \\ +2(1-w_H)w_H w\sigma_H\sigma_S\rho_{SH} \end{array}\right]\right)\right\}
\end{aligned} \tag{99}
$$

Conditional on no jump prior to t

$$
E_{W_T|t^*>T}\left(W_T^{1-\gamma}\right) = W_0^{1-\gamma}\exp\left\{ T(1-\gamma)\left[\begin{array}{l} \mu\left(1-w_H\right) + \left[w_H\left(1-\theta\right) + \left(1-w_H\right)w\right]q \\ -\dfrac{\gamma}{2}\left[\begin{array}{l} w_H^2\sigma_H^2 + \left(1-w_H\right)^2\left(\sigma_M^2 + w^2\sigma_S^2\right) \\ +2(1-w_H)w_H w\sigma_H\sigma_S\rho_{SH} \end{array}\right] \end{array}\right]\right\} \tag{100}
$$

Evaluating the integral following similar steps as in the bankruptcy case without human capital gives

$$
U\left(W_0, w\right) = W_0\left(\begin{array}{l} \exp\left[\left(1-\gamma\right)T\left(\mu\left(1-w_H\right) - \dfrac{\gamma}{2}\left[\begin{array}{l} w_H^2\sigma_H^2 + \left(1-w_H\right)^2\left(\sigma_M^2 + w^2\sigma_S^2\right) \\ +2(1-w_H)w_H w\sigma_H\sigma_S\rho_{SH} \end{array}\right]\right)\right] \\ \times\ \left\{ y + \left(1-y\right)\exp\left[(1-\gamma)\left[w_H\left(1-\theta\right) + \left(1-w_H\right)w\right]qT - qT\right]\right\} \end{array}\right)^{\frac{1}{1-\gamma}} \tag{101}
$$

Where

$$y = \frac{\left[\theta\, w_H + (1 - w_H)(1 - w)\right]^{1-\gamma}}{1 - (1-\gamma)\left[w_H(1-\theta) + (1-w_H)\, w\right]} \tag{102}$$

The diversified equivalent fraction of wealth to a position w in the single stock in this case is

$$\begin{aligned} x = {} & \exp\left\{-\frac{\gamma T}{2}\left[(1-w_H)^2 w^2 \sigma_S^2 + 2 w_H (1-w_H)\, w \sigma_H \sigma_S \rho_{HS}\right]\right\} \\ & \times \left\{\frac{y + (1-y)\exp\left[(1-\gamma)\left[w_H(1-\theta) + (1-w_H)\, w\right] qT - qT\right]}{y(0) + (1-y(0))\exp\left[(1-\gamma)\left[w_H(1-\theta)\right] qT - qT\right]}\right\}^{\frac{1}{1-\gamma}} \end{aligned} \tag{103}$$

With $y(0)$ equal to y evaluated at w=0.

APPENDIX D: RECONCILIATION OF CHAPTER 4 RESULTS WITH MEULBROEK (2002)

Meulbroek (2002) uses the Merton's (1973) continuous time CAPM to determine the average private value of a constrained investment in a single security. Merton's model is a complete markets model of asset prices where investors trade assets without friction. At each instant in time individual asset prices obey geometric Brownian motion and satisfy the famous beta pricing relationship where assets earn expected returns in proportion to their systematic risk (or beta). Take the case of a security (S) with beta sensitivity to the diversified market portfolio (D) of 1. Its rate of return over a very short interval of time satisfies:

$$r_S = r_D + \varepsilon_S \tag{104}$$

The term ε_S captures the idiosyncratic risk of the stock with $E(\varepsilon_S \mid r_D) = 0$, $Var(r_D) = \sigma_D^2$ and $Var(\varepsilon_S) = \sigma_S^2$. Also assume the presence of a risk free asset with rate of return r_F. The variables R_D and Z_S in section 4.2 are the discrete gross return counterparts of r_D and ε_S here.

In the continuous time CAPM two-fund separation prevails: all investors, irrespective of their degree of risk aversion, hold a well diversified portfolio that is a simple combination of the risk free asset and the efficiently diversified market portfolio D. The leverage choice at any instant in time involves trading off the expected portfolio return linearly against its standard deviation. Meulbroek considers the counterfactual experiment of constraining an investor to hold a fixed investment in the single security for time interval T, unnecessarily bearing unrewarded idiosyncratic risk. An investor could leverage an investment in the diversified asset/ (effectively moving along the Capital Allocation Line) by borrowing at the risk free rate to create a portfolio as risky as the single stock (total variance $\sigma_D^2 + \sigma_S^2$) that offers an expected return of

$$E\left(r_S^L\right) = r_F + \frac{E\left(r_D - r_F\right)}{\sigma_D}\sqrt{\sigma_D^2 + \sigma_S^2} \tag{105}$$

The difference between this market leveraged return and the expected return on the single stock is interpreted as the return premium necessary to compensate an individual who is forced to hold the single stock. Recall that the Sharpe ratio on any risky portfolio P is defined as:

$$S_P = \frac{E\left(r_P\right) - r_F}{\sigma_P} \tag{106}$$

Where the terms $E\left(r_P\right)$ and σ_P are, respectively, the expected return and standard deviation of return of the portfolio P. The Sharpe ratio measures the reward to risk tradeoff for an investor that increases weight on the risky asset in a two asset portfolio of risky and risk free assets. Meulbroek's diversification premium can be expressed in terms of the Sharpe ratio of the diversified asset:

$$E\left(r_S^L\right) - E\left(r_S\right) = S_D\left[\sqrt{\sigma_D^2 + \sigma_S^2} - \sigma_D\right] \tag{107}$$

This is illustrated diagrammatically in Figure 2.

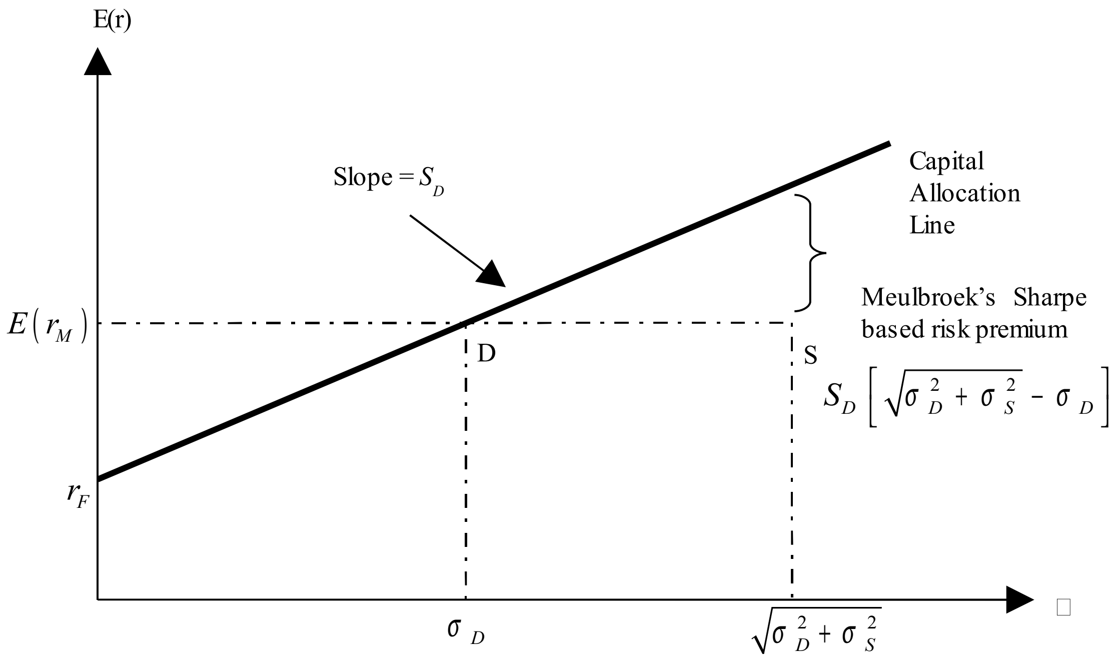

Figure 2: Diagrammatic Representation of the Meulbroek Measure of Welfare Cost Associated with a Concentrated Position in a Single Stock

Meulbroek converts the risk premium to a present value amount using standard discounting concepts. If $1 worth of the single stock is bought at market price today, its expected market value T periods from now is $e^{E(r_S)T}$. The present value of this future expected amount is found by applying an appropriate discount rate. Meulbroek asserts that the appropriate discount rate is $E\left(r_S^L\right)$ so the private value for $1 market value worth of the single security is:

$$Q_M = e^{-\left\{E\left(r_S^L\right)-E(r_S)\right\}T} \tag{108}$$

For any positive spread between the required and market discount rate, Meulbroek's private value, Q_M, is bounded between 0 and 1 ensuring the private value of the holding is always less than market value of the security. Strictly speaking $E\left(r_S^L\right)$ is only a valid discount rate for the investor if his optimal choice when not constrained to hold the single security is the combination of the risk-free asset and D that yields that same standard deviation as the single security. If this is the case, and if the single stock commands the required private risk premium, the investors constrained choice would obtain the risk return characteristics of his optimal unconstrained portfolio choice.[1] In the continuous time CAPM, the investor at any point in time trades off mean and standard deviation of the instantaneous portfolio return such that preferences can be represented diagrammatically by quadratic indifference curves in mean-standard deviation space (this follows from the iso-elastic preferences of all investors in the model). Figure 3 illustrates a scenario where the employee's optimal choice is not the levered portfolio with the same risk as S, leading to a higher required risk premium (and hence higher discount rate) on the constrained investment in the single security.

[1] Assuming the investor is atomistic so his constrained demand for the single stock does not affect its price.

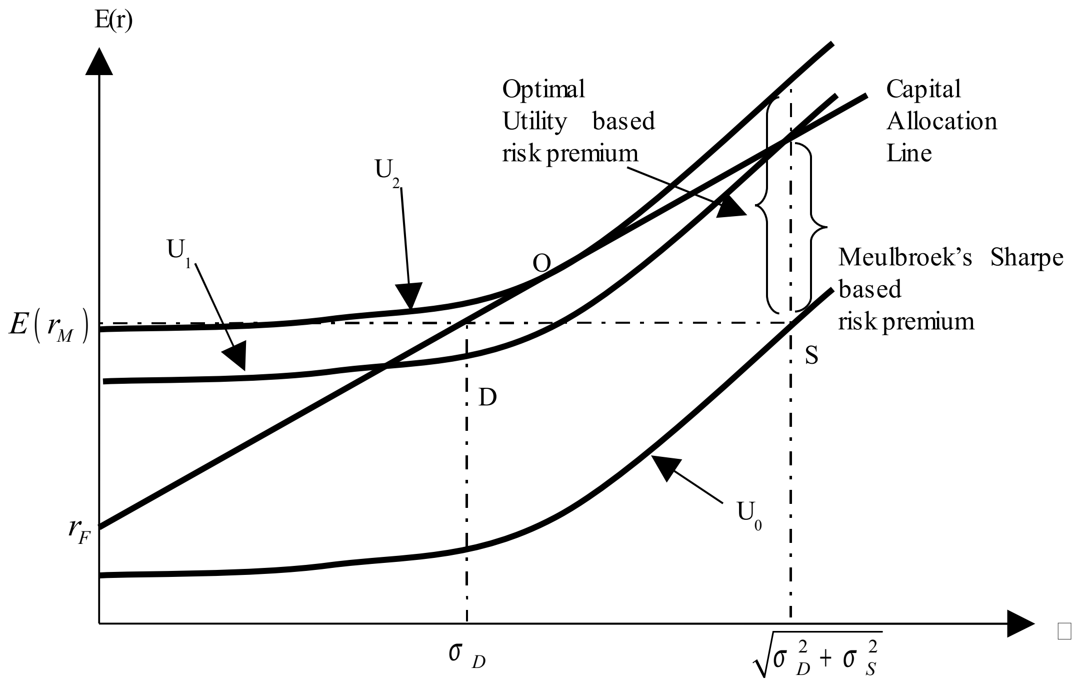

Figure 3: Demonstration of Meulbroek vs Optimal Preference Based Welfare Measures

On the other hand, allowing the investor a leverage choice when not constrained by ownership of the single security, but excluding this choice when the investor does own the single security will tend to overstate the required risk premium on the constrained investment. A clean measure of welfare loss from constrained exposure to idiosyncratic risk should ideally be disentangled from the leverage choice. Fortunately with iso-elastic investor preferences, allowing an optimal leverage choice when constrained and unconstrained is equivalent in terms of risk premium to not allowing the leverage choice in either case (this is derived in section 5). The utility equivalent risk premium without leverage is illustrated diagrammatically in figure 4 in comparison with Meulbroek's for a particular level of risk aversion. This concept of the welfare loss from holding the constrained position in S is the one used throughout this paper. In general, the risk premium measured in this way could be more or less than Meulbroek's depending on the level of risk aversion assumed. This is not considered a weakness relative to Meulbroek's since her risk premium is only consistent with a stochastic discount factor for a particular level of risk aversion.

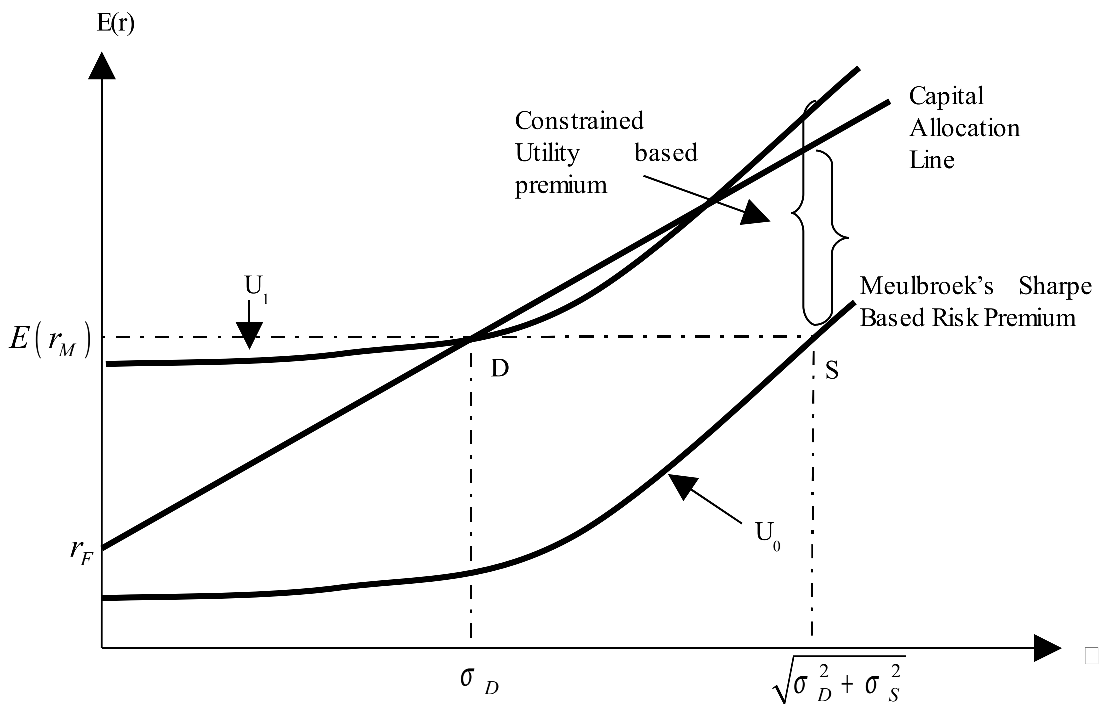

Figure 4: Demonstration of Meulbroek vs Preferences Based Welfare Measures

The private value of the exposure to the single security should be affected by ownership of other assets. The extension is straightforward. Assume the partially diversified investor is compelled to hold a portfolio *P* comprising a continuously rebalanced share w invested in the single stock and share (1 – *w*) in the diversified market portfolio. Maintaining previous assumptions, *P* has mean return E(r_M) and variance of return $\sigma_P^2 = \sigma_D^2 + w^2\sigma_S^2$. For taking on this level of portfolio risk, a diversified rational investor would require an expected return of:

$$E\left(r_P^L\right) = r_F + \frac{E\left(r_D - r_F\right)}{\sigma_D}\sqrt{\sigma_D^2 + w^2\sigma_S^2} \qquad (109)$$

A private value is established by recognizing that only fraction *w* of the investor's portfolio is undiversified so fraction (1 - *w*) will be valued by the employee at its full market value and each $1 of the undiversified fraction w has private value

$$Q_M = \mathrm{e}^{-\left[\frac{\sigma_P - \sigma_D}{w}\right]S_D T} \qquad (110)$$

The private value of the single stock holding increases as its share declines. More general results on the private value including non-tradable outside assets such as human capital cannot be considered within the confines of a frictionless markets asset pricing model model. The remainder of this chapter develops a private value that is similar to Meulbroek's, but based on a utility rather than equilibrium asset pricing methodology. The virtue of this approach is that it allows consideration of other non-tradable assets, especially human capital, and richer asset pricing specifications, such as including bankruptcy shocks. This methodology yields a private value that is analogous to Meulbroek's Q_M.

One way to reconcile the Meulbroek's private value with the utility based measure used in this paper is to recall that the solution to the two asset portfolio problem between a risky asset D and the risk free asset F under constant relative risk aversion satisfies

$$w_D = \frac{E\left(r_D - r_F\right)}{\gamma\sigma_D^2} \qquad (111)$$

Where w_D is the optimal choice of D and γ is the coefficient of relative risk aversion. This relates the Sharpe ratio to risk tolerance. Meulbroek's measure of welfare is based on comparing the single stock to a suitably leveraged diversified position of comparable risk. If γ is chosen such that the leveraged position is optimal (i.e. $w_D = \sqrt{\sigma_D^2 + \sigma_S^2} / \sigma_D$) then the required excess compensation under Meulbroek's measure has a utility based interpretation:

$$E\left(r_S^u - r_S\right) = \gamma \sqrt{\sigma_D^2 + \sigma_S^2}\left[\sqrt{\sigma_D^2 + \sigma_S^2} - \sigma_D\right] \tag{112}$$

In comparison, the constant return measure derived in this paper is[2]

$$E\left(r_S^u - r_S\right) = \frac{\gamma \sigma_S^2}{2} \tag{113}$$

[2] This follows from equation (31) with w equal to 1.

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