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Adding Convertibles to Long-Term Capital Market Assumptions

How to Estimate Returns, Volatilities, and Correlations

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Executive Summary

- **Convertibles are a notable enhancement to a traditional 60/40 portfolio and this white paper provides institutional investors with a framework for including convertibles in proprietary asset allocation models**
- **Over the past 25 years, U.S. convertibles have outperformed U.S. large cap equity, U.S. investment grade core fixed income, U.S. high yield debt, and performed in-line with U.S. small/mid cap equity with materially less risk[1]**
- **As outlined in this paper and based on the Horizon Actuarial composite estimates, over the next 10 years, we project U.S. convertibles to outperform U.S. large cap equity, U.S. small/mid cap equity, U.S. investment grade core fixed income, and U.S. high yield debt**
- **Allocating to convertibles can enhance performance and meaningfully increase Sharpe Ratios in both equity and fixed income portfolios, given the asset class is characterized by equity-like returns with less volatility[2]**

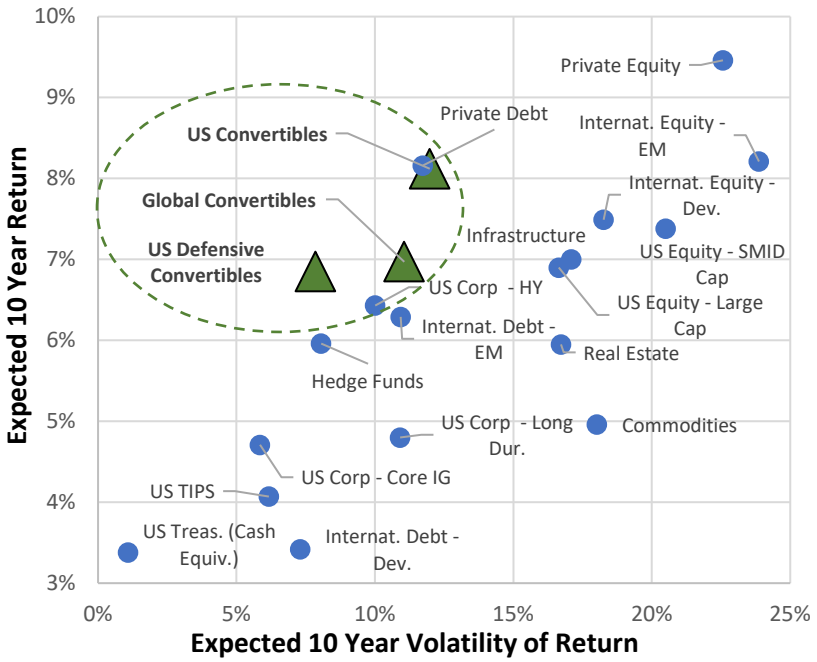
The purpose of this white paper is to present a mathematical framework to forecast convertible return, volatility, and correlations to other asset classes in order to integrate the convertible asset class into long-term capital market asset allocation models. As a basis for our forecasts, we use return, volatility, and correlation forecasts of other, more widely followed asset classes provided by Horizon Actuarial Services' 2023 Survey of Capital Market Assumptions ("Horizon Actuarial Survey"), published in August of 2023 with composite assumptions from 42 investment advisors and consultants.[3]

Our framework to estimate long-term capital market return assumptions for convertibles can be broken down into three components: Current Yield, Beta Return, and Residual Return.

Our forecasted expected returns were 8.12% per annum for U.S. convertibles, 6.85% per annum for U.S. defensive convertibles (Appendix A), and 6.97% per annum for global convertibles. Our expected volatility forecasts were 11.98% per annum for U.S. convertibles, 7.85% per annum for U.S. defensive convertibles, and 11.06% for global convertibles. Figure 1 shows these risk and return metrics versus other asset class estimates provided by Horizon Actuarial's survey.

We also estimated the correlation of convertibles to other asset classes, which allows us to analyze the effect of allocating to convertibles within an equity and fixed income "bucket" of a broader portfolio. This yielded the following key observations:

Figure 1. Convertibles Have Equity-Like Expected Return with Less Expected Volatility



Source: Horizon Actuarial Services, Advent Capital Management.

- **In an equity "bucket", a 10% and 15% allocation to U.S. convertibles increases the expected Sharpe Ratio by 6% and 10%, respectively, and for global convertibles, a 10% and 15% allocation increases the expected Sharpe Ratio by 4% and 5%, respectively.[2]**
- **In a fixed income "bucket", a 10% and 15% allocation to U.S. convertibles increases the expected Sharpe Ratio by 30% and 43%, respectively, and for global convertibles, a 10% and 15% allocation increases the expected Sharpe Ratio by 18% and 25%, respectively.[2]**

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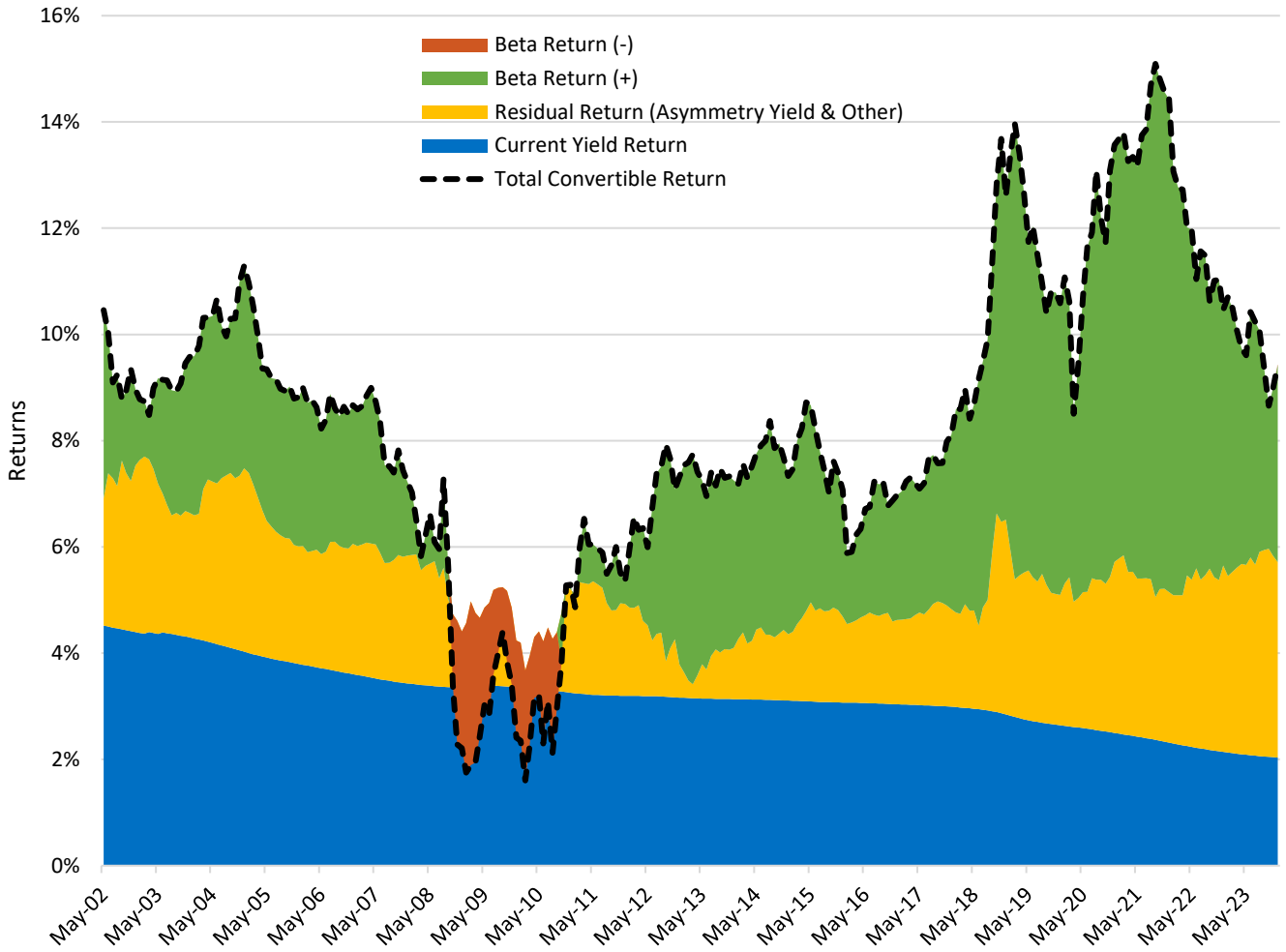
1. Forecasting Convertible Expected Return Components

To understand the drivers of return, we break down the total return of convertibles into three components: Current Yield, Beta Return, and Residual Return.

Expected Convertible Return = Current Yield + Beta Return + Residual Return (Asymmetry Yield & Other)

Figure 2 illustrates the effects of these three components on rolling 10-year historical U.S. convertible returns.[4] As observed in Figure 2, U.S. convertible trailing returns are sensitive to their end-date, ranging from an annualized return of over 14% for the 10-year period from October 2011-2021 to an annualized return of under 2% from January 1999-2009. In both cases, extreme economic environments had a significant impact on return. In this white paper, we do not try to predict these extreme events, but rather focus on long-term drivers of return and performance relative to other asset classes.

Figure 2. Historical Components of U.S. Convertible Return (Trailing 10-year Annualized)



Source: ICE Data Services.

1a. Convertible Current Yield

*Expected Convertible Return = **Current Yield** + Beta Return + Residual Return (Asymmetry Yield & Other)*

The first component of our forecasted convertible return is the current yield of convertibles (illustrated in blue in Figure 2). The current yield of convertibles reached over 8% in the early 1990s, but has mostly remained between 2% and 4% since then. With the recent return to higher rates, this component will likely become a more significant portion of convertible return over the next 10 years. We therefore use **a combined new issue and broad market current yield, and forecast current yield for U.S. and global convertibles to be 2.53% and 2.31%, respectively.**[5]

1a1. Why Use Current Yield Versus Yield to Maturity?

Forecasting returns for fixed income asset classes typically involves yield to maturity. However, in estimating the return of convertibles, current yield is a more reliable and usable metric than yield to maturity. Yield to maturity is based on the assumption that bonds will pay par at maturity, and this is only the case for a portion of convertibles, as many are converted into stock. In fact, for any convertible with a likelihood of being converted, the value of the option results in convertibles having a negative yield to maturity, which is not helpful in understanding the return prospects of the asset class. Additionally, the price movement of the convertible will be largely captured in the other components of convertible return: beta return (Section 1b) and residual return (Section 1c).

1a2. Determining the Proper Current Yield Estimate

To determine the proper current yield estimate, it is important to keep in mind that when issuing a convertible, an issuer is trading possible future equity dilution in return for reduced interest expense. New issue current yields have increased significantly over the past several years and range from approximately 2% to 4% for new issues brought to market in 2023.[6] **Moving forward, as lower coupon convertible debt will be rolled into higher coupon convertible debt, the average current yield will likely move closer to that of new issues.** For this reason, we use a combined new issue and broad market current yield as the return forecast for the next 10 years, which is 2.53% annualized for U.S. convertibles and 2.31% annualized for global convertibles.

1b. Convertible Beta Component of Return

*Expected Convertible Return = Current Yield + **Beta Return** + Residual Return (Asymmetry Yield & Other)*

The second component of our forecasted convertible return comes from the convertible's sensitivity (or beta) to the convertible issuer's equity ("underlying equity"). We refer to this component as "beta return," which is illustrated in green and red in Figure 2. Beta return is mostly influenced by the convertible equity option's sensitivity to the underlying equity (delta), but is also impacted by the convertible's sensitivities to credit spreads (omicron), interest rates (rho), and volatility (vega). The median 10-year annualized contribution of beta return has been 285 basis points per year, but this can vary from as much as around 1000 basis points per year when equities have done well, to around -300 basis points per year when equities have performed poorly (at the trough of the Global Financial Crisis).[4] We compute beta return as follows:

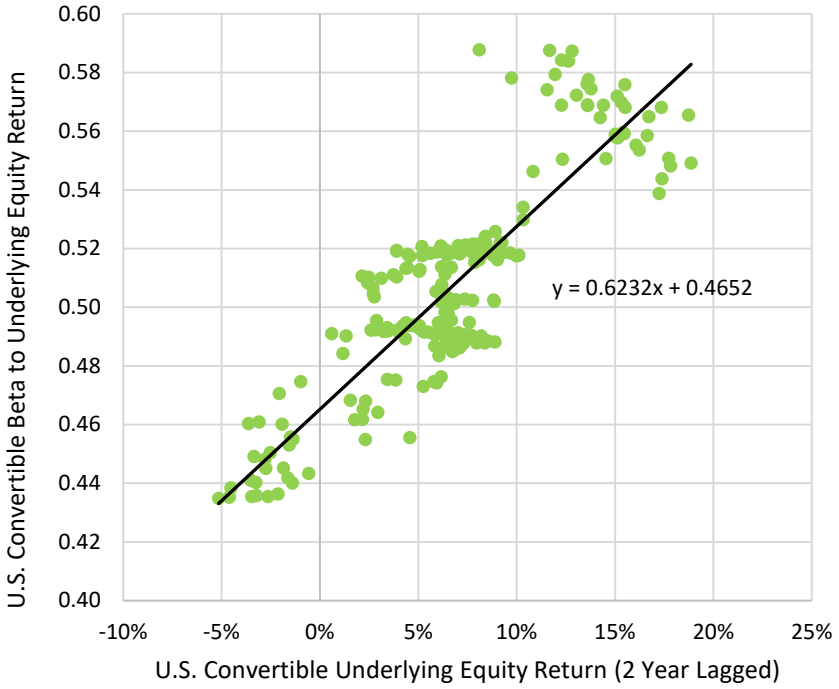
***Beta Return** = Beta of Convertibles to their Underlying Equity x Convertible Underlying Equity Return*

1b1. Estimating the Beta of Convertibles to Convertible Underlying Equity Using a Linear Regression

*Beta Return = **Beta of Convertibles to their Underlying Equity** x Convertible Underlying Equity Return*

Historically, there has been a meaningful relationship between the beta of convertibles to their underlying equities ("beta") and the convertible underlying equity return. **Assuming this relationship will be preserved into the future, we can use a linear regression model to effectively estimate the future beta of convertibles.** As illustrated in Figure 3, we regress the trailing 10-year beta of convertibles, against the lagged trailing 10-year returns of their underlying equities. The linear regression model equation allows us to predict the future beta (y-variable) using a forecasted value for the convertible underlying equity return (x-variable). This relationship exists due to the positive asymmetry (gamma) convertibles exhibit. In other words, the more equity prices appreciate, the more the embedded option equity sensitivity (delta) will increase. During long bull markets, therefore, beta tends to be higher as convertible deltas are higher, and during long bear markets, beta tends to be lower as convertible deltas fall. However, since convertible underlying equity returns have greater endpoint sensitivity than beta, the underlying equity return of 24 months ago is a better predictor of beta today. Therefore, we lag the convertible underlying equity returns by 24 months. The calculation is as follows:

Figure 3. Regression of U.S. 10 Year Convertible Beta to Underlying Equity Return vs. U.S. 10 Year Convertible Underlying Equity Return (2 Year Lagged)[7]



Source: ICE Data Services.

	Beta of Convertibles to Underlying Equities	Regression Equation
U.S. Convertibles[7]	0.48	(0.6232 * Underlying Equity Return) + 0.4652
Global Convertibles[8]	0.49	(0.2585 * Underlying Equity Return) + 0.4865

Due to the 2-year lag, the inputs for "Underlying Equity Return" in the above regression equations include two years of historical convertible underlying equity returns and eight years of the forecasted convertible underlying equity returns, which are expanded on in the following section.

1b2. Estimating Convertible Underlying Equity Return

Beta Return = Beta of Convertibles to their Underlying Equity x ***Convertible Underlying Equity Return***

In order to calculate the future beta of convertibles to convertible underlying equities using the linear regression model from Section 1b1, and to solve for beta return, we need estimates for future U.S. and global convertible underlying equity returns. **To best estimate future U.S. and global convertible underlying equity returns, we use another linear regression**

model based on the existing relationship of convertible underlying equities to other asset classes from the Horizon Actuarial Survey.

Determining the Appropriate Index to Use for the Underlying Equity Return Regression Model

Since U.S. convertibles, in many cases, are issued by U.S. small and mid cap ("SMID cap") companies rather than large cap companies, **the underlying equities of U.S. convertibles have a SMID market cap bias** with an R-squared to U.S. large cap equity of 0.77 and an R-squared to U.S. SMID cap equity of 0.88.[9] The typical reason companies issue convertibles is to reduce interest expense in exchange for an option on the company's stock. This trade-off tends to be of greater value for SMID cap companies that may have less access to advantageous straight-debt terms, and convertibles serve as a way to monetize their higher growth rates and equity volatility. It is also important to note that 20 out of 25 of the current largest members of the S&P 500 (as of 12/31/2023) have had convertibles as a part of their capital structure (e.g., Apple, Amazon, Tesla). Oftentimes, convertibles are the only way to have debt exposure to many innovative and growth companies as they tend to be the only form of debt financing on the issuer's balance sheet.

For global convertible equities, we compared returns relative to both the U.S. SMID cap and U.S. large cap indices, as well as to ex-U.S. developed country and emerging market ("EM") equity indices. We found that global convertible equities have a significant sensitivity to U.S. SMID cap equities and to EM equities, but large cap U.S. or ex-U.S. developed country equities do not have a meaningful impact on the significance of the model. **Therefore, to calculate U.S. convertible underlying equity beta to SMID cap, we use a regression of historical U.S. convertible underlying equity returns (y-variable) to historical SMID cap equity index returns (x-variable). For global convertibles, we use a two-factor regression of historical global convertible underlying equity returns (y-variable) to historical SMID cap and EM equity index returns (x-variables).**

Calculating the Future Convertible Underlying Equity Return

Using the Horizon Actuarial Survey forecasts for the risk-free rate (U.S. T-bill), SMID cap equity returns, and EM equity returns, we are able to estimate the U.S. and global future convertible underlying equity return from the models. See Table 1[10] below for calculations and Appendix B for additional information on the models used.

Table 1: Future Convertible Underlying Equity Model Return Calculation (Rf = Risk Free Rate)

U.S. Convertible Underlying Equity Model Return Formula
(SMID Return – Rf) x Convertible to SMID Beta + Rf
U.S. Convertible Underlying Equity Model Return Calculation
(7.38% - 3.38%) x 1.179 + 3.38% = 8.10%

Global Convertible Underlying Equity Model Return Formula
((SMID Return - Rf) x Convertible to SMID Beta + (EM Return - Rf) x Convertible to EM Beta) + Rf
Global Convertible Underlying Equity Model Return Calculation
(7.38% - 3.38%) x 0.778 + (8.21% - 3.38%) x 0.215 + 3.38% = 7.53%

Source: Horizon Actuarial Services, Bloomberg, Advent Capital Management.

Dividend Yield Impact on the Underlying Equity Return Calculation

There is one additional factor to consider in our model: dividend yield. While convertible investors receive a coupon in lieu of a dividend, as well as compensation for increased or special dividends, the regular dividend is not directly passed on to the convertible investor. The portion of the expected equity return relevant to the convertible is the total return less the dividend yield. We use the historical median U.S. and global convertible index dividend yield of 1.12% and 1.66%, respectively, which **results in an expected U.S. convertible underlying equity return ex-dividend of ~6.98% annualized (8.10% - 1.12%) and an expected global convertible underlying equity return ex-dividend of ~5.87% (7.53% -1.66%) annualized.**[11]

1b3. Calculating Beta Return Estimate

Using our linear regression model from Section 1b1 and our forecast for U.S. convertible underlying equity return from Section 1b2, we can now calculate the beta return estimate.

	10-year Beta Return		Beta Of Convertibles to Underlying Equity		Convertible Underlying Equity Return ex-Dividend
U.S. Convertibles*	3.37%	=	0.48	X	6.98%
Global Convertibles*	2.91%	=	0.49	X	5.87%

*Difference in calculation is due to rounding

Calculating Conservative Case and Optimistic Case Beta Returns

Conservative Case: Using the more conservative return assumptions provided in the Horizon Actuarial Survey, which are representative of the 25th percentile of return assumptions of 6.40% and 7.50% for SMID cap and EM equities, respectively, U.S. and global convertible underlying equity return estimates would be 5.82% and 4.96%, respectively. **This leads to an annualized 10-year conservative beta return estimate of 2.78% for U.S. convertibles and 2.44% for global convertibles.**

Optimistic Case: Using the more optimistic return assumptions provided by the Horizon Actuarial Survey, which are representative of the 75th percentile of return assumptions of 8.10% and 9.30% for SMID cap and EM equities, respectively, U.S. and global convertible underlying equity return estimates would be 7.82% and 6.67%, respectively. **This leads to an annualized 10-year beta return estimate of 3.81% for U.S. convertibles and 3.31% for global convertibles.**

1b4. How "Other" Factors (Spread Omicron, Rate Rho, and Vega) are Captured in our Estimate of Beta Return

The beta of convertibles to their own underlying equities is primarily a function of the equity sensitivity of the embedded equity option, called "delta." However, empirically we find that beta return is usually higher than the theoretical delta, which suggests that there is sensitivity to other factors impacting beta return. As we will expand on below, these sensitivities, which include **equity delta, spread omicron, rate rho, and volatility vega – to the extent they are correlated to the underlying equity price – are reflected in the beta return of convertibles.** Only the uncorrelated portion of these factors would then "show up" in the alpha or residual. We will evaluate the impact of **uncorrelated** rate, spread, and volatility changes on the residual long-term return of convertibles in Section 1c.

Impact of Credit Spread Sensitivity (Omicron)

Omicron represents credit sensitivity of the bond portion of a convertible relative to the stock price. Credit spreads are often highly correlated to stock price movements since the market cap of the company provides a "cushion" for outstanding debt. While convertibles exhibit relatively low credit spread sensitivity (omicron), there is some sensitivity,

particularly in lower delta "bond-like" convertibles. **Overall, the more highly correlated the credit spread is to the underlying equity, the more the beta return reflects any changes in credit spread.**

Impact of Interest Rate Sensitivity (Rho)

The bond portion of a convertible is also sensitive to changes in risk-free interest rates. There is usually a macro-economic relationship between interest rates and average spread levels, and equity prices. Rates and spreads are typically inversely correlated, since a stronger economy drives rates higher and spreads lower, and a weaker economy drives rates lower and spreads higher. A major exception to this relationship occurs when central banks are implementing restrictive monetary policy and push rates higher even as spreads widen. This is what occurred in 2022 and 2023, leading to a positive correlation of spreads and rates rather than the usual negative correlation. Typically, the negative correlation of interest rates and credit spreads means that the increasing rates reduces the sensitivity of convertibles to changes in the convertible underlying equity.

Impact of Volatility Sensitivity (Vega)

Furthermore, the value of the equity option in a convertible increases as equity volatility increases; this property is called vega. Typically, stock volatility increases as equity prices decline and as credit spreads widen, so a significant portion of vega should be correlated to equity prices and therefore captured in the beta return.

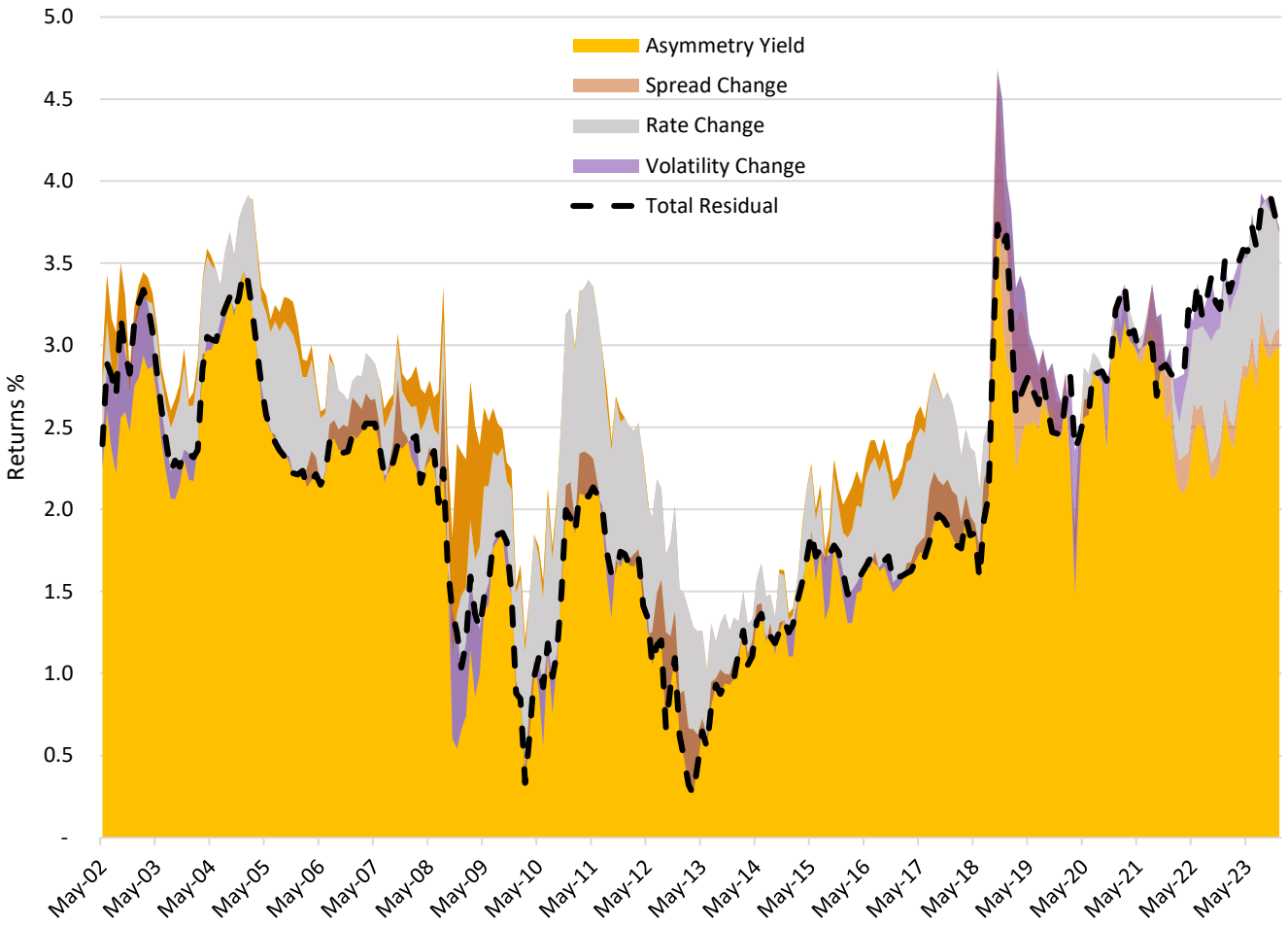
1c. Convertible Residual Return (Asymmetry Yield & Other)

Expected Convertible Return = Current Yield + Beta Return + ***Residual Return (Asymmetry Yield & Other)***

The third component of our forecasted convertible returns is the residual return (illustrated in yellow in Figure 2). The residual return is the incremental return above the sum of the current yield and beta returns. We use the median historical residual return as an estimate of the expected 10-year annualized residual return. **The median residual return is substantially positive, with a value of 222 basis points per year for U.S. convertibles and 175 basis points per year for global convertibles.**[12]

1c1. The Components of Residual Return

Figure 4. Components of the Residual Return of U.S. Convertibles



Source: ICE Data Services.

Asymmetry-Dispersion Yield ("Asymmetry Yield")

The historical residual return can be deduced by subtracting the historical beta and current yield returns from the historical total return. **This residual return, as illustrated in Figure 4, is mostly explained by the positive asymmetry** of convertibles and the dispersion of the convertible underlying equities**.** We refer to this characteristic as asymmetry-dispersion yield ("asymmetry yield"). Positive asymmetry is a fundamental characteristic of convertibles; over the long term, when stocks appreciate, convertibles tend to capture a significant portion of the upside, and when stocks fall, they tend to capture less of the downside. In aggregate, positive asymmetry meaningfully reduces the correlation and beta of convertibles to their underlying equities. This is true for both individual convertibles and portfolios of convertibles. In a portfolio, unless all equities are perfectly correlated, there will be some dispersion of return. All else equal, the convertibles from issuers whose stocks are advancing will participate in more of the upside, while convertibles tied to equities that are falling will participate in less of the downside. Therefore, even if the average underlying equity returns are unchanged, dispersion will cause the convertible portfolio to generate a positive asymmetry yield. The more asymmetry in the convertibles and the more dispersion in the underlying equities, the greater the benefit, or yield, earned. To understand more on the calculation of asymmetry yield, we present a numerical example in Appendix C.

Credit Spread (Omicron), Interest Rate (Rho), and Volatility (Vega) Impact on Residual Return

As explained in Section 1b4, most of the rate, spread, and volatility impact will likely have already been captured in the beta return estimate, to the extent they are correlated to convertible underlying equity prices. However, there is a small amount of movement in these three components that is **uncorrelated** to equity prices and not associated with asymmetry yield, which impacts the residual return.

To assess the impact of uncorrelated spreads, rates, and volatilities on residual return, we can regress the residual 10-year rolling returns on the 10-year rolling change in these three factors. After regressing the U.S. convertible residual return to the change in the 3-year U.S. treasury yield, the high yield spread over the 3-year treasury yield, and the VIX volatility index, it becomes clear that these three factors do not explain a significant portion of the residual return. Additionally, the coefficients of the residual return to rates, spreads, and volatilities are all very low, meaning that they have very little impact on the residual return.

Credit Loss Impact on Residual Return

One additional factor that is not captured in this analysis is the portion of credit loss. Most credit loss will be captured in the change in average credit spreads. However, in periods of extreme market environments when defaults are higher, like 2009, the impact of credit loss not captured in spread movement could be material and helps explain why the 10-year residual return and estimated asymmetry yield are lower from 2008 to 2018 (as shown in Figure 4).

Conclusion

It is therefore appropriate to use either the estimated historical median asymmetry yield alone, or the historical median total residual return in estimating convertible total return. The historical median value of the residual return for U.S. convertibles is 222 basis points per year, while the historical median asymmetry yield is 260 basis points per year. The proximity of these two values supports the conclusion that interest rates, credit spreads, and market volatility have a relatively insignificant impact on the expected residual return over the long term. We have chosen to use the more conservative of these two values (the historical median total residual return) in our forecast.

1d. Estimated Total Returns of Convertibles

Combining the three components of return for convertibles in Table 2 below, we arrive at our 10-year expected, conservative, and optimistic convertible return estimates. The expected, conservative, and optimistic returns represent the median, 25th, and 75th percentile of forecasts, respectively. Table 3 shows our projected convertible return estimates alongside other asset class return estimates provided in the Horizon Actuarial Survey.

Table 2. Conservative, Expected, and Optimistic Asset Class 10-year Return Estimates

	Conservative U.S. Convertibles	Conservative Global Convertibles	Expected U.S. Convertibles	Expected Global Convertibles	Optimistic U.S. Convertibles	Optimistic Global Convertibles
Current Yield	2.53%	2.31%	2.53%	2.31%	2.53%	2.31%
Beta Return	2.78%	2.44%	3.37%	2.91%	3.81%	3.31%
Residual	2.22%	1.75%	2.22%	1.75%	2.22%	1.75%
Total Return	**7.53%**	**6.50%**	**8.12%**	**6.97%**	**8.56%**	**7.37%**

Source: Advent Capital Management.

Table 3: Horizon Actuarial Return Forecasts and Advent U.S. and Global Convertible Return Estimates

	Conservative Forecasted Returns	Median Forecasted Returns	Optimistic Forecasted Returns
U.S. Convertibles	7.53%	**8.12%**	8.56%
Global Convertibles	6.50%	**6.97%**	7.37%
U.S. Equity - Large Cap	6.20%	**6.90%**	7.70%
U.S. Equity - Small/Mid Cap	6.40%	**7.38%**	8.10%
Non-U.S. Equity - Developed	6.80%	**7.49%**	8.10%
Non-U.S. Equity - Emerging	7.50%	**8.21%**	9.30%
U.S. Corp Bonds - Core IG	4.40%	**4.71%**	5.10%
U.S. Corp Bonds - Long Dur.	4.10%	**4.80%**	5.40%
U.S. Corp Bonds - High Yield	6.10%	**6.43%**	6.80%
Non-U.S. Debt - Developed	2.80%	**3.42%**	4.00%
Non-U.S. Debt - Emerging	5.90%	**6.29%**	7.00%
U.S. Treas. (Cash Equiv.)	2.80%	**3.38%**	3.80%
TIPS (Inflation-Protected)	4.00%	**4.07%**	4.30%
Real Estate	5.40%	**5.95%**	6.70%
Hedge Funds	5.30%	**5.96%**	6.50%
Commodities	3.90%	**4.96%**	6.20%
Infrastructure	6.30%	**7.00%**	7.40%
Private Equity	8.70%	**9.46%**	9.90%
Private Debt	7.60%	**8.16%**	8.60%

Source: Horizon Actuarial Services, Advent Capital Management.

2. Forecasting Convertible Volatility

2a. Forecasting U.S. Convertible Volatility

As stated previously, U.S. convertible equity returns are highly correlated to SMID cap equity returns. It should then logically follow to model U.S. convertible volatility relative to SMID cap equity volatility. However, a linear regression of convertible volatility to SMID cap equity volatility results in a low R-squared. Understanding that U.S. convertible underlying equities have relatively high idiosyncratic volatility, we can model convertible volatility relative to the systematic and idiosyncratic components of SMID cap equity. **Separating SMID cap volatility into idiosyncratic and systematic components results in a meaningful regression model of U.S. convertible volatility.**

2a1. How to Separate U.S. SMID Cap Volatility into Systematic and Idiosyncratic Components

The Horizon Actuarial Survey forecasts a volatility of 16.64% for U.S. large cap stocks and 20.51% for U.S. SMID cap stocks. It also forecasts a correlation of SMID cap stocks to large cap stocks of 0.89. This implies that SMID cap stocks will have systematic volatility relative to large caps of 18.25% and idiosyncratic volatility of 9.35%, using the mathematical volatility relationships described in Table 4 below. This methodology can be applied to the entire track record of the SMID cap index, allowing us to create a regression model.

Table 4: Deriving Systematic and Idiosyncratic Volatility from Other Asset Class Forecasts

	Action	Equation
Step 1	We derive the beta of one index relative to another using the ratio of estimated volatilities and the estimated correlations from the Horizon Actuarial Survey. If historical returns are available for both indices, this can simply be calculated as the slope between both data series.	**Beta of Index 2 relative to Index 1 = (Volatility of Index 2 / Volatility of Index 1) * (Correlation of Index 1 relative to Index 2)**
Step 2	We identify systematic volatility of an index relative to another index.	**Systematic Volatility of Index 2 to Index 1 = (Total Volatility of Index 1) * (Beta of Index 2 relative to Index 1)**
Step 3	We derive idiosyncratic (uncorrelated) volatility of an index relative to another index by subtracting out the systematic (correlated) volatility from the total volatility. This is done geometrically.	**Idiosyncratic Volatility of Index 2 = ((Total Volatility of Index 2)^2 – (Systematic Volatility of Index 2)^2)$^{1/2}$**

Calculations for U.S. SMID Cap Systematic and Idiosyncratic Volatility Relative to U.S. Large Cap

		Volatility Estimate	Correlation to Large Cap	Beta to Large Cap	Systematic Volatility	Idiosyncratic Volatility
Index 1	**Large Cap**	16.64%	1.00	1.000	16.64%	0.00%
Index 2	**SMID Cap**	20.51%	0.89	1.097	18.25%	9.35%

Source: Horizon Actuarial Services.

2b. Forecasting Global Convertible Volatility

For global convertible volatility, we were able to achieve a meaningful model using a multi-factor regression of three equity and two fixed income asset classes. Because the higher credit quality U.S. convertibles comprise the largest percentage of the global convertible index, the model that gives the best results for global convertible volatility is a blend of U.S. investment grade ("IG") credit, U.S. high yield debt, U.S. SMID cap equity, non-U.S. developed market equity, and non-U.S. emerging market equity volatility. Building a multi-factor model, we are able to solve for future global convertible volatility.

2c. Future U.S. and Global Convertible Volatility Models and Calculations

U.S. convertible volatility and global convertible volatility regression outputs are shown in Table 5[13] and Table 6,[14] respectively. U.S. convertible volatility and global convertible volatility (y-variables) are predicted with the volatilities derived and retrieved from the Horizon Actuarial volatility forecasts (x-variables).

Table 5. U.S. Convertible Volatility

Multiple R	0.8101
R Square	0.6562

	Regression Coefficients	Horizon Actuarial Volatility Forecast
Intercept	0.0462	
SMID Idiosyncratic Vol.	0.6852	9.35%
SMID Systematic Vol.	0.0522	18.25%
U.S. Volatility		**11.98%**

Source: Horizon Actuarial Services, Bloomberg.

Table 6. Global Convertible Volatility

Multiple R	0.9679
R Square	0.9368

	Regression Coefficients	Horizon Actuarial Volatility Forecast
Intercept	-0.0051	
U.S. SMID Cap	0.0821	20.51%
U.S. IG Fixed Income	0.2048	5.85%
U.S. High Yield	0.2350	10.01%
Non-U.S. Dev. Equity	0.3669	18.26%
EM Equity	-0.0149	23.87%
Global Volatility		**11.06%**

Source: Horizon Actuarial Services, Bloomberg.

3. Forecasting Convertible Correlations to Other Asset Classes

Horizon Actuarial Services provides average estimated long-term asset class correlations and volatilities. When asset class volatility forecasts exist, the correlation of convertibles relative to those asset classes can be determined if convertible idiosyncratic volatility with respect to these asset classes can also be forecasted. Convertible idiosyncratic volatility will have a relatively high correlation to other asset class volatility, such as SMID cap equity. It can also have relatively low correlation to asset class volatility such as U.S. investment grade credit. The calculation of convertible correlation to the other 17 asset classes provided by Horizon Actuarial can be broken down into a series of steps in Table 7. Convertible correlation and covariance outputs to other asset classes are provided in Table 8, and complete derivations, correlations, and covariance matrices for all 19 asset classes are provided in Appendix D.[15]

Table 7. Derivation of Convertible Correlation to Other Asset Classes

	Action	Explanation / Equation
Step 1	Calculate historical volatility for all 17 Horizon Actuarial Survey asset classes, plus U.S. convertibles and global convertibles, using index return streams	For this step, we used daily data to compute a rolling, 10-year trailing volatility
Step 2	Calculate convertible idiosyncratic volatility relative to each Horizon Actuarial Survey asset class, historically	See Table 4 in Section 2a for equations and calculations
Step 3	Regress convertible idiosyncratic volatility against the historical index volatility for each Horizon Actuarial Survey asset class	**We assume this relationship will persist into the future, and use this assumption as the basis in calculating convertible future correlations. After this step, everything is simply derived mathematically.**
Step 4	Using the slope and intercept assumptions from Step 3, solve for future convertible idiosyncratic volatility (y-variable) using Horizon Actuarial Survey volatility assumptions (x-variable)	For example, U.S. convertible idiosyncratic volatility relative to large cap stocks equals: ~5.83% = (0.10) x 16.64% + 0.08
Step 5	Solve for convertible systematic volatility relative to each asset class using the total volatility from Table 5 & 6 and the idiosyncratic volatility calculated in Step 4	**Convertible Systematic Volatility = (Convertible Total Volatility^2 – Idiosyncratic Volatility^2)$^{1/2}$** ~10.47% = (11.98%^{2} – 5.83%^{2})$^{1/2}$
Step 6	Solve for convertible relative volatility, beta, and correlation relative to each asset class	**Convertible Relative Volatility = Convertible Total Volatility / Survey Asset Class Volatility** ~0.72 = 11.98% / 16.64% **Convertible Beta relative to Asset Class = Convertible Systematic Volatility / Survey Asset Class Volatility** ~0.63 = 10.47% / 16.64% **Convertible Correlation relative to Asset Class = Convertible Beta to Asset Class / Convertible Relative Volatility** ~0.87 = 0.63 / 0.72
Step 7	We constrain the correlation estimate derived in Step 6 by adjusting the correlation above the maximum 10-year rolling historical correlation, to the maximum historical correlation, and below the minimum 10-year rolling historical correlation, to the minimum historical correlation.	

Source: Horizon Actuarial Services, Advent Capital Management.

Table 8. U.S. and Global Convertible Correlation & Covariances to Other Asset Classes

	U.S. Correlation	Global Correlation	U.S. Covariance	Global Covariance
U.S. Convertibles	**N/A**	**0.92**	N/A	1.214%
U.S. Equity - Large Cap	**0.87**	**0.84**	1.741%	1.545%
U.S. Equity - Small/Mid Cap	**0.91**	**0.85**	2.230%	1.932%
Non-U.S. Equity - Developed	**0.61**	**0.83**	1.334%	1.667%
Non-U.S. Equity - Emerging	**0.57**	**0.73**	1.644%	1.919%
U.S. Corp Bonds - Core IG	**0.09**	**0.18**	0.063%	0.115%
U.S. Corp Bonds - Long Dur.	**0.07**	**0.14**	0.086%	0.174%
U.S. Corp Bonds - High Yield	**0.57**	**0.63**	0.688%	0.700%
Non-U.S. Debt - Developed	**0.06**	**0.35**	0.052%	0.284%
Non-U.S. Debt - Emerging	**0.24**	**0.52**	0.314%	0.623%
U.S. Treas. (Cash Equiv.)	**(0.03)**	**0.03**	-0.003%	0.003%
TIPS (Inflation-Protected)	**0.05**	**0.11**	0.039%	0.073%
Real Estate	**0.59**	**0.69**	1.189%	1.277%
Hedge Funds	**0.94**	**0.89**	0.909%	0.790%
Commodities	**0.45**	**0.52**	0.964%	1.031%
Infrastructure	**0.70**	**0.84**	1.438%	1.583%
Private Equity	**0.82**	**0.85**	2.217%	2.118%
Private Debt	**0.45**	**0.61**	0.639%	0.790%

Source: Bloomberg, Horizon Actuarial Services, Advent Capital Management.

4. Asset Allocation Including Convertibles

Convertibles, which exhibit properties of both equity and fixed income securities, are commonly placed into either the equity or fixed income "bucket" within a broader diversified portfolio. Therefore, using the outcomes from our return, volatility, and correlation forecasts, combined with information from the Horizon Actuarial Survey, we can analyze the projected impact that allocating to convertibles will have on returns and risk within both the equity and fixed income portion of a broader portfolio.

Adding Convertibles into an Equity Bucket within a Broader Portfolio

To illustrate the impact of convertibles in an equity bucket, we constructed a portfolio based on Horizon Actuarial's "Hypothetical" portfolio including U.S. large cap equity, U.S. SMID cap equity, non-U.S. developed equity, and non-U.S. emerging market equity.[2] **A 10% and 15% pro-rata allocation to U.S. convertibles can increase the Sharpe Ratio of the equity bucket by 6% and 10%, respectively. A 10% and 15% pro-rata allocation to global convertibles can increase the Sharpe Ratio of the equity bucket by 4% and 5%, respectively.**

Adding Convertibles into a Fixed Income Bucket within a Broader Portfolio

To illustrate the impact of convertibles in a fixed income bucket, we constructed a portfolio based on Horizon Actuarial's "Hypothetical" portfolio including U.S. IG corporate credit, U.S. long duration corporate credit, U.S. high yield debt, non-U.S. developed market debt, non-U.S. emerging market debt, U.S. 1-year treasury bills, and US TIPS.[2] **A 10% and 15% pro-rata allocation to U.S. convertibles can increase the Sharpe Ratio of the fixed income bucket by 30% and 43%, respectively. A 10% and 15% pro-rata allocation to global convertibles can increase the Sharpe Ratio of the fixed income bucket by 18% and 25%, respectively.**

5. Conclusions

Using the mathematical framework and analysis described in this white paper, we are able to draw the following conclusions regarding the prospective returns, volatilities, and correlations of convertibles relative to other asset classes.

Returns: The components of our convertible return forecast are current yield, beta return, and the residual return (asymmetry yield & other). See Table 2 from Section 1d below.

	Conservative U.S. Convertibles	Conservative Global Convertibles	Expected U.S. Convertibles	Expected Global Convertibles	Optimistic U.S. Convertibles	Optimistic Global Convertibles
Current Yield	2.53%	2.31%	2.53%	2.31%	2.53%	2.31%
Beta Return	2.78%	2.44%	3.37%	2.91%	3.81%	3.31%
Residual Return	2.22%	1.75%	2.22%	1.75%	2.22%	1.75%
Total Return	**7.53%**	**6.50%**	**8.12%**	**6.97%**	**8.56%**	**7.37%**

Volatility: U.S. convertible volatility is best represented by a two-factor model relative to SMID cap equity systematic and idiosyncratic volatility. Global convertible volatility is best represented by a muti-factor regression model of U.S. investment grade ("IG") corporate debt, U.S. high yield debt, U.S. SMID cap equity, non-U.S. developed market equity, and non-U.S. emerging market equity volatility.

- U.S. and global convertibles are projected to have a volatility of 11.98% and 11.06% annualized, respectively.

Correlation: Correlations can be derived from a linear model of idiosyncratic volatility and the expected volatility ratio between convertibles and other asset classes.

Key Conclusions:

- **The projected Sharpe Ratio of U.S. and global convertibles is higher than all other liquid asset classes forecasted in the Horizon Actuarial Survey.**
- **U.S. convertible's 10-year projected return is 8.12%, which is 122 basis points higher than Horizon Actuarial forecasts for large cap equity, 341 basis points higher than core fixed income, and 169 basis points higher than high yield debt.**
- **U.S. convertible issuers' equities behave like SMID cap equity indices with a beta of 1.17, but the convertible indices have meaningfully less volatility and positive asymmetry. This gives the U.S. convertible index a lower beta of 0.61 and a high positive intercept (alpha) of 2.72% per year relative to SMID cap equity.[16]**
- **In an equity "bucket", a 10% and 15% allocation to U.S. convertibles increases the expected Sharpe Ratio by 6% and 10%, respectively, and for global convertibles, a 10% and 15% allocation increases the expected Sharpe Ratio by 4% and 5%, respectively.[2]**
- **In a fixed income "bucket", a 10% and 15% allocation to U.S. convertibles increases the expected Sharpe Ratio by 30% and 43%, respectively, and for global convertibles, a 10% and 15% allocation increases the expected Sharpe Ratio by 18% and 25%, respectively.[2]**

Appendix A. Modeling Defensive Convertibles

Defensive convertibles are a viable and proven lower volatility convertible strategy that can serve as an enhanced fixed income alternative. Therefore, we have applied the same expected return and volatility forecasting methodologies described in this paper to defensive convertibles. Metrics and calculations are below and are using the ICE Defensive Convertible Index (Q988) since its inception on 12/19/2017.

Expected Returns:

Defensive Convertible Expected Returns[17]	
Expected Current Yield (From Section 1a)	**2.53%**
Beta Return	(7.86% - 1.32%) x 0.282 = **1.84%**
Beta of Convertibles to Convertible Underlying Equity (12/19/2017 – 12/31/2023)	**0.282**
Median Dividend Yield (12/19/2017 -12/31/2023)	**1.32%**
Underlying Equity Return (using beta of convertible underlying equity to SMID cap equity from 12/19/2017 - 12/31/2023)	1.12 X (7.38% -3.38%) + 3.38% = **7.86%**
Residual Return (12/19/2017 -12/31/2023)	**2.48%**
Total Return	**6.85%**

Volatility:

Because defensive convertibles are more bond-like than the overall convertible index, forecasting volatility versus both U.S. SMID cap equity (Russell 2500 Total Return Index) and High Yield credit (ICE BofA U.S. High Yield Index (H0A0)) is the most viable option and results in the best model (using 90-day rolling volatility).

Defensive Convertible Volatility		
Multiple R	0.9581	
R Square	0.9179	
	Regression Coefficients	**Horizon Actuarial Volatility Forecast**
Intercept	0.0110	
U.S. SMID Cap	0.2731	20.51%
High Yield	0.1152	10.01%
Defensive Vol. Estimate		**7.85%**

The return and volatility estimates give defensive convertibles an expected Sharpe Ratio of 0.44 (using the 3.38% risk free rate from Horizon Actuarial's survey), which is higher than all other asset classes forecast in this paper.

Appendix B. Convertible Equity Alpha Consideration & Fama-French 5 Factor Model With Convertibles

Convertible Equity Alpha Consideration

Our estimates of convertible underlying equity returns in Table 1 do not include any temporal alpha relative to broad equity indices. The decision not to include temporal alpha is supported by the record of U.S. convertible underlying equities outperforming SMID cap equities 49.1% of the time (and underperforming 50.9% of the time) which is not statistically significantly different from a random outcome.[18] Also, the 8.12%, 6.85%, and 6.97% U.S. convertible, U.S. defensive convertible, and global convertible return estimates, respectively, reflect the Horizon Actuarial Survey expectation that U.S. small and mid cap equity ("SMID cap") will outperform U.S. large cap equity, which is typically favorable for the convertible asset class. Therefore, there is limited evidence to suggest persistent outperformance or underperformance of convertible underlying equities relative to SMID cap equity over full economic and market cycles.

Fama-French 5 Factor Model with Convertibles

We also evaluated U.S. convertible equity returns in a 5 factor Fama-French framework and found that convertible equities have a negligible +10 basis point per year residual relative to the 5 factors. Since the Horizon Actuarial Survey contains no expectations for 3 out of the 5 factors, we use the simpler linear SMID cap equity model in this paper. Investors and consultants with explicit Fama-French factor forecasts may choose to use the factor betas presented in the table below.[19]

		FF Factor Betas					10Y Trailing Residual		
Convertible Factors of Return	**Current Ratio**	**Mkt-RF**	**SMB**	**HML**	**RMW**	**CMA**	**Median**	**Average**	**Volatility**
Convertible Bonds	0.9594	0.6064	0.2708	(0.1516)	(0.1254)	(0.0562)	2.59%	2.74%	3.0%
Convertible Preferreds	0.0406	0.7202	0.1025	0.2215	(0.2451)	(0.1579)	1.09%	0.42%	7.6%
Weighted Average		0.6110	0.2639	(0.1364)	(0.1303)	(0.0604)	2.53%	2.64%	3.2%
Underlying Equity Factors of Return	**Current Ratio**	**Mkt-RF**	**SMB**	**HML**	**RMW**	**CMA**			
Convertible Bonds	0.9594	1.2070	0.3713	(0.0330)	(0.4398)	(0.1227)	0.30%	0.27%	4.9%
Convertible Preferreds	0.0406	1.2053	0.1883	0.9176	(0.5732)	(0.3870)	-4.44%	-4.42%	5.1%
Weighted Average		1.2069	0.3639	0.0056	(0.4452)	(0.1334)	0.10%	0.08%	4.9%

Appendix C: Asymmetry-Dispersion Yield Example Calculation

The amount of asymmetry in a convertible portfolio is measured by a value called gamma, which is the change in sensitivity of a convertible embedded option relative to stock prices (delta) as stock prices change. For example, a gamma of 0.5 means that as stock prices rise 1%, the sensitivity of the convertible option value relative to the stock price (delta) increases by 0.5%. Conversely, if the stock price falls 1%, delta will decrease by 0.5%, making the convertible more "bond-like." Therefore, if a portfolio has positive gamma, **convertibles will gain more from advancing underlying equities than they will lose on declining underlying equities.** Consider a portfolio where all positions have a delta of 0.50 or "50" and gamma of 0.5%, and there is stock price dispersion of 25%. In other words, half of the underlying equities are up 25% and half are down 25%. The delta of the advancing convertibles will increase from 50 to 62.5 and the delta of declining convertibles will fall from 50 to 37.5. The changes in delta are not instantaneous and occur gradually as stock prices change. This means

that for the purposes of calculating returns, on average the delta will be "halfway" between 50 and 62.5, which is 56.25 for the advancers and "halfway" between 50 and 37.5, which is 43.75 for decliners. We then sum the product of the initial portfolio weight multiplied by the average delta multiplied by the equity return. This is (50% x 56.25 x 25%) + (50% x 43.75 x -25%) = 1.5625%. Notice that the stock price change of 25% was first applied to the delta, after which the adjusted delta was multiplied by the stock price change again to calculate return. The equation can therefore be simplified to the following:

Expected Asymmetry-Dispersion Yield = (Average Gamma / 2) x (Expected Stock Price Dispersion)^2

Appendix D. Derivations, Correlation, Covariance Matrices

Source: Bloomberg, Horizon Actuarial Services, Advent Capital Management.

Derivation of Convertible Correlation to Other Asset Classes

		Step 3		Step 4	Step 5	Step 6			Step 7		
Asset Class	Survey Volatility	Slope	Intercept	Idiosyncratic Vol.	Systematic Vol.	Relative Vol.	Beta	Correlation	Historical Min.	Historical Max.	Adj. Correl. Est.
U.S. Convertibles	11.98%										
U.S. Equity - Large Cap	16.64%	(0.10)	0.08	5.83%	10.47%	0.72	0.63	**0.87**	0.75	0.92	**0.87**
U.S. Equity - Small/Mid Cap	20.51%	(0.20)	0.09	5.03%	10.87%	0.58	0.53	**0.91**	0.86	0.94	**0.91**
Non-U.S. Equity - Developed	18.26%	(0.13)	0.11	8.81%	8.11%	0.66	0.44	**0.68**	0.51	0.61	**0.61**
Non-U.S. Equity - Emerging	23.87%	(0.12)	0.12	9.09%	7.81%	0.50	0.33	**0.65**	0.41	0.57	**0.57**
U.S. Corp Bonds - Core IG	5.85%	0.60	0.08	11.59%	3.03%	2.05	0.52	**0.25**	(0.26)	0.09	**0.09**
U.S. Corp Bonds - Long Dur.	10.91%	(0.52)	0.16	10.25%	6.20%	1.10	0.57	**0.52**	(0.29)	0.07	**0.07**
U.S. Corp Bonds - High Yield	10.01%	(0.33)	0.12	8.52%	8.42%	1.20	0.84	**0.70**	0.20	0.57	**0.57**
Non-U.S. Debt - Developed	7.31%	0.25	0.09	10.93%	4.91%	1.64	0.67	**0.41**	(0.13)	0.06	**0.06**
Non-U.S. Debt - Emerging	10.93%	0.46	0.08	12.54%	*	1.10	*	-	0.24	0.40	**0.24**
U.S. Treas. (Cash Equiv.)	1.09%	6.07	0.08	15.04%	*	10.99	*	-	(0.29)	(0.03)	**(0.03)**
TIPS (Inflation-Protected)	6.17%	(0.12)	0.12	10.98%	4.78%	1.94	0.77	**0.40**	(0.19)	0.05	**0.05**
Real Estate	16.72%	(0.09)	0.11	9.64%	7.11%	0.72	0.43	**0.59**	0.41	0.74	**0.59**
Hedge Funds	8.06%	(1.04)	0.10	1.82%	11.84%	1.49	1.47	**0.99**	0.87	0.94	**0.94**
Commodities	18.02%	(0.11)	0.12	10.48%	5.80%	0.66	0.32	**0.48**	0.06	0.45	**0.45**
Infrastructure	17.10%	(0.15)	0.11	8.05%	8.87%	0.70	0.52	**0.74**	0.56	0.70	**0.70**
Private Equity	22.57%	(0.12)	0.09	6.83%	9.84%	0.53	0.44	**0.82**	0.72	0.82	**0.82**
Private Debt	11.73%	*	*	11.13%	4.43%	1.02	0.38	**0.37**	0.45	0.91	**0.45**
Global Convertibles	11.06%										
U.S. Convertibles	11.98%	0.47	(0.01)	4.43%	10.13%	0.92	0.85	**0.92**	0.61	0.94	**0.92**
U.S. Equity - Large Cap	16.64%	0.20	0.01	4.76%	9.99%	0.66	0.60	**0.90**	0.50	0.84	**0.84**
U.S. Equity - Small/Mid Cap	20.51%	0.08	0.03	4.98%	9.87%	0.54	0.48	**0.89**	0.57	0.85	**0.85**
Non-U.S. Equity - Developed	18.26%	(0.03)	0.06	4.93%	9.90%	0.61	0.54	**0.90**	0.69	0.83	**0.83**
Non-U.S. Equity - Emerging	23.87%	(0.00)	0.06	5.96%	9.32%	0.46	0.39	**0.84**	0.52	0.73	**0.73**
U.S. Corp Bonds - Core IG	5.85%	1.31	0.01	9.05%	6.36%	1.89	1.09	**0.58**	(0.19)	0.18	**0.18**
U.S. Corp Bonds - Long Dur.	10.91%	0.38	0.04	8.50%	7.07%	1.01	0.65	**0.64**	(0.23)	0.14	**0.14**
U.S. Corp Bonds - High Yield	10.01%	0.15	0.06	7.74%	7.90%	1.10	0.79	**0.71**	0.18	0.63	**0.63**
Non-U.S. Debt - Developed	7.31%	0.44	0.04	7.21%	8.39%	1.51	1.15	**0.76**	0.18	0.35	**0.35**
Non-U.S. Debt - Emerging	10.93%	0.25	0.06	8.52%	7.05%	1.01	0.64	**0.64**	0.31	0.52	**0.52**
U.S. Treas. (Cash Equiv.)	1.09%	1.39	0.07	8.78%	6.73%	10.15	6.17	**0.61**	(0.25)	0.03	**0.03**
TIPS (Inflation-Protected)	6.17%	0.68	0.04	8.28%	7.34%	1.79	1.19	**0.66**	(0.13)	0.11	**0.11**
Real Estate	16.72%	0.02	0.06	6.36%	9.05%	0.66	0.54	**0.82**	0.31	0.69	**0.69**
Hedge Funds	8.06%	1.59	(0.08)	5.13%	9.80%	1.37	1.22	**0.89**	0.76	0.95	**0.89**
Commodities	18.02%	0.10	0.06	7.48%	8.15%	0.61	0.45	**0.74**	0.14	0.52	**0.52**
Infrastructure	17.10%	(0.03)	0.05	4.85%	9.94%	0.65	0.58	**0.90**	0.67	0.84	**0.84**
Private Equity	22.57%	0.04	0.04	4.65%	10.03%	0.49	0.44	**0.91**	0.77	0.85	**0.85**
Private Debt	11.73%	*	*	8.77%	6.74%	0.94	0.57	**0.61**	0.49	0.85	**0.61**

Horizon Actuarial Expected Correlation Matrix with U.S. and Global Convertibles

#	Correlation Matrix	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	**U.S. Convertibles**	**1.00**																		
2	**Global Convertibles**	**0.92**	**1.00**																	
3	U.S. Equity - Large Cap	**0.87**	**0.84**	1.00																
4	U.S. Equity - Small/Mid Cap	**0.91**	**0.85**	0.89	1.00															
5	Non-U.S. Equity - Developed	**0.61**	**0.83**	0.81	0.77	1.00														
6	Non-U.S. Equity - Emerging	**0.57**	**0.73**	0.68	0.66	0.76	1.00													
7	U.S. Corp Bonds - Core IG	**0.09**	**0.18**	0.26	0.22	0.24	0.24	1.00												
8	U.S. Corp Bonds - Long Dur.	**0.07**	**0.14**	0.25	0.21	0.24	0.21	0.86	1.00											
9	U.S. Corp Bonds - High Yield	**0.57**	**0.63**	0.64	0.65	0.61	0.60	0.47	0.39	1.00										
10	Non-U.S. Debt - Developed	**0.06**	**0.35**	0.17	0.13	0.27	0.22	0.60	0.57	0.26	1.00									
11	Non-U.S. Debt - Emerging	**0.24**	**0.52**	0.50	0.47	0.53	0.60	0.55	0.48	0.61	0.43	1.00								
12	U.S. Treas. (Cash Equiv.)	**(0.03)**	**0.03**	(0.06)	(0.07)	(0.05)	(0.04)	0.16	0.07	(0.05)	0.16	0.05	1.00							
13	TIPS (Inflation-Protected)	**0.05**	**0.11**	0.14	0.11	0.15	0.18	0.64	0.57	0.32	0.49	0.40	0.16	1.00						
14	Real Estate	**0.59**	**0.69**	0.56	0.55	0.50	0.42	0.25	0.24	0.45	0.18	0.38	(0.01)	0.19	1.00					
15	Hedge Funds	**0.94**	**0.89**	0.68	0.69	0.68	0.64	0.24	0.21	0.60	0.14	0.48	(0.01)	0.16	0.43	1.00				
16	Commodities	**0.45**	**0.52**	0.33	0.34	0.40	0.40	0.07	0.02	0.34	0.11	0.25	(0.02)	0.19	0.25	0.38	1.00			
17	Infrastructure	**0.70**	**0.84**	0.64	0.60	0.60	0.54	0.29	0.32	0.54	0.24	0.45	(0.03)	0.21	0.47	0.52	0.38	1.00		
18	Private Equity	**0.82**	**0.85**	0.73	0.71	0.66	0.60	0.16	0.17	0.50	0.12	0.39	(0.07)	0.08	0.45	0.60	0.30	0.55	1.00	
19	Private Debt	**0.45**	**0.61**	0.51	0.52	0.49	0.46	0.14	0.16	0.61	0.06	0.36	(0.07)	0.08	0.35	0.54	0.29	0.42	0.54	1.00

Horizon Actuarial Expected Covariance Matrix with U.S. and Global Convertibles

#	Covariance Matrix	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	**U.S. Convertibles**	**1.435%**																		
2	**Global Convertibles**	**1.214%**	**1.223%**																	
3	U.S. Equity - Large Cap	**1.741%**	**1.545%**	2.769%																
4	U.S. Equity - Small/Mid Cap	**2.230%**	**1.932%**	3.037%	4.207%															
5	Non-U.S. Equity - Developed	**1.334%**	**1.667%**	2.461%	2.884%	3.334%														
6	Non-U.S. Equity - Emerging	**1.644%**	**1.919%**	2.701%	3.231%	3.313%	5.698%													
7	U.S. Corp Bonds - Core IG	**0.063%**	**0.115%**	0.253%	0.264%	0.256%	0.335%	0.342%												
8	U.S. Corp Bonds - Long Dur.	**0.086%**	**0.174%**	0.454%	0.470%	0.478%	0.547%	0.549%	1.190%											
9	U.S. Corp Bonds - High Yield	**0.688%**	**0.700%**	1.066%	1.334%	1.115%	1.434%	0.275%	0.426%	1.002%										
10	Non-U.S. Debt - Developed	**0.052%**	**0.284%**	0.207%	0.195%	0.360%	0.384%	0.257%	0.455%	0.190%	0.534%									
11	Non-U.S. Debt - Emerging	**0.314%**	**0.623%**	0.909%	1.054%	1.058%	1.565%	0.352%	0.572%	0.667%	0.344%	1.195%								
12	U.S. Treas. (Cash Equiv.)	**-0.003%**	**0.003%**	-0.011%	-0.016%	-0.010%	-0.010%	0.010%	0.008%	-0.005%	0.013%	0.006%	0.012%							
13	TIPS (Inflation-Protected)	**0.039%**	**0.073%**	0.144%	0.139%	0.169%	0.265%	0.231%	0.384%	0.198%	0.221%	0.270%	0.011%	0.381%						
14	Real Estate	**1.189%**	**1.277%**	1.558%	1.886%	1.527%	1.676%	0.245%	0.438%	0.753%	0.220%	0.694%	-0.002%	0.196%	2.796%					
15	Hedge Funds	**0.909%**	**0.790%**	0.912%	1.141%	1.001%	1.231%	0.113%	0.185%	0.484%	0.082%	0.423%	-0.001%	0.080%	0.579%	0.650%				
16	Commodities	**0.964%**	**1.031%**	0.990%	1.257%	1.316%	1.721%	0.074%	0.039%	0.613%	0.145%	0.492%	-0.004%	0.211%	0.753%	0.552%	3.247%			
17	Infrastructure	**1.438%**	**1.583%**	1.821%	2.104%	1.873%	2.204%	0.290%	0.597%	0.924%	0.300%	0.841%	-0.006%	0.222%	1.344%	0.717%	1.171%	2.924%		
18	Private Equity	**2.217%**	**2.118%**	2.742%	3.287%	2.720%	3.232%	0.211%	0.419%	1.130%	0.198%	0.962%	-0.017%	0.111%	1.698%	1.091%	1.220%	2.123%	5.094%	
19	Private Debt	**0.639%**	**0.790%**	0.995%	1.251%	1.050%	1.288%	0.096%	0.205%	0.716%	0.051%	0.462%	-0.009%	0.058%	0.686%	0.511%	0.613%	0.842%	1.430%	1.376%

Appendix E. Alternative Approach to Estimating Future Convertible Correlations

There is an alternative approach to estimating convertible correlation to other asset classes that includes using convertible betas to other asset classes, correlation estimates from Horizon Actuarial, and volatility estimates from Horizon Actuarial. A general framework of the process is described below.

First, the linear beta of every asset class to each other is derived using Horizon Actuarial-provided future correlation and volatility estimates, where the number of asset classes is equal to "N", and results in an "N x N" linear beta table. Then, a multi-factor regression of returns is performed for convertibles to all of the other asset classes. This results in a table of multi-factor betas, or put another way, "N" vectors of multi-factor coefficients. Ex-ante convertible linear beta estimates to each asset class are then calculated from the historical multi-factor coefficients by taking the sum-product of the multi-factor betas of the "N-1" asset classes to convertibles, multiplied by the ex-ante linear betas of the other classes. Once ex-ante linear betas of convertibles to the other asset classes have been created, the correlation of convertibles to other asset classes is derived using the corollary formula (*Correlation = Beta / Volatility Ratio)*. This approach worked well for equity and bond asset classes, producing reasonable convertible correlations. However, the inclusion of some alternative asset classes in the multi-factor regression process distorted the results of this approach. Essentially, convertibles showed such a high correlation to some alternatives that those asset classes were given high multi-factor betas, while stock and bond asset classes were given very small betas. This could be due to the importance of the convertible asset class to many hedge funds, which have historically derived profits from convertible arbitrage. Furthermore, the calculations resulted in correlation estimates greater than 1, which is not meaningful because it implies negative idiosyncratic volatility.

End Notes

1. Source: Bloomberg. Data is as of 12/31/2023. U.S. convertibles are represented by the ICE BofA US Convertible Excluding Mandatory Index (V0A0). U.S. large cap equity is represented by the S&P 500 Index (SPX). U.S. small/mid cap equity is represented by the Russell 2500 Index (RU25INTR). U.S. investment grade core fixed income is represented by the ICE BofA US Corporate Index (C0A0). U.S. high yield is represented by the ICE BofA US High Yield Index (H0A0).
2. Source: Horizon Actuarial Services, Advent Capital Management. The equity and fixed income buckets are based on the "Hypothetical" portfolio, which is a diversified portfolio provided in the Horizon Actuarial Survey. Allocations used are in the table below. Risk free rate used is the U.S. treasury forecasted return provided by Horizon Actuarial (3.38%).

Bucket	Asset Class	Equity Bucket Allocation			Fixed Income Bucket Allocation		
	Convertibles (U.S. and Global)	0.0%	10.0%	15.0%	0.0%	10.0%	15.0%
Equity	U.S. Equity - Large Cap	47.1%	42.4%	40.0%	-	-	-
	U.S. Equity - Small/Mid Cap	23.5%	21.2%	20.0%	-	-	-
	Non-U.S. Equity - Developed	17.6%	15.9%	15.0%	-	-	-
	Non-U.S. Equity - Emerging	11.8%	10.6%	10.0%	-	-	-
Fixed Income	U.S. Corp Bonds - Core IG	-	-	-	23.1%	20.8%	19.6%
	U.S. Corp Bonds - Long Dur.	-	-	-	7.7%	6.9%	6.5%
	U.S. Corp Bonds - High Yield	-	-	-	15.4%	13.8%	13.1%
	Non-U.S. Debt - Developed	-	-	-	15.4%	13.8%	13.1%
	Non-U.S. Debt - Emerging	-	-	-	7.7%	6.9%	6.5%
	U.S. Treas. (Cash Equiv.)	-	-	-	15.4%	13.8%	13.1%
	TIPS (Inflation-Protected)	-	-	-	15.4%	13.8%	13.1%

3. Throughout this paper, unless otherwise indicated, "Horizon Actuarial" represents Horizon Actuarial Services LLC, an actuarial consulting firm that publishes an annual "Survey of Capital Market Assumptions" that collects capital market forecasting information from 42 investment advisors. More information on the survey can be found at www.horizonactuarial.com.
4. Source: ICE Data Services. Data is monthly starting from 5/31/1992, which is the earliest date that data is available for the underlying equities of the constituents of the ICE BofA US Convertible Excluding Mandatory Index (V0A0) ("V0A0 Underlying Equities"), and ending on 12/31/2023. Throughout this paper, unless otherwise indicated, U.S. convertibles are represented by the ICE BofA US Convertible Excluding Mandatory Index (V0A0).
5. Source: ICE Data Services. Data is as of 12/31/2023. U.S. convertible current yield is a combined value of the ICE BofA New Issue U.S. Convertible Index (VNEW) and V0A0. VNEW current yield is weighted at 83.80% and V0A0 current yield is weighted at 16.20% based on a straight-line migration using the V0A0 expected life of 3.24 years as of 12/31/2023. Throughout this paper, unless otherwise indicated, global convertibles are represented by the ICE BofA Global 300 Convertible Index (VG00). In lieu of a global new issue index, our global convertible current yield is derived by adding the VNEW's current yield to the difference between the current month's V0A0 and VG00 current yield, and then further adding the difference between the VNEW's current yield and our U.S. convertible current yield estimate.

6. Source: Bloomberg. Data is as of 12/31/2023. New issue current yield range of 2% and 4% is represented by the 25th and 75th percentiles respectively of new issues brought to market in 2023 using the V0A0 January 2024 universe.
7. Source: ICE Data Services, Bloomberg. Data is monthly from 5/31/1992 through 12/31/2021 for the "Underlying Equity Return" which is represented by the V0A0 Underlying Equities, and from 5/31/1994 through 12/31/2023 for "Beta of Convertibles to Underlying Equities" which is represented by the beta of the V0A0 to the V0A0 Underlying Equities (R^2 = 0.74).
8. Source: ICE Data Services, Bloomberg. For the "Underlying Equity Return," data is monthly starting from 12/31/2003, which is the earliest date that data is available for the underlying equities of the constituents of the VG00 ("VG00 Underlying Equities"), and ending on 12/31/2021, and from 12/31/2005 through 12/31/2023 for "Beta of Convertibles to Underlying Equities," which is represented by the beta of the VG00 to the VG00 Underlying Equities (R^2 = 0.30).
9. Source: Bloomberg. Throughout this paper, unless otherwise indicated, U.S. small and mid-cap equities ("SMID cap") are represented by the Russell 2500 Index (RU25INTR) and U.S. large cap equities are represented by the S&P 500 (SPX). Data is monthly starting from 5/31/1992, which is the earliest date that data is available for the V0A0 Underlying Equities, and ending on 12/31/2023. All index returns throughout this paper are total returns.
10. Source: Bloomberg, Advent Capital Management. For U.S. convertibles, data is monthly starting from 5/31/1992, which is the earliest date that data is available for the V0A0 Underlying Equities, and ending on 12/31/2023. For global convertibles, data is monthly starting from 12/31/2003, which is the earliest date that data is available for the VG00 Underlying Equities, and ending on 12/31/2023. Throughout this paper, unless otherwise indicated, Emerging Market equities ("EM") are represented by the MSCI Emerging Markets Index (MXEF).
11. Source: ICE Data Services. Data is monthly and using the V0A0 and VG00 earliest consistent current yield data available, starting from 8/31/1991 and 9/30/2000 respectively, and ending on 12/31/2023.
12. Source: ICE Data Services. For U.S. convertibles, data is monthly starting from 5/31/1992, which is the earliest date that data is available for the V0A0 Underlying Equities, and ending on 12/31/2023. For global convertibles, data is monthly starting from 12/31/2003, which is the earliest date that data is available for the VG00 Underlying Equities, and ending on 12/31/2023.
13. Source: Horizon Actuarial Services, Bloomberg. Data is daily starting from 3/8/1991, which is the date of the earliest consistent Russell 2500 Index data available, and ending on 12/31/2023.
14. Source: Horizon Actuarial Services, Bloomberg. Data is monthly starting from 9/30/2003, which is the earliest date that data is available for the FTSE Developed All Cap Ex-U.S. Index (AD09X), and ending on 12/31/2023. U.S. High Yield is represented by the ICE BofA U.S. High Yield Index (H0A0). U.S. IG Fixed Income is represented by the ICE BofA U.S. Corporate Index (C0A0). Non-U.S. Dev. Equity is represented by the FTSE Developed All Cap Ex-U.S. Index (AD09X), and EM Equity is represented by the MSCI Emerging Markets Index (MXEF).
15. Source: Bloomberg. See the table below for representative indices and start dates used for idiosyncratic return regressions (Step 3) for each asset class. Data is daily using the V0A0 market open dates. Regressions and historical maximum and minimum correlations are starting from 10/31/1995, which is the earliest consistent daily data of the VG00, and ending on 12/31/2023, or the date of the earliest consistent daily data for each respective index, through 12/31/2023.

	Asset Class	Reference Index (Bloomberg Ticker)	Regression Start Dates (U.S. and Global)
1	U.S. Convertibles	ICE BofA US Convertible Excluding Mandatory Index (V0A0)	10/31/1995
2	Global Convertibles	ICE BofA Global 300 Convertible Index (VG00)	10/31/1995
3	U.S. Equity - Large Cap	S&P 500 Index (SPX)	10/31/1995
4	U.S. Equity - Small/Mid Cap	Russell 2500 Index (RU25INTR)	10/31/1995
5	Non-U.S. Equity - Developed	FTSE Developed All Cap Ex-U.S. Index (AD09X)	9/23/2003
6	Non-U.S. Equity - Emerging	MSCI Emerging Markets Index (MXEF)	10/31/1995
7	U.S. Corp Bonds - Core IG	ICE BofA U.S. Corporate Index Total Return (C0A0)	10/31/1995
8	U.S. Corp Bonds - Long Dur.	ICE BofA 10+ Year U.S. Corporate Index (C9A0)	10/31/1995
9	U.S. Corp Bonds - High Yield	ICE BofA U.S. High Yield Index (H0A0)	10/31/1995
10	Non-U.S. Debt - Developed	FTSE World Government Bond Index (SBNUU)	10/31/1995
11	Non-U.S. Debt - Emerging	Bloomberg Emerging Global Total Return Index (I01486US)	11/30/1998
12	U.S. Treas. (Cash Equiv.)	United States 1-year Treasury Bill (GC03)	10/31/1995
13	TIPS (Inflation-Protected)	Bloomberg U.S. Treasury Inflation Notes (LBUTTRUU)	4/15/1998
14	Real Estate	Dow Jones U.S. Real Estate Index (DJUSRE)	10/31/1995
15	Hedge Funds*	BarclayHedge Hedge Fund Index (BGHSHEDG)	10/31/1995
16	Commodities	Bloomberg Commodity Index (BCOM)	10/31/1995
17	Infrastructure	S&P Global Infrastructure Index (SPGTIND)	11/19/2001
18	Private Equity	S&P Listed Private Equity Index (SPLPEQTY)	11/24/2003
19	Private Debt**	Bloomberg Debt Private Equity Index (PEDEBT)	See Footnote

*Returns are monthly

**The private debt asset class had limited data available, so we used quarterly average 5-year trailing idiosyncratic volatility starting from 6/29/2012 through 9/30/2015 as a proxy for estimating the future idiosyncratic volatility to U.S. and global convertibles. We chose these date ranges because that is the time period when PEDEBT volatility most accurately matched the 11.73% Horizon Actuarial private debt volatility expectation. Data for historical maximum and minimum correlations is quarterly starting from 3/30/2007 and ending on 9/29/2023.

16. Source: Bloomberg. Data is monthly starting from the inception of the V0A0 Index on 12/31/1987, and ending on 12/31/2023.
17. Source: ICE Data Services. Data is daily starting from 12/19/2017, which is the date of the earliest consistent data for the ICE Defensive Convertible Index (Q988), and ending on 12/31/2023. Due to limited data, the future estimate of "beta of convertibles to convertible underlying equities" is calculated using the historical beta from 12/19/2017 through 12/31/2023.
18. Source: ICE Data Services. Data is monthly starting from 5/31/1992, which is the earliest date that data is available for the V0A0 Underlying Equities and ending on 12/31/2023.

19. Source: ICE Data Services. Data is monthly starting from 12/31/1994, which is the date of the earliest consistent data for the underlying equities of the constituents of the V0S0, and ending on 1/31/2024. Convertible bonds are represented by the ICE BofA US Convertible Excluding Mandatory & Preferred Index (V0S0) and the convertible preferreds are represented by the ICE BofA US Convertible Preferred Excluding Mandatory Index (V0P0), which when combined, result in the V0A0. More information on the Fama-French model can be found at mba.tuck.dartmouth.edu/pages/faculty/ken.french.

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