by Maggie Queen and Richard Roll

Firm Mortality: Using Market Indicators to Predict Survival

A firm may disappear from the public marketplace for several reasons. It may go bankrupt, be suspended from trading or delisted, in which case its shareholders are likely to experience unfavorable results. Or a firm may merge with or be acquired by another firm, in which case the results for shareholders may be quite favorable. An examination of five readily available market indicators—firm size, price, return, volatility and beta—reveals that all but beta can be of use in predicting favorable and unfavorable firm mortality.

Size seems to be the best predictor of both favorable and unfavorable mortality over both the long and short terms. The smallest firms have about even odds of disappearing, for favorable or unfavorable reasons, within a decade. The largest firms have a mortality rate of about 20 per cent over two decades.

The effect of market price varies depending on whether price is used as the sole predictor or in conjunction with the other variables. As the sole predictor, price shows a monotonic negative relation to unfavorable mortality, but both high and low-priced firms tend to have lower favorable mortality rates than mid-priced firms. When used with the other predictors, however, price has a strong positive relation to favorable mortality and no relation to unfavorable mortality.

Total return and total volatility of return both appear to have strong predictive powers. As return increases, the likelihood of unfavorable mortality declines and the likelihood of favorable mortality increases, while high total volatility increases the rates of both types of mortality. When one skips a year between calculating these variables and observing mortality, however, return and volatility retain their predictive abilities only for unfavorable mortality. The predictive powers of these variables appear to be at least partly ascribable to the effects of mortality events that are announced in the year during which the variables are calculated but not consummated until the following year.

BANKRUPTCY IS GENERALLY considered to be an unfavorable event for shareholders. For a publicly listed company, however, bankruptcy is not the only route to mortality. A firm may go private, be acquired, merged or liquidated. Firm mortality thus may not necessarily be a sad event for investors, although it may very well be an occasion for mourning on the part of other interested groups, including employees, managers, lenders, borrowers, clients, suppliers, tax collectors and members of the community in which the firm is located.

This article examines whether firm mortality can be predicted on the bases of such publicly available market data as firm size (i.e., market capitalization), price, total return in a previous period, total volatility of return and volatility of return relative to a market index (beta). We give

Maggie Queen is a doctoral student at the Graduate School of Management of the University of California at Los Angeles. Richard Roll is Allstate Professor of Finance at the Graduate School of Management of the University of California at Los Angeles and Vice President, Mortgage Securities Department, Goldman, Sachs & Co.

statistics on total mortality and assess the difference in predictability between mortality that is favorable to shareholders and mortality that is unfavorable.

Previous Studies

Companies may disappear from the public marketplace in several ways. Surprisingly, there seems to be no well developed theory for predicting which companies will merge, be exchanged, delisted or suspended. There are, however, a number of empirical studies of the probability of bankruptcy.

Beaver pioneered the use of financial ratios to predict bankruptcy.[1] By comparing matched samples of failed firms versus nonfailed firms, he discovered that several readily available ratios were significant predictors of failure.[2]

Altman used linear discriminant analysis to improve the predictive ability of bankruptcy models.[3] Altman based his model on a sample of firms that had filed Chapter XI bankruptcy petitions during the period 1946 to 1965. Five variables (from a set of 42) provided the most efficient discriminant function.[4] When validated against the same sample on which the model was based, error rates were relatively small for one or two years prior to bankruptcy, but quite large for three to five years prior.

Altman's technique is appealing because it evaluates the ability of several ratios taken together to assess the financial health of a firm. One ratio alone might not contain enough information to reveal all the relevant characteristics of a firm. The accuracy of prediction achieved by Altman was greater than that achieved by Beaver with a single predictor, especially with data for the year just prior to bankruptcy. However, Beaver was able to predict bankruptcy up to five years prior to failure, while Altman's accuracy dropped sharply even for the second year prior to bankruptcy.

Deakin modified Altman's model to include Beaver's 14 best predictors.[5] Deakin also employed a version of discriminant analysis to assign a probability to membership in the failed and nonfailed groups. Deakin's classification accuracy was greater than Altman's when validated against the sample from which the estimation was made, but it decreased significantly when validated against a holdout sample. The error rate for the prediction appeared to be random from year to year for the six years prior to failure, which suggests that the results are sample-specific.

In addition to the above problem, Deakin's method relies heavily on the assumption that the variables were distributed as the multivariate normal distribution. Diamond showed that this assumption is not necessarily correct.[6] Diamond attempted more rigorous tests of the discriminant function in order to determine if improved predictive ability were possible. He used stepwise discriminant analysis, principal components analysis and optimal discriminant plane techniques but could not improve on the accuracy achieved by other discriminant analysis studies.

Altman, Haldeman and Narayanan attempted to improve the accuracy of Altman's earlier model by including several refinements in the statistical techniques; the sample was updated and the data were made more precise.[7] These changes did improve classification accuracy.

An alternative to using discriminant analysis is to use a conditional probability model. Ohlson predicted bankruptcy utilizing nine ratios.[8] The most significant variable was firm size calculated as the log of total assets divided by the GNP price level index.

These empirical bankruptcy studies suffered from two handicaps—the limited number of bankrupt firms available for analysis and the relative insensitivity of accounting data.

The limited number of bankrupt firms reduces statistical power and also seduces the investigator into pooling data from several years. If different years are associated with differing incidences of bankruptcy, pooling can mask important explanatory factors. Furthermore, the number of bankrupt firms is often insufficient to allow validation with a holdout sample.

The use of accounting data has several disadvantages. Two alternative accounting methods represent at least one measurement error, and this affects the predictive ability of the model. Another disadvantage relates to timing. As Ohlson notes:

> "Realistic valuation of a model's predictive relationships requires that the predictors are (would have been) available for use prior to the event of failure. Now, it is of course true that annual reports are not publicly available at the end of the fiscal year, since the financial statements must be audit-

1. Footnotes appear at end of article.

> ed. . . . most previous studies have used Moody's Manual to derive the pertinent financial ratio, and the Manual does not indicate at what point in time the data were made available. . . . The timing issue can be expected to be serious for firms which have a high probability of failure in the first place. Such firms are in poor shape and the auditing process could be particularly problematic and time consuming."

Of course, these handicaps do not imply that accounting data are irrelevant or meaningless for prediction, but certainly caution is warranted in interpreting results.

Research Design

In order to avoid the disadvantages of accounting data, we relied solely on market information to predict the survival of firms. We employed five of the most popularly monitored indexes of individual firms—price, average return, volatility of return, beta and market capitalization.

There are various theoretical arguments about why these variables may or may not be relevant for predicting survival. We intend to finesse such subtleties because the spirit of our analysis is strictly "actuarial," not "medical." In other words, we are interested in *whether* a particular variable predicts survival, not *why* it does. Thus we do not discuss the role of beta in the Capital Asset Pricing Model, nor whether or not individual firm variance should predict average returns. It suffices that each predictor is easy to compute and simple to use.

The Data

We obtained data on stock prices, returns, numbers of shares and reason for disappearance from the Center for Research in Security Prices (CRSP). The CRSP database contains daily return information for all New York and American stock exchange common stocks from July 1, 1962 through December 31, 1985.

CRSP classifies a security's status at a point in time as follows:

0 unknown
1 not applicable or unspecified, i.e., still in existence
2 merged
3 exchanged
4 liquidated
5 delisted by the exchange
6 halted by the exchange
7 suspended by the SEC

We classified a company as surviving if it was included in categories 0 or 1. A company was considered nonsurviving if it was included in any of the remaining categories.

Our five predictor variables are:

- **size of firm**, computed as the closing price multiplied by the number of shares outstanding on the same date;
- **price**, as given by the closing price;
- **total return**, computed as the total return over a period including reinvested distributions to shareholders, such as dividends, and capital adjustments, such as splits;
- **variance of return**, calculated as the simple-product moment variance of the daily returns; and
- **beta**, the relative volatility of the stock as compared with a market index (the CRSP value-weighted index of all listed stocks).[9]

Each of these variables was measured either at the exact end of each year (price and size) or over an entire year (return, beta and variance). No observations beyond the end of the year were included in any predictor's calculation; thus, since the beta used five leading observations, the last daily return in its calculation was the sixth trading day before the year's end.

Method

Using the predictor variables calculated from 1962 data, we began by classifying our sample of N securities into 10 groups, ranked according to the value of each variable. With N being the total number of securities allocated to ranks and (N/10) the largest integer equal to or less than N/10, the last nine groups had (N/10) firms and the first group N-9(N/10) firms.

Using the total number of firms in each group in the first sample year (1962), we then calculated the nonsurvival rate in every year following 1962. Firms present in the dataset at the end of 1962 but not at the end of 1963 comprised the first year's mortality group. For the base year 1962, mortality rates can be computed for 23 subsequent years, 1963 through 1985. Using the firms present at the end of the next base year, 1963, a total of 22 subsequent mortality rates can be computed. After performing calculations with all base years, we had 23 one-year mortality rates, 22 two-year rates, 20 three-year rates, and so on.

The next step was to calculate average mortality rates. These were simply the sum of all one-year mortality rates divided by 23, all of the two-year rates divided by 22, etc. Of course, we had only one sample year (1962) for which we could measure the survival rate over 23 years and, except for the one-year mortality rates, the averages are not composed of independent observations. For example, the two 22-year survival rates, for sample years 1962 and 1963, have 21 years in common. Unavoidably, the farther out the term mortality rate estimates are, the more subject they become to statistical estimation error.

Note that a firm's ranking by predictor variable adjusts in every sample year as a result of the delisting and new listing of securities, and as a result of the firm's relative performance. The predictor variables and thus the ranks are updated annually.

The Predictions

If a variable is important in predicting the survival of firms, then the mortality rates should show a monotonic differential trend across ranks over a period of years. In the absence of such a pattern, we may conclude that the factor is not an effective predictor.

We calculated three mortality rates for each factor. The first is the mortality rate for all CRSP categories. The other rates isolate specific causes, depending on whether the cause represents good or bad news for shareholders. For example, Categories 2 to 4 (merger, exchange and liquidation) may be favorable events, whereas Categories 5 to 7 (delisted, halted trading, suspended by the SEC) are probably unfavorable.

Total mortality was calculated as the number of companies merged, exchanged, liquidated, delisted by the exchange, halted by the exchange and suspended by the SEC divided by the total number of companies. The favorable mortality rate was calculated as the number of companies merged, exchanged or liquidated divided by the total number of companies. Unfavorable mortality was calculated as the number of companies delisted by the exchange, halted by the exchange, and suspended by the SEC divided by the total number of companies.

Empirical Results, Single Variables

Figures A through E plot the mortality rates classified by each of the five predictor variables. Each figure shows the cumulative mortalities for six of 10 decile categories, ranked by the predictor variable. The appendix contains tables with all the numerical results.

Size

Figure A shows that firm size is a strong predictor of survival. On average, about 8 per cent of the firms in the smallest-size decile disappear during the first year; 50 per cent disappear within 12 years. A firm in the smallest-size decile has only slightly better than even odds of surviving a decade.

Firms in the largest-size decile are much more likely to be around for a long time. Only about 1 per cent expire in the first year, and about 80 per cent survive for 23 years, our longest observation period. Nevertheless, when one considers that the largest decile is composed of the best known firms in the United States, it may be surprising that as many as 20 per cent disappear after two decades.

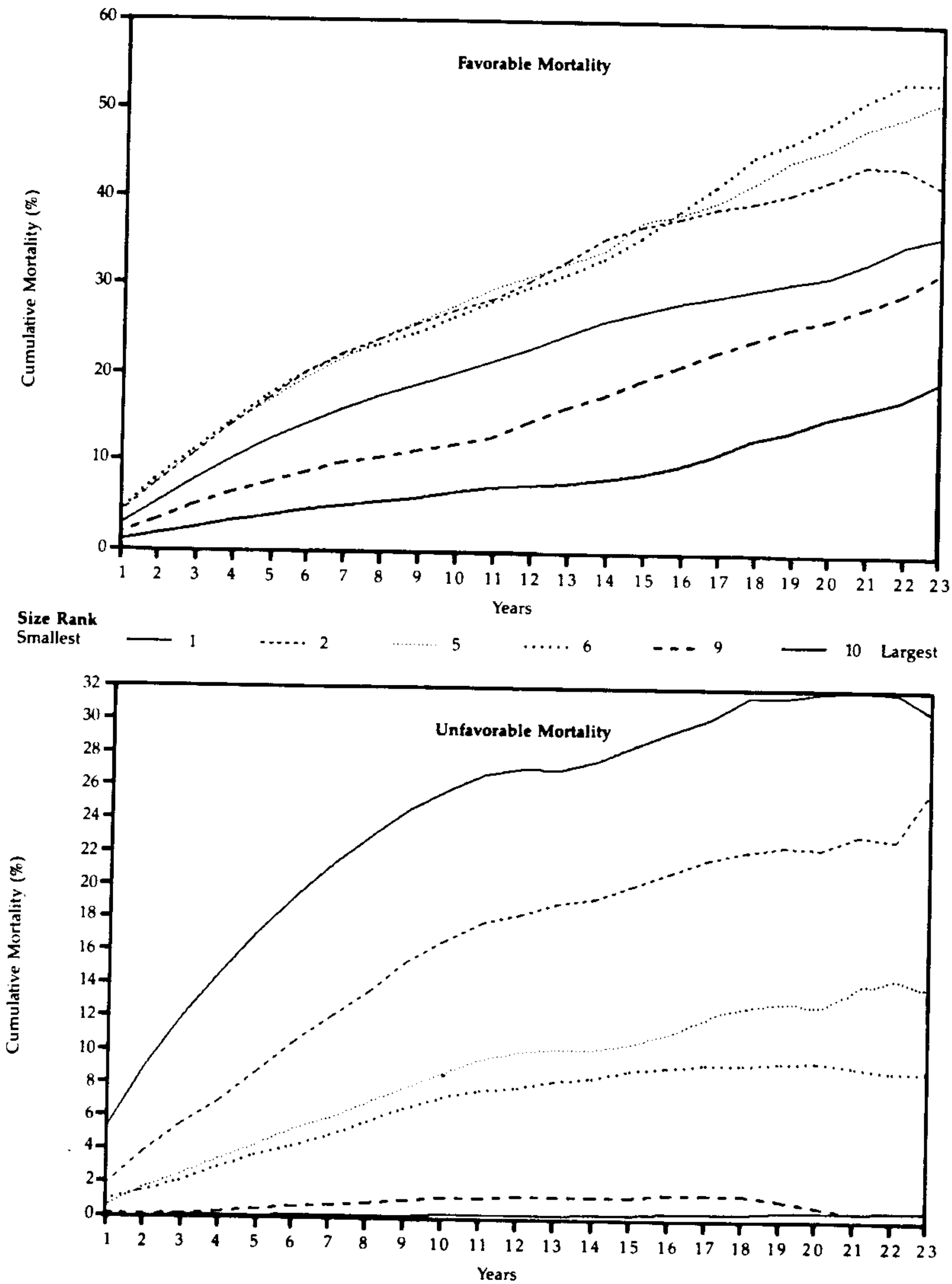
There is a strong inverse relation between *unfavorable* mortality and size. As the bottom panel of Figure A shows, unfavorable mortality increases as size decreases, over all observation periods. About one-quarter of the smallest firms are halted, delisted or suspended from trading within a decade, and about 5 per cent actually meet this fate within one year. In contrast, less than 1 per cent of the largest firms expire from unfavorable causes, even over the longest observation interval.[10]

We have reason to believe, moreover, that our mortality rates are somewhat understated for the smaller firms. To calculate size, we must know both the firm's price and number of shares at the end of the base year. Unfortunately, number of shares is missing from the CRSP database in some cases, and it is more likely to be missing for the smaller firms than for the larger ones.[11] This reduces the discriminatory power of the predictor.

In most cases, the disappearance of large firms can be attributed to the more favorable events of merger, exchange or liquidation. Notice also, from the top panel of Figure A, that size is *not* a monotonic predictor for this type of mortality. Firms in the medium-size group have higher mortalities due to favorable causes than either larger or smaller firms. About one-quarter of the firms in the middle deciles (2 through 7) merge, are exchanged or are liquidated within a decade, while the rate is considerably less than 20 per cent in the remaining deciles.

The relation between firm size and favorable versus unfavorable mortality suggests that relatively small firms are unlikely to survive over long periods, but that they are roughly as likely

Figure A Size at End of Previous Year as Predictor of Mortality



to be swallowed up by larger firms as they are simply to fail on their own. Medium-sized firms are much less likely to fail, but they disappear with significant frequency nonetheless; indeed, the frequency of favorable mortality is even higher for them than for the smallest firms.

Market Price

Figure B plots the mortality rates of firms ranked by the closing price at the end of the year. Almost 10 per cent of the lowest decile of price-ranked firms disappear within one year, 50 per cent vanish after a decade, and three-quarters are gone after two decades. Firms in the lowest price-ranked decile actually show somewhat greater mortality than those in the smallest-size decile.[12] There is also substantial total mortality in the higher-price deciles.

The relation between price and mortality rate shows up more strongly in the *unfavorable* mortality case than in the favorable case. Unfavorable mortality is much higher in the lower price-ranked deciles, and the relation between price and unfavorable mortality is strongly monotonic across deciles. In contrast, favorable mortality is about as likely in the highest-price decile as it is in the lowest-price decile; it may be slightly higher in the middle deciles than at either extreme, but this effect is not pronounced.

Note that unfavorable mortality rates are somewhat higher in the highest-price decile than in the largest-size decile. Unfavorable mortality reaches 5 per cent after two decades in the highest-price decile, but it never exceeds 1 per cent in the largest-size decile.

Price and size are the only two predictor variables, of the five variables we employ, measured at a single point in time. They are observed on the last trading day of a calendar year just preceding the period over which mortality is computed. We now turn to an examination of the other three variables, return, volatility and beta, which are calculated using data from an entire preceding base year.

Return

For firms present at the end of a calendar year, we calculated total returns during the year and used them to form 10 return-ranked groups. The mortality rates of these groups were then computed over subsequent periods.

Figure C shows that there is some tendency for the lowest-return decile to have higher unfavorable mortality rates and lower favorable rates than the other deciles. Overall, almost 50 per cent of the firms in the lowest decile expire after a decade, while the mortality rate for the higher deciles is in the 35 to 40 per cent range and does not display a monotonic relation with the ranking variable.

Although favorable mortality shows little *long-term* connection with return in the base year, the *first year's* favorable mortality rate does increase monotonically with return in the immediately preceding year. This is undoubtedly due to mergers and other favorable events **announced** during the base year, which elicit a positive return around the announcement date, but which are **consummated** later, during the first year of observed mortality.

Unfavorable mortality shows just the opposite correspondence to return in the short run. The lower the return in the base year, the higher the unfavorable mortality in the immediately subsequent year. Again, this is probably the result of unfavorable announcements in the base year, which lead to disappearance of the firm soon afterward.

There is a tendency for negative returns in the base year to be associated with higher unfavorable mortality rates over many future years. About one-quarter of the lowest return-ranked firms disappear within a decade, a figure nearly twice as high as any other decile. However, the decile of *highest* base-year returns has somewhat larger mortality rates in the long run than do intermediate deciles. Perhaps this can be explained by volatility: Firms in *either* the highest or lowest return-ranked deciles may have a tendency to be more risky in general. Even if a risky firm performs well in one base year, it may be more likely to fail in a future period when conditions are less favorable.

Volatility

Support for the view that high-return deciles are more risky is evident in Figure D, which presents mortality rates of volatility-ranked firms. Volatility is measured as the statistical variance of daily returns during the base year.

There is a clear association between volatility and mortality. On average for all causes of mortality, the association is positive. The highest-volatility decile experiences about 50 per cent mortality within a decade, while the lowest decile shows less than a 20 per cent mortality.

When we distinguish between favorable and unfavorable causes, we see a much different

Figure B Price at End of Previous Year as Predictor of Mortality

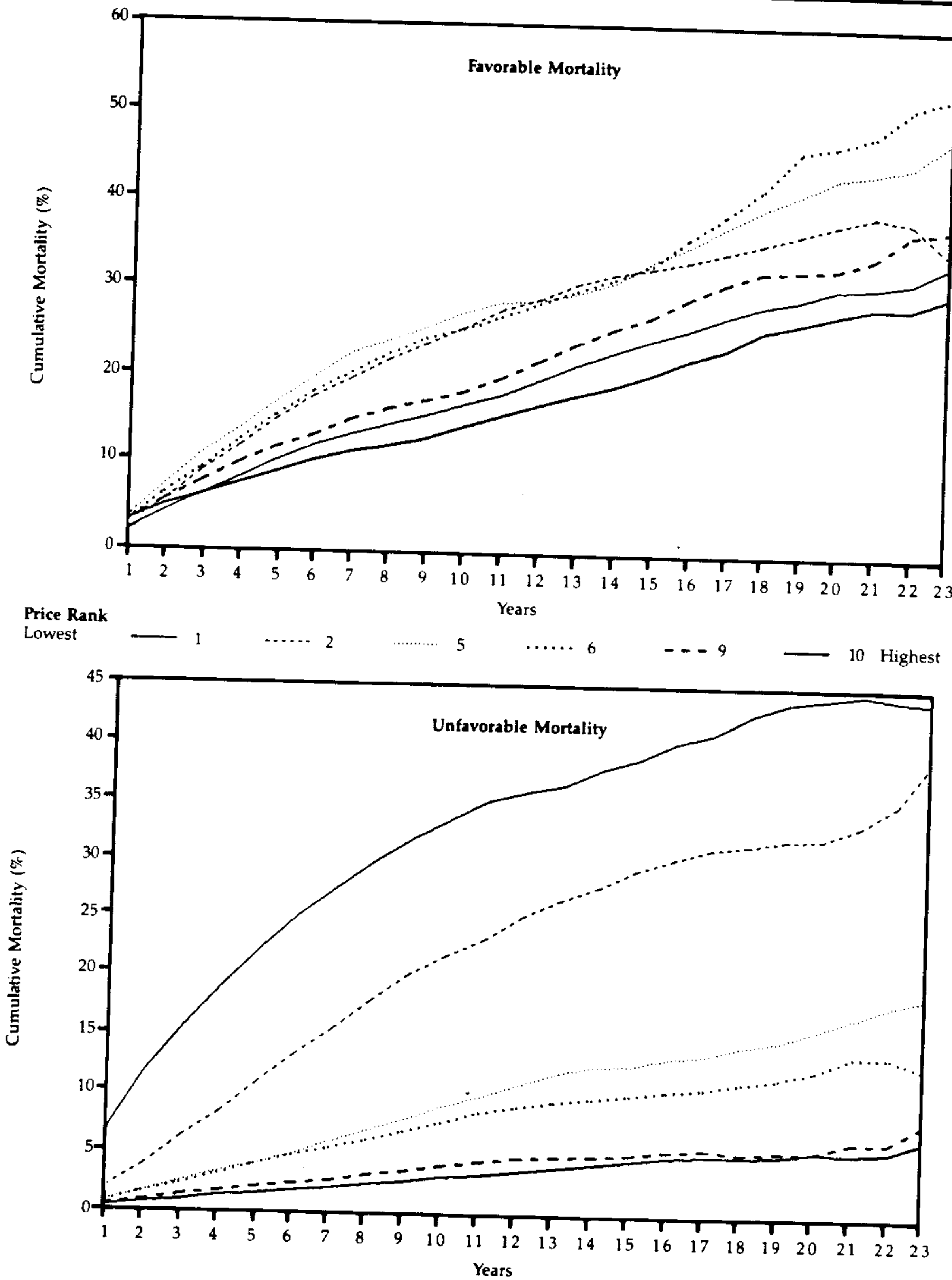


Figure C Return During Previous Year as Predictor of Mortality

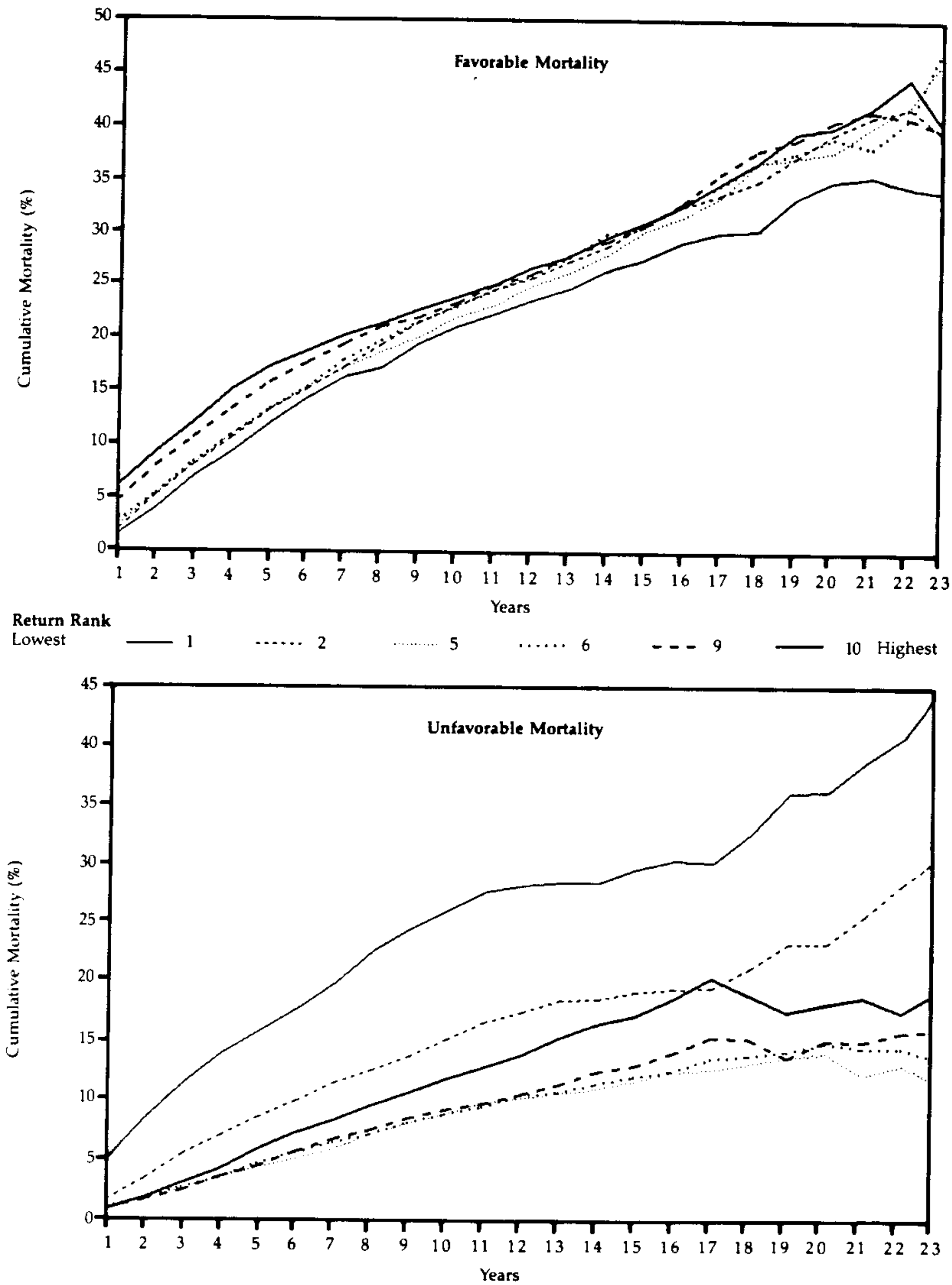


Figure D Volatility During Previous Year as Predictor of Mortality

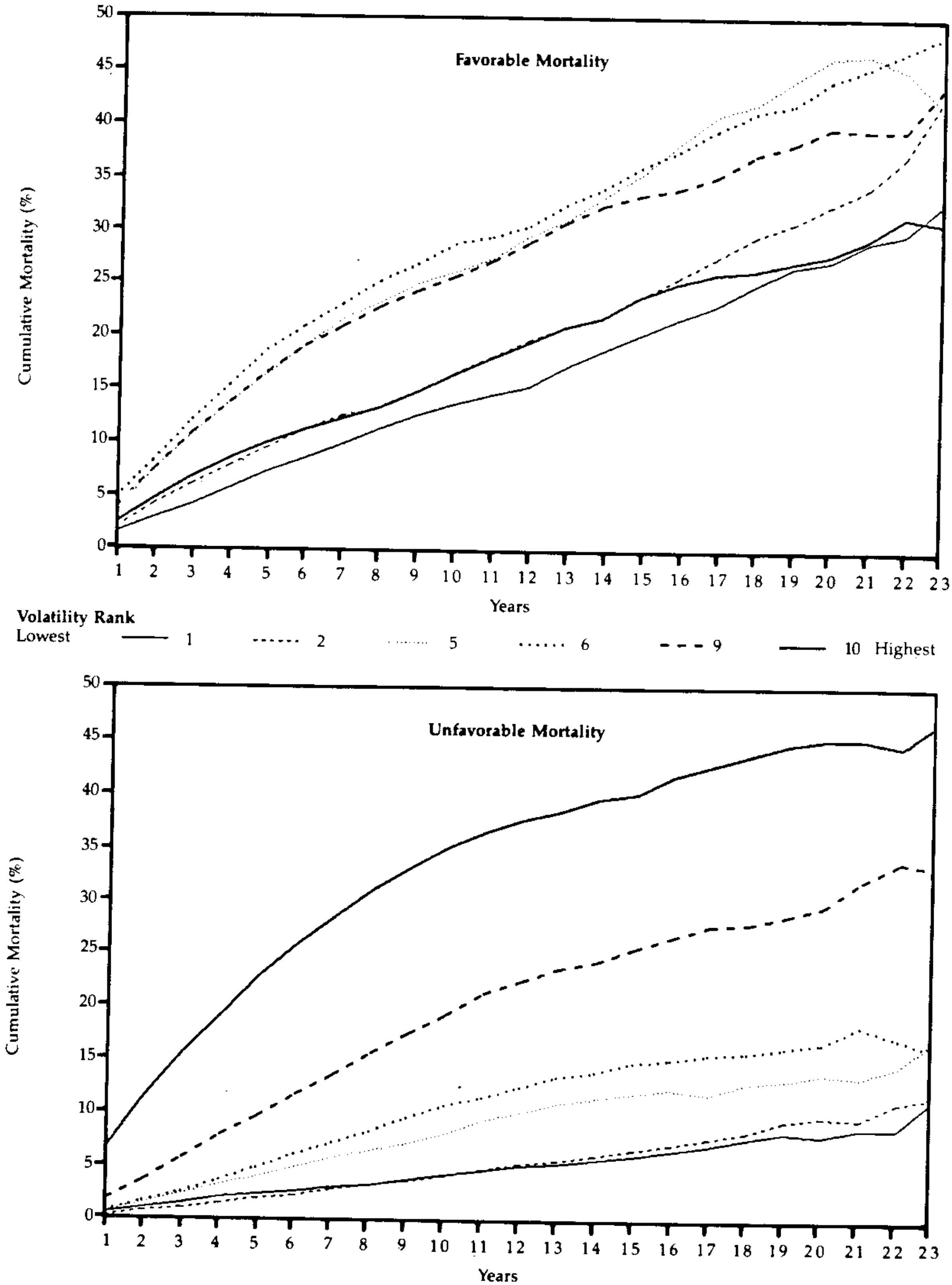


Figure E Beta During Previous Year as Predictor of Mortality

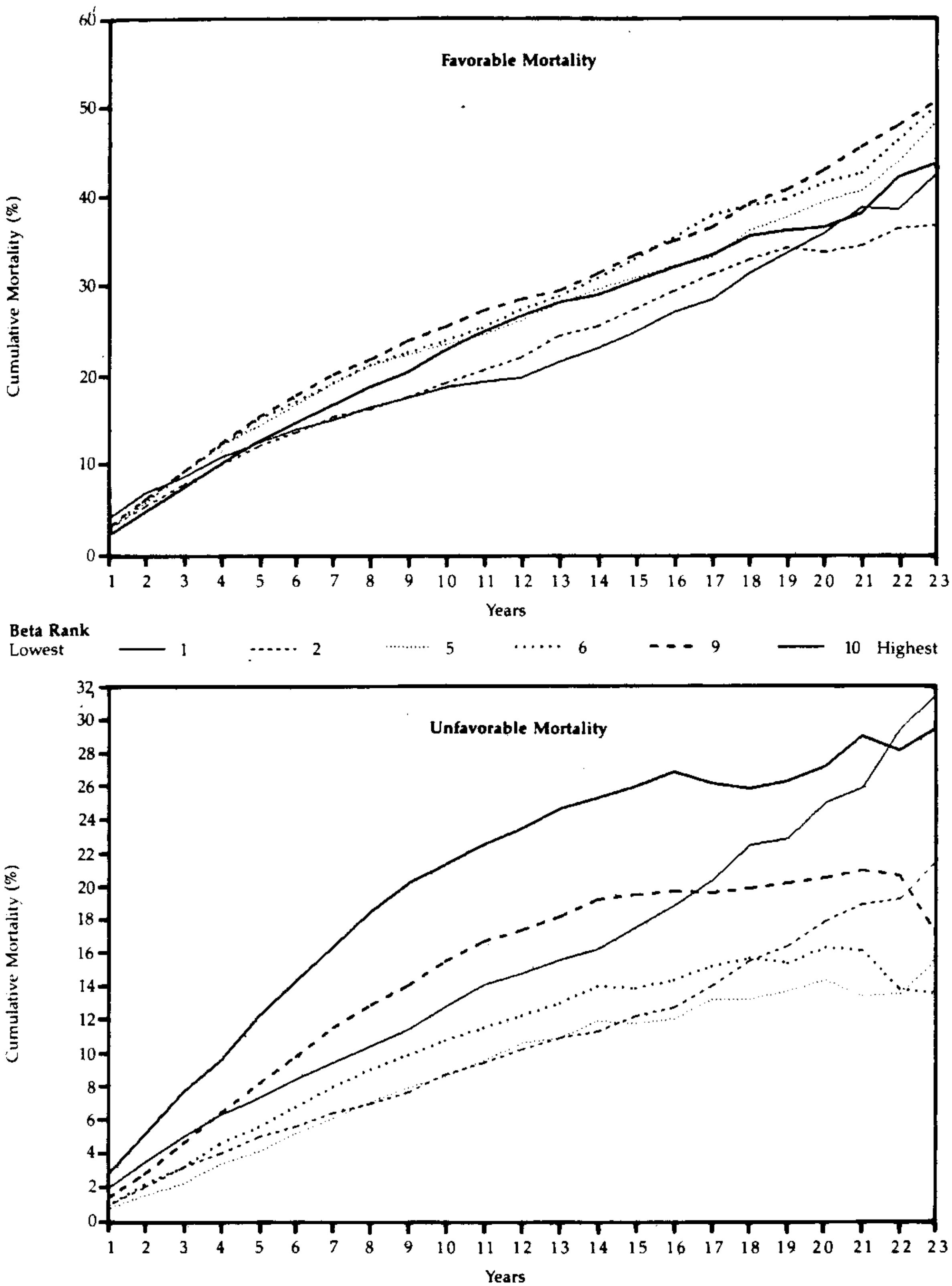


Figure F Mortality Response to Firm Size

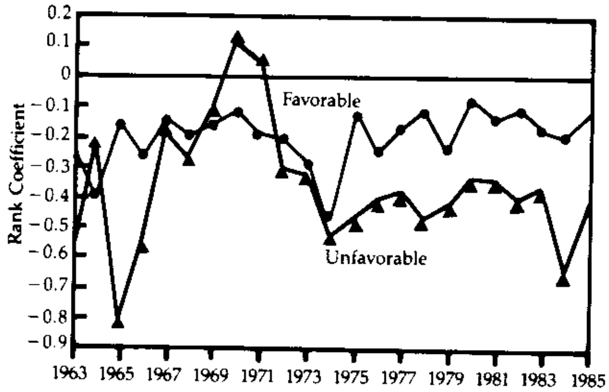
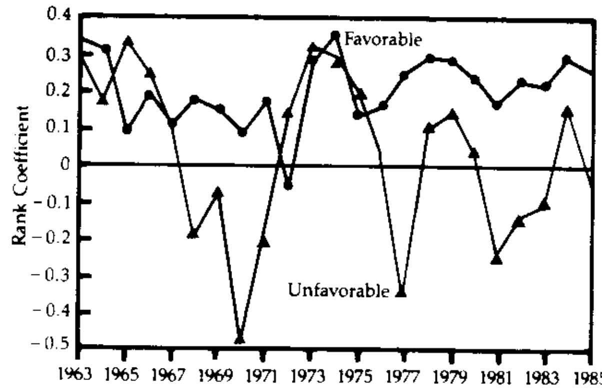


Figure G Mortality Response to Market Price



pattern. Unfavorable mortality has a strong positive association with volatility. The mortality rates are monotonically ranked, and the highest decile displays a rate often 10 times the rate in the lowest decile.[13]

Favorable mortality is *not* monotonically associated with volatility. Firms in either the lowest or the highest volatility-ranked deciles have much *lower* favorable mortality rates than firms in the middle deciles. For instance, after a decade, firms in the middle volatility deciles all show mortality rates of at least 25 per cent, but the highest and lowest deciles' rates are only around 15 per cent.

Apparently, firms with medium volatility are more attractive candidates for merger and liquidation. Perhaps for distinctly different reasons, high-volatility firms and low-volatility firms are less desirable in corporate recombinations. One might conjecture that low-volatility firms are concentrated in particular industries, such as electric power generation, that are less subject to merger activity, while high-volatility firms may be high-growth, high-risk and less subject to takeover because they are more difficult to evaluate.

Beta

Figure E shows the mortality rates of firms ranked by beta, the so-called systematic risk of the firm, relative to a value-weighted index (and corrected for nonsynchronous trading and other market frictions).

Of our five variables, beta clearly has the least power to predict mortality. There seems to be a slight tendency for firms in *either* the highest or lowest beta deciles to have higher rates of *unfavorable* mortality, but the effect is not dramatic.

There seems to be virtually no association between beta and favorable mortality. For example, mortality rates after a decade range between 18 and 25 per cent over all beta-ranked deciles and the relation is not monotonic. This is an extremely weak pattern in comparison with the other predictor variables.

Discriminating Between the Predictors

The results just discussed involve predictions by five **single** variables, at least four of which show considerable predictive power. Univariate predictors are inadequate, however, for at least two reasons. First, the variables are themselves

Table I Multiple Regressions of Mortality on Predictor Variable Ranks, One-Year Predictions

T-Statistic	*Size*	*Price*	*Return*	*Variance*	*Beta*
	Effect on Total Mortality				
Average Individual-Year T-Statistic	−3.286	2.701	0.851	3.168	−2.170
T-Statistic of Average over Years	−11.536	9.977	4.153	7.763	−5.820
	Effect on Favorable Mortality				
Average Individual-Year T-Statistic	−2.357	2.530	2.241	2.289	−2.016
T-Statistic of Average over Years	−10.242	10.532	7.196	6.636	−4.693
	Effect on Unfavorable Mortality				
Average Individual-Year T-Statistic	−2.096	0.315	−1.478	1.446	−0.696
T-Statistic of Average over Years	−8.615	0.830	−4.647	5.167	−3.396

Figure H Mortality Response to Total Return

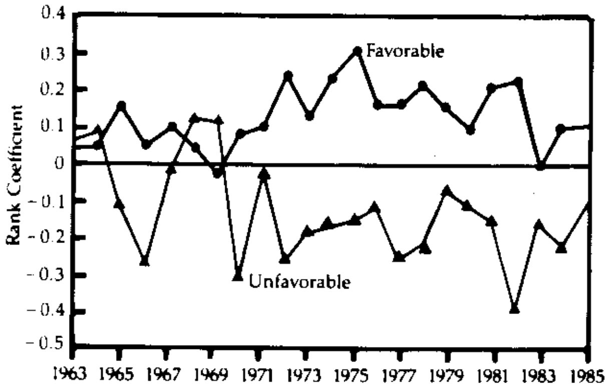
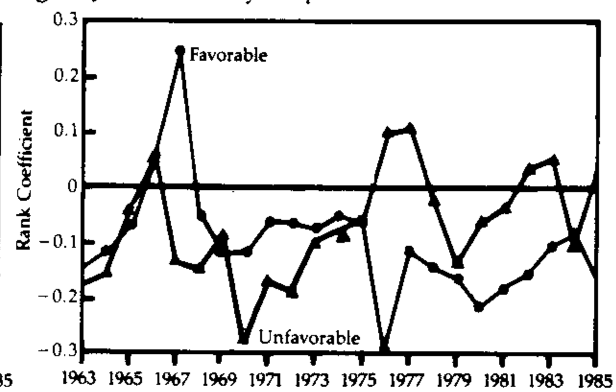


Figure J Mortality Response to Beta



associated. It is well known, for instance, that firm size is inversely related to volatility, so predictions by size and by volatility may simply be two manifestations of the same underlying predictor. Second, mortality may be predicted better with combinations of variables. There are multiple causes of mortality, and distinct market measures could conceivably contain differential information about these causes. We turn, therefore, to a multivariate approach.

Predicting Next Year's Mortality

The first set of results involves multiple logistic regressions of mortality in the year following the predictions made by all five of the predictor variables. Figures F through J show the coefficients for each predictor variable and for each of the 23 prediction years.

Table I gives significance levels for all of the predictor variables. These were calculated in two ways—(1) as an average of the individual results and (2) as a t-statistic calculated for the mean coefficient over all years assuming that the years are independent.

Figure F presents the predictive ability of firm size for both favorable and unfavorable mortality over each of the 23 prediction years. The "rank coefficient" gives the marginal impact of the firm's decile ranking, holding constant all other predictor variables.[14] For favorable mortality, the coefficient is negative in every single year, indicating that large firms are much less likely to merge, be exchanged or be liquidated (the favorable mortality events). For unfavorable mortality, the coefficient is negative in all but two years, indicating a strong (negative) relation between firm size and bankruptcy, suspension or delisting. The regression t-statistics indicate extremely significant size coefficients in virtually every year and for both mortality categories (see Table I).

Holding constant the other predictor variables, year-end market price has a strong positive relation with favorable mortality *only* (Figure G). Evidently, price is relatively high at the end of the year when a firm is going to be the target of a takeover or when some other favorable event is about to occur or has already been announced. There is no significant marginal effect of price on unfavorable mortality.

The multivariate significance of price is exactly the *opposite* of its univariate significance. Taken by itself, price is strongly and *negatively* related to *unfavorable* mortality. In the univariate comparisons, price must be acting as a proxy for one of the other variables, probably size, with which price is most closely correlated.

Total return in the previous year (Figure H) shows a strong positive relation with favorable mortality and a strong negative relation with unfavorable mortality. This may be attributable to news about the pending mortality announced in the previous calendar year. Firms about to expire for bad reasons have negative returns, while firms about to be acquired or liquidated have positive returns in the prior period.

Figure I Mortality Response to Volatility

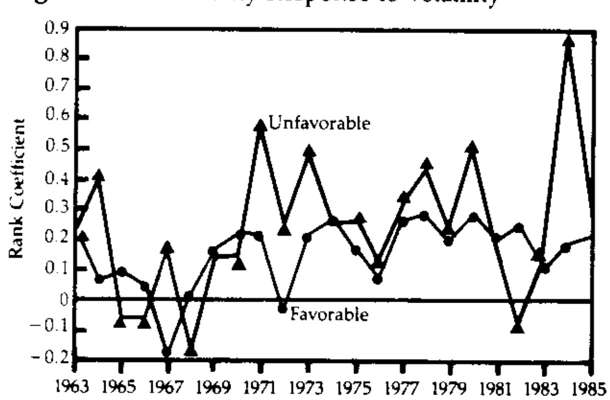


Table II Multiple Regressions of Mortality on Predictor Variable Ranks, Five-Year Predictions

T-Statistic	*Size*	*Price*	*Return*	*Variance*	*Beta*
Effect on Total Mortality					
Average Individual-Year T-Statistic	−6.372	3.181	0.339	2.926	−0.926
T-Statistic of Average over Years	−7.678	4.463	0.885	9.855	−5.098
Effect on Favorable Mortality					
Average Individual-Year T-Statistic	−4.545	3.034	0.939	1.443	−0.417
T-Statistic of Average over Years	−32.078	6.777	1.809	3.765	−0.345
Effect on Unfavorable Mortality					
Average Individual-Year T-Statistic	−4.297	0.778	−0.862	2.476	−0.553
T-Statistic of Average over Years	−4.128	1.684	−0.342	6.849	−1.211

Volatility (Figure I) is strongly associated with *both* favorable and unfavorable mortality. This is no surprise for the unfavorable case; high volatility leads to trouble with a greater frequency. It would also appear, however, that highly volatile firms might be more tempting targets, even abstracting from firm size.[15]

Finally, the firm's beta during the previous year (Figure J) has a generally negative association with favorable mortality, holding constant the other variables. *Ceteris paribus*, low-beta firms seem more likely to be merged, exchanged or liquidated. There is a less significant connection between beta and unfavorable mortality.[16]

Predicting Longer-Term Mortality

The results presented thus far have included predictions of mortality only over the shortest observation interval, one year. Evidence about the effectiveness of predicting cumulative mortality over a longer period is given in Table II, which contains results for four five-year, non-overlapping, prediction intervals. A multivariate logistic regression was calculated between the cumulative mortality rate over five years and the predictor variables for a single base year.

Size is still statistically significant for both types of mortality. Return and beta are no longer significant for *either* mortality type. Variance is still strongly related to unfavorable mortality (positively), but is only marginally significant for favorable mortality. Price is still significant for favorable mortality, but it has been weakened, and it remains insignificant for unfavorable mortality.

Accounting for Announcement Bias

As we have noted, we are suspicious of the apparent predictive ability of the price and return variables. Their power for both unfavorable and favorable mortality could derive in part from announcements about pending mortality events *prior* to the end of the base year.

A high return and high price in the base year predict favorable mortality, while a low return and low price predict unfavorable mortality. Perhaps pending events are sometimes announced before year-end but are not consummated until after the New Year. We would make a mistake by counting them as mortalities in the second year, because the fact of their pending demise was actually known in the first year.

In order to test whether such a possibility is responsible for the predictive power of return and size (or even of the other variables), we repeated the multivariate predictive tests, skipping an entire year between the base year and the mortality year. We measured price, return, size, variance and beta as of the end of, say, 1981, and we used them to predict mortality during calendar year *1983*, skipping 1982 entirely and eliminating from the sample firms that disappeared during 1982. This eliminated events announced in 1981 and consummated in 1982. Of course, we would expect the predictive power of *all* the variables to be reduced to some extent, because the predictions are now delayed by at least one entire year. Table III gives the results.

Size remains an extremely potent predictor of mortality, both favorable and unfavorable. This is all the more impressive because firm share data are often missing from the CRSP database and thus the size variable includes fewer observations.

Price still predicts favorable mortality, at least if one is willing to accept the t-statistic calculated from the average over years as a measure of significance. It remains insignificant for unfavorable mortality.

Return still predicts unfavorable mortality to some extent, yet its power is greatly reduced

Table III Multiple Regressions of Mortality on Predictor Variable Ranks, with One Year Skipped Between Predictor Measurement Year and Mortality Measurement Year

T-Statistic	*Size*	*Price*	*Return*	*Variance*	*Beta*
Effect on Total Mortality					
Average Individual Year T-Statistic	−2.629	1.269	−0.449	1.171	−0.362
T-Statistic of Average over Years	−9.783	5.786	−1.219	3.176	−0.773
Effect on Favorable Mortality					
Average Individual Year T-Statistic	−1.978	1.289	0.401	0.525	−0.144
T-Statistic of Average over Years	−9.687	5.853	1.174	1.149	0.088
Effect on Unfavorable Mortality					
Average Individual Year T-Statistic	−1.683	−0.025	−1.152	0.937	−0.357
T-Statistic of Average over Years	−7.233	−0.390	−3.227	4.068	−1.727

and it no longer has *any* predictive ability for favorable mortality.[17] Our suspicions about this variable were apparently well founded: The relation between return in a base year and favorable mortality in the immediately subsequent year is probably attributable to mergers and other favorable mortality events announced before the end of the base year.

What is perhaps surprising is the weakening of total variance as a predictor of mortality. It is still significant for unfavorable mortality but is no longer positively associated with favorable mortality. Perhaps its prior significance can be ascribed to the same cause: Favorable announcements in the base year may increase *measured* volatility.

Finally, beta is no longer significant for either favorable or unfavorable mortality. Its previous power was more limited than the other variables, and even that may have been attributable to an announcement bias. It seems possible that the beta measured during the base year was reduced toward zero as nonsystematic announcement events lowered the correlation between firm and market returns. Thus, low-beta firms were more likely the subjects of mortality-related announcements that preceded the end of the base year. ■

Footnotes

1. W. Beaver, "Financial Ratios as Predictors of Failure," *Empirical Research in Accounting: Selected Studies, Supplement to Journal of Accounting Research* 5 (1966), pp. 71–111.
2. The ratios were cash flow/total assets, net income/total assets, total debt/total assets and, especially, cash flow/total debt. The last had predictive powers even as early as five years before the event.
3. E. Altman, "Financial Ratios, Discriminant Analysis and the Prediction of Corporate Bankruptcy," *Journal of Finance*, September 1968, pp. 589–609.
4. These were working capital/total assets, retained earnings/total assets, earnings before interest and taxes/total assets, market value equity/book value of total debt, and sale revenue/total assets.
5. E. Deakin, "A Discriminant Analysis of Predictors of Business Failure," *Journal of Accounting Research*, Spring 1972, pp. 167–179.
6. H. Diamond, Jr., "Pattern Recognition and the Detection of Corporate Failure" (Ph.D. dissertation, New York University, 1976).
7. E. Altman, R. Haldeman and P. Narayanan, "Zeta Analysis, a New Model to Identify Bankruptcy Risk of Corporations," *Journal of Banking and Finance*, June 1977, pp. 29–54. They capitalized all noncancellable operating and financing leases. Interest was assigned to liabilities, contingency reserves were added to equities, minority interest was deducted from assets and nonconsolidated subsidiaries were consolidated by pooling. The economic values of goodwill and other intangibles were written off against equities. Capitalized interest, capitalized research and development and deferred charges were deducted from earnings. The 27-variable set was limited to seven discriminating variables using stepwise exclusion.
8. J. Ohlson, "Financial Ratios and Probablistic Prediction of Bankruptcy," *Journal of Accounting Research*, Spring 1980, pp. 109–131.
9. Friction in the trading process may bias estimates of the market model beta parameter. In order to avoid estimation error, we used the beta estimator of K. Cohen, G. Hawawini, S. Maier, R. Schwartz and D. Whitcomb ("Friction in the Trading Process and the Estimation of Systematic Risk," *Journal of Financial Economics*, August 1983, pp. 263–278) with five leads and lags.
10. These results are consistent with several previous studies of firm capitalization. J. Horrigan ("The Determination of Long-Term Credit Standing with Financial Ratios," *Empirical Research in Accounting: Selected Studies, Supplement to Journal of Accounting Research* 6 (1966), pp. 44–62) found

that size was an important determinant of bond ratings, presumably reflecting the rating agencies' awareness that size predicts unfavorable mortality. Dun & Bradstreet reveal that the frequency of failure per 1,000 firms is lower for larger firms. Ohlson ("Financial Ratios," *op. cit.*) found that size was an important predictor of bankruptcy (although his measure differs from ours). J. Warner ("Bankruptcy Costs: Some Evidence," *Journal of Finance*, May 1977, pp. 337–347) and J. Ang, J. Chua and J. McConnell ("The Administrative Costs of Corporate Bankruptcy: A Note," *Journal of Finance*, March 1982, pp. 219–226) provide evidence that suggests that direct bankruptcy costs appear to constitute a smaller proportion of a firm's value as value increases. Relatively large firms also tend to have more diversified lines of business and are therefore less prone to bankruptcy if one line should fail.

11. For example, if we rank firms by market price at the end of each year, the number of shares data missing from the lowest-price decile is 26.1 per cent on average, while it is only 2.01 per cent in the highest-price decile.
12. But this may be attributable to absence of share data for small firms and a concomitant reduction in predictive power for the size variable.
13. This is consistent with several bankruptcy theories. The Gambler's Ruin model used in several studies (see, e.g., W. Feller, *An Introduction to Probability Theory and Its Applications* (New York: Wiley, 1968) and J. Vinso, "A Determination of the Risk of Ruin," *Journal of Financial and Quantitative Analysis*, March 1979, pp. 77–100) and alternative models (see, e.g., J. Scott, Jr., "The Probability of Bankruptcy: A Comparison of Empirical Prediction and Theoretical Models," *Journal of Banking and Finance*, September 1981, pp. 317–344) suggest that variance should be an effective predictor of bankruptcy (i.e., be an efficient predictor of delisting, halting or suspension). R. Castanias ("Bankruptcy Risk and Optimal Capital Structure," *Journal of Finance*, December 1983, pp. 1617–1636) demonstrated that a positive relation between variance and default will obtain if firms' earnings are normally distributed.
14. The regression equations have the following form:

$$\ln[p/(1-p)] = \mathbf{XB},$$

where p is the mortality probability for one year, **X** a vector of ranks (for size, price, etc.) and **B** a vector of coefficients. Thus $(dp/p)/d\mathbf{X} = (1-p)\mathbf{B}$, the percentage change in mortality probability given an increase in rank of one place, is **B** times the survival probability $(1-p)$.

15. Remember that size was also included in the regression.
16. However, the t-statistic of the average coefficient over all years still indicates statistical significance.
17. Based on the t-statistic of the average over years.

Appendix
Mortality Tables

Size (Market Capitalization) at End of Previous Year—Total Mortality

Years

Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	8.0	14.4	20.2	25.2	29.9	34.0	37.7	40.9	43.6	45.9	48.3	50.1	51.7	53.8	55.8	57.5	59.1	61.2	62.2	63.1	65.0	67.1	66.9
2	5.5	11.4	16.5	21.3	26.2	30.9	34.6	37.8	41.3	43.9	46.4	49.0	51.9	54.7	56.8	58.5	60.6	61.7	63.1	64.5	66.9	66.4	67.6
3	5.7	11.0	16.1	20.9	25.3	29.0	32.2	35.3	38.1	41.1	43.1	45.1	47.4	48.7	50.8	53.6	56.9	60.0	62.7	65.0	64.6	66.4	69.0
4	4.8	9.4	13.7	17.9	22.0	25.8	29.5	32.7	35.6	37.8	40.0	42.7	45.5	47.8	50.1	53.1	55.4	57.4	59.3	61.4	62.4	63.7	66.2
5	4.5	9.2	13.5	17.8	21.2	24.8	27.7	30.9	33.8	36.6	39.3	41.1	42.7	44.1	47.7	49.4	51.7	54.6	57.5	58.7	61.9	63.8	64.8
6	4.9	9.6	13.5	17.5	21.4	24.5	27.3	29.3	31.4	34.0	36.1	38.0	39.8	41.7	44.6	47.9	50.8	54.3	55.8	58.2	60.3	62.1	62.1
7	3.8	7.5	11.1	14.8	18.1	20.9	23.2	25.2	26.9	28.4	30.2	32.0	33.9	36.2	38.8	42.0	44.7	47.0	49.6	52.8	55.2	57.0	56.6
8	3.2	5.7	8.1	10.6	13.2	15.4	17.2	18.9	20.5	21.8	23.4	24.8	26.8	28.5	30.3	32.7	35.3	37.7	40.1	42.1	44.0	44.8	45.5
9	1.8	3.4	5.4	6.8	8.2	9.5	10.6	11.5	12.4	13.4	14.2	16.0	17.6	18.9	20.7	22.5	24.1	25.5	26.7	27.3	28.4	29.8	32.4
10	1.0	1.9	2.6	3.5	4.2	5.0	5.5	6.0	6.5	7.1	7.7	7.9	8.2	8.6	9.2	10.2	11.5	13.2	14.4	15.8	16.8	17.9	20.0

Size (Market Capitalization) at End of Previous Year—Favorable Mortality

Years

Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2.6	5.2	7.9	10.2	12.4	14.2	15.9	17.4	18.7	20.0	21.4	22.8	24.4	26.0	27.0	28.0	28.8	29.6	30.4	31.1	32.6	34.7	35.7
2	3.7	7.4	10.8	14.0	17.1	20.0	22.2	23.8	25.6	27.1	28.4	30.5	32.8	35.3	36.7	37.6	38.8	39.5	40.6	42.1	43.7	43.4	41.4
3	4.2	8.1	11.7	15.3	18.4	21.0	23.4	25.5	27.4	29.4	30.9	32.2	33.7	34.6	36.2	38.9	42.0	45.2	46.5	48.0	47.8	49.2	53.8
4	4.0	7.6	11.0	14.0	17.1	20.0	22.4	24.7	26.8	28.4	29.7	31.8	34.2	36.6	38.4	40.8	42.6	44.5	46.7	47.8	48.3	50.4	53.1
5	3.9	7.5	10.8	14.1	16.7	19.4	21.6	23.8	25.8	27.6	29.6	31.0	32.5	33.9	37.1	38.1	39.5	41.7	44.3	45.6	47.9	49.2	51.0
6	4.0	8.0	11.3	14.4	17.6	20.0	22.1	23.3	24.6	26.4	28.1	29.8	31.3	33.1	35.5	38.6	41.4	44.7	46.3	48.6	51.0	53.2	53.1
7	3.4	6.7	9.7	12.9	15.5	18.0	19.8	21.4	22.7	23.9	25.1	26.3	27.8	30.0	32.4	35.4	38.1	40.7	43.1	45.8	48.3	50.4	50.3
8	3.0	5.2	7.4	9.6	12.0	13.7	15.2	16.6	17.9	18.9	20.1	21.1	23.0	24.5	26.2	28.5	31.0	32.8	34.8	36.2	37.5	38.2	39.3
9	1.8	3.3	5.1	6.5	7.6	8.8	9.9	10.6	11.4	12.1	12.9	14.6	16.2	17.5	19.3	20.9	22.5	23.9	25.3	26.3	27.7	29.2	31.7
10	1.0	1.8	2.5	3.3	3.9	4.6	5.1	5.5	6.0	6.7	7.2	7.5	7.8	8.2	8.8	9.7	11.0	12.7	13.7	15.2	16.1	17.3	19.3

Size (Market Capitalization) at End of Previous Year—Unfavorable Mortality

Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	5.2	8.9	12.0	14.7	17.1	19.3	21.3	23.0	24.5	25.7	26.7	27.1	27.0	27.6	28.5	29.4	30.2	31.5	31.5	31.8	31.9	31.8	30.5
2	1.8	3.8	5.5	7.0	8.7	10.5	12.1	13.6	15.4	16.7	17.8	18.3	19.0	19.3	20.1	20.9	21.7	22.2	22.5	22.4	23.2	23.0	26.2
3	1.5	2.7	4.3	5.5	6.7	7.8	8.6	9.6	10.5	11.5	12.1	12.7	13.5	13.9	14.4	14.4	14.8	14.6	15.9	16.8	16.8	17.2	15.2
4	0.7	1.7	2.5	3.6	4.6	5.6	6.8	7.6	8.4	9.1	9.9	10.6	11.1	11.0	11.4	12.0	12.5	12.7	12.4	13.5	13.8	13.3	13.1
5	0.5	1.6	2.5	3.5	4.3	5.3	6.0	6.9	7.8	8.7	9.5	10.0	10.2	10.2	10.6	11.2	12.0	12.9	13.1	12.9	14.0	14.6	13.8
6	0.9	1.5	2.1	3.0	3.7	4.3	5.0	5.8	6.6	7.3	7.7	7.9	8.3	8.5	9.0	9.2	9.4	9.4	9.5	9.6	9.3	9.0	9.0
7	0.4	0.8	1.4	1.9	2.5	2.9	3.3	3.7	4.0	4.3	4.9	5.4	5.9	6.0	6.1	6.4	6.6	6.4	6.5	7.0	6.9	6.6	6.2
8	0.1	0.4	0.7	1.0	1.2	1.7	2.0	2.3	2.6	2.9	3.3	3.7	3.7	3.9	4.1	4.2	4.3	4.9	5.3	5.9	6.5	6.6	6.2
9	0.1	0.1	0.2	0.3	0.5	0.7	0.8	0.9	1.1	1.3	1.3	1.4	1.4	1.4	1.4	1.6	1.6	1.6	1.3	0.9	0.6	0.7	0.7
10	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7

(Years)

Price at End of Previous Year—Total Mortality

Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	9.4	16.7	22.5	28.0	33.0	37.6	41.3	44.5	47.5	50.4	53.1	55.6	58.0	61.0	63.5	66.0	68.2	71.1	73.1	74.6	75.4	75.4	77.4
2	4.5	9.6	15.6	20.7	26.2	31.3	35.8	40.4	44.4	47.9	51.4	54.7	57.6	59.9	62.1	63.9	65.9	67.0	68.8	70.4	72.6	73.8	74.1
3	4.6	10.5	15.6	20.8	25.6	29.5	33.7	37.5	41.3	44.1	47.2	50.1	53.0	55.4	57.8	59.8	61.4	64.2	65.7	66.9	68.5	72.8	76.1
4	4.4	9.3	14.4	19.1	23.4	27.9	31.6	35.3	38.3	41.1	43.8	46.4	48.8	51.5	54.0	57.0	60.4	63.1	65.3	66.6	68.0	69.7	70.7
5	4.4	9.1	13.7	17.5	21.5	25.3	29.0	31.5	34.0	37.1	39.0	40.3	42.1	44.0	46.4	48.9	51.2	54.1	56.6	59.2	61.0	62.9	66.8
6	3.9	8.1	11.8	15.9	19.8	23.4	26.4	29.1	31.7	33.7	36.1	38.2	40.0	41.6	43.8	47.0	49.9	53.6	58.2	59.7	62.1	65.3	65.4
7	4.0	7.7	11.5	15.3	18.4	21.3	23.7	25.8	28.0	30.3	31.9	34.5	36.5	39.0	41.8	43.8	46.6	49.5	51.5	55.2	59.3	59.2	62.0
8	3.9	7.1	10.6	13.8	16.7	18.7	20.2	22.1	24.5	26.6	29.0	30.9	33.3	35.2	37.0	39.4	42.2	43.7	45.3	48.0	48.2	50.2	50.7
9	3.8	6.7	9.3	12.0	14.2	16.0	18.0	19.8	21.1	22.7	24.8	27.0	29.2	31.1	32.6	35.1	36.9	38.0	38.4	38.7	40.8	43.7	45.9
10	3.7	5.9	7.4	9.3	10.8	12.4	13.8	14.7	15.9	17.8	19.2	20.9	22.4	23.8	25.5	27.4	28.9	30.8	32.0	33.4	34.2	34.5	37.1

(Years)

Price at End of Previous Year—Favorable Mortality

Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2.3	4.5	6.5	8.5	10.4	12.2	13.5	14.6	15.7	17.0	18.1	19.9	21.6	23.2	24.6	25.8	27.2	28.5	29.4	30.6	30.9	31.5	33.7
2	2.7	5.7	9.1	12.1	15.1	17.8	19.9	22.1	23.9	25.7	27.8	29.1	30.8	32.0	32.7	33.5	34.6	35.6	36.8	38.0	39.0	38.3	34.6
3	3.4	7.4	10.8	14.1	17.3	19.8	22.2	24.1	26.3	27.7	29.0	30.5	32.1	33.6	35.2	36.5	37.1	38.8	39.4	39.9	40.4	43.9	45.4
4	3.3	7.1	10.5	13.7	16.6	19.6	21.8	24.3	26.1	27.5	28.7	30.5	31.7	33.5	35.3	37.4	39.4	40.9	42.3	43.1	44.9	45.4	45.9
5	3.7	7.5	11.2	14.0	17.1	20.0	22.8	24.2	25.7	27.5	28.6	28.9	29.8	31.1	33.5	35.3	37.5	39.6	41.4	43.2	43.8	44.7	47.8
6	3.3	6.6	9.5	12.8	15.6	18.4	20.6	22.8	24.5	25.6	27.1	28.7	30.2	31.5	33.2	36.2	38.9	42.0	46.2	47.0	48.2	51.4	52.7
7	3.6	6.8	9.7	12.6	15.1	17.2	18.8	20.3	21.8	23.4	24.5	26.5	28.0	30.3	32.9	34.8	37.5	40.1	41.8	44.9	48.9	48.8	51.2
8	3.3	6.1	9.1	11.9	14.2	15.7	16.6	18.1	20.0	21.7	23.5	25.0	27.3	28.9	30.6	32.7	35.0	36.8	38.4	40.3	40.3	41.7	42.4
9	3.3	5.8	8.0	10.2	12.0	13.4	15.2	16.5	17.4	18.5	20.1	22.1	24.1	25.9	27.3	29.4	31.1	32.5	32.7	33.0	34.2	37.1	37.6
10	3.4	5.2	6.5	7.9	9.2	10.5	11.6	12.3	13.1	14.5	15.8	17.1	18.3	19.3	20.7	22.3	23.6	25.7	26.7	27.7	28.6	28.6	30.2

(Years)

Price at End of Previous Year—Unfavorable Mortality

Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	6.9	11.8	15.7	19.2	22.2	25.1	27.5	29.8	31.7	33.4	35.0	35.8	36.4	37.8	38.8	40.2	41.0	42.6	43.7	44.0	44.5	44.0	43.8
2	1.8	3.8	6.3	8.4	10.9	13.4	15.6	18.0	20.2	21.9	23.3	25.3	26.7	27.8	29.3	30.3	31.2	31.5	32.0	32.1	33.3	35.2	39.5
3	1.2	2.9	4.5	6.3	8.0	9.4	11.1	12.9	14.5	16.1	17.9	19.3	20.7	21.5	22.5	23.2	24.2	25.4	26.2	27.0	28.2	28.6	30.2
4	1.1	2.2	3.8	5.2	6.6	8.1	9.5	10.8	12.0	13.5	14.8	15.8	16.9	17.8	18.5	19.4	20.8	22.0	22.8	23.4	23.1	24.3	24.9
5	0.7	1.5	2.4	3.3	4.0	4.9	6.0	7.0	8.0	9.1	10.0	11.0	12.0	12.7	12.8	13.5	13.7	14.5	15.1	16.0	17.1	18.2	19.0
6	0.6	1.5	2.3	3.1	4.0	4.8	5.5	6.2	7.0	7.8	8.7	9.2	9.6	10.0	10.3	10.7	10.9	11.5	11.9	12.6	13.8	13.8	12.7
7	0.4	0.9	1.6	2.5	3.3	4.0	4.8	5.4	6.1	6.8	7.4	8.0	8.5	8.6	8.8	8.9	9.1	9.3	9.6	10.3	10.4	10.4	10.7
8	0.5	0.9	1.3	1.7	2.4	2.9	3.4	3.8	4.4	4.8	5.4	5.8	6.0	6.2	6.4	6.6	7.2	6.9	6.9	7.6	7.9	8.5	8.3
9	0.4	0.8	1.3	1.7	2.1	2.4	2.7	3.2	3.6	4.1	4.5	4.8	5.0	5.1	5.2	5.6	5.8	5.5	5.7	5.7	6.6	6.6	8.3
10	0.3	0.6	0.9	1.3	1.5	1.8	2.1	2.4	2.7	3.1	3.3	3.7	4.0	4.4	4.7	5.1	5.2	5.2	5.3	5.7	5.6	5.8	6.8

(Years)

Return During Previous Year—Total Mortality

Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	6.9	13.2	18.9	23.7	28.3	32.7	36.6	40.2	44.4	47.5	50.3	52.1	53.5	55.1	57.3	59.7	60.3	63.0	69.6	71.0	73.9	75.0	78.7
2	3.8	8.8	13.9	18.0	22.3	25.7	29.3	32.4	35.6	38.7	41.5	43.4	45.8	47.4	50.2	52.0	53.2	56.1	60.4	62.5	66.6	70.1	69.8
3	3.3	7.4	11.5	15.9	19.5	23.0	26.2	29.4	31.8	34.7	37.5	40.8	43.1	44.2	46.7	48.4	49.5	53.2	56.2	57.7	62.2	63.8	63.4
4	3.2	7.6	12.2	15.9	19.3	22.8	25.9	28.7	32.0	34.9	37.5	40.0	42.6	44.6	47.2	48.7	50.0	54.0	56.6	57.2	60.1	60.7	64.4
5	3.4	7.4	11.0	14.7	17.9	20.8	23.5	26.1	28.5	31.2	33.2	35.5	37.1	39.3	42.1	44.1	46.2	49.8	50.9	52.0	52.3	55.1	58.5
6	3.9	7.5	11.5	14.7	18.5	21.6	24.9	27.4	30.3	32.3	34.4	36.8	38.8	41.7	42.9	45.6	48.1	50.5	51.9	54.1	52.5	55.4	62.0
7	4.0	8.1	11.6	15.6	19.1	22.7	24.9	27.4	29.3	31.3	33.9	36.1	38.6	41.5	43.1	45.7	49.0	49.0	49.3	50.7	51.8	54.4	59.0
8	5.0	8.9	12.5	16.1	19.8	23.2	25.5	27.9	29.4	31.3	33.4	35.8	38.5	40.1	42.5	45.4	48.6	50.1	50.6	53.5	53.3	53.9	55.6
9	5.8	9.9	13.4	17.3	20.6	23.7	26.7	29.1	31.0	33.0	35.0	36.9	39.4	41.8	43.9	47.1	51.0	53.2	52.5	55.8	56.6	56.8	55.6
10	7.2	11.4	15.4	19.7	23.6	26.4	29.0	31.4	33.8	36.1	38.1	40.8	43.3	46.2	48.4	51.4	55.3	55.9	57.1	58.3	60.6	62.1	59.0

(Years)

Return During Previous Year—Favorable Mortality

Rank	Years 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.7	4.2	7.1	9.4	12.1	14.5	16.4	17.3	19.6	21.2	22.4	23.7	24.8	26.4	27.5	29.1	30.0	30.2	33.3	34.8	35.2	34.2	33.8
2	2.1	5.3	8.2	10.7	13.4	15.4	17.4	19.5	21.6	23.2	24.7	25.8	27.3	28.7	30.8	32.5	33.5	34.8	37.1	39.3	40.9	41.7	39.0
3	2.3	4.9	7.4	10.5	12.9	15.2	17.5	19.5	21.1	22.8	24.4	26.1	27.3	28.1	30.3	32.4	34.1	36.4	37.7	37.8	41.3	42.7	41.5
4	2.4	5.7	9.0	11.5	13.8	16.2	18.2	20.0	22.0	24.1	25.9	27.4	29.5	31.4	33.7	34.5	35.6	38.8	40.5	41.4	42.0	42.7	43.4
5	2.5	5.5	8.3	11.0	13.4	15.5	17.3	18.8	20.2	22.1	23.2	25.0	26.3	27.9	30.2	31.5	33.4	36.5	37.0	37.6	40.0	42.0	46.8
6	2.9	5.6	8.5	11.0	13.5	15.6	18.1	19.9	21.7	23.1	24.6	26.0	27.7	30.0	30.6	32.9	34.4	36.5	37.5	38.9	38.0	40.8	48.3
7	3.3	6.5	8.9	12.0	14.5	17.3	18.5	20.1	21.3	22.5	24.2	25.8	27.7	29.3	30.5	32.7	35.3	35.6	36.8	37.5	39.5	42.0	46.8
8	4.0	7.3	10.1	12.8	15.4	17.6	19.0	20.8	21.4	22.1	23.3	25.2	27.2	28.3	30.3	32.6	35.0	36.8	37.2	39.7	38.9	39.8	42.4
9	4.8	8.1	10.8	13.5	15.9	17.8	19.6	21.2	22.1	23.5	25.0	26.1	27.9	29.2	30.7	32.9	35.5	37.7	38.7	40.5	41.4	40.8	39.5
10	6.3	9.4	12.2	15.3	17.4	18.9	20.4	21.5	22.8	24.0	25.1	26.7	27.8	29.6	31.0	32.6	34.7	36.6	39.3	39.9	41.8	44.4	39.5

Return During Previous Year—Unfavorable Mortality

Rank	Years 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	5.1	8.6	11.5	14.0	15.9	17.8	20.0	22.6	24.5	26.0	27.6	28.2	28.4	28.4	29.6	30.3	30.1	32.6	36.0	36.1	38.6	40.7	44.9
2	1.6	3.5	5.5	7.1	8.7	10.1	11.6	12.7	13.8	15.3	16.7	17.6	18.5	18.6	19.3	19.5	19.6	21.3	23.3	23.3	25.7	28.4	30.7
3	0.9	2.5	4.0	5.3	6.4	7.5	8.5	9.6	10.5	11.6	13.1	14.4	15.5	15.8	16.2	15.8	15.4	16.8	18.5	19.7	20.6	20.6	21.5
4	0.8	1.8	3.1	4.3	5.3	6.5	7.5	8.5	9.7	10.6	11.4	12.3	13.0	13.3	13.5	14.2	14.4	15.3	16.0	15.8	18.1	18.0	21.0
5	0.9	1.8	2.6	3.6	4.4	5.2	6.0	7.2	8.2	9.0	9.9	10.4	10.7	11.2	11.8	12.6	12.8	13.3	13.8	14.2	12.3	13.1	11.7
6	1.1	1.9	2.8	3.6	4.8	5.7	6.6	7.3	8.3	9.0	9.6	10.6	10.9	11.6	12.2	12.7	13.7	14.0	14.4	15.1	14.6	14.6	13.7
7	0.6	1.6	2.6	3.6	4.5	5.3	6.3	7.2	7.9	8.7	9.6	10.2	10.8	12.1	12.5	13.0	13.7	13.4	12.5	13.2	12.3	12.4	12.2
8	0.9	1.6	2.4	3.3	4.3	5.5	6.3	7.0	7.8	9.0	9.9	10.5	11.2	11.8	12.1	12.7	13.5	13.3	13.3	13.7	14.2	14.1	13.2
9	0.9	1.7	2.5	3.7	4.6	5.8	6.9	7.7	8.7	9.4	9.9	10.7	11.5	12.6	13.1	14.2	15.5	15.4	13.8	15.3	15.2	16.0	16.1
10	0.9	1.9	3.1	4.3	6.0	7.4	8.5	9.7	10.8	12.0	12.9	14.0	15.4	16.6	17.3	18.7	20.5	19.1	17.7	18.4	18.9	17.7	19.5

Volatility During Previous Year—Total Mortality

Rank	Years 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2.1	3.9	5.8	8.0	9.7	11.4	13.1	14.8	16.5	18.1	19.3	20.4	22.7	24.4	26.2	28.1	30.0	32.6	34.9	35.1	37.5	38.4	44.0
2	2.2	4.9	7.2	9.4	11.5	13.6	15.6	16.6	18.4	20.8	23.1	25.1	26.6	28.0	30.5	32.6	35.2	37.7	40.0	41.9	43.6	48.1	54.1
3	3.5	6.5	9.7	12.7	15.7	18.7	20.7	22.9	24.4	26.5	28.4	30.7	32.2	35.0	36.7	38.8	41.3	44.3	45.9	48.7	50.6	54.6	54.1
4	3.9	8.0	11.7	15.3	18.9	21.8	24.5	27.4	30.0	32.2	34.6	36.7	39.0	40.8	43.9	46.6	49.9	52.0	54.4	55.3	56.6	58.0	57.6
5	4.2	8.9	13.1	17.0	20.6	24.3	27.6	30.0	32.3	34.3	36.9	39.7	42.2	44.7	47.2	50.5	52.8	54.7	57.4	59.9	59.8	59.5	58.5
6	5.4	9.9	14.7	19.3	23.9	27.3	30.7	34.1	36.9	39.8	41.3	43.3	46.1	48.1	50.9	52.7	55.1	57.0	58.2	60.8	63.8	64.1	64.4
7	5.4	10.6	15.5	20.3	24.4	28.5	32.1	35.2	38.8	41.3	44.0	46.6	49.4	51.2	52.9	55.3	57.3	60.9	62.7	64.5	66.2	67.7	70.7
8	4.8	9.9	14.8	20.0	24.5	29.0	32.7	36.0	39.1	41.9	44.5	47.4	49.2	51.9	53.8	56.8	58.9	61.1	63.6	65.3	67.0	68.9	68.8
9	5.7	11.2	16.8	21.9	26.6	31.0	34.7	38.7	41.9	45.0	48.6	51.4	54.5	56.6	58.8	60.4	62.7	65.0	67.0	69.2	71.4	73.1	76.6
10	9.4	16.7	22.9	28.2	33.4	37.5	41.1	44.6	48.0	51.6	54.6	57.2	59.3	61.5	63.9	66.8	68.7	69.9	71.5	72.8	74.2	75.7	77.6

Volatility During Previous Year—Favorable Mortality

Rank	Years 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.5	2.8	4.1	5.7	7.2	8.5	9.9	11.3	12.6	13.6	14.5	15.3	17.2	18.7	20.2	21.6	22.9	24.8	26.5	27.1	28.8	29.6	32.4
2	1.9	4.1	6.0	7.8	9.5	11.2	12.6	13.3	14.7	16.6	18.1	19.7	20.9	21.8	23.8	25.5	27.4	29.3	30.6	32.2	33.9	36.9	42.4
3	2.8	5.3	7.9	10.4	12.8	15.4	16.9	18.5	19.7	21.3	22.8	24.4	25.7	28.2	29.3	31.1	32.9	35.3	36.7	38.7	39.7	43.7	42.9
4	3.3	6.7	9.6	12.5	15.5	17.5	19.7	21.8	23.6	25.2	27.0	28.8	30.7	32.1	34.7	37.1	39.8	41.2	43.6	43.9	45.2	45.6	45.9
5	3.5	7.3	10.7	13.7	16.4	19.1	21.6	23.2	24.9	26.0	27.3	29.4	30.9	33.0	35.1	38.1	40.7	41.8	44.1	46.1	46.3	44.9	41.5
6	4.7	8.2	12.1	15.4	18.7	20.9	23.1	25.2	26.8	28.6	29.3	30.4	32.3	33.9	35.8	37.4	39.3	41.0	41.7	44.0	45.3	46.8	48.3
7	4.6	8.7	12.0	15.7	18.7	21.5	23.5	25.4	27.4	28.5	30.3	31.9	33.6	34.5	36.2	38.1	39.4	42.5	43.6	44.6	46.1	47.1	49.8
8	3.8	7.6	10.8	14.4	17.1	19.7	21.9	23.8	25.4	26.8	28.3	29.8	30.8	32.7	33.7	36.1	38.4	40.9	43.3	43.9	45.2	45.9	43.9
9	3.8	7.3	10.8	13.7	16.6	19.1	20.9	22.8	24.2	25.6	27.1	28.8	30.7	32.2	33.2	33.8	35.0	37.0	38.1	39.5	39.3	39.3	43.4
10	2.4	4.6	6.7	8.5	10.0	11.2	12.3	13.4	14.8	16.5	18.0	19.5	20.9	21.8	23.8	25.0	25.9	26.2	27.0	27.7	29.1	31.3	30.7

Volatility During Previous Year—Unfavorable Mortality

Rank	Years 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.6	1.1	1.6	2.1	2.4	2.7	3.1	3.3	3.8	4.3	4.7	5.1	5.4	5.7	6.1	6.6	7.1	7.8	8.4	8.1	8.7	8.8	11.6
2	0.3	0.8	1.1	1.6	2.0	2.3	2.9	3.3	3.7	4.2	4.8	5.4	5.6	6.1	6.7	7.2	7.8	8.4	9.4	9.8	9.6	11.2	11.7
3	0.7	1.1	1.8	2.3	2.8	3.3	3.7	4.3	4.7	5.1	5.5	6.1	6.4	6.7	7.3	7.6	8.4	9.0	9.3	10.0	10.9	10.9	11.2
4	0.6	1.3	2.0	2.8	3.4	4.2	4.7	5.5	6.4	7.0	7.5	7.9	8.3	8.7	9.2	9.5	10.1	10.9	10.8	11.3	11.4	12.4	11.7
5	0.7	1.6	2.4	3.3	4.1	5.0	5.8	6.5	7.2	8.1	9.3	10.1	11.0	11.5	12.0	12.3	11.9	12.9	13.2	13.8	13.5	14.6	17.1
6	0.7	1.7	2.6	3.8	5.0	6.2	7.3	8.4	9.6	10.8	11.6	12.5	13.5	14.0	14.9	15.2	15.7	15.9	16.3	16.7	18.4	17.2	16.1
7	0.8	1.9	3.3	4.4	5.5	6.8	8.3	9.6	11.2	12.5	13.5	14.6	15.7	16.6	16.5	17.1	17.7	18.3	19.0	19.6	20.0	20.6	21.0
8	1.0	2.2	3.8	5.5	7.3	9.0	10.5	11.9	13.4	14.7	16.0	17.4	18.2	19.0	19.8	20.3	20.3	20.1	20.3	21.4	21.6	22.6	24.4
9	1.8	3.7	5.8	8.0	9.7	11.7	13.6	15.7	17.5	19.2	21.3	22.5	23.6	24.3	25.6	26.6	27.7	27.9	28.7	29.6	32.0	33.7	33.2
10	6.7	11.6	15.8	19.3	22.9	25.9	28.5	31.0	33.1	35.0	36.5	37.6	38.4	39.6	40.1	41.7	42.7	43.7	44.6	45.1	45.1	44.4	46.8

Beta During Previous Year—Total Mortality

Rank	Years 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	6.5	11.0	14.4	17.9	20.5	23.2	25.1	27.6	29.5	32.1	34.0	35.3	37.6	39.7	42.9	46.2	49.2	54.2	56.9	61.1	64.9	68.0	74.1
2	4.2	8.0	11.6	14.5	17.7	19.9	22.4	23.8	25.9	28.4	30.5	32.7	35.8	37.2	40.0	42.5	45.7	48.7	51.0	52.0	53.8	55.9	58.6
3	4.0	7.3	10.5	13.7	17.0	20.0	22.7	24.9	26.9	29.1	31.7	34.2	36.1	37.9	39.8	41.8	44.4	45.3	47.7	49.9	52.8	54.2	52.2
4	4.4	8.3	12.5	15.8	19.7	22.5	24.9	27.1	29.4	31.5	33.7	36.2	38.5	41.0	43.6	46.3	49.2	50.9	52.9	52.8	53.8	54.6	53.2
5	4.1	8.0	11.9	16.2	19.1	22.8	25.9	28.7	30.8	32.7	34.5	37.3	39.5	42.0	43.3	44.7	46.9	49.9	51.9	54.2	54.3	57.6	64.0
6	4.4	8.8	13.1	17.4	21.5	24.8	28.0	31.1	33.4	35.4	37.6	40.3	42.7	45.4	47.5	50.2	53.5	55.1	55.4	58.3	59.1	60.3	64.0
7	4.2	9.1	13.3	17.8	21.2	24.5	27.4	30.3	33.7	36.5	39.0	41.3	43.4	45.7	48.0	50.2	52.8	54.2	57.0	58.0	59.7	58.1	61.1
8	4.6	9.5	14.3	18.7	22.5	26.6	29.8	33.0	36.1	38.6	41.0	43.6	45.3	46.9	48.5	51.4	52.4	54.7	57.8	58.2	57.2	58.8	57.1
9	4.8	9.7	14.6	19.6	24.4	28.5	32.4	35.4	38.7	41.7	44.7	46.6	48.3	51.2	53.6	55.4	56.7	59.6	61.3	63.8	66.7	69.1	68.5
10	5.5	10.7	16.0	20.6	25.8	30.1	34.2	38.2	41.6	45.1	48.2	50.9	53.4	54.9	57.1	59.4	60.1	62.0	63.0	64.2	67.4	70.3	73.4

Beta During Previous Year—Favorable Mortality

Rank	Years 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	4.3	7.2	9.0	11.2	12.8	14.4	15.4	16.8	17.8	19.0	19.6	20.1	21.8	23.3	25.1	27.3	28.7	31.6	33.8	36.0	38.8	38.6	42.5
2	3.1	5.7	8.2	10.2	12.5	14.0	15.7	16.5	17.9	19.5	20.9	22.3	24.7	25.8	27.6	29.6	31.5	33.1	34.4	33.9	34.7	36.5	36.9
3	3.2	5.5	7.7	10.0	12.4	14.4	16.3	17.6	18.9	20.0	21.8	23.4	24.9	26.3	28.1	28.9	30.9	32.1	33.5	35.9	37.1	38.0	36.0
4	3.4	6.3	9.4	11.8	14.5	16.5	17.9	19.4	21.0	22.4	23.9	25.6	27.3	29.0	30.5	32.0	34.1	34.7	36.0	36.1	36.1	34.8	33.5
5	3.1	6.1	9.4	12.5	14.7	17.2	19.5	21.4	22.6	23.8	24.8	26.4	28.3	29.9	31.2	32.4	33.4	36.4	37.8	39.5	40.7	43.9	48.3
6	3.3	6.4	9.6	12.5	15.5	17.5	19.6	21.6	23.0	24.2	25.7	27.6	29.2	31.1	33.2	35.6	38.1	39.2	39.8	41.7	42.7	46.3	50.2
7	2.8	6.5	9.7	13.0	15.6	17.7	19.4	21.2	23.3	24.9	26.5	28.2	29.6	31.7	32.9	35.2	37.8	39.0	41.3	43.0	44.6	42.4	41.4
8	3.4	7.1	10.4	13.4	15.8	18.9	20.8	22.7	24.2	25.5	26.7	28.2	29.2	30.7	32.2	34.7	36.0	38.1	40.7	41.0	39.9	40.2	38.9
9	3.3	6.5	9.5	12.7	15.7	18.2	20.5	22.2	24.2	25.8	27.5	28.8	29.7	31.6	33.7	35.3	36.7	39.4	40.8	43.1	45.6	48.0	50.7
10	2.4	5.1	7.8	10.5	13.0	15.2	17.2	19.1	20.8	23.2	25.2	26.9	28.4	29.3	30.8	32.3	33.7	35.8	36.4	36.8	38.3	42.2	43.8

Beta During Previous Year—Unfavorable Mortality

Rank	Years 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2.1	3.7	5.2	6.5	7.5	8.6	9.6	10.6	11.6	13.0	14.3	15.0	15.8	16.4	17.7	19.0	20.5	22.6	23.0	25.1	26.0	29.4	31.6
2	1.1	2.2	3.4	4.2	5.2	5.8	6.6	7.2	7.9	8.9	9.6	10.4	11.1	11.5	12.4	12.9	14.2	15.7	16.6	18.1	19.1	19.4	21.7
3	0.8	1.8	2.8	3.6	4.5	5.5	6.2	7.1	7.9	8.9	9.7	10.7	11.1	11.4	11.8	12.8	13.5	13.3	14.2	14.1	15.7	16.2	16.3
4	1.0	2.0	3.1	4.0	5.1	5.9	6.8	7.5	8.2	8.9	9.7	10.6	11.2	12.0	13.1	14.2	15.1	16.2	16.9	16.7	17.6	19.8	19.7
5	0.9	1.7	2.4	3.6	4.3	5.4	6.3	7.3	8.1	8.8	9.7	10.8	11.1	12.1	12.0	12.2	13.4	13.4	13.9	14.5	13.6	13.7	15.8
6	1.1	2.4	3.4	4.8	5.8	7.0	8.2	9.2	10.1	11.0	11.7	12.5	13.2	14.2	14.1	14.6	15.4	15.9	15.6	16.5	16.3	14.0	13.8
7	1.3	2.5	3.5	4.7	5.5	6.6	7.8	8.9	10.3	11.3	12.3	12.9	13.5	13.8	14.9	15.0	14.9	15.2	15.6	15.0	14.9	15.5	19.7
8	1.1	2.4	3.9	5.2	6.5	7.5	8.8	10.1	11.7	12.9	14.1	15.3	16.0	16.1	16.3	16.6	16.3	16.5	17.0	17.1	17.2	18.6	18.2
9	1.5	3.0	4.8	6.6	8.4	10.0	11.7	13.1	14.3	15.7	16.9	17.6	18.4	19.4	19.7	19.9	19.8	20.1	20.4	20.7	21.1	20.8	17.2
10	2.9	5.4	7.9	9.7	12.4	14.5	16.6	18.7	20.4	21.5	22.7	23.6	24.8	25.4	26.1	27.0	26.3	26.0	26.4	27.3	29.1	28.2	29.6