Joint Risk of DB Pension Underfunding and Sponsor Termination: Incorporating Options-Based Projections and Valuations into PIMS

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1. Introduction

When a plan sponsor with an underfunded plan becomes insolvent, the difference between the value of the plan's assets and its termination liabilities represents a liability for the Pension Benefit Guaranty Corporation. Hence, accurately modeling the joint statistical distribution over time of defined benefit pension underfunding and sponsor terminations (henceforth referred to as defaults) is critical for estimating PBGC's prospective cash flows and evaluating its financial position.

Modeling that joint distribution in a stochastic model such as PIMS could be accomplished in a variety of ways. In choosing between modeling approaches, considerations include whether salient statistical properties of historical data can be matched, whether the approach is conceptually sound, tractability, transparency, and auditability. Also important is whether the approach provides the information needed to answer important questions about the financial position of the PBGC, the value of the insurance it provides, and how those quantities would be affected by various types of policy changes.

Based on the documentation made available to reviewers, it appears that the current approach in PIMS to modeling the joint risk of underfunding and default does a reasonable job of capturing its statistical properties and its effects on the distribution of projected PBGC cash flows, although some aspects of the implementation might be improved and it would be helpful if the metrics provided to evaluate performance were expanded.

Most importantly, the current approach has a fundamental but correctable shortcoming – it does not allow PIMS to be used to answer questions about valuation of future streams of cash flows.[1] Currently PBGC does not disclose information on the fair value of prospective costs and revenues on its financial or budgetary accounting statements, although it reports the value of assets and liabilities from trusteed plans on a fair value basis. Moving to a modeling strategy in PIMS that accommodates fair value estimation of prospective cash flows, and reporting those results, would allow policymakers and the public to evaluate the overall financial condition of PBGC on a consistent and economically interpretable basis.[2]

In what follows, I outline how an options-based approach to modeling the joint distribution of defaults and underfunding in PIMS might be implemented while preserving the strengths of the current model. Moving to an options-based approach would allow PIMS to be used to estimate fair values of future liabilities. The changes also would simplify and make more transparent some aspects of risk modeling, while preserving PIMS detailed modeling of other system features such as firm-level liabilities and their evolution, demographics, and program rules for the size and timing of benefit payments. It is likely that such changes would have a significant effect on the perceived financial position of PBGC. For example, CBO (2005) reported that valuing PBGC's prospective net liabilities using an options-based approach doubled their estimated value relative to discounting the same expected liabilities at Treasury rates, as is PBGC's current practice.

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[1] However, PIMS is used to calculate actuarial present values based on discounting with Treasury rates.

[2] See Lucas (2012) for a more complete discussion of fair value estimates for federal guarantee programs.

2. Options-based Approach to Projecting and Valuing Future PBGC Cash Flows

Pension insurance is a type of put option. Specifically, pension insurance gives a firm that sponsors defined benefit pension plans the right to "put" or transfer their underfunded plans to the PBGC in the event that it becomes insolvent, in exchange for annual premiums. As such, sponsor financial distress and plan underfunding are the two key determinants of PBGC's prospective costs.

Future sponsor failures, plan underfunding, and stock market performance are correlated events. Those correlations have a first-order effect on the value of PBGC insurance, and also they affect the distribution of PBGC's prospective cash flows. When the pace of economic activity slows, firm revenues, stock market values and interest rates all tend to decline. These changes increase both the probability of financial distress for sponsors and plan underfunding. The more severe a downturn, the greater the likely number of failures and the extent of underfunding in plans insured by PBGC. The correlation between downturns and high-cost periods for the PBGC is also strengthened by the fact that, as sponsors become more distressed, they are less likely to make required pension contributions, and that the PBGC will tend to experience lower recovery rates during downturns. Some of those correlations can be clearly seen in historical data on bond defaults and recovery rates on bonds. For example, Figure 1 shows the positive correlation between corporate bond defaults and the business cycle and the negative correlation between recovery rates and the business cycle. Figure 2 shows that those relationships are particularly pronounced for speculative-grade firms (those rated below investment grade).

Figures 1 and 2 here

The correlations between sponsor failures, plan under-funding, and stock market performance have important implications for valuing PBGC's prospective cash flows. Because future liabilities of the PBGC will tend to be relatively high during economic and stock market downturns, and relatively low when times are good, and because the value of economic resources is higher in downturns than in upturns, the fair or market value of those liabilities is higher than the present value of expected future liabilities currently reported by the PBGC (which do not account for the cost of correlated risk). The fair value of future premium payments also is affected by market risk, but there are two partially offsetting effects: Premium collections have tended to rise during downturns because the variable portion of premiums on average increases. However, during downturns it is more probable that sponsors would fail to make required premium payments.

The discrepancy between fair value estimates and the present value estimates that PBGC currently reports arises from the choice of discount rates. Specifically, the current PIMS procedure uses Treasury rates for calculating discounted values. Present values derived using Treasury rates are often described as "actuarial present values," which differ from fair or market values because they neglect the effect of market risk on value. Specifically, the discount rates that the market would use to calculate the value of future PBGC payouts to beneficiaries is lower than the 30-year Treasury rates (increasing the present values of those prospective cash outflows), and the discount rates the market would apply to insurance premiums are higher (decreasing the present value of those prospective cash inflows).

The most important benefit of an options-based approach is that it generates fair value estimates for PBGC insurance and other cash flow streams such as premium payments – implicit in an options-based approach is a set of market discount rates that properly value prospective

PBGC cash flows. Although an options-based approach may initially seem more complicated than alternative approaches to risk-adjusting discount rates, an options-based approach has the advantage of reliability. Attempts to infer market discount rates using other approaches tend to be more difficult and error-prone. A further benefit of an options-based approach is that it provides a relatively parsimonious framework for projecting defaults and underfunding, but one that has enough flexibility to capture the time path, volatility and correlation structures of those quantities that are observed in aggregate time series data and cross-sectional firm data.

PBGC insurance is sometimes referred to as a “compound put option” because PBGC is liable for a company's pension obligations only if the company is bankrupt *and* if its dedicated pension assets fall short of the value needed to cover vested pension obligations (see Figure 3). That is, the plan can be significantly underfunded with no ultimate cost to the PBGC if the plan assets increase to cover the liabilities before the firm fails. Conversely, fully or overfunded plans still represent a risk to the PBGC because future declines in plan asset value or increases in liability value can cause it to become underfunded.

Figure 3 here

Compound put options cannot be accurately valued using standard options pricing models like the Black Scholes Merton model. However, advances in numerical options-based modeling of default probabilities, (along the lines of Crosbie and Bohn 2003), and the implementation of a related stochastic “risk-neutral” valuation model for PBGC by the Congressional Budget Office (described in CBO 2005), demonstrate the feasibility of using an options-based model for the PBGC while maintaining a realistic representation of many of the programs’ complexities.

In options-based approaches to default modeling, a key insight is that firm default is also a type of put option. When the market value of a firm's assets fall below some trigger point (usually represented as a function of the firm's short and long-term liabilities), it is in the interest of the firm's shareholders to default rather than to honor the liabilities. Thus the likelihood of default depends on the statistical properties of the firm's assets and liabilities, which in turn may depend on other variables such as the performance of the aggregate stock market. Plan assets, some of which are typically invested in the stock market or in assets correlated with the stock market, are also exposed to stock market risk. Figure 4 gives an example of the evolution of a firm's asset values that ultimately ends in insolvency. Figure 5 shows the hypothetical evolution of plan assets over the same period. In the example of Figures 4 and 5, even though the firm is insolvent PBGC experiences no loss because plan assets exceed termination liabilities. Options-based approaches effectively look at the costs to PBGC across all possible joint paths of firm assets and plan assets.

Figures 4 and 5 here

A complete explanation of how default probabilities and underfunding levels are linked to aggregate stock market realizations and other variables in an options-based approach is beyond the scope of this report, although I would be pleased to discuss specific alternatives for implementation in more detail with PBGC staff. At an abstract level, those linkages are captured in a natural way by explicitly linking the probability distribution of the future financial condition of sponsors (importantly, firm market asset values and leverage) and plan funding levels with the stochastic path of realizations of stock market outcomes, calibrated so as to reproduce the joint distribution of defaults and underfunding seen in historical data. Differences across firms are generated by modeling stochastic firm-specific shocks that are uncorrelated with market returns and that reflect the firm-specific volatilities implied by market data. The correlation between individual sponsors and the market will vary depending on the sponsor's estimated equity and asset betas (which are measures of correlation with the market).

For a more complete description of an options-based implementation that follows that logic and that seems to me to be satisfactory in most respects, see Appendix C of CBO (2005). Yet, as discussed below, a shortcoming of CBO's (2005) model relative to the current PIMS implementation is that pension liability growth is not carefully modeled, and CBO assumes that liability growth is uncorrelated with market conditions. It would be feasible and desirable to combine PIMS more detailed modeling of plan liabilities with an options-based approach to modeling defaults and underfunding.

3. Comparison with PIMS Modeling Approach

To evaluate the changes to PIMS that would be necessary to incorporate into it an options-based approach to valuing future cash flows, it is useful to take an inventory of the similarities and differences between the current PIMS implementation and an options-based approach.

The two approaches share fundamental similarities in their structures and logic. Those include the fact that both are calibrated to make key economic and demographic variables and stochastic driving processes consistent with historical statistics. The simulated paths of the variables predicted by the model are generated using those calibrated stochastic shock processes. Some shocks are assumed to be independent across firms and across time, while others are correlated. Both models calculate future PBGC liabilities along each simulation path firm-by-firm, with the outcome dependent on whether a firm meets the conditions for default and on its pension funding level when it defaults. Stochastic probabilities of firm defaults are correlated with plan underfunding and with an aggregate variable related to the health of the economy. Both approaches also incorporate the rules that determine premium contribution rates and payouts to plan participants.

There are also key differences between the two approaches. For one, whereas many variables and shocks are used as inputs into the statistical model of bankruptcy probabilities used in PIMS, the options-based approach generally abstracts the various sources of uncertainty into two: (1) a common shock which is the priced portion of which is related to aggregate stock returns, and (2) an idiosyncratic firm-specific shock. In an options-based approach, there are more explicit linkages over time in the behavior of each sponsor's financial condition and funding status: The common and idiosyncratic shocks affect the evolution over time of a firm's asset values and liability values, and plan asset and plan liability values. (In principle it would be possible to include additional shocks in an options-based model as long as they are assumed to represent risks not priced by the market.)

Under the options-based approach, the explicit dependence of firm funding levels and default events on a common aggregate shock to stock returns in the options-based model allows the various cash flows of interest (e.g., future liabilities and premium payments) to be derived as functions of the realizations of aggregate stock market returns. That relationship allows the cash flows to be valued as stock market derivatives. Specifically, a standard approach can be used to calibrate a version of the model in terms of so-called "risk-neutral probabilities." The fair value of PBGC's future obligations can then be calculated based on the expected values of future cash flows, weighted by their risk-neutral probabilities, discounted to the present at the risk-free rates in the model.

4. Implications of Moving to Options-based Approach

We next highlight some of the important implications of moving to an options-based approach. As described above, the fundamental differences from the current PIMS approach would be to (1) change the modeling of the relation between asset returns, funding levels and sponsor default probabilities; and (2) incorporate the market price of risk through the asset returns process in present value calculations. Apart from those two differences, the comparisons described below are on an "all else equal" basis: Quantities such as the mean and variance of asset returns, portfolio composition, the statistical properties of future liabilities and so forth are assumed to be the same as in the current PIMS implementation. The purpose of implicitly holding other assumptions fixed in the discussion here is to facilitate comparisons; I have not attempted here to evaluate the reasonableness of most of those assumptions.

A. The fair market rate for discounting future payouts is less than the risk-free rate because of the market risk associated with the put options written by PBGC. The **present value of prospective PBGC liabilities therefore would be significantly higher** than PIMS estimates, which currently use Treasury rates for discounting future benefit payments. Correspondingly, the implied **insurance premiums that would need to be collected from sponsors in order to cover those liabilities would be higher**.

<u>Discussion.</u> Currently PBGC discounts its liabilities for future benefits with interest factors that, together with the mortality table used by PBGC, approximate the price in the private-sector annuity market at which a plan sponsor or PBGC could settle its obligations. Under an option-based approach, that practice would still be used for liabilities arising from plans that had already been terminated, and possibly for probable terminations. For liabilities already incurred, discount

rates based on annuity rates generate fair value estimates of liability values. However, applying annuity rates to prospective liabilities produces estimated costs that are significantly lower than the fair value costs of those liabilities. Hence, the lower effective discount rates associated with an option-based approach would only apply to projections of contingent liabilities arising from future insolvencies of underfunded plans.

The effect of using options-based (market) discount rates would be to significantly increase the present value of liabilities arising from future plan terminations, and to increase the fair value insurance premiums for active plans (i.e., the premiums that would need to be charged to cover the liabilities). The probable magnitude of those effects was illustrated in CBO (2005), which compared the present value of prospective liabilities of the PBGC in 2005, using market discount rates versus Treasury rates over horizons ranging from 10 to 20 years. The effect of taking the cost of market risk into account was to approximately double the present value costs (see Table 1). Translating that effect into premiums, the fair value premium would be roughly double the estimated breakeven premium estimated using Treasury rates.[3]

Table 1 here

B. The **investment policy** that would reduce the risk of PBGC's exposure to future losses **would involve a short position in the stock market**, or equivalently the purchase of stock market put options.

Discussion. Adopting an options-based approach in PIMS would underscore the observation made by a number of financial experts, that PBGC's current policy of investing a significant

[3] The precise mapping from estimates of the present value of liabilities to the adjustment needed to premium rates to recover the present value is more complicated because it would take into account the correlation of premium collections with market conditions.

portion of the assets it manages in the stock market has the effect of doubling down on stock market risk, increasing the volatility of PBGC's net position and the risk to taxpayers, and reducing transparency. For already-terminated plans or probable terminations, PBGC would minimize its risk by investing in primarily in bonds with durations matched to its pension liabilities. To hedge against the risk of future underfunded plan terminations, the options-based approach implies taking a short position in the stock market, for instance by using S&P index futures or buying S&P put options.

C. Volatility in PBGC's reported financial condition that arises from individual sponsor moving in and out of the group identified as creating a "reasonably possible exposure" could be eliminated if that portion of PBGC's financial reports were replaced with options-based estimates of the present value of future losses.

<u>Discussion.</u> The options-based approach could be used as an alternative to the current statistics reported by PBGC on its "reasonably possible" exposure. Under our alternative, rather than identifying at-risk sponsors by a variety of criteria (such as below-investment grade credit ratings or missed minimum funding contribution), the potential future liabilities from all sponsors (based on analysis of those above some threshold size) could be taken into account each year. Estimates of future exposure would be less volatile because, whereas attributes like credit ratings or missed payments move in discrete jumps, the factors that affect the probability and severity of a plan terminating tend to vary more smoothly with market conditions. It should be noted that the volatility in reported financial condition associated with identifying specific at-risk firms also would be reduced by using PIMS current approach to estimating the value of future liabilities.

At the same time, adoption of an options-based approach would not preclude identification and analysis of sponsors that represent pending terminations and probable losses.

In fact, a separate analysis of those plans (as is done now) is clearly important for disclosing the near-term developments likely to significantly affect PBGC's financial position.

5. Conclusions

Incorporating an options-based approach into PIMS for estimating the joint distribution of default probabilities and underfunding, and using the model to infer market discount rates for valuing PBGC insurance, would improve the information available to policymakers and the public on PBGC's finances. This would also make PIMS a more versatile tool for policy analysis. Most importantly, it would provide fair value estimates of the value of PBGC insurance, a quantity not now provided by the PBGC. Such a change appears to be technically feasible, and it would build on the existing strengths of PIMS in incorporating detailed modeling of prospective benefit obligations and program rules.

In terms of the technical feasibility of moving to an options-based approach, PIMS already utilizes stochastic simulation to project cash flows, and its logic takes into account the statistical correlations between variables that are assumed to drive sponsor default probabilities and underfunding. The main technical change that would be required in PIMS would be to reengineer the statistical processes driving those key quantities to link them more explicitly to a model of stock market risk. The resulting distributions of defaults and underfunding, both at the plan and aggregate levels, would be calibrated to be consistent with historical data, both cross-sectional and time series. With that change in the characterization of the driving statistical process, it would be straightforward to incorporate risk-neutral pricing of all PBGC cash flows, which in turn would make it possible to report on the market values of PBGC insurance, premium payments, and other cash flows associated with the program.

The main cost to PBGC of moving to an options-based approach would be the time and effort it would take to implement, test, document, and communicate the changes, and the risk that errors would be introduced. Those costs might be mitigated by the availability of information from the Congressional Budget Office (CBO) on how they implemented an options-based approach in a related model designed to evaluate the cost of prospective PBGC liabilities and policy options.

Finally, reviewers were tasked with answering three specific questions:

1. What improvements over the short and medium term might render the PIMS models more accurate in terms of the insurance function of the pension insurance system?
2. What improvements can be implemented in PIMS to make the models better-suited to alternative policy simulations (e.g., changes in premium structures, investment profiles, or funding rules)?
3. What new ways of communicating results would help stakeholders better understand the results?

In light of this analysis, my recommendations would be (1) make it a priority to develop the capacity to value on a fair value basis prospective cash flows using PIMS by implementing an options-based approach; (2) use that capacity to report the effects of policy changes on the system's fair value financial position; and (3) to replace the current present value estimates of reasonably possible losses and other quantities with fair value estimates in PBGC's financial reports and other publications.

Appendix: Comments on Specific Modeling Assumptions and Possible Alternatives

The purpose of this Appendix is to indicate some specific types of changes that could be made to the PIMS model that might generally improve the accuracy and transparency of the model, and that would facilitate a transition to an options-based approach to projecting and valuing future PBGC cash flows. My understanding of current modeling practices is primarily based on PBGC (2009); some statements from that document are included below in quotations. A caveat is that some of my comments may reflect misunderstandings of the documentation or the model, but it is hoped that those might point to places where current practices might be clarified.

In PIMS, the change in the log of nominal interest rates is modeled as an autoregressive process or a random walk. By contrast, modern models of interest rates generally feature mean-reversion. Section 5 defends assuming a random walk and expresses concern that a mean-reverting model would falsely push rates to historical levels. However, that long-run parameter can be chosen to correspond to the best available forecast given current and future expected policies as well as historical data.

More generally, for all PIMS input variables and model parameters, the forecasts employed should be as forward-looking as possible, informed by historical data but also taking into account structural changes in policies or the economy. The heavy reliance on historical regressions over very long historical periods should be reexamined, in light of recent changes for all key variables. For instance, academic and practitioner estimates of the equity premium have generally declined relative to historical averages.

In any case, if the real rate is held constant and only inflation varies, it would seem more sensible to directly statistically model the inflation process.

On the stock return, the disturbance term is "assumed to be drawn from the joint normal distribution of economy-level disturbances." The volatility of aggregate stock returns is a variable that can be measured fairly precisely, and it seem misleading to rhetorically equate it to economy-level disturbances in that real economic variables (e.g., employment, output, inflation) are much less volatile than the stock market. Getting the risk of stock returns right is important both for projecting levels of underfunding and for finding the fair value of PBGC liabilities (because they are contingent claims on the stock market). If the real interest rate is assumed to be constant, it seems inconsistent to assume that real stock returns could have a temporal drift. It appears that in the practical implementation described later in the documentation, stock returns are modeled as a random walk and volatility is consistent with historical data, which seems appropriate.

Estimating the evolution and distribution of firm employment over time is clearly important for calculating the distribution of termination liabilities. However, it seems to add unnecessary complexity to also use it as a determinant of firm bankruptcy probabilities. Whereas firms do tend to shed workers when they are distressed, the assumption about the random variable driving employment does not really add new information about bankruptcy probabilities, which ultimately must be calibrated to match empirical levels and correlations. Simulating firm cash flow as an indicator of financial health also seems like an unnecessary complication that captures a real world correlation, but one that is not helpful in the context of the model for improving on estimates of default rates. The distribution of future bankruptcies can be calculated using simpler methods that depend on fewer variables. Under a more parsimonious options-based approach, parameters can be calibrated to match historical probabilities of and cross-firm correlations of bankruptcy.

To implement an options-based approach, the modules used to calculate bankruptcy probabilities as described in equation (2-25) could be replaced by a structural model of bankruptcy probabilities as in CBO (2005). Such a model would depend on aggregate stock returns, the idiosyncratic risk associated with individual firms or industries' equity returns and firm asset betas, the firm's initial leverage, a model of leverage adjustments over time, and a rule for triggering bankruptcy based on the difference between estimated firm assets and firm liabilities. In that setup, model parameters can be adjusted to ensure that realized bankruptcy rates correspond to historical frequencies for firms of different credit ratings and other characteristics. Those same drivers would be used under an options-based approach to consistently model firm pension assets and the probability of underfunding for each firm over time. PIMS incorporates much more plan-specific information about pension liabilities, employee demographics, benefit payments, and so forth than does CBO, and that additional information could continue to be used to generate estimates of future liabilities that are likely to be more accurate than those from the more stylized CBO (2005) model.

"This value of firm equity is not directly used by any calculation of firm bankruptcy probability or pension funding." This is surprising in light of the fact that standard structural approaches to estimating bankruptcy rest heavily on firm equity value as an indicator of bankruptcy.

"Following previous models, PIMS uses plan sponsor data from the Compustat database. These data include time series on market assets, book debt, equity value, cash flow, employment, and industry affiliation." Compustat does not report the market value of assets because it does not estimate the market value of debt; those values must be estimated, for instance using an options pricing model as in CBO (2005).

The return on plan assets appears to be the same for all sponsors looking at the Chapter 2 description. But as noted in Chapter 5, actual investment policies vary across firms, with some taking more risk than others. To the extent that more at-risk firms follow riskier investment strategies, taking into account that source of heterogeneity would tend to increase projected PBGC liabilities and costs. Data on plan asset composition is available for many of the sponsors, particularly for the larger publicly-traded firms. It is not clear whether that information is incorporated into the model, or whether variation is randomly assigned. It seems relatively straightforward to incorporate actual differences across plans. And as others have noted, it would be sensible to expand the asset modeling to include a larger number of asset classes to better capture investment behavior by firms.

It is not clear that the approach of creating partner firms is the best way to capture the distribution of outcomes associated with smaller firms. An alternative would be to directly model key aspects and correlations of the drivers of liabilities, default rates, and underfunding for smaller firms, relying on available data for those types of firms and setting parameters to match historical outcomes in terms of default correlations, probabilities, funding levels, and so forth.

In Chapter 5 the critical model correlations generally are evaluated in terms of how they were inferred from historical data. That is useful information, but the critical question for evaluating the model is whether the critical model outputs, such as the distribution of (under)funding levels and the default rates for firms with different characteristics, are in line with historical data. That analysis occurs to some extent in Chapter 6, particularly for the critical bankruptcy estimates. What isn't reported and is less clear is whether the implied bankruptcy probabilities remain reasonable as the model is simulated forward. That is, the inputs into the logit model evolve for each firm over time, and it seems important to check that the distribution of bankruptcy rates for instance in the 10th year looks as reasonable as the distribution in the 2nd year of a simulation.

The discussion of mean reversion in the documentation is apparently inconsistent with PBGC's current practices. It states, "When applied to the firm equations, mean reversion processes have the additional complication that all firms revert to the same mean." In practice, PIMS does use mean reversion for firm ratios, and it uses different mean reversion levels in some cases (as for the financial industry).

It would be surprising if driving stochastic process for the model—the system of equations (5-4) to (5-10)–were stationary over the entire 70-year period that the estimates are based on (or even for the relatively volatile 1972-1998 period used to estimate some covariances). It would be helpful to provide information about parameter stability across sub-periods. The model seems to be used most often to make projections 10 years out. If parameter estimates do seem to vary across different historical periods, the best model for the next 10 years may be quite different than one estimated using 70 years of data.

The documentation notes that only a fraction of plan sponsors have credit rating data available, which limits the direct use of credit ratings and their transition probabilities as a way to evaluate bankruptcy probabilities. However, academic papers show that credit ratings can be predicted with a fair degree of accuracy from the types of data that are available in Compustat. Hence pseudo-ratings could be estimated for firms that could be used to evaluate whether the model-implied default patterns over time conformed to historical experience.

The introductory chapter of PBGC (2009) notes that pension insurance is related to a put option on the stock market, and it surveys the older literature on valuing PBGC insurance using an options-based approach. But this discussion fails to recognize is that it is possible to numerically implement an options-based approach to forecasting and valuing cash flows using more modern approaches, along the lines developed by Moody's KMV and implemented in CBO (2005)[4]. Those developments demonstrate the feasibility of an options-based approach that captures other important dimensions of system complexity. They also underscore the significant difference that approach makes in terms of implied valuations. It would be appropriate to include an updated version of that introductory discussion that notes those developments in future versions of PIMS documentation.

[4] See Crosbie and Bohn (2003) for a description of the KMV model. Hsieh et al. (1994), Marcus (1987), and Pennachhi and Lewis (1994) are older examples of options-based approaches.

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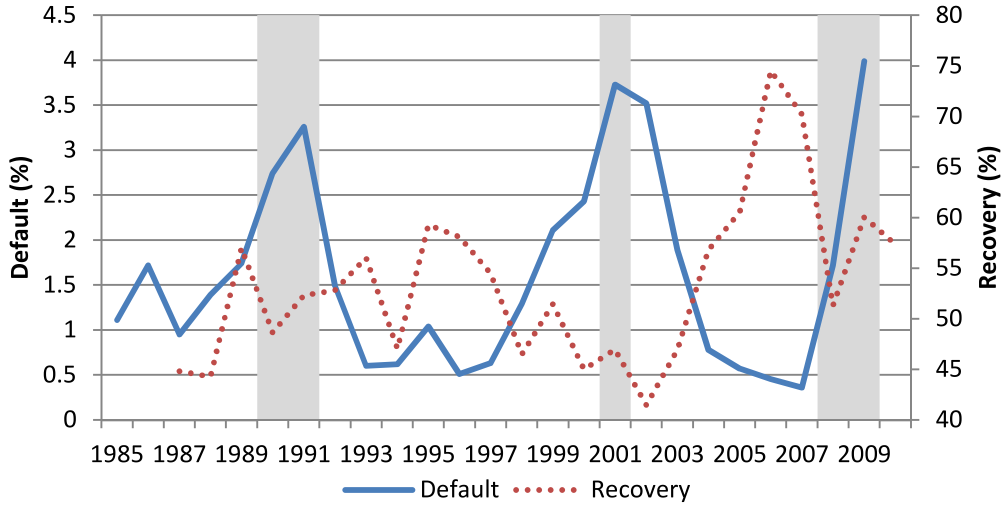

Figure 1. Corporate bond default and recovery rates. *Source:* Congressional Budget Office based on data from "Default, Transition, and Recovery: S&P 2009 Annual Global Corporate Default Study and Rating Transitions," Table 1 (March 2010), and data from Standard and Poor's CreditPro (1/28/11). Shaded areas indicate periods of recession as identified by the NBER.

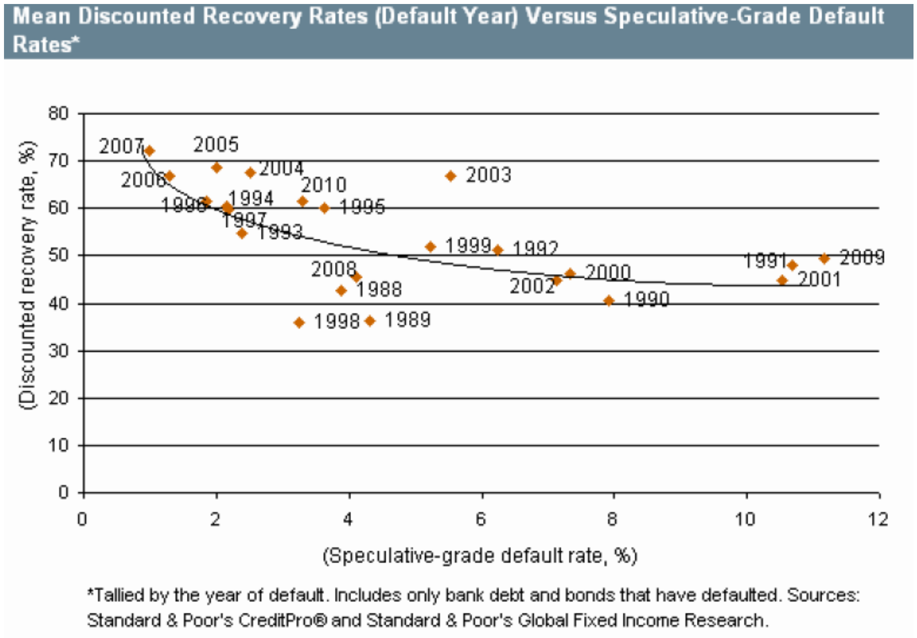

Figure 2. Mean discounted recovery rates (default year) versus speculative-grade default rates.

Sources: Standard & Poor's CreditPro® and Standard & Poor's Global Fixed Income Research.

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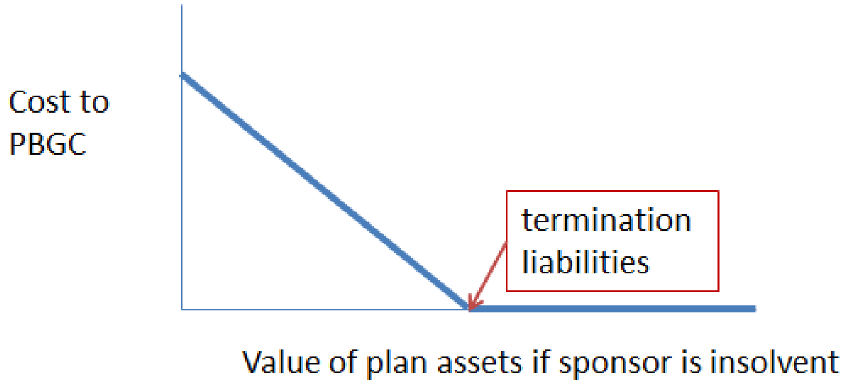

Figure 3. Insurance as a put pption. *Source:* Author’s elaboration.

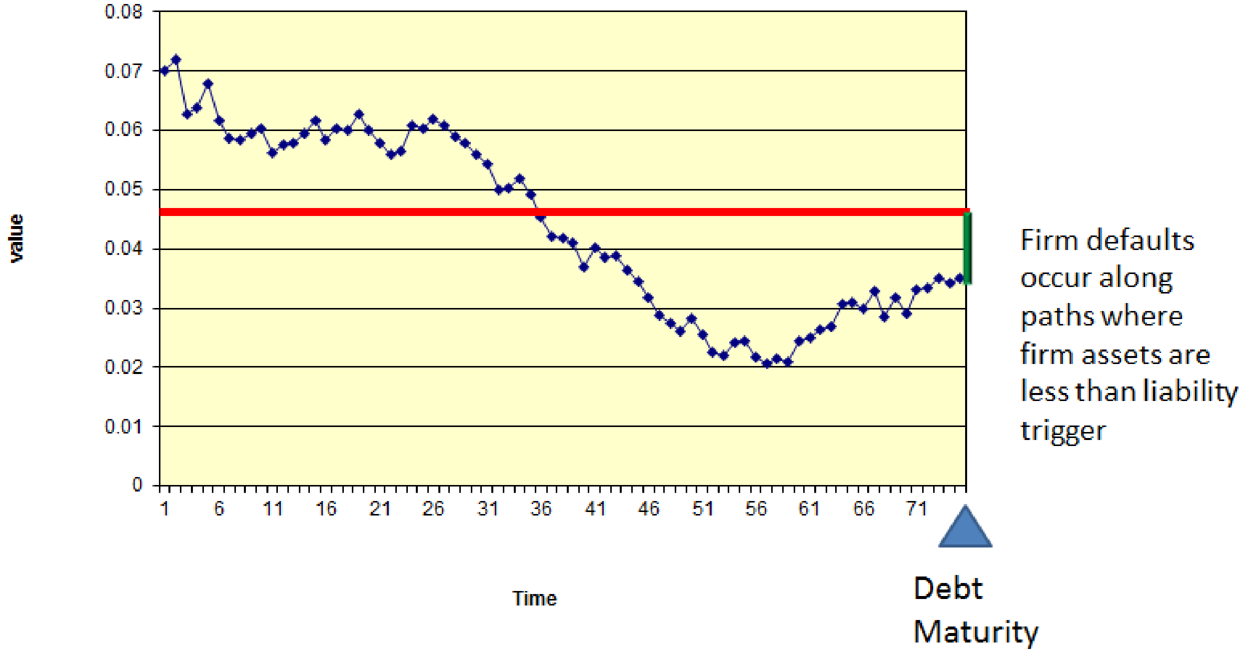

Figure 4. Sample time path of firm assets. *Source:* Author's elaboration.

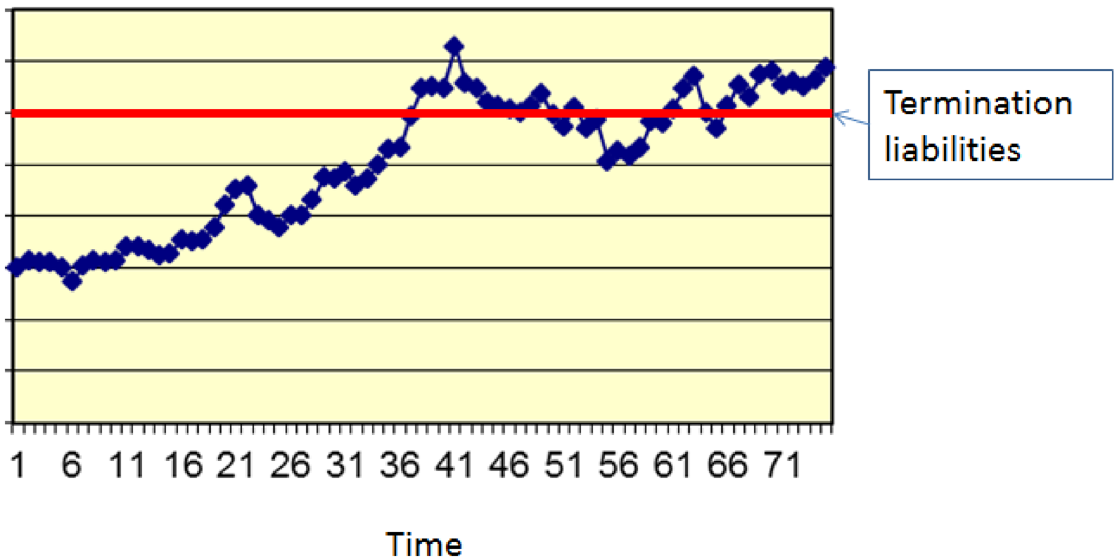

Figure 5. Sample time path of plan assets. *Source:* Author's elaboration.

Table 1 PBGC's Prospective Net Costs for Single-Employer Plans Over 10-, 15-, and 20-Year Horizons

PBGC's Prospective Net Costs for Single-Employer Plans Over 10-, 15-, and 20-Year Horizons

(Billions of dollars)

	Discounted Value at Treasury Rates, Excluding Cost of Risk	Market Value, Including Cost of Risk[a]
10-Year Net Costs	32.4	63.4
15-Year Net Costs	45.8	95.7
20-Year Net Costs	55.0	118.6

Source: Congressional Budget Office.

Notes: Numbers do not include the accumulated deficit

Discounting the average insurance loss at a Treasury rate yields the amount that, if invested in Treasury securities today, would grow to cover the average of future expenses. It is not, however, enough to pay an insurer to cover the cost of the entire distribution of future expenses, which is what the higher market-value cost represents.

a. Estimated price that a private insurer would charge, in addition to current premiums, to accept the obligations arising from terminations over the indicated time period.

Notes: Numbers do not include the accumulated deficit. Discounting the average insurance loss at a Treasury rate yields the amount that, if invested in Treasury securities today, would grow to cover the average of future expenses. It is not, however, enough to pay an insurer to cover the cost of the entire distribution of future expenses, which is what the higher market-value cost represents. *a*. Estimated price that a private insurer would charge, in addition to current premiums, to accept the obligations arising from terminations over the indicated time period.

Source: Congressional Budget Office (2005).