JANUARY 31, 2017

SUBTASK 4.4 REPORT

EVALUATION OF THE STOCHASTIC MODELING PROCESS

One of Three 18-Month Reports

IN-DEPTH TECHNICAL REVIEW OF THE PENSION BENEFIT GUARANTY CORPORATION'S MULTIEMPLOYER AND SINGLE-EMPLOYER PENSION MODELS

Prepared for:

Social Security Administration
6401 Security Blvd.
Baltimore, MD 21235
Contract SS00-15-30598

Prepared by:

FTI Consulting, Inc.
3 Times Square
New York, NY 10036

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Introduction

In July 2015, the Social Security Administration (SSA) engaged the FTI Consulting team (FTI) to conduct an 18-month, in-depth technical review of the Pension Benefit Guaranty Corporation's (PBGC) single-employer (SE) and multiemployer (ME) Pension Insurance Modeling System (PIMS). Task 4 of the Statement of Work (SOW) consists of 10 subtasks required for this in depth review - nine specific areas of review and a final report.[1] Three of the subtask reports are due at the end of each of the six-, 12- and 18-month periods. This report for Subtask 4.4, along with those for Subtasks 4.6 and 4.8, is due at the end of the 18-month period. As a part of our review of PIMS, this report documents our evaluation of the stochastic modeling process.

Given the ongoing evolution of the PIMS model, certain questions originally expected to be addressed under this subtask in the SOW for this project have been eliminated. These include items (e.g., market risk pricing) addressed in depth by prior audits, including the audit by Buck Consultants (http://www.pbgc.gov/documents/PIMS/ME-PIMS-Final-Report-2012.pdf) and the paper by Deborah Lucas (http://www.pbgc.gov/documents/PIMS/WP2013-16-Lucas.pdf).

We address the following key questions[2] raised in Subtask 4.4:

- There is a "partner" firm system in which each simulated firm has a number of "partner" firms that are in effect given parallel simulations. There also is a resampling setup under which 10 post-valuation simulations are carried out for each simulated plan valuation. Do these reweighing and re-sampling schemes successfully replicate the distribution that would be seen without these steps?
- What is your assessment of the consistency of assumptions about the same parameters used within each model and across the two models?

[1] Social Security Administration, Evaluation of the Pension Benefit Guaranty Corporation's Pension Models, Description/Specification/Work Statement, page 14.

[2] The SOW also asked "Is parameter uncertainty implemented correctly?" In our discussions with PBGC staff, we were informed that PIMS no longer models parameter uncertainty, and therefore we do not further address that question.

Authors and Contributors

Authors

Alok Khare, Ph.D., CFA, CAIA
FTI Consulting, Inc.

Liaw Huang, Ph.D., FSA, MAAA, EA, FCA
The Terry Group

Contributors

Stephen Prowse, Ph.D., CFA
FTI Consulting, Inc.

Glenn Meyers, Ph.D.
FTI Consulting, Inc.

John Moore, FSA, MAAA, FCA, EA
The Terry Group

Jeff Leonard, FSA, MAAA, EA
FTI Consulting, Inc.

Findings

Evaluation of Partner Firm System in SE-PIMS

Before presenting our findings, it is useful to briefly review the PIMS simulation approach and the related partner firm system – an ad hoc sampling approach unique to PIMS.

PIMS follows a two-stage "nested simulation" approach to arrive at a distribution of its future potential liabilities:

- Stage 1: Economic scenario generation using stochastic methods to capture systematic risk
- Stage 2: For each economic scenario, generation of multiple liability scenarios for the sample to capture idiosyncratic risk ("re-sampling")

The simulated sample comprises a) actual firms and b) artificial ("junior") partner firms assigned to **some** of the actual firms (also called "source" firms or "senior" partners) in the sample. Each junior partner is a scaled-down (20%) replica of the associated senior partner. The source firms are categorized into different strata based on the funding ratio of their largest-liability plan. The number of partners assigned to all source firms in a given stratum is the same, and depends upon the total liability of the firms not included in the sample and having funding ratios in that stratum.

In other words, source firm liabilities are "reweighted" through this ad hoc partner system, it being assumed that in any given funding-ratio stratum, the reweighted portfolio of firms is similar, in terms of all relevant characteristics, to the portfolio of firms NOT included in the sample.

In our opinion, cost considerations notwithstanding, use of this approach to extrapolate PBGC's insolvency risk is unlikely to produce results sufficiently applicable to assess insolvency risk of the full population of covered plans. Below we provide our recommendations to reduce the differences between the simulated and actual distributions of PBGC's future liabilities and net financial positions, and provide some added insight into the character of the simulated distribution.

Systematic Risk in the Simulated Distribution

1) We repeat two of our prior recommendations relevant for improving capture of systematic risk in the simulated distribution.
    - PBGC should consider improving processes that generate stock returns and interest rates by incorporating fat tails in the simulated distributions (Subtask 4.1 report, page 5).
    - PBGC should consider adding economy and industry wide contagion to its models for probability of bankruptcy (Subtask 4.3 report, page 6).
2) PBGC should implement more economic scenarios for improving capture of systematic risk in the simulated distribution.[3]

[3] In its feedback, PBGC noted that they agree with this recommendation and already have the goal of increasing number of simulated economic scenarios to 10,000 and will try to implement this in the redesign of PIMS.

Idiosyncratic Risk in the Simulated Distribution

1) To improve capture of idiosyncratic risk in the simulated distribution using the current partner firm system, PBGC should consider:

    - Developing a statistical criterion to determine the number of partner firms assigned to related source firms.

    - Allowing the size and number of partner firms in a funding ratio stratum to vary for better matching of the partner firms, in terms of all relevant characteristics, to the portfolio of firms NOT included in the sample.

    - Conducting periodic sensitivity analyses to assess the impact of using a static simulation sample that ignores voluntary plan terminations and plan freezes.

2) PBGC should update PIMS documentation to properly describe the claim examination process in PIMS code in the event of bankruptcy. Our review of the relevant PIMS code indicates that for each bankrupt firm, PIMS does the claim examination on a plan-by-plan basis. However, PIMS 2010 documentation notes that PIMS assumes that a sponsor would merge under- and overfunded plans in a bankruptcy and examines a firm's plans on an aggregate basis. In their comments, PBGC informed us that PIMS 2010 documentation is incorrect.

3) PBGC should consider increasing the number of firms in the sample to better capture idiosyncratic risk. For the firms not included in the sample, instead of using the present partner firm system, PBGC should consider using a "replicating" portfolio based on a methodology that has been well researched for its ability to replicate economic performance of the actual portfolio.

    - Given the speed at which computing hardware and methods are advancing, PBGC should consider adopting a regular medium-term review (say every three to five years) to examine the need to update and improve the simulation process and set aside resources for performing the updates, if needed.

Stress Testing

Irrespective of the simulation approach PBGC adopts, PBGC staff would work with a complex system, which can be difficult to explain to policy makers. Therefore, we recommend that PBGC should consider:

1) Supplementing PIMS with a stress testing module that computes PBGC's potential liabilities under (easily understood) deterministic adverse economic scenarios.[4]

    - For developing adverse economic scenarios, PBGC could start with a review of economic stress scenarios developed by large US banks under guidance of the Federal Reserve Bank. PBGC would need to supplement

[4] For related discussions on stress testing, see also Subtask 4.9 report, pages 36 – 37.

such economic scenarios with additional inputs such as stress (e.g., due to deregulation) in select industries important for assessing insolvency risk that PBGC faces.

- PIMS already has the capability to use pre-defined simple deterministic economic scenarios. A stress testing module can build on that capability to incorporate all parameters required in a full stress scenario.

2) Identifying economic conditions giving rise to large liabilities in stochastic simulation and comparing those conditions to stress scenarios that give rise to similar liabilities. This will help PBGC develop insights for a) likelihood and sources of future liabilities and b) updating its simulation methodology.

Evaluation of Consistency of Assumptions

PIMS is a microsimulation model built with an object-oriented programming language, which has several major programming components such as the economy, firms, plans, IRS and PBGC to model the dynamics of the pension insurance system. The appropriateness of the assumptions associated with different components is reviewed in the Subtasks 4.1, 4.2, and 4.3 reports. In this report, we do not address the appropriateness of the assumptions, but given the assumptions PIMS currently uses, we discuss the relationships between the assumptions in these components and determine whether they are integrated and internally consistent across different components and models within PIMS. Below are our findings:

1) Given the current modeling methodology PIMS uses, we find the assumptions generally consistent across different components. See the primary section on Evaluation of Consistency of Assumptions below for more details.

2) The linkage of economy-level, industry-level, and firm-level error components involves variances and correlations that may have significantly changed since they were estimated. PBGC should review these correlations in relationship to their impact on the bankruptcy probabilities.

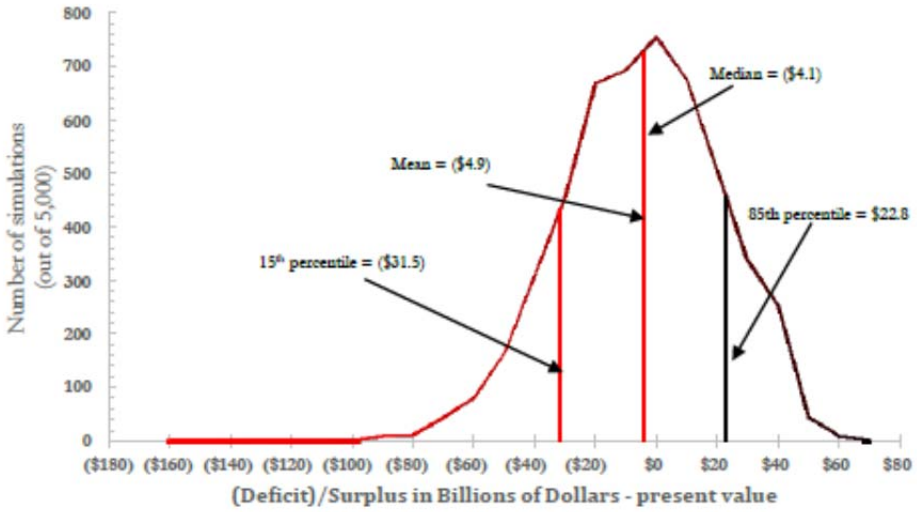
3) There are two areas of linkage that are systematically important for modeling the pension insurance system. The first area is asset-liability modeling and the second area is underfunding-bankruptcy modeling. Currently the PIMS modeling methodology has not reflected all the important interactions in these two areas. While PIMS assumptions are internally consistent in its current state, substantial work may be required to maintain consistency if PIMS were modified to implement our recommendations.

Evaluation of the Partner Firm System in SE-PIMS

Here, we review the partner firm system used in PIMS modeling of sponsor failure risk for SE plans to assess whether the system successfully replicates the distribution that would be seen without these steps.[5]

The figure below provides the simulated distribution reported in the PBGC FY 2014 Projections Report.

Figure – PBGC Potential 2024 SE Financial Position[6]



Current Practice

Stochastic Simulation

As PBGC recognizes:

> The events that PBGC insures against … have the possibility of catastrophic outcomes. There are two ways in which catastrophic loss levels can occur. First, in periods of poor equity returns, exposure and bankruptcies tend to increase, creating the potential for substantial claims. We call this **systematic, or market, risk**. Second, some companies can incur adverse financial conditions independent of market returns. Since many insured plans are very large, a small number of bankrupt plan sponsors can generate large claims. We call this **idiosyncratic, or random, risk**.
>
> Presumably, the probability of a catastrophic event is low, but the losses that could occur in these events arguably dominate PBGC's potential future costs.[7] [Emphasis added.]

[5] Our review is based on the model as described in Pension Insurance Modeling System, *PIMS System Description for PIMS SOA "Core" (vFY09.1), Version 1.0* Revised 9/22/2010 [henceforth "PIMS 2010 Guide"]. Confirmed by PBGC staff as still applicable at the time of this writing.

[6] PBGC FY 2014 Projections Report, page 33.

[7] 1998 Pension Insurance Data Book ("PBGC 1998 Data Book"), page 11.

PBGC uses PIMS, which is a stochastic simulation model, to arrive at its liabilities' distribution arising from both systematic and idiosyncratic risk. Technically, the simulation approach employed by PIMS can be thought of as a "Stochastic–on–Stochastic" or a nested simulation approach. The approach has two stages:

- Stage 1: Economic scenario generation using stochastic methods to capture systematic risk
- Stage 2: For each economic scenario, generation of multiple liability scenarios to capture idiosyncratic risk

PIMS simulation comprises 500 economic scenarios with each scenario representing "a random draw of economic experience over the chosen n years."[8]

For a given economic scenario, PIMS performs 10 different liability scenarios ("cycles") for all firms in the sample.[9] In other words, for the same economic scenario, bankruptcy experience for various firms in the sample varies across cycles. The sample comprises actual and artificial (or junior) partner firms associated with some actual firms in the sample. The firms, which have junior partners, are called source firms or senior partners.

At the beginning of each cycle in any scenario, a source firm and all of its junior partners have the same financial ratios in year zero but experience different financial outcomes over various years in the cycle.[10] With these simulated financial outcomes, the bankruptcies are simulated independently for each source firm and its partners. Since bankruptcy probabilities depend on the size of the firm, the partner firms, being 20% of the source firm, are more likely to go bankrupt than the source firm. Therefore, in any given year in a cycle, the bankruptcy probabilities of a source firm and its partner firms are different. Further, the bankruptcy probabilities also vary across cycles.

The Simulated Sample and the Partner Firm System

According to the PIMS 2010 Guide, "there are almost 10,000 PBGC-insured plans in the United States with at least 100 participants."[11] Of these (single-employer) plans, PIMS uses only about 4% of plans in its simulations due to "plan and plan sponsor data limitations and computational constraints."[12]

The plans of the actual firms in the sample "represent almost half of all [PBGC] insured [SE] plans' liabilities and underfunding."[13]

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[8] PIMS 2010 Guide, pages 2-22.

[9] Each cycle represents "new sets of random draws of firm financial variables and new bankruptcy draws." [PIMS 2010 Guide, pages 2-22.]

[10] PIMS 2010 Guide, pages 2-21 noting "Each PIMS firm draws its sequence of financial ratios and employment using the respective autoregressive equations, consistent with the estimated covariances matrices."

[11] PIMS 2010 Guide, pages 2-20. As of the end of FY2014, PIMS insured a total of 22,344 SE plans. [2014 Pension Insurance Data Tables, table titled "PBGC Data Book At A Glance"]

[12] PIMS 2010 Guide, pages 2-20. For distributions of liabilities and net financial position reported in the FY2014 Projections Report, PIMS used a sample of 383 firms having 490 plans to simulate the distribution reported in the FY14 Projections Report. [Based on the number of entries in the database FIRM and PLAN; some firms have a weight of zero, thus the actual number of firms and plans could be less than the number of entries in the respective tables.]

PBGC exercises its judgment and the criteria below to select firms included in the sample.

> The plans selected for the sample are those with sponsors that have the largest shares of total plan liabilities in the single-employer defined benefit system and where (1) sufficient publicly accessible data is available on the sponsor to use the SE-PIMS bankruptcy probability model, and (2) plan details can be sufficiently captured in the SE-PIMS Model.[14]

The sample of actual firms is expanded by including artificial partner firms to some of the actual firms in the sample.[15] For example, PBGC does not assign any partner firms to airlines and "attempts to directly include as much as possible of the airline industry in the PIMS sample."[16] Each partner firm is an artificial scaled-down replica of the associated senior partner (i.e., the actual firm). Presently the scale factor is set at 20%,[17] which means that the plan liabilities, assets, earnings, contribution requirements, firms' employment levels and equity values, etc. are all set equal to 20% of the corresponding values for the associated source firm.[18]

All firms are categorized into different strata based on the funding ratio of their largest plan liabilities.[19] The number of partners assigned to all source firms in a given stratum is the same.

The number of partner firms (i.e., weights for source firms[20]) is chosen such that the distribution of liabilities[21] of all firms (actual and artificial partners) in the sample by funding ratio "approximates the

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[13] PIMS 2010 Guide, pages 2-20.

[14] PBGC FY 2014 Projections Report, page 50.

[15] Our description here is based on the File "SE_weighting_fy13.xlsx" sent by PBGC; henceforth PBGC 2013 Sample Weights File. Both the PIMS 2010 Guide and the FY 2014 Projections Report do not provide these details.

[16] PBGC 2013 Sample Weights File noting "Since airline plans are able to use some industry-specific funding rules, PRAD's current policy to not weight up PIMS sample of airline plans. Instead, PRAD attempts to directly include as much as possible of the airline industry in the PIMS sample."

[17] PIMS 2010 Guide, pages 2-20, footnote 11 noting "Current assumptions scale the partners' plans to one-fifth the size of the sample firms plans." Also, see PBGC FY 2014 Projections Report, page 50 noting "Because the SE-PIMS sample is drawn from larger than average plans and corporations, each partner is scaled (in plan size and sponsor size) to one-fifth the size of its source."

[18] PBGC staff explained that 20% weight is chosen on the basis that average liabilities of the plans of the firms not included in the sample are about 20% of the plans included in the sample.

[19] PBGC 2013 Sample Weights File, Sheet "Intro" noting firms are "aggregated by funding ratio [of their largest plan (defined as $ of liabilities)] in 10%-wide bands" with lowest band being 50% to 60%. In other words, funding ratio bands are 50% to 60%; 60% to 70% and so on.

[20] PBGC 2013 Sample Weights File, Sheet "firms_wts". The total weight assigned to each source firm equals one plus the number of partner firms multiplied by 0.2. PBGC imposes the following additional restrictions on total weight assigned to each source firm: a) no smaller than 1.0 (each sponsor in PIMS is allowed, at a minimum, to represent itself); b) no larger than 4.0 (ad hoc rule to avoid large concentrations of weight on any particular plan/sponsor); c) a multiple of 0.2 (partner sponsors, created in PIMS where weights exceed 1.0, are intended to be one-fifth the size of the sample sponsor).

[21] PBGC 2013 Sample Weights File, Sheet "Intro" noting:
"The liability measure used for this spreadsheet's comparisons is funding target liability. Since data is aggregated from plans using different discount rates, the universe data has had all liabilities adjusted to a common discount rate. For FY13 PIMS, that common rate is 5.72% (the universe-average effective rate)."

distribution of plan liabilities by funding status in the insured universe."[22] To determine the number of partner firms, PBGC "does not have a single objective measure for assessing a best fit"[23] and the numbers are chosen by trial and error through a visual examination to minimize differences between the actual distribution and the distribution based on liabilities for the firms (actual and partners) in the sample for the three distributions below:[24]

- The distributions of liabilities by funding ratio
- Cumulative distributions of liabilities by funding ratio
- Cumulative distributions of underfunding by funding ratio

In short, PIMS is collapsing the universe of insured SE plans by selecting some source firms with large liabilities and "**reweighting**" these source firms' plan liabilities through the partner firm system to come up with a sample for PIMS simulation; it being assumed that *in any given funding-ratio stratum*, the reweighted portfolio of firms is similar, in terms of all relevant characteristics, to the portfolio of firms NOT included in the sample.

Appendix 1 provides a list of partner weights and number of partners assigned to various plan sponsors.[25] The plan sponsors having a partner weight of zero means that they were not included in the sample analyzed for the FY14 Projections Report. The plan sponsors not having a partner have the partner weight as one and the number of partners assigned as zero.

Appendix 2 provides charts showing the above three distributions using actual universe data and weighted partner firm data for the sample analyzed for the FY14 Projections Report.[26]

Distribution of Liabilities

Generally speaking, expected PBGC liability is a product of: (a) the probability of bankruptcy ("PD") and (b) given a firm bankruptcy, its claim on PBGC ("LGD"). The distribution of the potential liabilities arises through:

- Variation of PD over time – As PD depends upon both economic and firm-specific conditions; PD varies across both economic scenarios and across cycles within each economic scenario.
- Variation of LGD over time – LGD varies only across economic scenarios because there is no difference in the value of plan assets and liabilities across cycles in any given economic scenario; the value of assets and liabilities being determined *solely* by the stock returns and interest rates associated with the relevant economic scenario.

As noted earlier, PIMS generates 500 economic scenarios. For each economic scenario, PIMS generates 10 different cycles of firm bankruptcies to "obtain a **better estimate of the mean cost** of each [economic] scenario and … an estimate of within-scenario variance in claims cost."[27] [Emphasis added.]

[22] FY 2014 Projections Report, page 50. The report explains: "For example, the weighted sample's total value of plan liabilities among plans between 50 to 60 percent funded is compared to the same total for the insured universe, and similarly for plans 60 to 70 percent funded, 70 to 80 percent funded, etc. Partners are allocated for a best fit to the entire distribution." [FY 2014 Projections Report, page 51.]

[23] PBGC 2013 Sample Weights File, Sheet "firms_wts".

[24] PBGC 2013 Sample Weights File, Sheet "firms_wts".

[25] Based on input database FIRM.

[26] Based on PBGC 2013 Sample Weights File.

In each cycle, PIMS computes bankruptcy probabilities and determines which firms are bankrupt.[28] If a firm (actual or artificial) is simulated to go bankrupt, all of its sponsored plans terminate.[29] There will be a claim against PBGC if a plan is less than 80% funded based on its termination liability.[30]

For plans leading to a claim against PBGC, PIMS transfers assets and liabilities of these plans to PBGC.[31] Assets, liabilities, and underfunding are multiplied by the associated firm weights that are simulated to go bankrupt. For example, consider a plan that is associated with one source firm and 10 partner firms of that source firm. If in a given year, the source firm and three of the 10 partner firms go bankrupt, then the assets and liabilities of this plan will be scaled by the factor 1.6 (equals the sum of the weight one for the source firm and the weight 0.2 for each partner firm) and transferred to PBGC.[32] The remaining seven live partners with a total weight of 1.4 will move on to the next year. If in the next year, two more partners go bankrupt, the assets and liabilities of the plan in that year will be scaled by the factor 0.4 and transferred to PBGC.[33]

Adequacy of PIMS Reweighting and Re-Sampling Approach

In our opinion, cost considerations notwithstanding, use of the above approach to extrapolate PBGC's insolvency risk (i.e., generate distribution of future liabilities) is unlikely to produce results sufficiently applicable to assess the insolvency risk of the full population of covered plans. The main challenge in assessing PBGC's assumed insolvency risk is a large variance in potential claims in the future due to low-probability catastrophic events (technically called "fat tails").

As discussed above, PBGC's insolvency risk arises from two sources – systematic risk and idiosyncratic risk. Two questions relevant for determining whether PIMS correctly determines the distribution of potential future liabilities for the universe of SE plans that the agency insures are:

- Does the current simulation process to assess insolvency risk adequately capture the *systematic risk*; particularly the mean, variance and the fat tails in the distribution of potential future liabilities?[34]
- Does the current simulation process to assess insolvency risk adequately capture the *idiosyncratic risk*; particularly the mean, variance and the fat tails in the distribution of potential future liabilities?

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[27] PIMS 2010 Guide, pages 2-22.

[28] This is done in the PBGC.cpp module, which has a "process_bankruptcy" routine that goes through each cycle and each plan sponsored by the firm to see if there is a claim against PBGC.

[29] This is based on the code contained in Firm.cpp module made available to us.

[30] The 2014 Projections Report, page 52 states that "A plan presents a loss to participants and/or the pension insurance program if its sponsor is simulated to experience bankruptcy and the plan is less than 80 percent funded for termination liability."

[31] This is based on the code contained in PBGC.cpp module made available to us.

[32] This assumes that given the asset and liabilities in that year, the plan is deemed to be eligible to be transferred to PBGC.

[33] This assumes that given the asset and liabilities in the next year, the plan is again less than 80% funded and generates a claim against PBGC.

[34] According to the PBGC 1998 Data Book, PBGC initially used only 300 economic scenarios and has since increased to 500 economic scenarios.

Both questions are equally important for properly simulating the distribution of PBGC's potential future liabilities because PBGC's potential exposure produced by PIMS comes **almost equally** from idiosyncratic and systematic risks.[35]

Systematic Risk in the Simulated Distribution

We start by repeating two recommendations (from our prior reports) relevant for improving the capture of systematic risk in the simulated distribution.

- For each economic scenario, PBGC should consider improving processes that generate stock returns and interest rates by incorporating fat tails in the simulated distributions, which, as PBGC recognizes, is extremely important for successfully capturing the distribution of potential liabilities. Fat tails can arise because of the non-normal distribution of certain variables, or increasing volatilities and correlations at unfavorable scenarios. Currently these aspects are not incorporated into PIMS economic scenario generation. (Subtask 4.1 Report, page 5).
- PBGC should consider adding economy and industry-wide contagion to its models for probability of bankruptcy. (Subtask 4.3 report, page 6).

Another relevant issue is the number of economic scenarios needed to adequately simulate the entire distribution of the two key economic variables that PIMS simulates (stock returns and interest rates). In this connection, it is helpful to consider private insurers' approaches for determining Solvency Capital Requirements ("SCR"). On a global level, insurers often determine SCR at a 99.5% confidence level,[36] which implies that one would need to simulate a minimum of 10,000 economic scenarios.[37]

Therefore, we recommend that PBGC should consider increasing the number of simulated economic scenarios for improving the capture of systematic risk in the simulated distribution. PBGC informed us that their goal is to have 10,000 economic scenarios and they will try to implement this within the redesign of PIMS. We agree with this goal and strongly recommend that PBGC implement this in the redesign.

Creating additional economic scenarios is neither difficult nor computationally expensive. However, because of the nesting approach, each additional economic scenario also requires computation of additional liability valuation cycles, which can be computationally expensive depending on the current state of PBGC computing hardware.[38] PBGC informed us that through use of dedicated servers and multi-thread processers, PBGC has managed to reduce current SE-PIMS run time considerably.

[35] PBGC 1998 Data Book, page 16 noting "It turns out that about half of the variation in potential claims is explained by movements in stock returns and interest rates; the rest is attributable to idiosyncratic risk."

[36] SCR determined at a 99.5% confidence level "corresponds to the economic capital an insurance company needs to hold in order to limit the probability of ruin to 0.5%." [Dimitrakopoulos, Georgios N., "Least Square Monte Carlo Simulation vs. Stochastic–on–Stochastic for Variable Annuities and Exotic Options with BS/Heston-CIR–a comparison of GPU and Intel Phi implementations," The University of Manchester Working Paper, 2013; hence forth Dimitrakopoulos (2013) at page 5.]

[37] Dimitrakopoulos (2013), page 5 noting "a minimum of 10.000 outer [Economic] scenarios would be needed" to determine SCR at a 99.5% confidence level.

[38] Even with the current approach of using 10 cycles per economic scenario, going to 10,000 economic scenarios could significantly increase computation cost and as we discuss later, the current approach of 10 cycles per

In this connection, we would like to draw PBGC's attention to the fact that there are faster alternative simulation approaches that might be worth considering when PBGC decides to scale-up economic scenarios 20 times (from current 500 to 10,000) in the redesign of PIMS. Scaling-up might result in much longer run times compared to current run times, even with use of dedicated computing resources, and there might be need to further reduce run times.

Alternatives to Nested Simulation

Like PBGC, banks and insurers[39] need to simulate distribution of their future liabilities to determine capital requirements. There is a large amount of literature on the topic of capital requirement assessment for banks and insurers and the related literature provides several computationally efficient alternatives. While a full review of this literature is outside the scope of this report, we would like to draw attention to a well-known alternative that PIMS could consider – Least Squares Monte Carlo Simulation ("LSMC").[40] "The main idea of the LSMC is to decrease the number of the scenarios of the second stage [i.e., cycles]."[41] As a result, with the use of techniques like LSMC, PIMS can considerably increase the number of economic scenarios to fully capture all possible economic outcomes in the future. [42]

Idiosyncratic Risk in the Simulated Distribution

As noted earlier, PIMS reweights actual firms included in the sample by supplementing the sample with junior partners for some actual firms to replicate the universe of insured-SE plans. In other words, the partner firms in the sample can be thought of as a "replicating" portfolio for the firms not included in the sample.

Therefore, an important consideration is whether the partner firm methodology adequately captures the economic performance of the actual pension insurance system under various economic conditions. As we noted in our Subtask 4.2 report, and as standard sampling theory suggests, "by virtue of its non-random character, the sample of SE plans inputted into PIMS cannot be assumed to be representative of all insured SE plans."[43] In this connection, we also note that we did not see any empirical testing reported in support of the partner-firm system.

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economic scenario might not be enough to get to the level of accuracy which insurers typically use in determining their SCR.

[39] Like PBGC, banks too face insolvency risks. Many insurers offer guaranteed products such as variable annuities that expose them to risks similar to the ones that PBGC faces.

[40] Longstaff, Francis A., and Eduardo S. Schwartz, "Valuing American options by simulation: a simple least-squares approach," Review of Financial Studies, 14 (1) 2001, pages 113-147.

[41] Dimitrakopoulos (2013), page 6.

[42] While LSMC was initially developed as a method to efficiently determine conditional expectation, LSMC is now used to determine the entire distribution including tail values such as 99.5% value at risk.

[43] FTI Subtask 4.2 Report, page 25.

Potential Improvements to the Current Partner Firm

Method to Determine Number of Partner Firms

As noted earlier, firms in the simulated sample are categorized into different strata based on the funded ratio of the largest plan a firm sponsors. This categorization seems reasonable because, in general, plans with lower funded ratios tend to generate higher claims against PBGC.

Within a given stratum, PIMS uses the partner firm methodology presumably to simulate economic performance of the firms (and net liabilities associated their insured plans) in that stratum. Recall that each partner firm is a scaled-down (20%) copy of the associated source firm and that firm's plans. The number of partner firms is chosen such that the distribution of liabilities[44] of all firms (sources and their partners) in the sample "approximates the distribution of plan liabilities by funding status in the insured universe."[45]

Instead of the trial and error method used by PBGC to determine the number of partners assigned to each source firm,[46] we recommend PBGC consider developing a statistical criterion to accomplish the same objective. For example, PBGC could use a linear programming approach that satisfies constraints imposed by the three distributions that PBGC uses for calibration purposes.[47]

In this connection, we also note that idiosyncratic risk can vary considerably across industries and PBGC could allow the size and number of partner firms in a funding ratio stratum to vary to better capture that variation. This approach can be readily implemented in PIMS, since PIMS has the size and number of partner firms as parameters.

The re-sampling approach that PIMS adopts through multiple cycles is in principle akin to the standard statistical technique of bootstrapping used to determine sampling distribution of the statistic of interest. An important issue is the number of cycles required to adequately simulate the entire distribution of the idiosyncratic risk.

PIMS uses only 10 cycles to capture the distribution of idiosyncratic risk. PIMS notes that "[e]xperimentation suggests that we exhaust the added benefit of additional cycles at ten cycles."[48] It is unclear as to what is the meaning of added benefit. It is plausible that PIMS gets stable estimates of mean/median and in-scenario variance of potential liabilities. However, we are trying to simulate the **entire** distribution of idiosyncratic risk, especially at the tail, and it is not clear that only 10 cycles will successfully simulate the **entire** distribution especially if PIMS is updated to include fat tails in the

[44] PBGC 2013 Sample Weights File, Sheet "Intro" noting:

"The liability measure used for this spreadsheet's comparisons is funding target liability. Since data is aggregated from plans using different discount rates, the universe data has had all liabilities adjusted to a common discount rate. For FY13 PIMS, that common rate is 5.72% (the universe-average effective rate)."

[45] FY 2014 Projections Report, page 50.

[46] Total weight for a source firm determines the number of partner firms associated with that firm. For example, a weight of 1.4 means two partner firms.

[47] Another potential approach is to follow a standard statistical least squares approach and determine the number of partners ("weights") in various strata so that chosen weights minimize the sum of least squares distance between the desired distribution and the distribution implied by weights for the three distributions that PBGC uses for calibration purposes.

[48] PIMS 2010 Guide, pages 2-22.

distribution of economic variables and contagion in modeling the probability of default. We recommend that PBGC revisit this issue in the redesign of PIMS with increased economic scenarios and examine if 10 cycles are still enough to get a stable distribution.

Sensitivity Analysis to Assess the Impact of the Static Nature of the Simulated Sample

The sample of firms that PIMS simulates is static in the sense that "the starting universe of pension plans covered by PBGC remains constant, except as a result of insolvencies."[49] In other words, PIMS does not consider "the effect of voluntary plan terminations nor of new freezes of benefit accruals within existing plans."[50] As Brown et al. (2013) note:

> In reality, there will be some voluntary plan terminations and potentially a quite significant number of new freezes. For example, from 2008 to 2012 the proportion of PBGC-insured plans that had undergone a partial or a complete accrual freeze increased from 24.3% to 35%.[51]

Voluntary plan terminations and plan freezes are part of the de-risking activities that companies have undertaken in recent years. The risk transfer study that PBGC conducted in 2015 is a good step in this direction.[52] In our Subtask 4.2 report, we commented on how PIMS can be modified to model de-risking activities by plan sponsors, but that report does not address the modeling of de-risking with respect to the partner firm methodology.

Here we note that the static nature of the partner firm assumes that the distribution of financially strong versus financially weak firms remains stable throughout forecast. PBGC's 2015 Risk Transfer Study observed that risk transfer events are "only slightly less likely in RP [reasonably possible] plans that might pose a risk to PBGC than plans classified as Remote (13.4% versus 14.6%)."[53] Therefore, the distribution of financially strong versus financially weak firms may not have significantly changed due to de-risking activities.

However, it is difficult to project as to which firms will undertake such de-risking activities in the future. Further, "[t]here are not good statistical models to project these activities."[54]

Therefore, in our opinion, PBGC should consider performing periodic sensitivity analyses that analyze the impact of voluntary terminations and freezes by some select firms and reporting the results of such analyses along with the distribution of its net financial positions.[55]

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[49] Brown, Jeffrey R., Douglas J. Elliott, Tracy Gordon, and Ross Hammond, "A Review of the Pension Benefit Guaranty Corporation Pension Insurance Modeling System," *The Wharton School, Pension Research Council Working Paper*, September, 2013 [henceforth Brown et al. (2013)], pages 1-63, noting at page 34.

[50] Brown et al. (2013), page 36.

[51] Brown et al. (2013), page 36.

[52] Ranade, N., et al, "Risk Transfer Study Plan Years 2009 – 2013", 2015.

[53] PBGC's 2015 Risk Transfer Study, page 26.

[54] Brown et al. (2013), page 36.

[55] Brown et al. (2013), page 36.

PIMS Documentation Update

As discussed earlier, in each cycle, PIMS computes bankruptcy probabilities and determines which firms are bankrupt.[56] If a firm (actual and artificial) is simulated to go bankrupt, all of its sponsored plans terminate.[57] There will be a claim against PBGC if a plan is less than 80% funded based on its termination liability.[58]

Our review of the relevant PIMS code indicates that PIMS performs the claim examination on a plan-by-plan basis.[59] However, the PIMS 2010 Guide notes that PIMS examines a firm's plans "**as a unit** under the assumption that a sponsor would merge under- and overfunded plans in a bankruptcy."[60] [Emphasis added.] In other words, "If the market value of **assets of all plans** sponsored by the firm is 80% or more of the **combined termination liabilities for all the plans**, there is no claim. … Otherwise, PBGC trustees the plans, i.e. it assumes the plans' assets and liabilities."[61] [Emphasis added.] The 80% threshold is based on PBGC's past claim experiences.

As such, there is a discrepancy between the PIMS code and the PIMS 2010 Guide. PBGC staff in their comments informed us that PIMS 2010 Guide is incorrect and needs to be updated.

<u>Alternative to the Partner Firm System</u>

While the partner firm system was a reasonable empirical approach when initially designed given the state of computing hardware at that time, it is not clear that PBGC should continue using this approach in the future.[62]

One potential way is to expand, wherever feasible, the number of firms included in the simulated sample.[63] Irrespective of the sample size used, use of the current partner system, in our opinion, is inadequate to capture risk arising from potential liabilities from plan sponsors not included in the sample. Instead PBGC should consider developing an alternative method (e.g., replicating portfolio) for plan sponsors not included in the simulated sample. For, example, Lucas (2013) notes:

> An alternative [to the partner firm system] 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

[56] This is done in the PBGC.cpp module, which has a "process_bankruptcy" routine that goes through each cycle and each plan sponsored by the firm to see if there is a claim against PBGC.

[57] This is based on the code contained in Firm.cpp module made available to us.

[58] The 2014 Projections Report, page 52 states that " A plan presents a loss to participants and/or the pension insurance program if its sponsor is simulated to experience bankruptcy and the plan is less than 80 percent funded for termination liability"

[59] Based on our review of the process_bankruptcy module in the file PBGC.cpp

[60] PIMS 2010 Guide, pages 7-10, footnote 92.

[61] PIMS 2010 Guide, pages 7-10 also noting that "the liabilities are valued using PBGC's assumptions regarding interest and mortality rates."

[62] Lucas, Deborah, "Joint Risk of DB Pension Underfunding and Sponsor Termination: Incorporating Options-Based Projections and Valuations into PIMS," University of Michigan Retirement Research Center (MRRC) Working Paper, WP 2013-290(j), 2013, page 17 noting "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."

[63] PBGC staff informed us that data preparation cost is main challenge in expanding the sample size.

historical outcomes in terms of default correlations, probabilities, funding levels, and so forth.[64]

There is a vast amount of literature on relevant methodologies for creating replicating portfolios.[65] Most insurers and banks deal with portfolios of assets and liabilities as complex as the one PIMS simulates to determine their capital requirements and often use replicating portfolio methodology for assets that cannot be directly modeled for simulation purposes. We recommend that PBGC review methods used by banks and insurers and related literature to help develop an alternative to the partner firm system.

PBGC should also consider regularly reviewing and investing in its computing hardware and methods as that might make it easy to implement large sample and replicating portfolio methods. In this connection, we note that computing hardware and methods continue to develop at a fast pace and it might not be practical to update hardware too frequently. Therefore, we recommend PBGC incorporate a medium-term plan in its planning process to update its hardware every few years (e.g., three to five years) as well as review advances in numerical computing applicable to PIMS.

Stress Testing

Irrespective of the simulation approach PBGC adopts, PBGC has to deal with a complex system, which can be difficult to explain to policy makers.

Therefore, we recommend that PBGC consider supplementing PIMS with some stress test scenarios, which policy makers can easily comprehend. Scenarios which replicate economic conditions during the Great Depression or the 2008 financial crisis are easy to comprehend and the sources of liabilities that PBGC might have to assume under such adverse scenarios can be easily identified. For example, in presenting a scenario like the 2008 financial crisis, PBGC could present alternative liability estimates under clearly understood assumptions such as allowing large plan sponsors like General Motors to fail or bailing them out.

To develop adverse economic scenarios, PBGC could start with a review of economic scenarios developed by large US banks under guidance of the Federal Reserve Bank (the "Fed"). These scenarios are available in banks' financial disclosures as well as in various documents submitted to the Fed. PBGC would need to supplement such economic scenarios with additional inputs such as stress in select industries important for assessing insolvency risk that PBGC faces.

PIMS already has the capability to use pre-defined simple deterministic economic scenarios. A stress testing module can build on that to incorporate all parameters required in a full stress scenario. For example, stress testing may involve modeling yield curves or contagion outside of current PIMS.

[64] Lucas, Deborah, "Joint Risk of DB Pension Underfunding and Sponsor Termination: Incorporating Options-Based Projections and Valuations into PIMS," University of Michigan Retirement Research Center (MRRC) Working Paper, WP 2013-290(j), 2013, page 17.

[65] For example, see Burmeister, Curt, Mike Dorsel, and Patricia Matson, "F3– Replicating Portfolios in the Insurance Industry," Presentation at the Investment Symposium organized by Society of Actuaries, March 2010. A complete survey of these replicating portfolio methodologies is outside the scope of this report.

Further, we recommend that PBGC identify economic conditions giving rise to large liabilities in stochastic simulation and compare those conditions to scenarios that give rise to similar liabilities. This will help PBGC develop insights for a) likelihood and sources of future liabilities and b) updating its simulation methodology.

Evaluation of Consistency of Assumptions

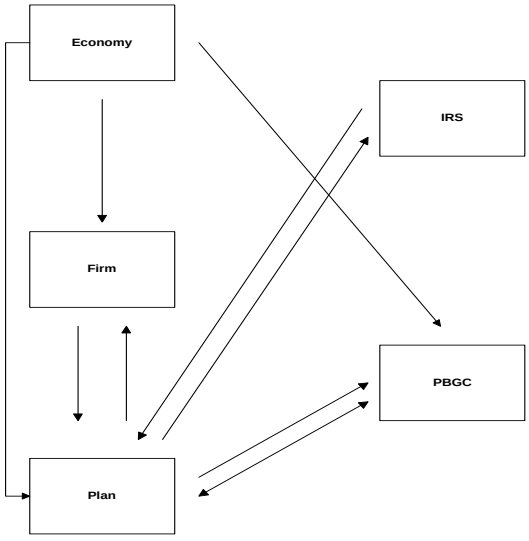
In this section, we review PIMS linkages between various modules (i.e., economy, firm, and plan, etc.), related assumptions and consistency of assumptions about the same parameters used within SE-PIMS and ME-PIMS.[66] The appropriateness of the assumptions and our recommended changes have been discussed in the Subtasks 4.1, 4.2 and 4.3 reports. The discussion in this section is on internal consistency given the assumptions PIMS currently uses.

Current Practice

PIMS Modules and Their Linkages

PIMS is a microsimulation model built with an object-oriented language, which has several major programming components such as the economy, firms, plans, IRS (which sets the rules regulating minimum-required contributions), and PBGC to model the dynamics of the pension insurance system. Each component influences other components and is influenced by other components. A schematic flow process of a PIMS simulation is explained in Chapter 7 of the PIMS 2010 Guide.[67]

Figure 7-1 PIMS Entities



[66] Our review is based on the model as described in the Pension Insurance Modeling System, *PIMS System Description for PIMS SOA "Core" (vFY09.1), Version 1.0* Revised 9/22/2010 [henceforth "PIMS 2010 Guide"] and the document *Key Differences Between SE-PIMS and ME-PIMS* [henceforth "Key Differences"]. Confirmed by PBGC staff as still applicable at the time of this writing.

[67] PIMS 2010 Guide, page 113.

PIMS was first constructed to simulate the single-employer pension insurance program. Each simulation in SE-PIMS begins with the same initial conditions for the economy, firms, plans, and PBGC. Then for each economic scenario, each firm in the sample, and each year in the forecast, PIMS calculates the firm's financial ratios for every cycle and partner firm. SE-PIMS also calculates the pension plan information for each plan sponsored by the firm. Then the bankruptcy probability can be calculated for each cycle and partner firm. Finally, SE-PIMS determines if bankruptcy has occurred and updates the PBGC component accordingly.[68]

The ME-PIMS follows a similar program flow, but has added a cash flow model to simulate the booking of the present value of PBGC's financial assistance to insolvent plans. The plan-level calculation is also expanded to include the modeling of a funding improvement plan, rehabilitation plan, and the Multiemployer Pension Reform Act (MPRA).

The assumptions associated with different entities (and our recommended changes) are reviewed in our previous reports. The assumptions in the economy component are reviewed in the Subtask 4.1 report. The assumptions associated with the plans, IRS, and PBGC components are reviewed in the Subtask 4.2 report. The assumptions associated with the firms and PBGC components are reviewed in the Subtask 4.3 report. Given the assumptions PIMS currently uses, in this report we discuss the relationships between the assumptions in these components and determine whether they are integrated and internally consistent across different components and models within PIMS. Our review is on the internal consistency of PIMS itself, and not on the consistency of PIMS assumptions with other assumptions used by other divisions of PBGC.

For example, consider the plan component. The economy-level assumptions of stock returns and nominal long-term government bond yield impact plan asset returns and the valuation of plan liabilities. The cash flows in and out of a plan will be impacted by the assumptions in the IRS component and the PBGC component, because the IRS component influences plan contributions and the PBGC component influences the payment of PBGC premiums. Thus, regardless of whether the interest rate process or the stock return process is appropriate, consistent assumptions are needed to generate reasonable results.

Current Assumptions

For easy reference, the table below summarizes the main assumptions in each entity and the relationships between the assumptions as implemented in PIMS.

Category	Assumptions	Relationships
Economic Level See Subtask 4.1 report for additional details	**Nominal long-term government bond yield and stock return** A bivariate lognormal distribution with prescribed variances and correlation. Stock return modeled to have a risk premium over the long-term government yield. **Real interest rate** = 0.64% (parameter input) **Productivity** = 1.65% (parameter input) **Inflation** = (1+Nominal interest rate) /(1+ real interest rate) – 1 **Wage growth** = (1+ productivity) * (1+ inflation) - 1	Covariate between interest rate and stock returns Parameter uncertainty not implemented
Firm Level See Subtask 4.3 report for	**Employment** A random walk process	Multivariate normal distribution involving employment, equity-to-debt ratio, cash flow-to-debt

[68] PIMS 2010 Guide, pages 117 – 122.

additional details	**Equity-to-debt ratio (or equivalently asset-to-debt ratio)** An autoregressive process with a dummy variable for the financial industry **Cash flow-to-asset ratio** An autoregressive process with a dummy variable for the financial industry **Firm equity** A random walk process **Bankruptcy** The equation for the probability of bankruptcy uses the firm's contemporaneous financial health variables (equity-to-debt ratio, cash flow, firm equity, and employment). The model simulates changes to these variables correlated with changes in the economy to determine probability of bankruptcy. PIMS's bankruptcy probability formulas generally do not vary by industry, except for the financial and utilities industries, and for a few large companies, especially in the retail industry.	ratio and firm equity Error terms at economy level, industry level and firm level, adjusted for heteroscedasticity Parameter uncertainty not implemented
Plan Level See Subtask 4.2 report for additional details	**Treasury bond return** Long-term government bond yield plus capital gain due to interest rate changes using a bond maturity of 20 years **Bond returns in plan asset portfolios and in PBGC's fixed income portfolio** Long-term government bond yield plus capital gain due to interest rate changes using a bond maturity of 30 years **Corporate bond yield** The long-term corporate bond yield is modeled with a spread of 1.1% over the long-term government bond yield per economic assumption parameters. PIMS simulates a mean reversion process from the current spread to the 1.1% spread. **PBGC's liability valuation interest rate (i.e., the annuity purchase rate)** 30% of the spread of the corporate bond yield over the long-term government bond yield (i.e., a long term spread of 0.33% over the long-term government bond yield) **Discounting future PBGC claims** For discounting future present values to the current reporting date, PIMS uses the simulated long-term government bond yield generated for the particular year and economic scenario. **Plan liability valuation and valuation interest rate** SE-PIMS derives the valuation interest rate from corporate bond yields. ME-PIMS assumes the actuarial interest rate to remain constant at the level reported on Schedule B. The termination liability interest rate is the same as PBGC's liability valuation interest rate. **Cash balance interest crediting rate** Different interest crediting rates are possible based on government or corporate yields. **Plan asset return:** Weighted as 48% stock, 23% long-term government bond returns	Consistency of various valuation interest rates and inflation Consistency of plan asset returns with interest rates and equity returns Consistency of the level of benefits with inflation and wage growth Consistency of the number of plan participants with the level of employment

	(30-year maturity), and 30% long-term government bond yields, with a -2.5 basis-points additive return adjustment.[69] All plans are assumed to have identical asset allocations. **Plan participants** ME-PIMS assumes historical hiring distributions continue to bring the active population to a stochastically-determined level. ME-PIMS models changes in employment levels to reflect economic variables, resulting in a mean net decrease in active population of 1.3% per year across all scenarios. No industry-specific employment trends are assumed. SE-PIMS assumes a stationary mean active participation level unless the plan is frozen. **Benefit level** ME benefit-level and employer-contribution increases vary annually with some correlation to modeled economic conditions in each future year. Benefit Improvements – ME: For flat-dollar plans not in critical or endangered status, benefit multipliers are assumed to increase annually by the rate of increase in average wages. Benefit Improvements – SE: For flat-dollar plans, multipliers in SE-PIMS are assumed to increase annually by the rate of inflation and productivity growth. For salary-related plans, the benefit formula is assumed to remain constant, but annual salary is assumed to increase based on inflation, productivity growth, and a factor measuring merit and/or seniority. Benefit improvement restrictions are not applicable in PIMS. Salary merit increase scale is imputed from current age/service/salary distribution PIMS assumes base wage rates increase by 3% per year for liability calibration. For both ME and SE, in case of a plan freeze, PIMS assumes no new entrants, no further benefit accruals, and no multiplier growth For both ME and SE, PIMS assumes no post-retirement benefit increases (COLAs). Plan Accrual Benefit Restrictions – SE: PIMS assumes a plan is permanently frozen once the funded percentage is below 60%.	
Plan level – demographic See Subtask 4.2 report for additional details	**Demographic assumptions** Plan specific retirement, disability and termination tables. ME-PIMS surveys plan demographics to facilitate cash flow modeling. In SE-PIMS, all participants are assumed to be male and are assumed to elect straight life annuities, based on prescribed healthy male	Generally speaking, demographic assumptions, such as retirement and termination rates, are plan specific, not related to economic or firm level factors.

[69] Weights do not add to 100% due to rounding.

	table. SE-PIMS imputes the distribution of inactive participants by performing a 100-year projection of the current active population furnished by the schedule SB and normalizes to the actual inactive counts. **Mortality** ME Mortality: For experience (plan aging), ME-PIMS uses the RP2000 combined healthy table projected with scale AA to projection year; for determining PV of PBGC assistance, PIMS uses RP2014 combined healthy male and female tables projected 13 years beyond the applicable valuation year using the MP2014 scale. SE Mortality: For experience (plan aging), SE-PIMS uses the RP2000 combined healthy male table projected with scale AA to projection year; for determining underfunding at termination, PIMS uses RP2014 combined healthy male mortality projected 13 years beyond the applicable valuation year using the MP2014 scale.	Underestimating mortality improvement can lead to a systematic understatement of plan liabilities.
PBGC level See Subtasks 4.2 and 4.3 reports for additional details	**PBGC Assets** All ME program assets are in revolving funds invested in U.S. Treasury securities. Asset returns in ME-PIMS are bound by the modeling of Treasury returns in future years. SE-PIMS tracks the Trust Fund (trusteed plan assets) and Revolving Fund assets separately. PIMS uses different investment asset allocations for the Trust Fund and the Revolving Fund assets. PBGC assets are adjusted externally via post-PIMS processing to reflect the one-year delay in the employers' payment of variable-rate premiums. **PBGC Premiums** In ME-PIMS, premiums are based on the rate under current law, reflecting doubling in 2015 under MPRA, with projected rates increasing under the indexing provisions in the current law. SE-PIMS models current law PBGC premiums with projected rates increasing under the fixed increases and indexing provisions in current law. **Other PBGC Assumptions** Other assumptions include PBGC's expenses, booking and unbooking of PBGC claims, funding ratio threshold for recognizing PBGC claims, recovery percentage, PBGC's benefit guarantees, and PBGC's financial statement valuation.	PIMS's modeling of PBGC's asset returns are internally consistent with its economic assumptions, and should be consistent with PBGC's asset allocation policy. PIMS's modeling of PBGC's premium collection reflects current law and the desire of plan sponsors to minimize PBGC premium expenses. Indexing for PBGC premium rates and benefit guarantees are consistent with PIMS's inflation assumption. Other PBGC assumptions are mostly related to PBGC's own experience dealing with plan terminations (SE) and financial assistance (ME).

IRS level See Subtask 4.2 report for additional details	**Funding Rules** Reflects enacted pension legislation with simplifications where appropriate. **Plan Sponsor Behavior** ME assumptions include Funding Improvement Plans, Rehabilitation Plan, MPRA utilization, plan sponsor contributions, and mass withdrawal. SE assumptions include employer contributions above the minimum-required level, the use of credit balances, and the payment of the variable rate premiums.	Generally speaking, the funding rules don't change with respect to other assumptions. PIMS's assumptions in this area are primarily for the purpose of calculation simplification and liability calibration. PIMS models the indexing prescribed in the funding rules consistently with its inflation assumption and/or wage growth assumption. PIMS models actuarial smoothing of assets and interest rates consistently with its interest rate and plan asset return assumption in each macroeconomic scenario. Actions taken by multi-employer plan trustees and plan sponsors are generally based on an analysis of historical experience, and are consistent with plan funded status and general economic conditions. Plan sponsor behavior should reflect the plan sponsors' response to legislative changes.

Evaluation of the Consistency of Assumptions

While certain assumptions used by PIMS should be changed (as discussed in our Subtasks 4.1, 4.2, and 4.3 reports), given the modeling methodology and assumptions PIMS currently uses, except otherwise noted below, we find the assumptions internally consistent across different entities and models within PIMS, as summarized in the table in the previous section. We now comment on the consistency of assumptions in the following categories:

1. **The consistency of interest rates:** Interest rates impact (1) fixed income asset returns, (2) the valuation of plan liabilities for funding and plan termination, (3) valuation and discounting of PBGC's financial positions, (4) interest crediting in a cash balance benefit, and (5) lump sum distributions. PIMS generates long-term government bond yields first, and then derives corporate bond yields and annuity purchase rates as a spread over the long-term government bond yields. Fixed income asset returns are calculated based on yields and changes in yields. A review of PIMS's interest rate process is in the Subtask 4.1 report. Given PIMS's current interest rate process, these calculations involving interest rates appear to be linked correctly to PIMS's government bond yields or corporate bond yields.

2. **The consistency of asset returns:** Stock returns impact plan assets returns, PBGC's asset returns, and bankruptcy probability through its impact on firm financials and plan underfunding. A review of PIMS's stock return process is in the Subtask 4.1 report. Given PIMS's current stock

return process, the linkage of stock returns to asset returns appears to be reasonable for both SE-PIMS and ME-PIMS.

3. **The employment level**: Employment levels are linked to firm bankruptcy probability and the number of active plan participants (for ME-PIMS a decrease of 1.3% is additional to the simulated employment level). A review of PIMS modeling of the employment level is in the Subtask 4.1 report. Given PIMS's current modeling of the employment level, the linkages between employment level and the number of active plan participants appear to be reasonable.

4. **Wage growth and inflation:** Wage growth rates are linked to benefit improvements. Inflation is used to convert cash flows/equities from a real basis to a nominal basis. Indexing as required by current legislation is linked to the respective wage growth or inflation assumptions. A review of wage growth and inflation assumption is in the Subtask 4.1 report. Given PIMS's current modeling of wage growth and inflation, PIMS's implementation of these linkages appears to be reasonable.

5. **Plan-specific actuarial assumptions:** Assumptions that are specific to an individual pension plan, firm or PBGC are usually based on the respective historic experiences of the entities. The plan assumptions should be realistic and updated periodically. These assumptions, while important, do not have a significant systematic impact on the risk exposure of PBGC. PIMS currently does not link these plan-specific assumptions with other economic assumptions. However, in stress testing scenarios, they may be linked. For example, in stress-testing pension plan cash flows, accelerated retirements may be linked with poor asset returns. In such a situation, PIMS would need to be modified to reflect such linkage.

6. **Legislation changes:** Companies and plan trustees react to changes in the regulatory environment. They may (1) fund in excess of legal requirements, (2) fund in order to avoid PBGC premiums, (3) terminate plans in response to increased PBGC premiums, and/or (4) utilize a funding improvement plan, rehabilitation plan or MPRA. Consistency of assumptions requires PIMS to model anticipated plan sponsor responses to changes in the regulatory environment. PIMS currently has such assumptions, as discussed in the Subtask 4.2 report; however, these assumptions need to be updated as actual experiences emerge.

7. **The linkage of economy-level, industry-level, and firm-level error components:** PIMS stochastically generates variability in equity-to-debt ratio, employment level, cash flow-to-asset ratio, and firm equity using these error components.[70] These quantities in turn generate variability in bankruptcy probability. This is the way macroeconomic factors (i.e., interest rate and stock returns) and industry classification systematically impact bankruptcy probabilities. We note the following:

    a. The variance and correlation for the interest rate and stock return in the economy error components (as documented in PIMS 2010 Guide Table 5-2, page 96) appears to be different from those used in generating macroeconomic scenarios (as documented in the 2014 Projections Report).[71] PBGC should footnote that the actual errors for the interest rates and stock returns derived from the macroeconomic scenarios may be used instead of being generated in this process.

[70] PIMS 2010 Guide, pages 89 – 98.

[71] PIMS 2010 Guide, Table 5-2, page 96; 2014 Projections Report, Table 2, page 55.

b. For equity-to-debt ratio and cash flow-to-asset ratio, the variance of the firm error components is much larger than the variance of the economy error components or the industry error components.[72] If PBGC continues to use the current modeling approach, it should review whether these variances and correlations have changed significantly, especially after the 2008-2009 financial crisis.

c. Some correlations may produce offsetting effects on bankruptcy probability. For example, Table 5-2 in the PIMS 2010 Guide shows that stock return is positively correlated with equity-to-debt ratio, but negatively correlated with cash flow-to-asset ratio.[73] When the stock return is low, equity-to-debt ratio will be lower, but the cash flow-to-asset ratio will be higher. They produce an offsetting impact on bankruptcy probability. It is expected that low stock returns should correlate with increased bankruptcy probability, but it is unclear if the correlation in PIMS's economy error components will produce the expected results. Therefore, we recommend that PBGC review these correlations in relationship to their impact on bankruptcy probabilities.

There are two areas of linkage that are systematically important for modeling the pension insurance system. The first area is asset-liability modeling where assets may be invested to hedge liabilities, commonly referred to as liability-hedging assets versus return-seeking assets. The second area is underfunding-bankruptcy modeling where macroeconomic factors can drive both plan underfunding and bankruptcy probability. Currently PIMS's modeling methodology has not reflected all the interactions that are possible in these two areas. While PIMS assumptions are internally consistent in its current state, substantial work may be required to maintain consistency if PIMS were modified to implement our recommendations.

For example, if a yield curve is used instead of a single long-term interest rate, then care must be given so that the fixed-income returns, or more generally the returns of liability-hedging assets, moves in a way that is consistent with the movement of the yield curve. This involves complexity that is currently not modeled by PIMS.

Similarly, if bankruptcy modeling is updated to include economic contagion, then care must be taken to ensure that asset return modeling is updated as well as to incorporate different economic regimes.

[72] PIMS 2010 Guide, Table 5-2, 5-4, 5-5.

[73] PIMS 2010 Guide, Table 5-2.

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Ranade, N., et al, "Risk Transfer Study Plan Years 2009 – 2013", 2015.

PBGC FY 2014 Projections Report

2014 Pension Insurance Data Tables, table titled "PBGC Data Book At A Glance"

1998 Pension Insurance Data Book

PIMS Code Files

PIMS code in process_bankruptcy module contained in the file PBGC.cpp as made available to us.

PIMS code contained in the file Firm.cpp module as made available to us.

Spreadsheet Files

"PBGC File "SE_weighting_fy13.xlsx"

Appendix 1: Partner Weight and the Number of Partners Used in FY14 Projections Report

#	Name	Partner Weight	Number of Partners
1	Plan Sponsor 1	1	0
2	Plan Sponsor 2	1.6	3
3	Plan Sponsor 3	3.2	11
4	Plan Sponsor 4	1.6	3
5	Plan Sponsor 5	1.6	3
6	Plan Sponsor 6	1.6	3
7	Plan Sponsor 7	1.6	3
8	Plan Sponsor 8	1.8	4
9	Plan Sponsor 9	3.2	11
10	Plan Sponsor 10	1.6	3
11	Plan Sponsor 11	1.6	3
12	Plan Sponsor 12	1.6	3
13	Plan Sponsor 13	3.6	13
14	Plan Sponsor 14	3.2	11
15	Plan Sponsor 15	1.6	3
16	Plan Sponsor 16	2.4	7
17	Plan Sponsor 17	1.8	4
18	Plan Sponsor 18	0	0
19	Plan Sponsor 19	1.6	3
20	Plan Sponsor 20	1.6	3
21	Plan Sponsor 21	1.6	3
22	Plan Sponsor 22	1.8	4
23	Plan Sponsor 23	1.6	3
24	Plan Sponsor 24	1.6	3
25	Plan Sponsor 25	1.8	4
26	Plan Sponsor 26	1.6	3
27	Plan Sponsor 27	1.6	3
28	Plan Sponsor 28	1.6	3
29	Plan Sponsor 29	3.2	11
30	Plan Sponsor 30	3.8	14
31	Plan Sponsor 31	2.2	6
32	Plan Sponsor 32	2.4	7
33	Plan Sponsor 33	1.6	3
34	Plan Sponsor 34	1.6	3
35	Plan Sponsor 35	1.8	4

36	Plan Sponsor 36	1.8	4
37	Plan Sponsor 37	3.2	11
38	Plan Sponsor 38	1.6	3
39	Plan Sponsor 39	1.6	3
40	Plan Sponsor 40	1.6	3
41	Plan Sponsor 41	1.6	3
42	Plan Sponsor 42	1.6	3
43	Plan Sponsor 43	1	0
44	Plan Sponsor 44	1.8	4
45	Plan Sponsor 45	1.6	3
46	Plan Sponsor 46	2.2	6
47	Plan Sponsor 47	1.8	4
48	Plan Sponsor 48	1.6	3
49	Plan Sponsor 49	1.6	3
50	Plan Sponsor 50	1.6	3
51	Plan Sponsor 51	1.6	3
52	Plan Sponsor 52	1.6	3
53	Plan Sponsor 53	3.2	11
54	Plan Sponsor 54	1.6	3
55	Plan Sponsor 55	1.6	3
56	Plan Sponsor 56	1.8	4
57	Plan Sponsor 57	1.8	4
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60	Plan Sponsor 60	1.6	3
61	Plan Sponsor 61	1.6	3
62	Plan Sponsor 62	1.8	4
63	Plan Sponsor 63	2.4	7
64	Plan Sponsor 64	1.6	3
65	Plan Sponsor 65	2.4	7
66	Plan Sponsor 66	1.6	3
67	Plan Sponsor 67	1.8	4
68	Plan Sponsor 68	1.6	3
69	Plan Sponsor 69	2.4	7
70	Plan Sponsor 70	1.8	4
71	Plan Sponsor 71	0	0
72	Plan Sponsor 72	1	0
73	Plan Sponsor 73	1.6	3
74	Plan Sponsor 74	1.6	3

75	Plan Sponsor 75	1.6	3
76	Plan Sponsor 76	3.2	11
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79	Plan Sponsor 79	1.6	3
80	Plan Sponsor 80	2.4	7
81	Plan Sponsor 81	1.6	3
82	Plan Sponsor 82	1	0
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84	Plan Sponsor 84	1.8	4
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88	Plan Sponsor 88	1.6	3
89	Plan Sponsor 89	1.6	3
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95	Plan Sponsor 95	1.6	3
96	Plan Sponsor 96	1.8	4
97	Plan Sponsor 97	3.2	11
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99	Plan Sponsor 99	3.2	11
100	Plan Sponsor 100	1.8	4
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107	Plan Sponsor 107	1.6	3
108	Plan Sponsor 108	3.2	11
109	Plan Sponsor 109	1.6	3
110	Plan Sponsor 110	0	0
111	Plan Sponsor 111	3.2	11
112	Plan Sponsor 112	2.4	7
113	Plan Sponsor 113	0	0

114	Plan Sponsor 114	1.8	4
115	Plan Sponsor 115	0	0
116	Plan Sponsor 116	3.2	11
117	Plan Sponsor 117	1.6	3
118	Plan Sponsor 118	3.6	13
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131	Plan Sponsor 131	1.6	3
132	Plan Sponsor 132	1.6	3
133	Plan Sponsor 133	1.8	4
134	Plan Sponsor 134	3.2	11
135	Plan Sponsor 135	1.8	4
136	Plan Sponsor 136	0	0
137	Plan Sponsor 137	1.6	3
138	Plan Sponsor 138	1.8	4
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141	Plan Sponsor 141	3.6	13
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146	Plan Sponsor 146	2.4	7
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148	Plan Sponsor 148	2.4	7
149	Plan Sponsor 149	1.6	3
150	Plan Sponsor 150	1.8	4
151	Plan Sponsor 151	1.8	4
152	Plan Sponsor 152	1.8	4

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166	Plan Sponsor 166	3.2	11
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187	Plan Sponsor 187	1.6	3
188	Plan Sponsor 188	1.6	3
189	Plan Sponsor 189	1.8	4
190	Plan Sponsor 190	2.4	7
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213	Plan Sponsor 213	1.6	3
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222	Plan Sponsor 222	1.6	3
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225	Plan Sponsor 225	1.6	3
226	Plan Sponsor 226	1.8	4
227	Plan Sponsor 227	1.6	3
228	Plan Sponsor 228	1.8	4
229	Plan Sponsor 229	1.6	3
230	Plan Sponsor 230	2.2	6

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232	Plan Sponsor 232	1.6	3
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234	Plan Sponsor 234	1.6	3
235	Plan Sponsor 235	3.2	11
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266	Plan Sponsor 266	1.6	3
267	Plan Sponsor 267	3.2	11
268	Plan Sponsor 268	3.2	11
269	Plan Sponsor 269	1.6	3

270	Plan Sponsor 270	2.4	7
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275	Plan Sponsor 275	1.6	3
276	Plan Sponsor 276	1.8	4
277	Plan Sponsor 277	0	0
278	Plan Sponsor 278	3.6	13
279	Plan Sponsor 279	1.8	4
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281	Plan Sponsor 281	1.6	3
282	Plan Sponsor 282	1.8	4
283	Plan Sponsor 283	1.8	4
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285	Plan Sponsor 285	1.6	3
286	Plan Sponsor 286	1.6	3
287	Plan Sponsor 287	3.2	11
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292	Plan Sponsor 292	1.8	4
293	Plan Sponsor 293	0	0
294	Plan Sponsor 294	1.8	4
295	Plan Sponsor 295	1.8	4
296	Plan Sponsor 296	1.8	4
297	Plan Sponsor 297	1.8	4
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301	Plan Sponsor 301	1.6	3
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303	Plan Sponsor 303	1.6	3
304	Plan Sponsor 304	1.8	4
305	Plan Sponsor 305	2.2	6
306	Plan Sponsor 306	0	0
307	Plan Sponsor 307	1.6	3
308	Plan Sponsor 308	1.6	3

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321	Plan Sponsor 321	1.8	4
322	Plan Sponsor 322	1.6	3
323	Plan Sponsor 323	1.8	4
324	Plan Sponsor 324	3.2	11
325	Plan Sponsor 325	3.2	11
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328	Plan Sponsor 328	1.8	4
329	Plan Sponsor 329	1.8	4
330	Plan Sponsor 330	1.8	4
331	Plan Sponsor 331	1.6	3
332	Plan Sponsor 332	0	0
333	Plan Sponsor 333	1.8	4
334	Plan Sponsor 334	0	0
335	Plan Sponsor 335	1.6	3
336	Plan Sponsor 336	0	0
337	Plan Sponsor 337	1.8	4
338	Plan Sponsor 338	2.2	6
339	Plan Sponsor 339	1.6	3
340	Plan Sponsor 340	1.8	4
341	Plan Sponsor 341	1.6	3
342	Plan Sponsor 342	1.6	3
343	Plan Sponsor 343	0	0
344	Plan Sponsor 344	1.6	3
345	Plan Sponsor 345	1.6	3
346	Plan Sponsor 346	3.8	14
347	Plan Sponsor 347	1.8	4

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350	Plan Sponsor 350	2.2	6
351	Plan Sponsor 351	1.8	4
352	Plan Sponsor 352	0	0
353	Plan Sponsor 353	3.2	11
354	Plan Sponsor 354	3.8	14
355	Plan Sponsor 355	1.8	4
356	Plan Sponsor 356	1.8	4
357	Plan Sponsor 357	2.2	6
358	Plan Sponsor 358	1.6	3
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368	Plan Sponsor 368	1.6	3
369	Plan Sponsor 369	1.6	3
370	Plan Sponsor 370	1.8	4
371	Plan Sponsor 371	0	0
372	Plan Sponsor 372	0	0
373	Plan Sponsor 373	1.6	3
374	Plan Sponsor 374	1.8	4
375	Plan Sponsor 375	1.8	4
376	Plan Sponsor 376	1.8	4
377	Plan Sponsor 377	1.6	3
378	Plan Sponsor 378	2.2	6
379	Plan Sponsor 379	1.8	4
380	Plan Sponsor 380	1.8	4
381	Plan Sponsor 381	1.6	3
382	Plan Sponsor 382	2.2	6
383	Plan Sponsor 383	3.2	11

Appendix 2: Universe Versus PIMS Weighted Liabilities from FY13 Single-Employer PIMS Weighting Spreadsheet