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Made Poorer by Choice: Worker Outcomes in Social Security v. Private Retirement Accounts

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Comments welcome.

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Abstract

Can the freedom to choose how retirement funds are invested leave workers worse off? We analyze social risks of allowing choice, using the Social Security system as an example. Comparing a privatized alternative with the current system via simulation, we document that choice in both equity allocation and equity composition lead to increased income inequality and risk of shortfalls relative to currently promised benefits. While private accounts disproportionately increase shortfall risk for low-income workers, allowing choice increases risk for all workers (even with high return outcomes). Our results suggest that restricted choice should be a central component of private-account-based systems.

> We can never insure one hundred percent of the population against one hundred percent of the hazards and vicissitudes of life, but we have tried to frame a law which will give some measure of protection to the average citizen and to his family against the loss of a job and against poverty-ridden old age.
>
> President Franklin Delano Roosevelt at signing of 1935 Social Security Act

Since its inception in 1935, critics have questioned the long-term financial viability of Social Security (Lowenstein 2005). Under the current system, payroll tax receipts fund retiree benefits, and assets are invested in special obligation treasury bonds (Gross 2010). Throughout most of Social Security's history, payroll tax inflows have exceeded benefit outflows. In 2010, benefits exceeded payroll taxes and this funding deficit is expected to worsen in the coming decades absent reform.

A variety of strategies have been proposed in response to Social Security's pending shortfall. These range from increases in the payroll tax and retirement age to privatization of Social Security. In 2001, the President's Commission to Strengthen Social Security proposed three models for Social Security reform which all incorporated voluntary personal accounts. Each election season thrusts possible Social Security reforms front and center, with many reform plans favoring some form of private retirement accounts (PRAs).

In addition to suggesting that PRAs would earn strong returns, proponents of some plans argue they benefit workers by allowing them to choose how their retirement savings are invested. This is consistent with standard finance theory, which suggests that having more choices can only improve potential investment outcomes. However, to realize this improvement, investors must choose investments wisely. In the context of PRAs, there are two relevant issues. First, many investors fail to participate in stock markets or allocate only a small fraction of their financial assets to equities (see Campbell 2006 for a review). Thus, meaningful simulations of PRA outcomes should consider the impact of allocation choice on potential outcomes. Second, extant evidence suggests that many investors fail to effectively diversify within their equity portfolios (Barber and Odean 2000; Calvet, Campbell, and Sodini 2009; Goetzman and Kumar 2008). If the tendency to underdiversify extends to PRAs, outcomes for retirees become more dispersed, and the probability of income shortfalls relative to currently-promised Social Security benefits increases. Both allocation choice and equity choice involve decision risk that materially affects aggregate PRA outcomes.

In this paper, we emphasize the potentially deleterious effects of allocation choice and equity choice on workers' outcomes under a PRA system. To estimate the magnitude of decision risk arising from allocation and equity choice, we run simulations of retirement benefits for a representative cohort of over 3,000 workers born in the US in 1979. The wages, demographic characteristics, and mortality of our cohort are generated by CORSIM, a dynamic micro-simulation model of the United States population.[1] Via simulation, we compare retirement benefits under the current Social Security system (SS benefit) for each worker to the payout he would expect if his social security taxes were diverted to a private retirement account (PRA income).

We compare results from a baseline setting without investment choice to settings in which workers can choose their allocation to stocks and bonds, their equity investments within their stock portfolio, or both. In the baseline scenario (without investment choice), workers are required to invest 60% of their PRA in a stock index and 40% in a bond index during their savings years[2]. Upon retirement, accumulated savings are invested in a variable annuity based on a 60/40 stock/bond portfolio. In the scenario with allocation choice, workers are allowed to choose an equity allocation different from 60%, which they retain throughout their working years. In the scenario with equity choice, workers are allowed to choose their stock investments, while bond investments remain indexed. In each scenario we consider, we require workers to invest in the same (60/40) variable annuity at retirement. We assume this portfolio earns an average return of 7.7%, which is roughly in line with expected returns used by major state pension funds across the US (Novy-Marx and Rauh 2008) and long-term return forecasts used by defined- benefit plans in the US based on survey evidence from Aon Hewitt Inc. (2011a). We assume market volatility is equal to its historical average.

Under the scenario allowing allocation choice, we calibrate variation in retirement stock allocation using the observed variation in stock-bond allocations in the 2010 Survey of Consumer Finances. Under the scenario allowing equity choice, some workers beat the market while others underperform. To calibrate the cross-sectional variability of investment outcomes, we estimate cross-sectional variation in returns earned in tax-deferred retirement accounts using data from a large U.S. discount brokerage. In each scenario we consider, savings are invested in an indexed variable annuity after retirement.

In our simulations, we estimate the probability that a worker earns PRA income below her Social Security benefit, which we refer to as an income shortfall. Investment choice materially increases the probability of an income shortfall. In our baseline simulation without allocation

[1] CORSIM was developed by Steven Caldwell at Cornell University. The model was purchased by the U.S. Social Security Administration, which adapted it for internal use under the name POLISIM. The model was also adapted for use by the Canadian and Swedish governments (see Caldwell 1996, Caldwell and Morrison 2000, and http://www.strategicforecasting.com/corsim/index.html).

[2] We do not claim that a 60/40 stock/bond portfolio is the optimal asset allocation. We choose this mix as a benchmark because it is frequently recommended to investors and has been used in related research (Feldstein and Ranguelova 1998, 2001).

or equity choice, the risk that an individual worker experiences an income shortfall at age 88 is 33.4%. Allocation choice increases this risk to 38.5%, while equity choice increases it to 45.2%. With both allocation choice and stock investment choice, the probability of an income shortfall is 48.0%; conditional on an income shortfall, mean PRA retirement income is about half of the promised Social Security benefit.

We define a worker to be at risk of an income shortfall if her PRA income is less than her promised Social Security benefit in more than 25% of simulations and refer to the proportion of the worker population at risk of an income shortfall according to this definition as "percent-at-risk." Without investment choice, the percent-at-risk at age 88 is 62.8%; allocation choice increases this risk to 77.4%, equity choice increases it to 95.1%, and allocation and equity choice increases it to 95.5%. With equity choice, more than 19 out of 20 workers have greater than 25% probability that age 88 PRA income will fall short of promised Social Security benefits. The erosion in PRA performance with allocation choice results from workers who allocate a relatively small percentage of their retirement accounts to equity, while the erosion in PRA performance with equity choice results from workers failing to effectively diversity their stock investments.

Market returns play a big role in the attractiveness of PRAs. However, investment choice leaves investors with a high probability of income shortfalls, even if they are fortunate enough to enjoy high market returns during their saving years. Each of our simulations can be thought of as a generation of workers who experience a different market outcome. We sort simulations into quintiles based on the market outcomes during workers' saving years. For the top quintile of market outcomes, the 60/40 stock/bond index portfolio earns an impressive average return of 10.6%. Despite the impressive returns, the probability of an income shortfall for a worker is 7.0% at age 88 without investment choice. With allocation choice, the probability of a shortfall more than doubles, to 15.2%. Equity choice nearly triples this risk (to 19.9%), while allocation and equity choice increases it to 25.6%. Without choice, the percent-at-risk conditional on being in the top return quintile is 4.1% at age 88. Allocation choice increases it to 20.4%, while equity choice increases it to 29.0%, and allocation and equity choice to 42.1%. The increase in risk from allowing choice has a large effect even in the best market conditions. If both allocation and equity choice are allowed, more than 4 out of 10 workers face greater than 25% risk that PRA income will fall short of promised Social Security benefits at age 88 despite being in the top quintile of market returns.

Our analysis highlights the importance of two dimensions of choice in a PRA system. First, limiting equity options in a PRA system to well-diversified and low cost options is important to reduce the risk generated by equity choice. While at first blush this might seem like a simple policy solution to the decision risk that we document, the reality is not as obvious. As we discuss in detail later, in the Australian Superannuation Guarantee (PRA) system and the market for US 401(k) plans, investor choice was initially limited, but has expanded rapidly over time.[3] In Australia, the additional options resulted in widely different outcomes for investors. In US 401(k) plans, expanding options led to higher fees as new options were tilted toward more expensive actively managed funds (Brown, Liang and Weisbenner 2007). Second, ensuring investors have the appropriate tools to make a well-informed asset allocation decision is important.

Our analysis also highlights the potential distributional effects of a switch from Social Security to PRAs. Current Social Security benefits are regressive (low-income workers earn higher benefits per dollar contributed than high-income workers). When we sort on income quintiles, the distributional effects of PRAs are clear. Without investment choice, the bottom quintile of wage earners has a 53.9% probability of an income shortfall at age 88. With allocation choice, this probability grows to 60.3%, while equity choice increases it to 63.0%, and allocation and equity choice to 68.2%. All workers in the bottom quintile of wage earners have greater than 25% probability of an income shortfall at age 88. By contrast, workers in the top earnings quintile have a 15.2% chance of an income shortfall at age 88 without investment choice, which grows to 18.3% with allocation choice, 27.7% with equity choice, and 28.2% with allocation and equity choice. For these high-income workers, equity choice still increases retirement risk: their percent-at-risk at age 88 is zero without choice, 2.3% with allocation choice, 73.5% with equity choice, and 75.8% with allocation and equity choice.

The distributional effects of PRAs generally hit black and Hispanic workers, who are more likely to be low wage earners, the hardest. Absent offsetting public policy initiatives, simply diverting Social Security taxes to PRA accounts will leave low-income workers with high probabilities of income shortfalls relative to currently-promised Social Security benefits. Allowing choice of investments in private accounts compounds this effect.

In summary, our simulation-based analysis yields three insights. First, allowing allocation choice in PRAs increases the probability of an income shortfall relative to Social Security benefits, as some workers will allocate a relatively small amount of their investment portfolio to stocks. Second, allowing equity choice increases the probability of an income shortfall relative to Social Security benefits, as some workers will fail to effectively diversify. Third, owing to the

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[3] The Bush proposal for Social Security reform, summarized in the 2001 Report of the President's Commission on Strengthening Social Security and Creating Personal Wealth for Americans, offered two tiers of investment. Tier 1 was modeled after the federal government Thrift Savings Plan with limited investment choice, but Tier 2 afforded more choice in an effort to provide competition and choice among fund providers.

regressive nature of Social Security benefits, the probability of an income shortfall is much higher for low wage earners. The first two insights generalize to self-directed retirement accounts intended to provide for basic living needs in retirement: with greater allocation choice and greater equity choice workers are more likely to fall short of their minimum goals than if they invest in a balanced portfolio of equity and bond index funds.

After presenting our results, we argue several features of our simulation-based evidence underestimate the effect of choice on workers' retirement outcomes. For example, our simulations prohibit bequests of PRAs, require the purchase of indexed variable annuities in retirement, assume investment expenses are less than those currently charged by mutual funds, and assume all investors have the same ability to pick stocks and mutual funds.

I. Institutional Background and Related Literature

I.A. Current Social Security Program

Social Security provides guaranteed retirement benefits to those who contribute to the system during their working years. While the majority of Social Security benefits go to retirees, the disabled and family members of beneficiaries also receive benefits. The system is often referred to as a defined-benefit pay-as-you-go (PayGo) system as current taxes are used to pay benefits to current retirees. The Social Security program was adopted as a response to the Great Depression, with the first benefits being paid in 1940.

Social Security was intended as insurance against "…poverty-ridden old age," to borrow the words of President Roosevelt. In keeping with the goal of reducing post-retirement poverty, Social Security benefits are higher (as a proportion of contributions) for lower-income workers. As we discuss in detail later in the paper, the current benefit formula is based on three income tiers, which results in two bend points. The maximum monthly social security benefit is approximately $2,500.[4]

Currently, the Social Security tax is 12.4% (a temporary reduction to 10.4% was enacted as part of the Tax Relief Act of 2010, which was extended through 2012). Until recently, Social Security tax receipts have exceeded benefits with the surplus credited to the Social Security Trust Fund. According to the 2012 Board of Trustees Report (p.3), a combination of the Trust Fund and tax receipts will be sufficient to pay Social Security benefits, as currently promised, until 2033.

[4] http://ssa-custhelp.ssa.gov/app/answers/detail/a_id/5/~/maximum-social-security-retirement-benefit

To address this funding shortfall, several proposed solutions would preserve the insurance features of Social Security through various mechanisms. These proposals include increasing the retirement age, indexing benefits to CPI instead of wage inflation, and increasing either the tax rate or amount of earnings subject to tax (the income ceiling).

Administrative projections suggest that to remain solvent for the next 75 years, the Social Security tax would need to immediately increase from 12.4% to 15.0%, (Board of Trustees 2012, p.4). As discussed below, in our simulations, we assume that PRA contributions are consistent with the 15% tax rate since it is this rate that would render the current system solvent on a going-forward basis.[5]

I.B. Private Retirement Accounts (PRAs)

Some have proposed more fundamental changes, arguing we should implement private retirement accounts (PRAs). These proposals do not address the funding shortfalls discussed above. Instead, they emphasize individual ownership and responsibility, and allow individuals to choose how retirement assets are invested.

In his 2004 State of the Union address, President Bush made the case for PRAs: "Younger workers should have the opportunity to build a nest egg by saving part of their social security taxes in a personal retirement account. We should make the Social Security System a source of ownership for the American people." Though proposals vary in their details (see Murphy and Welch 1998 for a summary of several proposals), individuals would generally have ownership of their retirement accounts and, potentially, broad discretion over how they are managed.

While many privatization reform plans initially restrict investment choice, restrictions often give way to more choice over time. For example, Australia legislation to adopt a PRA (the Superannuation Guarantee) was passed in 1992. When first introduced, employees had very limited choices available (Fear and Pace 2009). Over time, the choices available to employees have expanded, an expansion accelerated by the passage of the Superannuation Legislation Amendment (Choice of Fund) Act in 2004. Workers invest through a superannuation fund, often referred to as super funds. In 2011, there were hundreds of super funds. Each super fund may offer workers a wide variety of investment options (one fund offered 2,700). The investment options offered by a super fund have few restrictions and can include mutual funds, individual stocks, hedge funds, private equity, and property trusts (to name a few).

The experience in 401(k) retirement plans in the US is also informative. Brown, Liang, and Weisbenner (2007) document the number of options available to workers has increased over

[5] The projected solvency tax rate has ranged from 14.14% to 15.01% between 2007 and 2012.

time. In addition, the new options tend to be actively managed equity funds that charge higher fees and earn lower returns. More recently, brokerage windows, which allow investors to direct 401(k) assets to a brokered accounts and individual equities, have become an increasingly popular. Aon Hewitt (2011b) reports the percentage of plans that offer brokerage windows has increased from 12% in 2001 to 29% in 2011.

Some have argued for expanding choice in the current reform models. Michael Tanner, Director of the Cato Institute Project on Social Security Privatization, testified before President Bush's commission on Social Security reform and argued in favor of broad investment choice, suggesting individuals "…should be given as wide a range of investment opportunities as possible, consistent with regulatory safeguards against fraud or speculation. While investing in 'Singapore derivatives' or your brother-in-law's South American gold mining stock is clearly not envisioned, there is no reason to limit workers to two or three index funds."[6]

The anticipated benefits of personal accounts include direct ownership (including heritability) and higher expected returns from investing in equities and other securities. Several studies (for example, Diamond and Geankopolos 2003; Modigliani, Ceprini, and Muralidhar 2003) point out the returns and risks from investing in equities could be incorporated into Social Security without adding to the administrative costs of managing many individual personal accounts.

We are not the first to study the welfare implications of PRAs. However, we add more detailed assumptions regarding risks and expected returns faced by workers in their forced savings accounts. For example, the Bush Commission's projections assume that all personal accounts are invested in a 50/50 portfolio of equities and bonds that earn a constant annual real rate of return of 4.6%; a constant return assumption is clearly unrealistic when workers invest in risky assets (particularly stocks).

Feldstein and Liebman (2002) consider the distributional aspects of Social Security by considering worker-level outcomes, but do not model variation in market outcomes or risks arising from workers' different investment choices. They conclude that virtually all demographic groups benefit from a shift to PRAs. Our results differ from theirs for two main reasons. They assume a non-stochastic (risk-free) annual after cost logarithmic real portfolio return of 5.5 percent on PRA investments. Thus their assumed portfolio return is higher than ours. More importantly, they assume no variation in annual portfolio returns and thus do not explore distributional impacts of low realized market returns.

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[6] Testimony of Michael D. Tanner Director, before the President's Commission to Strengthen Social Security, October 18, 2001, http://www.ssa.gov/history/reports/pcsss/Tanner_Testimony.pdf.

In an analysis closer to our own, Feldstein and Ranguelova (2001) analyze outcomes of a representative investor who invests in a PRA and conclude the representative investor generally fares well under PRAs. They assume that personal accounts are invested in a 60/40 portfolio of equities and bonds, which earns a stochastic annual real return of 6.5%.[7] The returns earned in personal accounts vary across cohorts, but *not* across individuals within a cohort. Variation in outcomes across cohorts captures the risk that a particular generation of workers will experience a poor investment outcome. Gollier (2008) and Shiller (2006) also study this generational risk. We extend this line of inquiry by allowing for variation in returns across cohorts and, more importantly, allowing variation in investment choice across individuals within a cohort.

Our first departure from prior studies is to allow for allocation choice in an investor's PRA. None of the aforementioned models study the impact of allocation choice—the mix of stocks and bonds chosen by each individual in their investment portfolio. This is an important dimension of choice that almost certainly has a big impact on expected outcomes for workers.

Our second innovation is to consider cross-sectional variation in the equity returns of individual workers. Even when investors experience the same market return, their personal investment results will vary. Modeling this cross-sectional variation in performance is important, as some investors will beat the market, while others will underperform. There is considerable evidence that individual investors do not manage portfolios optimally. Barber and Odean (2000) argue investors trade too aggressively and earn poor returns as a result. While most of the return shortfall can be traced to transaction costs, some of the shortfall appears to result from perverse stock selection ability on the part of individual investors (Odean 1999; Barber, Lee, Liu, and Odean 2009). Investors also fail to diversify their retirement portfolios by, for example, overinvesting in their employer's stock (Poterba 2003; Benartzi 2001). Goetzmann and Kumar (2008) argue investors fail to diversify their stock portfolios. Benartzi and Thaler (2001, 2007) argue investors follow naïve diversification strategies in their retirement plans. Calvet, Campbell, and Sodini (2009) analyze complete portfolios for Swedish households. While the median household holds a well-diversified portfolio, some households hold portfolios that are severely underdiversified. In addition, households with low education and wealth are less likely to participate in the stock market and more likely to invest inefficiently if they do participate. Similarly, Grinblatt,

[7] Feldstein and Ranguelova (2001) assume a mean annual real log return of 5.5% on a 60/40 stock/bond portfolio (with a standard deviation of 12.5%), which corresponds to a mean level return of approximately $6.5\% = \mathrm{e}^{\left(5.5\% + \frac{(125)^2}{2}\right)} - 1$. Using the parameters employed by Feldstein and Ranguelova and our simulation technology, we are able to generate results close to theirs for a representative investor. We argue that our main results differ from theirs because they overestimate the market risk premium by using historical averages.

Keloharju, and Linnainmaa (2011) and Grinblatt, Ikäheimo, Keloharju, and Linnainmaa, (2012) show that cognitive abilities positively affect both stock market participation and trading performance among Finnish investors. In summary, there are many reasons to believe there will be high cross-sectional variation in investor outcomes.

By modeling outcomes at the individual rather than cohort level, we are also able to identify demographic patterns that emerge when we shift from an insurance-based Social Security program to PRAs. Under the current Social Security scheme, those who earn low wages during their lifetime receive proportionately greater benefits than high-wage earners. Thus, a worker-level analysis allows us to estimate the probability of an income shortfall for different demographic groups, which is clearly important given the regressive nature of Social Security benefits.

II. Data and Methodology

We compare PRA income, where workers invest in a 60/40 stock/bond portfolio and purchase a variable annuity in retirement, to currently-promised Social Security benefits, where retirement benefits are based on a worker's earnings history. We simulate the experiences for 10,000 generations of workers. Each generation shares the same income profile, but experiences a different market return.

We use simulated data for lifetime earnings of a cohort of 3,655 individuals born in 1979, which we obtained from CORSIM. CORSIM provides a detailed micro-simulation of incomes for a representative sample of the US population. CORSIM basically develops projections of income based on numerous sources (e.g., Survey of Consumer Finances, Panel Study of Income Dynamics, and The US Census). See Caldwell (1996) and Caldwell and Morrison (2000) for details. The CORSIM micro-simulations have been used in studies by Caldwell et al. (1999) and Gokhale and Kotlikoff (1999, 2002). The data include demographic details (e.g., race and gender), annual earnings subject to social security benefits, and year of death.

In Table 1, we present descriptive statistics on lifetime earnings of the 1979 birth cohort by decade from 1999 through 2069. Mean and median income increase with age until the cohort reaches age 50 and then tails off quickly as workers retire. In Figure 1, we plot the percentage of the cohort still living by age for the CORSIM data, which are quite similar to projections from the Social Security administration.

II.A. Estimating Social Security Benefits

We estimate a currently promised Social Security benefit for each worker in each year during retirement based on the algorithm used to calculate Social Security benefits described in

Board of Trustees (2012) and assuming a retirement age of 67.[8] The current algorithm used by Social Security establishes a benefit level for each worker at retirement. Once a benefit level has been established, it increases each year based on cost of living adjustments (discussed below). The Social Security Act specifies that several parameters, which affect benefit levels, be set annually based on changes in economic conditions (Board of Trustees 2012). Key parameters include the index factor for wages, the increase to the highest wage level eligible for benefits, and the increase in benefits to account for inflation. In this section, we describe the algorithm used by the current Social Security system to highlight the importance of each parameter.

A. 1. Average Indexed Monthly Earnings (AIME) and Bend Points

To calculate the promised benefit for an individual worker, we first index the worker's capped annual wages to age 60 (wages earned after age 60 are not indexed). Capped wages in each year represent the lower of the worker's actual wage and the maximum wage subject to Social Security taxes and eligible for benefits. The index rate represents changes both in cost of living and real wage rates, and tends to exceed inflation (specifically the index depends on CPI-W published by the Bureau of Labor Statistics). Of indexed wages, the top 35 years are used to calculate Average Indexed Monthly Earnings ("AIME").

AIME is compared to two benefit cutoff levels ("Bend Points"). The worker's retirement benefits are calculated by adding 90% of wages below the first Bend Point, 32% of wages between the two Bend Points, and 15% of wages above the second bend point. Figure 2 illustrates the application of Bend Points to AIME for a cohort retiring in 2012. The Bend Points introduce concavity into retiree benefits as a function of preretirement income. We parameterize our model using baseline estimates discussed below, primarily relying on Board of Trustees (2012).

Each year, the Social Security Administration calculates an Average Wage Index (AWI) based on prevailing wages subject to Social Security Tax (Board of Trustees 2012). Historically, the increases in the Bend Points have been close to increases in the Average Wage Index. Our analysis uses the same parameter to increase both of these items. We use the compound annual growth rate of changes to bend points from 1980 to 2010 to estimate a base case index rate of 4%; this rate is used to index wages and Bend Points to retirement-age (2044) price levels.

A. 2. Benefit Base

The Benefit Base represents the maximum wage subject to social security taxes. Wages that exceed the Benefit Base in any year are set equal to the Benefit Base in the calculation of

[8] The normal Social Security retirement age varies from 65 for those born in 1937 and earlier to 67 for those born in 1960 or later.

benefits. The cap for 2012 is $110,100; to estimate future Benefit Base levels we use an estimate of 4%, which equals the assumptions we make regarding wage inflation and is close to the 3.9% compound annual growth rate of the Benefit Base between 1985 and 2010 (see http://www.ssa.gov/oact/cola/cbb.html).

Annual benefits are adjusted each year to reflect cost of living increases. In scenario analysis, Board of Trustees (2012, p.8) estimates future cost of living increases to be between 1.8% and 3.8%. We use 3%, which is close to the realized benefit increase for the period from 1985 to 2010 of 2.8%[9] and is near the midpoint of the Board of Trustees range. In Appendix A, we present a Social Security benefit calculation example for an individual worker.

II.B. Private Retirement Account (PRA) Income

As an alternative to Social Security, we assume workers are required to save the equivalent of their Social Security tax in a defined-contribution PRA. In our base case, we assume workers invest their PRAs in portfolios with a 60% allocation to equities and 40% allocation to bonds with annual rebalancing. The simulated returns on 60/40 portfolios are 7.7% per year. In retirement, we assume all workers buy a variable annuity. Thus, mortality risk is pooled, but each worker continues to bear market risk in retirement. We assume any balances in the PRAs of those who die before retirement are transferred to a common pool that continues to earn returns until the cohort retires and is then used to help finance the cohort's variable annuity.

B. 1. Savings Rate

Our simulations assume a savings rate of 9.36%. We arrive at our assumed savings rate in two steps. First, as a base we use the 15% tax rate, which would guarantee current OASDI benefit levels over the next 75 years (Board of Trustees 2012, p.4). Second, we estimate the proportion of total OASDI benefits that are paid as a retirement benefit to a primary wage earner. Social security benefits include payments to retirees (including spouses and children), survivors of individual beneficiaries, and the disabled (labeled old-age (OA), survivor (S), and disability (D) benefits, respectively). These benefits are funded through the Social Security tax (OASDI). To estimate the proportion of the 15% solvency tax required to secure retirement benefits for an employee, we calculate the percentage of total benefits (OASDI) paid as retirement benefits from 1995-2011 in Table 2. The percentage of total benefits paid as retirement benefits is very stable with an average of 62.4%. Given this evidence, we assume that 62.4% of the 15% solvency tax (i.e., 9.36%) is required to fund the cohort's promised Social Security benefits. Thus, in our PRA

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[9] See http://www.ssa.gov/oact/cola/colaseries.html.

simulations we assume 9.36% of each worker's income (up to the Social Security wage cap) is diverted to a PRA and, upon retirement at age 67, is used to fund an annuity that would replace a worker's promised Social Security benefit.

B. 2. Portfolio Returns without Choice

We assume the annual return on a 60/40 stock/bond portfolio is 7.7% per annum. We assume stocks earn a mean annual level return of 9.1%, while bonds earn 5.5%, and that the inflation rate is 3% (consistent with Social Security projections as discussed in section I.A.2.). Assuming one-month Treasury Bills earn 60 bps over inflation, which is consistent with historic averages, we implicitly assume an equity risk premium v. T-Bills of 5.5% = 9.1% - 3.6%.

In this section, we discuss the reasoning behind these assumptions. To calibrate our return assumptions, we begin with data from Ibbotson Associates for the postwar period 1946 to 2008. Our equity returns are based on the S&P 500 Index (Ibbotson's large company stock index) and corporate bond returns are based on the Ibbotson long-term corporate bond series. Real returns are calculated by deducting (CPI) inflation in each year. The mean and standard deviation of the log real returns on equity are 6.0% and 18.6%, while the corresponding values for long-term corporate bonds are 1.8% and 10.3%. The covariance between the two series is 0.006, yielding a correlation between stock and bond returns of 31%.

We project nominal returns on stocks and bonds that are consistent with the inflation assumptions underlying our benefit and income projections. Our benefit calculations generally assume a wage (CPI-W) inflation rate of 4%. The CORSIM income projections assume wage inflation in the same ballpark.[10] Historically, wage inflation is about 1% higher than CPI inflation.[11] Thus, we adjust our real returns on stocks and bonds to reflect an assumed inflation rate of 3% yielding nominal mean log returns on stocks and bonds of 9.0% and 4.8%, respectively.[12]

We shave the assumed log return on stocks by two percentage points, from 9% to 7%; this is equivalent to shaving the level return on stocks from 11.3% to 9.1%.[13] We do so for two reasons. First, there is a general consensus that realized returns in the 20th century represent an

[10] We have simulated wage patterns for six cohorts born between 1974 and 1979. We estimate the embedded wage inflation assumption by first calculating aggregate wages by age, cohort, and year. We then calculate the mean change in wages across the six cohorts for each age. From the age of 30 to 50, the average change in wages is 4.95%.

[11] For example, over the 40-year period from 1969-2008 the real wage differential (i.e., wage inflation less CPI inflation) averaged 0.8 percentage points (2010 Board of Trustees Report, p.98).

[12] During the 1946 to 2008 period, CPI inflation averaged 4.03%, and the nominal mean log return on stocks and bonds were 9.9% and 5.8%, respectively.

[13] $9.1\% = e^{\left(7\% + \frac{(.186)^2}{2}\right)} - 1$, and $11.3\% = e^{\left(9\% + \frac{(.186)^2}{2}\right)} - 1$.

equity premium puzzle (Mehra and Prescott 1985). As a result, several scholars argue in favor of an expected equity premium well below historic averages. Fama and French (2002, p.657) argue dividend and earnings growth models yield an equity risk premium estimates that are closer to the true expected value; in the 1951-2000 sample period, the dividend and earnings growth model yield estimates of the equity risk premium that are 3.1 to 4.9 percentage points *less* than the historical equity return, which suggests our assumption of a mean equity return 2 percentage points below its historical average may be conservative. Our assumptions regarding stock returns yield a healthy equity risk premium v. long-term corporate bonds of 3.6% = 9.1% - 5.5%. Given the default risk of corporate bonds, the equity risk premium v. long-term government bonds would be greater than 3.6%, which is still above many equity risk premium estimates. For example, Arnott and Bernstein (2002, pp.80-81) argue "…[the] observed real stock returns and the excess return for stocks relative to bonds in the past 75 years have been extraordinary… The historical average equity risk premium, measured relative to 10-year government bonds as the risk premium investors might objectively have expected on their equity investments, is about 2.4 percent…" Siegel (2005, p.70) reviews evidence on the equity risk premium and reaches a similar conclusion: "…there are good reasons why the future equity risk premium should be lower than it has been historically, projected compound equity returns of 2-3 percent over bonds will still give ample reward for investors willing to tolerate the short-term risks of stocks." Diamond (2000) reaches a similar conclusion, suggesting realistic GDP growth estimates are consistent with long-term stock returns considerably lower than 7%.

Second, the lower stock return yields a level portfolio return in our simulations of 7.7%, which is within the 7.3% to 8.5% range of expected returns used by U.S. state pension funds in 2005 (Novy-Marx and Rauh 2008). Hewitt Associates (2011a) conducts surveys of clients who manage defined-benefit plans and reports the average forecast of long-term returns for US providers to be 7.7% in 2010. (The average across the 23 countries where Hewitt conducts surveys is 6.1%.) Merely applying the historic rate of return on stocks would yield a 60/40 portfolio return of 9.0% per year, which is above the highest return estimate of 8.5% used by only five state pension funds in 2005 (Colorado, Connecticut, Minnesota, New Hampshire, and Pennsylvania) and higher than the average rate Hewitt reports for 22 of 23 countries, the exception being Brazil where defined-benefit plans use a rate of 11.5%.

In our simulations, we draw stock and bond log returns from a bivariate normal distribution with means of 7.0% and 4.8%, standard deviations of 18.6% and 10.3%, and a correlation of 31.3%. The simulated log returns are converted to level returns to calculate the level return on a 60/40 stock/bond portfolio.

From the portfolio return, we deduct a portfolio administration expense of 0.40% annually (the same rate used by Feldstein and Ranguelova 2001). Whether this is high or low depends on the nature of the choices available in PRAs. For example, if investors are able to choose from the universe of mutual funds currently offered, the 0.40% would be low. The asset-weighted expense ratio for equity mutual funds is 1.11%, while that for bonds is 0.78% (Khorana, Servaes, and Tufano 2009). These expenses would likely be higher if workers were allowed to trade individual stocks, as commissions and spreads would erode returns (Barber and Odean 2000).

B. 3. Portfolio Returns with Choice

a) Stock-Bond Allocation Choice

Most individually controlled retirement account plans (e.g., 401(k)s, Keoghs, IRAs) as well as the alternative PRA proposals in the 2001 Report of the President's Commission on Strengthening Social Security and Creating Personal Wealth for Americans allow investors to choose their stock-bond allocation. To assess the impact of allocation choice on outcomes, we consider simulation with and without allocation choice. In our baseline simulations, we assume all investors choose a 60/40 stock/bond allocation. In our allocation choice simulations, we model variation in choice using the observed stock allocation in retirement accounts.

To estimate the variation in stock allocation in retirement accounts, we use the 2010 Survey of Consumer Finance (SCF) dataset. For each household in the dataset, we sum investments in IRAs, Keoghs, and 401k plans. For those households with a positive balance in at least one of these retirement accounts, we calculate the percentage of the account allocated to stock. Since we are focused on allocations during workers savings years, we restrict the analysis to households under the age of 68. For the households with positive balances in retirement accounts and a head of household under the age of 68, the average (median) balance in these retirement accounts is $145,000 ($38,000), and the average (median) household allocates 48% (46%) of the account investments to stock, and allocations do not differ greatly by age group in the 2010 SCF and are similar to those reported in the 2004 and 2007 SCF.[14]

In Figure 3, we present the percentiles of stock allocation for these households. About 12% of households have no allocation to stocks and about 14% of households allocate 100% of their investments to stock. In our simulations that allow allocation choice, for each worker, we sample from a uniform distribution from 0 to 100, round to the nearest integer, and identify the

[14] The average equity allocation ranges from 43% for those in their 60s to 52% for those in their 20s. The mean and median household allocation to equity in tax-deferred retirement accounts were close to 50% in the 2004 and 2007 SCF datasets.

stock allocation for the corresponding percentile from Figure 3. This stock allocation is then used as the stock-bond allocation for the worker during all of his saving years.

We model the allocation choice in this way for two reasons. First, we do not know workers risk preferences so we implicitly assume the risk appetites are randomly assigned. Second, investors' allocation choices in defined contribution retirement accounts (e.g., contribution rates, asset allocation decisions, and investment in own company stock) are influenced by plan default options (e.g., Beshears, Choi, Laibson, and Madrian 2008, 2009) and choice framing (Benartzi and Thaler 2001, 2007). This suggests that at least some investors' observed choices are not determined based on solving a portfolio optimization problem. Alternatively, we could model allocation choice as a function of demographic characteristics. For example, stock market participation tends to be lower for the less wealthy, so we might assume that low-income workers are more likely to spurn equity investment in their retirement accounts. As we document later, a lower equity allocation tends to increase the probability of an income shortfall; thus, lower equity allocations for low-income workers would further increase their probability of an income shortfalls for this group.

b) Stock Investment Choice

When investors have choices other than index funds, individual investment outcomes will vary from market returns. To calibrate the extent of this variation, we use realized returns in tax-deferred retirement accounts at a large discount broker in the US over the period 1991 to 1996. The dataset contains records for 78,000 households, but we limit our analysis to households' equity investments in tax-deferred retirement accounts for which we have complete positions during a calendar year (so we can reliably estimate the annual return earned in a household's tax-deferred account). Thus, the sample size ranges from about 16,000 households in 1991 to 24,000 in 1996. The mean (median) investment in a tax-deferred account is \$33,000 (\$15,000) across household years. (See Barber and Odean (2000) for a complete description of these data.) These households invest in a combination of individual stocks and mutual funds. For the average household, the tax-deferred account represents 79% of their total equity investments at the broker and 36% of the tax-deferred account is held in mutual funds with the remainder in individual stocks. For each household, we calculate the monthly portfolio return by matching month-end positions to Center for Research in Security Prices (CRSP) data on stock and equity mutual fund returns. From these monthly returns, we calculate an annual return for each household. These annual returns are used to calibrate the variation in annual returns across households.

In Table 3, we present the mean level and log return across households and the cross-sectional standard deviation of returns. Across the six-year sample period, the average annual return earned by households is 18.1% (before deducting transactions costs), slightly less than the average return on the S&P 500 (18.4%) and the CRSP value-weighted market index (18.9%) over the same period. The cross-sectional standard deviation in log returns averages 24% across the six-year sample period.

To model this cross-sectional variation in returns, we assume the cross-sectional distribution of household log returns is normally distributed with a standard deviation equal to 24% (i.e., the annual standard deviation of the household log returns reported in Table 2). Thus, household log returns exhibit two sources of variation: time-series variation in equity market returns (18.6% from above) and cross-sectional variation in household returns (24%). We assume these two sources of variation are normally distributed and independent. Thus, combining variation in equity market returns and the cross-sectional variation in household returns, the time-series standard deviation of the household log return is $30.4\% = \sqrt{.186^2 + .240^2}$.

In our choice-based simulations, we assume all investors invest in a 60/40 stock bond portfolio with annual rebalancing and bond returns do not vary across investors. However, each investor earns a different return on his or her stock portfolio, though the investors collectively earn the simulated market return. To simulate this cross-sectional variation, we proceed in two steps. First, in each simulated year we draw a market return for equity, which is common for all investors. Second, for each investor we add idiosyncratic volatility to the annual stock market return. Some investors beat the market, while others underperform.[15]

We implicitly assume the variation in outcomes across households is random within and across years. We do so for modeling simplicity, but this likely underestimates the effect of equity choice on the variation in outcomes that would be observed in a PRA system since a household that is undiversified in one year is likely to remain undiversified in subsequent years.

B. 4. The Variable Annuity

We assume cohort members begin work at age 21 and retire at age 67. The aggregate value of the cohorts' PRAs at retirement is used to finance a variable annuity for the cohort. Denote the aggregate value of assets of the cohort up to age 68 as V_{68}, the aggregate annuity payment at age 68 (the first year of retirement) as A_{68}, the expected return of the portfolio as R, the

[15] The log market return is drawn from a normal distribution with a mean of 4.2% and a standard deviation of 18.6%. Idiosyncratic volatility is added by drawing from a normal distribution with mean zero and standard deviation of 24.0%. The two draws are added to yield the household's equity return for the year. We preserve the assumed level return on equity (9.1%) by shaving the log return on equity from 7.0% to 4.2%. Thus, the choice-based simulations assume the same annual level return on the 60/40 stock/bond portfolio (7.7%) as in the no-choice simulations.

inflation rate i, and the expected number of cohort members alive at age t as N_t based on actual mortality in the CORSIM dataset. Then, $A_{68} = V_{68} / APV_{68}$, where

$$APV_{68} = \sum_{t=68}^{100} \frac{N_t}{N_{68}} \left(\frac{1+i}{1+R}\right)^{(t-68)}$$

represents the actuarial present value (APV) of an expected $1 real annual payment for the rest of an individual's life. In subsequent years, the aggregate annuity payment changes as realized returns will differ from expected returns.

Because realized returns differ from expected returns, PRAs generate volatile retirement income. In years with strong market returns, the income from the PRA will increase, while in years with poor market returns, the income will decrease. These changes can be dramatic. Assume the investor's variable annuity payout is tied to a 60/40 stock/bond portfolio with an expected return (R) of 7.7%. From 1929 to 1931, this stock/bond portfolio dropped by over 40%, and in 2008 it dropped by almost 20%. During these two episodes, retirees depending on variable annuity income would have experienced negative income shocks of a similar magnitude.

Each cohort member who retires receives a portion of the aggregate annuity payout, where the portion is the ratio of the retiree's PRA value to the total value of all currently living retirees' PRAs, where all PRA values are measured at retirement. Those who die before retirement contribute to the aggregate cohort pool V_{68}, but do not receive a portion of the cohort's variable annuity. Thus, the denominator used to calculate each retiree's portion of the cohort annuity excludes the value of the PRAs for those who die prior to retirement. We use the mortality tables implied in CORSIM data, but assume all cohort members still alive at age 99 all die at age 100 (see Figure 1). We present an example of the cohort annuity calculation in Appendix B.

III. Results

III.A. Main Results

We evaluate outcomes at the ages of 68, 78, and 88. We calculate the probability that a worker's PRA income is less than the Social Security benefit, which we refer to as the probability of an income shortfall. We measure probability of income shortfalls in two ways. First, we calculate the probability of an income shortfall across all workers and all simulations. We refer to this metric as worker outcomes. Second, we report the percentage of workers who experience income shortfalls in more than 25% of simulations. While the 25% cutoff is somewhat arbitrary, this measure emphasizes the safety-net nature of Social Security for many workers and the asymmetrical effect on utility of losses versus gains relative to promised payments. This metric measures the percentage of workers with a risk of more than one quarter of being worse off with a PRA. We refer to this metric as percent-at-risk.

Our main results are presented in Table 4 and represent the outcomes across 10,000 simulations. We present four sets of results, where we alternatively consider outcomes with/without allocation choice and with/without stock investment choice. In each panel of this table and those that follow, we present results in the following matrix format:

No Stock Investment Choice 60/40 Stock/Bond Allocation	With Stock Investment Choice 60/40 Stock/Bond Allocation
No Stock Investment Choice Stock/Bond Allocation Choice	With Stock Investment Choice Stock/Bond Allocation Choice

Across all workers and without stock investment or allocation choice (top left, Panel A), the probability of an income shortfall ranges from 22.4% at age 68 to 33.4% at age 88. Solely allowing allocation choice while restricting stock investment choice (bottom left, Panel A) increases the probability of an income shortfall with a range of 28.4% at age 68 to 38.5% at age 88. Solely allowing stock investment choice while restricting allocation choice (top right, Panel A), has a larger impact on the probability of an income shortfall, with a range of 38.6% at age 68 to 45.2% at age 88. Allowing both allocation and stock investment choice (bottom right, Panel A) yields a further increase in the probability of an income shortfall to 48.0% at age 88. Income shortfalls are both common and material. For example, conditional on observing an income shortfall, a worker's expected retirement income at age 88 is 58.9% of the promised Social Security benefit at age 88 in the no choice scenario and 51.0% of the promised Social Security benefit with both allocation and equity choice.

In Panel B, we present percent-at-risk. These results indicate a substantial percentage of the worker population has greater than a 25% probability of an income shortfall and the percent-at-risk increases dramatically with investment choice. Without allocation or stock investment choice, the percent-at-risk is 35.5% at age 68 and 62.8% at age 88. With allocation choice, the percent-at-risk is 44.7% at age 68 and 77.4% at age 88. With both allocation choice and equity choice, the percent-at-risk is 75.2% at age 68 and 95.5% at age 88.

Three common patterns emerge in these simulations. First, the probability of an income shortfall increases with age. The erosion of the performance of the PRA with age can be traced to the observation that the median payout from the variable annuity grows less than the mean payout in retirement years. To see this, consider a worker who retires at age 65 with $100 savings. The worker buys a 35-year variable annuity with an 8% expected return, 14% standard deviation, and

3% growth rate.[16] We simulate the payouts the worker can expect from this variable annuity at each age from 66 to 100. Figure 4 depicts the 25th percentile, median, 75th percentile, and mean outcome at each age across the simulations. Note the average outcome from the variable annuity is precisely what the worker would expect from a straight annuity (i.e., no return variance) with an 8% expected return and 3% growth rate. Per $100 investment, the straight annuity would pay $6.18 at age 66, $16.87 at age 100, and grow by precisely 3% in each year.[17] However, the gap between the mean and median payout from the variable annuity increases with age. This result can be traced to the increased volatility of outcomes associated with the market risk borne by the worker who purchases a variable annuity.

Second, the probability of an income shortfall increases with equity choice. The preceding discussion also explains why workers are more likely to experience an income shortfall when faced with more stock investment choice. Some workers will fail to diversify completely, which will increase the volatility of their outcomes. Increased volatility of investment outcomes does not affect the average return earned by workers. In each period, workers in aggregate earn the same return, regardless of choice. However, choice induces more volatility in worker outcomes over time, which causes the median worker outcome to drop and thus increases the probability of an income shortfall under the PRA scheme.

Third, allocation choice also increases the probability of an income shortfall. The main reason for the erosion in performance when we allow allocation choice is the fact that many workers have relatively small allocations to stock. Workers who choose lower allocations to stock have a greater probability of an income shortfall in retirement because of the low average expected return on their investment portfolio. We verify this conclusion by sorting households into quintiles based on their stock/bond allocation in the allocation choice simulations. The top two quintiles have mean allocations to stocks of 66 and 97% (respectively), and simulation results for these households are very close to our baseline results with a fixed 60/40 stock/bond allocation. Thus, the higher expected returns that result from a relatively high allocation to stocks offsets the higher volatility that results from the riskier allocation. However, the bottom allocation quintile has an average stock allocation of only 3%, and the probability of an income shortfall jumps to 43.1% at age 68 and 52.5% at age 88 without stock investment choice, and to 43.5% at age 68 and 53.1% at age 88 with stock investment choice. The percent-at-risk for these risk averse

[16] In these simulations, we assume the log return of the portfolio is normally distributed with a mean of 6.9% and a standard deviation of 12.9%. This corresponds to a level return of 8% and a standard deviation of 14%.

[17] The $6.18 annuity payout at age 66 represents is based on the 35-year annuity factor at a 8% discount rate, 3% growth rate, and an assumed investment portfolio of $100 at age 65, $100/16.19 = $6.18.

households jumps to 68.8% at age 68 and 94.3% at age 88 without stock investment choice, and to 69.7% at age 68 and 95.4% at age 88 with stock investment choice. Over the long periods for which we simulate returns, stocks usually outperform bonds. Thus, in our simulations workers are better off with substantial equity positions. However, as discussed in Section IV, our assumptions that annual logged equity returns are independent and normally distributed lead us to underestimate the likelihood of poor equity performance over long periods.

III.B. Results by Income

These results indicate that investors in PRAs will have a substantial probability of income shortfalls relative to their promised Social Security benefit. In this section, we document the probability of an income shortfall varies dramatically across income groups – a result which can be traced to the regressive nature of Social Security benefits (see Figure 2).

To investigate this issue, we partition workers into quintiles based on indexed lifetime earnings to age 67 (see Appendix A for a sample calculation). The results of this analysis are presented in Table 5. In Panel A, we present worker outcomes for each income quintile. With no allocation or stock investment choice, there are dramatic differences in outcomes by income quintile. The probability of an income shortfall for a worker from the lowest income quintile ranges from 48.0% at age 68 to 53.9% at age 88, while the same probability for a worker from the highest income quintile ranges from 4.5% at age 68 to 15.2% at age 88. For all income groups, both allocation choice and equity choice increases the probability of a shortfall. However, the main story that emerges from this table is an immediate shift to a PRA scheme would leave low-income workers with a much higher probability of an income shortfall than high-income workers.

In Panel B, we present the percent-at-risk and the distributional effects of PRA accounts are even starker. Without allocation or stock investment choice, *no one* in the top income quintile has a greater than 25% probability of experiencing a PRA income less than their promised Social Security benefit. With equity choice, the percent-at-risk among the top-quintile wage earners ranges from 8.9% at age 68 to 73.5% at age 88. In contrast, the entire population of the low income wage earners (the bottom 20% of lifetime indexed earnings, discussed above) has greater than a 25% probability of an income shortfall in retirement (regardless of the choice scenario). With allocation choice, nearly all workers in the bottom two income quintiles have greater than a 25% risk of an income shortfall at ages 78 and 88. With stock investment choice, all workers in the bottom four quintiles face this risk.

III.C. Results by Ethnic Group

The results by income groups also have implications for PRA outcomes for different ethnic groups, since income varies considerably across ethnic categories with hispanic and black workers generally earning lower wages than their white counterparts. The CORSIM data identifies workers in six broad ethnic categories, the largest three being white-nonhispanic (73% of all workers), black-nonhispanic (13%), and white-hispanic (7%). (The remaining three ethnic categories are black-hispanic, other-hispanic, and other-nonhispanic.)

In Table 6, we present results for the three major ethnic categories. The results for white workers mirror the results for our overall sample, since they represent a large percentage of all workers. Black workers fare somewhat worse. When we look at black worker outcomes (Panel A), we see a slight increase in the probability of a PRA shortfall relative to white workers. The gap between white and black workers is somewhat larger when we analyze the percent-at-risk (Panel B). Without allocation or stock investment choice, the risk of an income shortfall for black workers is 25.7% at age 68 and 34.8% at age 88 risk. Allocation choice increases this risk to between 32.2% at age 68 and 40.0% at age 88 while increases it to 41.7% at age 68 and 46.5% at age 88, and both allocation and equity choice to 43.9% at age 68 and 49.4% at age 88. Hispanic workers have the biggest risk of experiencing a PRA income less than their promised Social Security benefit and this risk increases with both allocation and stock investment choice.

Differences in outcomes across ethnic categories can be traced to lower incomes earned by black and Hispanic workers. Investment choice increases the probability of an income shortfall for all ethnic groups. Furthermore, the welfare losses from experiencing a PRA income less than promised Social Security benefits are potentially greater for ethnic groups because they are more likely to depend upon Social Security for the majority or the entirety of their retirement income. Social Security payments account for 100% of income for 21.3% of white, 42.2% of black, 32.9% of Asian, and 44.7% of Hispanic beneficiaries 65 or older; they account for 100% of income for 93.9% beneficiaries 65 or older who are in the bottom income quintile, irrespective of ethnic background.[18]

III.D. Results by Market Outcomes

To investigate how market outcomes affect generational outcomes, we partition simulations into quintiles based on the market return earned during the cohort's savings years. The results of this analysis are presented in Table 7.

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[18] http://www.ssa.gov/policy/docs/statcomps/income_pop55/2010/sect09.html#table9.a3

Not surprisingly, market risk plays a huge role in the attractiveness of PRAs. The mean level return on the 60/40 stock/bond portfolio in the bottom quintile of generational outcomes is 4.7% -- a mere 1.7% over inflation. The probability of an income shortfall in these bottom-quintile market outcomes is quite high, ranging from 60.9% at age 68 to 66.0% at age 88 across all workers. The percent-at-risk is also high; all workers have greater than a 25% probability of an income shortfall at age 88 during bottom-quintile market outcomes. Choice has a modest impact as everyone fares poorly when the generational return on the investment portfolio is poor.

In strong (top quintile) market conditions, the portfolio earns a return of 10.6%. Without choice, workers have a low probability of an income shortfall (ranging from 1.2% at age 68 to 7.0% at age 88). Allocation choice increases these probabilities (ranging from 6.5% at age 68 to 15.2% at age 88), while equity choice increases them dramatically (ranging from 12.3% at age 68 to 19.9% at age 68) and the combination of allocation and equity choice even more (15.7% at age 68 and 25.6% at age 88). Thus, even in strong market conditions, 1/4th of the worker population experiences income shortfalls at age 88 with allocation and equity choice. Similarly, the percent-at-risk in these high return outcomes is very low (ranging from 1.0% at age 68 to 4.1% at age 88). However, with allocation choice, the percent-at-risk jumps dramatically (ranging from 3.5% at age 68 to 20.4% at age 88). Equity choice increases this risk, ranging from 13.1% at age 68 to 29.0% at age 88, and from 23.1% at age 68 to 42.1% at age 88 with both allocation choice and equity choice. These results indicate a sizable fraction of workers – above 2/5^{ths} at age 88 – face greater than 25% risk of an income shortfall even in the best market conditions when both allocation and equity choice are allowed.

The analysis of results by market outcomes highlights the importance of assumptions regarding the returns on stocks and bonds. Small adjustments to the assumed return on these investments have dramatic effects on the relative attractiveness of PRAs.

IV. Discussion

Our simulations compare the outcomes from PRAs to promised Social Security benefits. We use Social Security Administration projections regarding a number of parameters in our model. While this puts us on solid footing for estimating current outcomes, the Social Security system is a pay-as-you-go system whose funding depends on tax rates, retirement age, and the ratio of workers to retirees, which itself is a function of retirement age. Our simulations assume tax rates required to guarantee social security payments through 2075 and a retirement age of 67. Implicit in our analysis is the assumption that the current ratio of workers to retirees will be stable across generations. Increases in the worker-retiree ratio would improve the financial footing of Social

Security, while decreases would require modifications to benefits, taxes, or the retirement age to remain solvent.

We have made reasonable assumptions regarding the returns to stocks and bonds. Feldstein (1997, p.22) argues one advantage of a PRA type system is the increased availability of capital for private investment, which he argues could drive down the return on capital by 20% (from historic average of 9% to 7.2%). Lower returns on capital are the equivalent of lower expected returns for investors. Lower expected returns would make PRAs less attractive to workers, but the increased investment could generate positive externalities. We do not consider either the effect of lower returns or additional investment in our simulations.

In many ways, the outcomes we present underestimate the potential income shortfalls and the distributional effects of PRAs. In the PRA scheme we model, we have prohibited bequests, forced purchase of variable annuities, assumed investors who self-manage their accounts do not pay high fees or sacrifice expected returns, and assumed all investors have the same ability to pick stocks and mutual funds. Furthermore, our distributional assumptions likely underestimate the probability of dramatically poor equity returns. We discuss each of these factors in turn.

We have pooled bequests and ignored variation in outcomes during retirement years. Our implementation of PRAs assumes that any remaining balance in the PRA when a worker dies is used to fund payouts for living cohort members. If workers are allowed to bequest the remainder of their PRA, payouts from PRAs will be reduced and the probability of an income shortfall would increase. If workers are not forced to buy a variable annuity in their retirement years, many will continue to self-manage their accounts. Few U.S. households currently buy annuities, an observation referred to as the "annuity puzzle." (Inkman, Lopes, and Michaelides 2011 present recent evidence on the annuity puzzle.) The continued self-management of PRAs would further increase the volatility of outcomes across workers and increase the probability of income shortfalls.

We do not charge a performance penalty to workers who self-manage their portfolios. There is considerable evidence that individual investors underperform appropriate benchmarks when managing their own investment portfolios (Barber and Odean 2000; Barber and Odean 2001; Grinblatt and Keloharju 2001; Barber, Lee, Liu, and Odean 2009). Furthermore, the average mutual fund charges expenses far greater than the 40 bps assumption used in our simulations. Khorana, Servaes, and Tufano (2008) document asset-weighted average bond and stock expense ratios in the US are 0.78% and 1.11%, respectively. Including load fees amortized over a five-year holding period, total shareholder costs for bond and stock funds are 1.05% and 1.53%, respectively. Attaching a performance penalty or higher fees to self-managed investment accounts would further erode the performance of PRAs and increase the probability of an income shortfall.

We do not consider predictable variation in performance across investors. In our simulations, we assume all investors earn the same expected return. However, there is strong evidence that investment outcomes predictably vary across investors (see Barber and Odean 2011 for a review). For example, the wealthy tend to earn stronger returns than the poor (Barber and Odean 2000), and the young perform better than the old (Korniotis and Kumar 2011. High IQ investors earn stronger returns than low IQ investors (Grinblatt, Keloharju, and Linnainmaa 2011) and also pay lower fees on their mutual funds (Grinblatt, Ikäheimo, Kelaharju, and Knupfer 2012). Thus, the combined evidence provides strong support for the possibility that young, wealthy, and smart investors will earn stronger returns than others. Adding this cross-sectional variation in expected returns would increase the differences in outcomes for low- and high-income workers.

We do not model the well-documented relation between stock market participation and wealth (Campbell 2006). In our simulations that allow allocation choice, we find that a low allocation to stocks results in a lower expected return on a worker's investment portfolio and a much higher probability of an income shortfall. If low-income wage earners are less likely to allocate their investment portfolio to stocks, the probability of a shortfall for low-income workers will be higher than the estimates we obtain.

Finally, our simulations underestimate the probability of bad market outcomes. In our simulations we assume that equity index returns follow a lognormal distribution, which implies logged returns are normally distributed. However, empirically observed logged returns are negatively skewed.[19] Thus our simulation underestimates the likelihood of large negative equity returns. As discussed above, we estimate the mean and standard deviation of logged returns from 1946–2008 historical returns, reducing the mean by 2 percentage points in response to recent academic estimates of the equity risk premium. We assume that the returns earned in sequential years are independent and thereby ignore the possibility that a crisis in financial markets may feedback into the real economy thereby affecting subsequent market returns. Thus we underestimate, perhaps severely, the probability that equity markets will underperform over long periods. To illustrate this point, imagine that at the beginning of 1990 one had estimated the mean annual logged return and variance of the Japanese stock market from 1947 through 1989.[20] Forecasting the distribution of returns from 1990 through 2012, one would have estimated that the realized 22-year

[19] Over the 1946-2008 sample period, the skewness coefficient of the annual logged return on the S&P 500 is -0.83 ($p<.01$).

[20] For this analysis, we use the Global Financial Data Japan Nikko Securities Composite Total Market Return Index.

logged return of -0.44 had a probability of less than 1.5 in 10 million (0.000000147). Had one reduced the assumed mean logged return by 2 percentage points—as we do the historical mean logged return in our simulations—one would have estimated the realized 22-year logged return had a probability of 0.00000116. This example highlights the dangers of forecasting from historical returns. While one in a million events do occur, biased econometric models are more common. Our simulations underestimate the likelihood of poor market performance over long horizons. We choose to acknowledge this bias rather than attempt to compensate with controversial ad hoc assumptions.

V. Conclusion

We compare the worker-level outcomes of a private retirement account (PRA) system to the current Social Security system. We do so by conducting simulations across workers and generations. When workers are required to invest in a stock and bond index fund, we document that 22.4% of age 68 retirees and 33.4% of age 88 retirees have PRA payouts that fall below their currently promised Social Security benefit. With allocation choice, the risk of lower income increases to 28.4% at age 68 and 38.5% at age 88; with equity choice, it grows to 38.6% at age 68 and 45.2% at age 88; with both allocation and equity choice, it grows to 40.2% at age 68 and 48.0% at age 88.

The probability that a worker experiences PRA income less than her promised Social Security benefit varies with a workers' lifetime earnings because of the regressive nature of Social Security benefits. Without choice, the bottom quintile of lifetime wage earners have a 48.0% (53.9%) chance of an income shortfall at age 68 (age 88), while the top quintile has a 4.5% (15.2%) chance of an income shortfall at age 68 (age 88).

These results highlight the importance of restricting equity options to well-diversified low-cost investment options in PRAs. Indeed, the notion of restricted choice has been a part of several proposals. While restricted choice can reduce some of the PRA shortfall that we document, a restricted choice model raises questions beyond the scope of the current paper: Who would choose the suitable investments in the restricted choice set? Would the choices be publicly or privately managed? To what extent would political influence affect the choices available (and fees charged) to investors? There is also considerable evidence that framing affects investor choices (Benartzi and Thaler, 2001 and 2007; Brown et al., 2007) making the presentation of alternative investment options to investors important.

Our results also highlight the importance of allocation choice—the mix of stocks and bonds that workers elect in their investment portfolios. Thus, ensuring investors are equipped with the financial tools that will enable them to make appropriate allocation choices given their risk preferences will be important.

Our simulations focus on PRAs as an alternative to Social Security. However, our central message applies more broadly to self-directed retirement plans, including 401(k) plans. Offering workers more investment choice is likely to reduce the standard of living in retirement for many of them.

Most models in economics presume that agents are better off with more choice or with a larger opportunity set. However, this is only true for investors if they are equipped with the knowledge, skill, and discipline to select optimal investment portfolios. If investors fail to diversify, underperform benchmarks, pay high fees, or refrain from participating in stock markets, choice will not necessarily lead to better outcomes. Indeed, many investors will be made poorer by choice.

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Figure 1: Cohort mortality

This figure presents cohort mortality as a function of age based on the number of individuals alive at age 21. Data are from the 1979 CORSIM cohort simulation.

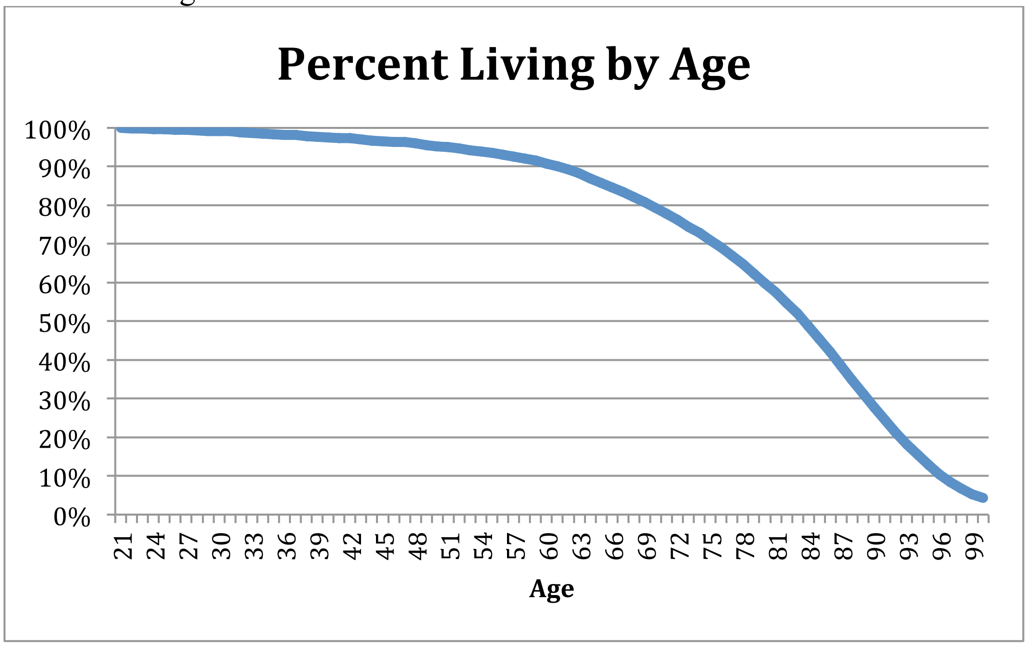
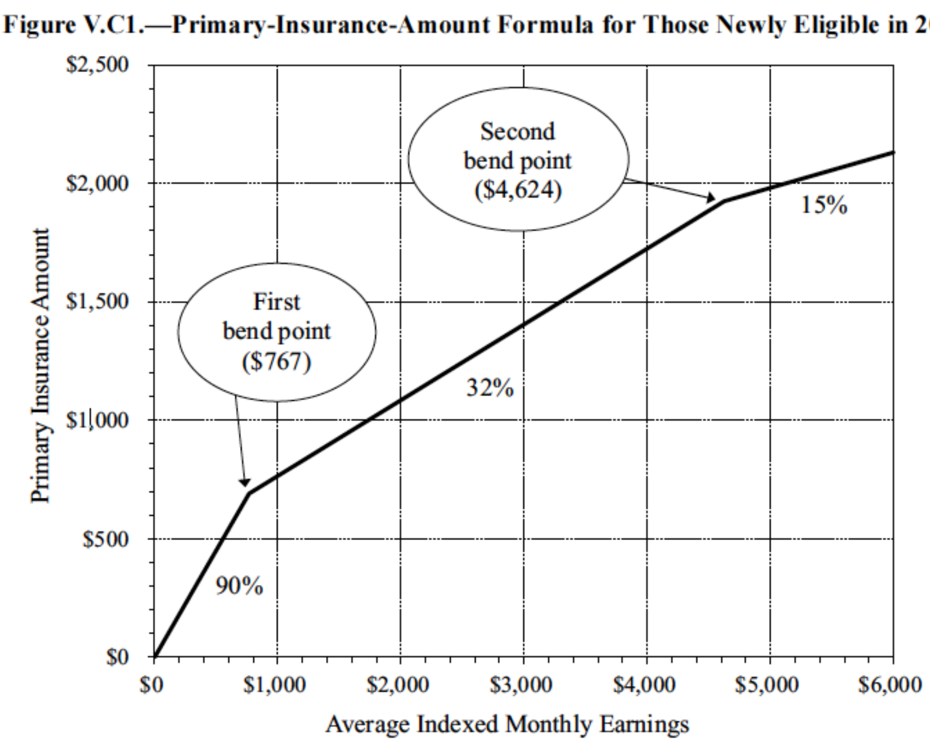


Figure 2: Bend points and Average Indexed Monthly Earnings (AIME)



Source: Board of Trustees 2012 Report, p.111.

Figure 3: Stock Allocation in Retirement Accounts

The figure depicts the percentage allocation to stocks in IRA/Keogh/401K accounts for households with investments in at least one retirement account and the head of household is less than age 68 in the 2010 Survey of Consumer Finances dataset.

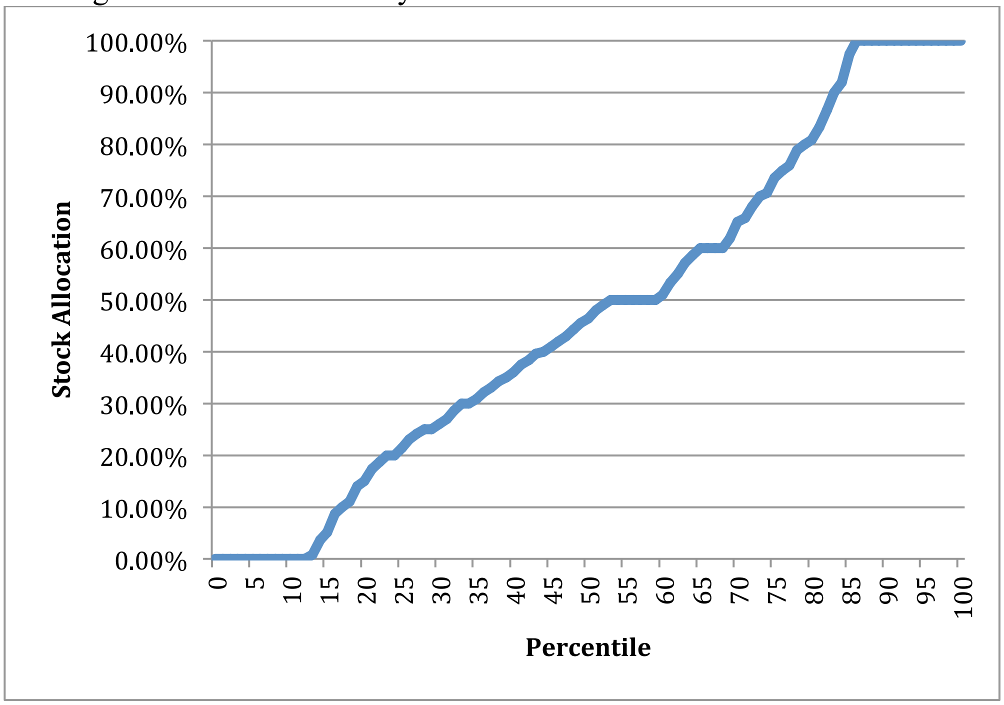


Figure 4: Distribution of Variable Annuity Payout by Age

This figure depicts the distribution of the annual payout at various ages for a $100 variable annuity purchased at age 65. The parameters used to calculate the payout are a 3% growth rate, 8% expected return, and 14% standard deviation of returns.

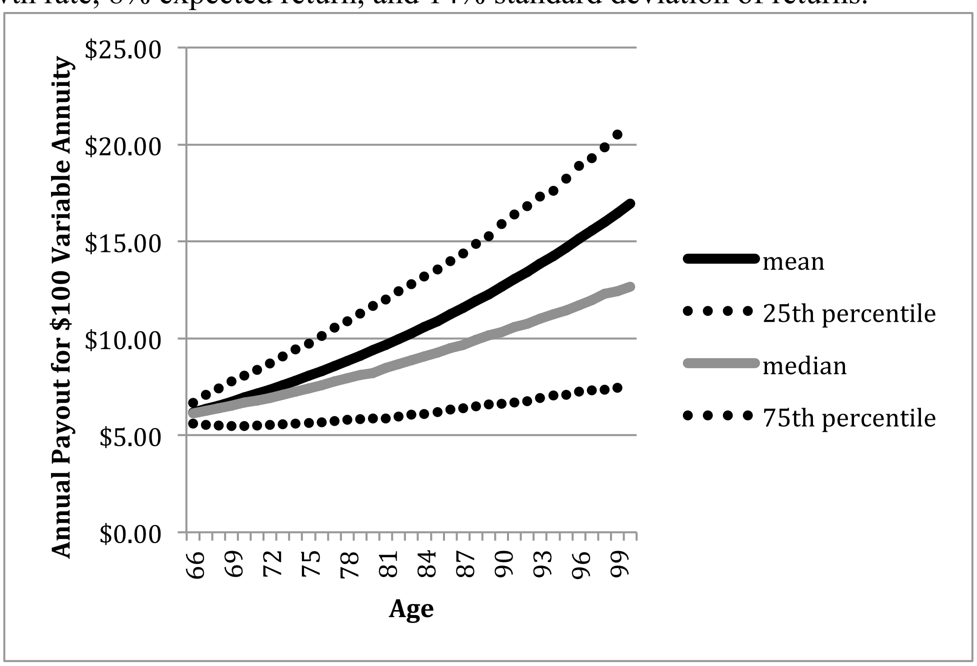


Table 1: Cohort earnings by age

This table reports summary statistics for earnings of individuals in the CORSIM data (1979 birth year) by age.

			Earning Statistics					
Year	Age	No. Living	Mean	Median	Std. Dev	75%	25%	No. (=0)
1999	20	3,619	8,297	4,429	10,925	12,330	48	883
2009	30	3,585	41,814	28,055	53,913	63,199	4,466	599
2019	40	3,525	76,544	48,480	110,507	108,741	6,710	634
2029	50	3,443	121,688	72,085	189,085	167,242	7,131	679
2039	60	3,281	121,217	21,725	289,070	155,679	0	1,293
2049	70	2,866	39,647	0	244,837	0	0	2,302
2059	80	2,165	16,673	0	105,647	0	0	1,959
2069	90	1,003	2,169	0	20,542	0	0	976

Table 2: Primary Retiree Benefits and Total OASDI Benefits, 1999-2011

	Benefits ($ Billions)		
Year	Retired Worker	Total OASDI	Percent Retired Workers / Total
1995	203.1	328.8	61.8
1996	211.3	343.2	61.6
1996	220.8	358.2	61.6
1998	230.3	371.8	61.9
1999	236.8	382.8	61.9
2000	249.6	402.0	62.1
2001	268.9	431.9	62.3
2002	281.6	453.7	62.1
2003	291.5	470.7	61.9
2004	304.2	493.2	61.7
2005	321.7	520.7	61.8
2006	342.8	522.8	65.6
2007	364.3	585.0	62.3
2008	384.0	615.4	62.4
2009	424.0	675.5	62.8
2010	443.4	701.6	63.2
2011	461.2	725.1	63.6

Source: Board of Trustees Reports, 1996-2012

Table 3: Annual Level and Log Household Returns

Household returns are based on data from a large discount broker from 1991 to 1996. The table presents mean annual level and log returns for equity (mutual funds and individual stocks) investments in tax-deferred accounts across households. Returns are before transaction costs (loads and redemption fees on mutual funds, commissions and bid-ask spread on common stocks). Mutual fund returns are net of operating expenses. The market return is based on the total return on the S&P 500 index.

		Level Return			Log Return	
	Households	**Mean**	**Std. Dev.**	**Market Return**	**Mean**	**Std. Dev.**
1991	16,116	34.6	47.5	33.6	25.5	28.1
1992	19,568	8.7	28.5	9.0	5.0	26.9
1993	21,800	15.5	26.2	11.5	12.0	22.1
1994	23,278	-4.0	18.8	-0.6	-6.1	21.4
1995	23,607	32.9	31.5	35.7	26.1	22.1
1996	24,250	21.1	29.6	21.3	16.5	23.7
Mean	21,437	18.1	30.4	18.4	13.2	24.0

Table 4: Retirement Outcomes for Private Retirement Accounts v. Social Security
The table simulates outcomes for 10,000 generations of workers who save 14.2% of their income during working years and invest the proceeds in a 60/40 stock/bond portfolio. Each generation includes over 3,000 representative worker income profiles; income profiles are static across simulations. The log returns on stocks and bonds are drawn from a bivariate normal distribution with means of 7% and 4.8%, standard deviations of 18.6 and 10.3%, and a correlation of 31%. When households are allowed choice in their stock investments, we increase the standard deviation of the stock return at the household level to 30.4% while retaining the same aggregate level return on stocks.
Worker Outcomes represent the percentage of outcomes across simulations where the worker has lower retirement income from PRA than promised Social Security benefit.
Percent at Risk represents the percentage of workers where retirement income across PRA simulations is lower than promised Social Security benefit in more than 25% of simulations.

	Age	No Stock Investment Choice	With Stock Investment Choice
		Panel A: Worker Outcomes (% PRA < SS Benefit)	
60/40	68	22.4	38.6
Stock/Bond	78	28.9	42.6
Allocation	88	33.4	45.2
Stock/Bond	68	28.4	40.2
Allocation	78	34.5	45.0
Choice	88	38.5	48.0
		Panel B: Percent at Risk (% of workers for whom PRA < SS Benefit in >25% of simulations)	
60/40	68	35.5	77.8
Stock/Bond	78	48.2	89.3
Allocation	88	62.8	95.1
Stock/Bond	68	44.7	75.2
Allocation	78	63.0	88.3
Choice	88	77.4	95.5

Table 5: Retirement Outcomes for Private Retirement Accounts v. Social Security by Quintiles of Lifetime Earnings

We sort workers into quintiles based upon their earnings through age 65 and present outcomes by income quintiles.

Worker Outcomes represent the percentage of outcomes across simulations where the worker has lower retirement income from PRA than promised Social Security benefit.

Percent at Risk represents the percentage of workers where retirement income across PRA simulations is lower than promised Social Security benefit in more than 25% of simulations.

		No Stock Investment Choice across Lifetime Earnings Quintiles					Stock Investment Choice across Lifetime Earnings Quintiles				
	Age	1 (Lo)	2	3	4	5 (Hi)	1 (Lo)	2	3	4	5 (Hi)
		Panel A: Worker Outcomes (% PRA < Social Security Benefit)									
60/40 Stock/Bond Allocation	68	48.0	32.8	16.4	10.2	4.5	60.4	50.0	35.4	28.0	19.2
	78	52.3	39.4	24.5	17.8	10.5	62.4	53.0	39.8	33.0	24.5
	88	53.9	42.6	29.2	23.1	15.2	63.0	54.5	42.4	36.0	27.7
Stock/Bond Allocation Choice	68	57.5	41.3	22.3	14.3	6.5	67.0	53.3	36.0	27.3	17.2
	78	59.8	46.5	30.3	22.5	13.4	68.3	56.6	41.9	34.2	24.1
	88	60.3	48.8	34.5	27.5	18.3	68.2	57.8	44.9	38.0	28.2
		Panel B: Percent at Risk (% of workers for whom PRA < SS Benefit in >25% of simulations)									
60/40 Stock/Bond Allocation	68	100.0	74.6	3.2	0.0	0.0	100.0	100.0	100.0	80.1	8.9
	78	100.0	99.8	38.4	1.8	0.0	100.0	100.0	100.0	100.0	45.4
	88	100.0	100.0	87.1	20.2	0.0	100.0	100.0	100.0	100.0	73.5
Stock/Bond Allocation Choice	68	100.0	98.7	24.6	0.2	0.0	100.0	100.0	99.8	72.6	3.6
	78	100.0	100.0	90.6	21.7	0.0	100.0	100.0	100.0	100.0	40.3
	88	100.0	100.0	100.0	77.7	2.3	100.0	100.0	100.0	100.0	75.8

Table 6: Retirement Outcomes for Private Retirement Accounts v. Social Security by Ethnic Category

Worker Outcomes represent the percentage of outcomes across simulations where the worker has lower retirement income from PRA than promised Social Security benefit. Percent at Risk represents the percentage of workers where retirement income across PRA simulations is lower than promised Social Security benefit in more than 25% of simulations.

		No Stock Investment Choice			Stock Investment Choice		
	Age	White	Black	Hispanic	White	Black	Hispanic
Panel A: Worker Outcomes (% PRA < Social Security Benefit)							
60/40 Stock/Bond Allocation	68	20.8	25.7	28.8	37.1	41.7	44.4
	78	27.4	31.4	34.9	41.3	44.8	47.9
	88	31.9	34.8	40.1	44.0	46.5	51.1
Stock/Bond Allocation Choice	68	26.5	32.2	35.6	38.4	43.9	47.1
	78	32.9	37.2	41.0	43.6	47.6	51.1
	88	36.9	40.0	45.6	46.6	49.4	54.6
Panel B: Percent at Risk (% of workers for whom PRA < SS Benefit in >25% of simulations)							
60/40 Stock/Bond Allocation	68	31.4	43.1	51.9	75.0	84.6	89.5
	78	44.1	56.2	62.8	87.8	93.0	96.5
	88	59.7	66.2	77.7	94.6	96.9	98.5
Stock/Bond Allocation Choice	68	40.4	54.5	59.7	72.1	82.9	87.1
	78	59.6	68.7	77.5	86.9	92.0	94.8
	88	75.3	80.9	87.7	94.8	96.9	98.5

Table 7: Retirement Outcomes for Private Retirement Accounts v. Social Security by Generation Return Quintiles

We sort generations into quintiles based upon the market returns earned during savings years.

Worker Outcomes represent the percentage of outcomes across simulations where the worker has lower retirement income from PRA than promised Social Security benefit.

Percent at Risk represents the percentage of workers where retirement income across PRA simulations is lower than promised Social Security benefit in more than 25% of simulations.

		No Investment Choice across Generation Return Quintiles					With Investment Choice across Generation Return Quintiles				
		1 (Lo)	2	3	4	5 (Hi)	1 (Lo)	2	3	4	5 (Hi)
	Age	4.7%	6.5%	7.6%	8.8%	10.6%	4.7%	6.5%	7.6%	8.8%	10.6%
Panel A: Worker Outcomes (% PRA < Social Security Benefit)											
60/40 Stock/Bond Allocation	68	60.9	30.8	13.9	5.1	1.2	68.9	49.7	36.6	25.6	12.3
	78	64.9	40.5	23.1	12.0	4.0	70.6	53.8	40.8	31.1	16.5
	88	66.0	45.6	29.7	18.4	7.0	70.8	56.4	43.6	35.4	19.9
Stock/Bond Allocation Choice	68	62.3	36.1	23.1	13.9	6.5	67.7	50.0	39.2	28.1	15.7
	78	65.1	43.9	30.8	21.5	11.1	69.8	54.8	44.6	34.7	21.3
	88	66.1	47.8	36.9	26.4	15.2	70.1	57.3	48.5	38.5	25.6
Panel B: Percent at Risk (% of workers for whom PRA < SS Benefit in >25% of simulations)											
60/40 Stock/Bond Allocation	68	85.9	41.3	23.1	6.0	1.0	100.0	89.6	66.9	41.3	13.1
	78	98.5	67.2	36.3	18.5	2.0	100.0	98.0	81.1	56.0	22.2
	88	100.0	82.4	47.8	26.4	4.1	100.0	100.0	88.7	74.0	29.0
Stock/Bond Allocation Choice	68	88.3	50.8	35.3	21.2	3.5	100.0	84.6	67.3	43.7	23.1
	78	98.6	76.1	49.0	32.8	12.4	100.0	96.7	84.7	64.7	33.7
	88	100.0	86.6	69.4	43.2	20.4	100.0	100.0	94.3	78.9	42.1

Online Appendix A: Sample Calculation of Individual Worker Benefit

Table A1: Worker Earnings History

Age	Capped Earnings	Wage Index Factor	Earnings in Age 60 $
21	21,020	4.6164	97,034
22	18,295	4.4388	81,209
23	23,328	4.2681	99,567
24	26,752	4.1039	109,788
25	24,551	3.9461	96,881
26	28,627	3.7943	108,620
27	33,482	3.6484	122,155
28	33,468	3.5081	117,408
29	39,956	3.3731	134,778
30	46,066	3.2434	149,410
31	45,809	3.1187	142,861
32	30,514	2.9987	91,503
33	32,595	2.8834	93,982
34	35,047	2.7725	97,168
35	49,920	2.6658	133,079
36	56,386	2.5633	144,535
37	65,134	2.4647	160,538
38	65,938	2.3699	156,268
39	71,408	2.2788	162,721
40	63,575	2.1911	139,301
41	67,966	2.1068	143,194
42	76,308	2.0258	154,585
43	90,960	1.9479	177,180
44	82,743	1.8730	154,977
45	82,124	1.8009	147,901
46	89,514	1.7317	155,010
47	93,750	1.6651	156,101
48	99,855	1.6010	159,872
49	84,943	1.5395	130,765
50	75,575	1.4802	111,870
51	96,220	1.4233	136,951
52	115,240	1.3686	157,714
53	88,465	1.3159	116,414
54	91,927	1.2653	116,317
55	91,788	1.2167	111,674
56	109,443	1.1699	128,033
57	106,964	1.1249	120,320
58	118,064	1.0816	127,698
59	18,851	1.0400	19,605
60	17,329	1.0000	17,329
61	6,162	1.0000	6,162
62	9,914	1.0000	9,914
63	6,383	1.0000	6,383
64	9,900	1.0000	9,900
65	27,554	1.0000	27,554
66	12,546	1.0000	12,546
67	0	1.0000	0

Table A2: Calculation of Social Security Benefit

Sum of top 35 years of earnings:	4,678,689	**Bend**	**Bend**
Average Monthly	11,140	**Rates**	**Points**
Amount from Bend 1	2,724	90%	3,027
Amount from Bend 2	2,596	32%	18,247
Amount from excess over Bend 2	0	15%	
Total PayGo Benefit, monthly	5,320		
Annual OASI Benefit	**63,842**		

Online Appendix B: Sample Calculation of Cohort Annuity (9.36% Savings Rate)

Table B1: Cohort Savings during work years

Year	Age	Cohort N	Portfolio Return	Total Cohort Savings	Total Annuity Payment	Cohort Total PRA
2000	21	3615	7.08%	3,510,237	--	3,510,237
2001	22	3612	11.33%	4,494,684	--	8,402,490
2002	23	3611	46.80%	5,723,520	--	18,057,992
2003	24	3606	30.86%	6,848,644	--	30,480,084
2004	25	3603	58.73%	8,022,317	--	56,403,622
2005	26	3598	8.35%	9,182,326	--	70,297,891
2006	27	3595	2.96%	10,299,179	--	82,677,144
2007	28	3592	17.04%	11,170,265	--	107,932,544
2008	29	3588	4.68%	11,821,554	--	124,806,039
2009	30	3586	-10.91%	12,525,095	--	123,717,295
2010	31	3583	9.93%	12,991,315	--	148,987,892
2011	32	3575	9.12%	13,842,094	--	176,420,059
2012	33	3568	36.36%	14,135,112	--	254,695,289
2013	34	3562	-1.49%	14,711,924	--	265,599,934
2014	35	3555	20.02%	15,815,162	--	334,575,920
2015	36	3551	24.75%	16,315,291	--	433,684,921
2016	37	3548	-8.77%	17,069,598	--	412,735,575
2017	38	3539	15.80%	18,103,720	--	496,036,243
2018	39	3533	-5.04%	18,491,333	--	489,528,443
2019	40	3526	7.25%	19,608,810	--	544,606,320
2020	41	3522	-7.94%	20,611,005	--	521,987,848
2021	42	3517	-6.71%	21,203,425	--	508,172,708
2022	43	3510	11.89%	22,505,845	--	591,081,538
2023	44	3496	17.15%	23,109,908	--	715,587,327
2024	45	3489	19.50%	23,802,635	--	878,902,690
2025	46	3485	-0.42%	24,999,281	--	900,231,768
2026	47	3481	-15.27%	25,855,641	--	788,592,557
2027	48	3472	-21.67%	27,192,902	--	644,876,733
2028	49	3456	0.32%	28,109,321	--	675,022,841
2029	50	3444	16.23%	28,713,112	--	813,319,589
2030	51	3436	-1.68%	29,610,902	--	829,283,813
2031	52	3421	16.41%	29,262,289	--	994,663,562
2032	53	3408	42.74%	29,763,329	--	1,449,540,078
2033	54	3396	11.18%	29,766,114	--	1,641,432,032
2034	55	3380	-7.97%	28,595,016	--	1,539,123,791
2035	56	3365	-7.46%	28,961,067	--	1,453,247,775
2036	57	3343	50.74%	28,445,269	--	2,219,023,669
2037	58	3329	9.25%	27,644,569	--	2,452,033,512
2038	59	3309	8.62%	27,558,698	--	2,690,869,995
2039	60	3282	10.61%	25,908,605	--	3,002,370,490
2040	61	3255	-5.99%	24,906,994	--	2,847,566,501
2041	62	3229	-3.79%	22,478,669	--	2,762,081,101
2042	63	3190	-7.74%	19,232,269	--	2,567,394,521
2043	64	3143	-2.12%	16,388,067	--	2,529,287,363
2044	65	3102	10.33%	13,215,883	--	2,803,817,269
2045	66	3060	-0.48%	10,939,725	--	2,801,329,628
2046	67	3017	1.74%	8,446,755	--	2,858,464,715

Table B2: Cohort Savings and Annuity Payments during Retirement Years

Year	Age	Cohort N	Portfolio Return	Total Cohort Savings	Total Annuity Payment	Cohort Total PRA
2047	68	2969	9.75%	--	261,103,196	2,875,925,165
2048	69	2919	9.02%	--	267,744,603	2,867,654,605
2049	70	2866	25.61%	--	315,908,522	3,286,193,332
2050	71	2811	20.19%	--	356,263,817	3,593,302,841
2051	72	2753	-9.74%	--	301,277,806	2,941,927,935
2052	73	2691	-7.34%	--	261,054,700	2,464,905,701
2053	74	2634	5.55%	--	258,027,127	2,343,705,780
2054	75	2565	13.98%	--	273,989,086	2,397,356,101
2055	76	2495	3.90%	--	264,902,008	2,225,858,539
2056	77	2421	35.46%	--	333,112,231	2,682,040,189
2057	78	2339	-24.93%	--	231,132,565	1,782,271,917
2058	79	2252	25.73%	--	267,671,057	1,973,147,527
2059	80	2165	-6.61%	--	229,921,415	1,612,880,582
2060	81	2076	-4.28%	--	201,893,617	1,341,961,539
2061	82	1979	-3.71%	--	177,301,737	1,114,936,683
2062	83	1879	-7.50%	--	148,966,171	882,308,864
2063	84	1764	24.86%	--	167,051,157	934,592,908
2064	85	1640	17.00%	--	173,833,573	919,598,991
2065	86	1521	2.73%	--	158,450,572	786,271,143
2066	87	1392	-6.60%	--	129,581,478	604,834,397
2067	88	1258	30.96%	--	146,724,187	645,383,961
2068	89	1131	7.32%	--	135,434,288	557,183,662
2069	90	1003	9.22%	--	125,501,319	483,068,386
2070	91	881	2.05%	--	107,621,359	385,341,779
2071	92	764	1.82%	--	90,912,951	301,448,702
2072	93	655	7.87%	--	80,436,160	244,742,225
2073	94	559	20.28%	--	78,990,687	215,379,337
2074	95	464	0.60%	--	63,100,057	153,561,742
2075	96	372	14.06%	--	55,203,640	119,953,022
2076	97	301	-3.48%	--	41,245,067	74,532,004
2077	98	244	-5.52%	--	30,219,705	40,195,800
2078	99	190	3.90%	--	23,390,233	18,372,782
2079	100	156	-2.02%	--	18,002,284	0