Cross-Asset Impact of Rising Interest Rates

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Abstract
We investigate the cross-asset impact of rising interest rates. A detailed account of the market sentiment toward the Federal Reserve interest rate hikes is given, followed by a systematic regression analysis of the correlations between the treasury curve factors and four other asset classes including credit, equity, commodity, and currency markets. Lastly, we develop a cross-asset portfolio based on our findings to anticipate the rising interest rates.

Keywords
Interest Rate Hikes — Yield Curve Factors — Nelson-Siegel Model — Cross-Asset Impact — Credit Spreads — Equity Returns — Commodity Prices — Currency Rates — Portfolio Construction

Contents

1. Introduction

In response to the 2008 financial crisis and its aftereffect, the Federal Reserve (the Fed) launched several countermeasures, including Quantitative Easing and rate cuts, to provide liquidity and support the financial markets. In January 2008, the Fed announced an emergent rate cut of 75 bps from the 4.25% benchmark rate, which was followed by a series of aggressive subsequent cuts throughout the year. By the end of 2008, as shown in Figure (1), the Federal Funds Rate (FFR) was kept in the $[0, 25]$ bps bracket and was effectively zero. Treasury yields on government debt in several countries have fallen to vanishingly low values since then. This remained as the status quo for 8 years until December 2015, when the FOMC committee decided to raise the Fed Fund Target Rate

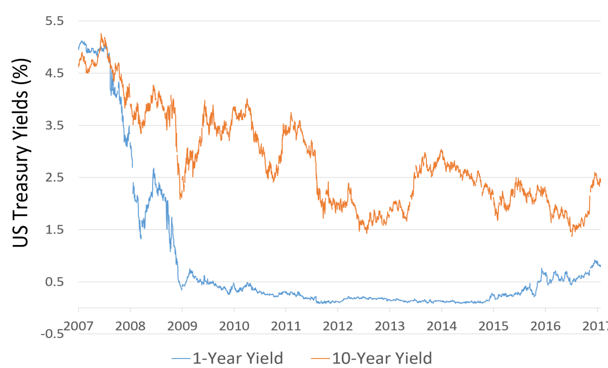

Figure 1. One- and ten-year constant maturity US Treasury zero-coupon bond yields from 2000 to 2017. Data source: Bloomberg.

(FFTR) by 25 bps for the very first time since the crisis. This was followed by a second rate hike in December 2016 which signals a strong possible beginning of rising rate cycle in the years to come [1].

The impact of rate hikes is profound since it can significantly alter or even reverse the financial landscape that has been taken for granted for years. An understanding of the term structure of interest rates and its cross-asset impact requires attention both for portfolio management and for macroeconomic and monetary policy analysis. Given the complicated nature of interest rates and their far-fetching effect on the overall financial markets, we structure our study into three interrelated sections to better assess and quantify their impact. In Section 2, we first start with a discussion on the probability of rate hikes using an estimation method based on 30-day Fed Fund Futures. This is then followed, in Section 3, by the study of yield curve modeling with the use of a dynamic Nelson-Siegel model. We conclude this section by conducting an empirical Granger causality examination on the driving factors of the yield curve factors and the macroeconomic variables (Capital Utilization, CPI, and FFR) to establish the relationship between the shape of the yield curve and the FFR. Lastly, in Section 4, we explore the linkages between the yield curve and different financial markets including the credit, equity, commodities, and currency markets using regression methods.

With the aid of models explored in the previous sections, we propose an index weighting scheme of portfolio construction that exploits such structures in Section 5.

2. Market Sentiment

The Fed has historically announced FOMC decision dates for the following year during the summer months. To estimate the market sentiment toward the future scenario of rising interest rates, we describe in detail a method of implying the forward rates from the market data of Fed Fund Futures and predict the probabilities of interest rate hikes at FOMC meetings for the remaining months of 2017 [2].

Forward Rates

At a given calculation day, denote the meeting dates by d_i, $i = 1, \cdots, N$, the futures price associated with the month of d_i by F_i, and the forward rate from d_i to d_{i+1} by $f_{i,i+1}$, where $i = 1, \cdots, N$. The goal is to estimate $f_{i,i+1}$ and the probability of interest rate hikes from F_i for the front-month $i = 1$ and all subsequent months $i = 2, \cdots, N$.

For the front-month associated with d_1, if there is no FOMC meeting in the following month or the announcement in the following month occurs late enough not to have an effect on the futures price (Figure (2) upper panel), it can be assumed that the futures price in the following month is an unbiased estimator of the front-month forward rate f_{12}:

$$f_{12} = 100 - F_2. \tag{1}$$

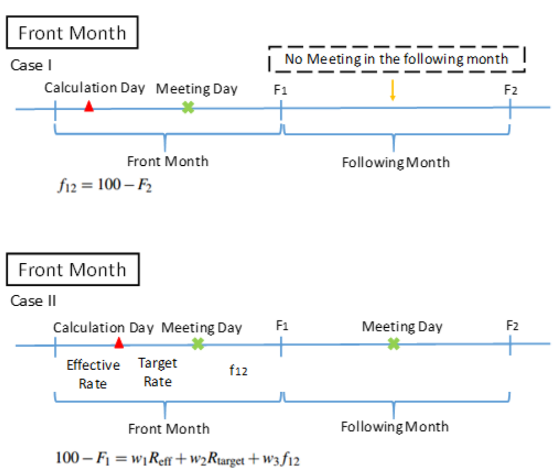

Figure 2. Front-month forward rate.

If, however, there is a meeting in the following month (Figure (2) lower panel), the futures market is potentially pricing in both the front-month's announcement and the following month's announcement. Thus we estimate the front-month's futures price as a day-weighted average of the following three rates:

- The Fed Fund Effective Rate R_{eff}, applicable to the days prior to the calculation day;
- The Fed Fund Target Rate R_{target}, in effect from the calculation day to the meeting day;
- The forward rate f_{12} implied by Fed Fund Futures, for the remainder of the front-month.

In other words,

$$100 - F_1 = w_1 R_{\text{eff}} + w_2 R_{\text{target}} + w_3 f_{12}, \tag{2}$$

where

$$w_1 = \frac{\text{Calculation Day - 1}}{\text{Days in Front-Month}},$$
$$w_2 = \frac{\text{Meeting Day - Calculation Day + 1}}{\text{Days in Front-Month}},$$
$$w_3 = 1 - w_1 - w_2.$$

Eq.(2) is solved for f_{12}.

For the subsequent months associated with d_i, $i = 2, \cdots, N$, again, if there is no FOMC meeting in the month following the month associated with d_i (Figure (3) upper panel),

$$f_{i,i+1} = 100 - F_{i+1}. \tag{3}$$

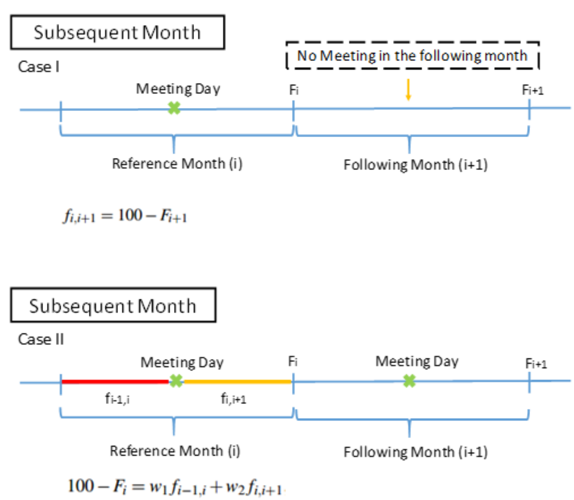

Figure 3. Forward rates in subsequent months.

If, however, there is a meeting in the following month (Figure (3) lower panel), we estimate the futures price of the reference month as a day-weighted average of the following two rates:

- The forward rate $f_{i-1,i}$ estimated in the previous step, applicable to the days prior the meeting day d_i;
- The forward rate $f_{i,i+1}$ for the remainder of the month associated with d_i.

Meeting Date	Probability of Hike	Probability of Cut	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	2-2.25
2017/03/15	50.0%	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2017/05/03	66.6%	0.0%	33.4%	50.0%	16.6%	0.0%	0.0%	0.0%	0.0%
2017/06/14	78.4%	0.0%	21.6%	44.2%	28.4%	5.8%	0.0%	0.0%	0.0%
2017/07/26	81.7%	0.0%	18.3%	40.6%	30.8%	9.4%	0.9%	0.0%	0.0%
2017/09/20	88.7%	0.0%	11.3%	32.1%	34.6%	17.5%	4.1%	0.3%	0.0%
2017/11/01	90.1%	0.0%	9.9%	29.6%	34.3%	19.6%	5.8%	0.8%	0.0%
2017/12/13	95.2%	0.0%	4.8%	19.4%	31.8%	27.2%	12.9%	3.4%	0.4%

Table 1. As of February 27, 2017 end of day, projection of the probability of interest rate hikes at 2017 FOMC meetings, with the FFTR falling into the brackets of the form $[i, i+1] \times 0.25\%$, $i = 2, \cdots, 8$. The probability of an interest rate hike in March 2017 is estimated to be 50%. The most likely estimate of the number of interest rate hikes by the end of 2017 is 2.

In other words,

$$100 - F_i = w_1 f_{i-1,i} + w_2 f_{i,i+1}, \tag{4}$$

where

$$w_1 = \frac{\text{Meeting Day of } d_i}{\text{Days in Month of } d_i},$$
$$w_2 = 1 - w_1.$$

Eq.(4) is solved for $f_{i,i+1}$, $i = 2, \cdots, N$, successively.

Interest Rate Hikes

Given the forward rates $f_{i,i+1}$, $i = 1, \cdots, N$ implied from the futures data, we estimate the transition probability of an interest rate hike at d_i, conditioned on the information available up to $d_i - 1$, by

$$P_{i|i-1} = \frac{f_{i,i+1} - f_{i-1,i}}{\delta}, \tag{5}$$

where $\delta = \pm 25$bps is the typical change in the Federal Funds Target Rate. We set the initial condition f_{01} to be the lower boundary of the bracketing interval $[k, k+1] \times 25$bps of f_{12} for an integer k. Typically, $|f_{i,i+1} - f_{i-1,i}| < 25$bps. Thus, the future scenario tree can be constructed by a repeated application of the transition probabilities. We absorb the probabilities at level zero, and do not allow negative interest rates.

Following the method outlined in this section, we make a projection on the probabilities of interest rate hikes at 2017 FOMC meetings, using the market data of Fed Fund Futures as of February 27, 2017. As tabulated in Table (1), we observe that the probability distribution of the interest rate hikes gradually extends to the end of higher rates as time evolves. The chances that the Fed will hike rates at its March meeting have been increasing in the past few weeks. According to our estimate, the probability is now at 50%. By the end of 2017, the distribution is estimated to peak at target rate $\in [1, 1.25]$ and we expect to observe 2-3 interest rate hikes.

3. Yield Curve

Changes in the FFR place significant influence on the yield curve, which further affect different aspects of the financial markets. Therefore, to understand the impacts of rising rates, it is necessary to build connections between the FFR and the yield curve.

Past studies in literature have shown that rising FFR drives up the level of the yield curve. However, increased rates discourage investment, which may adversely impact economic growth in the long run, resulting in recessions. Hence the long-term yield usually increases to a lesser extent than its short-term counterpart, leading to an upward-shifted but flattened yield curve. In this section, we analyze this relationship through a Nelson-Siegel decomposition of the yield curve followed by a Vector Auto-Regression (VAR) model including macroeconomic factors.

Dynamic Nelson-Siegel Model

An adapted version of the dynamic Nelson-Siegel model [4],

$$y_t(\tau) = R_t + S_t\left(1 - \frac{1 - e^{-\lambda\tau}}{\lambda\tau}\right) + C_t\left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right) + \varepsilon_t(\tau), \tag{6}$$

subject to a measurement disturbance $\varepsilon_t(\tau)$, is employed to characterize the time-varying cross-section of zero-coupon yields, where t denotes time and τ denotes maturity. Although the parsimonious Nelson-Siegel curve is not suited for an accurate calibration of market data, it is well known in financial literature to be flexible at identifying the driving factors of the yield curve. Note that the conventional level factor is redefined to adapt for the low-rates environment, where $R_t = y_t(\tau \to 0)$ represents the short rate, $S_t = y_t(\tau \to \infty) - y_t(\tau \to 0)$ represents the slope, and $e^{-\lambda\tau} C_t \sim y_t''(\tau \to \infty)$ represents the curvature. In the past eight years of low interest rates, we expect the short rate factor $R_t(\tau)$ to be near zero.

We assume that the dynamic movements of $(R_t, S_t, C_t)^T$ follow a vector autoregressive process of first order

$$\begin{pmatrix} R_t - \mu_R \\ S_t - \mu_S \\ C_t - \mu_C \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} R_{t-1} - \mu_R \\ S_{t-1} - \mu_S \\ C_{t-1} - \mu_C \end{pmatrix} + \begin{pmatrix} \eta_R \\ \eta_S \\ \eta_C \end{pmatrix},$$

where a_{ij} denote the transition matrix elements for $i, j = 1, 2, 3$ and $t = 1, \cdots, T$ denotes the time index. The vector $(\mu_R, \mu_S, \mu_C)^T$ represents the factors' mean and $(\eta_R, \eta_S, \eta_C)^T$ denotes the stochastic residuals. In combination with the measurement equations (6) for a cross-section of yields $\tau = \tau_1, \cdots, \tau_N$, a state-space system is formed.

Data and Model Estimation

Under the normality assumption of transition and measurement disturbances:

$$\begin{pmatrix}\eta\\ \varepsilon\end{pmatrix} \sim N\left[\begin{pmatrix}\mathbf{0}\\ \mathbf{0}\end{pmatrix}, \begin{pmatrix}\mathbf{Q} & \mathbf{0}\\ \mathbf{0} & \mathbf{H}\end{pmatrix}\right],$$

we apply the method of Kalman filter and maximum-likelihood estimation to obtain the monthly time series of yield curve factors $(R_t, S_t, C_t)^T$ since January 2009. A cross-section of 11 constant maturity yields (1M, 3M, 6M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y, 20Y, 30Y) from January 2009 to January 2017 is used for estimation. In Figures (4) and (5), it's shown that the US treasury 1M yield and the difference between US Treasury 30Y-1M yields serve as reasonable empirical estimates for the first two Nelson-Siegel factors, respectively. It is also observed from the estimated time series that an increasing short rate since the end of 2015 is accompanied by a continuing decrease in steepness of the yield curve.

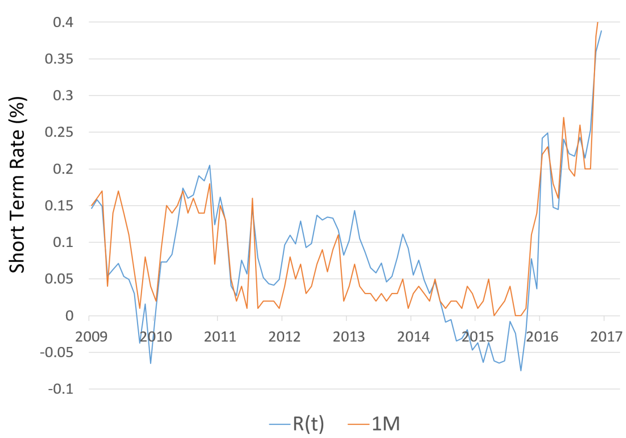

Figure 4. Estimated short rate factor $R(t)$ and US Treasury 1-month yield, monthly time series from January 2009 to January 2017. Data source: Bloomberg.

Linkage to Federal Funds Rate

Given the short rate and slope factors as a representation of the yield curve, we now characterize its relationship with three key macroeconomic variables: Federal Funds Rate (FFR), manufacturing capacity utilization (CU) to measure the level of real economic activity relative to potential, and the consumer price index (CPI) to capture the impacts from inflation [5], through the following VAR model:

$$X_t = c + \sum_{j=1}^{p} \Pi^j X_{t-j} + \varepsilon_t. \tag{7}$$

Here X_t denotes the 6×1 vector of the endogenous variables $\{R_t, S_t, C_t, \mathrm{FFR}_t, \mathrm{CU}_t, \mathrm{CPI}_t\}$, c is a 6×1 vector of intercept terms, Π^j are the 6×6 matrices of autoregressive coefficients, for $j = 1, \cdots, p$, and ε_t is the vector of random disturbances.

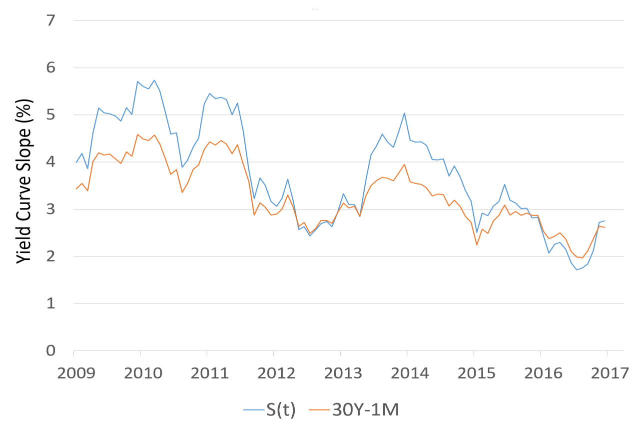

Figure 5. Estimated slope factor $S(t)$ and the difference between US Treasury 30Y-1M yields, monthly time series from January 2009 to January 2017. Data source: Bloomberg.

The optimal lag length p is determined to be 2 based on standard information criteria. To establish the causal relationship between the monetary policy and fixed income instruments, a Granger causality test is then performed on the monthly time series of the Federal Funds Rate and the yield curve factors. The results are reported in Table (2).

Method	Factors	Lag	Coeff.	p-value
Nelson-Siegel	Short Rate	1	$+0.35$ (0.14)	0.002
		2	$+0.34$ (0.15)	
	Slope	1	$< 10^{-2}$ (1.00)	0.029
		2	-2.85 (1.07)	
Empirical Est.	1M	1	$+0.50$ (0.13)	$< 10^{-4}$
		2	$+0.44$ (0.14)	
	30Y$-$1M	1	$< 10^{-2}$ (0.68)	0.066
		2	-1.59 (0.69)	

Table 2. Results of VAR model and Granger causality Test. Standard errors appear in parentheses

We make the following observations from the VAR model. Firstly, it is suggested that the short rate factor is affected by the first two lags of the Federal Funds Rate, while the slope factor is affected by the second lag only. This is caused by the delayed impact of monetary policies on the long-term debt market. Increase in the Federal Funds Rate leads naturally to a rising short rate factor and a decreasing slope factor. From Equation (6), an increasing R_t is associated with an upward shift in the yield curve. At the same time, a decreasing S_t results in a flattening yield curve. This result is consistent with the economic intuition discussed at the beginning of the section. Finally, the VAR model also suggests that the Federal Funds Rate is not significant in explaining the dynamics of the curvature factor C_t, in agreement with past literature [3]. Therefore, we exclude the curvature factor in the remaining sections of the paper.

A similar VAR model calculation is performed on the normalized yield curve factors using z-scores to compare the relative magnitudes of the FFR impact on the short rate and the slope. The results, not reproduced here for brevity, indicate that the short rate is impacted to a larger extent than the slope.

4. Cross-Asset Impact

To measure the differential impact of interest rates in various markets, we incorporate the two driving factors R_t and S_t of interest rate yield curve described in Section (3) in the following regression model:

$$\mathscr{R}_t = \alpha + \sum_{j=0}^{L} \beta_j^R r_{t-j} + \sum_{j=0}^{L} \beta_j^S s_{t-j} + \gamma z_t + \varepsilon_t, \tag{8}$$

where $\mathscr{R}_t$ denotes the daily percentage change of an index characterizing a selected asset class, r_t is the daily net change of the short rate factor R_t, s_t is the daily percentage change of the slope factor S_t, ε_t is the error term, $t = 1, \cdots, T$ is the daily time variable, L is the lag order in time and T is the total sample size. For simplicity, we use the 1M US treasury yield as an empirical estimate of the short rate R_t and the 30Y-1M spread as an empirical estimate of the slope factor S_t. To examine the idiosyncratic dependence of each disaggregated sector on the interet rates, a systematic factor return z_t for an associated aggregate index is included. The systematic factor z_t is suppressed when $\mathscr{R}_t$ is itself chosen to be the aggregate index to examine the impact on the asset class as a whole. Note that we included both contemporaneous and lagged explanatory rates variables to investigate the co-movements and potential under-reaction effects.

Based on the above OLS model, we estimate the industry sensitivities to interest rates by the β-coefficients and test whether they are significantly different from zero. The statistical inference is based on the HAC covariance matrix estimator from Newey and West (1987). To check the statistical significance of β-coefficients, we run the regression models with a variety of lag orders $L = 1, \cdots, 5$ days. In this section, we choose the parsimonious model with $L = 1$ corresponding to a one-day lag to report the estimated β-coefficients in Table (3)-(9). Entries are populated only for those estimates significant at the 5% level. Standard errors appear in parentheses.

Credit Market

For the credit market, $\mathscr{R}_t$ in Eq. (8) represents the daily percentage change of the disaggregated CDX spread for an industry sector categorized by GICS. The systematic factor z_t represents the daily percentage change of the associated aggregate CDX spread, Investment Grade or High Yield, respectively. The systematic factor z_t is suppressed when $\mathscr{R}_t$ is chosen to represent an aggregate CDX.

In this section, we report the empirical results on a selected list of industries and countries from the regression analysis, using the daily time series of Bloomberg CDX Spreads Index from Sep. 2011 to Jan. 2017, tabulated in Tables (3)-(5).

Markit CDX	β_0^R	β_0^S
Investment Grade	−18.63 (5.4)	−53.24 (5.9)
High Yield	+3.82 (1.0)	+10.57 (1.4)
Municipal Index		−22.55 (5.1)

Table 3. North America credit market represented by aggregated Markit CDX Indices.

Market	β_0^R	β_1^R	β_0^S
Europe	−26.71 (5.4)		−67.68 (8.3)
Japan	−10.11 (4.0)	−10.95 (4.1)	−22.62 (5.2)
Asia Ex. Japan		−7.57 (3.6)	−30.62 (6.2)
Emerging Mkt.	+1.56 (0.7)		+4.29 (1.1)

Table 4. International Investment Grade credit market represented by iTraxx CDX Indices for international markets.

From the Tables (3) and (4), we observe that in the developed markets, an upward movement of the yield curve generally is negatively correlated with investment grade credit spreads. The fundamental reason is that both US Treasury yields and credit spreads are driven by the same underlying economic condition. A rising level of rates is generally accompanied by an improving economic environment, hence companies are less likely to default, and the credit spread tends to decrease. At the same time, we also observe significant negative correlations between the CDX indices and the slope factors. This result is in agreement with Berd *et al.*[6], who attribute this negative correlation to the quantitative easing (QE) programs exercised by central banks after the financial crisis. Since QE directly reduces the long-term interest rates, the yield curve flattens over the QE-filled period. As observed from Figure (5), the general trend of the slope factor is indeed decreasing in steepness from 2009 to 2017. During the same period, after controlling the impacts from the parallel shifts in yield curve, credit spread widens with uncertainty about the strength of the economic recovery, which results in this negative correlation.

At the same time, however, banks and other financial institutions may expect the rates to rise further in the future. Therefore, they may impose stricter scrutiny on riskier corporates and charge them larger credit spreads. This explains the positive correlation between interest rates and the high-yield credit spreads. Similarly, as issuing entities in the emerging markets are generally considered to be riskier due to the weak corporate structure and the lack of government regulations, a rising level of interest rates is generally accompanied by a widening in the associated credit spreads.

Scoping into the North America Investment Grade bonds markets, while the impacts from upward shifts of the yield curve are generally negative, one exception is the financial

I.G. Sector	β_0^R	β_1^R	β_0^S
Energy		−8.23 (2.7)	−11.81 (4.6)
Materials			−11.33 (5.6)
Consumer Disc.			−6.73 (3.3)
Health Care			−8.86 (3.2)
Financials Sr.		−4.99 (2.4)	−14.16 (3.4)
Financials Sub.	+10.85 (6.0)		
Info. Tech.		−5.04 (2.2)	−10.93 (2.9)
Telecom.		−4.40 (2.3)	
Utilities			−9.20 (4.2)

Table 5. North America Investment Grade credit market represented by Markit CDX Indices for sectors. Industrial and Consumer Stapes sectors are omitted from the table because statistical significance of the corresponding β-coefficients is not observed.

sector of subordinated debt. This is because the reference obligations for the Financials Sub. index are subordinated level notes issued by financial institutions. Therefore, the spreads for these notes tend to widen as the rate rises. Meanwhile, the Financials Senior index is referenced to senior level notes with better performance. Our results indicates that, as the yield curve shifts upward, the financial sector of senior debt enjoys a decreasing spread.

Equity Market

For the equity market, $\mathscr{R}_t$ in Eq. (8) represents the daily percentage return for an industry sector categorized by GICS from Jan. 2009 to Jan. 2017. The systematic factor z_t represents the daily percentage return of a market benchmark, for example, the aggregate S&P Composite 1500 Index for the United States. The systematic factor z_t is suppressed when $\mathscr{R}_t$ is itself a market benchmark. The results are tabulated in Tables (6)-(7).

For the market as a whole, a steeper yield curve implies an optimistic market performance in the future, hence the expectation of future equity market gets improved. Therefore, a steeper yield curve leads stock indices to rise. This is consistent with our regression results as stock indices are all positively correlated with the slope factor of the yield curve. At the same time, we also observe strong positive correlation between the stock indices and the short rate. This follows from the fact that rising rates is usually accompanied by improving economic conditions, which generally lead to a bull stock market. Besides, one interesting observation from Table (6) is that, for the US equity market, the magnitude of the estimated β-coefficients is consistently larger for small-cap stocks. This observation suggests an inverse relationship between the sensitivities to interest rates and market capitalization.

The differential impact of interest rates on industries is, however, more richly structured. Not all sectors of the economy respond to economic issues in the same manner. Our regression analysis for disaggregated stock indices for a variety of industries is reported in Table (7).

Stock Index	β_0^R	β_0^S
United States		
Russell 3000	+8.40 (1.8)	+27.57 (2.1)
S&P 1500	+8.32 (1.8)	+27.24 (2.0)
S&P Largest-cap 100	+8.24 (1.7)	+25.77 (1.9)
S&P Large-cap 500	+8.27 (1.7)	+26.77 (2.0)
S&P Mid-cap 400	+8.67 (1.9)	+30.27 (2.4)
S&P Small-cap 600	+9.06 (2.1)	+32.25 (2.5)
Europe		
STOXX 50	+11.75 (1.9)	+34.14 (2.6)
STOXX 600	+9.29 (1.5)	+26.68 (2.1)
FTSE 100	+9.36 (1.5)	+26.63 (2.0)
FTSE Mid 250	+7.36 (1.6)	+22.92 (2.1)
FTSE 350	+8.24 (1.5)	+23.04 (1.8)
Asia		
Shanghai-Shenzhen	+5.48 (1.7)	+5.87 (2.1)
Hang Seng	+4.42 (2.0)	+12.10 (2.2)
JPX-Nikkei 400†	+4.70 (2.4)	+19.22 (3.9)
World		
Emerging Market	+7.13 (1.5)	+18.65 (2.0)
Developed Market	+7.36 (1.4)	+24.34 (2.0)
World	+7.34 (1.4)	+23.64 (1.9)

Table 6. Equity market represented by various indices.
† For JPX-Nikkei 400, the statistical significant β-coefficients are β_1^R and β_1^S with lag 1. They are tabulated in the same columns to save space.

Energy and Investment Banking are the two sectors found to show a positive relationship with the interest rate. The positive correlation observed in the Energy market could be interpreted as the cost effect. Since increasing interest rates strengthen USD, it becomes much cheaper to import raw materials, especially crude oil, which lowers the cost for the energy companies significantly. Although strong USD also harms export, the Energy sector is not greatly affected because it is not export-oriented in the US. For the Investment Banking sector, the overall impact of rising interest rates is positive because interest rate spreads of deposit and loan tend to widen during a rate hike cycle, driving up the firm's profits. Banks tend to benefit from rising interest rates since they should reverse the net interest margin compression they have been experiencing during the zero interest rate policy environment.

Some other sectors are shown to behave in agreement with the conventional wisdom of an inverse relationship between interest rates and stock prices.

Consumer staples is to some extent counter-cyclical. The demand varies little but the cost goes up a lot when the economy is good. Thus, the stock index return is negatively correlated with the contemporaneous rates in level and in slope. The impacts on telecommunication and utilities markets are

Industry	β_0^R	β_0^S
Energy	+2.83 (1.0)	+5.67 (1.3)
Industrial		+1.91 (0.6)
Consumer Staples	−1.55 (0.6)	−2.34 (1.0)
Food & Staples Retailing	−1.46 (0.7)	−1.96 (0.9)
Investment Bank	+5.24 (1.5)	+11.83 (2.5)
Telecomumincation	−3.35 (0.8)	−4.52 (1.3)
Utilities	−4.51 (1.0)	−9.07 (1.6)
Real Estate	−5.71 (1.8)	−18.64 (2.2)
REITs	−5.84 (1.8)	−18.96 (2.2)

Table 7. North American stock market represented by S&P Supercomposite Sub-Industry Index aggregated with respect to GICS (Global Industry Classification Standard). Materials, Consumer Discretionary, Health Care, and Information Technology sectors are omitted from the table because statistical significance of the corresponding β-coefficients is not observed. Several lower-level industry groups: Food & Staples Retailing, Investment Banking, and REITs are added.

Commodity	β_0^R	β_1^R	β_0^S
BCOM Index	+4.32 (1.2)		+16.24 (1.3)
Energy			
WTI	+5.21 (1.7)		+14.91 (2.2)
Brent	+4.32 (1.6)		+11.99 (2.0)
Natural Gas			−9.79 (2.8)
Gasoline	+3.54 (1.9)	+3.85 (2.0)	+9.63 (2.2)
Gasoil		+4.42 (1.5)	+11.13 (2.0)
Heating Oil	+3.34 (1.7)	+3.60 (1.7)	+8.60 (1.8)
Metals			
Gold	−6.70 (1.3)		−15.92 (1.9)
Silver	−4.84 (1.9)		−15.95 (2.8)
Platinum			−6.71 (1.8)
Aluminum			+4.94 (1.7)
Copper	+3.59 (1.6)		+11.56 (1.9)
Agriculture			
Corn	−4.09 (2.1)		−6.30 (2.1)
Cotton			+3.62 (2.0)†

Table 8. Commodity futures in Energy, Metals, and Agriculture market represented by Dow Jones-UBS Indices. † The β_0^S coefficient for cotton is significant at 7% level.

also consistent with intuition. Utilitiy company usually pays steady dividends, therefore it serves as a substitute for bonds when rates are low. Rising rates cause investors to shift to bond investment, and thus stock prices of utility companies drop. The impact of interest rates on the real estate market can be understood from two angles. Investors tend to shift funds away from the real estate market as rising interest rates increase the returns generated by other competing investments. On the other hand, prospective homebuyers are now faced with rising mortgage rates, which impact their decisions to buy a house, and thus negatively affecting the real estate market.

No statistically significant relationship between interest rates and the remaining industry sectors (Materials, Consumer Discretionary, Health Care, and Information Technology) has been observed in our analysis.

Commodity Market

For the commodities market, $\mathscr{R}_t$ in Eq. (8) represents the daily percentage return for Dow Jones-UBS Indices for futures contracts from Jan. 2009 to Jan. 2017. The systematic factor z_t represents the daily percentage return of the Bloomberg Commodity Index (BCOM) calculated on an excess return basis and reflects the overall commodity futures price movements. The index rebalances annually, weighted 2/3 by trading volume and 1/3 by world production, and weight-caps are applied at commodity, sector, and group levels for diversification. The systematic factor z_t is suppressed when $\mathscr{R}_t$ is chosen to be BCOM Index. The results are tabulated in Table (8).

The regression results show that in the energy market, upward shifts in the yield curve lead commodity indices to rise, while flattening of the yield curve leads the indices to drop. From the relationship established in Section 3, an increase in the Federal Funds Rate also leads to a drop in the steepness of the yield curve, but the impact is less significant than it has on the short rate. Thus, although the increasing short rate and the flattening yield curve are two competing factors of commodity prices, we focus on the short rate factor.

Generally speaking, as real interest rates (adjusted for inflation) rise, capital flows into higher yielding assets. This reduces the demand for precious metals like gold, silver and platinum, which translates to a drop in commodity prices, hurting the market participants. From our regression analysis, the impact of rising short rates on the price of precious metals is indeed adverse. Commodities in energy sector will benefit from an increasing demand as global economic growth improves. The same argument applies for the market of industrial metals, for example, aluminum and copper.

Relatively weak statistical significance is observed in the agriculture market. We examined a selected list of agricultural products in our regression analysis, including corn, wheat, soybean, coffee, sugar, and cotton, among which only the corn market exhibits a statistically significant dependence on the interest rates. This is mainly because rising rates may decrease both demand and supply of the agricultural products. On the demand side, rising rates increases the financial costs of consumers, hence decreasing the demand. On the supply side, rising rates also increase the financing costs of farms, who would therefore prefer to plant less.

Our result also shows that the overall impacts of rising rates on the commodity index follow that of the energy sector. This is because more than 30% of the Bloomberg Commodity Index components are assigned to energy. It's natural for the market index to follow its behavior.

Currency Market

For the currency market, $\mathscr{R}_t$ in Eq. (8) represents the daily percentage change of spot foreign exchange rates of a selected list of countries with respect to US Dollars. No systematic factor z_t is used in the regression analysis for the currency market. The results are tabulated in Table (9).

From the regression results, we observe that the contemporaneous slope factor remains significant. For most of the currencies under investigation, we note that a drop in the slope factor leads the currencies of the other countries to depreciate. Therefore, under a rising rate environment, USD usually appreciates against the other currencies. The only exceptions are noted for Japanese Yen (JPY), Swiss Frank (CHF) and Chinese Yuan (CNY). Japan has been experiencing stagnation in its economy: its GDP dropped by around 20% from 2009 to 2016. Meanwhile, its interest rates are negative, and deflation pressure remains high in the economy. Therefore, changes in the US Fed Funds Rate might not have the expected impact on JPY. As for CHF, driven by its safe heaven status, CHF can retain the value apart from external economic turbulence. Although over the years, China has been giving more flexibility to its currency, CNY is still heavily controlled by the People's Bank of China. Therefore, it is natural to see that CNY is not correlated with the US Fed Funds Rate.

Currency	β_0^R	β_0^S
	G10	
Euro		+3.73 (1.4)
Japanese Yen	−5.60 (1.0)	−13.81 (1.3)
British Pound		+4.80 (1.5)
Canadian Dollar	+2.59 (0.9)	+10.23 (1.2)
Australian Dollar	+3.57 (1.1)	+10.39 (1.7)
New Zealand Dollar		+6.53 (1.7)
Swiss Franc		
Norwegian Krone	+2.20 (1.1)	+8.06 (1.7)
Swedish Krona	+3.27 (1.2)	+7.87 (1.8)
	BRICS	
Brazilian Real	+3.76 (1.5)	+9.78 (2.1)
Russian Ruble	+5.30 (1.4)	+14.81 (1.7)
Indian Rupee		+3.71 (0.9)
Chinese Yuan		
South African Rand	+3.52 (1.6)	+9.87 (2.4)

Table 9. Regression analysis of spot foreign exchange rates with respect to interest rates for a selected list of currencies in G10 and BRICS countries.

Foreign exchange markets are affected by a wide array of factors ranging from foreign/domestic policies and economic/political conditions. Our model based on the US treasury yield curve might not be able to capture all the driving factors. Therefore, we exclude this asset class when constructing our portfolio in Section 5.

5. Portfolio Construction

To take advantage of a rising rate environment, we develop a cross-asset portfolio and simulate its performance under a historical scenario from 2004 to 2006, during which a significant rise in the Federal Funds Rate was observed after an extended period of low interest rates, as shown in Figure (6), similar to the situation we are anticipating today.

Figure 6. Federal Funds Effective Rate during the period 2004-2006. Data source: Bloomberg.

To compare the portfolio performance against a generic diversified benchmark, we use the following indices [7]:

- Treasury — Barclays US Total Treasury Index
- Equity — S&P 500 Index
- Commodities — Bloomberg Commodity Index
- Credit — Barclays Credit Index

for each asset class and an equal-weighting combination (25% captial allocation) for the combined cross-asset portfolio (the Benchmark Index Portfolio). For simplicity, we adopt an equal weighting scheme in our capital allocation and exercise a buy and hold strategy. In fact, studies have shown that an equally weighted portfolio does no worse than more complex optimizations [8, 9]. Based on our findings in the previous sections, we first construct the single-asset portfolio for each market. Then they are combined to form a cross-asset portfolio with four asset classes. The portfolio construction for individual asset classes is discussed below:

Equity. Based on the regression analysis in Section 4.2, we observe that the rising short rate factor has a positive impact on the energy sector and the investment banking industry. For the equity asset class, we adopt a long-only scheme by assigning 50%-50% capital allocation to the Level-1 Energy Sector Index and the Level-4 Investment Banking Index categorized under GICS. The portfolio performance in the 2004-2006 is compared against the S&P 500 Index and shown in Figure (7). The Sharpe ratio is 1.45 for the constructed portfolio and 0.44 for S&P 500 Index. The maximum drawdown is 13.6% for the constructed portfolio and 7.2% for S&P 500 index.

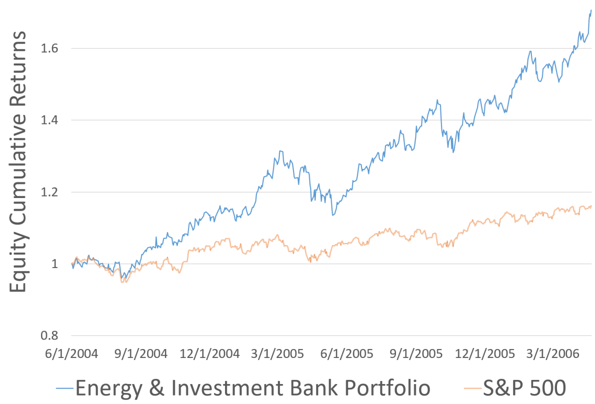

Figure 7. Equity portfolio performance during the period June 2004 - June 2006, compared against the S&P 500 Index.

Treasury. In a rising-rate environment, investment in short-term bonds tends to outperform mid- and long-term bonds. This follows from our discussion in Section 3 that rising FFR impacts the short-term yields to a greater extent than the long-term yields, leading to an upward-shifted but flattened yield curve. However, long-term bonds still serve as a safeguard when rate hikes do not happen as expected. Investors can sidestep the uncertain rate environment by using the barbell strategy, which takes long positions in both short- and long-term bonds, while avoiding bonds of intermediate maturities. For the fixed-income asset class, we construct our portfolio by assigning 50% of the capital to the US Treasury Index with maturities ranging from 1 to 3 years, and the remaining 50% to the US Treasury Index with maturities greater than 20 years. The portfolio performance in 2004-2006 is compared against the Barclays US Total Treasury Index and shown in Figure (8). The Sharpe ratio is 0.2 for the constructed portfolio and -0.03 for the benchmark index. The maximum drawdown is 4.6% for the constructed portfolio and 2.8% for the benchmark.

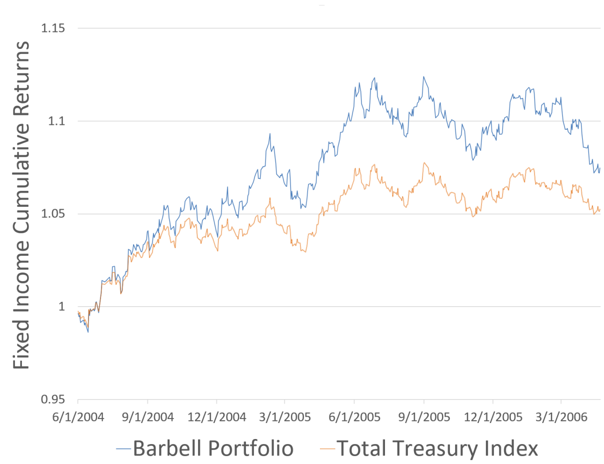

Figure 8. Treasury portfolio performance during the period June 2004 - June 2006, compared against the Barclays US Total Treasury Index.

Commodities. Based on the regression analysis in Section 4.3, we observe that the rising short rate factor has a positive impact on gas & oil products and industrial metals because of the improved economic conditions. For the commodities asset class, we create a portfolio by assigning equally-weighted capital allocation to the following five kinds of commodities: WTI crude oil, gasoline, gasoil, heating oil, and copper. Since ETFs tracking commodity indices are available in the market, the Bloomberg commodity indices are used as guidelines for portfolio construction and backtesting[1]. The portfolio performance in 2004-2006 is compared against the Bloomberg Commodity Index and shown in Figure (9). The most significant growth driver of our portfolio is the copper index, which witnessed a 3-fold increase during the time period under investigation. The Sharpe ratio is 1.37 for the constructed portfolio and 0.39 for the benchmark index. The maximum drawdown is 18.6% for the constructed portfolio and 11.9% for the benchmark index.

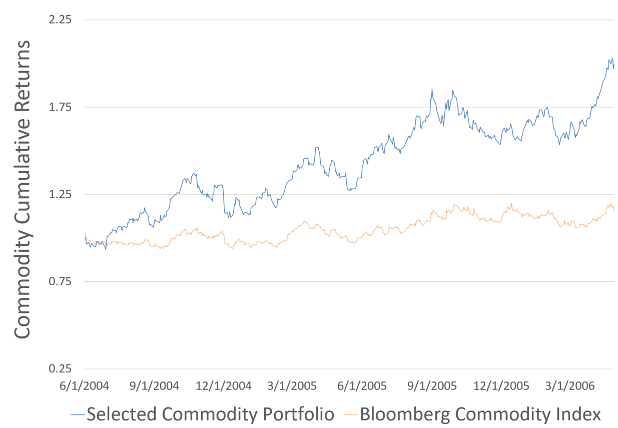

Figure 9. Commodities portfolio performance during the period June 2004 - June 2006, compared against the Bloomberg Commodity Index.

Credit. For the credit market, the results from the regression analysis suggest that investing in the High Yield and Emerging Market credit spreads is profitable in an environment of rising rates. The underlying credit risks, however, remain high for these two sectors. To manage the risk level, we make no specific index weighting for the credit asset class and only use the benchmark Barclays Global Aggregate Credit Index in our portfolio.

Cross-Asset Portfolio. We combine the single-asset portfolios investigated earlier with the Barclays Credit Index to form a cross-asset portfolio. Again, an equally-weighted scheme is adopted for the capital allocation of each asset class. The resulting portfolio is compared against the Benchmark Index Portfolio and shown in Figure (10). From June 2004 to April

[1] It is understood that ETFs cannot fully track the indices due to the existence of roll cost. Since ETFs were not widely traded during the backtesting period, indices serve as good substitutes for our research purpose.

Asset Class	Strategy
Equity Market	
Capitalization	Large capitalization stocks are less sensitive to rising interest rates. Reference Table 6.
Industry Sectors	Favor the energy sector and financial industry. Underweight utilities, telecom., and real estate. Reference Table 7.
Fixed Income Market	
Treasuries	Favor short term bonds. Barbell or ladder strategies.
Credit Swap Index	Benefits High yield, Emerging Market, Financials sub CDX. Reference Table 3 , 4 & 5.
Commodities Market	
Energy	Energy will benefit from improving economic conditions. Reference Table 8.
Metals	Favor industrial metals over precious metals as economy improves. Reference Table 8.

Table 10. Cross-asset portfolio strategy for a rising interest rate environment [10]. This report is for research only and in no event should it be used as a guideline to purchase or sell a security.

2006, our portfolio return beats the Benchmark Index Portfolio return by 30%. The Sharpe ratio is 1.53 for the constructed cross-asset portfolio and 0.42 for the Benchmark Index Portfolio. The maximum drawdown is 6.9% for the constructed portfolio and 2.7% for the Benchmark Index Portfolio.

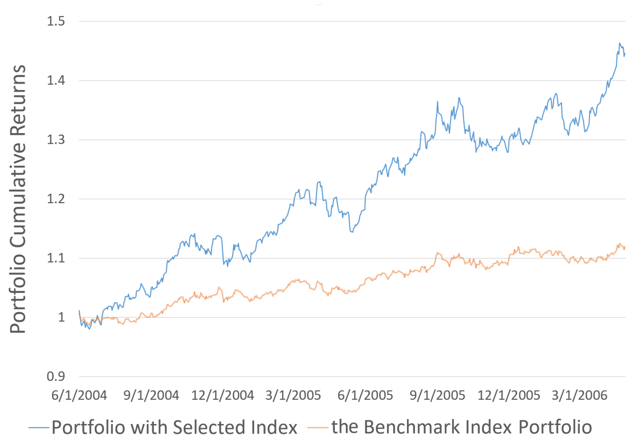

Figure 10. Cross-asset portfolio performance during the period June 2004 - June 2006, compared against the diversified Benchmark Index Portfolio.

Asset Class	Portfolio Sharpe	Portfolio Max DD	Benchmark Sharpe	Benchmark Max DD
Equity	1.45	13.6%	0.44	7.2%
Treasury	0.2	4.6%	−0.03	2.8%
Commodity	1.37	18.6%	0.39	11.9%
Total	1.53	6.9%	0.42	2.7%

Table 11. Cross-asset portfolio performance for a rising interest rate environment. Sharpe denotes Sharpe ratio and Max DD denotes maximum drawdown.

Finally, we summarize the asset selection strategy described above and the resulting portfolio performance in Table (10) and Table (11).

6. Conclusions

This paper sets out to investigate the impacts of rising interest rates on the shape of the yield curve and on different asset classes both domestically and internationally. Based on our regression analysis of market indices on the short rate factor and slope factor, a cross-asset portfolio is constructed to anticipate an environment of rising interest rates and verified by a simulation in a similar historical scenario from 2004 to 2006.

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