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Granular Portfolio Dynamics: The Importance of Joint Credit-Market Risk Modeling

Abstract

In this paper, we show the importance of jointly modeling market and credit risks for analyzing asset portfolio dynamics. Specifically, we calculate portfolio risk-decomposition, risk contribution, and economic capital using a new risk-integrated solution accounting for market and granular credit dynamics. We further show how different the interaction between market and credit risks can be for different assets and sub-portfolios with different characteristics (maturity, rating, R-squared, etc.). These differences in joint market-credit effects highlight the value of a risk-integrated analysis and cast doubt on commonly used simple adjustments, such as copulas, to integrate results from separate market and credit systems. These simple adjustments will likely make some assets seem overly attractive, leading to poor investment decisions.

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1. Introduction

Institutional investors who manage a portfolio of assets are often exposed to both market and credit risks. Understanding the interactions between these risks becomes especially important at longer horizons, for example when the assets are used to support long-term liabilities. Given the complexity of modeling different risks together, it is common practice to model market (interest rate, exchange rate, equity, spread, etc.) and credit risk in separate systems, and then integrate with simplified top-down assumptions like copulas. For example, combining Credit and Market Value-at-Risk (VaR) into Aggregate VaR requires a correlation parameter. Estimates of this parameter are sensitive to the portfolio composition and market conditions, making it difficult to rely on historical data and leading many investors to simply use heuristic values. As we will show in this paper, the interaction between market and credit risks can be very different across assets and sub-portfolios, making it extremely challenging to find a simple general adjustment to account for the joint impact for all instruments in the portfolio. These simple adjustments will likely make some assets seem overly attractive, leading to poor investment decisions.

Some credit systems make simplifying assumptions on market risks, for example, assuming deterministic interest rates, and as a result, miss a core driver of bond values. Market risk systems can sometimes capture high-level credit effects, but without granular credit modeling, they are not designed to capture the full concentration and diversification effects of the credit portfolio. Capturing the effects for the entire portfolio requires representation of individual credit instruments as well as a granular correlation model that can account for diversification effects across industries, countries, asset classes, etc.

In this paper, we use a new bottom-up Risk-Integrated Credit Solution (RICS) to show the importance of jointly capturing granular credit and market risks in projecting portfolio dynamics, such as pricing and risk/return measures that flow into many business applications. RICS brings together a market leading correlation model using a variant of the Moody's Analytics Global Correlation Model™ (GCorr)[1] and a cutting-edge market risk modeling (MA Scenario Generator[2]). Specifically, RICS accounts for three sources of interaction between market and credit risks:

1. The factors driving market risks are correlated with those driving credit migrations and defaults. The model differentiates between 61 countries, 49 industries and hundreds of commercial real estate and retail loan factors.
2. The values of credit-risky instruments are calculated based on the realization and future dynamics of spreads, exchange rates, and interest rates along each trial.
3. The reinvestment of cash payments from credit-risky instruments accounts for stochastic market risks (e.g., roll up at the stochastic risk-free rate for reinvestment in cash).

Using RICS, we show how the joint effects of credit and market risks can vary significantly across different portfolios. RICS also allows us to distinguish between different safe assets in which to hold capital, and their effect on the required economic capital. It is a multi-period simulation tool that accounts for mean-reversion dynamics and economic cycles, which opens the door to applications with longer horizons like Strategic Asset Allocation (SAA), cashflow and duration matching, and long-term portfolio management and risk measurement. We first illustrate the importance of capturing these joint dynamics for a portfolio of corporate bonds, and then extend the analysis to a portfolio with multiple asset classes.

2. Portfolio Dynamics with Interest Rate Risk

2.1 Interest Rate Risk Effects on Portfolio Value Distribution

To illustrate how the interaction between market and credit risks can be drastically different for different sub-portfolios, we first emphasize the role interest rate risk plays in the analysis of portfolio dynamics. Interest rate risk is an important consideration for institutional investors at any time, but especially in current market conditions, given the possibility of either prolonged low rates or accelerating inflation due to the unprecedented fiscal and monetary stimulus. Therefore, it is important to have models that capture a wide array of future economic scenarios. RICS simulates portfolio values accounting for bond risks, including interest rate and spread risk, along with defaults and migration. We use a stylized corporate bond portfolio as an example. This stylized

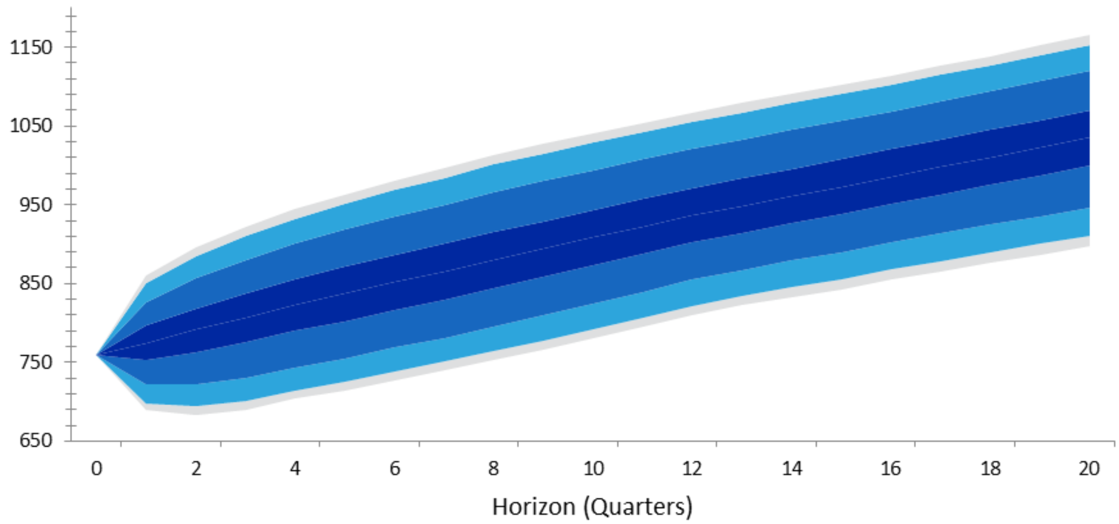
[1] The GCorr model is a multi-factor correlation model, consisting of close to 1,000 geographical, sectoral, and national and regional macroeconomic factors and inter-asset class correlations for a broad range of asset classes (public and private firms, CRE, retail, sovereign, and project finance). For more information, see "Modeling Credit Correlations: An Overview of the Moody's Analytics GCorr Model" by Huang, Lanfranconi, Patel, and Pospisil (2012).

[2] MA Scenario Generator generates scenarios for economic risk factors and asset returns using Monte Carlo techniques. For more information, see "Real World Best Views Calibrations" by Hibbert, Jessop, and Aldasani-Khyami (2018).

portfolio consists of 152 issuers, with ratings ranging from Aaa to Caa3, and R-Squared (RSQ) from 0.05 to 0.35. It contains 760 bonds maturing between 1 to 20 years, with par coupons paid at semi-annual frequency and stochastic recovery.

Figure 1 shows the projected value distributions of the stylized portfolio with stochastic interest rate models. We plot percentiles of the portfolio value distribution (0.5th to 99.5th) for projection horizons ranging from 1 to 20 quarters.

Figure 1 Portfolio Value Distribution: Full Portfolio with Stochastic Interest Rates.



Figures 2 and 3 break down the portfolio into investment grade bonds with long (greater than three years) and short (less than three years) maturities. The figures assess the impact of introducing stochastic interest rates. We can see clearly that bonds with higher sensitivity to interest rates (longer duration) indeed have a much wider distribution with stochastic interest rates. Interest rate dynamics also directly affect the value of any cash accumulated from the portfolio. In this example, we assume that any cash collected from coupon, principal, and recovery payments are rolled up with the risk-free short rate. Figure 3 shows the projected value distribution for the sub-portfolio of only short-term investment grade bonds (up to three-year maturity). While stochastic interest rates have a minor effect on the value distribution of these bonds early on, it starts to have a significant impact after three years, when the bonds have all matured, and all payments are held in cash.

Figure 2 Portfolio Value Distribution: Investment Grade and Long Maturity.

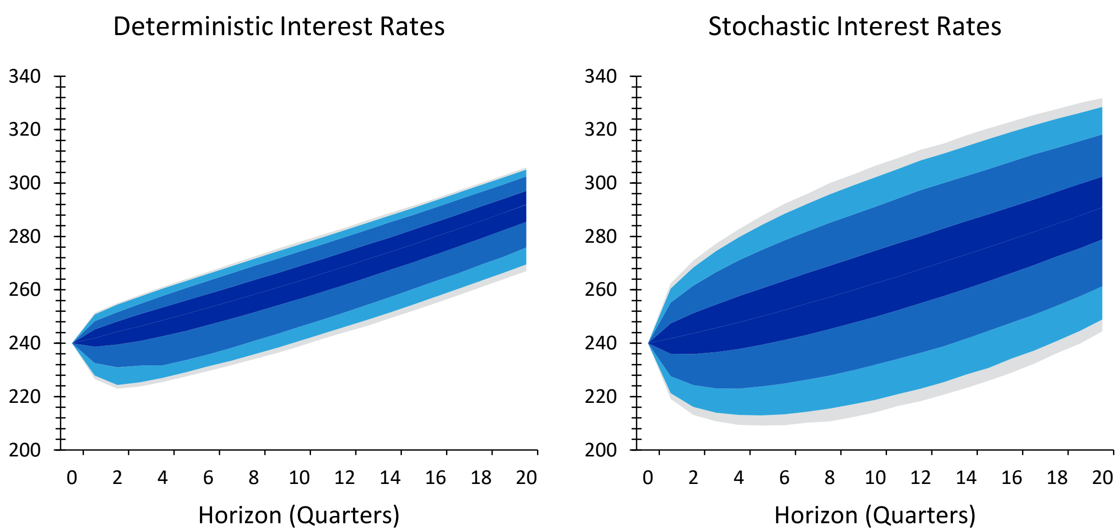
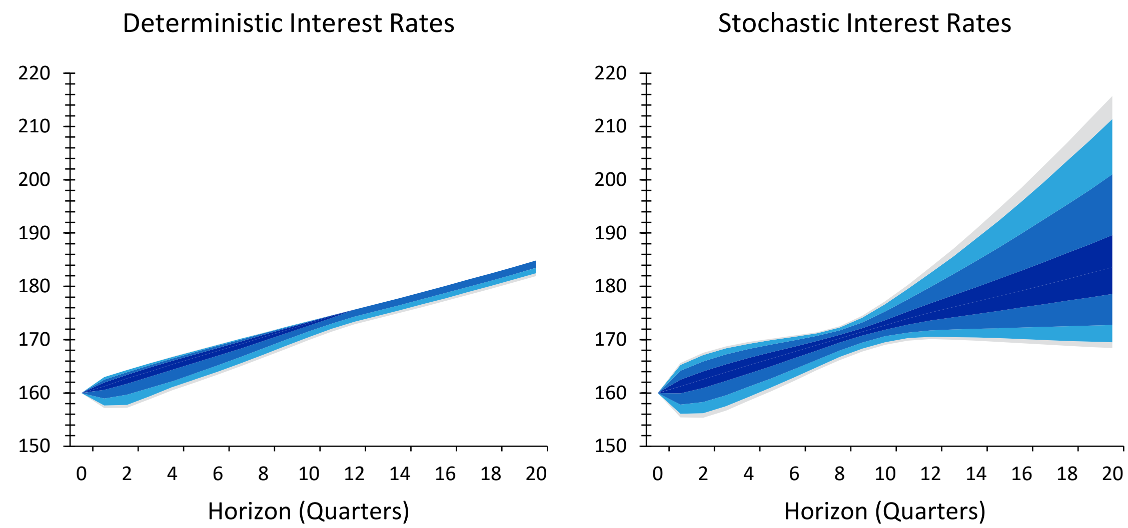


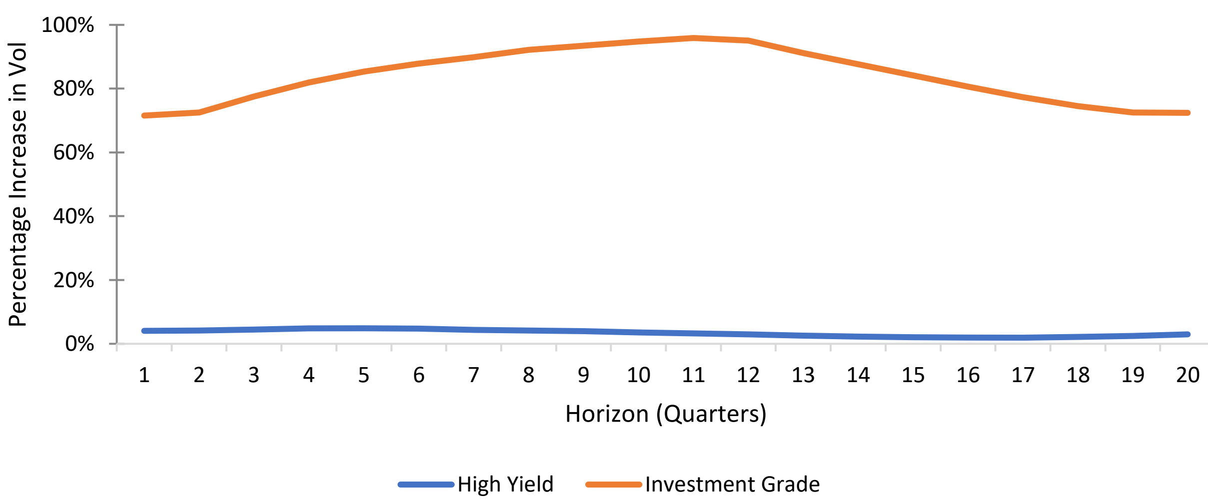
Figure 3 Portfolio Value Distribution: Investment Grade and Short Maturity



In a risk integrated system, where cashflows are uncertain, interest rate sensitivity (duration), is also a function of credit conditions. The fact that cashflows are uncertain means that, if the probability of default is higher, duration is lower, as more distant cashflows are less likely and recovery is more likely earlier. This means that bonds of the same maturity, but with different credit ratings, will have different durations, and so will have very different distributions due to stochastic interest rates. Figure 4 shows that when using stochastic interest rates, the volatility of the portfolio nearly doubles for the investment grade portfolio, but only slightly increases for the high yield portfolio.

In sum, there does not exist a single correlation parameter in the context of a Gaussian copula that can correctly capture the joint effects of credit and interest rate risks for all portfolio instruments. Moreover, a change in credit quality for a specific sector of the portfolio further invalidates any copula calibration based on current credit conditions. These different effects of interest rate risk on different credit instruments illustrate why integrating risks from separate market and credit systems is extremely challenging without a bottom-up approach to risk integration.

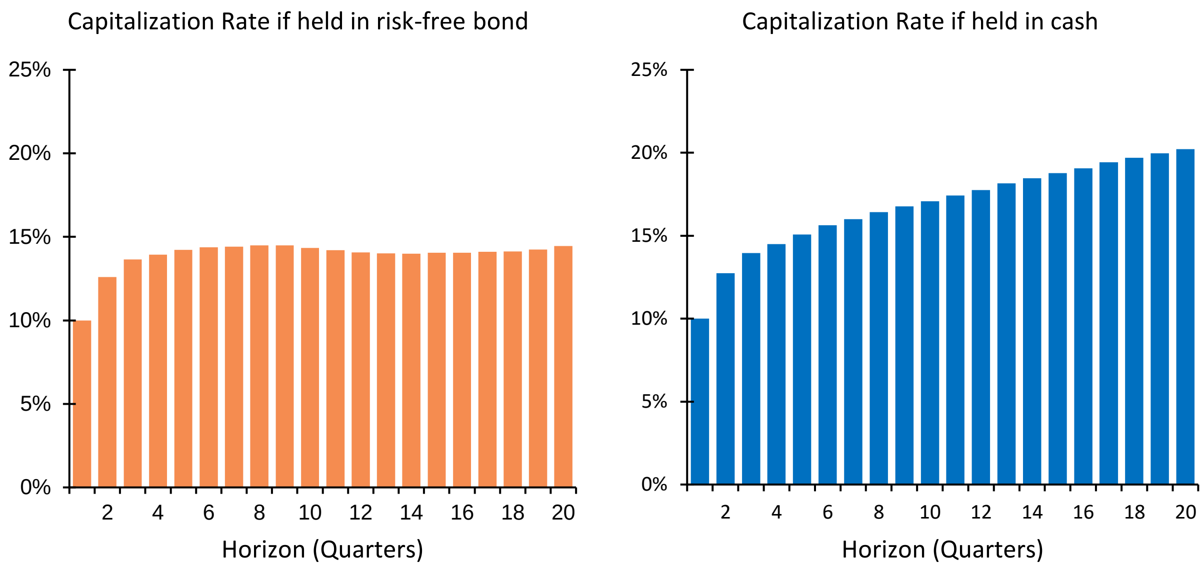
Figure 4 Portfolio Value Distribution: Additional Volatility Due to Stochastic Rates for IG/HY Sub-Portfolios.



2.2 Interest Rate Risk Effects on Economic Capital Calculation

Integrating stochastic interest rates into the projection of assets also enables institutional investors to more robustly calculate the amount of capital to hold in “safe assets” today in order to cover losses at any specific future horizon. Here, we define capital as the analysis date value of safe assets required to cover the difference between the 99th-percentile of the value distribution and the expected value (a.k.a., 99% capital in excess of expected loss). While these “safe assets” are not susceptible to credit risk, they can be highly sensitive to interest rate dynamics. Jointly modeling IR dynamics with granular credit allows us to distinguish between different "safe assets" and their effect on the required economic capital. To illustrate, Figure 5 distinguishes two ways of holding capital, either in treasury bonds (left) or in cash (right). In each plot, we present the term structure of the capitalization rate defined as portfolio capital amount per unit notional. Note, this capitalization rate accounts for credit risk, spread risk, and interest rate risk.

Figure 5 Capitalization Rate Term Structure.



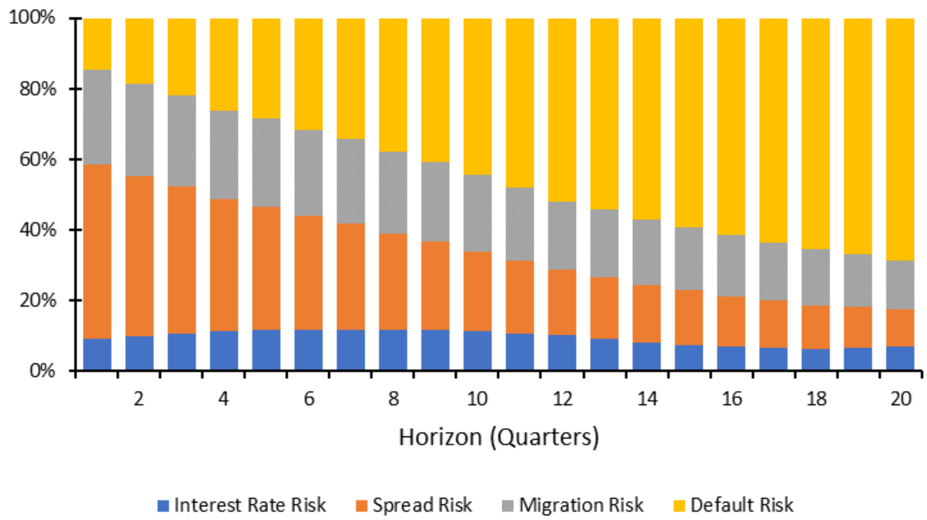
The term structures in Figure 5 represent the capitalization rate required to meet the cumulative losses to a specific horizon rather than the marginal value required in addition to previous horizons. Treating each horizon independently means that when capital is held in treasury bonds (with maturity equals horizon for each horizon), the capital required today is only determined by credit losses. However, the rolled-up value of capital at horizon is also subject to uncertainties in future interest rates when held in cash. In this case, cash roll-up is lower in some trials and higher in others, and these variations, together with their interaction with credit events, determine the capital required today. Therefore, holding capital in cash requires a higher capital amount to be put aside for all future horizons due to interest rate risk effects.

This is another example where jointly modeling credit and market risks demonstrates that simple assumptions, such as discounting capital using the initial yield curve, may miss important dynamics.

3. Decomposing Total Risk into Different Components

Jointly modeling different risks also allows us to better understand the types of risk we are most exposed to. We use the same bond portfolio described in Section 2 to illustrate this idea. Figure 6 decomposes the total portfolio risk (represented as portfolio standard deviation) into interest rate risk, spread risk, migration risk, and default risk. For example, the risk attributed to interest rate dynamics is calculated as the difference in standard deviation between the full portfolio distribution, and a "muted" version, where each value is averaged across trials that differ only in their interest rate state, but are otherwise the same (in terms of rating, spread, etc.). We observe that interest rate risk accounts for roughly 10% of the risk throughout the 20-quarter projection. As expected, default risk becomes more pronounced over time as the cumulative probability of default increases. Last, as the remaining duration of the bond portfolio decreases, spread risk and migration risk diminish.

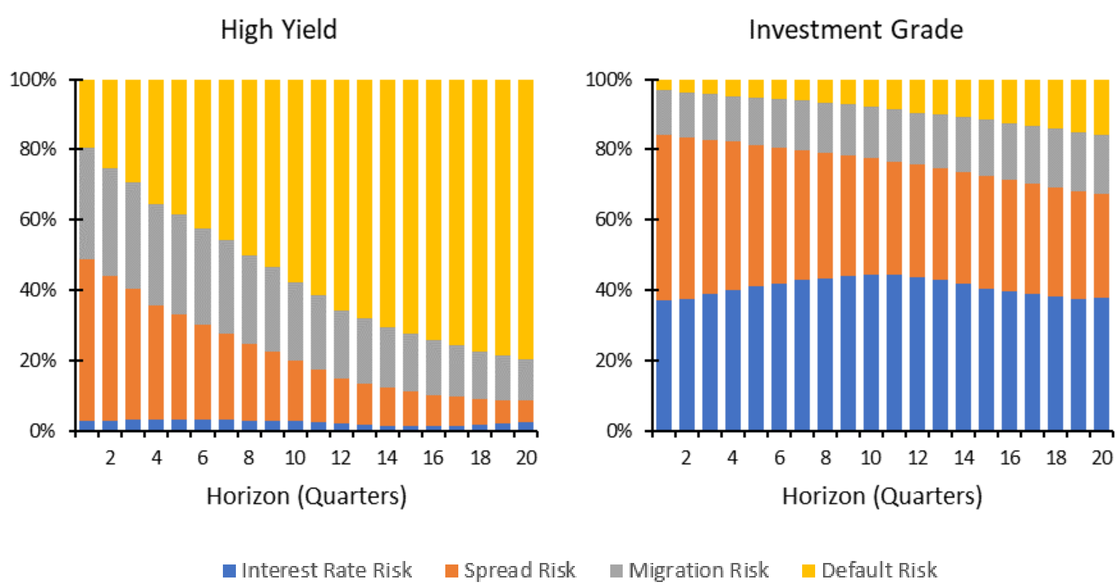
Figure 6 Risk Decomposition: Full Portfolio.

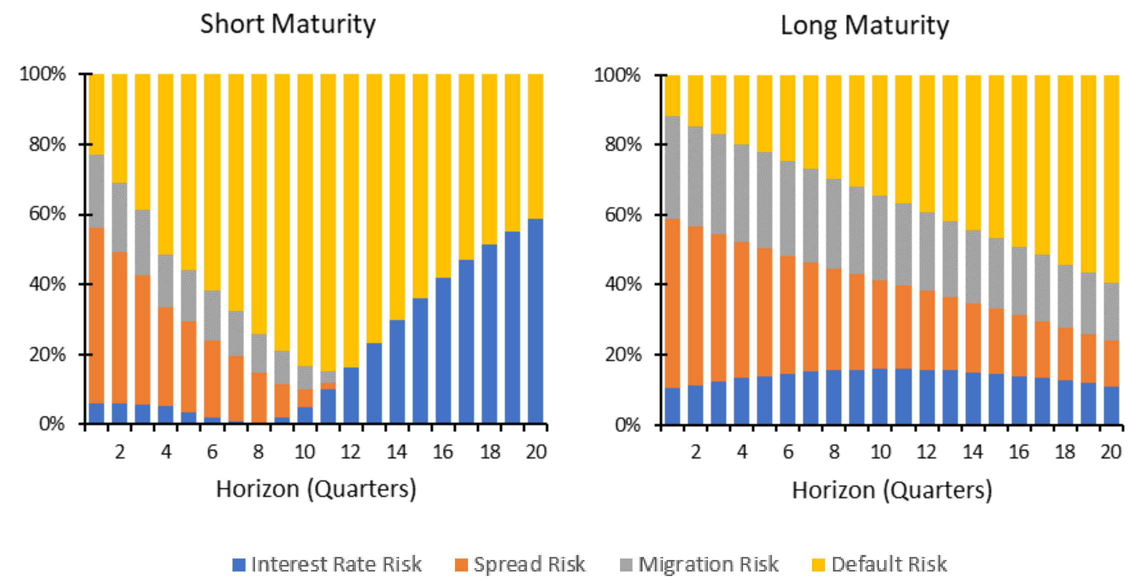


We also observe that different assets are more sensitive to different types of risk. Figure 7 shows example comparisons of sub-portfolios representing different maturity ranges and credit qualities. As expected, most of the risk of the high-yield portfolio comes from default, while the investment grade portfolio is much more sensitive to interest rate and spread risks. Once all bonds have either matured or defaulted in Q12 for the short-term portfolio, it is no longer sensitive to spread risk and migration risk, and it is increasingly dominated by interest rate risk due to the cash roll-up effect. Note, default risk still shows even after all bonds matured, because it captures variations in portfolio value across trials due to default events that have occurred prior to the bonds' maturing.

This exercise further illustrates the importance of jointly modeling credit and market risks. In contrast, using a credit-only system with a general adjustment representing market risks cannot adequately capture the sensitivity of different sub-portfolios or instruments to the different types of risk.

Figure 7 Risk Decomposition: Sub-Portfolios.





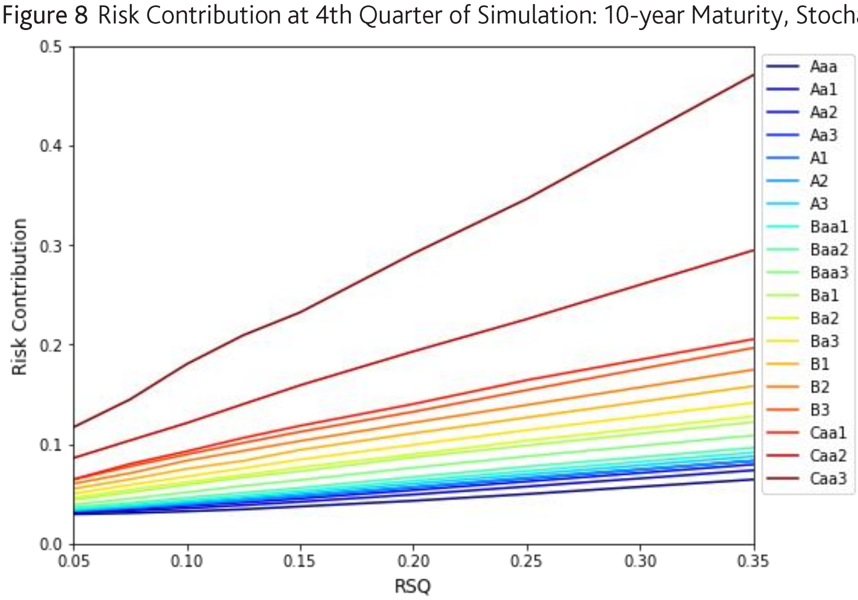
4. Allocation of Portfolio Risk

4.1 Risk Contribution Analysis for a Corporate Bond Portfolio

One fundamental problem institutional investors face is identifying individual instruments or groups of instruments that are the main drivers of portfolio risk. This analysis is critical for evaluating whether these instruments provide sufficient compensation for the marginal risk they impose on the portfolio. This section uses Risk Contribution (RC) as a measure of the marginal contribution of an instrument to the standard deviation of portfolio value, defined as the normalized covariance between the instrument value and the portfolio value. Given that covariances are additive and sum to the total portfolio risk (portfolio variance), RC offers a natural way to allocate portfolio risk. In our integrated market-credit system, RC accounts for contributions due to both credit and market risk variations.

Risk contribution is higher for instruments with either higher individual risk or stronger correlation with the overall portfolio. Figure 8 shows both of these effects, where we plot RC at a four-quarter horizon for all 10-year bonds by rating and RSQ. Bonds with worse ratings (more risk) or higher RSQs (more correlation) have higher risk contribution.

Figure 8 Risk Contribution at 4th Quarter of Simulation: 10-year Maturity, Stochastic Interest Rates.

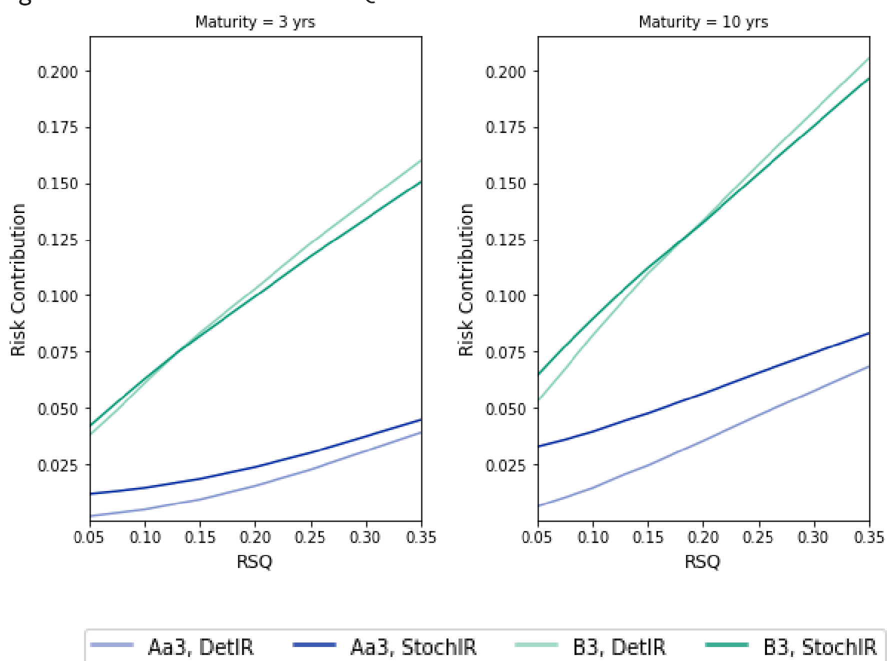


Comparing the risk contribution of different instruments with stochastic and deterministic interest rates in Figure 9 allows us to see the interaction of duration, interest rates and credit dynamics. Looking first at investment grade bonds, we see that with deterministic rates (light blue lines) the 10-year bond has a higher RC than the 3-year bond across all RSQ values. This is because stochastic spreads and migrations have a bigger impact on the 10-year bond than the 3-year bond. Moving from deterministic to stochastic rates (light blue to dark blue lines), the RC of the 10-year bond increases much more than that of the 3-year bond. This is because (1) it has a higher risk, due to the higher sensitivity to variations in interest rates, and (2) it is more correlated with the rest of the portfolio, because the interest rate risk increases co-movements between bonds of longer duration.

High yield, low quality, bonds demonstrate somewhat different behavior to that of investment grade bonds. The green lines in Figure 9 show this comparison. Taking the deterministic rate case first, we can see that the 10-year bond still has a higher RC than the 3-year bond for all levels of RSQ. However, switching to stochastic rates only increases RC for the low RSQ bonds and by far less than in the investment grade case. This follows as the duration of the riskier bonds is much lower than their safer counterparts, making the effect of interest rate variation less pronounced.

Furthermore, for high yield bonds with high RSQs introducing stochastic rates actually reduces RC. To explain this behavior, let us examine how RSQ impacts bond duration through risk premium. In RICS, investors demand compensation for risk borne, and so riskier bonds must have higher spreads. But, as in CAPM, investors are only compensated for taking systematic risk, not idiosyncratic risk. This means that investors require higher returns from issuers more exposed to systematic risk (i.e., those with higher RSQ), resulting in higher spreads for these bonds. High-yield bonds with high RSQs have the highest spreads, leading to lower duration relative to the rest of the portfolio. They are less sensitive to interest rates, and therefore, less correlated with the full portfolio when rates are stochastic, resulting in a lower RC.

Figure 9 Risk Contribution at 4th Quarter of Simulation.



This is another example of how different the effect of interest rate risk can be on different credit instruments, making it hard to capture in a simple general adjustment, and highlighting the importance of a risk-integrated system.

4.2 Risk Contribution Analysis for a Portfolio with Multiple Asset Classes

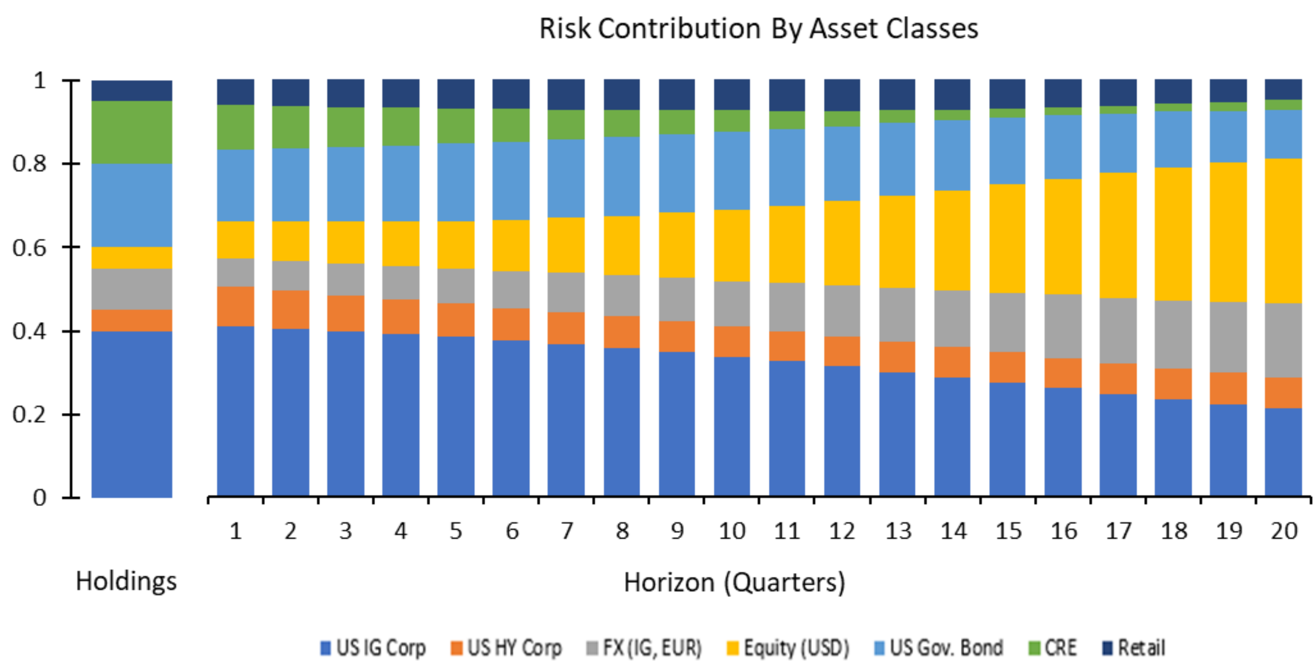
The above analyses demonstrate the importance of capturing market risks even for a bond portfolio. When introducing other asset classes into the portfolio, the interactions across asset classes produce even more complicated dynamics over time that are difficult to capture in a series of single-step analyses due to mean-reversion effects, reinvestment assumptions, etc. This section demonstrates this point using a buy-and-hold portfolio with multiple asset classes, assuming any cashflows received are held in cash. Specifically, we add U.S. Government bonds to U.S. IG corporate bonds as "safe" assets and introduce a U.S. equity index, a

Euro IG corporate bond portfolio (EUR denominated), a Commercial Real Estate (CRE) loan portfolio, and a Retail loan portfolio (residential mortgage) as “yield-seeking” assets, in addition to HY corporate bonds. The left bar in Figure 10 shows the initial holding amount in each asset class as a percentage of the portfolio, and the bars on the right show the risk contribution of each asset class calculated period-by-period over a 20-quarter simulation.

During the first quarter of the simulation, we observe that some risky assets already exhibit higher contributions than their holding amounts. For example, U.S. HY corporate bonds and equity only consist of 5% of the holding amount each at time 0, but exhibit RC in the first quarter of 10% and 9%, respectively. Due to the assumption of reinvestment in cash, as the simulation progresses and assets apart from equity mature, the RC of equity increases.

The portfolio is parameterized to capture the typical characteristics of each asset class. For example, we assume CRE loans are short term (5 years maturity) and have higher RSQ (15%), whereas, Retail loans are longer-term (15 years maturity) and lower RSQ (5%), and equity has no clear maturity. These differences in asset class characteristics affect sensitivities to both credit and market risks, resulting in different RC patterns by asset class over time. This further demonstrates how significantly different joint effects of credit and market risks by asset class can be.

Figure 10 Risk Contribution: Multi-Asset-Class Portfolio (buy-and-hold).



5. Summary

This paper demonstrates the importance of modeling credit and market risks in an integrated system when analyzing portfolio dynamics. Focusing on interest rate dynamics, we show how a risk-integrated solution allows institutional investors to project the distribution of portfolio value, more accurately accounting for the different joint effects on sub-portfolios and individual instruments. We further demonstrate the implications of integrated-risk analysis for risk management, e.g., capital calculation and decomposed portfolio risks into interest rate, spread, migration, and default to illustrate material differences between sub-portfolios in their exposure to these risk types. Finally, we use risk contribution to allocate portfolio risks to each instrument in a corporate-bond portfolio and to different asset classes within a multi-asset class portfolio. These exercises highlight the challenge of integrating risks from separate credit and market systems and promote the use of an integrated market-credit risk modeling solution as a consistent framework for analyzing dynamics of portfolios with different asset compositions.