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### Publication Date

2003-01-31

# Stochastic Forecasts of the Social Security Trust Fund

Report for the Social Security Administration

Jan. 31, 2003

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**Executive Summary:** We present stochastic forecasts of the Social Security trust fund by modeling key demographic and economic variables as historical time series, and using the fitted models to generate computer simulations of future fund performance. We evaluate several plans for achieving long-term solvency by raising the normal retirement age (NRA), increasing taxes, or investing some portion of the fund in the stock market.

Stochastic population trajectories by age and sex are generated using the Lee-Carter and Lee-Tuljapurkar mortality and fertility models. Interest rates, wage growth and equities returns are modeled as vector autoregressive processes. With the exception of mortality, central tendencies are constrained to the Intermediate assumptions of the 2002 Trustees Report. Combining population forecasts with forecasted per-capita tax and benefit profiles by age and sex, we obtain inflows to and outflows from the fund over time, resulting in stochastic fund trajectories and distributions.

Under current legislation, we estimate the chance of insolvency by 2038 to be 50%, although the expected fund balance stays positive until 2041. An immediate 2% increase in the payroll tax rate from 12.4% to 14.4% sustains a positive expected fund balance until 2078, with a 50% chance of solvency through 2064. Investing 60% of the fund in the S&P 500 by 2015 keeps the expected fund balance positive until 2060, with a 50% chance of solvency through 2042. An increase in the NRA to age 69 by 2024 keeps the expected fund balance positive until 2047, with a 50% chance of solvency through 2041. A combination of raising the payroll tax to 13.4%, increasing the NRA to 69 by 2024, and investing 25% of the fund in equities by 2015 keeps the expected fund balance positive past 2101 with a 50% chance of solvency through 2077.

## Introduction

The federal government has four principle tools for extending the life of the social security (Old-Age and Survivors Insurance and Disability Insurance, or OASDI) trust fund. It must either raise taxes, cut benefits, increase fund returns by investing in equities, or pay for any shortfalls out of general revenue or bond sales. Exactly who pays for social security reform and when depends on which of these options are exercised. Unfortunately, decisions about which options to enact are clouded by uncertainty about future economic and demographic outcomes and the inherent complexity of the system. Crucial to this endeavor, then, is a concise set of fund forecasts that clearly explain the consequences of any given policy.

Given assumptions about future demographic and economic conditions, forecasting the growth of the fund and the effects of policy changes is largely a matter of bookkeeping. Such forecasts are precise, but inaccurate due to uncertainty in such assumptions. By gauging this uncertainty on the basis of historical variation and incorporating it into our estimates explicitly, we construct probabilistic forecasts that are imprecise but accurate. For a given policy scenario, for example, we estimate the probability of insolvency for any given horizon, rather than estimating a single date of insolvency. This moves beyond the traditional approach of calculating “high”, “medium”, and “low” forecasts

## Background

At the end of 2001, the combined OASDI fund held a total of \$1.213 trillion in the form of government securities. Annual expenditures for the calendar year 2001 totaled \$439 billion, but income including interest totaled \$602 billion, so the fund balance increased \$163 billion from the end of 2000.

According to intermediate forecasts from the actuaries of the Social Security Administration (SSA), such fund increases will continue until about 2020, at which point the balance of the fund will top out at nearly \$3.8 trillion in 2002 dollars. Thereafter, the benefits paid to newly retiring baby boomers will exceed the total income received in taxes, and the fund will be depleted by 2041.

Keeping tax rates fixed, an older population has a harder time supporting its retirees, since it has fewer workers and hence less tax revenue per retiree. Our society is inexorably aging as mortality falls and fertility remains relatively low. Figure 2 shows a 100-year forecast of the old-age dependency ratio, defined as the number of persons aged 65 and over divided by the number of persons aged 20 to 64. The middle line is the median forecast, and the outer lines show a 95% confidence interval. The ratio is projected to increase on average well beyond the retirement of the baby boomers. The sheer demographics necessitate substantial and permanent changes in the system.

## Structure of social security

The OASDI account balance at the end of this year is equal to the balance at the end of last year plus annual tax income and interest, minus benefit payments, railroad retirement, and

administrative expenses (see Figure 3.) Taxes increase or decrease year-to-year depending on the rate of real wage growth during the year, and benefits shift up or down according to past real wage growth, since benefits depend on past earnings. The total amount of interest earned on the fund obviously depends on the interest rate earned on the collection of special U.S. Treasury bonds purchased by the Social Security Administration, mostly in earlier years..

We estimate total taxes into the system in any given year by multiplying per-capita age- and sex-specific tax profiles by age- and sex-specific population estimates, and summing across sexes and ages. Likewise, benefits are estimated with a set of per-capita age- and sex-specific benefit schedules and population estimates for that year. (These tax and benefit schedules are shown in Figure 1 for the starting year, 2001.) Given such schedules and population estimates on a year-to-year basis, in addition to the interest rate, administrative expenses and railroad retirement (the last two being relatively small in size), forecasting the balance year-to-year is a straightforward exercise in accounting. The difficulty is mostly in estimating the future inputs.

## Uncertainty in forecasts

There are four rough categories of uncertainty in the accounting system described above. First, demographic uncertainty has been well recognized. We treat fertility and mortality as stochastic, while setting immigration rates at levels assumed by the SSA actuaries. Economic uncertainty also intrudes. We treat real interest rates and the growth of real wages as stochastic; these reflect the volatility of inflation as well. When modeling equities investment, we also model rates of return on the stock market stochastically.

Another significant source of uncertainty is the behavior of future workers and retirees. If the age at normal retirement were raised an additional year, would workers work an extra year, or would they continue to take early retirement? It is also impossible to know exactly what labor force participation rates may be at other ages, or to what extent women will continue their advance into the labor force.

Fourth, there is a broad range of structural economic changes that could intervene in unpredictable ways. Examples include major technological innovations, the globalization of trade and capital, feedback to or from other economic/demographic variables, or some other dynamic interaction with demographic or behavioral forces.

We attempt to gauge demographic and economic uncertainty through the use of fitted time series models. Long time series data exist on mortality and fertility by age, along with economic series such as the rate of real wage growth, interest rates, and stock market returns. The size of the historical variation in these series, as estimated by the variances of the innovation terms in our models, provides a measure of uncertainty about the future behavior of the series. By repeatedly simulating future trajectories of these time series models with independent pseudorandom innovations, we can generate an entire distribution of fund balance trajectories over time, along with cost rates, income rates, and actuarial balances.

The last two categories of uncertainty are more difficult to model stochastically. Instead, we treat the behavior of retirees by allowing for the deterministic adjustment of various parameters in our model, such as hazard rates of retirement by age, in order to assess the impact of different

modes of behavior. Immigrants are also added in deterministically. We do not consider any economic/demographic interactions, feedback, or dramatic structural economic changes.

## Options for extending solvency

The first policy option we consider is an increase in the payroll tax. Presently legislated at 12.4%, we construct a set of four incremental increases in the tax level up to 14.4%. We always assume these increases occur immediately, and proportionately across sexes and ages.<sup>1</sup>

Next, we treat the issue of benefit cuts in the form of upward adjustments in the normal retirement age (NRA). This is the age at which workers become eligible to receive full benefits, set at 65 under current legislation. Workers can also opt to retire as early as 62, the Early Retirement Age (ERA), but the benefits are reduced; or, they can wait until as long as age 70, receiving increased benefits. Most persons retire early at age 62, and of those remaining, most retire at 65. That is to say, the hazard rate for retirement peaks dramatically at ages 62 and 65, and there is some low “background” rate of retirement at all other ages.

Presently, the NRA is scheduled to increase by two months of age per year for six years. This started in 2000 (raising it to 66 by 2005), and shifts again starting in 2017 (raising it to 67 by 2022).<sup>2</sup> We consider a number of alternative, accelerated schedules of NRA increases, raising the final NRA to various values from 67 to 69 at various rates of change over time. For all of these schedules, the ERA remains at 62, but penalties for early retirement increase accordingly since they depend on exactly how many months of age prior to the NRA retirement is taken. We do not assume that individuals will continue working for the extra years imposed, so taxes do not necessarily increase at ages where the NRA is shifted up. Thus, by age at retirement we really mean the age at which benefits are started. We assume that the peak in the retirement hazard at 62 remains, but that the peak in retirement at the NRA shifts upward according to the given schedule of shifts.

Third, we consider a set of plans to invest some portion of the fund in equities. The SSA’s intermediate scenario assumes bonds will yield a 3% real return annually in the future, compared with historical returns of about 7% for broad equities indices such as the Standard & Poor 500 (S&P500). Arguments have been made in favor of investing a substantial proportion of the fund balance to the stock market. Investment could be implemented either through the control of an independent board of trustees, or through the creation of individual retirement accounts controlled by earners themselves. Detractors of such schemes argue that the risk implied by short-term fluctuations in the stock market may outweigh potential gains. Others argue that the creation of a politically isolated investment program is unrealistic. Here we simply report the probability distributions for outcomes.

We assume a small portion of the trust fund is invested in equities at an initial date of 2005, and the invested proportion of the fund is increased linearly over time until 2015, when a ceiling is reached. For example, 1% of the fund would be invested in equities starting in the year 2005, and this proportion would be linearly increased over a period of 10 years, to be fixed at some proportion thereafter. As a proxy for stock market returns, we use the S&P500, for which a long historical time series exists. Since interest rates and equities returns have been correlated historically, we model them jointly in vector autoregressive form. Average market returns are

constrained around a mean of 7% in the long run, and interest rates are constrained to 3% on average.

Finally, there is the potential to combine these three options in some form. We treat such possibilities by considering a three-dimensional “policy space”. This can be constructed by translating each of the above options into scalar form (e.g. the tax rate, the proportion of the fund invested in the long run, and the number of years added to the NRA), and scaling a set of perpendicular axes accordingly. We then evaluate a common criterion at a set of evenly spaced points throughout the space (e.g. the probability of insolvency by some horizon), we interpolate to estimate the full response surface, and we find isoquants on these surfaces.

## Evaluation of outcomes

For a system as complicated as the trust fund, there are numerous criteria used for actuarial assessment. Cost rates and income rates provide annual measures of flows into and out of the fund. The cost rate for a year is defined as total yearly expenditures (including all benefits, administrative expenses, and railroad retirement) divided by the taxable payroll (total combined taxable wages and self-employment income). The cost rate was about 11% in 2001 and is projected to rise to 20% by 2075 according to the SSA intermediate scenario. The yearly income rate is total tax income (including taxes on benefits) for the year divided by the taxable payroll. This was about 12.7% in 2001, and is projected to increase to about 13.4% by 2075.

The summarized cost rate for horizon  $T$  is the present value of total expenditures through  $T$ , divided by the present value of total taxable payroll through  $T$ . The SSA projects a summarized cost rate of 15.59% for the horizon 2002-2076 using the intermediate assumptions.

Similarly, the summarized income rate is the present value of all taxes collected through  $T$ , divided by the present value of total taxable payroll through  $T$ . To evaluate the long term balance through  $T$ , one first adds the beginning fund balance into the summarized income rate, defined as the adjusted summarized income rate. This is projected to be 13.72% for 2002-2076.

The summarized actuarial balance for horizon  $T$  is the difference between the adjusted summarized income rate and the summarized cost rate, equal to  $13.72\% - 15.59\% = -1.87\%$  for horizon  $T = 2076$ . That the balance is negative implies a long-term imbalance. This percentage is equal to the payroll tax increase that would be required to maintain a positive balance through 2076, raising the rate from 12.4% to 14.27% starting in 2002. Multiplying the summarized actuarial balance times the present value of total taxable payroll through 2076 yields about \$4 trillion, which is the immediate cash infusion which would keep the system solvent through 2076 under SSA’s intermediate scenario.

## The Stochastic Model

Other stochastic models for OASDI include a simple model by Sze (1995), and a relatively complex model by Holmer (1995; now known as the EBRI model). In comparison, our model includes detailed stochastic projection of demographic change. Our analytic structure provides a transparent way of incorporating changes (e.g., in policy or behavioral assumptions), is explicitly designed to include multivariate stochastic processes (e.g., of economic variables), and provides a clearly defined strategy for evaluating multiple measures of risk.

We employ a demographic-economic model of the OASDI system. Tuljapurkar and Lee (2000), in an IUSSP volume on intergenerational transfers, set out the modeling framework and some of its dynamic properties. Lee and Tuljapurkar (1998a) describe the evolution of the model to include a detailed analysis of benefit and retirement profiles. Lee and Tuljapurkar (1998b) summarizes recent findings that incorporate simplified models of some economic variables. See also Lee and Tuljapurkar (2000).

Our model is an analytically specified, dynamic, stochastic recursion (Lee and Tuljapurkar, 1994; Lee and Tuljapurkar, 1997; Lee and Tuljapurkar, 1998a). The starting point for the model is a detailed stochastic model of demographic change based on Lee and Tuljapurkar (1998a). Figure 4 shows forecasts of the median total population over time, together with 67% and 95% confidence intervals. With the exception of mortality, our demographic and economic forecasts are scaled to match the SSA's 2002 intermediate assumptions *on average* in the long run.<sup>3</sup> Thus, in the long run, the total fertility rate is constrained to 1.95 on average, annual growth in real wages is constrained to 1.1%, and the real effective interest rate is constrained to 3.0%. Mortality is estimated using the Lee-Carter model (see below). Real returns on equities are constrained to 7% on average. Immigration estimates are deterministic, consisting of the same intermediate age- and sex-specific forecasts used by the SSA.

We calibrate the model by running it with deterministic assumptions that are nearly identical to the SSA's intermediate forecasted demographic and economic assumptions. We find that our model in this case tracks fairly closely the cost and income rates for the OASDI fund over the same 75 year projection period. The only output-based component of the model that we explicitly adjust to match the SSA's forecasts is the disability cost rate; all other sources of income and expenditure are simply observed to confirm that there is general agreement with the SSA forecast. We have also carried out validation studies of model components (e.g., mortality forecasts, Tuljapurkar and Boe, 1998a; ex-post validation of population projections by Tuljapurkar and Boe, 1998b and Lee and Miller, 2001).

## Model Outputs

For any given set of policy assumptions, say a particular scenario of change in the NRA, the outputs of the model are generated as a large set (typically 1000) of alternative future trajectories generated by repeated stochastic simulations. Now consider any outcome of interest, say the trust fund balance in the year 2026. The trajectories of the model will yield a set of possible values for that year, and the probability distribution of those values will be the probabilistic forecast. We may compute consistent statistical descriptors (probabilities, averages, standard deviations, and so on) for any desired outcome from the set of model trajectories. It is important to note that in our model the probability distribution of trajectories always yields a consistent probability distribution of outcomes involving ratios, sums of ratios, and so on. This kind of consistency is not automatic with scenarios.

Next, we consider the OASDI trust fund balance over time, starting with the known balance at the end of calendar year 2001, and forecasting over a 100-year horizon. The "baseline" assumptions we use are those of the current legislation: The payroll tax rate is held constant at 12.4%, the NRA is raised to 66 and 67 starting in 2000 and 2017 respectively, and there is no

investment in equities. Under these assumptions, our model generates a set of 1,000 random trust fund trajectories, of which ten are plotted in Figure 5. Each trajectory is unique, as it results from a unique set of input trajectories (mortality, fertility, real wage growth, interest rates), so trajectories can reach exhaustion on different dates. Figure 6 shows the median fund balance with a 67% confidence interval (meaning that 67% of the trajectories at any given point in time fell within this range). The dotted line shows the average (or expected) fund balance at each point in time. This trajectory differs noticeably from the median balance trajectory since the distribution of fund balances at a given point in time is typically asymmetrical.

Next, we observe the first date at which each fund reaches exhaustion for each trajectory. A histogram of these dates, displayed in Figure 7, indicates the probability distribution, or the relative odds, that exhaustion will occur in any range of years. The median year of insolvency is 2038, several years short SSA's intermediate estimate; our interpretation is that there is a 50% chance the fund will last beyond the end of 2037. There is a 1.9% chance that the fund will reach exhaustion by 2026, and an 85% chance that it will reach exhaustion by 2052. There is only a 1.1% chance that the future will be so favorable such that the fund will stay solvent through 2101. (The last bin at 2101 includes trajectories that remained positive throughout the 100-year simulation, horizon and which may remain positive indefinitely.)

Figure 8 is a histogram of summarized actuarial balances for a 75-year horizon, through 2076. The median balance is -2.55%, somewhat more pessimistic than the SSA intermediate forecast (-1.87%). This is due in part to the somewhat higher life expectancies predicted by the Lee-Carter model of mortality. Our estimated 95% confidence interval for the 75-year actuarial balance is -6.40% to 0.08%, comparable the SSA's high-cost/low-cost range of -5% to 0.44%.

Figure 18 shows the quantiles of the distribution in the Trust Fund Ratio (the assets at the beginning of the year as a percentage of the outgo during the year) over the 75-year period through to 2076. The peak in the median of the TFR occurs in 2015, coinciding with SSA's medium-cost Trust Fund Ratio peak.

## Evaluation of policy alternatives

Table 1 shows results for many of the simulations described below.

### Tax increases

We started with four sets of additive payroll tax increases implemented immediately in 2002, raising the rate from 12.4% to 13.4%, 14.4% and 14.9%. Figure 9 shows histograms of the dates of exhaustion for each of these scenarios, with the baseline distribution at the top, and Figure 10 shows histograms of the actuarial balances. With a tax increase of 1%, the median date of insolvency is 2048 (compared with 2038 for no tax increase), and the chance of insolvency by 2052 falls to 57% (compared with 85%). At a tax rate of 14.4%, the life of the fund is extended roughly another twenty years, with a median date of insolvency at 2065, and the chance of insolvency by 2052 falls to 26%. When the tax rate is increased to 14.9%, the median fund lasts for just about 75 years (so the chance of insolvency by 2076 is about half), and the chance of insolvency by 2052 is only 14%.



### **NRA changes**

Next, we set the tax rate to the legislated 12.4%, and implemented four sets of accelerated NRA shifts in two stages.<sup>4</sup> Presently, the NRA is scheduled to increase by two months of age per year for six years, starting in 2000 (raising it to 66 by 2005), and again starting in 2017 (raising it to 67 by 2022). Using the same six year phase-in period, we first construct a set of four accelerated NRA schedules. These raise the NRA:

- 1) to 66 by 2005, and again to 67 by 2011;
- 2) to 66 by 2005, to 67 by 2012, and to 68 by 2023;
- 3) to 66 by 2005, to 67 by 2012, and to 68 by 2017;
- 4) to 66 by 2005, to 67 by 2012, to 68 by 2017, and to 69 by 2023.

Figure 11 shows a histogram of the dates of exhaustion for each scenario, and Figure 12 shows the distributions of the 75-year summarized actuarial balances. The effect of the first accelerated NRA shift is quite minimal. The median year of insolvency is unchanged, and the median actuarial balance is only shifted from -2.55% to -2.45%. Increasing the NRA an additional year to 68 by 2023 has a slightly more dramatic effect. The expected fund balance remains positive until 2045, and the chance of insolvency by 2041 is 50%, or 23% by 2052. The median 75-year actuarial balance rises to -2.07%, an improvement of nearly half a percent over the presently legislated result. Accelerating the change to age 68 by six years in time, however, has almost no effect, as the median of insolvency is not budged, and the median actuarial balance only improves to -1.97%. When the NRA is raised to 69, the expected fund balance remains positive until 2047, and the chance of solvency is 50% through 2042, while the median 75-year actuarial balance is -1.6%, still well-short of long-term solvency.

### **Equities investment**

Next, we fixed the NRA changes and tax rate as currently legislated, and experimented with investment in equities. In each scenario, we invest 1% of the total fund balance in the S&P500 starting in 2005. We then linearly increase this percentage to some fraction (e.g. 15%) over a period of 10 years, after which the proportion of the fund is the market is set to this fraction indefinitely.<sup>5</sup> We used values of 15%, 30% 45% and 60% for this long-run investment fraction. After 2015, the proportion of the fund is readjusted at the end of each year to keep the fraction invested constant.

Figure 13 shows the histograms of dates of exhaustion for the four scenarios, with the baseline scenario (no investment) at the top. A 15% level of equities investment has a very minor impact on the fund, allowing for only one additional year to either the median year of exhaustion, or solvency of the expected fund balance. Increasing the fraction to 30% adds one more year to the median year of exhaustion (2040), but the expected fund balance now remains positive until 2046. Increasing investment to 45% again only adds two more years to the median year of exhaustion (2042), but now the expected balance stays positive until 2051. Finally, the highest level of investment, at 60%, only extends the median year of exhaustion one more year to 2043, but the expected fund balance remains positive until 2060.

The significant divergence between the average and median fund balances indicates that equities investment drastically increases the asymmetry of fund balances. This distributional asymmetry

is demonstrative of the approximate lognormality of fund balances at certain points in time. Stock prices (as well as population stocks) can be approximated by multiplicative processes with normally distributed growth rates. As a result, the distribution of a stock price (and similarly the fund balance) at a given point in time can have a very long right tail. The outcome is that the average balance can be substantially positive even when the median balance is negative and the median year of insolvency has long passed.

Of course, this occurs to some extent without any investment in equities (population growth and bond returns generate the same lognormality), but the effect is magnified with investment. Increasing the level of fund investment to an unrealistic level, such as a 90% investment in equities by 2005, creates an even more drastically skewed distribution of fund balances. In that scenario, the median year of insolvency is only extended to 2052, but the average fund balance stays positive indefinitely! Of course, such an extremely high upper tail implies economically unrealistic levels of growth. Our model is not equipped to deal with such drastic distortions, but at moderate levels of investment this effect may be more realistic. Note that modeling the fund deterministically ignores this effect completely because one assumes constant positive returns.

The distributional behavior of the fund balances under increasing investment demonstrates another interesting prediction. Detractors of investment point to the increased riskiness of equities investment. Note that in Figure 13, the left side of the distribution of years of insolvency shifts very little. This is to say that even the worst-case investment returns imply no more risk than the worst-case bond returns.

Of course, bonds can also lose money in real terms; the question is whether the potential gain (7% over 3.0% on average) offsets the increased variability. According to our estimates, it usually does. In either the 45% or the 60% investment scenario, there is only an 18% chance that the fund balance will be lower in 2040 than if no equities investment had taken place. At the 60% level, there is only a 13.1% chance that insolvency will come at an earlier date because of investment. At the 45% investment level, there is only an 11.4% chance that insolvency will come at an earlier date.

### **Combined policy changes**

Considered separately, the above methods for achieving solvency require substantial changes to extend the median life of the trust fund more than a few years. Tax increases and large benefits cuts are both highly unpopular, and investment alone does not provide a big enough boost. Another alternative would be a combination of some form.

We examine this question by exploring the overall “policy space” available to policymakers. First, we construct three two-dimensional policy spaces, using each of the possible pairs of combined methods: taxes and benefits, taxes and investment, and benefits and investment. An outcome of interest can then be plotted as the third dimension to create a “policy surface”.

Figure 14 shows the probability of fund solvency through 2051, as a function of NRA change and investment level. As described above, five NRA schedules were employed, each using six years of time for each year of NRA adjustment. The first is the legislated schedule (resulting in a final NRA of 67 by 2022), the second is an accelerated shift to age 67 by 2012, and so on, with

the most dramatic change incorporating an NRA of 69 by 2023. The proportion of fund invested is that fraction of the fund invested in the S&P500 after a 10-year phase-in, starting in 2001. This is set at 15% increments from 0% to 60%, as in the section above. The probability of solvency through 2051 is only 15% when no changes are legislated, and at the other extreme, the probability increases to 54% when 60% of the fund is invested in equities by 2015, and the NRA is shifted to age 69 by 2023.

Suppose one is interested in finding those combinations of NRA increase and equities investment which result in equivalent outcomes, according to the risk measure for example. Figure 15 shows combinations of NRA change and investment which give the same probability of solvency through 2051, obtained by interpolating Figure 14. Each line indicates combinations which yield the same probability of solvency through 2051. As described above, the most dramatic improvement is achieved in the increase from an NRA of 67 to 69.

Figure 16 shows the probability of solvency until 2051 by 25 different combinations of NRA change and tax increases. The NRA shift schedules are the same as in Figure 14, and the tax increases are in 0.5% steps up to 2% (for tax rates of 12.4%, 12.9%, 13.4%, 13.9%, and 14.4%). Clearly, the move towards solvency is more dramatic when implemented through tax increases as compared to NRA increases. A 2% tax increase alone raises the likelihood of solvency to 74% for the next 50 years, but even the most dramatic NRA shift fails to raise the 50-year probability of solvency above 30% if taxes are not changed. A moderate combination of both shifts, such as an NRA of 68 by 2017 and a 1% tax increase, results in a fairly substantial improvement. This combination raises the chance of solvency through 2051 to 58% and extends the median year of insolvency out to 2056.

Figure 17 shows the chance of solvency until 2051 by various combinations of tax increases and investment levels. Again, tax increases pack a much more potent punch than investment at any level. An investment level of 30% combined with a 1% tax increase raises the chance of solvency to 56%.

When all three policy options are employed, a substantial boost is gained from the synergistic effect between investment and increasing external cash flows. By incorporating a 1% tax increase with 25% equities investment by 2015, and an NRA shift schedule resulting in a final NRA of 69 by 2023, the median year of exhaustion is extended to 2077 while the expected fund balance stays positive beyond 2101. There is a 79% chance of maintaining solvency through 2051 under this plan, and there is a 38% chance that the fund would remain solvent through the next century.

## Conclusions

We consider three tools for achieving solvency, both separately and in combinations: Taxes, NRA changes, and equities investment. Considered separately, fairly substantial changes are required to extend the life of the OASDI trust fund with any certainty. An immediate tax rate increase to 14.9% would be required to extend the fund beyond 2077. The NRA would have to be raised to 69 by 2023 to postpone the median year of exhaustion by only 4 years. Equities investment alone, even at unrealistically aggressive levels, cannot postpone fund insolvency for more than ten to fifteen years, at least according to the median fund balance (and the mean may

be a misleading statistic in these scenarios).

However, combinations of adjustments can have more dramatic effects. A combined 1% tax increase and NRA shift up to age 69 by 2023 would extend the median year of insolvency to 2062. By incorporating a 25% level of investment in equities, the boost supplied by these changes would be magnified, extending the median year of insolvency out to 2077.

Equities investment has both drawbacks and advantages. The main drawback is that when not supplemented with additional cash, the impact at any reasonable level of investment is minimal. Also, there is non-negligible chance that some losses would occur. When the proportion of the fund in equities is increased to 45% by 2015, there is an 18% chance that the balance would be lower in 2040 than would result from pure bond investment.

The advantage to equities investment is that it could compound income or savings obtained from other changes in the system. When combined with a moderate tax increase and/or NRA change, the impact of investment is much more substantial. The cost of the higher returns associated with equities investment is greater variability. However, the probability of insolvency never increases when investment is undertaken, regardless of the horizon or investment level.

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## **Acknowledgements**

Funding to update the stochastic simulations to 2002 was provided by a grant from Berkeley's NIA funded Center for the Economics and Demography of Aging and from a grant from NIA, AG11761, which also partially supported writing this report. Earlier work on development of the basic model was carried out at with support from the latter grant, and also at Mountain View Research under a grant from NICHD, HD32124. Development of the model was also supported by grants from the Social Security Administration through the Michigan Retirement Research Consortium. The Social Security Administration generously provided some data needed to update portions of the model. The opinions and conclusions are solely those of the author(s) and should not be construed as representing the opinions or policy of the Social Security Administration or any agency of the Federal Government.

## Appendix: Summary of the model

The U.S. Social Security system is of a PAYGO retirement system in which government collects payroll tax revenues specifically for the OASDI (Old Age, Survivors, and Disability Insurance) program. These funds are held in a Trust Fund whose assets are invested in special obligations of the US Treasury at a legislated interest rate. The Social Security Administration determines benefit eligibility and benefit levels in accord with legislated rules, and pays benefits to beneficiaries (retired and disabled workers and their eligible dependents and survivors).

The dynamics of the Trust Fund are described in terms of these variables.

Symbol	Definition
t	Time in years
a	Age in years
s	Sex (male or female)
B(t)	Balance in the Trust Fund in year t in Constant Dollars
r(t)	Real Interest Rate in Year t
T(s,a,t)	Per-capita taxes paid in year t into public retirement and disability system, by age, sex
H(s,a,t)	Per-capita benefits received in year t from public retirement and disability system, by age, sex
A(t)	Administrative cost of system as fraction of benefits paid out
p(t)	Rate of growth of real wages (i.e., productivity growth) in year t
I(t)	Real interest earned in year t
T(t)	Total taxes collected by system in year t
H(t)	Total benefits paid out in year t
N(s,a,t)	Number of individuals in year t by sex, age
K(t)	Aggregate rate of taxation of retirement and disability benefits

The dynamics of the system are summarized by the recursion equation

$$B(t+1) = B(t) + I(t) + \sum T(s,a,t) N(s,a,t) - \sum H(s,a,t) N(s,a,t) - A(t) H(t) + K(t) H(t)$$

The sums in this equation are taken over both age and sex. Note that we are using age-sex-specific schedules for taxes and benefits, and these need to be updated over time.

Our updating procedures are based on several sources. First, we employ many of the assumptions made by the Trustees of the Social Security Administration (SSA), as described in



the annual Trustees' Reports to Congress, and also in the series of Actuarial Studies published by the Actuaries of the SSA. Second, we have independently evaluated and analyzed many of these factors as part of our modeling efforts (Lee and Tuljapurkar 1998a, b, Tuljapurkar and Boe 1998a, b). Third, we have explored many of the issues and alternatives discussed in the Report of the Technical Panel on Assumptions and Methods, published by the SSA in 1996. Finally, we have studied many aspects of existing analyses of factors that go into the dynamics of the system (as discussed in the research literature, e.g., Steurle and Bakija 1994). Below we present a rather brief summary of our methods for updating the various components of the model.

Tax levels may change for several reasons: (a) productivity gains (at rate  $p(t)$ ) increase the level of real wages; (b) labor force participation rates and unemployment rates may change; (c) there may be changes in the legislated tax-rate for taxes paid into the system; (d) there may be changes in the income distribution such that the effective tax rate changes (e.g., in the US, there is a sliding income cutoff for OASDI contributions, but income levels generally are rising so that an increasing proportion of annual earned wages may exceed the cutoff level over time); (e) the tax rate on benefits paid out may change over time due to increases in the rate as well as changes in the proportion of individuals subject to such taxes.

We update the aggregate schedules  $T(s,a,t)$  by using a multiplier at all ages that reflects real wage growth, a second multiplier that reflects changes in the tax rate for distributional and legislative reasons, a third multiplier that reflects changes in unemployment relative to the base year, and an age-sex dependent multiplier that accounts for changes in labor force participation rates relative to the base year. An aggregate multiplier is used to reflect the rising tax rate on benefits that is expected over the coming decades.

Benefits may change for different reasons: (a) productivity changes affect retirement benefits only by cohort, because after retirement a cohort receives no adjustments for changes in real wages; thus the productivity multiplier for benefits is lagged to reflect the age at retirement; (b) the age pattern of receipt of both retirement and disability benefits is a key factor. We adjust for receipt of retirement benefits by updating the schedule of benefits received in the main "retirement window" of ages 62 through 70. Age 62 is the earliest for receipt of benefits, by age 70 virtually all eligible persons are taking benefits. In between these ages is the normal retirement age (NRA), which is scheduled to increase from age 65 today to age 67 in the year 2022, in two phase-in periods. The phase-in of a new NRA is implemented by changing the age-pattern of the fraction of full benefits that can be received based on one's choice of a retirement age (i.e., less than 100 percent for early ages, 100 percent at NRA, and over 100 percent for ages over NRA). The updating procedure hinges on assumptions about the distribution of ages at retirement (i.e., ages at which the decision is made to take retirement benefits). The SSA assumptions, which are in agreement with other studies of age-specific retirement hazard rates, are combined with the age-pattern of benefit fractions for the NRA of all years, to provide an updating rule for the age-sex schedule of benefits paid between ages 62 and 70. At ages over 70, updating is used to factor in a compositional change in beneficiaries (as the fraction of widows and female survivors increases with age); (c) disability benefits are updated using changes in aggregate levels of insured coverage, changes in the prevalence rate of disability beneficiaries at ages below NRA, and the increase in disability pay-outs when disabled beneficiaries have to wait to reach an increased NRA before converting to regular retirement benefits. These procedures

are appropriately modified for different scenarios of NRA change.

Population by age and sex needs to be updated through time. For this we employ a stochastic projection model which is an updated and extended version of that presented in Lee and Tuljapurkar (1994). Mortality and fertility changes are described by stochastic time-series models. Central death rates  $m(x,t)$  for age  $x$  at time  $t$  are described by a Lee-Carter system,

$$\log[m(x,t)] = a(x) + b(x) k(t),$$

$$k(t) = k(t-1) - z + e(t),$$

where  $a$ ,  $b$ ,  $z$  are estimated statistically, as are the properties of the innovation  $e(t)$ . Fertility rates  $f(x,t)$  are described similarly,

$$f(x,t) = a1(x) + b1(x) k1(t),$$

$$k1(t) = c k1(t-1) + d u1(t) + e u2(t-1),$$

but with long-term fertility constrained to 1.95 in the long run. Immigration is set to the ultimate “intermediate” series of immigration levels that are assumed by SSA. Combining these in a cohort component projection yields stochastic sample paths of time series of population numbers by age and sex.

Economic forecasts are generated with constrained autoregressive models. Let  $r(t)$  be the real annual effective interest rate at time  $t$ , and let  $s(t)$  be the real annual year-to-year return on the S&P 500. We fit a constrained VAR(3) model to these two series, using data from 1940-2001. Typically, one fits an unconstrained VAR model, which here takes the form:

$$r(t) = \alpha_1 r(t-1) + \alpha_2 r(t-2) + \alpha_3 r(t-3) + \beta_1 s(t-1) + \beta_2 s(t-2) + \beta_3 s(t-3) + \varepsilon_r(t)$$

$$s(t) = \phi_1 r(t-1) + \phi_2 r(t-2) + \phi_3 r(t-3) + \theta_1 s(t-1) + \theta_2 s(t-2) + \theta_3 s(t-3) + \varepsilon_s(t).$$

Let  $g$  be the long run average interest rate (set at 3.0%), and let  $c$  be the long run average stock return (set at 7%). The constrained form of the model takes the form:

$$r(t) = \alpha_1 r(t-1) + \alpha_2 r(t-2) + \alpha_3 r(t-3) + \beta_1 s(t-1) + \beta_2 s(t-2) + \beta_3 s(t-3) + \varepsilon_r(t) \\ + g(1 - \alpha_1 - \alpha_2 - \alpha_3) - c(1 - \beta_1 - \beta_2 - \beta_3)$$

$$s(t) = \phi_1 r(t-1) + \phi_2 r(t-2) + \phi_3 r(t-3) + \theta_1 s(t-1) + \theta_2 s(t-2) + \theta_3 s(t-3) + \varepsilon_s(t) \\ - g(1 - \phi_1 - \phi_2 - \phi_3) + c(1 - \theta_1 - \theta_2 - \theta_3)$$

The real wage growth rate is modeled as an AR(1) constrained to 1.1% in the long run. We model this series independently of interest rates and stock returns as historically, the correlation between real wage growth and these two variables is quite small. Let  $w(t)$  be the percentage growth in real wages at time  $t$ , and let  $h$  be the long-run constraint. The model is:

$$w(t) = h + \Delta (w(t-1) - g) + \epsilon(t).$$

The program is launched from initial conditions at the end of the year 2001, and is calibrated to the known tax and benefit levels from the Annual Statistical Supplement to the Social Security Bulletin. The population projection is run first and the projections are stored. The updating process for benefits, taxes and trust fund balance is done in 1-year steps over the forecast horizon.

The program outputs include measures of stability in the trust fund, such as cost rates, income rates, and actuarial balances, as a function of time. Finally, we note that the program can be split to provide separate estimates of the OASI and DI program, and may be modified to include the effects of partial funding or partial privatization.

## Endnotes

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<sup>1</sup> This is a slightly unrealistic adjustment since our simulation begins in 2001, implying a retroactive tax increase; however we were interested in matching tax rate increases to actuarial balance estimates.

<sup>2</sup> Specifically, these shifts apply starting with the cohort reaching age 62 in each year of shift. Older cohorts are grandfathered into the old NRA. Thus there is a lag in the effect of NRA shifts, since the actual change in benefits payment does not occur until the younger cohort actually reaches the old NRA.

<sup>3</sup> Our forecasts are stochastic, meaning that we generate 1,000 trajectories for each scenario; an individual trajectory may take on a wide range of values, but on average they are constrained in the long run. They are not necessarily constrained to these averages in the short run because jump-off points (the initial values in the year before the forecasts are started) may differ from the long run averages.

<sup>4</sup> We have modified our methodology for implementing NRA changes in light of feedback provided to us by the SSA's actuaries (primarily Steve Goss). Thus our results for these scenarios appear slightly more pessimistic than the results of previous simulations.

<sup>5</sup> More precisely, once the set fraction has been reached, the proportion of the fund balance in equities is reset to this fraction at the beginning of each calendar year as long as there is a positive fund balance to invest. The balance during the year would vary.

Table 1. Simulation results for various scenarios

	Baseline <sup>1</sup>	NRA 68 <sup>2</sup>	NRA 69 <sup>3</sup>	1% Tax	2% Tax	30% S&P <sup>4</sup>	60% S&P <sup>5</sup>	NRA+S&P <sup>6</sup>	NRA+Tax <sup>7</sup>	S&P+Tax <sup>8</sup>	Combined <sup>9</sup>
Final NRA	67	68	69	67	67	67	67	69	69	67	69
Percentage of fund in equities	0	0	0	0	0	30%	60%	30%	0	30%	25%
Size of tax increase <sup>10</sup>	0	0	0	1%	2%	0	0	0	1%	1%	1%
Average date of insolvency	2041	2045	2047	2054	2078	2046	2060	2062	2075	2076	2101+
2.5th percentile date of insolvency	2027	2029	2029	2032	2038	2027	2027	2030	2035	2032	2036
16.7th percentile date of insolvency	2032	2033	2034	2038	2046	2032	2033	2035	2043	2040	2048
Median date of insolvency	2038	2041	2042	2048	2065	2040	2043	2048	2062	2056	2077
83.3rd percentile date of insolvency	2050	2056	2063	2072	2101+	2060	2085	2096	2101+	2101+	2101+
97.5th percentile date of insolvency	2079	2097	2101+	2101+	2101+	2101+	2101+	2101+	2101+	2101+	2101+
Probability of solvency through 2026	0.019	0.009	0.005	0.001	0.000	0.019	0.019	0.005	0.000	0.001	0.000
Probability of solvency through 2051	0.850	0.771	0.703	0.569	0.261	0.750	0.640	0.563	0.335	0.436	0.209
Probability of solvency through 2076	0.972	0.935	0.891	0.854	0.639	0.897	0.803	0.780	0.662	0.708	0.488
Probability of solvency through 2101	0.989	0.978	0.949	0.932	0.788	0.939	0.859	0.844	0.787	0.809	0.621
2.5 <sup>th</sup> percentile 75-yr summ. act. bal.	-6.40	-5.73	-4.93	-5.48	-4.47	N/A	N/A	N/A	-3.93	N/A	N/A
16.7 <sup>th</sup> percentile 75-yr summ. act. bal.	-4.21	-3.67	-3.03	-3.33	-2.32	N/A	N/A	N/A	-2.03	N/A	N/A
Median 75-yr summarized actuarial bal.	-2.55	-2.07	-1.60	-1.63	-0.62	N/A	N/A	N/A	-0.59	N/A	N/A
83.3rd percentile 75-yr summ. act. bal.	-1.03	-0.65	-0.33	-0.08	0.93	N/A	N/A	N/A	0.68	N/A	N/A
97.5th percentile 75-yr summ. act. bal.	0.08	0.42	0.69	1.05	2.08	N/A	N/A	N/A	1.71	N/A	N/A
Avg. balance as a percent of GDP in 2026	20	23	24	32	44	24	29	29	36	38	42
Avg. balance as a percent of GDP in 2051	-28	-16	-9	3	38	-15	11	11	26	31	54
Avg. balance as a percent of GDP in 2076	-147	-120	-90	-83	-8	-124	-46	-42	-14	-13	62
Avg. balance as a percent of GDP in 2101	-412	-361	-282	-293	-138	-379	-161	-177	-127	-135	54
2.5th percentile bal. as a % of GDP, 2076	-452	-383	-314	-323	-223	-413	-403	-291	-200	-287	-163
16.7th percentile bal. as a % of GDP, 2076	-234	-205	-168	-169	-102	-234	-214	-143	-94	-145	-65
Median balance as a percent of GDP, 2076	-121	-101	-75	-73	-25	-115	-95	-55	-24	-49	2
83.3rd percentile bal. as a % of GDP, 2076	-52	-37	-16	-8	71	-37	22	29	52	84	166
97.5th percentile bal. as a % of GDP, 2076	5	51	88	149	326	195	853	344	269	524	647

<sup>1</sup> Baseline (currently legislated) scenario: Payroll tax rate of 12.4%, NRA of 67 by 2022, and no investment in S&P 500.

<sup>2</sup> NRA raised to 68 by 2023.

<sup>3</sup> NRA raised to 69 by 2023.

<sup>4</sup> 30% of fund invested in S&P 500 by 2015.

<sup>5</sup> 60% of fund invested in S&P 500 by 2015.

<sup>6</sup> NRA raised to 69 by 2023 combined with 30% of fund invested in S&P 500 by 2015.

<sup>7</sup> NRA raised to 69 by 2023 combined with payroll tax rate of 13.4%

<sup>8</sup> Payroll tax rate of 13.4% combined with 30% of fund invested in S&P 500 by 2015.

<sup>9</sup> Combination of NRA increase to 69 by 2023, payroll tax rate of 13.4%, and 25% of fund invested in S&P 500 by 2015.

<sup>10</sup> All tax increases implemented starting in 2002.

Figure 1. Average tax and benefit level by age and sex, 2001

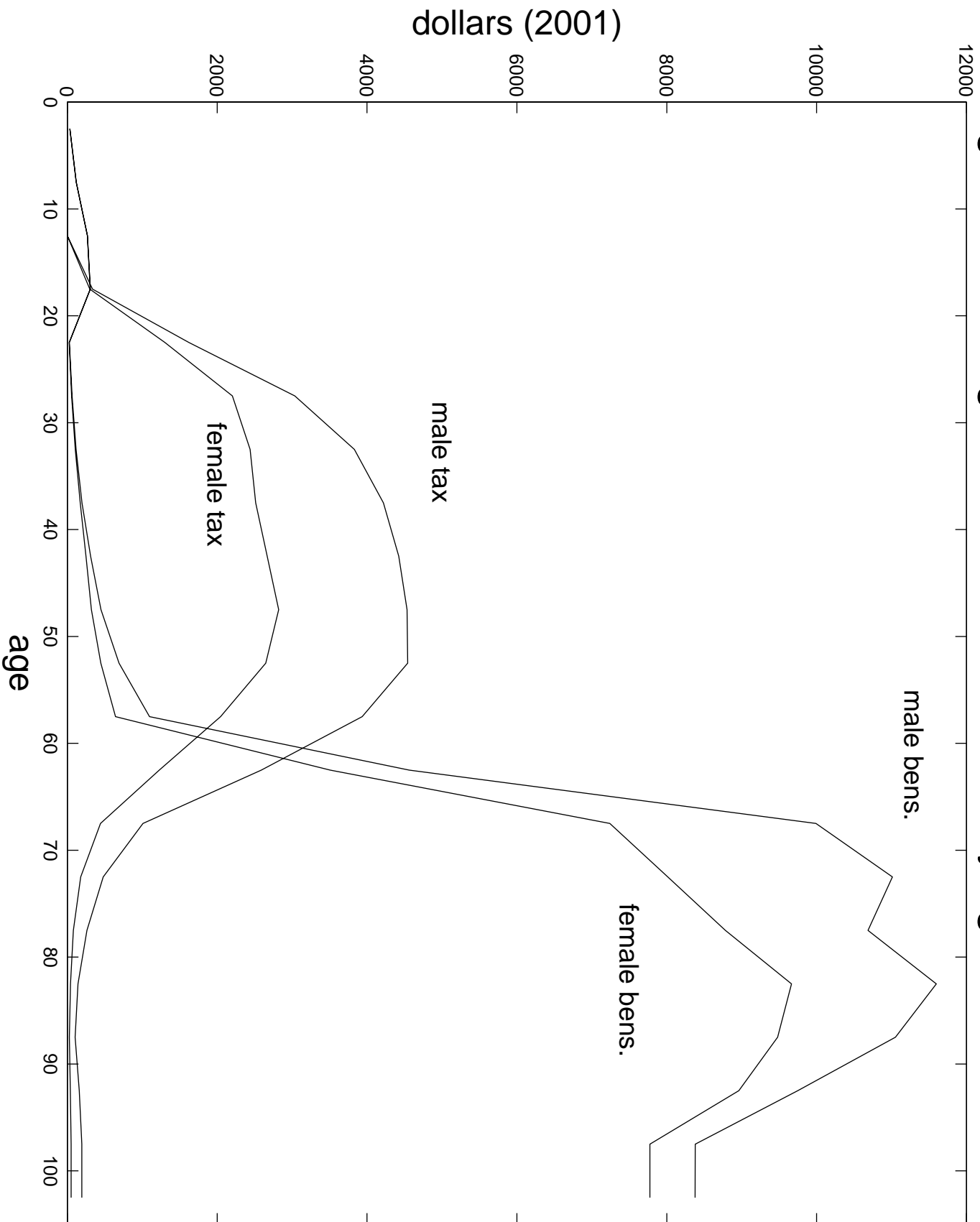
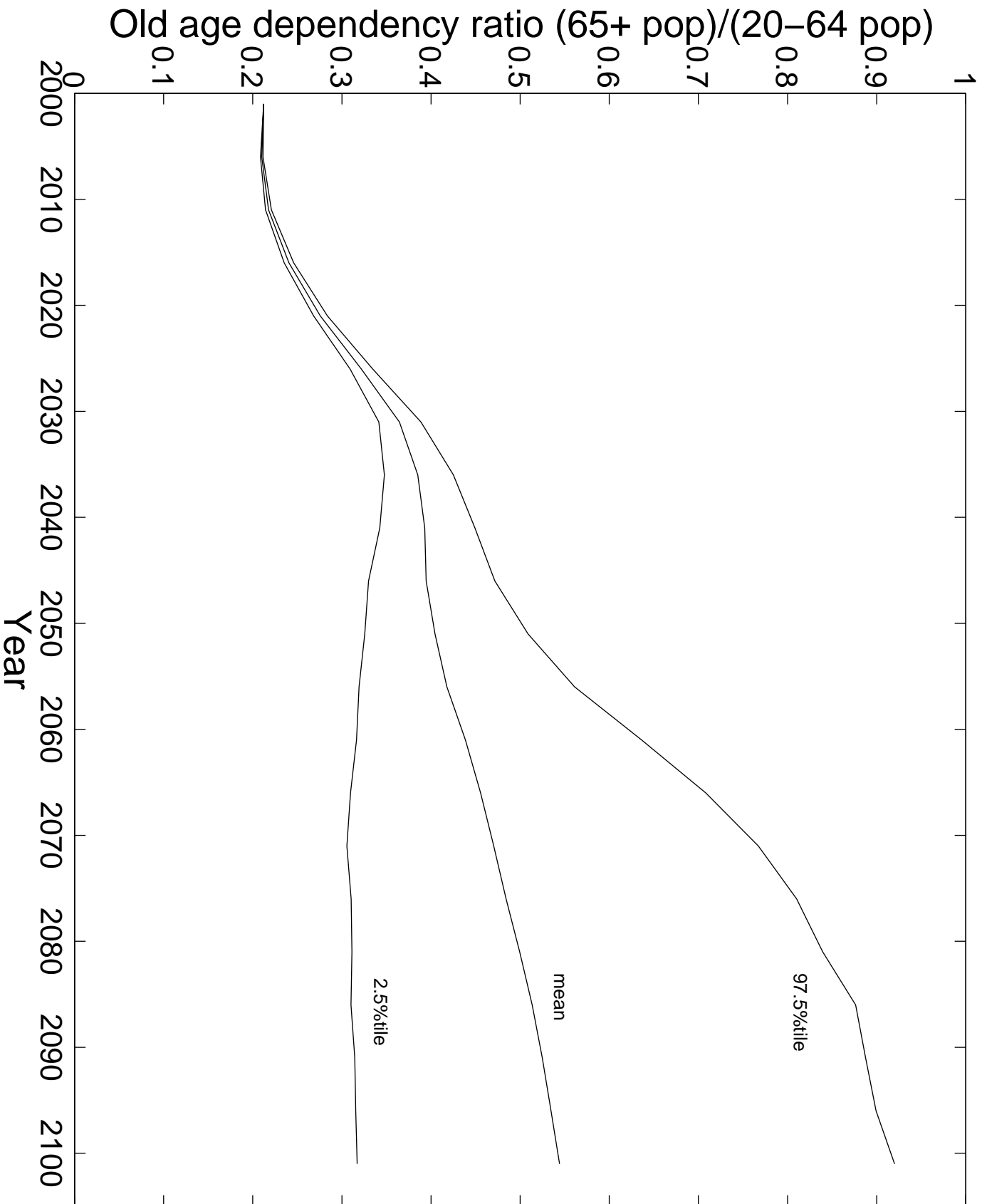


Figure 2. Old age dependency ratio (65+ pop)/(20–64 pop)



# Figure 3. Trust Fund Structure

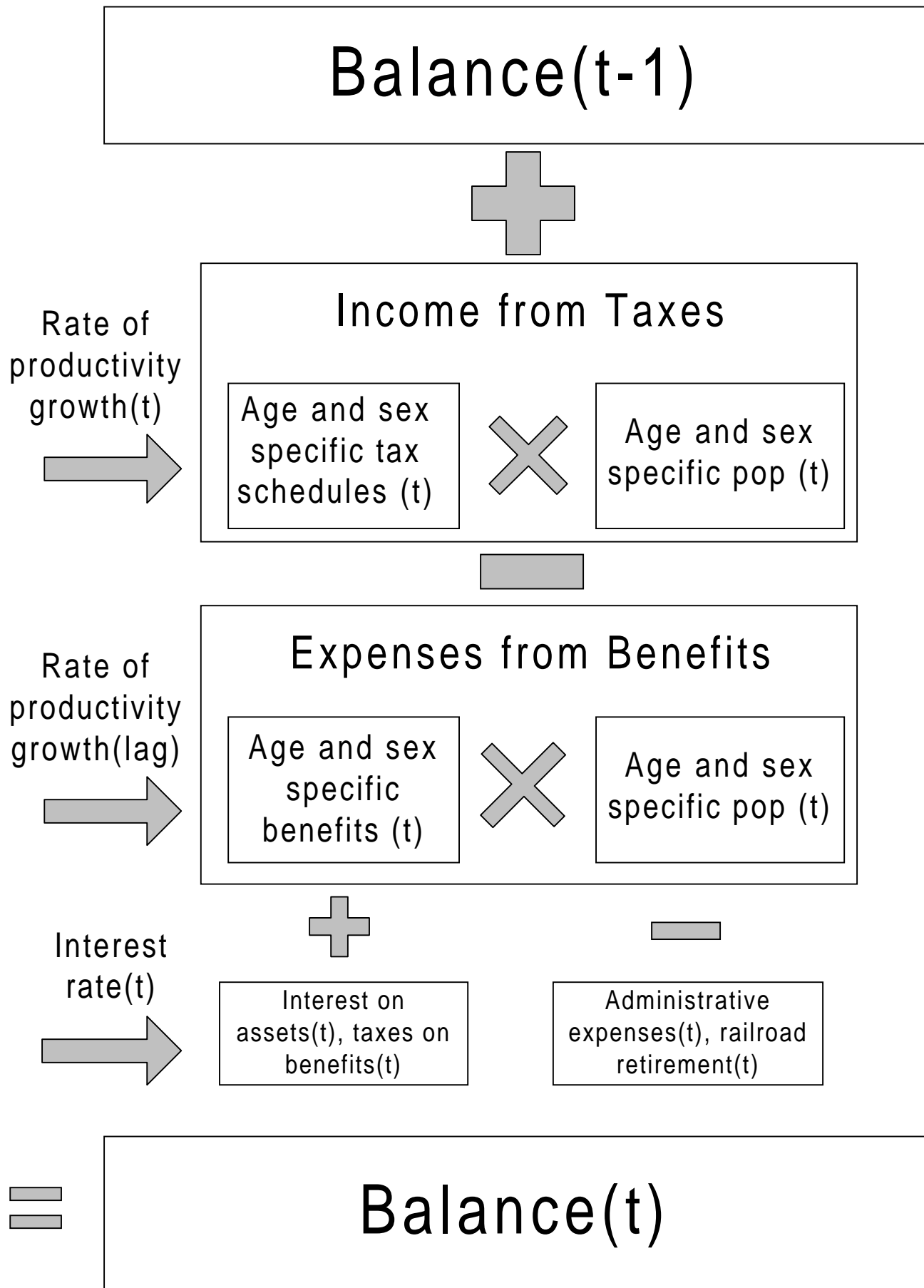


Figure 4. Total population forecasts (100's of millions), 2001–2101

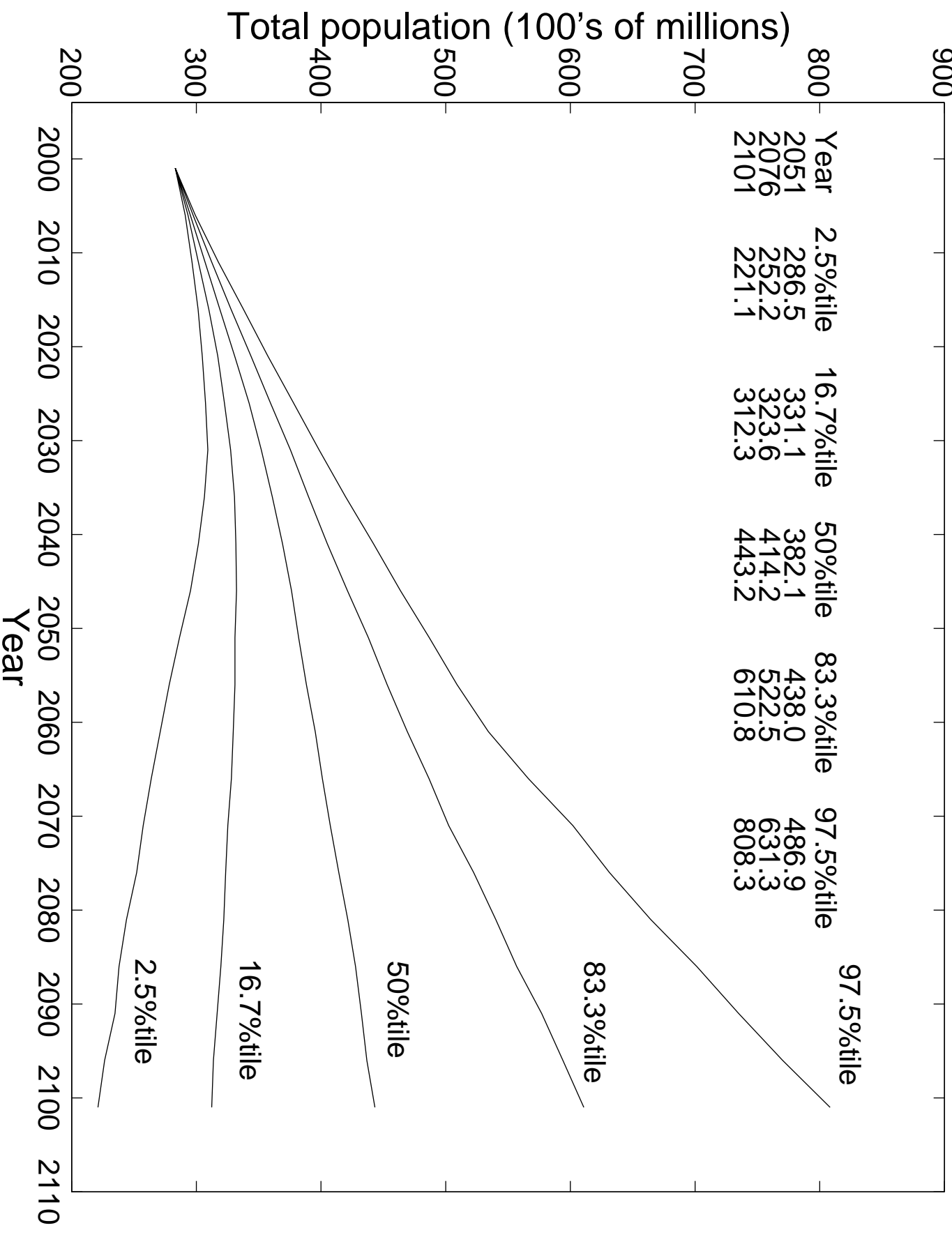




Figure 5. 10 random trajectories of fund balance, 2001–2050

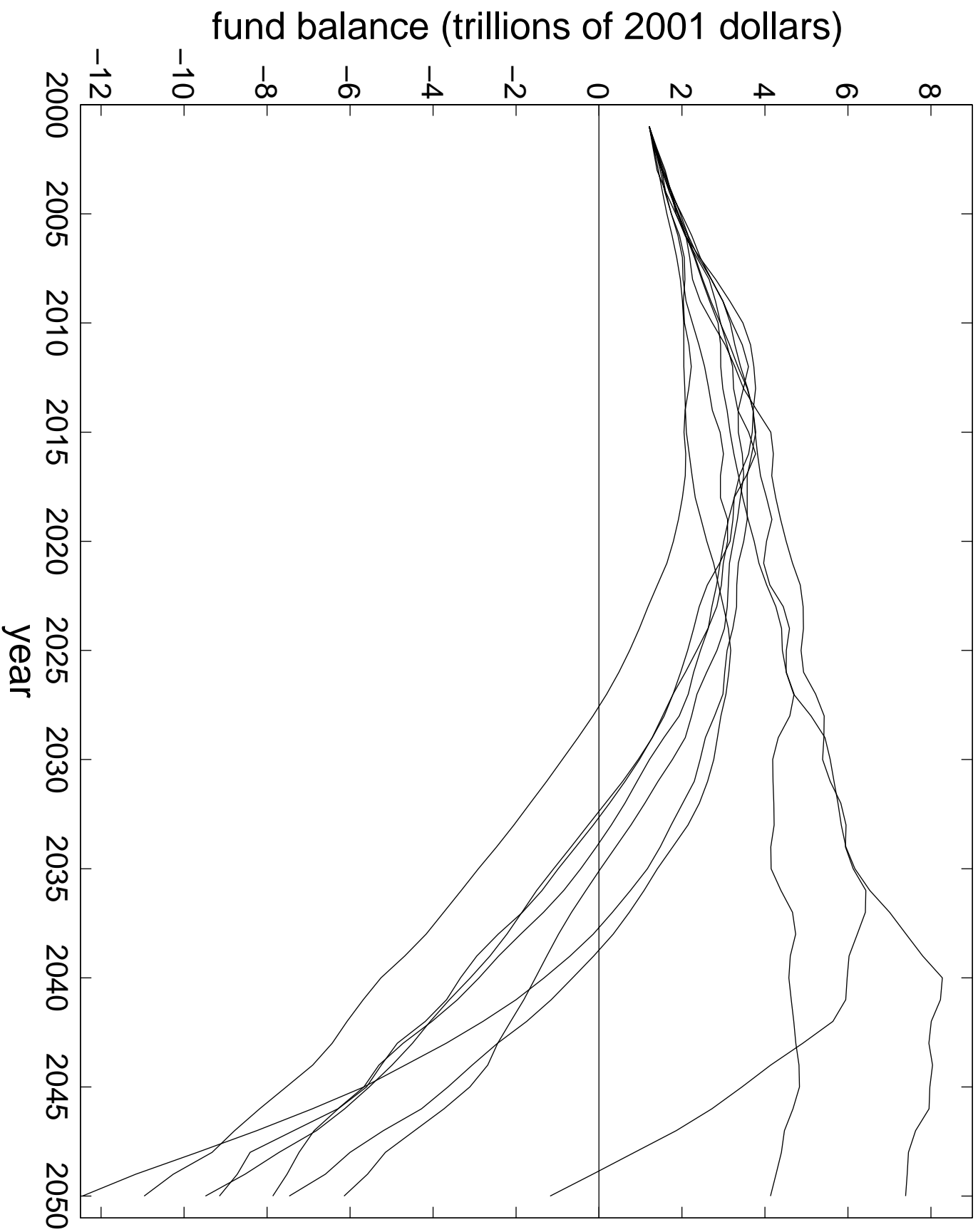


Figure 6. Trust fund balance, 2001–2045, with 67% C.I.

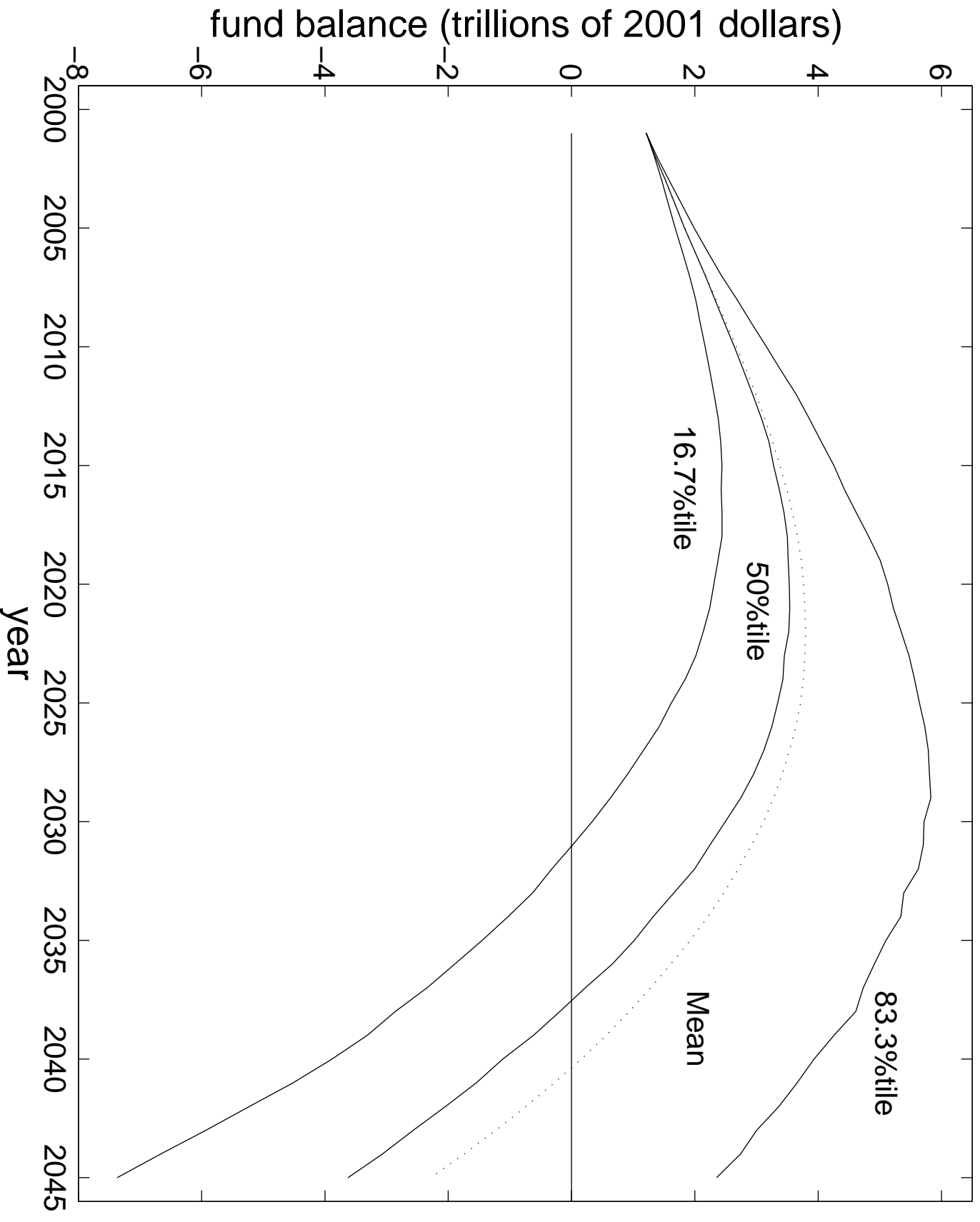


Figure 7. Probability distribution of date of insolvency

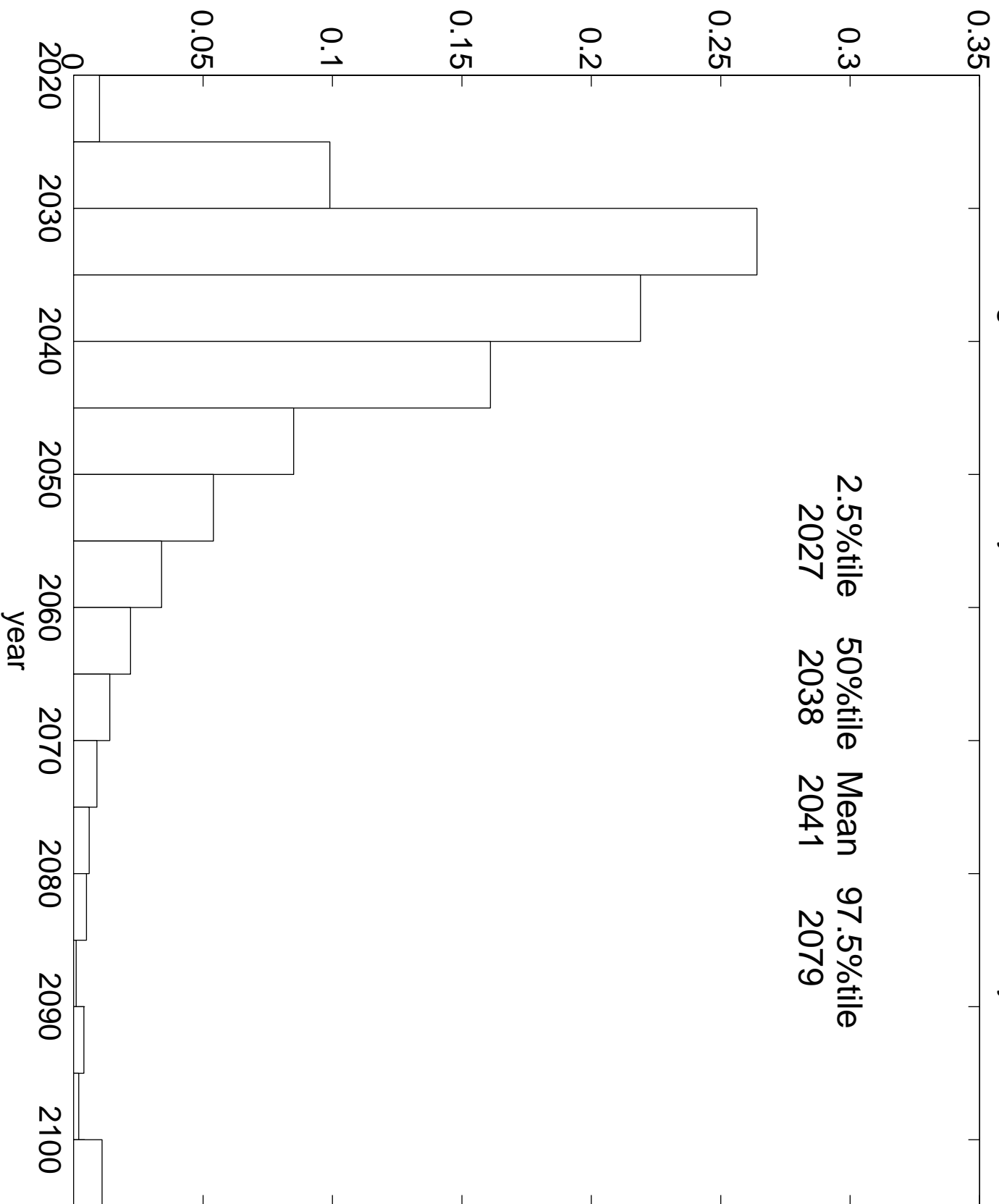


Figure 8. Distribution of 75-year summarized actuarial balance

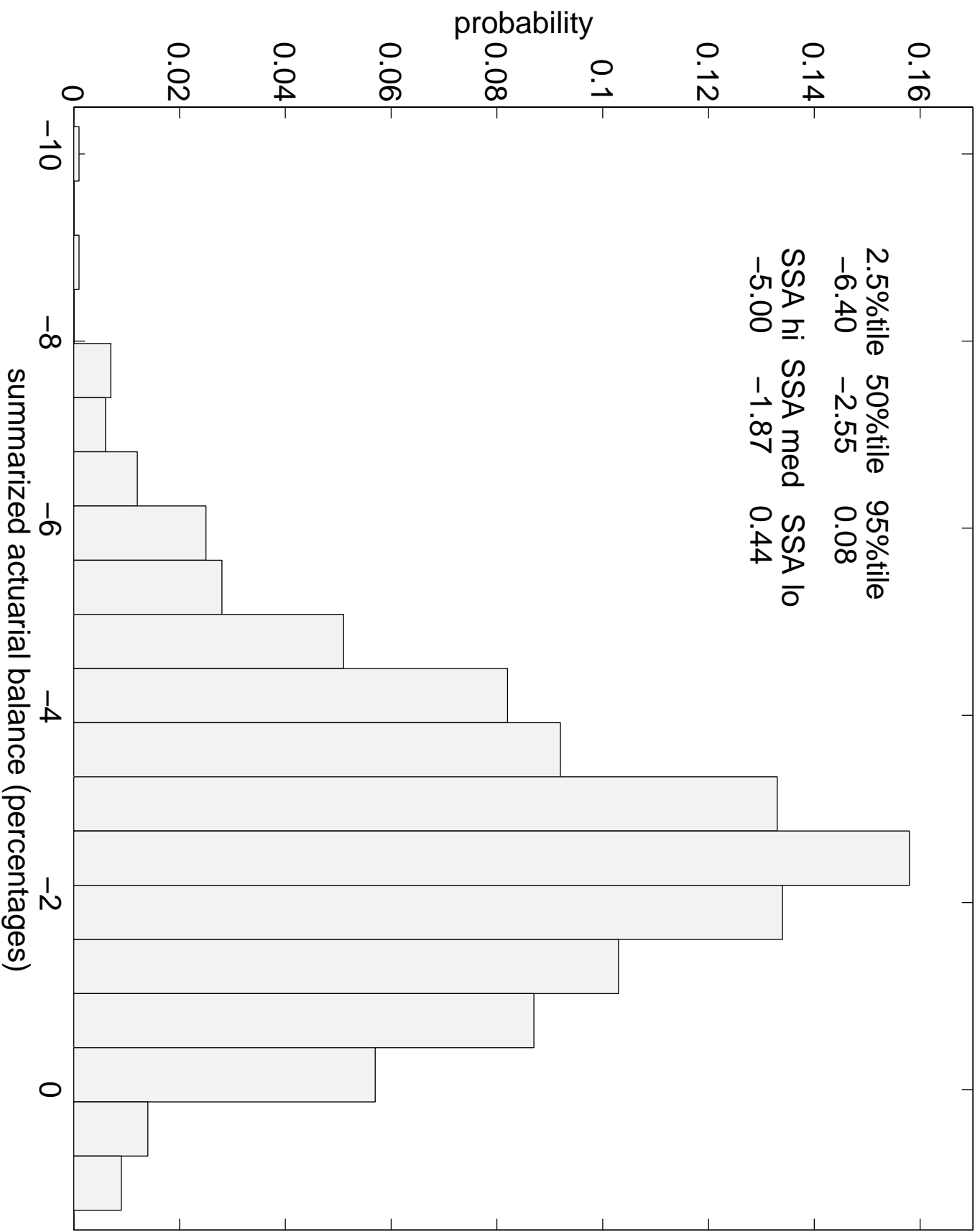


Figure 9. Distribution of dates of exhaustion, four levels of tax increase

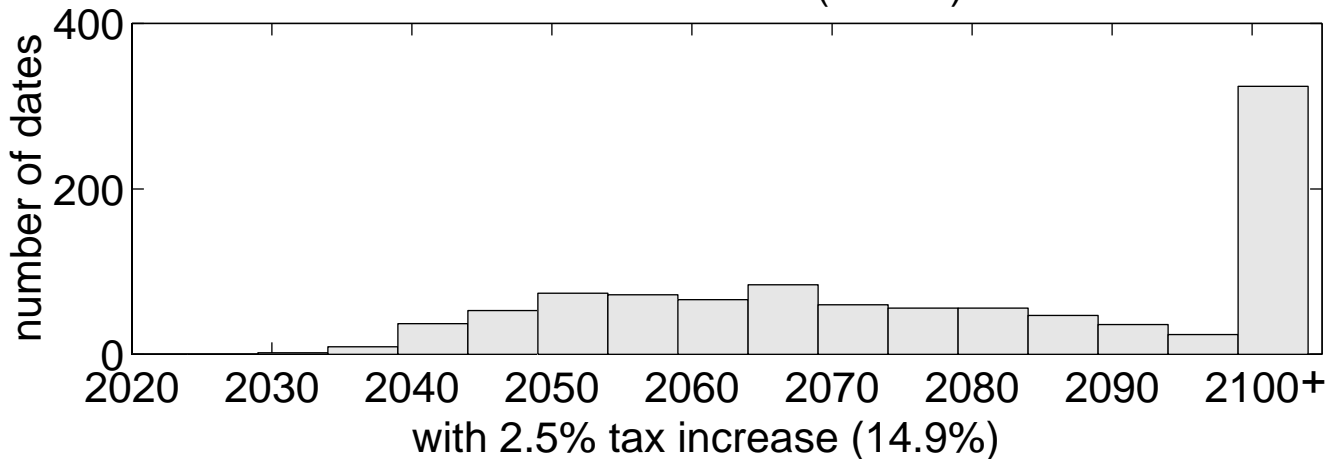
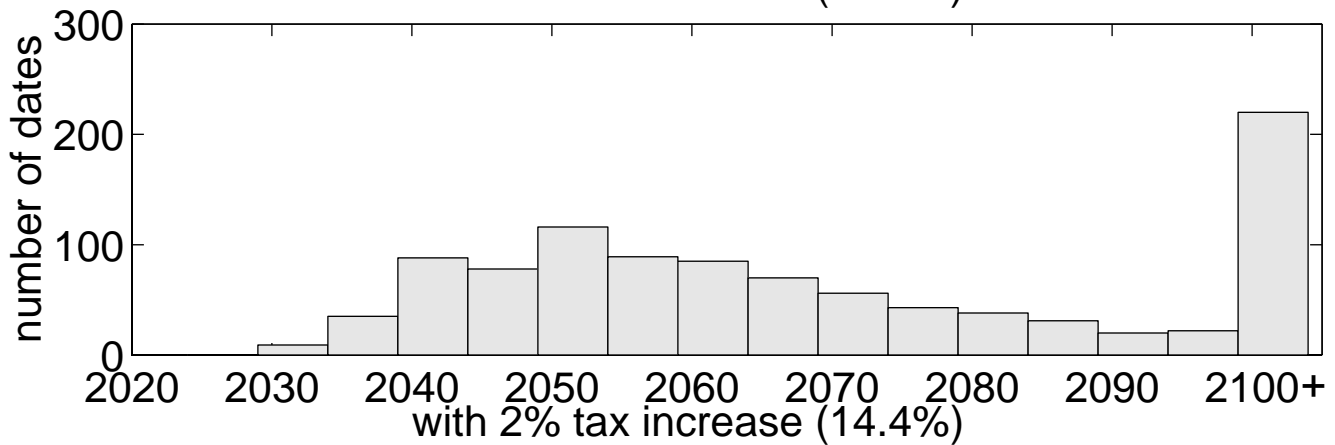
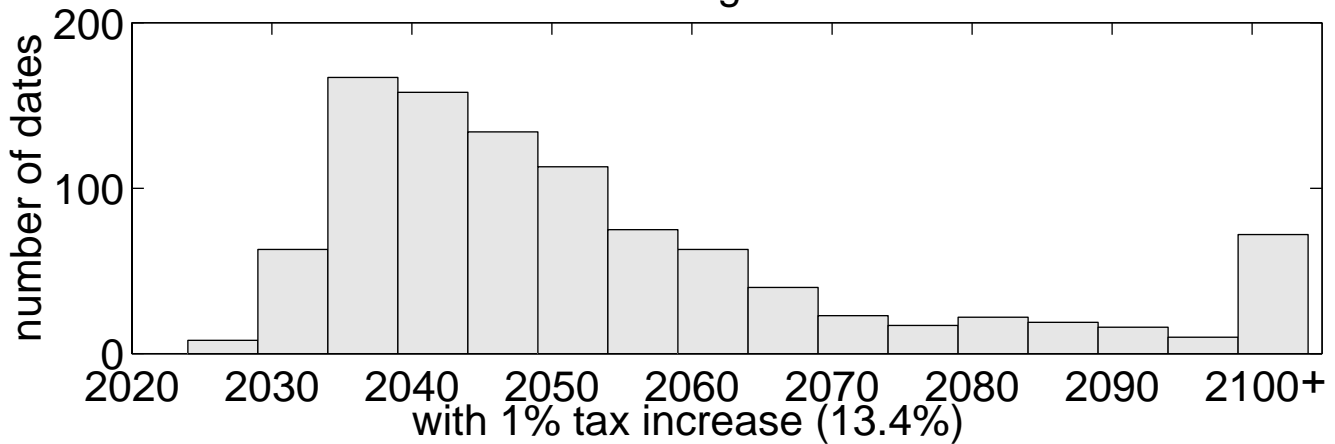
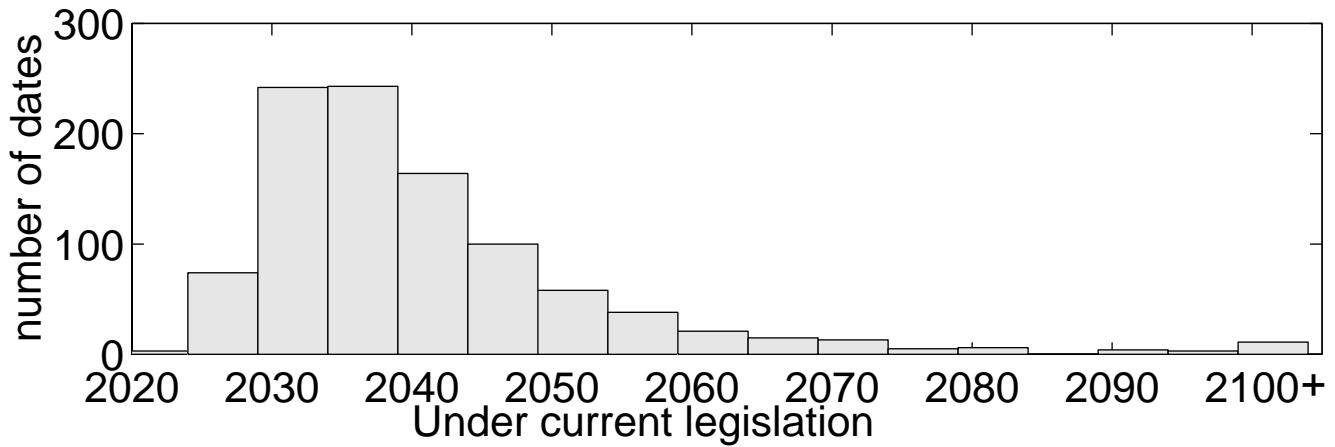


Figure 10. Distribution of actuarial balances, 4 tax increases

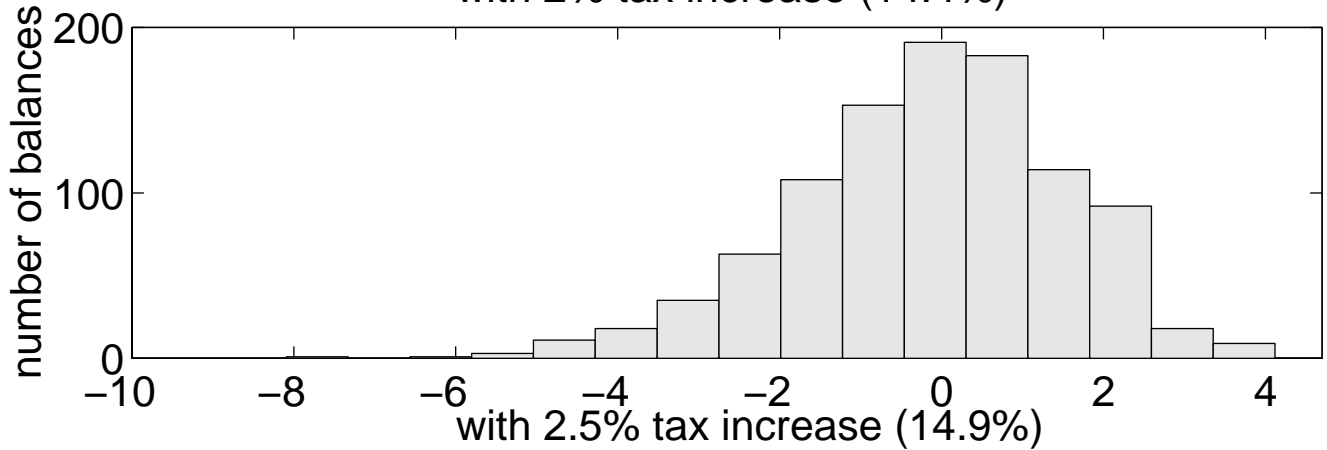
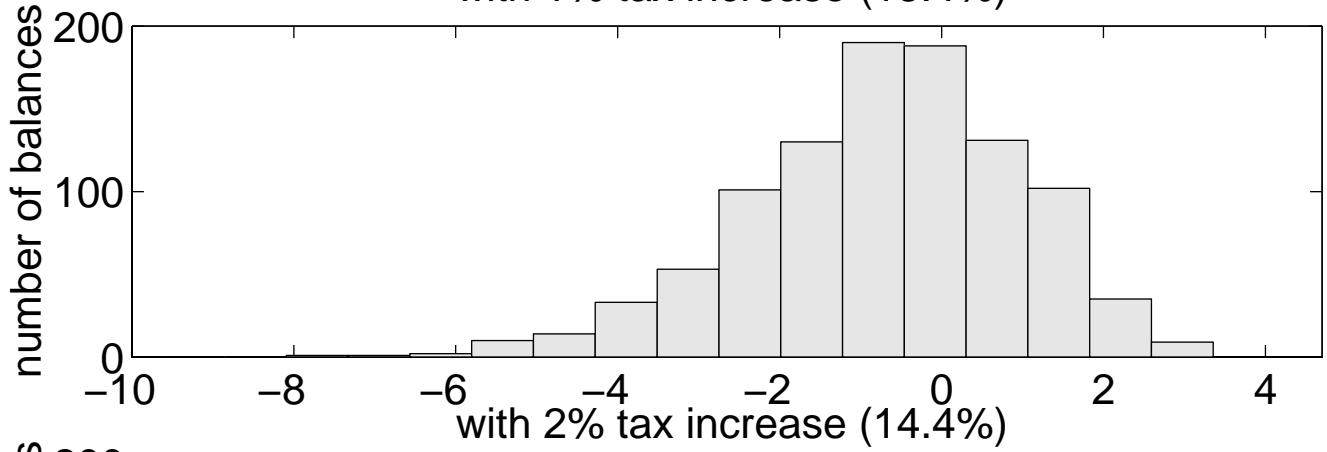
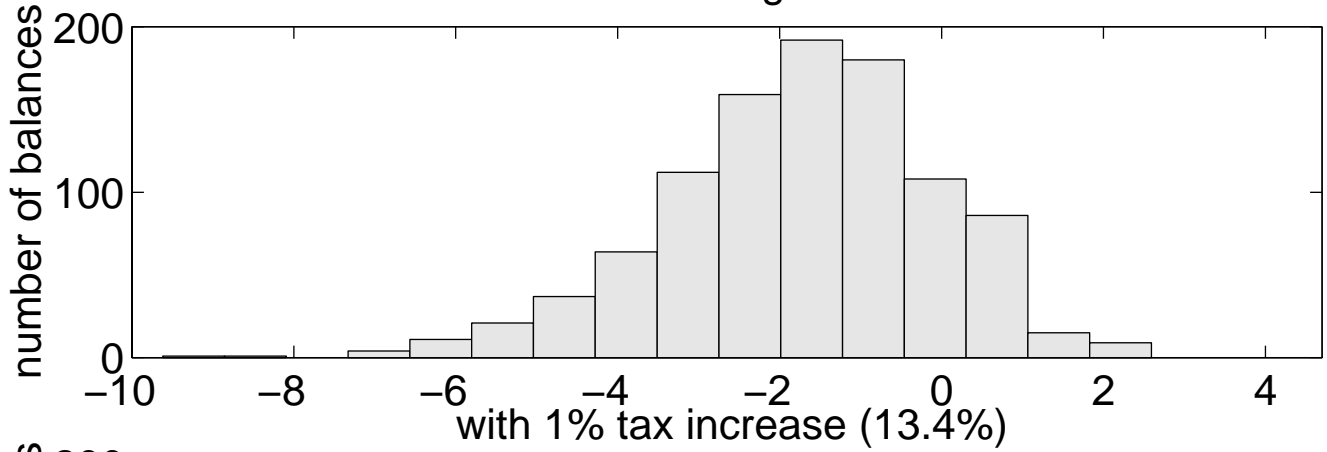
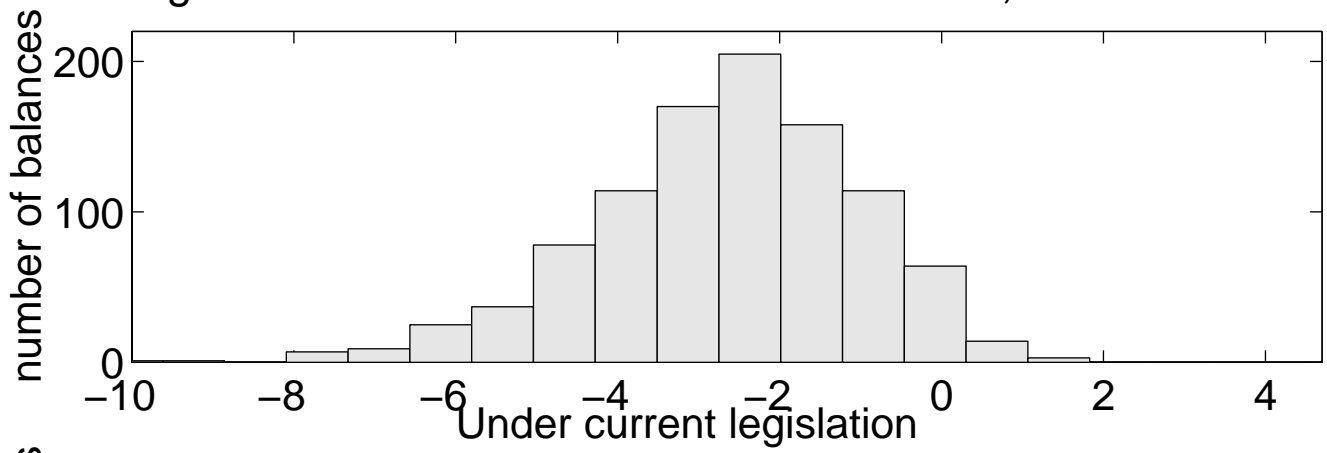


Figure 11. Dist. of dates of exhaustion, 5 schedules of NRA shift

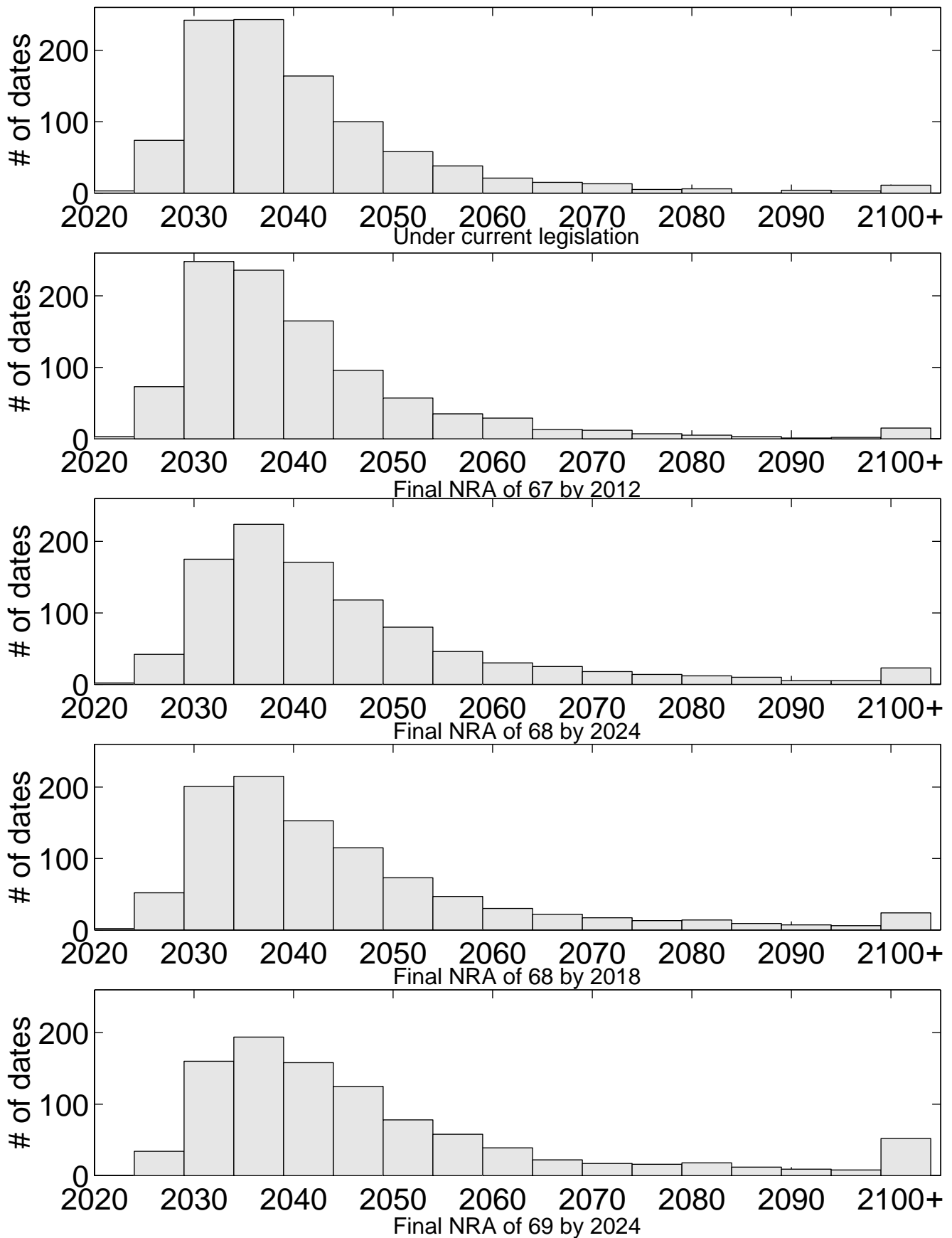


Figure 12. Dist. of actuarial balances, 5 schedules of NRA shift

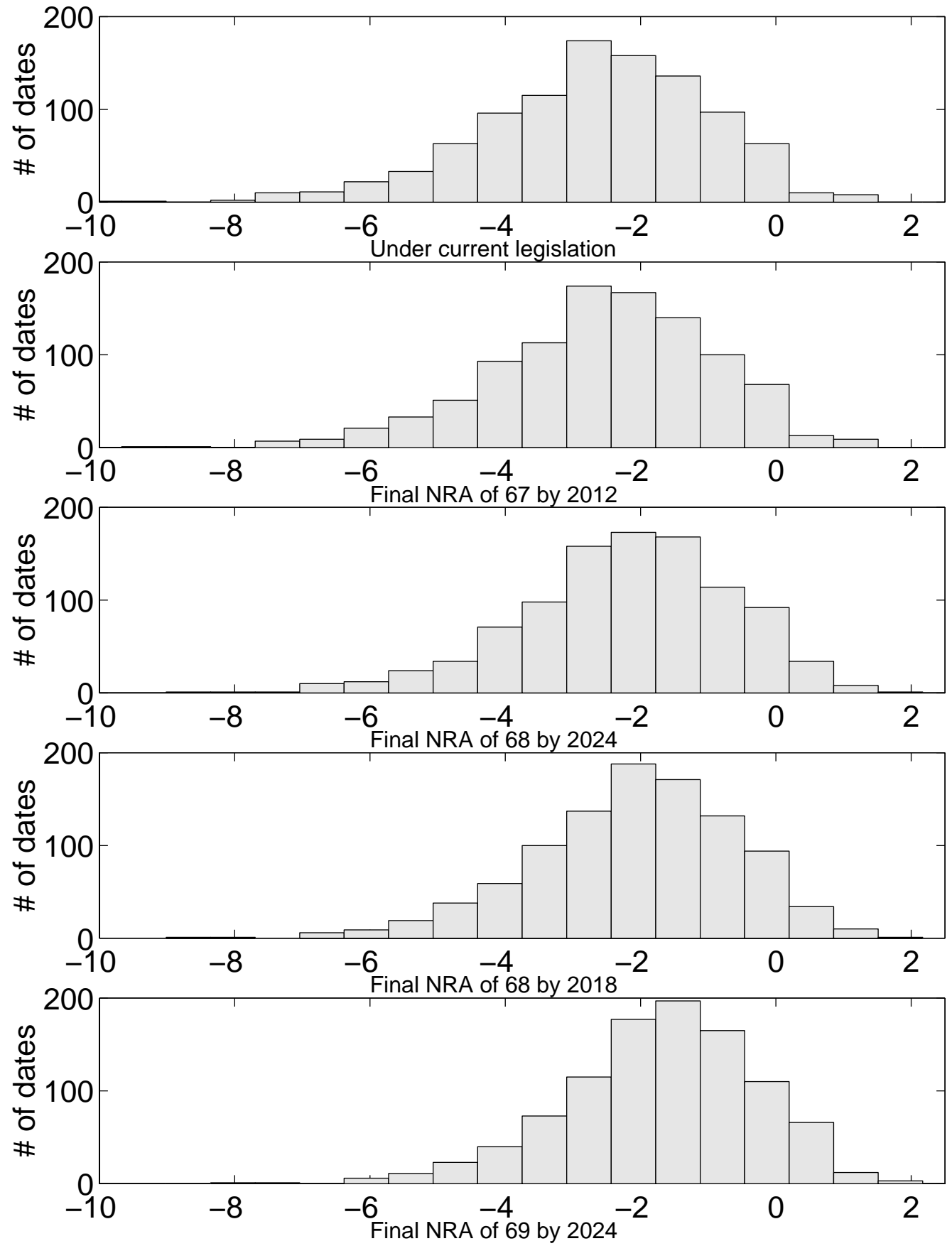




Figure 13. Dist. of dates of exhaustion, 5 levels of equities

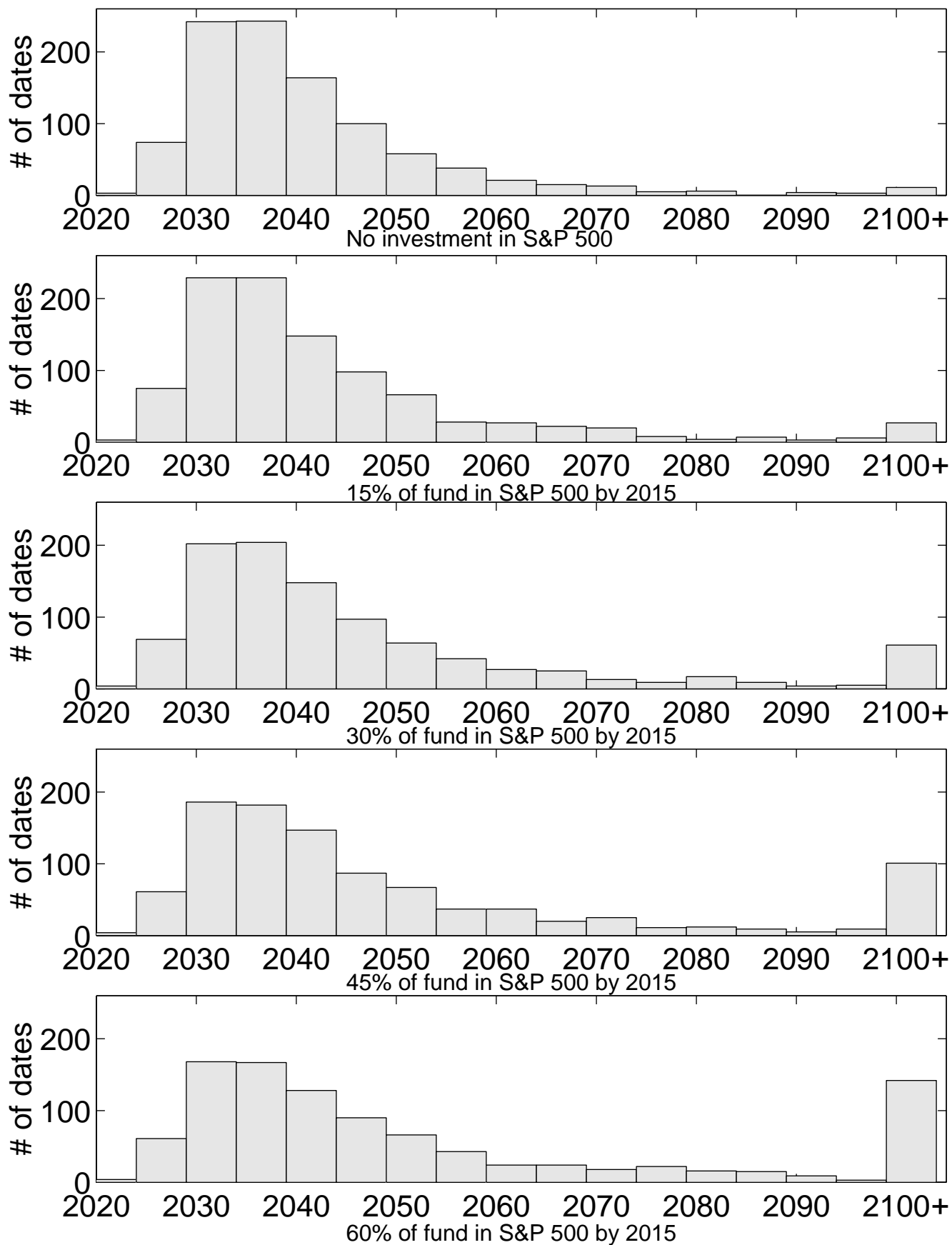


Figure 14. Chance of solvency until 2051, by NRA change and investment level

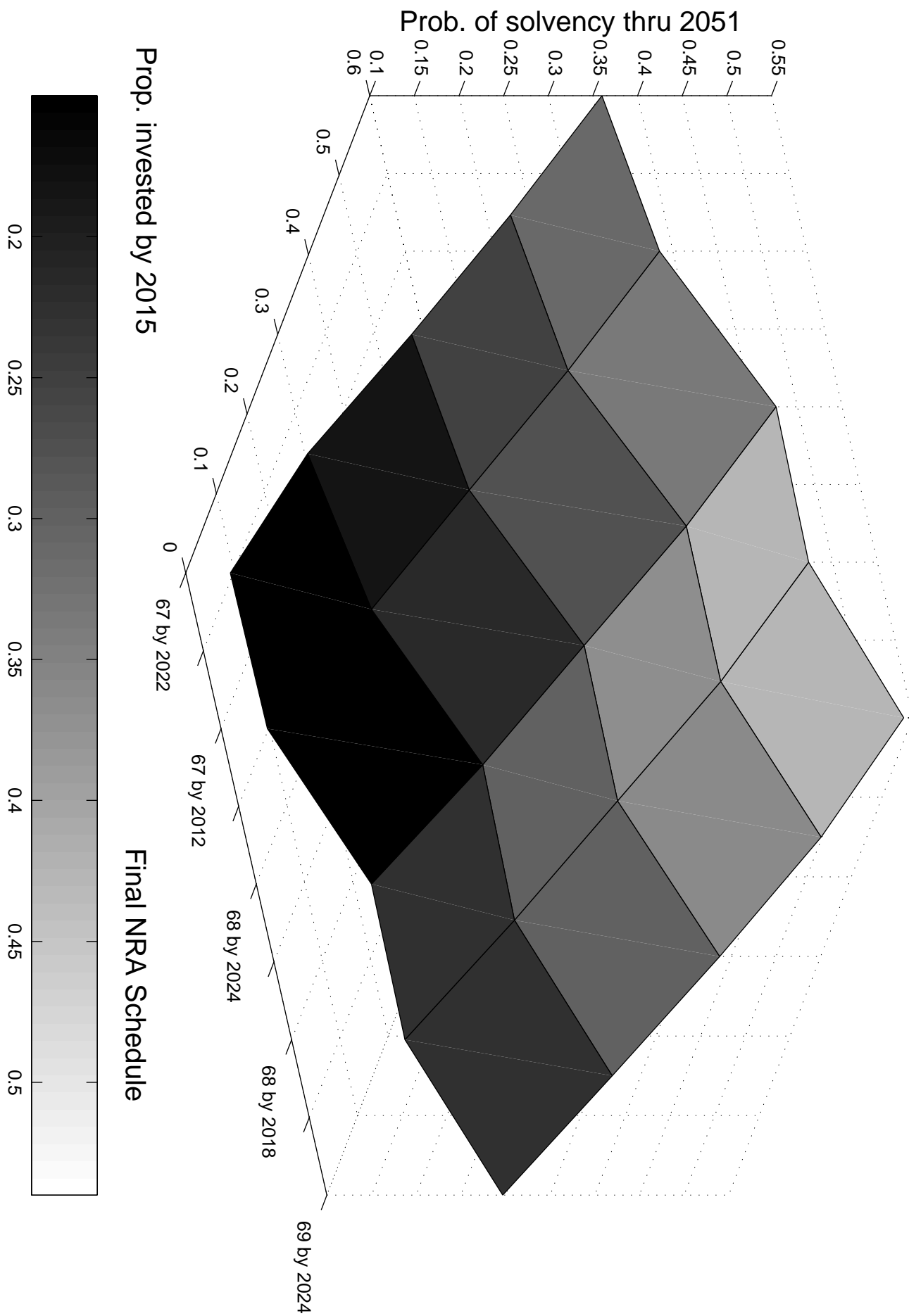


Figure 15. Lines of isorisk of insolvency by 2051, by investment level and NRA change

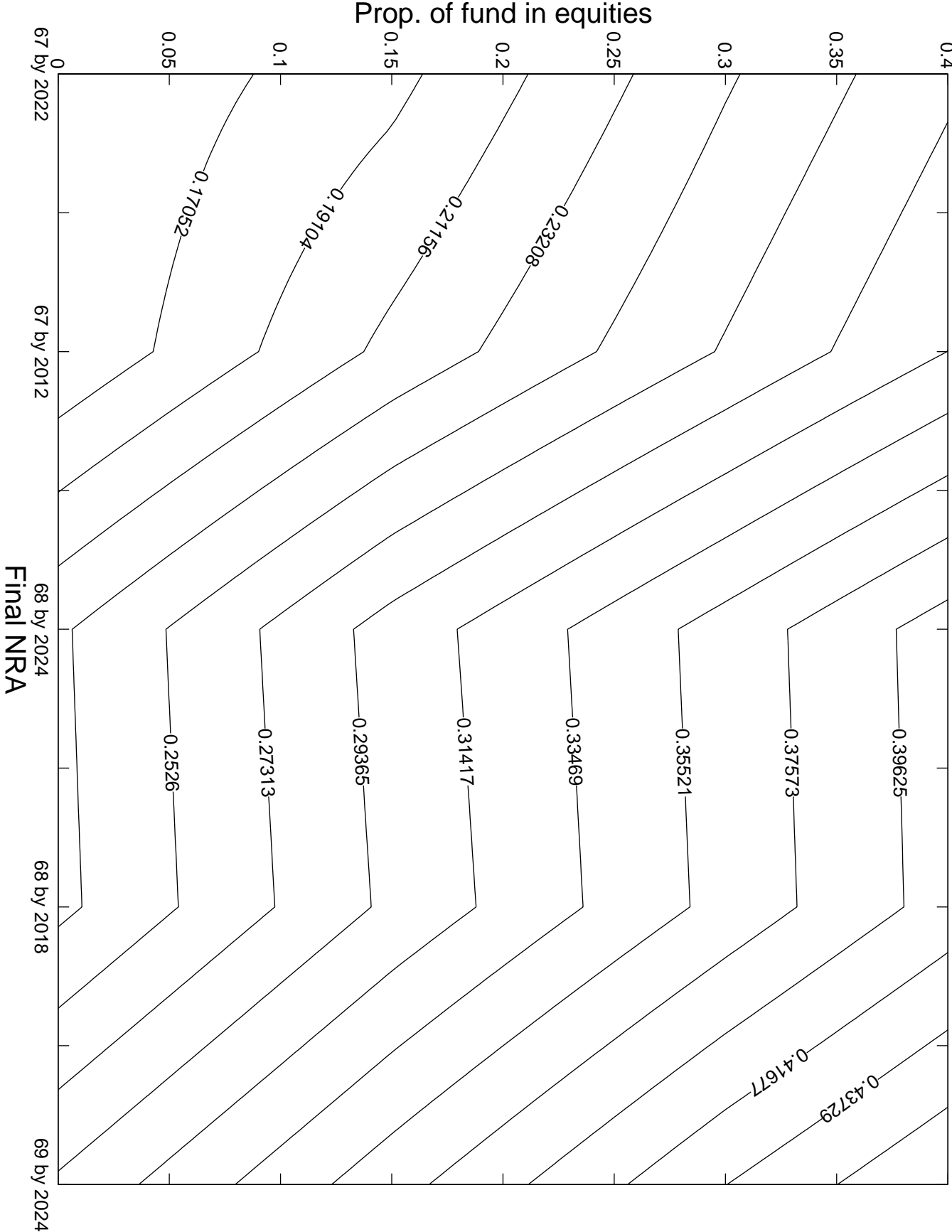


Figure 16. Chance of solvency until 2051, by tax increase and NRA change

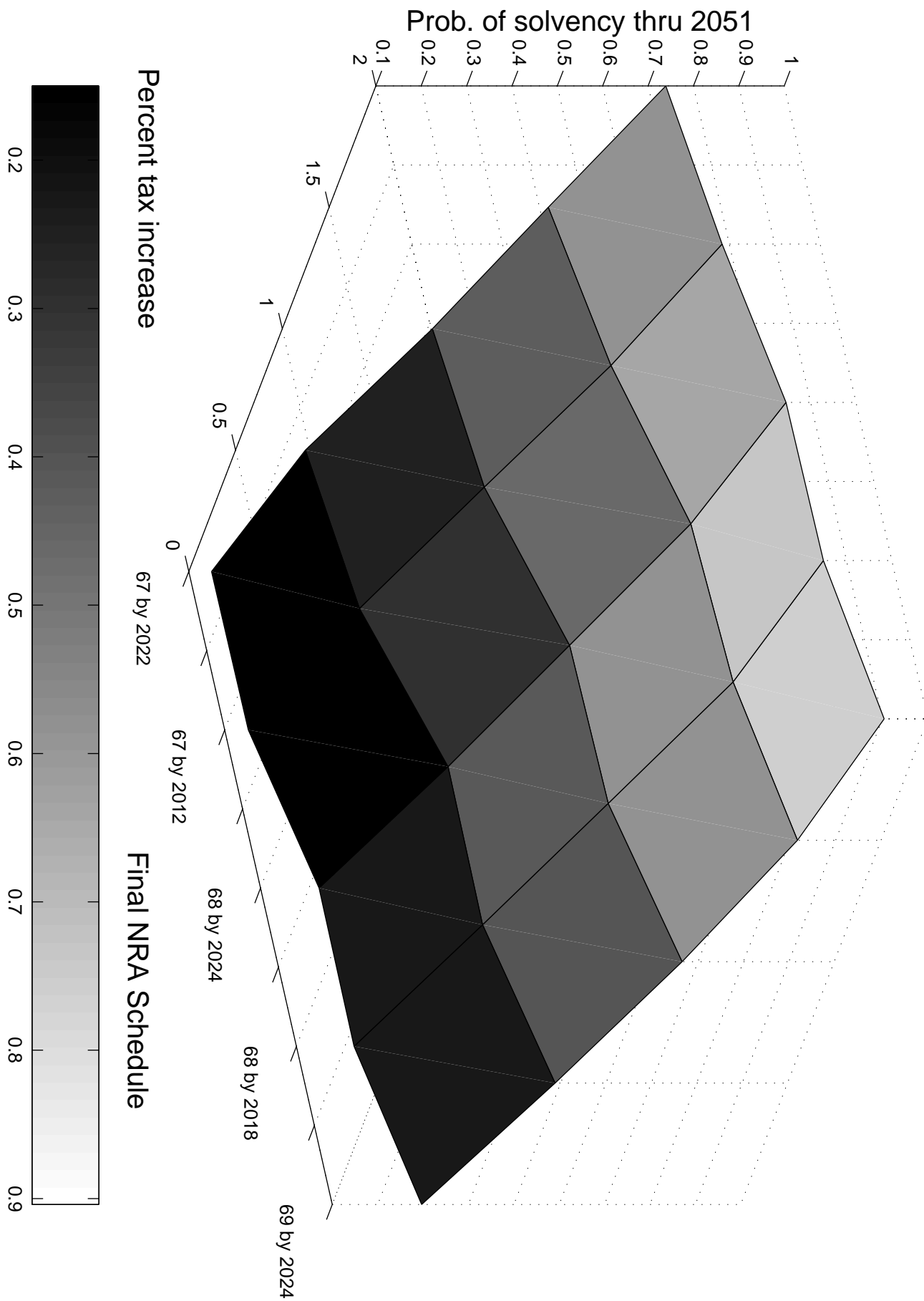


Figure 17. Chance of solvency until 2051, by tax increase and investment level

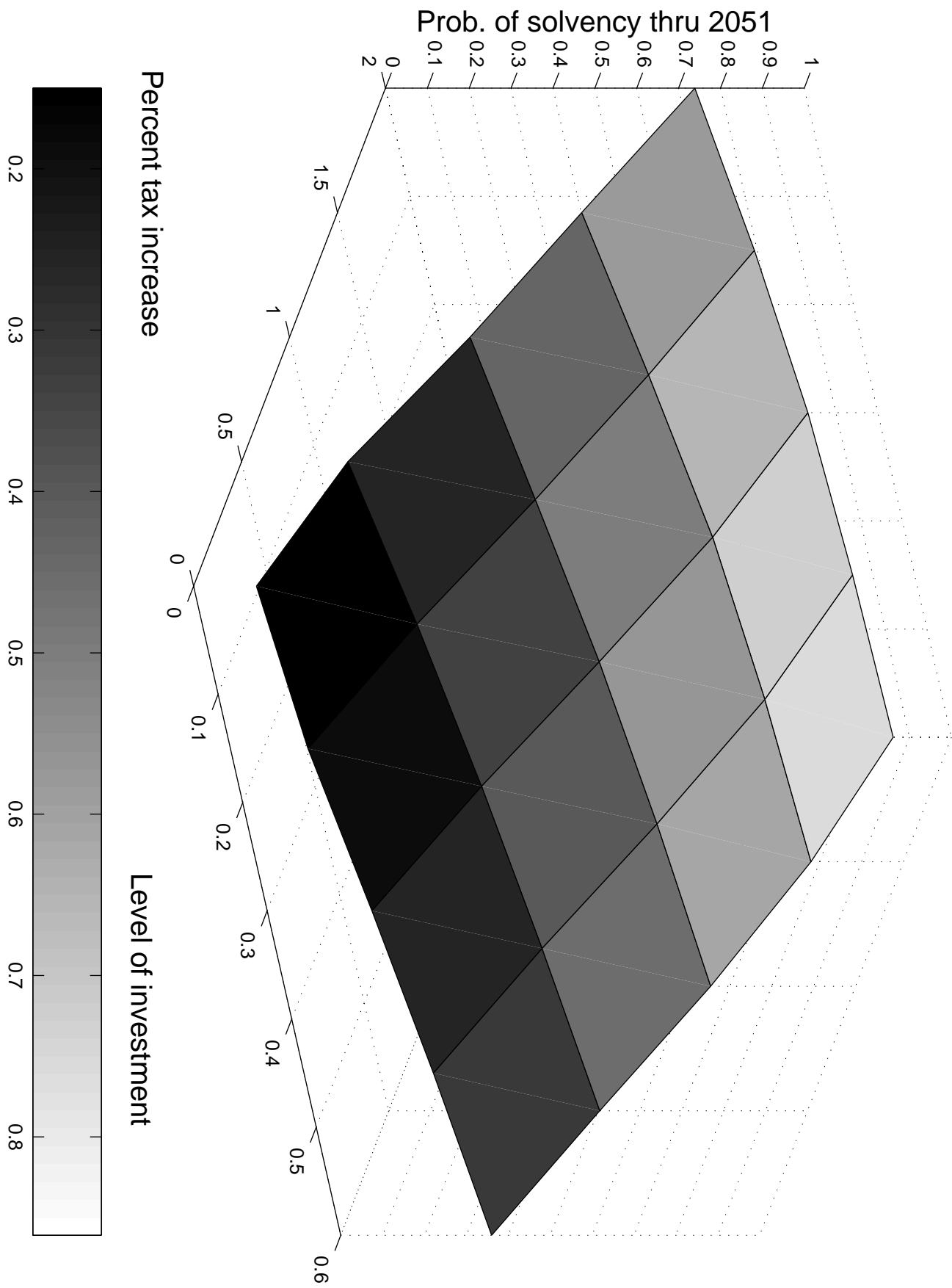


Figure 18. Distribution of OASDI Trust Fund Ratio

