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Chances are . . . Stochastic Forecasts of the Social Security Trust and Attempts to Save It

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Abstract

We present forecasts of the Social Security trust fund, modeling key demographic and economic variables as time series. We evaluate 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. Economic variables are modeled as vector autoregressive processes. With taxes and benefits by age and sex, we obtain inflows to and outflows from the fund over time.

Under current legislation, we estimate a 50% chance of insolvency by 2032. Investment in the market cannot keep the median fund solvent, even when the balance stays positive on average. The NRA must be raised to 71 by 2022 for a 66% chance of solvency beyond 2070. Solvency can also be achieved by raising the NRA to 68 by 2020, investing in the market, and increasing taxes one percent.

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Introduction

No government benefit program promises to impact the wallets of taxpayers and retirees more than social security. Declining mortality and the past baby boom have conspired to create an abundance of workers now on the verge of retirement with fewer young workers left to support them. To pay the benefits of these future retirees under current legislation, the system is about $4 trillion short of the balance it would need today in addition to future tax income. This debt will either be paid by taxpayers or reduced at the expense of retirees, either now or in the future. Who pays and when are at the core of the policy debate.

The federal government has four ways to extend 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 it in equities, or create additional federal debt through bond sales. Exactly who pays the social security debt 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, accounting shell games, and the inherent complexity of the system itself. Crucial to this endeavor, then, is a concise set of fund forecasts which clearly explain the consequences of any given policy.

Expert analysts are well equipped to deal with the logistical complexities. 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 the inputs. By gauging this uncertainty on the basis of historical variation and incorporating it into our estimates explicitly, we seek probabilistic forecasts which are imprecise but accurate. For a given policy scenario, for instance, 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, allowing the use of risk as a metric for evaluating policy outcomes. If desired, once could then weight the probabilities of outcomes by the associated pain or gain, but we have not done this.

Background

The OASDI trust fund is actually a combination of two funds which pay out monthly benefits to two groups of workers. The Federal Old-Age and Survivors Insurance (OASI) Trust Fund, established in 1940, provides for retired workers, their families and their survivors. The Federal Disability Insurance (DI) Trust Fund, established in 1956, provides for disabled workers and their families. At the end of 1997, the combined OASDI fund held a total of $656 billion in the form of government securities.[1] Annual expenditures for 1997 totaled $369 billion, but income totaled $458 billion, so the fund balance increased $89 billion from the end of 1996.

Intermediate forecasts from the actuaries of the Social Security Administration (SSA) project such fund increases until 2020, at which point the balance of the fund will top out at nearly $2 trillion in 1998 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 2032. The amount of benefits which are owed but unfunded by the projected tax income is enormous. To meet its obligations for the next 75 years, the fund would require an injection of about $4 trillion today, in addition to all other projected forms of income (including interest on the $4 trillion). However, this imbalance is not simply a result of the baby boomers' retirement; there is also long term pressure exerted by gains in life expectancy and chronic low fertility.

The mechanism by which demographic changes will likely cause this fiscal imbalance can be understood by examining inflows and outflows to the system as a function of the age of the participants. The fund may be thought of as an interest-earning bank account into which workers pay taxes, and out of which benefits are paid to recipients. Figure 1 shows the average tax paid by age for 1997, along with the average benefit received by age. Weighted by amount, taxpayers are about 30 year younger than recipients.

Keeping tax rates fixed then, 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 18 to 64. The center line is the median forecast, and the outer lines show a 95% confidence interval. The ratio is projected on average to increase well beyond the retirement of the baby boomers. The sheer demographics necessitate substantial and permanent changes in the system.

Structure of social security

A simplified representation of the system is shown in Figure 3. The account balance at the end of this year is equal to the balance at the end of last year plus tax income and interest, minus benefit payments, railroad retirement, and administrative expenses. 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. (Several other factors also influence the growth of taxes and benefits over time; see the appendix for a more detailed explanation of the system in the context of our model.) The total amount of interest earned on the fund obviously depends on the interest rate[2].

One can estimate total taxes into the system in any given year by multiplying age- and sex-specific tax schedules (like those in Figure 1) and age- and sex-specific population estimates, and summing across sexes and ages. Likewise, benefits can be calculated with a set of age- and sex-specific benefit schedules and population estimates for that year. 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 straightforward.[3] The difficulty is mostly in estimating the future inputs.

Although we ignore it in our forecasts, we emphasize that as a collection of federal debt, the fund represents not real wealth, but rather a promise to pay out a given amount of benefits.[4] The commitments of the system are backed up primarily by the willingness of future workers to pay the taxes that support it, rather than by the fund itself. Similarly, a commitment of additional federal debt to the system (as would be created by President Clinton's plan) would not represent a real way to meet the costs of the system, but rather a strengthening of the promise to do so.

In any case, given that any such promises are met, the fund is a convenient signal of the likely soundness of the system's internal finances under some future policy regime.

Uncertainty in forecasts

There are four rough categories of uncertainty in the accounting system described above. First, demographic uncertainty has been well recognized. Since there is no way to know what mortality, fertility and immigration rates will be in the future, it is impossible to know future population distributions exactly.

Economic uncertainty also intrudes. Historically, real wage growth and interest rates have varied substantially year-to-year, so there is no way to know exactly how future tax schedules, benefit schedules and bond returns should be fixed. If investment in equities is to be considered, so must the uncertainty about rates of return.

Another significant source of uncertainty is the behavior of future workers and retirees. For example, recent trends in the age at retirement suggest a desire on the behalf of workers to retire at younger ages. 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 which 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 uncertainty in the first two categories (demographic uncertainty 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

Ignoring the possibility of federal debt funding, the life of the fund may be extended by cutting benefits, raising taxes, or increasing fund returns through equities investment. We consider these three options both separately and in various combinations.

The first policy option we consider is an increase in the payroll tax. Presently legislated at 12.4%, we construct a set of five incremental increases in the tax level up to 14.9%. We always assume these increases occur immediately, and proportionately across sexes and ages.[5]

Next we treat the issue of benefit cuts. The most politically viable form of benefits cut seems to be some form of upward adjustment 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, starting in 2000 (raising it to 66 by 2005), and again starting in 2017 (raising it to 67 by 2022).[6] We consider a number of alternative, accelerated schedules of NRA change, raising it to various values between 67 and 71. 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. In another paper, we also consider an alternate set of runs in which some proportion of those individuals retiring at age 62 also postpone retirement until the scheduled NRA. Another factor of consideration in this setup is the proportion of those postponing retirement who roll over to disability for the extra years of postponement.

Third, we consider a set of plans to invest some portion of the fund in equities. The SSA assumes bonds will yield a 2.8% 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). Thus, arguments have been made in favor of investing a substantial proportion of the fund balance to the stock market. Investment could occur 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.

The question of risk depends to some extent on one's personal aversion. We seek a risk-neutral set of estimates, accomplished by explicitly building historical-sized market fluctuations into our forecasts and interpreting the results probabilistically. For instance, for a given investment scheme and horizon, we estimate the change in the probability of sustaining a loss, compared with bond investments.[7] Hence we do not weight risk in any sense, rather we measure it directly and report it for the reader's own interpretation.

We implement a set of investment schemes wherein some small portion of the trust fund is invested in equities at an initial date, and the invested proportion of the fund is increased gradually over time until a ceiling is reached. For example, 1% of the fund might be invested in equities in the year 2000, and this proportion would be linearly increased to 10% over a period of 15 years, to be fixed at 10% 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 2.8% 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 11.2% in 1998 and is projected to rise to about 20% by 2075 according to the SSA intermediate forecasts. 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 1998, and is projected to increase to about 13.4% by 2075.

The long run difference between the cost rate and income rate is the source of the enormous fiscal imbalance discussed above. To estimate the total long term imbalance for a particular horizon, it is useful to look at summarized cost rates and income rates. The summarized cost rate for horizon *T* is the present value of all total expenditures through *T*, divided by the present value of total taxable payroll through *T*. The SSA projects a summarized cost rate of 15.64% for the horizon 1998-2072 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 13.45% for 1998-2072.

The summarized actuarial balance for horizon *T* is the difference between the adjusted summarized income rate and the summarized cost rate, equal to 13.45% - 15.64% = -2.19% for horizon $T = 2072$. That the balance is negative implies a long term imbalance. This percentage is equal to the additive tax increase that would be required to maintain a positive balance through 2072, raising the rate from 12.4% to 14.59% starting in 1998. Multiplying the summarized actuarial balance times the present value of total taxable payroll through 2072 yields the $4 trillion figure mentioned above.

The MVR-UCB Model

We employ a demographic-economic model of the OASDI system. Tuljapurkar and Lee (1995), 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.

Our model is an analytically specified, dynamic, stochastic recursion –technical information on the model is summarized in the Appendix to this paper. The starting point for the model is a detailed stochastic model of demographic change based on the work in Lee and Tuljapurkar (1994).

With the exception of mortality, our demographic and economic forecasts are scaled to match the SSA's intermediate assumptions *on average* in the long run.[8] Thus, in the long run, the total fertility rate is constrained to 1.9 on average, growth in real wages is constrained to 0.9%, and the real effective interest rate is constrained to 2.8%. Mortality is estimated using the Lee-Carter model (see below). Compared to the SSA forecasts, this model predicts somewhat higher life expectancies on average. 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.

Given the complexity of the assumptions and structure, it is useful to calibrate the model. We do this by examining a special case of the model in which we employ assumptions that are close to the SSA's intermediate forecast. 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. 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).

Our model is similar in spirit to those of Leimer and Petri (1981) and Auerbach et al. (1994). The structure of the model makes possible analysis of the key demographic, economic, and policy components. 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.

Model Outputs

The MVR-UCB model is stochastic, meaning that for a given launch point, say the state of affairs in 1997, the model generates many alternative future trajectories. These trajectories are governed by historically determined probabilities – for example, trajectories over which fertility is high relative to its long-run average will be less likely than trajectories in which fertility displays historically typical variation. For any given set of conditions, 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. Now select any outcome of interest, say the size of future population in the year 2022. The trajectories of the model will yield a set of possible values of population in 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.

Figure 4 illustrates a demographic output, the distribution of total US population over time. Notice that the MVR-UCB model yields probabilities for any interval of population values. Thus in 2067, there is a two-thirds probability that the population will lie between 321.8 and 485.1 million. There is a probability of one-sixth that population will end up in the band of low values between 255.3 and 321.8 million; the much wider band of possible high outcomes between 485.1 and 603.9 million has only the same probability of one-sixth.

Next consider an output of greater interest here. We consider the OASDI trust fund balance over starting with the known balance at the end of 1997, forecasting over a 100-year horizon. The "baseline" assumptions we use are those of the current legislation: the 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, the MVR-UCB 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 67% of the trajectories at any given year fell between this range).

Now we observe the first date at which each fund reaches exhaustion. A histogram of these dates, displayed in Figure 7, indicates the probability distribution, the relative odds, that exhaustion will occur in any range of years. The median year of insolvency is 2032, in accordance with SSA's intermediate estimate; our interpretation is that there is a 50% chance the fund will last beyond 2032. There is a 3.8% chance that the fund will reach exhaustion by 2022, and a 90.7% chance that it will reach exhaustion by 2047. There is a 1% chance that the future will be so nicely adjusted that the fund will not reach zero by 2097. The extremely small odds of this outcome make it an unattractive gamble.

Figure 8 is a histogram of summarized actuarial balances for a 75-year horizon, 1998-2072. The median balance is -2.4%, slightly more pessimistic than the SSA intermediate forecast (-2.19%). This is due to the somewhat higher life expectancies predicted by the Lee-Carter model of mortality. Our estimated 95% confidence interval is -6.26% to -0.01%, fairly close to the SSA high-cost/low-cost range of -5.42% to -0.76%.

Evaluation of policy alternatives

First, we separately treat each of the three policy tools described above: tax increases, increases in the NRA, and equities investment. Then we consider the three possible pairs of combinations: tax increases and NRA increases, NRA increases and investment, and tax increases and investment. Finally, we present a plan for solvency which is a combination of all three alternatives. In an additional section, we treat President Clinton's plan, which is essentially a combination of federal debt creation and equities investment.

Three separate policy changes

We started with a set of 1% additive tax increases, immediately raising the rate from 12.4% to 13.4%, 14.4% and 14.8%; this last rate is not a 1% increase, but rather an increase of 2.4%, roughly equal in magnitude to the size of the median 75-year summarized actuarial balance. 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 2044 (compared with 2032 for no tax increase), and the chance of insolvency by 2047 falls to 59.4% (compared with 90.7%). At 14.4%, the life of the fund is extended another twenty years; the median date of insolvency is 2064, and the chance of insolvency by 2047 is only 23.4%. When the tax rate is increased to the full 14.8%, the median fund lasts for just about 75 additional years (so the chance of insolvency by 2072 is about half), and the chance of insolvency by 2047 is only 15%.

Next, we returned the tax rate to the legislated 12.4%, and implemented four sets of accelerated NRA shifts in two stages. 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 2012;
2) to 66 by 2005, to 67 by 2012, to 68 by 2019, to 69 by 2026, and again to 70 by 2033.

We then consider a second, more drastic set of NRA changes. Under these schedules, the NRA is shifted up by four months of age per year, requiring only three years for each full year of shift. We consider two sets of shifts, raising the NRA to 70 and 71. Here the NRA is scheduled to rise:

3) to 66 by 2002, to 67 by 2006, to 68 by 2010, to 69 by 2014, and again to 70 by 2018;
4) to 66 by 2002, to 67 by 2006, to 68 by 2010, to 69 by 2014, to 70 by 2018, and again to 71 by 2022.

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 NRA shift is quite minimal. The median year of solvency is increased by only one year, and the median actuarial balance is only shifted from -2.4% to -2.28%. Increasing the NRA to age 70 by 2034 has only a slightly more pronounced effect on the median date of insolvency, as it is three years to 2036. The effect on the median actuarial balance, a shift from -2.4% to -1.37%, is more dramatic.

Increasing the NRA in three year shifts has a more substantial impact on the insolvency date. Raising the NRA to age 70 by 2018 would extend the median year of exhaustion to 2044, and the probability of insolvency by 2047 would be decreased from 90.7% to 55.2%. The median actuarial imbalance would also be substantially reduced to -0.97%. Long-term solvency can be achieved by the final shift, raising the NRA to 71. Here the shift is drastic enough to sustain the initial positive momentum in the fund balance, and the median fund balance is shifted out beyond 100 years. Of course the median actuarial balance is also positive in this scenario, at 0.24%, and there is only a 27% chance of insolvency by 2047.

It should be noted that an NRA shift to age 71 by 2022 is indeed drastic. Remaining life expectancy for persons surviving to age 65 in 2022 is about 20 years in our forecasts, so the additional increase from 67 to 71 would cost them roughly 20% of their retirement on average.

Next, we fixed the NRA schedule 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 2000. We then linearly increase this percentage to some fraction (e.g. 10%) over a period of 15 years, after which the proportion of the fund is the market is permanently set to this fraction.[9] We used values of 10%, 20% 30% and 40% for this long-run investment fraction.

Figure 13 shows the histograms of dates of exhaustion for the four scenarios, with the baseline result at the top. A 10% level of equities investment has a very minor impact on the fund, allowing for only one additional year in the median year of exhaustion. Increasing it to 20% adds one more year, and increasing it yet again to 30% fails to gain a whole additional year. The highest level of investment shown, at 40%, only extends the median year of exhaustion to 2035.

Interestingly, however, the average fund balance was positive until 2041 in this scenario. The median balance beyond 2036 was negative, but the asymmetric distribution of fund balances during these years resulted in positive average fund balances. This distributional asymmetry is indicative 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 long right tail. The outcome is that the average balance can be positive even when the median balance is negative and the median year of insolvency has 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 in the year 2000, creates an even more drastically skewed distribution of fund balances. Here the median year of insolvency is only extended to 2045, 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 risk 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. Indeed, even if 90% of the fund were immediately invested in equities in the year 2000, the probability of fund exhaustion would not increase, regardless of the horizon. In fact the probability that the fund would be exhausted by 2022 would decrease slightly to 1.9%, compared with 3.8% for no equities investment.

Remember that bonds can also lose money in real terms; the question is whether the potential gain (7% over 2.8% on average) offsets the increased variability. According to our estimates, it usually does. In the 40% investment scenario, there is only a 10% chance that the fund balance will be lower in 2022 than if no equities investment had taken place. There is only a 3.1% chance that insolvency will come at an earlier date because of investment. The chance of losing money is more substantial in the short run; over a five-year horizon, there is a 30% chance that investing will result in a lower balance than a pure bond mix would give. Fortunately, the potential amounts lost are quite small in the initial stages of the phase-in.

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 until 2047, as a function of NRA change and investment level. 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 the three remaining shifts each add one additional year of NRA increase in an additional six-year period of time. The proportion of fund invested is that fraction of the fund invested in the S&P500 after a 15-year phase-in, starting in 2000. This is set at 10% increments from 0% to 40%, as in the section above. The probability of solvency until 2047 is less than 10% when no changes are made, and the probability increases to nearly 45% when 40% of the fund is invested and the NRA is shifted to age 70 by 2033.

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 insolvency by 2047, obtained by interpolating Figure 14.

Figure 16 shows the probability of solvency until 2047 by 30 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 2.5% (for a tax rate of 14.9%). Clearly, solvency is achieved more easily through tax increases. Tax increases alone can raise the likelihood of solvency to nearly 90% for the next fifty years, but even these fairly aggressive NRA shifts fail to raise the probability of solvency above 25% if taxes are not changed. A moderate combination of both shifts, such as an NRA of 68 by 2013 and a 1% tax increase, results in a fairly substantial improvement. This raises the chance of solvency to 58% and extends the median year of insolvency out to 2050.

Figure 17 shows the chance of solvency until 2047 by various combinations of tax increases and investment levels. Again, tax increases pack a much more potent punch then investment at any level. A level of 20% investment combined with a 1% tax increase raises the chance of solvency to 48%.

Note that when taxes are increased 1%, an investment of 20% yields a much more substantial gain than when no taxes are raised. This is because the increase in income through taxes is compounded when these additional taxes are also invested.

Such compounding also occurs when savings achieved through accelerated NRA shifts are invested. Indeed, when all three policy options are employed, a substantial boost is gained from this synergistic effect between investment and increasing external cash flows. By incorporating a 1% tax increase with 40% equities investment and an NRA shift schedule resulting in a final NRA of 68 by 2020, it is becomes possible to extend the median year of exhaustion to 2072. There is a 75% chance of maintaining solvency until 2047 under this plan, and there is a 38% chance that the fund would remain solvent through the next century.

Note that equities investment provides a substantial boost under this plan. When the 1% tax increase and the NRA change to 68 are implemented with no investment, the median year of bankruptcy is only 2051. Thus 40% investment adds an additional 21 years to the life of the fund in this scenario.

President Clinton's plan for extending social security

We model Clinton's plan by injecting a total of $2.7 trillion into the fund over a period of fifteen years starting in 2000. Also, we initialize a phase-in of equities investment, starting at 1% of the total fund in the S&P500 in 2000, and increasing this proportion to 15% until 2015, after which it is held constant at 15%.

This provides a substantial boost to the fund balance. Figure 18 shows a histogram of dates of exhaustion under this plan. We estimate that the median year of insolvency would be extended to 2059. There is only a 31% chance of insolvency by 2047, and there is a 36% chance that the fund would remain solvent until 2072.

When the $2.7 trillion debt injection is implemented alone, absent any investment, the median year of insolvency is 2052. Equities investment under Clinton's plan adds about seven years to the life of the fund.

Our numbers may be slightly optimistic here because no upward adjustment is made in future benefits. (Benefits increases would result from the relatively high assumed economic growth required to obtain surpluses because benefits depend on past earnings.)

Conclusions

We consider three tools for achieving solvency, both separately and in combinations: taxes, NRA chances, 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 14.8% would be required to extend the fund beyond 2070. The NRA would have to be raised to 71 by 2022 to achieve a high chance of long term solvency. Equities investment alone, no matter how aggressive, cannot postpone insolvency more than a few years, at least in the median.

However, combinations of adjustments can have more dramatic effects. A combined 1% tax increase and NRA shift up to age 68 by 2020 would extend the median year of insolvency to 2051. By incorporating a 40% level of investment in equities, the boost supplied by these changes would be magnified, extending the median year of insolvency out to 2072.

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 small losses would occur in the short run. When the proportion of the fund in equities is increased from 1% to 40% over 15 years starting in 2000, there is a 30% chance that the balance after five years would be lower than would result from pure bond investment. For a 15 year horizon, this probability falls to 16%. There is only a 3.1% chance that insolvency would occur at an earlier date as a result of the 40% equities 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. Also, the extra variability associated with equities investment seems to be well-balanced by the higher returns; the probability of insolvency never increases when investment is undertaken, regardless of the horizon or investment level.

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Appendix: Summary of the MVR-UCB model

The US 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

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

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 1.9 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 1940-1997. 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 2.8%), and let c be the long run average stock return (set at 7%). The constrained form of the model takes the form:

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

$$+ g(1- \alpha_1 - \alpha_2 - \alpha_3) - c(1 - \beta_1 - \beta_2 - \beta_3)$$

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

We estimate the parameter values as:

$\alpha_1 = 1.147;\ \alpha_2 = -.751;\ \alpha_3 = .465$
$\beta_1 = .0014;\ \beta_2 = -.0232;\ \beta_3 = -.0032$
$\phi_1 = 1.427;\ \phi_2 = -.201;\ \phi_3 = .083$
$\theta_1 = -.0989;\ \theta_2 = -.227;\ \theta_3 = -.0234$

The real wage growth rate is modeled as an AR(1) constrained to 0.9% 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:

$$w(t) = h + \rho\,(w(t\text{-}1) - g) + \epsilon(t)$$

where ρ is estimated as 0.514 and the SD of $\epsilon(t)$ is 1.412.

The program is launched from initial conditions in 1997 (we have used various launch years close to this date), 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

1. As it consists entirely of federally guaranteed bonds, the $656 billion held by the trust fund is nothing more than a government-backed "IOU", and as such this amount is reflected in the total federal debt. Strictly from the standpoint of the SSA, these bonds are as good as gold since everyone expects that the obligation will be met. Unfortunately, on the federal government's overall balance sheet there is no real money to pay off the bonds. Thus, should additional debt be acquired to meet the real requirements of retirees in 2020 through new bond sales, it is possible that the comparatively high interest rates required to sell those new bonds would impose a sizeable additional penalty on future taxpayers. This is all in addition to the $4 trillion in unfunded liabilities owed to retirees beyond 2032, which will likely incur even higher taxes or federal debt growth!

2. Since the fund holds a mixture of bonds with various maturities and returns, this is calculated directly as the effective interest rate earned by the fund year-to-year, *not* the interest rate offered on newly issued bonds during that year. We also subtract the percentage increase in the Consumer Price Index from nominal returns to yield a real rate of return.

3. One simply starts with the known present balance, subtracting out all expenditures and adding in total income to get the next year's balance. We calculate our forecasts in constant 1997 dollars, which avoids the need for modeling inflation. If one wishes to forecast the fund in nominal amounts however, some information concerning rates of inflation must also be provided.

4. This paper ignores the accounting issues (and the potential consequences) by taking the SSA's perspective, as do their actuaries. That is, we treat the trust fund balance as real, but by the same token we do not consider the possibility of creating additional federal debt as a means of fixing the system. (The exception is the section analyzing President Clinton's plan for extending the life of the fund, which explicitly creates additional federal debt). Nor do we address the issue of how the federal government will meet the bond obligations presently held by the SSA, which will be required for benefits starting in 2020. However, this is obviously an additional concern for taxpayers.

5. This is a slightly unrealistic adjustment since our simulation begins in 1998, implying a retroactive tax increase; however we were interested in matching tax rate increases to actuarial balance estimates.

6. 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 payout does not occur until the younger cohort actually reaches the old NRA.

7. Since we measure bond returns in real terms, it is possible to sustain year-to-year losses, just as in equities markets. This occurred in the mid 1970's and early 1980's, for example.

8. Our forecasts are stochastic, meaning that we generate 1,000 trajectories for each input; 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.

9. 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.

Figure 1. Average tax and benefit level by age and sex, 1997

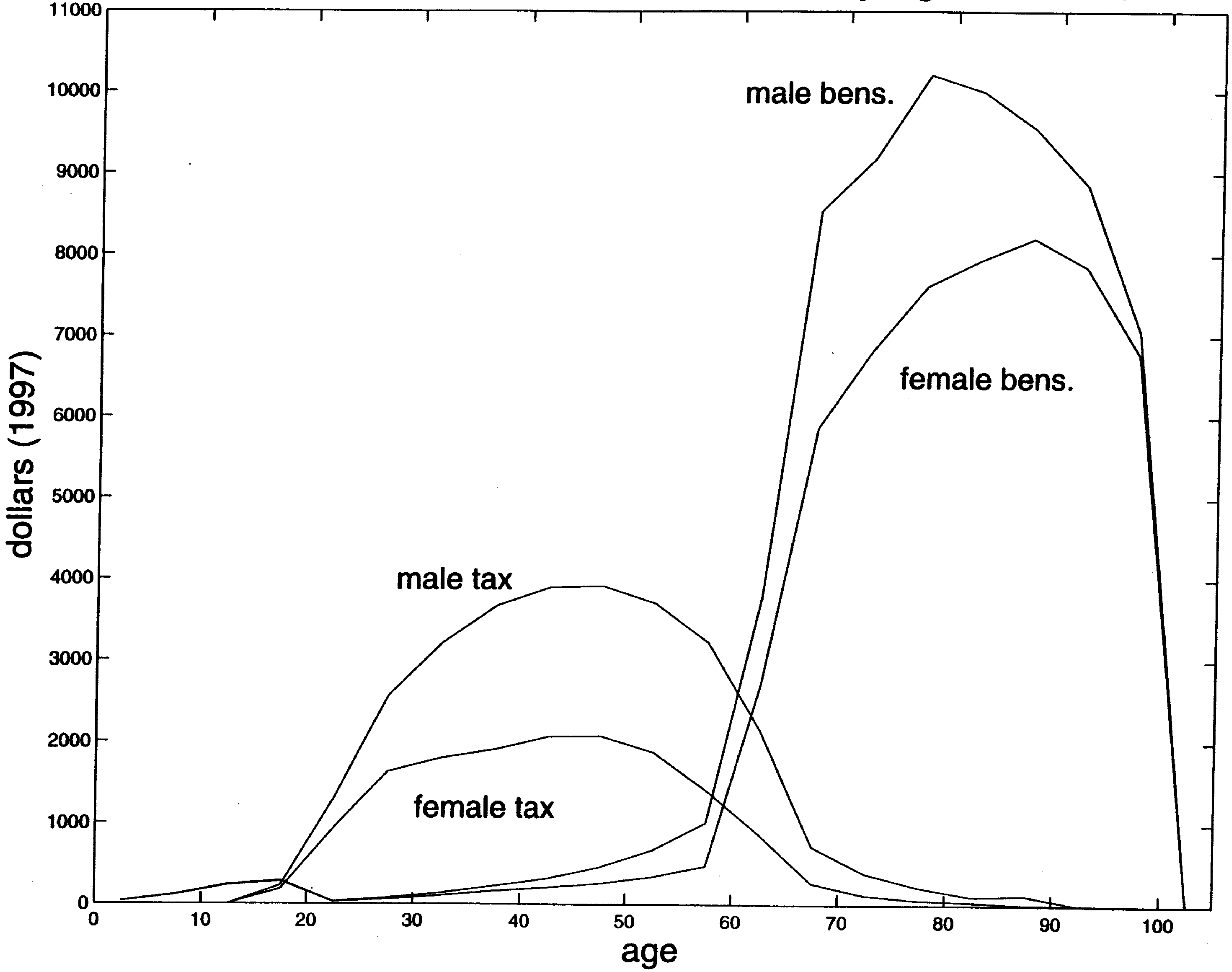


Figure 2. Old age dependency ratio (65+ pop)/(20–64 pop)

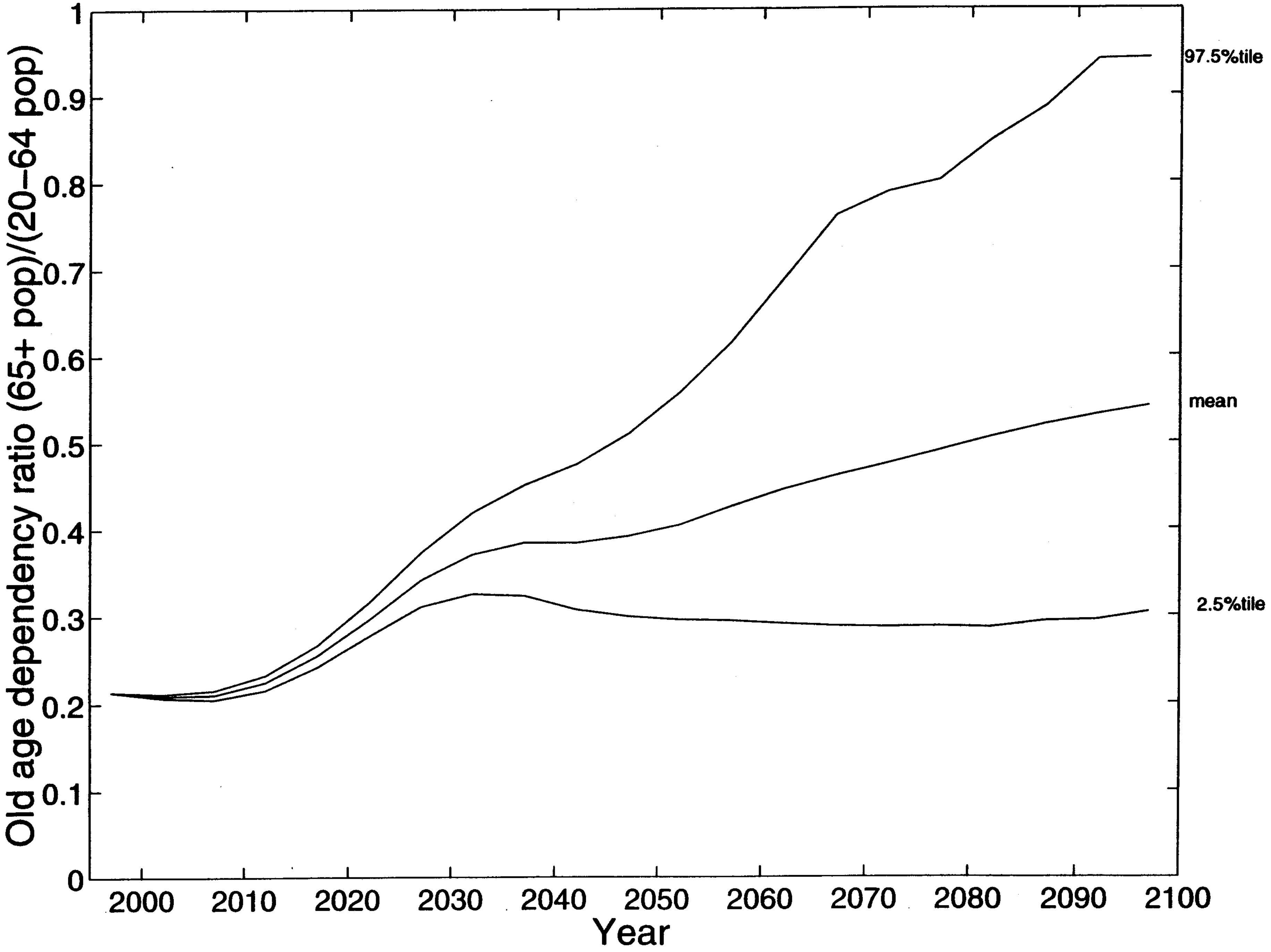


Figure 3. Trust Fund Structure

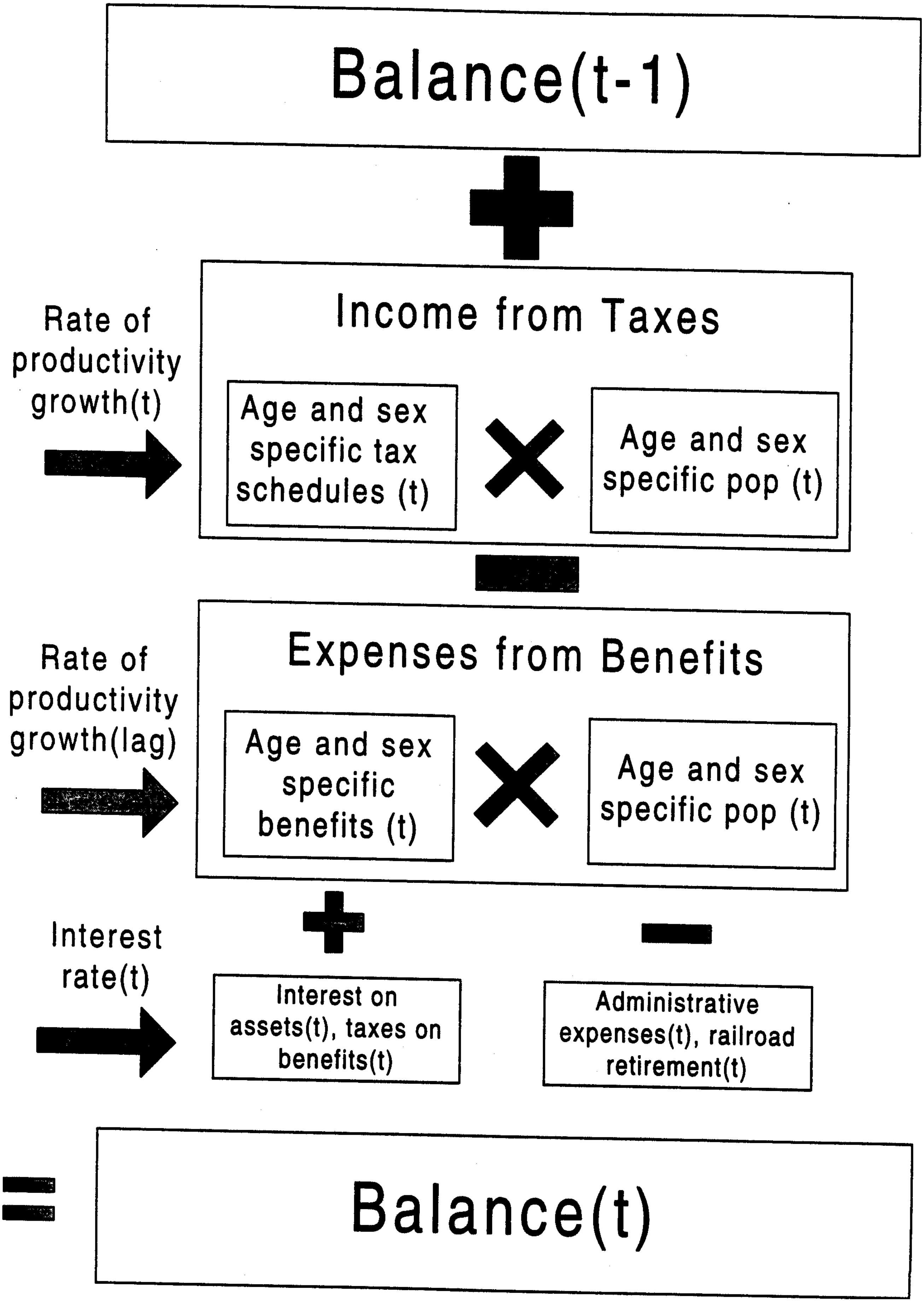
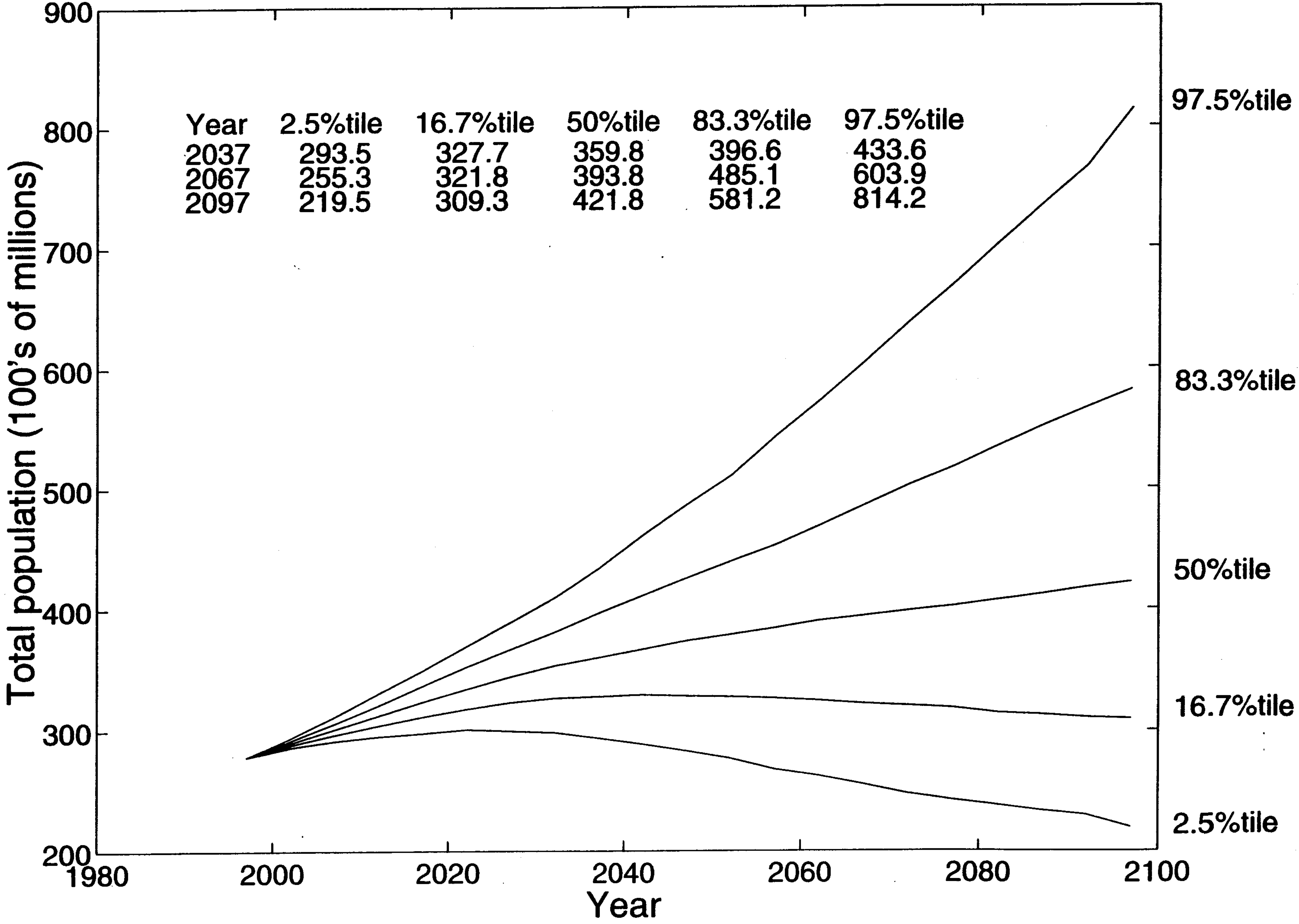


Figure 4. Total population forecasts (100's of millions), 1997–2097



Year	2.5%tile	16.7%tile	50%tile	83.3%tile	97.5%tile
2037	293.5	327.7	359.8	396.6	433.6
2067	255.3	321.8	393.8	485.1	603.9
2097	219.5	309.3	421.8	581.2	814.2

Figure 5. 10 random trajectories of fund balance, 1997–2045

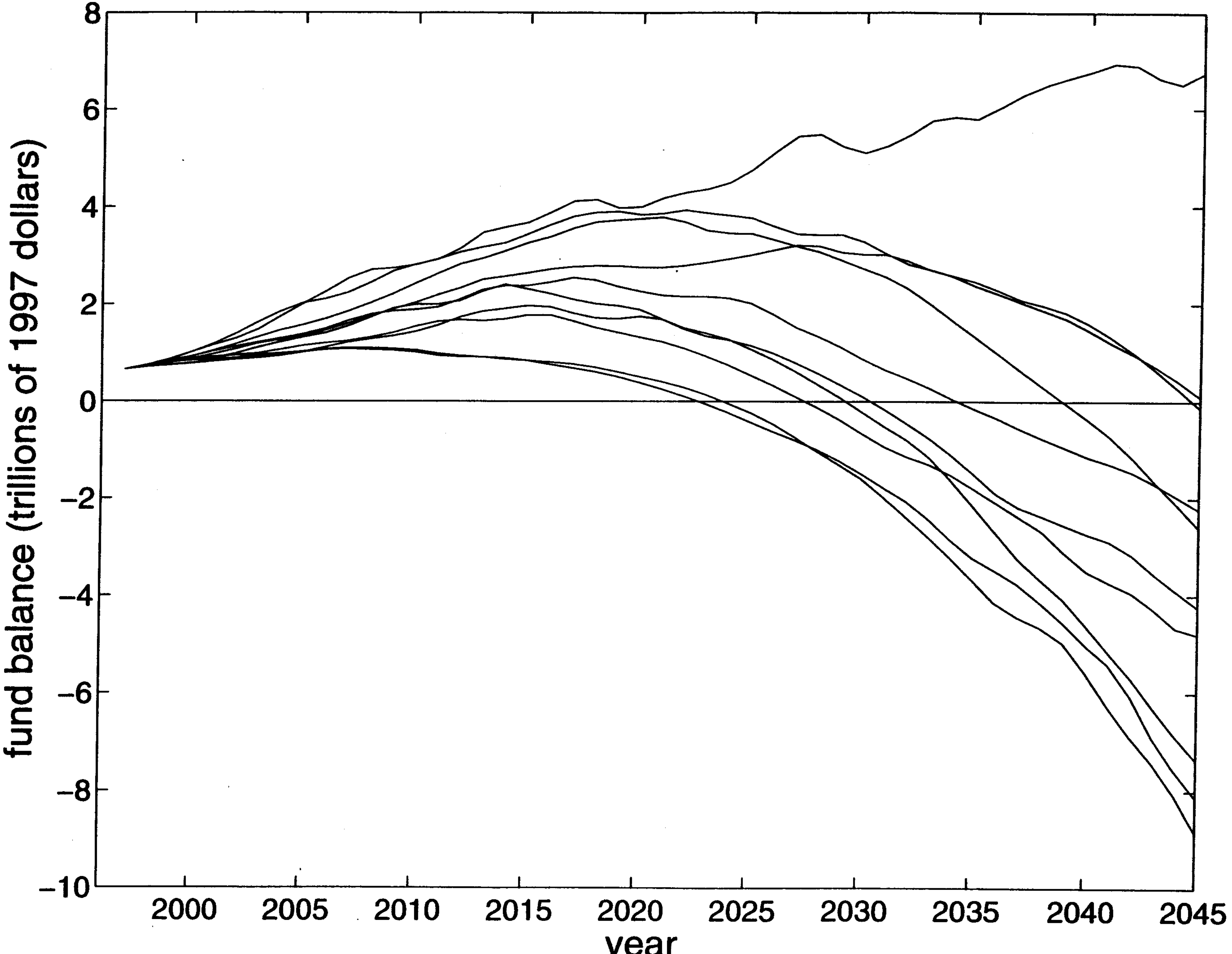


Figure 6. Trust fund balance, 1997–2041, with 67% C.I.

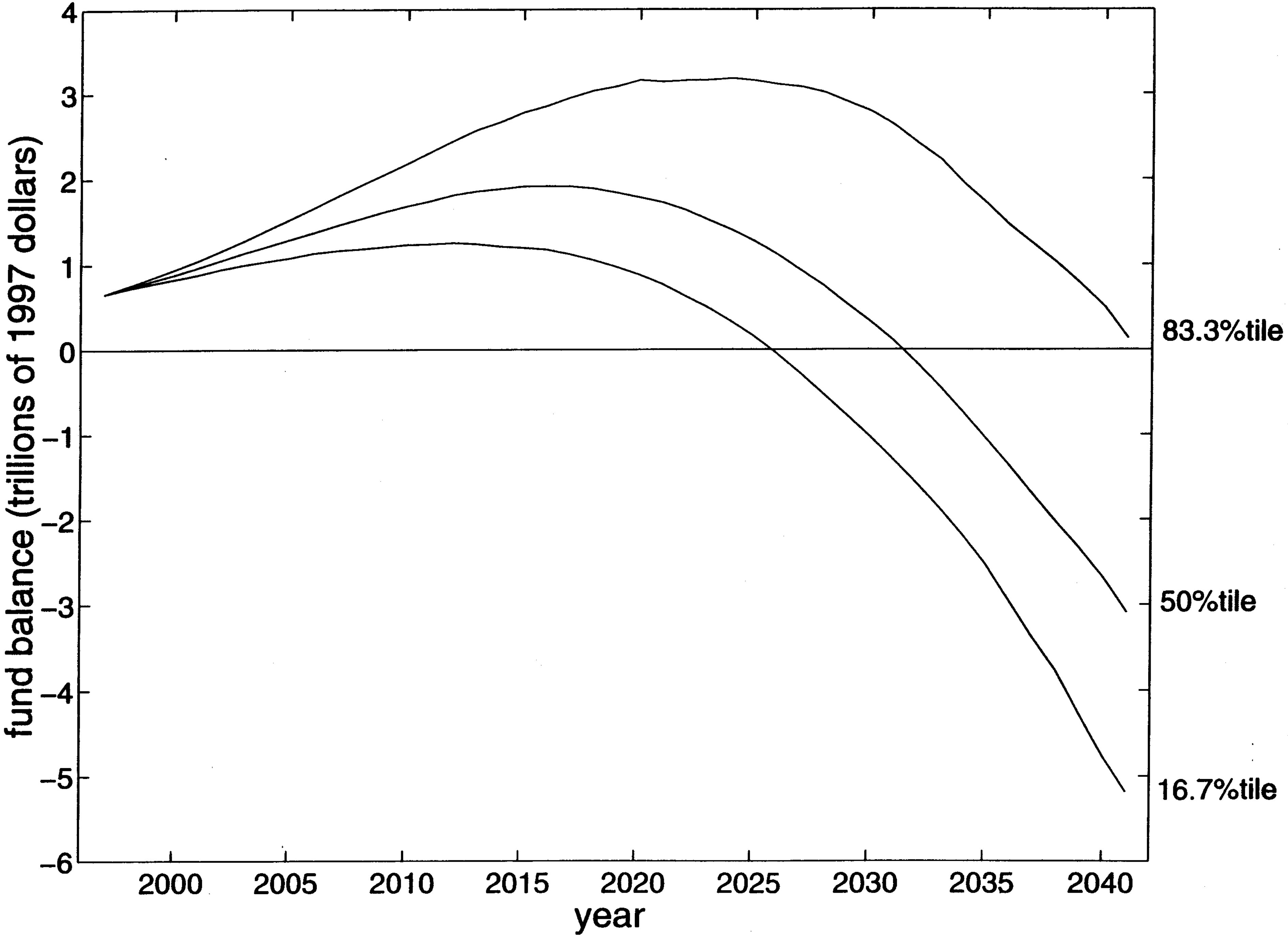


Figure 7. Probability distribution of date of insolvency

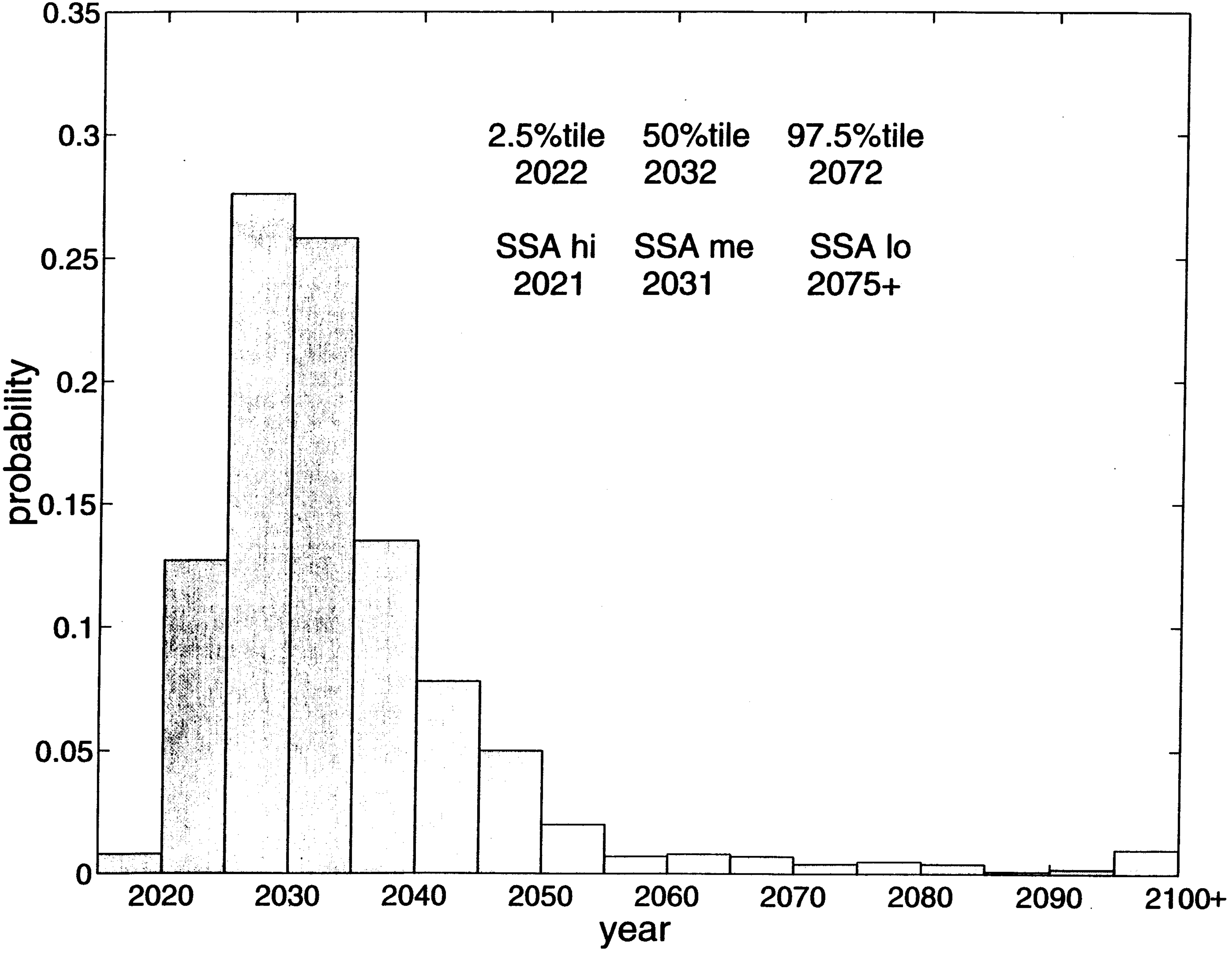


Figure 8. Distribution of 75–year summarized actuarial balance

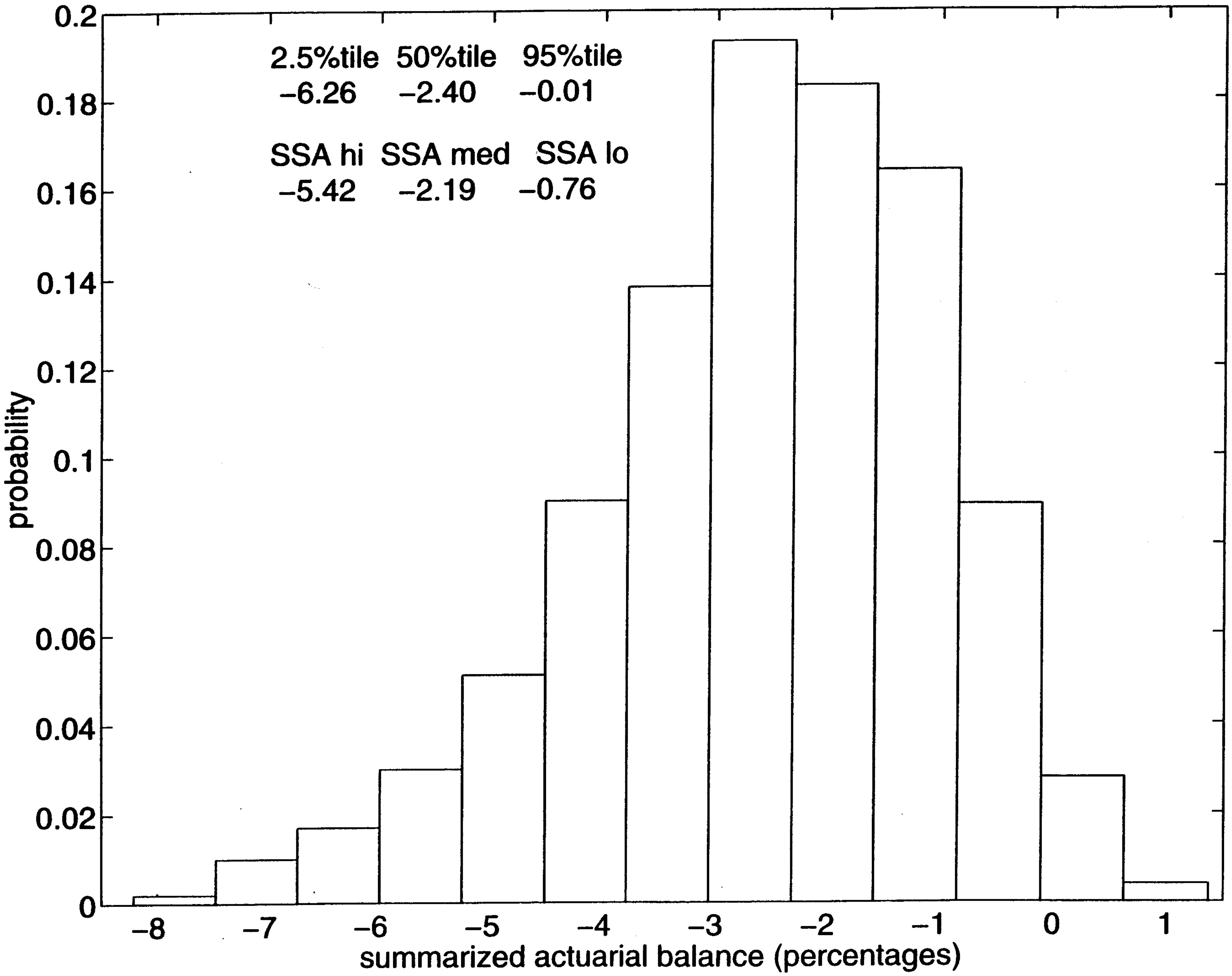


Figure 9. Distribution of dates of exhaustion, four levels of tax increase

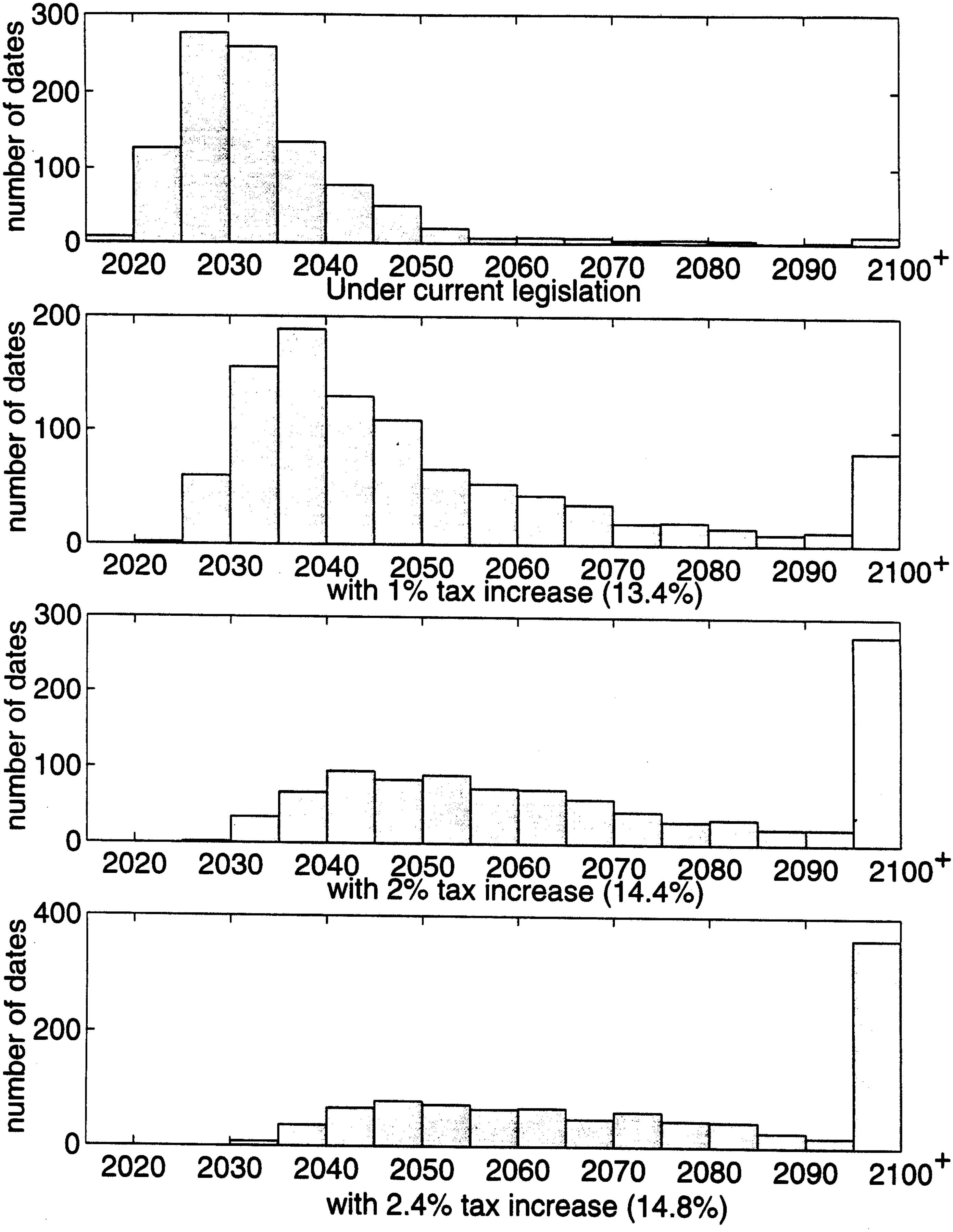


Figure 10. Distribution of actuarial balances, four levels of tax increase

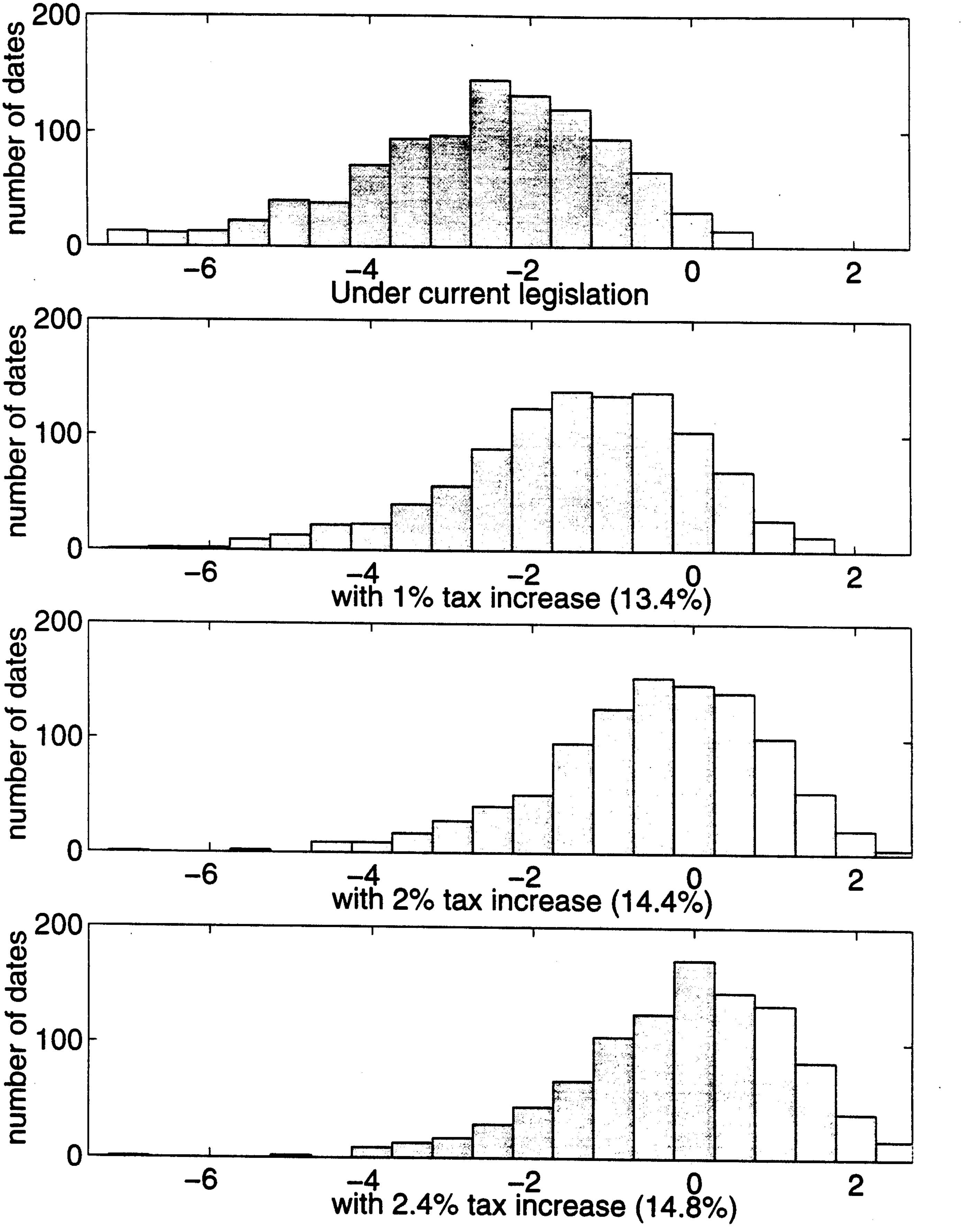


Figure 11. Distribution of dates of exhaustion, five schedules of NRA shift

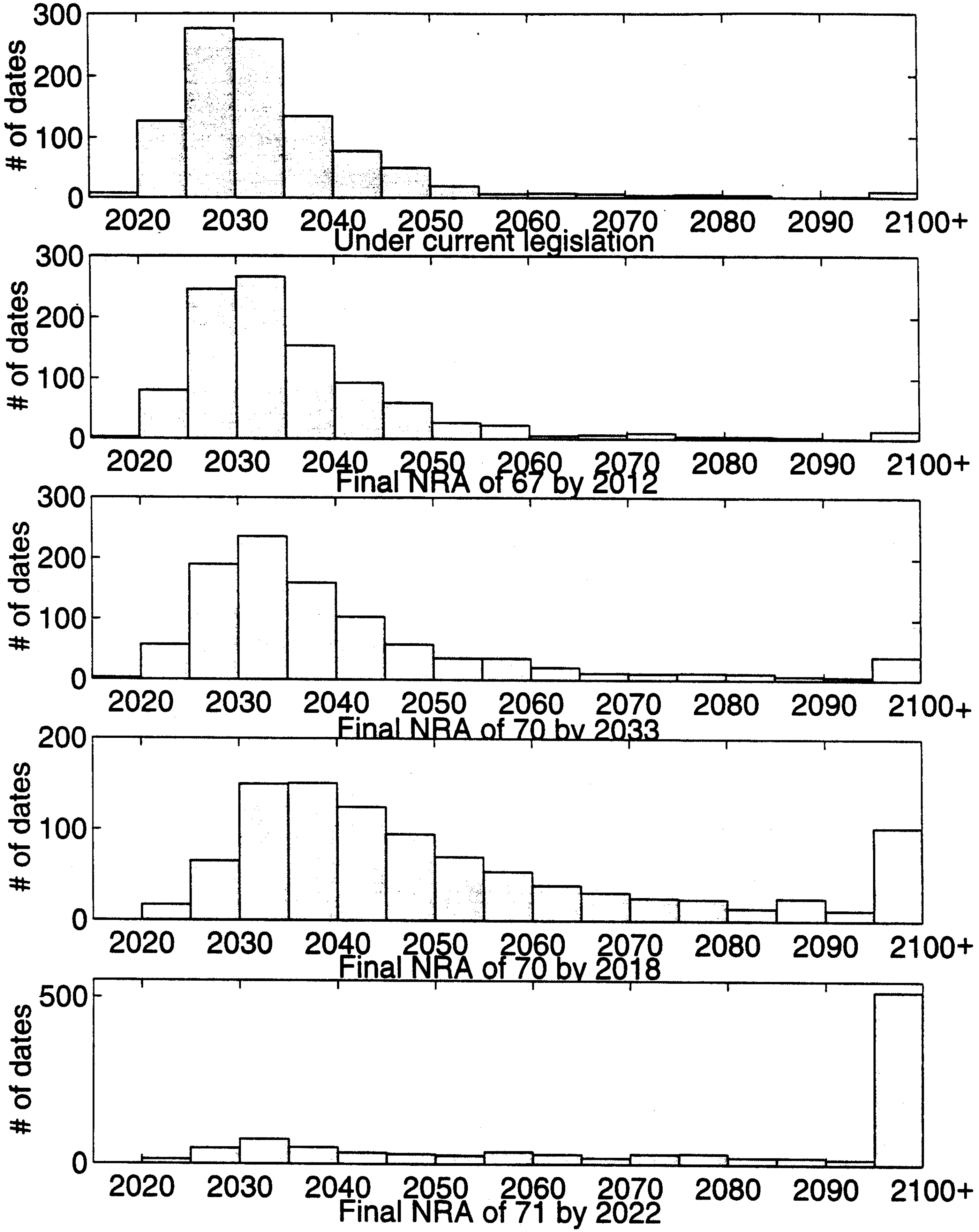


Figure 12. Distribution of actuarial balances, four schedules of NRA shift

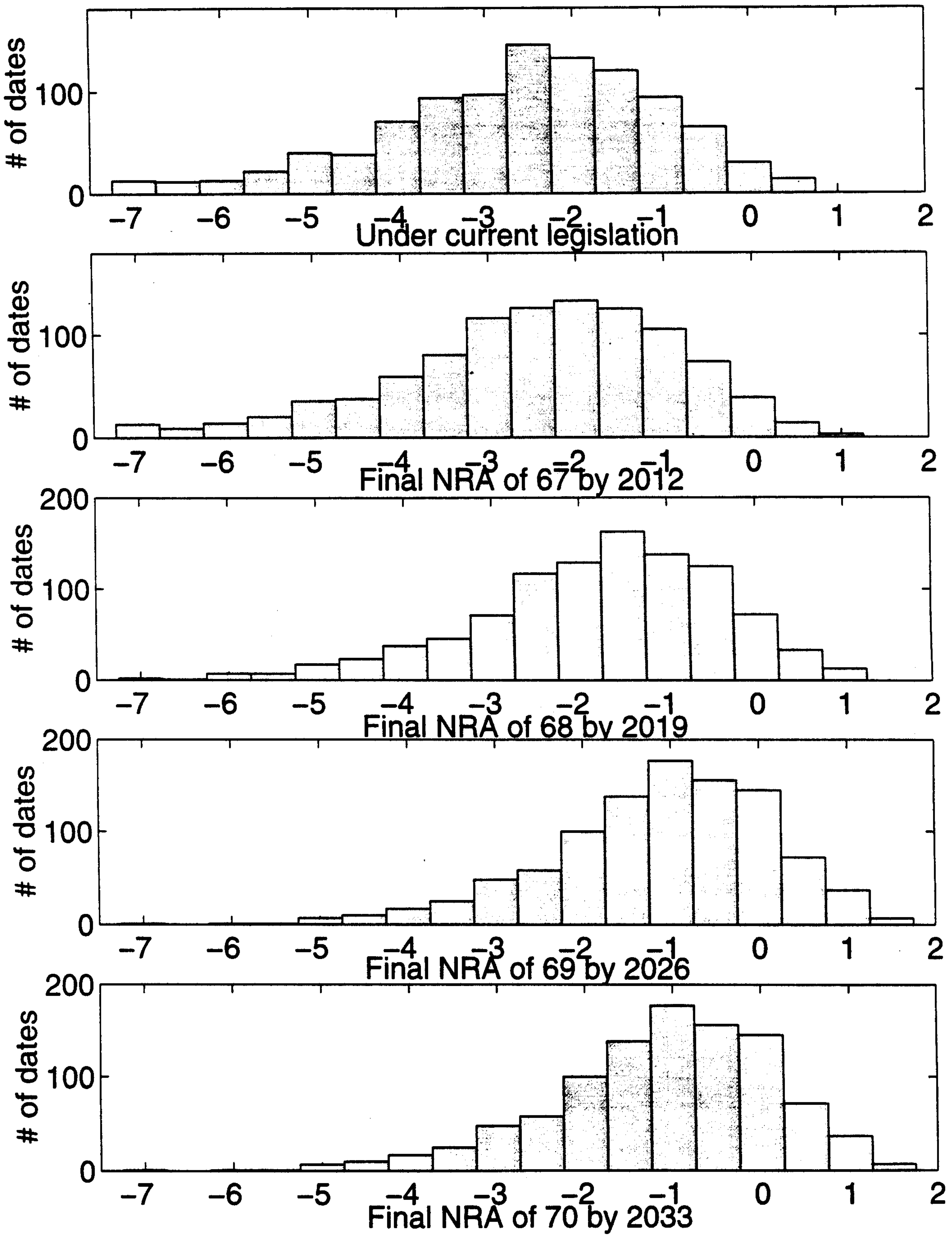


Figure 13. Distribution of dates of exhaustion, 5 levels of equities investment

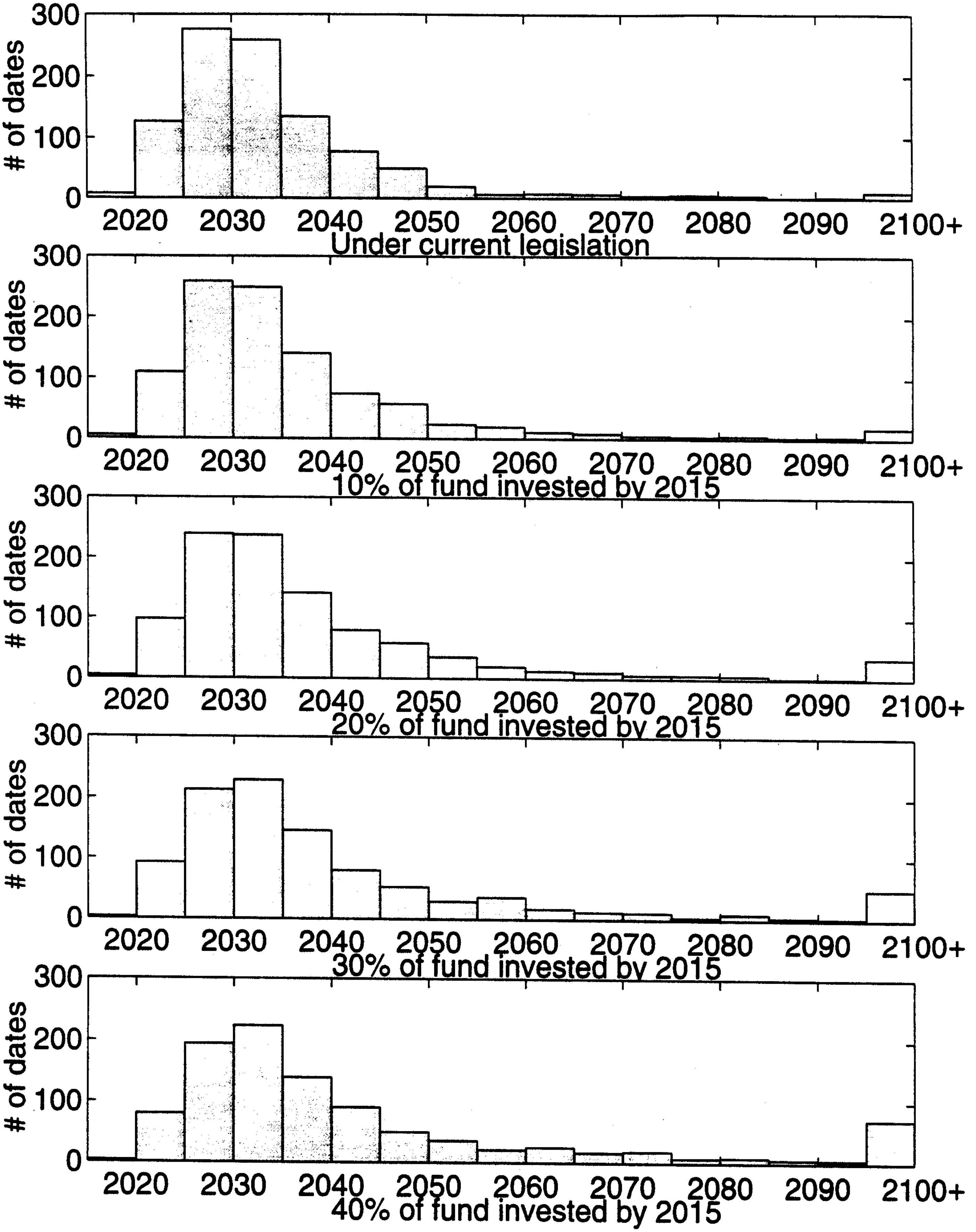


Figure 14. Chance of solvency until 2047, by NRA change and investment level

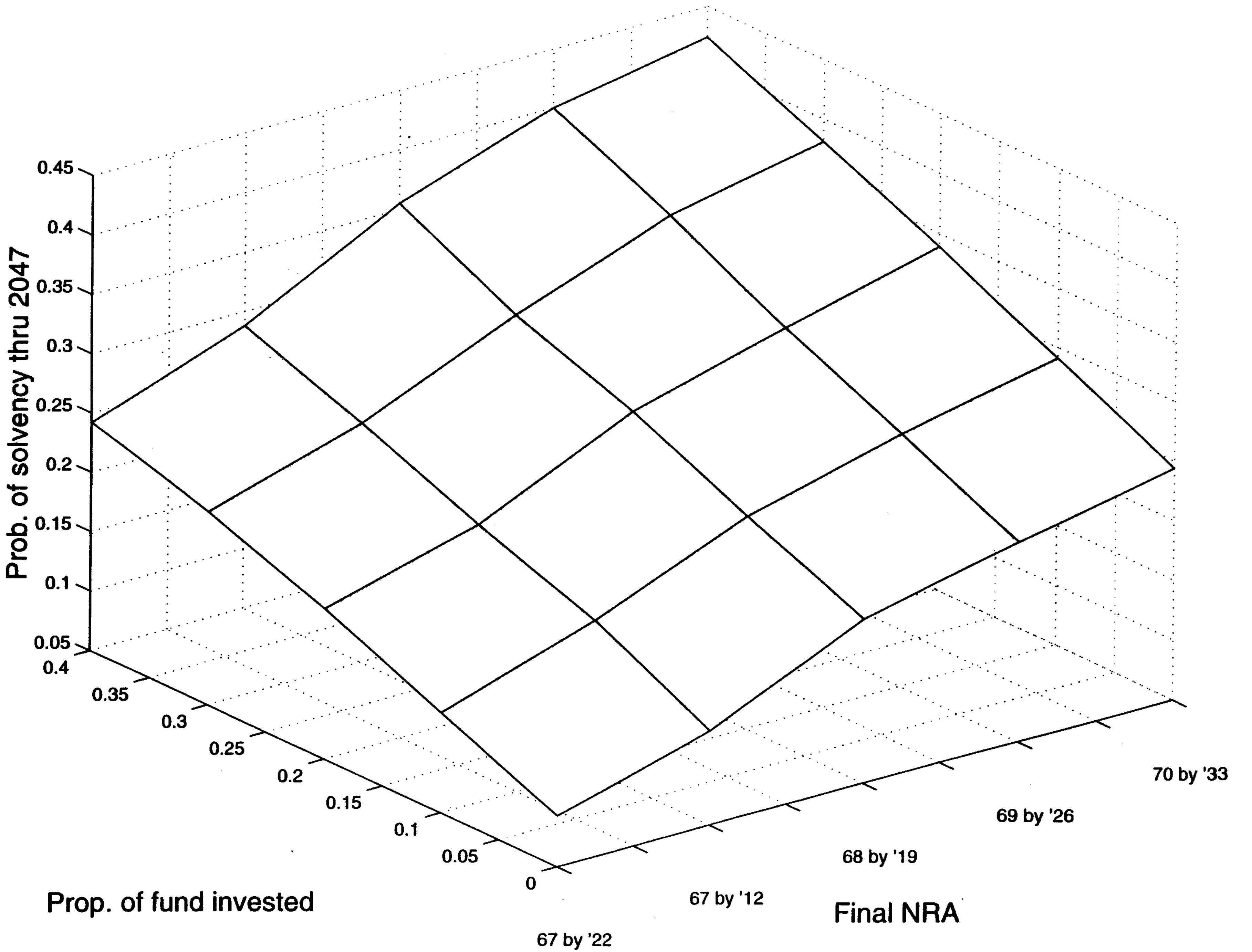


Figure 15. Lines of isorisk of insolvency by 2047, by investment level and NRA change

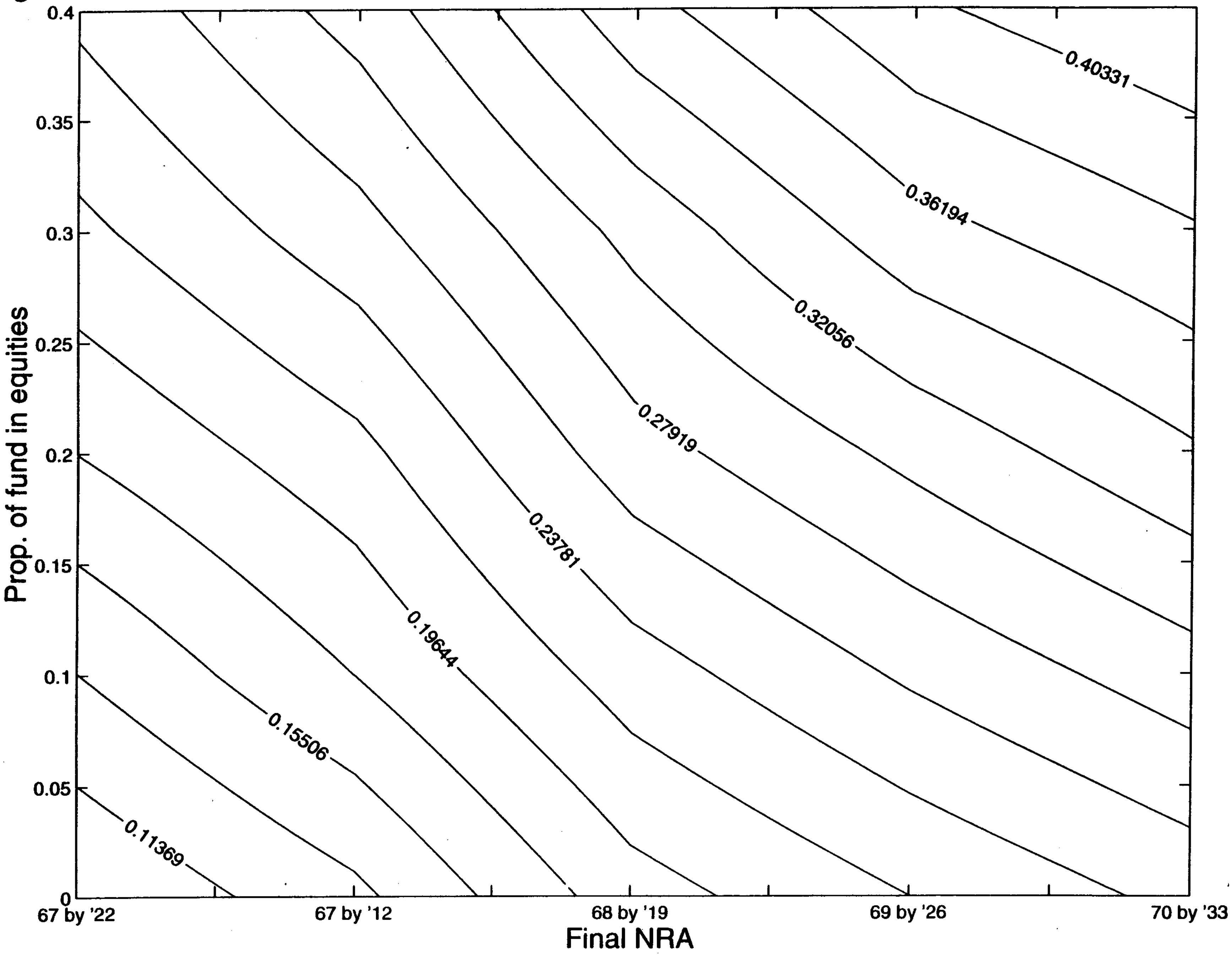


Figure 16. Chance of solvency until 2047, by tax increase and NRA change

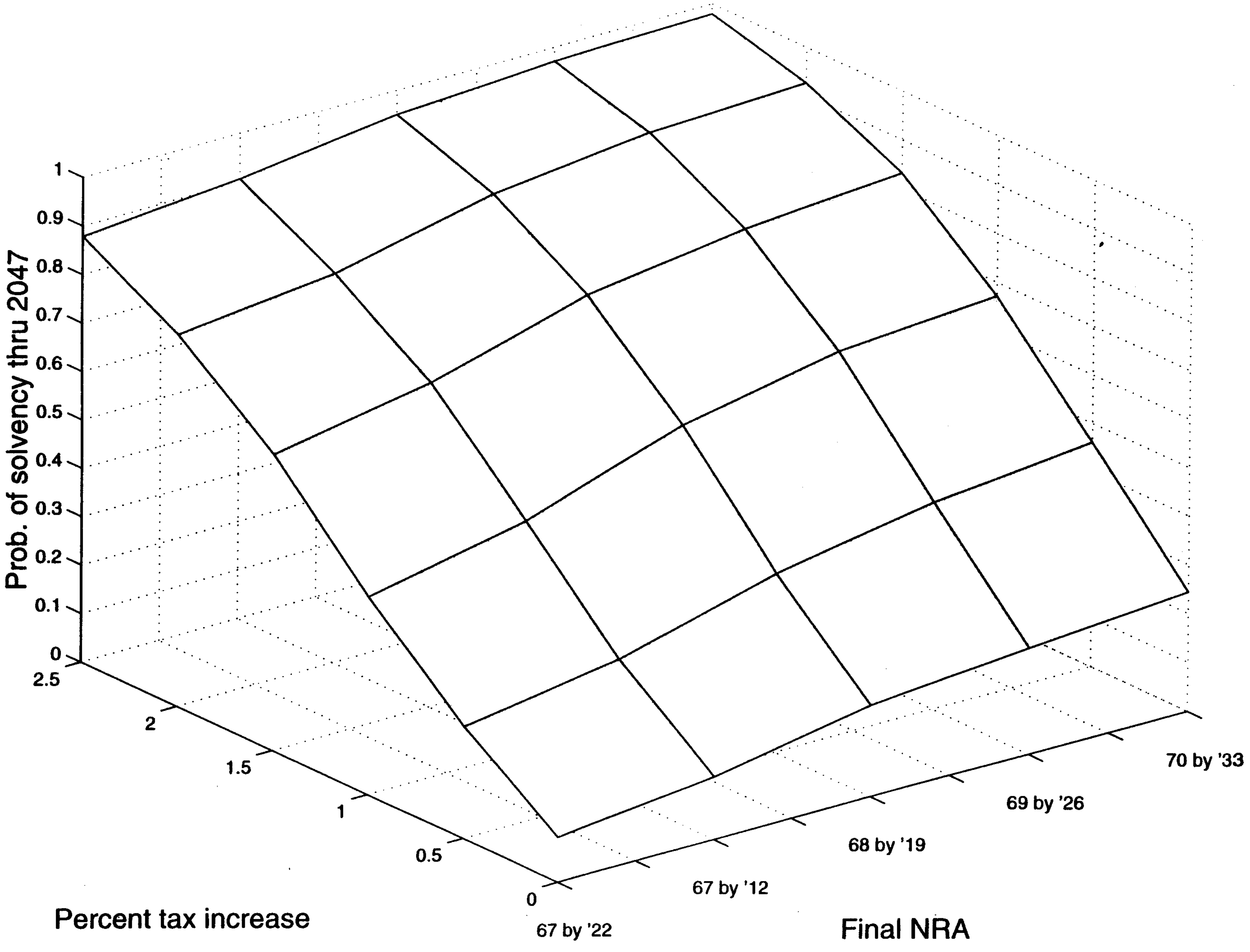


Figure 17. Chance of solvency until 2047, by tax increase and investment level

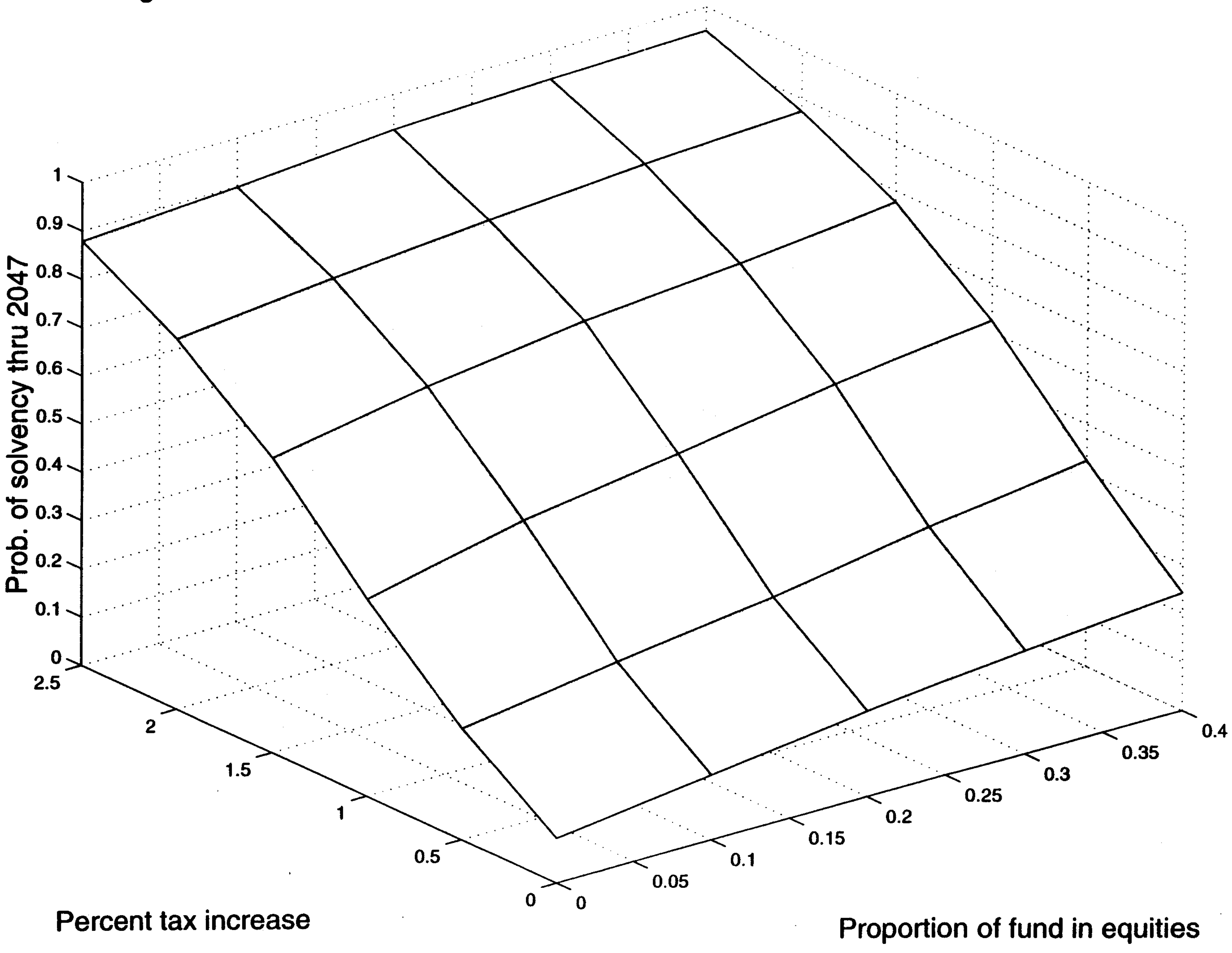
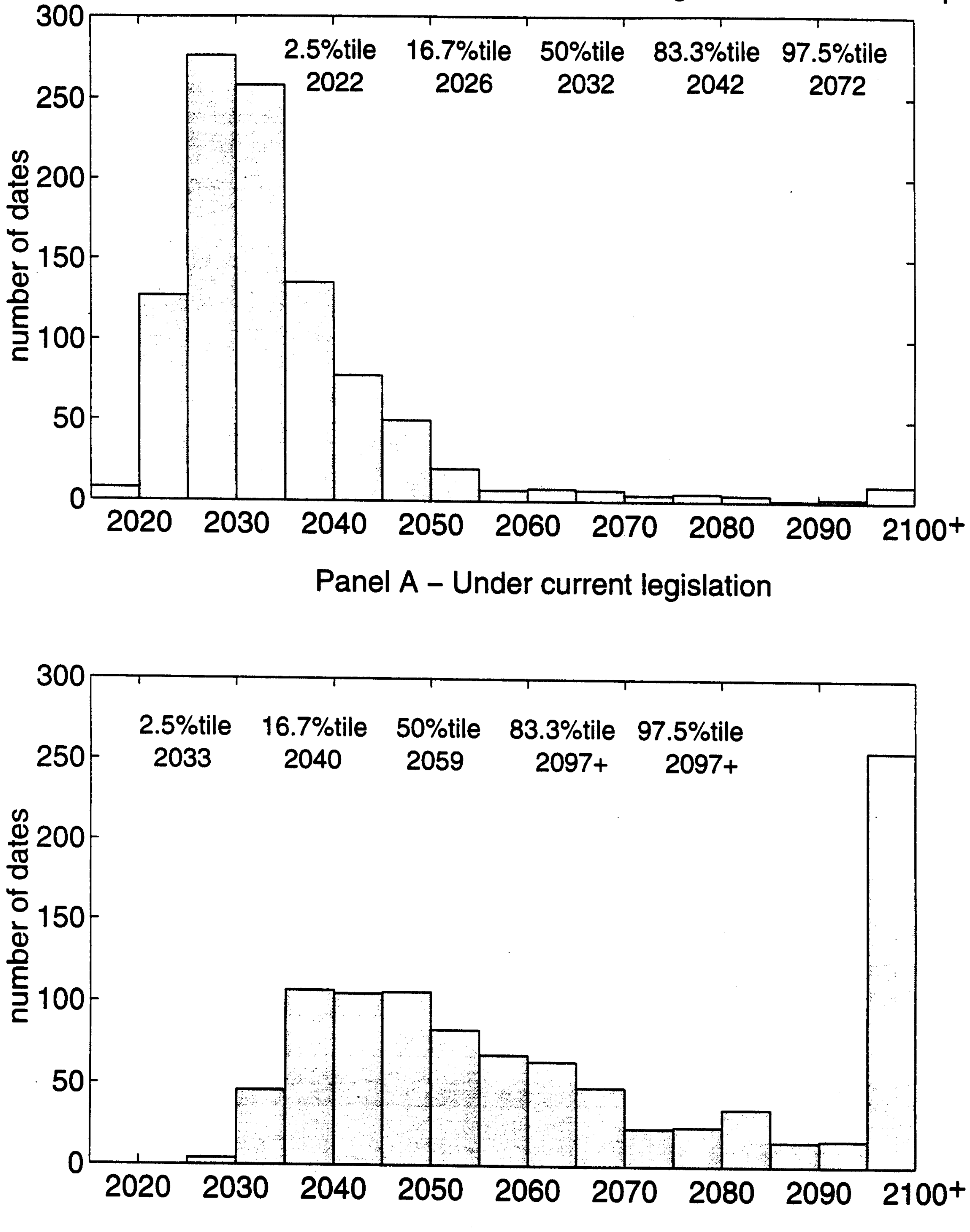


Figure 18. Distribution of dates of exhaustion, legislated vs. Clinton plan



Panel B – Under Clinton plan: +2.7 trillion, 15% investment over 15 years