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Source: *The Journal of Finance*, Vol. 37, No. 2, Papers and Proceedings of the Fortieth Annual Meeting of the American Finance Association, Washington, D.C., December 28-30, 1981 (May, 1982), pp. 595-604
Published by: Blackwell Publishing for the American Finance Association
Stable URL: http://www.jstor.org/stable/2327367
Accessed: 27/11/2009 08:17

THE JOURNAL OF FINANCE • VOL. XXXVII, NO. 2 • MAY 1982

SOFASIM: A Dynamic Insurance Model with Investment Structure, Policy Benefits and Taxes

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SOFASIM IS AN INTEGRATED model of a stock life insurance company, simulating most of the normal operations of an insurance company. SOFASIM, which stands for *Society of Actuaries Simulation Model* was a joint product of John Wooddy, Harry Markowitz, and the present authors. It was built under the auspices of the Society's Committee on Theory of Risk (COTOR), chaired by John Wooddy, to help solve the "GAAP" problem for stock life insurance companies. A stock company is one which is owned by its shareholders, while a mutual company is owned by its policyholders.

When accountants analyze the value of a company they usually examine the most recent three to five annual statements. They compare the growth of assets and liabilities and look at income and disbursements to get a feel for the company's earnings. The difficulty with using official (or "statutory") statements to study a life insurance company lies in the extremely conservative assumptions required by the various insurance departments for calculating statutory reserves—the principal insurance liability. Also, statutory reserves consider only mortality and interest. Prior to 1973, these were the only reserves used in publicly available asset and liability statements.

A more appropriate liability for purposes of analysis is the gross premium reserve. Actuaries calculate gross premium reserves using mortality rates, policy lapse rates, interest rates and expenses. In attempting to establish Generally Accepted Accounting Principles (GAAP) to estimate the value of life insurance companies owned by stockholders, the American Institute of Certified Public Accountants, in a preliminary draft of its 1972 *Audit Guide for Stock Life Insurance Companies*, proposed that gross premium reserves be used and that "most likely" values be assumed for mortality, lapse, interest, and expense rates. The actuaries argued, successfully, that a margin or "delta" should be added to or subtracted from these most likely rates to provide an allowance for adverse deviations [4]. The problem, then, was how to compute the deltas!

COTOR, recognizing the great significance of interest variation, decided to consult an economist. The economist chosen also happened to be a computer expert and one of the originators of the programming language SIMSCRIPT. Harry Markowitz pointed out the problem of attempting to analyze the relationship between market interest rates which are printed in the newspaper and rates of return which are actually earned on a company's investments. Consideration must be given to monies already invested in bonds at old rates, the maturity structure of the company's bond portfolio, reinvestment of periodic interest as

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well as cash from maturities, the differing effects of callable and non-callable bonds, and market interest rates which may shift for a relatively short period of time. All this is further complicated by the cash flow or needs generated by sales of insurance policies, collection of premiums, paying commissions, and payment of death, surrender and endowment benefits. Another area of the life insurance business which seemed important enough to warrant consideration was United States Federal income tax. The size and incidence of taxes as well as company planning relating to tax phases, carrybacks and carryforwards are vital to any analysis.

Thus, it seemed that the only practical way to take into account with any degree of accuracy the complex linkage between the market rate of interest, the company's earned rate of interest, the actuarial operations, and life insurance company taxes was by means of a dynamic simulation model.

In this paper we will first describe the model and then present several of its applications.

1. The Model

SOFASIM simulates the operations of a stock life insurance company. On the actuarial side these operations include selling new policies, paying death, surrender and endowment benefits, collecting premiums, paying commissions and other company expenses; and computing statutory reserves and cash surrender values. The financial side includes buying, selling and calling bonds as appropriate, receiving interest on bonds, collecting cash from maturing and called bonds and paying investment expenses. On the tax side, quarterly estimated and final income taxes are computed and taxes are paid or refunds collected as required. Annual summary statistics are stored and printed at the end of the simulation.

We will describe the SOFASIM inputs which specify the system to be simulated, the operations of the insurance company within the computer, and the outputs which summarize the performance of the simulated company.

Inputs

The simulated company may be a new company or a company already in existence. If it is an on-going company the initial inputs include the policy portfolio it currently holds, i.e., the number of policies of each type, size, issue year, and age-at-issue combination; as well as the bond portfolio, i.e., the number of bonds of various maturities, coupons and callability, and its current cash balance. Five years of tax-related and shareholder dividend related history are also required for tax calculations and dividend decision rules. A description of the insurance policies in force and any to be issued by the company in the future, must be entered. This description includes for each policy type, size, age-at-issue combination characteristics such as the gross premiums, sales rates, valuation bases and cash value bases. Commission tables, a stockholder dividend policy, and a desired investment portfolio are also required.

The environment in which this company operates is described by specifying mortality tables, lapse tables, commission tables, an interest rate structure, operating expense coefficients, investment expense coefficients, and tax rates. Many of these variables can be changed during the simulation. The tax computation can be suppressed. Deaths and lapses can be generated randomly using the mortality and lapse tables entries as their expected values or they can be generated deterministically using these table values to determine the actual integral number of deaths and lapses. Policy sales rates can also be either random or deterministic, but actual sales are also always integral.

Initially the inputs are transcribed onto twelve different SOFASIM input forms. The manual [6] describes in detail how each form is to be completed. The input data can be quite extensive; once entered it is stored on disc and future changes are usually accomplished by editing the disc files.

Event Execution—An Overview

The SOFASIM computer model performs three major functions: initialization, the processing of events, and the generation of final summary reports.

During initialization the values specified on the input forms are used to set up the initial conditions of the company and its environment. Inputs are edited extensively and all errors must be corrected before the simulation begins.

After initialization SOFASIM begins to process monthly events, nonmonthly but regularly scheduled events, and external events.

The general functions performed by the various monthly events are: process insurance policies, pay operating expenses, process existing investments, and buy or sell investments, in that order. Events which are executed periodically but not monthly are: decide the size of the dividend, pay the dividend, calculate estimated and final income taxes, pay taxes or collect refunds as appropriate and generate the annual reports.

External events are executed at the date and time specified on the input forms. Because SOFASIM is an event oriented simulation, at any time during the simulation, company parameters, commission tables, the desired investment portfolio, interest rates, mortality, valuation and lapse tables, or certain policy characteristics such as sales rates and gross premiums, can be changed. All such exogenous changes must be decided upon before the simulation starts.

These various monthly, nonmonthly but periodic, and exogenous events are described below in a bit more detail.

Actuarial Events

The monthly *process policies* event performs the following operation on each cohort, where a cohort represents a unique combination of policy type, age-at-issue, policy size and issue year. First, sales are generated for cohorts selling policies this month, keeping track of the month and year of issue. If sales are random the number of sales is drawn from the normal distribution using the input values as the means and standard deviations. If sales are non-random the actual number of sales is equal to the input value divided by twelve, rounded. The first annual premium is collected, commissions are paid, and cash is updated. Only annual premiums are permitted.

Next, endowments are matured, and term policies are expired where appropriate. Cash and year-to-date totals are updated. Cash is always kept current as are year-to-date totals by updating these values each time a change is made.

Lapses are generated in each anniversary month, i.e., once a year in the month that the sale occurred. Since the first annual premium has already been collected policies cannot lapse in the year of issue. Lapses can be random or deterministic. If random and the expected number is small a draw is made from the Poisson distribution. If the expected number is not small the draw is made from the normal distribution. Surrender benefits are paid based on the cash surrender factors updated each December.

Premiums are collected and commissions paid for all cohorts with this as their anniversary month.

Deaths are generated for each and every cohort each and every month, i.e., each cohort is exposed to twelve months of each policy year's mortality rates. Monthly mortality rates are calculated from the annual rates entered in the mortality tables. Deaths can be random or non-random. If random, the number of deaths is drawn from the Poisson distribution. Death benefits are paid.

In December cash surrender values and reserves to be used during the following year are calculated.

After the process policies event is complete, operating expenses are computed utilizing factors specified on the input forms. These include first year and renewal year's per policy expenses, the first year and renewal year's per thousand dollar expenses, and a monthly overhead expense. These costs are subtracted from cash, and year-to-date totals are updated.

Financial Events

SOFASIM's portfolio consists of cash and callable and/or noncallable bonds over a range of coupon-maturity combinations. Each month these existing investments are updated. First, short term interest is collected or paid on the outstanding positive or negative cash balance. Coupons are clipped for one-twelfth of the bonds held in each coupon-maturity combination. One-twelfth of the bonds which mature this year are matured each month.

A calculation is made for each coupon-maturity combination to determine whether any bonds should be called and, if so, what proportion (P) of them will be called.

$$P = B^*(C - L - A)$$

where C is the coupon of the specific bond considered, L is the rate on the longest bonds currently in the marketplace, A and B are user supplied decision parameters. If the formula gives P below zero or above one, P is set to zero or one respectively. Thus the proportion called depends on the excess of the bond's rate over the long rate plus a threshold A. The company's cash balance, capital gains or losses, if any, and the amounts invested in each call category and maturity combination are updated.

The last regular monthly event to occur is *buy or sell investments*. Bonds are bought at par and sold at a price calculated as a function of the interest rate structure. Each month a decision is made as to whether bonds need to be bought or sold depending on the ratio of cash to total reserves. The user specifies the range within which this ratio can vary before sales or purchases are initiated. Once a decision is made to buy or sell then a decision must be made concerning the maturity of the bonds to be bought or sold. This determination depends on the maturity structure of the bonds the company already holds and the specified desired maturity structure of the investment portfolio.

After sales and purchases are made, investment expenses are calculated as a function of the face value of the bonds held and the amount of the transactions made.

Among the non-monthly events, the *decide dividend* routine determines whether to change the current dividend rate. The dividend decided upon will be paid quarterly for the next four quarters beginning on the date specified. The *pay dividend* routine pays the dividend, updates cash and dividends paid out, and, if necessary, makes an accounting transfer from the policyholders' surplus account to the shareholders' surplus account. This transfer is required for tax purposes.

Tax Events

The routine which calculates estimated taxes four times a year and the final tax on December 31 of each year reasonably duplicates the current tax computation. Appropriate tax values, such as carry backs and carry forwards as well as total taxes paid, are updated. A tax payment or refund event is scheduled as appropriate. The *pay tax* routine pays estimated or final taxes, and updates cash. The *refund* routine collects any refunds. The last routine to occur each year, the *report and reset* routine, stores the actual values which are printed in the yearly summaries at the completion of the simulation. It resets year-to-date totals to zero.

The Outputs

Five types of output are produced. The first set is a line of summary statistics which is printed as each year is completed. Thus, if the run is terminated before its completion, one can determine how far the simulation ran and generally what happened in the years completed. The remainder of the output is printed after the run is finished.

The second table displays balance sheet information for each year. It lists the face value of investments held, the cash on hand at the end of the year, total assets, total reserves, the tax due as of year end, total liabilities, the various surpluses (policyholders', shareholders', and other).

The third table shows annual profit and loss data such as total premiums, investment income, investment expense, death benefits, matured endowments, surrender benefits, commissions, operating expenses, increase in reserves, gain from operations before taxes, federal income tax, and gain from operations after taxes. The fourth table is tax related, the fifth miscellaneous.

A historical summary is printed which shows the mean and standard deviation for gain after taxes and stockholder dividends. The "present value" of dividends and the gain from operations after taxes are computed with three discount rates: six percent, nine percent and twelve percent.

The final random seeds for deaths, lapses, and sales are printed. They may be used as input to subsequent runs which are designed to replicate the same company and enviroment but with new, independently drawn, random deaths, and/or lapses, and/or sales.

SOFASIM consists of approximately 1260 lines of SIMSCRIPT II.5 coding including comments. Of these, 108 describe actuarial events, 134 investment events, 226 do tax calculations and payments, 440 read and edit inputs, 216 summarize and print outputs, 28 are for control, and 108 define the "entities" of the simulated system. The level of financial and tax detail is unprecedented among life insurance company models.

Limitations and Extensions

SOFASIM omits various aspects of the life insurance business. For example, no provision is made for policy loans or for any investment vehicle other than fully taxable bonds. Also, since the model was originally built to deal with stock life companies, no option was included for dividends to policyholders. Such features can be incorporated with additional programming. At the request of two companies, the present authors modified SOFASIM to permit a direct change in the cash balance at any point in time without any tax effect. Thus a subsidiary receiving a lump sum from its owner or making one to its owner, can reflect this without affecting gain from operations. We have also developed a new model through reprogramming the routine which calculates reserves, to give GAAP rather than statutory reserves.

Some extensions to SOFASIM can be achieved by what we call "creative lying". Creative lying is the art of working within the framework of the specified inputs, but interpreting the input to mean something other than what the model expects, and interpreting the output to be consistent with the input. For example, suppose we want to analyze the investment results of a particular portfolio and investment strategy under specified market conditions using insurance underwriting results only to supply an appropriate cash flow. Then one large cohort can be designed to give the desired premium, commission, cash value, death claim, maturity, and reserve increase pattern. This holds down the cost and complexity of the needed runs.

2. Uses of the Model

Let us consider some uses of SOFASIM, starting with its application to the GAAP problem.

GAAP

The GAAP problem was to determine allowances for adverse deviations used in calculating GAAP reserves. These allowances were obtained by analyzing frequency distributions derived from Monte Carlo simulations. The distributions were of the present worth at issue of a closed block of life insurance policies valued within the context of an on-going company. Here present worth is defined as the present value at the beginning of year one of all the stockholder dividends paid during the simulation plus the discounted value of the statutory capital and surplus funds held at the end of the simulation.

SOFASIM can internally generate random variation in mortality and lapses, but random changes in market interest rates must be entered as input. Therefore, a separate model was constructed to generate the required sets of random interest rates. The Durand series [3] of long-term bond interest rates for each month from 1899 to 1976 was the raw data. The rate of change ($[i_1 - i_0]/i_0$) was calculated for each month. These rates were found to have a very low correlation with i_0. The cumulative distribution function of these rates of change was the input to our interest model. The output was values of i_t in a format which could easily be incorporated into the appropriate SOFASIM inputs.

In order to see the variability in present worth produced by randomness in mortality, we executed 25 runs with random mortality, but with deterministic lapses and interest rates. To see the additional variability due to the randomness in lapses, we ran 25 simulations with random lapses as well as random mortality, but again with deterministic interest rates. We also tested the effects of randomness in interest with another 25 runs, this time with interest, mortality and lapses all random. Finally, to test the hypothesis that these effects are additive, we executed 25 simulations with random interest, but with deterministic mortality and lapses.

Let us consider in detail our analysis of the additivity assumption. Two GAAP runs were executed for each of the 25 sets of interest rate histories. In one run of each pair, mortality and lapses were deterministic; in the other, mortality and lapses were random. In the latter case the random deaths and lapses occurred identically to those in a run with random mortality and lapses but with a constant interest rate. These runs are summarized in the table below.

No. of Runs	Label	Variables		
		Mortality	Lapses	Interest
1	PV_o	Deterministic	Deterministic	Deterministic
25	PV_{ML}	Random	Random	Deterministic
25	PV_{IML}	Random	Random	Random
25	PV_I	Deterministic	Deterministic	Random

Figure 1 gives an analysis of the additivity assumption. The x-axis shows the difference between the present value for simulations having random mortality and lapses, and the present value of the total company run completely deterministically. In other words, it shows the effect on a company of having random mortality and random lapses with interest at the same fixed level for all 25 runs. To get the values of the y-axis, we subtracted the present value of simulations having only interest random from the present value of runs with interest, mortality and lapses all random. That is, it shows the effect on a company of having random mortality and random lapses when the random interest effect is subtracted out. Thus, each point really is the result of four runs, whose present values we have denoted on the graph as: PV_O, PV_{ML}, PV_{IML}, and PV_I. For a given point on the graph, the ML run has the same deaths and lapses as the IML run. The IML run and the I run for that same point have identical interest rates month by month. Therefore, each point on the graph represents the effect of randomness of mortality and lapse arrived at from two different directions.

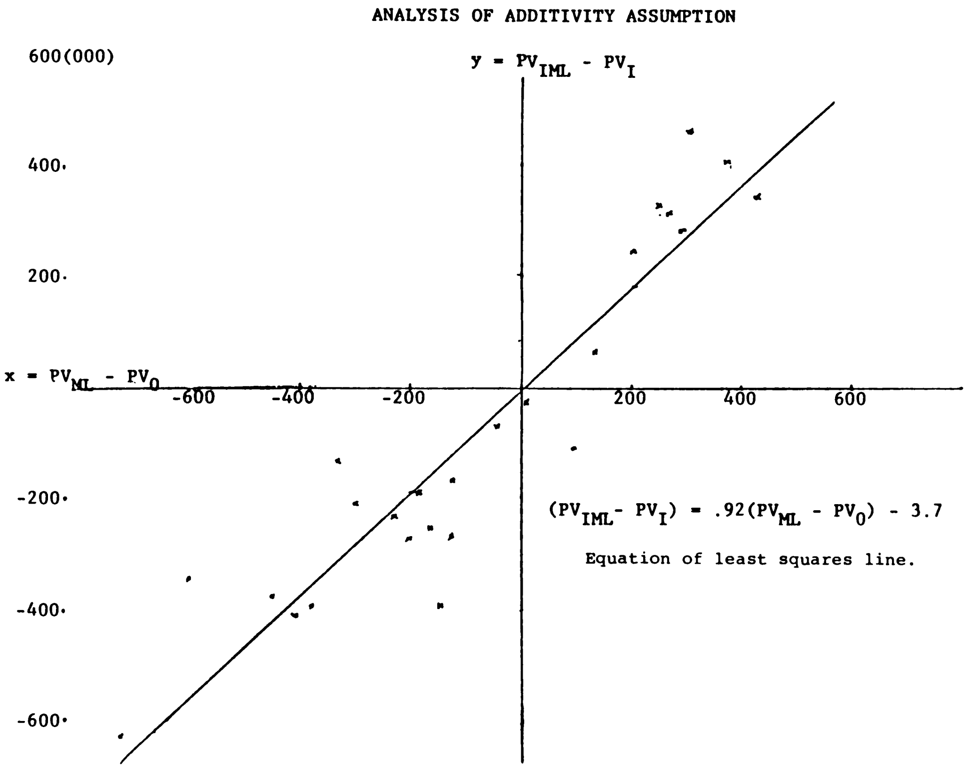

Figure 1. Analysis of Additivity Assumption

If the deltas were truly additive, that is, if the effect on present value of making mortality and lapse random was independent of whether interest was random or not, then the observations would lie along a 45° line through the origin. The line in the figure is the least squares fit to the actual observations. We see that the slope of the least squares line is quite close to one and its intercept is not significantly different from zero. This suggests that, on the average, the effects are additive. For further details of this and other aspects of the GAAP analysis see [2], [5], [7].

New York State Licensing

SOFASIM has many uses unconnected with GAAP. For example, a life insurance company desiring to become licensed in New York State must submit projections based on various estimates of new business. The company may choose its own assumptions for mortality, lapse, interest, and expenses and must forecast operating results considering a high level, a medium level, and a low level of new business. The projections must be for at least five years and longer if necessary, until operating gains emerge and continue to be positive.

For a newly organized company the following should be considered. Losses due to high first year commissions and expenses as well as conservative statutory reserves are all amortized during renewal years. The greater the volume of new business, the greater the initial losses, and the longer the time before operating profits are shown. Of course, as the profits emerge during the renewal years, they combine with the first year losses of future new issues. Finally, as operating gains develop, federal income taxes come into play to complete the picture.

For existing companies, new issue losses immediately merge into the financial results of prior years' issues of the ongoing company, which already has its operating history, dividend policy, and tax position. A high volume of new business could cause an operating loss, or it might cause enough of a decrease in gain from operations to change the tax phase or dividend payout.

All of these complexities and interrelationships are difficult to assess without an integrated model. The New York insurance department will accept SOFASIM printouts showing the effects of different new business assumptions on gains from operations.

Tax Planning

Life insurance companies are taxed on either investment income, or on total operating gains, or on a combination of the two. The recent trend toward very high interest rates is wreaking havoc on companies taxed on investment income. It is possible for a life insurance company earning as little as 13% on its investmets to be paying tax at more than a 100% marginal rate. Of course, this critical rate of return depends upon the make-up of each individual company.

SOFASIM can be used to test various market interest rate scenarios for those companies whose tax is based on investment income. For this purpose it is not necessary to reproduce the entire insurance policy portfolio. Rather, a few policy types and ages at issue can be used to reasonably reproduce the cash flow which would emerge from the insurance aspects of a company.

Taxable investment income is a function of the excess of the rate of income actually earned over the rate assumed in the calculation of life reserves. As this difference becomes too large, management must devise tax planning strategies. The taxable income earned can be lowered by investing in tax exempt municipals, or in deep discount bonds which have lower yields coupled with capital gain potential. Alternatively, the assumed valuation rate can be raised. Several insurance companies have embarked on "Project Update" which consists of (a) an increase in the face amount of old insurance policies and (b) a decrease in the reserve for these policies, accomplished by raising the assumed rate of interest. Thus the difference between actual and assumed interest rates is lessened, reducing taxable investment income.

Reinsurance is another way of providing relief during these times of very high interest. Input can be designed to simulate different forms of reinsurance to test if, when, and how reinsurance could have an impact on company taxes.

For tax purposes stock life insurace company surplus is considered to be divided into two parts: the policyholders' share and the company's share. Amounts credited to the policyholders' share become taxable at some indefinite date in the future. However, the total policyholders' share is limited by a formula which considers the size of reserves held at the end of the taxable year and the amount of premiums included in gain from operations for the year. If the balance in the policyholders' account exceeds this limitation, the excess must be subtracted from the account and must be included in taxable income. Here, too, SOFASIM can be used to project if and when the legal limitation might be exceeded. Management will then be in a position to encourage increased sales or to accept blocks of reinsurance which will result in increased reserves and increased premium income. This raises the limitation on the policyholders' share, and again defers taxes.

3. SUMMARY

During the course of its lifetime SOFASIM has been used in simple projects such as testing the effects of changes in premium scales, commission scales and/or reserve bases on taxes and surplus; testing different combinations of permanent and term plans of insurance considering variations in the investment market place; and testing the pattern of GAAP earnings by policy year of various plans of insurance. It has also been used in more complex projects such as studying retention limits using SOFASIM's stochastic facilities, testing profitability of various products with different expense allocations, and investigating the relationship in an inflationary environment between excess investment income and increasing costs for term and permanent insurance.

These are just a few of the model's possible uses. With "creative lying" and perhaps some actual programming changes, many more questions can now be asked and answered.

SOFASIM is currently available to any member of the Society of Actuaries through the time sharing facilities of National CSS. An insurance company with a large enough in-house computer and a SIMSCRIPT II.5 compiler could install SOFASIM, as could any of the more than 200 universities which already have SIMSCRIPT II.5 compilers.

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DISCUSSION

W. F. SHARPE*: Simulation seems to beget acronyms. The papers describe SOFASIM, FENSIM and PLASM. I have no product to describe, but in the spirit of the session, my comments may be characterized as ANTI-SIM.

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