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IAQF Student Case

Hedging and Funding Improvement: A Practical Strategy for Pension Funds

Executive Summary
An important issue facing modern defined-benefit pension funds is ensuring an adequate funding level relative to their discounted future liabilities. Fully funded pension managers may shift their focus towards immunizing their liabilities in order to de-risk and lock in their funding ratios. Underfunded portfolio managers face not only the issue of volatility, but also the danger of fund insufficiency. These managers need to devote their attention towards fund growth. In this paper we establish a liability hedging strategy involving iShares 20+ Year Treasury Bond ETF's (TLT) and the CDX.NA.IG Index. In addition, we use multiple simulations to find an optimal capital distribution for underfunded portfolios. Finally, we propose a stable transition strategy for pre-existing pension portfolios as well as a recurring adjustment strategy.

Contents

1. Introduction

One way in which defined-benefit pension funds measure their value is by assessing their funding ratio. This consists of comparing their current portfolio value with the discounted value of the fund's future liabilities. Therefore, a pension fund's status is directly affected by changes in liability discounting metrics. As a result of this, a key method by which pension funds de-risk is by assembling a portfolio that mimics the changes in liability. Since a fund's liabilities are primarily a function of corporate bond rates, interest rate and credit exposure are essential risk factors facing modern pension funds. In this paper, we analyze strategies which can be utilized by both fully funded and underfunded pension portfolio managers.

1.1 Fully Funded

For pension funds which are fully funded, developing an immunization strategy to hedge changes in the liability and lock in the funding ratio is a primary concern. In this situation, building a portfolio which is correlated with the liability stream is optimal to simply decreasing overall portfolio volatility. The latter case may indeed be counter-effective as we risk losing correlation with our projected liabilities. By creating portfolios which replicate the liability stream, these pension funds can help ensure that they remain highly funded.

In establishing a liability hedging strategy, we are concerned with three crucial points. The first and most obvious is that our hedge must have a comparable, or ideally surplus, yield relative to the liability discount rate. The second concern is that our hedge must match the interest rate exposure of our liability by matching its duration. Finally, any assets used in our portfolio must be sufficiently liquid for the scale of a pension fund portfolio. In this paper, we present a feasible hedging portfolio based on long-term bonds and credit default swaps in order to mimic corporate bonds with long duration and high liquidity. This portfolio is intended to help immunize the liability curve.

1.2 Underfunded Portfolios

For pension portfolios which are underfunded, our goal is not only to limit relative volatility, but to focus on growth with the intent of improving the funding ratio. As our hedging portfolio is intended as a relatively non-risky way to maintain the funding ratio, allotting the entire portfolio to this strategy will not ensure the excess return needed to improve said ratio. Therefore, we should invest some portion of our capital towards riskier, but potentially more rewarding investments. At the same time, we still wish to minimize our volatility. Based on historical data, the equity market has a higher return than the fixed income market in the long term scale appropriate to pension funds. Thus, we have chosen to base the growth portion of our portfolio on equities.

1.3 Macroeconomic Considerations

Our strategy for an underfunded pension portfolio is actually somewhat more appealing in the current market conditions than in recent history. Improving economic indicators strongly suggest a rise in interest rates in the near future. Firstly, the thirty year U.S. Treasury Bond yields are near historic lows. Secondly, the U.S. unemployment rate is at 5.8% [1] and new payroll employment was 257,000 for January 2015 [2]. These factors, among others, indicate a positive trend in the U.S. economy where low rates are neither very reasonable, nor sustainable. It is therefore beneficial for an underfunded pension manager to leave some exposure to liability, since increasing interest rates lowers the liability. There remains risk in betting on interest rates rising, however. One must consider the possibility that the EU accelerates its quantitative easing. This will push down EU interest rates, which will in turn pull U.S. interest rates lower. A safer alternative that we propose is to buy put swaptions to gain protection from interest rate falls, while simultaneously gaining appreciation if interest rates increase. In practice, this use of derivatives is generally a much more flexible way to adjust our exposure levels.

2. Immunizing a Fully Funded Portfolio

Due to recent market movements, pension funds are quite close to being fully funded. In this state, a principal concern of pension planners is to de-risk their portfolio. Pension funds can accomplish this by creating a portfolio that mimics the liability curve. Successful replication immunizes the pension fund against changes in the liability.

In this paper, we have chosen to use the non-proprietary Citibank Pension Liability Index (CPLI) as our standard for measuring liability. Established in 1995, the CPLI is a widely accepted benchmark for the discount rates used to measure the growth of pension liabilities. Pension funds that are fully funded and wish to immunize their liability endeavor to replicate the CPLI curve. To accomplish this, they must hedge two characteristics of the CPLI curve, duration and imbalance in the yield curve. By matching these factors, we can hedge both parallel and skewed shifts in the interest rate curve.

For our study, we chose to use the standard CPLI monthly return as the benchmark for portfolio return. The return data ranges from January 2010 to December 2014. The returns have a mean of 1.07% and a standard deviation of 3.33%. The duration of the standard CPLI is approximately 18 [3].

Since the CPLI is calculated primarily from long term U.S. AA corporate bonds, the most obvious strategy for attempting to hedge our liability risk is to simply purchase these AA bonds. Figure 1 illustrates the relationship between the CPLI returns and U.S. AA Corporate Bond Index returns.

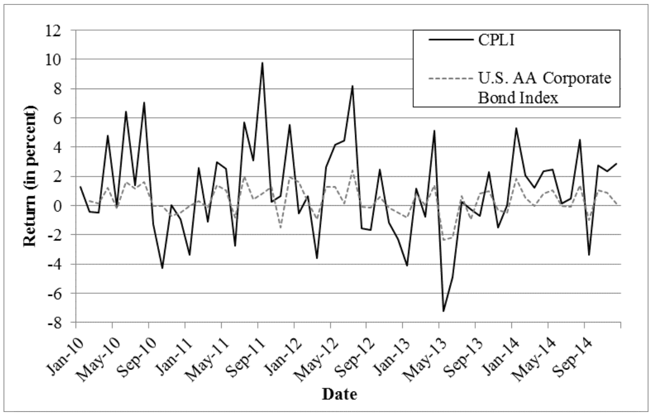

Figure 1. *This graph illustrates the relationship between the monthly percentage returns of the CPLI and the U.S. AA Corporate Bond Index between January 2010 and December 2014.*

As expected, the returns have a strong correlation of 0.795. However, the CPLI return is greater and more volatile than that of the U.S. AA Corporate Bond Index. This result is a consequence of the latter index having a duration of only 6.2 [4], smaller than the duration of the CPLI. Therefore, simply purchasing the U.S. AA Corporate Bond Index is insufficient. Furthermore, the number of long-maturity AA corporate bonds on the market in general is inadequate for the scale of our portfolio.

Although AA corporate bonds are not sufficient instruments for immunizing the CPLI, we can use them as a point of reference for constructing our portfolio. AA corporate bond returns can be decomposed into two parts: a risk-free interest rate element and a credit spread element. To hedge the former component, we chose to use iShares 20+ Year Treasury Bond ETF's (TLT) in our testing since they are both sufficiently liquid and have a long duration of 17.7 [5]. The long duration leads to a more exaggerated return than AA corporate bonds. The credit spread component can be hedged via credit derivatives. To properly represent the credit risk for AA corporate bonds, we chose the CDX.NA.IG Index which is comprised of 125 North American investment grade corporate credits. Mimicking a long position in risky AA corporate bonds entails selling protection on those bonds. Buying CDX.NA.IG assumes the same credit outlook as this position.

	Coefficients	Standard Error	t Stat	p-value
CDX.NA.IG 5Y TRI	3.03	0.70	4.34	1.7×10^{-4}
iShare 20+ Year Treasury Bond ETF (TLT)	0.91	0.09	10.19	6.3×10^{-11}

Table 1. *This table indicates the regression results upon decomposing the CPLI into the CDX.NA.IG 5Y Total Return Index and iShares 20+ Year Treasury Bond ETF factors.*

We conducted a multiple linear regression to identify the optimal weights for allocating TLT and the CDX.NA.IG Index within our immunization portfolio. We used the first half of the data (January 2010 - June 2012) to run the regression and left the remaining half (July 2012 - December 2014) to examine how well our portfolio replicates the CPLI. The R^2 for this regression is 0.81 with the p-value of the F-test being 1.58×10^{-10}.

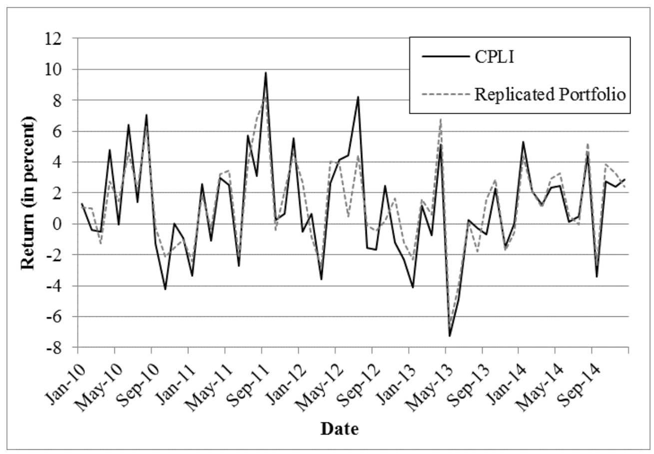

Figure 2. *This graph illustrates the relationship between the monthly percentage returns of the CPLI curve and the newly synthesized replicating portfolio of CDX.NA.IG and TLT.*

As we can see in Table 1, the coefficients are both individually and jointly significant. Our replicating portfolio can therefore be approximated as

$$3.03 \times \mathit{CDX.NA.IG\ Index} + 0.91 \times \mathit{TLT}.$$

Figure 2 shows the close relationship between our replicating portfolio and the CPLI. Notably, the testing period of the data matches the CPLI particularly well.

The tracking error, calculated as the replication return less the CPLI return, is examined in Figures

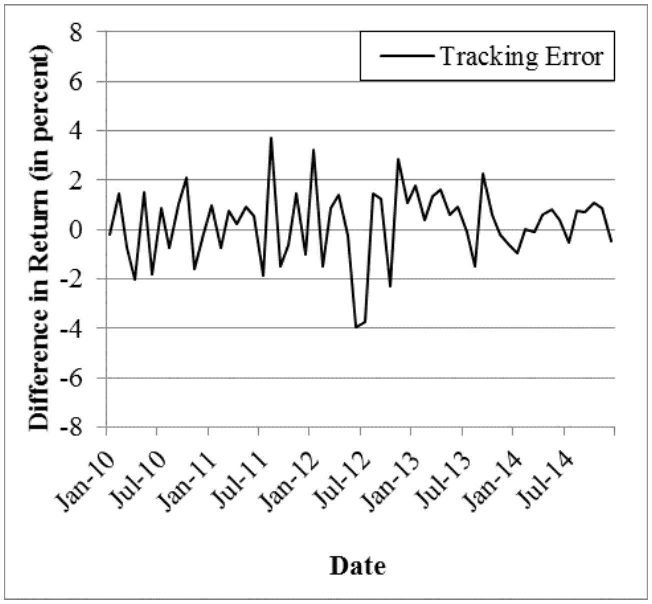

Figure 3. *This graph illustrates the tracking error between the percentage returns of the CPLI and our replicating portfolio of CDX.NA.IG and TLT.*

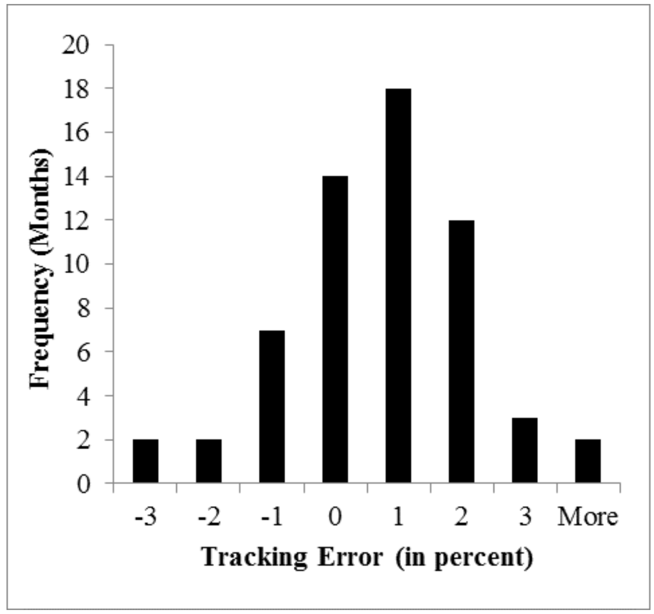

Figure 4. *This histogram depicts the number of months for which the tracking error was the indicated percentage.*

3 and 4. Figure 3 displays the tracking error over time, while Figure 4 depicts the approximate distribution of the tracking error on a monthly basis. In the latter, we can see that the error is roughly normally distributed with mean 0.216% and standard deviation 1.488%. The information ratio is 0.145.

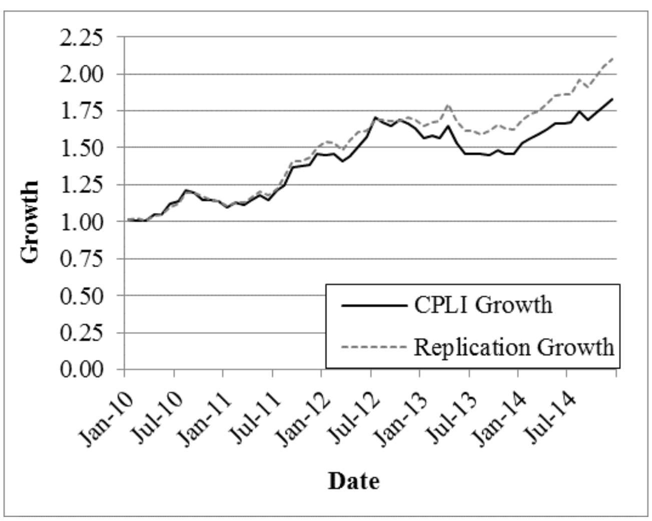

Figure 5. *This graph illustrates the growth of both the CPLI and our replicating portfolio from January 2010 through December 2014. The growth is calculated with the assumption that each starts at a neutral ratio of 1.*

In Figure 5, we compare the growth path of our hedging portfolio with that of the CPLI across the entire data range. The growth paths are quite similar during the regression period (January 2010 - June 2012), and our hedging portfolio slightly outperforms during the testing period (July 2012 - December 2014).

3. Underfunded and Seeking Excess Return

A more difficult problem arises when the funding ratio is less than one. Here, allocating all the capital towards liability immunization locks in the insufficient funding ratio. Instead, the pension fund must shift their focus towards portfolio growth with the goal of improving their funding ratio. However, allocating capital towards portfolio growth can lead to risk exposure, a feature that needs to be minimized. This growth-risk trade-off is conveniently captured in the information ratio[1]. Two major sources where we can gain return by enduring risk exposure are equity risk and credit risk. For convenience, we use the liability hedging portfolio, described above, to achieve the credit exposure.

[1] Here, we define the information ratio as the expected growth rate of the funding ratio over its volatility.

3.1 Objective

We define our funding ratio P to be

$$P = \frac{Assets}{Liabilities}$$

and our initial funding ratio to be P_0.

We denote the percentage return of the growth portion as r_g, the return of the liability hedging portion as r_ℓ, the risk-free return as r_f, and the liability growth as r_{cpli}. Below, we describe how we simulate these values.

We let w_g and w_ℓ be the weights invested in the growth and liability replicating portions of the portfolio. Since our best estimate for future liability return is the replicating portfolio described in the fully funded case, we use r_ℓ to estimate the liability returns r_{cpli}.

The fund ratio after one year is

$$P = P_0 \frac{1 + w_g r_g + w_\ell r_\ell + (1 - w_g - w_\ell) r_f}{1 + r_{cpli}}$$
$$\approx P_0 \frac{1 + w_g r_g + w_\ell r_\ell + (1 - w_g - w_\ell) r_f}{1 + r_\ell}$$

The goal is to find the values of w_g and w_ℓ that maximize the information ratio of the funding level's growth rate. The growth of the funding ratio can be described as

$$Growth = \frac{P - P_0}{P_0}$$
$$= \frac{P_0 \frac{1+w_g r_g + w_\ell r_\ell + (1-w_g-w_\ell) r_f}{1+r_\ell} - P_0}{P_0}$$
$$= \frac{1+w_g r_g + w_\ell r_\ell + (1-w_g-w_\ell) r_f}{1+r_\ell} - 1$$

3.2 Methodology for Simulations

Interest Rates When simulating future interest rates, the primary concern is to calibrate the implied future interest rate volatility. Here, we chose the one-factor Hull-White model which is calibrated to the implied swaption volatilities. This model also incorporates the expected future interest rate by capturing the current yield curve.

Equity For our simulations, we tested numerous equity instruments. Our results showed minimal difference between the Russell 3000, S&P 500, and Dow Jones Industrial Indices. We chose the S&P 500 Index for our study. Based off 50 year historical data, the S&P 500 Index averages an annual return of 8% [6]. The volatility, however, fluctuates with time and spot price. We chose to simulate the S&P 500 Index using a local volatility with a one-factor Hull-White interest rate hybrid model. Here, the local volatility model is calibrated to the option volatility surface. Some of the Monte Carlo paths generated using this model are shown in Figure 6.

Credit To model the future credit spread, we use an estimated value of 66 basis points. This represents the long term average of the replicating portfolio's historical credit spread [7].

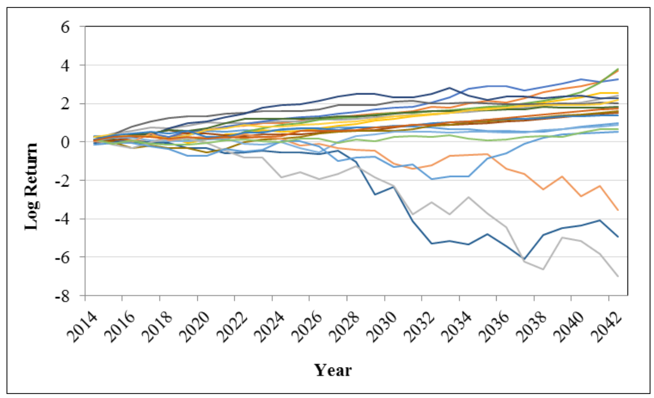

Figure 6. *This figure illustrates some of the Monte Carlo paths generated using the hybrid stochastic model.*

3.3 Analysis and Results

Our simulations show that the maximum information ratio is achieved when the weight w_ℓ is set to 1 (see Table 2 in the Appendix). Furthermore, the weight assigned to the equity portion of the portfolio does not affect the information ratio as long as the liability weight is fixed at 1. The inconsequential effect of the equity weight when the liability weight is set to 1 can be derived from the formulas in Section 3.1. Setting $w_\ell = 1$, we get

$$Growth = w_g \frac{r_g - r_f}{1 + r_\ell}$$

Since the return is proportional to w_g, scaling it will not change the information ratio.

The flat information ratio with respect to the equity weight allows pension planners flexibility in allocating their portfolio. This weight can be adjusted to accommodate the funding ratio and time horizon of the pension fund. For example, if the current funding ratio is 90% and the pension fund aims to be 95% funded in 5 years, then the required 5 year return is $\frac{0.95-0.9}{0.9} = 0.056$. Table 2 indicates that investing between 30% and 40% of the capital in equity should produce the proper return[2]. Using linear interpolation, we find that 37% is the appropriate weight for the equity portfolio. Table 2 also indicates that this investment has a volatility of 17.6% in 5 years, or 7.8% per annum. Considering that the volatility of the CPLI's annual return is 11.5%, our volatility is quite small.

4. Strategy for Portfolio Adjustments

4.1 Pre-existing Portfolios

Although we have described the optimal weights to allocate towards the equity and liability hedging portions of the portfolio, these goals may not be readily attainable. Most pension funds are already fully invested in a portfolio consisting of equity and bonds. A typical portfolio for a pension planner is 50% or 60% invested in equities with the rest invested in bonds. Since the transaction costs generated by unwinding such a position can be astronomical, completely changing their portfolio to match the optimal allocations described above may not be feasible.

Instead, the pension fund can use interest rate swaps and CDS contracts to gain the proper exposure to the fixed income market. Using these contracts, pension planners can achieve the interest rate and credit exposure needed to hedge the liability curve as done above using TLT and CDX.NA.IG. The proper equity exposure can also be achieved using total return swaps or equity futures. All these products have zero outlay and do not require the pension fund to unwind their pre-existing positions.

To illustrate this strategy, we assume, as above, a funding ratio of 90% and a time horizon of 5 years to achieve a 95% funding ratio. Furthermore, we assume that the current capital allocation is 60% in equity and 40% in risk-free bonds. As shown above, in this example the optimal equity market exposure is 37% and the risk-free exposure is 100%. To achieve this exposure, we can sell total return swaps to gain a -23% exposure to the equity market and increase our risk-free rate exposure to 63%. We can increase our interest rate exposure to 100% by trading interest rate derivatives.

4.2 Recurring Adjustments

As the current market is very volatile, a buy and hold strategy may be inappropriate for a dynamic market. For instance, if the funding ratio has already reached 95% after three years, our original strategy will be outdated. We suggest reexamining w_g and w_ℓ every year and, if necessary, readjusting these weights to correspond with our portfolio's growth needs. Giving consideration to transaction costs, we recommend using the zero outlay derivatives described above.

5. Conclusions

Defined-benefit pension funds are primarily concerned with how their portfolios' value compares with that of their discounted future liabilities. This funding level is integral in determining how a fund should allot their available capital.

An optimal strategy for fully funded portfolios is to immunize their future liabilities. Since, these liabilities are calculated using the CPLI, they can be hedged by replicating this curve. The CPLI curve is based on U.S. AA corporate bonds, which we can decompose into risk-free and credit-risky elements. We represent the risk-free element using iShares 20+ Year Treasury Bond ETF's (TLT) and the credit element using the CDX.NA.IG Index for investment grade corporate credits. We choose these securities

[2] Similar tables were produced for alternative time horizons. The 5 year table was included to accommodate this example.

since they are more liquid than AA corporate bonds and have durations which properly match our liability stream. Upon regression, we approximate our portfolio coefficients to be 3.03 for the CDX.NA.IG Index and 0.91 for TLT.

Underfunded portfolios have the additional concern of allocating capital towards a growth portfolio. As the equity market has produced generally favorable returns over the past half-century, we have chosen to use the S&P 500 Index to represent an attainable growth in our analysis. Our simulations utilize a local volatility with a one-factor Hull-White interest rate hybrid model. In our results, we have found optimal weights for distributing the capital of an underfunded portfolio between growth and liability-hedging elements.

We recognize that existing portfolios cannot immediately take advantage of the optimal solutions described in this paper. As such, we have suggested zero outlay transition strategies involving interest rate swaps, CDS contracts, and total return swaps. Furthermore, we recommend an annual reexamination of a portfolio's allocation weights.

References

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[7] Bloomberg L.P. *CDS spread*, Retrieved from Bloomberg database. 27 Jan. 2015.

Appendix

Expectation (in percent)

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0	18.51	16.66	14.81	12.96	11.10	9.25	7.40	5.55	3.70	1.85	0.00
0.1	20.02	18.17	16.32	14.47	12.62	10.77	8.91	7.06	5.21	3.36	1.51
0.2	21.53	19.68	17.83	15.98	14.13	12.28	10.43	8.58	6.72	4.87	3.02
0.3	23.04	21.19	19.34	17.49	15.64	13.79	11.94	10.09	8.24	6.39	4.53
0.4	24.55	22.70	20.85	19.00	17.15	15.30	13.45	11.60	9.75	7.90	6.05
0.5	26.07	24.21	22.36	20.51	18.66	16.81	14.96	13.11	11.26	9.41	7.56
0.6	27.58	25.73	23.88	22.02	20.17	18.32	16.47	14.62	12.77	10.92	9.07
0.7	29.09	27.24	25.39	23.54	21.69	19.83	17.98	16.13	14.28	12.43	10.58
0.8	30.60	28.75	26.90	25.05	23.20	21.35	19.50	17.64	15.79	13.94	12.09
0.9	32.11	30.26	28.41	26.56	24.71	22.86	21.01	19.16	17.30	15.45	13.60
1	33.62	31.77	29.92	28.07	26.22	24.37	22.52	20.67	18.82	16.97	15.11

Volatility (in percent)

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0	259.4	233.4	207.5	181.6	155.6	129.7	103.8	77.8	51.88	25.94	0.00
0.1	264.1	238.2	212.3	186.3	160.4	134.5	108.5	82.6	56.65	30.71	4.78
0.2	268.9	243.0	217.0	191.1	165.2	139.2	113.3	87.4	61.42	35.49	9.56
0.3	273.7	247.8	221.8	195.9	169.9	144.0	118.1	92.1	66.20	40.26	14.35
0.4	278.5	252.5	226.6	200.7	174.7	148.8	122.8	96.9	70.97	45.04	19.13
0.5	283.2	257.3	231.4	205.4	179.5	153.6	127.6	101.7	75.75	49.82	23.91
0.6	288.0	262.1	236.1	210.2	184.3	158.3	132.4	106.5	80.53	54.60	28.69
0.7	292.8	266.8	240.9	215.0	189.0	163.1	137.2	111.2	85.30	59.38	33.47
0.8	297.6	271.6	245.7	219.7	193.8	167.9	141.9	116.0	90.08	64.16	38.25
0.9	302.3	276.4	250.5	224.5	198.6	172.7	146.7	120.8	94.86	68.94	43.04
1	307.1	281.2	255.2	229.3	203.4	177.4	151.5	125.6	99.64	73.72	47.82

Information Ratio

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	N/A
0.1	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.11	0.32
0.2	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.10	0.11	0.14	0.32
0.3	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.11	0.12	0.16	0.32
0.4	0.09	0.09	0.09	0.09	0.10	0.10	0.11	0.12	0.14	0.18	0.32
0.5	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.13	0.15	0.19	0.32
0.6	0.10	0.10	0.10	0.10	0.11	0.12	0.12	0.14	0.16	0.20	0.32
0.7	0.10	0.10	0.11	0.11	0.11	0.12	0.13	0.15	0.17	0.21	0.32
0.8	0.10	0.11	0.11	0.11	0.12	0.13	0.14	0.15	0.18	0.22	0.32
0.9	0.11	0.11	0.11	0.12	0.12	0.13	0.14	0.16	0.18	0.22	0.32
1	0.11	0.11	0.12	0.12	0.13	0.14	0.15	0.16	0.19	0.23	0.32

Table 2. *This table describes the expectation, volatility, and information ratio of the 5 year funding level growth rate. In each chart, the horizontal axis represents* w_ℓ *and the vertical axis represents* w_g.