Master Thesis, Department of Finance

# Interest Risk Factors and Stock Returns of US Banks: The Effects of Size and Financial Crisis


## Abstract

We find that the effects of interest risk factors on US banks' stock returns are affected by banks' size, measured by market equity values, and income structures, measured by the ratios of interest income and interest expense. The effects of interest risk factors have changed after 2008 financial crisis. We regress banks' stock returns on risk factors and show that the loadings of interest risk factors either change from non-significant to significant or change from positive to negative after 2008 financial crisis. Such changes apply to all banking industry regardless banks' size, but the magnitude of changes increases as banks' size grows. The effects of financial crisis are associated with the changing economic environment, as well as banks' increasing interest income relative to interest expense. Furthermore, we find that simple measurements of interest risks such as changes of long-term Treasury returns or changes of long-term Treasury yields have consistent effects on US banks' stock returns, compared to other measurements such as unanticipated shocks in short-term interest rates.



Keywords: Interest risk, Bank stock returns, Size effects, Financial crisis, Income structure



Author: Guo Ma (41262) Bing Fu (41507)

Tutor: Adrien d'Avernas

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## I. Introduction

We study the effects of interest risk factors on US bank stock returns and connect such effects to banks' income structure. Banks, by engaging in business that borrows in short-term and invests in long-term, are exposed to specific risks, such as interest risk and credit risk, in addition to overall market risks. When short-term interest rate increases, the cost of borrowing may increase, hence banks may be less profitable. When long-term interest rate increases, the income of investments may increase, hence banks may be more profitable. As short-term and long-term interest rates are constantly changing, it is probably more important to look at the spread of short-term and long-term interest rates. If the stock market is efficient, such relations between interest rate changes and banking business would be reflected in the rise and fall of banks' stock prices.

Flannery and James (1984) show banks' stock returns are negatively correlated with interest rate changes because of the maturity difference between banks' assets and liabilities. They show an unanticipated increase in interest rate is associated with the fall of bank stock returns. On the other hand, the explanatory power of interest risk factor may be negligible. Schuermann and Stiroh (2006) suggest inclusion of interest risk factors and credit risk factors to CAPM and Fama-French three-factor model does not add meaningful information to explain the variations of banks' stock returns. In addition, Banks' size, measured by either book equity value or market equity value, could affect how banks' stock returns are related to interest rate changes. Gandhi and Lustig (2014) find the size anomalies that the stock returns of different size-sorted bank portfolios respond differently to interest risk factors. The interest risk factor loadings are only significant for portfolios composed by large size banks. Moreover, the 2008 financial crisis[1] could also affect the relations between interest risk factors and banks' stock returns. Bailey and Matyáš (2019) show that the change of the spread of government bond yields has significant loadings on banks' stock returns only after 2008 financial crisis.

Our thesis extends researches about banks' stock returns and interest risk factors in four ways.

First, we employ three previously used interest risk factors as measurements of different types of interest risks. The three factors are Slope factor, Shock factor and Return factor, representing

[1] We use 2008 financial crisis and financial crisis interchangeably in the Thesis. The financial crisis mentioned in our analysis is the 2008 financial crisis except it is otherwise specified.

changes of yield spread, unanticipated changes of short-term interest rate and changes of long-term interest rate, respectively. Considering the nature of banking business, banks' stock returns would behave differently to different types of interest risks, i.e. the factor loadings[2] would be different.

Second, we focus our analysis on the effects of banks' size, measured by market equity value, and 2008 financial crisis on the relations between interest risk factors and banks' stock returns. The goal is to examine whether the financial crisis changes the relations and whether such changes differ among banks of different sizes. If a bank's market equity value is big, its assets and liabilities tend to be big and its business tends to be complex, hence its exposure to interest risk is probably also big; and if a bank's exposure to interest risk is big, the effects of financial crisis, if there exists, tend to be big as well.

Third, we show the dynamic changes of risk factor loadings from 1975 to 2018 and compare the loadings of interest risk factors with those of common stock market factors. The logic is that, as correlations between risk factors have increased after financial crisis, if financial crisis affects banks' relations with interest risk factors, it is meaningful to see whether it also affects banks' relations with other risk factors. From this, we examine the patterns of how banks' response to interest rate changes are connected to business cycles.

Fourth, we connect interest risk factor loadings with banks' income structure. Because interest rate affects banks' interest income and expense, the ratio of interest income related to interest expense and the proportion of non-interest income are important to assess how interest rate changes may affect banks' profitability and hence banks' stock prices in an efficient market.

Our findings reveal the changing effects of interest risk factors on banks' stock returns. When banks are sorted to five portfolios by market equity value, lager size bank portfolios have bigger interest risk factor loadings in magnitude than smaller size portfolios. 2008 financial crisis has changed the relations between banks' stock returns and interest rate changes. For example, our findings show banks' stock returns are negatively related to interest rate changes before 2010, which is consistent with previous researches, but such relations change to negative after financial crisis. On the other hand, 2008 financial crisis does not change the relations between

[2] We use loadings and coefficients interchangeably in the Thesis unless otherwise specify.

banks' stock returns and other risk factors, such as the overall market factor and the risk factor related to size. Furthermore, the magnitude of interest risk factor loadings is connected to banks' income structure. The interest risk factor loadings are contributed by both the ratios of interest income divided by interest expense and the size of banks.

The interpretation of the changing effects of interest risk factors on banks' stock returns is consistent with the changing economic environment after financial crisis. The short-term interest rate has been close to zero for many years after 2010, an increase of short-term interest rate as well as long-term interest rate is probably a signal of better economic outlook, which is positive to banks' business performances and stock prices. Such situations happened several times when economy was in recession and interest rates had been lowered, but the effects of 2008 financial crisis is unprecedented. They are not only bigger but also longer.

Our thesis is organized as follows. Section II discusses related literature, including factor models, interest risk factors and size anomalies. Section III describes data sources, the methods of identifying banks, processes of constructing factors, and model specifications. Section IV presents results and analysis. Section V concludes.

## II. Literature review

To explain stock returns, various types of factors, including interest rate related factors, have received attention from researchers and have been investigated. Fama and French (1992) find that size and book-to-market variables have explanatory power on average stock returns. They later extend the variable list to include five common risk factors - three stock market factors and two bond market factors, and regress them on both bond and stock returns (see Fama and French, 1993). The two bond market factors – one is monthly return of long-term government bond minus one-month Treasury bill rate, and the other is monthly return of long-term corporate bonds minus the return of long-term government bonds – represent common risks from unexpected changes in interest rates and changes in the likelihood of default. By constructing an orthogonalized market factor, Fama and French (1993) suggest that, when explaining variations in stock returns, the risk information in these two bond market factors has been included in the overall market risk, hence the three stock market factors are sufficient to explain the variations in stock returns.

Schuermann and Stiroh (2006) subsequently extend Fama-French three stock market factors to include additional six factors that are identified to be relevant with banking industry, such as interest, credit, liquidity and volatility, and regress banks' weekly stock returns on these factors for each year from 1997 to 2005. Although they don't follow Fama and French (1993)'s approach to calculate the added risk factors, for instance, interest rate factor is computed as the change of three-month Treasury bill yield as well as the change of yield spread between ten-year and three-month Treasury bond instead, they also conclude that these factors don't add much explanatory power, i.e. the additional risk factors do not explain banks' stock returns better than the Fama-French three stock market factors. Especially, interest risk factors affect small size banks only slightly and the interest risk factors' effect is even weaker when it comes to large size banks.

On the other hand, there are other researches support the argument that interest rate has an extra influence on banks' stock returns. Flannery and James (1984) study banks' stock returns and interest rate changes by regressing equally weighted average stock returns of a commercial bank portfolio on two risk factors from 1976 to 1981; the two risk factors are overall market returns and an interest risk factor. They use the residuals of one-year Treasury weekly returns third-order autoregressive model (AR(3)), among others, to construct proxies of unanticipated changes in interest rates. Flannery and James (1984) show statistically significant, positive coefficients of the interest risk factors, suggesting inverse relations between banks' stock returns and interest rate changes.

Viale et al. (2009) attempt to identify the factors that are priced in bank stocks by testing alternative asset pricing models, e.g. CAPM, Fama-French three-factor and ICAPM model. They find that including a shock to yield curve slope is especially useful in explaining bank stock returns. English et al. (2018) examine U.S. bank holding companies' stock price exposures and show explicitly that stock prices drop substantially after the level of yield comes across an unanticipated increase or yield curve slope becomes steeper unanticipatedly. Especially, for those banks that engage heavily in maturity transformation, their stock prices react less negative. More recently, Bailey and Matyáš (2019) employ a Slope factor, i.e. the change of ten-year and one-month Treasury yield spread, and find that the Slope factor loadings are only significant after 2008 financial crisis for banks' stock returns. When banks are sorted by size and book-to-market ratios, the Slope factor loadings tend to be bigger as size or book-to-market ratios grow.

However, the largest banks may not be the most sensitive to interest risks. Gandhi and Lustig (2014) regress excess returns of size sorted US bank portfolios from 1970 to 2013 on Fama-French three stock market factors and two bond market factors similar to those in Fama and French (1993), i.e. one interest risk factor and one credit risk factor. Their results show that when banks are sorted by book equity value, the loading of interest risk factor for the largest size bank portfolio is not significant, and the magnitude is small, suggesting the largest banks are not sensitive to interest risks measured by excess returns on U.S. ten-year government bond total return index; when banks are sorted by market equity value, the loading of interest risk factor for the largest size bank portfolio becomes significant but the magnitude is still smaller than those of second and third largest size bank portfolios. Their results also suggest that the small and large banks have different exposure to these risks. Generally, the loadings are positive for large banks but negative for small banks. The positive loadings for large banks suggest the inverse relations between bank stock returns and changes in interest rate, which is consistent with Flannery and James (1984).

Schuermann and Stiroh (2006) go on to suggest that for the larger banks, adding interest risk factors into the model generates a more modest gain, when compared to that for the smaller banks. Previous research findings may help to give an explanation – large and sophisticated banks are likely to adopt a more aggressive risk management strategy and more actively use the interest rate and credit derivatives; therefore, large banks are able to hedge out a number of interest rate risk exposure. (see Instefjord (2005), Purnanandam (2007), Freixas and Rochet (2008), Lepetit et al. (2008) and Minton et al. (2009)) However, as Rampini et al. (2016) and Drechsler et.al (2018) show, while banks indeed present a maturity mismatch, interest rate derivatives still are not commonly used by them.

Another stream of the literature is on the dynamics of banks’ interest rate risk exposure. Compared to other industries, the banking industry is especially exposed to interest rate risk because of the nature of its business. The common wisdom argues that understanding how this risk exposure shift and how banks react to this exposure is important to managers, shareholders and policymakers (e.g. Delis and Kouretas (2011), Kasman et al. (2011), Haq and Heaney (2012) and Borio et al. (2017)). Calomiris and Nissim (2014) collect data of U.S. bank holding companies from 2000 to 2013 and report that both the coefficients of yield and credit-related variables decrease during and post 2008 financial crisis. Begenau et al. (2015) find large banks' interest risk exposure increased quickly after 1999 when most of the Glass-Steagall act was repealed, as their trading activities increased, such as interest-rate derivatives. On the other hand, large banks' credit risk exposure increased slowly until 2008 financial crisis.

Our thesis contributes to the researches on interest risk factors and banks' stock returns in following areas. First, we focus on the effects of size and 2008 financial crisis. By choosing different types of measurements and a longer time horizon to quantify the interest rate risk effects, we intend to make the results more comparable and consistent. Second, we examine the interest risk factors themselves, taking their increased correlations into account. Third, we compare the loadings of interest risk factors and those of common stock market risk factors. By plotting the dynamic changes of these factor loadings, we visualize the effects of size and 2008 financial crisis. Finally, we connect banks' interest risk sensitivity to their income structure. By regressing interest risk factor loadings on income structure ratios, we provide a possible explanation for the differences of banks' interest risk sensitivity.

## III. Data Sets & Methodology

### III.1. Identify Banks

Based on research purposes, there are various approaches to identify banks. The two data sources we use are Compustat and CRSP (Center for Research in Security Prices), accessed through WRDS (Wharton Research Data Services). Compustat and CRSP both provide SIC (Standard Industrial Classification) codes, which are four-digit numbers assigning a company to a specific industry. One of challenges by using SIC codes to identify banks is that because Compustat and CRSP use different approaches to obtain SIC codes, considerable differences exist in the SIC codes provided by Compustat and CRSP (Kahle and Walkling, 1996). For example, Bank One Corporation has two SIC codes (6712 and 6021) in CRSP but one SIC code (6020) in Compustat. With regard to the purpose of our thesis, note that whether choosing Compustat or CRSP SIC codes to identify financial firms could affect results (see Kahle and Walkling, 1996).

When using the four-digit SIC codes to assign firms to 48 industries, Fama and French (1997) give priority to Compustat then to CRSP. Firms with SIC codes within 6000-6099 and within 6100-6199 are classified as banks. On the other hand, Gandhi and Lustig (2014) use CRSP Header Standard Industrial Classification codes (hsiccd in CRSP) beginning with first two-digit 60 and Historical SIC codes (siccd in CRSP) 6712 to identify banks. Furthermore, they exclude inactive financial firms from the sample. Gandhi and Lustig (2014) find that in CRSP the firms with Historical SIC code 6712 seem to be all banking holding companies. These banking holding companies, some of which own very large banks in the US, would be excluded from the sample if using SIC codes beginning with 60 or 61.

Both approaches are not perfect. For example, by Gandhi and Lustig (2014)'s approach, there is a company with siccd 6712 and hsiccd 3669 in CRSP. The company is Pittway Corporation, a fire and burglar alarms company that was acquired by Honeywell in 2000. By Fama and French (1997)'s approach, firms such as VISA and MasterCard will be included in the bank portfolios. VISA and MasterCard have only one siccd (6099) in Compustat but various siccd (6153, 7389 and 7374) and hsiccd (7374) in CRSP. We also find American Express has various siccd (6052, 6141, 6712, 6199, 6141 and 6029) and hsiccd (6029) in CRSP, but only one siccd (6141) in Compustat. American Express will be counted as a bank by both approaches. Although VISA, MasterCard and American Express are all financial firms and American Express also directly provide credit to customers, they are not a typical commercial bank. We want to exclude them in our definition of banks.

We take a more conservative way to identify banks by only including firms in Compustat Bank Fundamentals Annual dataset[3]. By linking Compustat Bank Fundamentals Annual to CRSP and only including share code 10 or 11, we restrict our sample as US commercial banks. Such an approach contains mainly commercial banks, excluding financial firms like VISA and MasterCard. However, this approach is also not perfect. The main problem is that it also excludes some large banking holding companies. For example, for the largest 20 banks ranked by market equity value in June 2016, our sample excludes Citigroup Inc., Capital One Financial Corporation along with American Express, compared to other two approaches. The siccd of

[3] Compustat Bank Fundamentals Annual database only includes following SIC codes. 6020: Commercial banks; 6021: National commercial banks; 6022: State commercial banks; 6029: NEC Commercial Banks; 6035: Savings institutions, Fed-chartered; 6036: Savings institutions, not Fed-chartered. WRDS website, accessed April 27, 2020.

Citigroup Inc. is 6199 in Compustat and is 6021 in CRSP. The siccd of Capital One Financial Corporation is 6141 in Compustat and is 6021 in CRSP.

### III.2. Risk Factors

Along with Fama-French three stock market factors, we employ three measurements of interest risk factor and one measurement of credit risk factor for our analysis. For the results and analysis in sections IV.1, IV.2 and IV.3, we use monthly data of interest risk factors and credit risk factor. For sections IV.4 and IV.5, we extend the monthly interest risk factors to daily frequency.

We obtain Fama-French three stock market factors from WRDS which is originally from the website of Kenneth R. French. The three factors are Market (market excess return), SMB (small minus big) and HML (high minus low). Market factor represents the overall systematic risk. SMB and HML factors represent the risks in stock returns related to size and book-to-market equity value, respectively. The monthly Fama-French factors are used for sections IV.1, IV.2 and IV.3, and the daily frequency factors are used for section IV.4.

The three measurements of interest risk factor are described as follows.

(1) Slope factor. Changes of the yield spread between the ten-year Treasury bond and the one-year Treasury bond. This is a measure of yield spread change, similar to the Slope factor in Bailey and Matyáš (2019). The data of one-year and ten-year Treasury yields is from Federal Reserve Bank of St. Louis – FRED. The data is daily bases. We use the yields on the last trading day in each month to calculate the monthly Slope factor for sections IV.1, IV.2 and IV.3. We calculate daily changes of the yield spread between the ten-year Treasury bond and the one-year Treasury bond as the Slope factor for sections IV.4 and IV.5.

(2) Shock factor. The residuals of third-order autoregressive model (AR(3)) on one-year Treasury monthly excess return. This is a measure of unanticipated changes in short-term interest rate, similar to the third interest risk measurement in Flannery and James (1984). The one-year Treasury monthly return is obtained from CRSP US Treasury and Inflation Indexes on WRDS. The risk-free rate is the one-month Treasury bill rate included in the Fama-French factor dataset on WRDS which is originally from the website of Kenneth R. French.

(3) Return factor. Ten-year Treasury monthly excess return. This is a measure of long-term interest rate changes, similar to the first bond market factor in Fama and French (1993) and Gandhi and Lustig (2014). The ten-year Treasury monthly return is also obtained from CRSP US Treasury and Inflation Indexes on WRDS. The risk-free rate is the same rate to construct Shock factor. In section IV.4, we use daily changes of ten-year Treasury yields as a proxy for daily Return factor. Note that daily ten-year Treasury return data is available on WRDS, but we don't have the access currently.

The credit risk factor is the monthly return on a portfolio that is long on US investment grade corporate bond index and is orthogonal to each measurement of interest risk factor. The approach is similar to the credit risk factor in Begenau et al. (2015). The calculation contains two steps. First, we calculate monthly return of US investment grade corporate bond index. We obtain ICE BofA US Corporate Index Total Return Index Value from Federal Reserve Bank of St. Louis – FRED. We use the Index Value on the last trading day in each month to calculate the monthly return. Second, we regress this monthly return from the first step on the interest risk factor for each measurements of interest risk. The sum of the intercept and the residual from the regression is the credit risk factor.

The monthly data of Slope factor, Shock factor, Return factor and their corresponding credit risk factors, and the daily data of Slope factor and the proxy of Return factor are from 1975 to 2018.

Table 1 shows the correlations of risk factors. Fama and French (1993) show that the correlation between SMB and HML is only -0.08 for 1963-1991. This correlation has changed since then. The correlation between SMB and HML is -0.201 for 1975-2018 and changes to positive after financial crisis (0.101 for 2010-2018). Regarding interest risk factors, their correlations with Market, SMB and HML are small for 1975-2018 but relatively large for 2010-2018, especially for Slope and Return. The correlations among themselves are also small for 1975-2018, except the correlation between Slope and Shock is 0.573. These correlations become larger for 2010-2018. Especially, the correlation between Slope and Return is -0.922 for 2010-2018. The credit risk factors have close to zero correlations with their corresponding interest risk factors for 1975-2018 after the orthogonalization process. However, the correlations become relatively large for the subperiod 2010-2018.

**Table 1. Correlation Coefficients of Risk Factors**

| Risk Factors | Market | SMB | HML | Slope | Shock | Return | Credit* | Credit** | Credit*** |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1975-2018 | | | | |
| Market | 1 | | | | | | | | |
| SMB | 0.254 | 1 | | | | | | | |
| HML | -0.241 | -0.201 | 1 | | | | | | |
| Slope | 0.081 | 0.084 | 0.119 | 1 | | | | | |
| Shock | 0.050 | -0.100 | 0.058 | 0.573 | 1 | | | | |
| Return | 0.075 | -0.151 | -0.036 | 0.004 | 0.585 | 1 | | | |
| Credit* | 0.279 | -0.050 | -0.017 | 0.000 | - | - | 1 | | |
| Credit** | 0.328 | 0.036 | -0.039 | - | 0.000 | - | - | 1 | |
| Credit*** | 0.379 | 0.145 | 0.057 | - | - | 0.000 | - | - | 1 |
| | | | | | 2010-2018 | | | | |
| Market | 1 | | | | | | | | |
| SMB | 0.368 | 1 | | | | | | | |
| HML | 0.113 | 0.101 | 1 | | | | | | |
| Slope | 0.504 | 0.231 | 0.469 | 1 | | | | | |
| Shock | -0.280 | -0.196 | -0.180 | -0.226 | 1 | | | | |
| Return | -0.476 | -0.236 | -0.443 | -0.922 | 0.406 | 1 | | | |
| Credit* | -0.001 | -0.129 | -0.280 | -0.650 | - | - | 1 | | |
| Credit** | 0.149 | -0.066 | -0.201 | - | 0.121 | - | - | 1 | |
| Credit*** | 0.696 | 0.170 | 0.276 | - | - | -0.442 | - | - | 1 |

Note: Market (market excess return), SMB (small minus big) and HML (high minus low) are monthly Fama-French three stock market factors. Slope, Shock and Return are the three measurements of interest risks. Slope is the monthly changes of the spread between ten-year and one-year Treasury yields. Shock is the residuals of third-order autoregressive model (AR(3)) of one-year Treasury monthly excess return. Return is the ten-year Treasury monthly excess return. The risk-free rate is the same as in Fama-French factors. Credit is the monthly return on a portfolio that is long on US investment grade corporate bond index and is orthogonal to each measurement of interest risks from 1975 to 2018. Credit* is orthogonal to Slope factor. Credit** is orthogonal to Shock factor. Credit*** is orthogonal to Return factor. The monthly Fama-French factors, risk-free rate, one-year and ten-year Treasury returns are from WDRS. The one-year and ten-year Treasury yields, US investment grade corporate bond index are from Federal Reserve Bank of St. Louis – FRED. The correlation coefficients are calculated for period 1975-2018 and subperiod 2010-2018.

### III.3. Sorting Method and Stock Return Calculation

Like identifying banks, there are different ways assigning banks to groups by size. For example, regulators such as Federal Reserve Board use total assets to define bank sizes. A bank holding company with more than $250 billion total assets is considered as systemically important. Gandhi and Lustig (2014) sort banks to ten size groups by both book equity value and market equity value. The results are slightly different by these two sorting methods.

Consistent with the approach calculating Fama-French factors, we sort banks by market equity value. From 1970 to 2018, NYSE listed banks' market equity value in June each year is sorted to generate four breakpoints (20%, 40%, 60%, 80%). Then, banks listed on three stock exchanges NYSE, AMEX, NASDAQ are assigned to five groups (Size1 to Size5). For each size portfolio, we calculate value weighted average stock returns from July in year t to June in year t+1 in the same way when calculating value weighted average stock returns to construct Fama-French factors SMB and HML. Consistent with the results in Fama and French (1993), smaller size groups have a larger number of banks while larger size groups capture a larger proportion of total market equity value. For example, there are 289 banks in Size1 portfolio but only 12 banks in Size5 portfolio when forming bank portfolios in June 2016. On the other hand, Size1 portfolio only represents 6% of combined market equity value of all banks at that time, while Size5 portfolio represents 72% of combined market equity value. At the same time, the average total assets of Size1 portfolio is $1.8 billion, while the average total assets of Size5 portfolio is $707 billion.

Note that whether using NYSE or using all three stock exchanges NYSE, AMEX, NASDAQ to calculate breakpoints would affect the sorting process. Consequently, it may affect our results. When forming bank portfolios in June 2016, there are 407 banks in the sample, in which 52 banks listed on NYSE, 6 banks listed on AMEX and 349 banks listed on NASDAQ. The 52 banks on NYSE have total market equity value $962 billion, on average $18.5 billion per bank. The 349 banks on NASDAQ have total market equity value $255 billion, on average only $0.73 billion per bank. There are only 26 in 349 banks on NASDAQ whose market equity values are larger than median market equity value of banks on NYSE. For our research purpose, using NYSE for breakpoints can distinguish large banks from small banks better than using all three stock exchanges for breakpoints.

### III.4. Model Specifications

We use Stata 16.1 for all time-series data and OLS regressions. The standard errors are robust (default) standard errors. The coefficients, t statistics and indices of confidence levels, along with number of observations and adjusted R squares are presented in our thesis.

We begin our models by running time-series regressions of monthly excess returns of size sorted bank portfolios on common stock market risk factors, i.e. using CAPM and Fama-French three-factor model, with a dummy variable (Post) indicating the period after 2008 financial crisis. The results are presented in section IV.2.

(1) $$\text{Bank}_i\,(t) = \alpha_1 + \alpha_2 \cdot \text{Post} + \beta_1 \cdot \text{Market}\,(t) + \beta_2 \cdot (\text{Market}\,(t) \times \text{Post}) + \varepsilon$$

Bank – monthly value weighted average stock returns of bank portfolios minus risk-free rate. The index i indicates each size sorted bank portfolio or overall banking industry.

Market – monthly value weighted average stock returns of overall market portfolio minus risk-free rate.

Post – dummy variable, equals to 0 before 2010 and equals to 1 from 2010 to 2018.

(2) $$\text{Bank}_i\,(t) = \alpha_1 + \alpha_2 \cdot \text{Post} + \beta_1 \cdot \text{Market}\,(t) + \beta_2 \cdot (\text{Market}\,(t) \times \text{Post}) + \beta_3 \cdot \text{SMB}(t) + \beta_4 \cdot (\text{SMB}\,(t) \times \text{Post}) + \beta_5 \cdot \text{HML}\,(t) + \beta_6 \cdot (\text{HML}\,(t) \times \text{Post}) + \varepsilon$$

SMB – value weighted average returns of small size portfolios (small Market Equity value) minus value weighted average returns of big size portfolios (big Market Equity value).

HML – value weighted average returns of high value portfolios (high Book-to-Market ratio) minus value weighted average returns of low value portfolios (low Book-to-Market ratio).

We then add interest risk factors and credit risk factor to CAPM and Fama-French three-factor model for both overall banking industry and size sorted bank portfolios. As described in section III.2, we employ three measurements of interest risk factor, i.e. Slope, Shock and Return. The credit risk factor is orthogonal to each interest risk factor. We first only add dummy variable

(Post) to interest risk factors, so that the effects on interest risk factor coefficients could be separated. We further extend model (3) and model (4) to examine the effects of size and 2008 financial crisis on interest risk factor coefficients. The extended models will be discussed and presented in section IV.3 and IV.4.

$$(3) \qquad Bank_i(t) = \alpha + \beta_1 \cdot Market(t) + \beta_2 \cdot Interest_k(t) + \beta_3 \cdot (Interest_k(t) \times Post) + \beta_4 \cdot Credit_k(t) + \varepsilon$$

Interest – Interest risk factors. The index k indicates each measurement of interest risks, Slope, Shock and Return, described in section III.2

Credit – Credit risk factor, i.e. monthly return on a portfolio that is long on US investment grade corporate bond index and is orthogonal to each measure of interest risk factor, described in section III.2. The index k indicates the credit risk factor that is orthogonal to interest risk factor k, i.e. Slope, Shock or Return.

$$(4) \qquad Bank_i(t) = \alpha + \beta_1 \cdot Market(t) + \beta_2 \cdot SMB(t) + \beta_3 \cdot HML(t) + \beta_4 \cdot Interest_k(t) + \beta_5 \cdot (Interest_k(t) \times Post) + \beta_6 \cdot Credit_k(t) + \varepsilon$$

Finally, we construct a model to connect interest risk factor coefficients on banks' stock returns to banks' income structure. The goal is to find explanations for the dynamic changes of interest risk factor coefficients. The dependent variable is developed in section IV.4. The independent variables and the model will be discussed and presented in section IV.5.

## IV. Results

### IV.1. Market-to-Book ratios of size sorted bank portfolios

We begin our analysis by presenting Market-to-Book ratios of size sorted bank portfolios and compare them with the Market-to-Book ratios of overall banking industry and overall market portfolio.

Table 2 shows summary statistics of these Market-to-Book ratios. The average Market-to-Book ratio of overall market for 1970-2018 is 2.07 and the standard deviation is 0.76. The average Market-to-Book ratio of overall banking industry is 1.53 and the standard deviation is 0.68. This is consistent with previous researches that the Market-to-Book ratio of banking industry is lower than the ratio of market. The Market-to-Book ratio of the smallest size (Size1) bank portfolio has the lowest mean and standard deviation, while the ratio of the largest size (Size5) bank portfolio has the highest mean and the ratio of the second largest size (Size4) bank portfolio has the highest standard deviation.

Figure 1 shows monthly Market-to-Book ratios of overall market, overall banking industry and size sorted bank portfolios. The Market-to-Book ratios of overall banking industry are much closer to one from 1975 to 1995 and from 2008 to 2018 than other years, increasing and then decreasing during the time between these two periods. This is consistent with the findings in Atkesony et al. (2018), though our results show Market-to-Book ratios of the largest size bank portfolio reach as high as 4.99 in late 1990s. Note that before 2008 financial crisis, the Market-to-Book ratios of overall banking industry are much closer to those of overall market. After the dramatic declines during the financial crisis, the Market-to-Book ratios of overall market recover to pre-crisis levels while the Market-to-Book ratios of banking industry and size sorted bank portfolios remain at the low levels. The gaps of Market-to-Book ratios between overall market and banking industry become wider.

The changes of large size bank portfolios' Market-to-Book ratios that happen during and after financial crisis are more obvious when we take bank sizes into account. As shown in Figure 1, among five size sorted portfolios, large size bank portfolios (Size4 and Size5) have higher Market-to-Book ratios for most of the time prior to the financial crisis, even higher than the ratios of overall market in early 1970s and in the period from 1997 to 1999. Looking at the

**Table 2. Summary Statistics of Monthly Market-to-Book Ratio 1970-2018***

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Market | 2.07 | 0.76 | 0.85 | 4.69 |
| Bank | 1.53 | 0.68 | 0.59 | 4.14 |
| Size1(smallest) | 1.18 | 0.54 | 0.32 | 2.79 |
| Size2 | 1.47 | 0.60 | 0.60 | 3.66 |
| Size3 | 1.55 | 0.67 | 0.58 | 3.95 |
| Size4 | 1.60 | 0.83 | 0.38 | 4.79 |
| Size5(largest) | 1.62 | 0.73 | 0.59 | 4.99 |

*see Note in Figure 1

**Figure 1. Monthly Market-to-Book Ratio of Market and Bank portfolios 1970-2018**


Note: The monthly Market-to-Book ratios of stock market (Market) are the aggregated market equity values (ME) of all stocks in the market portfolio when constructing Fama-French factors divided by aggregated book equity value (BE) of the same stocks. ME and BE come from CRSP and Compustat, respectively. The calculations follow Fama and French (1993). The monthly Market-to-Book ratios of banking industry (Bank) and size sorted bank portfolios (Size1 to Size5) are calculated in the same way. Banks must be included in Compustat Bank Fundamentals Annual database and must be qualified for calculating Fama-French factors, i.e. at least appear two years on Compustat, with CRSP share code 10 or 11, etc. Banks are sorted to five portfolios by size (ME) in each June using NYSE breakpoints. The Market-to-Book ratios of each size sorted bank portfolio are then calculated from July to next June.

largest size bank portfolio (Size5) in particular, it often witnesses the highest Market-to-Book ratios, in other words, the closest to the overall market before 2008 financial crisis, but it turns to be at the bottom level post-crisis. On the other hand, small size bank portfolios (Size1, Size2 and Size3) have Market-to-Book ratios lower than the ratios of overall market for the whole sample period, and compared to large banks, they shift from a lower than ratios of larger size bank portfolios to an upper position post-crisis. This finding is more interesting if we associate it with Calomiris and Nissim (2014)'s research, in which they find that the financial crisis has changed investors' preferences when it comes to banking valuation – investors previously prefer high leverage banks because they enjoy more attractive cost of capital, but they tend to prefer lower leverage banks afterwards. Meanwhile, existing studies, such as George (2015), have shown that large banks tend to be funded less through equity than small ones. Hence, for those large banks, their declining Market-to-Book ratios may reflect the concerns of investors – large (the more leveraged) banks are associated with greater loans default risk and stricter regulatory requirements.

**IV.2. CAPM and Fama-French Three-Factor Model**

We first run time-series regressions on model (1) and model (2). The purpose is to examine the effects of size and 2008 financial crisis based on the basic asset pricing models.

Table 3A shows the results from model (1) CAPM. As expected, we see significant, close-to-one coefficients on Market factor ($\beta_1$) and non-significant, close-to-zero coefficients of intercepts ($\alpha_1$ and $\alpha_2$). The coefficients of the Market dummy variable ($\beta_2$) for the smallest size (Size1) bank portfolio and large size (Size4 and Size5) bank portfolios are not significant, suggesting that Market coefficients do not change for these bank portfolios after 2008 financial crisis. The coefficients of the Market dummy variable for Size2 and Size3 bank portfolios are significant and positive, suggesting increased systematic risks for these bank portfolios. The adjusted R squares of five size sorted bank portfolios are a little lower than that of banking industry. The adjusted R squares slightly increase with size, e.g. from about 0.48 for smaller size bank portfolios to about 0.52 for larger size bank portfolios.

Table 3B shows the results from model (2) Fama-French three-factor model. As size grows, the Market coefficients ($\beta_1$) increase, the SMB coefficients ($\beta_3$) decrease from above zero to

### Table 3A. Bank Excess Return on Market Factor 1970-2018

$$Bank_i(t) = \alpha_1 + \alpha_2 \cdot Post + \beta_1 \cdot Market(t) + \beta_2 \cdot (Market(t) \times Post) + \varepsilon$$

| Coefficient | Bank | Size1 | Size2 | Size3 | Size4 | Size5 |
|---|---|---|---|---|---|---|
| $\beta_1$ Market | 0.966*** (19.03) | 0.820*** (15.40) | 0.808*** (15.91) | 0.877*** (15.67) | 0.993*** (17.44) | 1.044*** (16.82) |
| $\beta_2$ Market × Post | 0.243* (2.42) | 0.0778 (0.85) | 0.388*** (3.53) | 0.269* (2.52) | 0.215 (1.75) | 0.197 (1.73) |
| $\alpha_1$ | 0.001 (0.54) | 0.002 (0.95) | 0.002 (1.29) | 0.002 (0.83) | 0.000 (0.01) | 0.000 (0.12) |
| $\alpha_2$ Post | -0.004 (-1.01) | 0.000 (0.10) | -0.003 (-0.76) | -0.005 (-1.23) | -0.003 (-0.70) | -0.003 (-0.77) |
| Observations | 588 | 588 | 588 | 588 | 588 | 588 |
| Adj. $R^2$ | 0.557 | 0.481 | 0.492 | 0.493 | 0.517 | 0.499 |

### Table 3B. Bank Excess Return on Fama-French Three Factors 1970-2018

$$Bank_i(t) = \alpha_1 + \alpha_2 \cdot Post + \beta_1 \cdot Market(t) + \beta_2 \cdot (Market(t) \times Post) + \beta_3 \cdot SMB(t) + \beta_4 \cdot (SMB(t) \times Post) + \beta_5 \cdot HML(t) + \beta_6 \cdot (HML(t) \times Post) + \varepsilon$$

| Coefficient | Bank | Size1 | Size2 | Size3 | Size4 | Size5 |
|---|---|---|---|---|---|---|
| $\beta_1$ Market | 1.143*** (22.68) | 0.886*** (20.03) | 0.924*** (18.45) | 1.021*** (17.17) | 1.170*** (17.92) | 1.247*** (20.03) |
| $\beta_2$ Market × Post | -0.044 (-0.50) | -0.236*** (-3.66) | -0.002 (-0.02) | -0.118 (-1.27) | -0.127 (-1.05) | -0.074 (-0.71) |
| $\beta_3$ SMB | -0.146* (-2.47) | 0.469*** (7.40) | 0.241*** (3.63) | 0.0185 (0.26) | -0.178* (-2.43) | -0.340*** (-4.77) |
| $\beta_4$ SMB × Post | 0.328* (2.35) | 0.387*** (3.49) | 0.697*** (5.22) | 0.772*** (5.93) | 0.603*** (3.82) | 0.325* (2.05) |
| $\beta_5$ HML | 0.727*** (9.10) | 0.735*** (11.65) | 0.773*** (9.44) | 0.712*** (8.48) | 0.697*** (7.77) | 0.682*** (7.02) |
| $\beta_6$ HML × Post | 0.295* (2.15) | 0.0475 (0.43) | 0.125 (0.89) | 0.228 (1.57) | 0.328 (1.93) | 0.380* (2.46) |
| $\alpha_1$ | -0.003 (-1.60) | -0.003 (-1.75) | -0.002 (-1.18) | -0.002 (-1.14) | -0.004 (-1.76) | -0.003 (-1.44) |
| $\alpha_2$ Post | 0.003 (0.82) | 0.008*** (3.42) | 0.005 (1.71) | 0.002 (0.77) | 0.004 (0.89) | 0.002 (0.65) |
| Observations | 588 | 588 | 588 | 588 | 588 | 588 |
| Adj. $R^2$ | 0.691 | 0.676 | 0.669 | 0.629 | 0.636 | 0.617 |

Note: t statistics in parentheses, * $p<0.05$ ** $p<0.01$ *** $p<0.001$. Bank is monthly value weighted average stock returns of bank portfolios minus risk-free rate. The index i in the model indicates banking industry (Bank) and each size sorted bank portfolio (Size1 to Size5). Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Banks are sorted to five portfolios by size (ME) in each June using NYSE breakpoints. Market (market excess return), SMB (small minus big) and HML (high minus low) are monthly Fama-French stock factors. Post is a dummy variable that equals to 0 from 1970 to 2009 and equals to 1 from 2010 to 2018. Risk-free rate is one-month Treasury bill rate.

below zero, the HML coefficients ($\beta_5$) are around 0.7 though. The intercepts ($\alpha_1$) and the corresponding dummy variables ($\alpha_2$) are negligible and non-significant. The pattern of Fama-French factor coefficients and intercepts is similar across the relative regressions in our thesis.

The coefficients of the Market dummy variable ($\beta_2$) are not significant and small except for the smallest size (Size1) bank portfolio. This is different from Table 3A, showing the impacts by adding SMB and HML factors. The coefficients of SMB dummy variable ($\beta_4$) are all significant and positive. For the Size5 bank portfolio, the SMB coefficients change from negative before 2008 financial crisis to close to zero after financial crisis (-0.340 plus 0.325), suggesting that the SMB factor does not explain the variations in the stock returns of the largest size bank portfolio after financial crisis. As we will show later, when implementing regressions for 2010-2018, the coefficients of SMB factor are not statistically significant and close to zero. The coefficients of HML dummy variable ($\beta_6$) are only significant for Size5 bank portfolios, suggesting the largest size bank portfolio responds more strongly to the HML factor after financial crisis. Adding SMB and HML factors increases adjusted R squares, which is consistent with previous researches (Fama and French (1992), Schuermann and Stiroh (2006)).

### IV.3. Interest and Credit Risk Factors

Now we extend the basic CAPM and Fama-French factor model to study the effects of interest risk factors on banks' stock returns. We first regress stock excess returns of overall banking industry on risk factors, then regress stock excess returns of size sorted bank portfolios on risk factors to examine the effects of size and how such effects are interacted with the effects of financial crisis.

Table 4A and Table 4B present the results of adding interest risk factors and credit risk factors to CAPM and Fama-French three-factor model. In both tables, the coefficients of Slope factor ($\beta_2$ Slope in Table 4A, $\beta_4$ Slope in Table 4B) are not significant at 5% confidence level and relatively small, while the coefficients of Slope dummy variable ($\beta_3$ Slope × Post in Table 4A, $\beta_5$ Slope × Post in Table 4B) are significant and relatively large, suggesting that the effect of Slope factor on banks' stock returns changes after 2008 financial crisis. The results are consistent with Bailey and Matyáš (2019). The signs and magnitudes of the coefficients of

Slope factor and Slope dummy variable are similar. The results are also in line with Schuermann and Stiroh (2006), in which they find that before financial crisis the interest risk factor that is similar to the Slope factor has significant coefficients for only three in nine years when regress bank stock returns on Fama-French three factors and additional bank specific risk factors.

Comparing Table 4B with Table 4A, after adding SMB and HML factors to the model, the magnitude and t statistics of the coefficient on Slope factor dummy variable are reduced. This suggests SMB and HML factors probably absorb part of the variations in bank stock returns explained by the Slope factor, especially after financial crisis. The positive sign of the coefficients suggests that if the yield curve becomes upward steeper the stock returns of banking industry will increase. This is understandable. Because banks borrow in short term and lend in long term, a steeper upward yield curve means banks are more profitable.

The coefficients of Shock factor in both Table 4A with Table 4B are significant and positive, which is consistent with Flannery and James (1984). The positive sign suggests the inverse moving directions of unanticipated interest rate changes and banks' stock returns. When the Shock factor increases, meaning a sudden decrease in short-term interest rate, banks will be able to reduce the cost of borrowing in short term and hence are likely to improve profitability. Adding SMB and HML factors, as shown in Table 4B, the magnitude of Shock coefficient ($\beta_4$ Shock in Table 4B) is reduced and the Shock dummy variable coefficient ($\beta_5$ Shock × Post in Table 4B) is significant at 5% confidence level. The effects of Shock factor on banks' stock returns change from positive (0.952) to negative (0.952 minus 3.261) after financial crisis, suggesting the change of the inverse relations mentioned above. Starting from 2007, the Federal Reserve Board gradually reduced short-term interest rate to near zero. We interpret the changing effects of the Shock factor on banks' stock returns as that the economic environment has changed. Because the short-term interest rate is close to zero after financial crisis, unanticipated interest rate changes probably means an unusual increase in short-term interest rate. Considering the economic and business environment during that period, this probably means that the Federal Reserve Board is confidence in the economic outlook and raises the interest rate, not predicted by the autoregression model. Such a raise and the reason behind the raise are positive to banking business. This could also suggest that long-term interest rate may also rise, which is another positive reason for bank stocks to rise.

**Table 4A. Bank Excess Return on Market, Interest and Credit Factors 1975-2018**

Bank (t) = α + $\beta_1$ · Market (t) + $\beta_2$ · Interest $_k$ (t) + $\beta_3$ · (Interest $_k$ (t) × Post) + $\beta_4$ · Credit $_k$ (t) + ε

| Coefficient | I. Slope | II. Shock | III. Return |
|---|---|---|---|
| $\beta_1$<br>Market | 0.921***<br>(16.85) | 0.990***<br>(18.35) | 0.937***<br>(16.58) |
| $\beta_2$<br>Slope | 1.045<br>(1.61) | | |
| $\beta_3$<br>Slope × Post | 11.02***<br>(5.79) | | |
| $\beta_2$<br>Shock | | 1.338***<br>(3.72) | |
| $\beta_3$<br>Shock × Post | | -3.302<br>(-1.61) | |
| $\beta_2$<br>Return | | | 0.330***<br>(3.36) |
| $\beta_3$<br>Return × Post | | | -1.571***<br>(-6.54) |
| $\beta_4$<br>Credit | 0.250*<br>(2.09) | -0.063<br>(-0.37) | -0.016<br>(-0.06) |
| α | -0.000<br>(-0.05) | -0.000<br>(-0.17) | 0.001<br>(0.43) |
| Observations | 528 | 528 | 528 |
| Adj. $R^2$ | 0.574 | 0.556 | 0.581 |

Note: t statistics in parentheses, * p<0.05 ** p<0.01 *** p<0.001. See Note in Table 4B.

The results of Return coefficients also show the change of sign after financial crisis and the reduce in magnitude by adding SMB and HML factors. The positive coefficients of the Return factor before financial crisis, which is similar to the results in Gandhi and Lustig (2014) regarding large size banks, suggest an increase in long-term government bond excess return will be associated with a rise in banks' stock returns. The results are also consistent with Flannery and James (1984) that the magnitudes of Return coefficients are smaller than Shock factor coefficients. Note that the relations between long-term government bond excess return and banks' stock return has changed from positive to negative after 2008 financial crisis, as the coefficients of the Return dummy variable are significantly negative. As shown in Table 4B, after financial crisis a one percent increase in long-term government bond excess return would be associated with 0.645 percent decrease in banks' stock returns (0.253 minus 0.898).

**Table 4B. Bank Excess Return on Five Risk Factors 1975-2018**

$$Bank(t) = \alpha + \beta_1 \cdot Market(t) + \beta_2 \cdot SMB(t) + \beta_3 \cdot HML(t) + \beta_4 \cdot Interest_k(t) + \beta_5 \cdot (Interest_k(t) \times Post) + \beta_6 \cdot Credit_k(t) + \varepsilon$$

| Coefficient | I. Slope | II. Shock | III. Return |
|---|---|---|---|
| $\beta_1$ Market | 1.108*** (22.47) | 1.145*** (25.65) | 1.129*** (23.36) |
| $\beta_2$ SMB | -0.079 (-1.35) | -0.055 (-0.94) | -0.045 (-0.73) |
| $\beta_3$ HML | 0.816*** (10.81) | 0.854*** (12.76) | 0.834*** (11.49) |
| $\beta_4$ Slope | 0.470 (0.88) | | |
| $\beta_5$ Slope × Post | 4.632** (2.81) | | |
| $\beta_4$ Shock | | 0.952** (3.05) | |
| $\beta_5$ Shock × Post | | -3.261* (-2.09) | |
| $\beta_4$ Return | | | 0.253** (3.18) |
| $\beta_5$ Return × Post | | | -0.898*** (-4.65) |
| $\beta_6$ Credit | 0.091 (0.85) | -0.143 (-1.00) | -0.314 (-1.50) |
| $\alpha$ | -0.003 (-1.67) | -0.003 (-1.64) | -0.001 (-0.74) |
| Observations | 528 | 528 | 528 |
| Adj. $R^2$ | 0.717 | 0.720 | 0.728 |

Note: t statistics in parentheses, * $p<0.05$ ** $p<0.01$ *** $p<0.001$. Bank is monthly value weighted average stock returns of banks minus risk-free rate. Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Market (market excess return), SMB (small minus big) and HML (high minus low) are monthly Fama-French stock factors. Post is a dummy variable that equals to 0 from 1970 to 2009 and equals to 1 from 2010 to 2018. Interest is the interest risk factor. The index k in the model indicates each measurement of Interest, i.e. Slope, Shock and Return. Slope is the monthly changes of the spread between ten-year and one-year Treasury yields. Shock is the residuals of third-order autoregressive model (AR(3)) of one-year Treasury monthly excess return. Return is the ten-year Treasury monthly excess return. Credit is the monthly return on a portfolio that is long on US investment grade corporate bond index and is orthogonal to each measurement of interest risks from 1975 to 2018. The index k in the model indicates the Credit factor that is orthogonal to the specific Interest. Risk-free rate is one-month Treasury bill rate.

Consistent with previous researches, coefficients of credit risk factor are not significant in most cases, except the case in Table 4A when Slope factor is used as a proxy of interest risk factor. Different measurements of interest risk factor seem affect the coefficients of credit risk factor. The sign of credit risk factor coefficients is positive when Slope factor is used as a proxy of interest risk factor, while the signs are negative when Shock or Return factor is used.

Table 5A and 5B extend Table 4A and 4B by using value weighted average stock returns of size sorted bank portfolios as dependent variables. The patterns of coefficients of the Market, SMB, HML, credit risk factors are similar to previous analysis. As bank portfolios' size grows, the Market coefficients increase from below one to above one, the SMB coefficients decrease from positive to negative, the HML coefficients are close to each other, and the credit risk factor coefficients are generally not significant. The adjusted R squares increase when adding SMB and HML factors, and adjusted R squares of small size bank portfolios increase more than those of large size bank portfolios.

The patterns of the coefficients of the interest risk factors show that stock returns of different size bank portfolios respond differently to interest rate changes. In Table 5A, the Slope factor coefficients ($\beta_2$) are significant for Size1 and Size3 bank portfolios. The Slope dummy variable coefficients ($\beta_3$) are significant for all size sorted bank portfolios, but the magnitude of Size1 bank portfolio's coefficient is about half of other size bank portfolios' coefficients. In Table 5B, similar to the impacts of adding SMB and HML factors shown in Table 4B, the coefficients of Slope factor and Slope dummy variable all decrease. The Slope dummy variable coefficient of Size1 bank portfolio is not significant in Table 5B, while the coefficients of other size bank portfolios all shrink to about half of those in Table 5A.

Similar to those in Table 4A, the coefficients of the Shock factor are all positive and significant and the coefficients of the Shock dummy variable are all negative and non-significant in Table 5A. Similarly, the Shock factor coefficients are all positive and significant, mostly decrease in magnitudes in Table 5B, compared to Table 5A. On the other hand, the Shock dummy variable coefficients in Table 5B are all negative and mostly significant, but the magnitudes do not change much. For all size sorted bank portfolios, the coefficients of Shock factor and Shock factor dummy variable have similar values, i.e. Shock factor coefficients are close to 1 and Shock dummy variable are close to -3 in Table 5B. This is also true for the overall banking industry, as the coefficients shown in Table 4B. This may suggest that the Shock factor affects

## Table 5A. Bank Excess Return on Market, Interest and Credit Factors, 5 Size Groups, 1975-2018

$$\text{Bank}_{\,i}\,(t) = \alpha + \beta_1 \cdot \text{Market}\,(t) + \beta_2 \cdot \text{Interest}_{\,k}\,(t) + \beta_3 \cdot (\text{Interest}_{\,k}\,(t) \times \text{Post}) + \beta_4 \cdot \text{Credit}_{\,k}\,(t) + \varepsilon$$

| Coefficient | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\beta_1$ | 0.707*** | 0.754*** | 0.810*** | 0.912*** | 1.006*** | 0.743*** | 0.818*** | 0.885*** | 0.986*** | 1.077*** | 0.710*** | 0.780*** | 0.837*** | 0.936*** | 1.030*** |
| Market | (12.56) | (14.32) | (13.78) | (15.37) | (15.58) | (13.19) | (15.22) | (15.19) | (16.93) | (17.57) | (12.23) | (13.85) | (13.80) | (15.82) | (15.89) |
| $\beta_2$ | 1.885** | 0.940 | 1.724** | 1.013 | 0.632 | | | | | | | | | | |
| Slope | (3.20) | (1.56) | (2.66) | (1.52) | (0.76) | | | | | | | | | | |
| $\beta_3$ | 5.583** | 10.78*** | 10.25*** | 11.55*** | 11.51*** | | | | | | | | | | |
| Slope × Post | (2.84) | (4.90) | (4.93) | (5.24) | (5.34) | | | | | | | | | | |
| $\beta_2$ | | | | | | 0.844** | 0.908** | 1.556*** | 1.610*** | 1.534** | | | | | |
| Shock | | | | | | (2.94) | (2.90) | (4.64) | (4.69) | (2.89) | | | | | |
| $\beta_3$ | | | | | | -2.700 | -3.241 | -2.443 | -3.709 | -3.892 | | | | | |
| Shock × Post | | | | | | (-1.45) | (-1.43) | (-1.09) | (-1.61) | (-1.75) | | | | | |
| $\beta_2$ | | | | | | | | | | | 0.197* | 0.275** | 0.388*** | 0.410*** | 0.410** |
| Return | | | | | | | | | | | (2.29) | (3.19) | (4.37) | (4.15) | (3.26) |
| $\beta_3$ | | | | | | | | | | | -0.898*** | -1.496*** | -1.600*** | -1.690*** | -1.653*** |
| Return × Post | | | | | | | | | | | (-3.95) | (-5.64) | (-6.31) | (-6.01) | (-6.07) |
| $\beta_6$ | 0.144 | 0.130 | 0.228 | 0.303* | 0.320* | 0.023 | -0.136 | -0.128 | -0.063 | -0.028 | 0.103 | -0.232 | -0.171 | -0.089 | -0.079 |
| Credit | (1.45) | (1.04) | (1.85) | (2.49) | (2.17) | (0.17) | (-0.73) | (-0.73) | (-0.37) | (-0.13) | (0.57) | (-0.78) | (-0.67) | (-0.41) | (-0.24) |
| $\alpha$ | 0.003 | 0.004 | 0.002 | -0.000 | -0.002 | 0.002 | 0.003 | 0.002 | -0.000 | -0.003 | 0.003 | 0.005* | 0.003 | 0.001 | -0.001 |
| | (1.72) | (1.79) | (0.84) | (-0.11) | (-0.95) | (1.09) | (1.34) | (0.86) | (-0.16) | (-0.92) | (1.61) | (2.13) | (1.43) | (0.61) | (-0.24) |
| Observations | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 |
| Adj. $R^2$ | 0.488 | 0.483 | 0.510 | 0.529 | 0.522 | 0.466 | 0.459 | 0.490 | 0.515 | 0.511 | 0.477 | 0.491 | 0.516 | 0.540 | 0.532 |

Note: t statistics in parentheses, * p<0.05 ** p<0.01 *** p<0.001. Bank is monthly value weighted average stock returns of each size sorted bank portfolio (Size1 to Size5, as index i in the model) minus risk-free rate. Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Then, Banks are sorted to five portfolios by market equity values in each June using NYSE breakpoints. Market, SMB (in Table 5B) and HML (in Table 5B) are monthly Fama-French stock factors. Post equals to 0 from 1970 to 2009 and equals to 1 from 2010 to 2018. Interest is the interest risk factor. The index k in the model indicates each measurement of Interest, i.e. Slope, Shock and Return. Slope is the monthly changes of the spread between ten-year and one-year Treasury yields. Shock is the residuals of third-order autoregressive model (AR(3)) of one-year Treasury monthly excess return. Return is the ten-year Treasury monthly excess return. Credit is the monthly return on a portfolio that is long on US investment grade corporate bond index and is orthogonal to each measurement of interest risks from 1975 to 2018. The index k in the model indicates the Credit factor that is orthogonal to the specific Interest. Risk-free rate is one-month Treasury bill rate.

# Table 5B. Bank Excess Return on Full Factors, 5 Size Groups, 1975-2018

$$\text{Bank}_{i}(t) = \alpha + \beta_1 \cdot \text{Market}(t) + \beta_2 \cdot \text{SMB}(t) + \beta_3 \cdot \text{HML}(t) + \beta_4 \cdot \text{Interest}_{k}(t) + \beta_5 \cdot (\text{Interest}_{k}(t) \times \text{Post}) + \beta_6 \cdot \text{Credit}_{k}(t) + \varepsilon$$

| Coefficient | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\beta_1$ | 0.760*** | 0.867*** | 0.951*** | 1.089*** | 1.226*** | 0.767*** | 0.901*** | 0.996*** | 1.135*** | 1.265*** | 0.783*** | 0.909*** | 0.988*** | 1.117*** | 1.251*** |
| Market | (19.28) | (17.30) | (16.84) | (17.61) | (20.11) | (21.21) | (18.96) | (19.64) | (20.26) | (23.22) | (20.29) | (18.03) | (18.65) | (19.89) | (20.87) |
| $\beta_2$ | 0.509*** | 0.295*** | 0.107 | -0.117 | -0.255*** | 0.530*** | 0.316*** | 0.140 | -0.089 | -0.233*** | 0.548*** | 0.343*** | 0.163* | -0.076 | -0.220** |
| SMB | (8.21) | (4.16) | (1.39) | (-1.52) | (-3.85) | (8.40) | (4.35) | (1.80) | (-1.16) | (-3.54) | (8.22) | (4.83) | (1.99) | (-0.97) | (-3.25) |
| $\beta_3$ | 0.731*** | 0.816*** | 0.773*** | 0.736*** | 0.812*** | 0.745*** | 0.849*** | 0.816*** | 0.781*** | 0.847*** | 0.758*** | 0.850*** | 0.812*** | 0.759*** | 0.829*** |
| HML | (12.85) | (9.75) | (9.39) | (8.70) | (9.16) | (14.06) | (11.24) | (11.09) | (10.12) | (10.67) | (13.68) | (11.02) | (11.27) | (10.12) | (9.57) |
| $\beta_4$ | 1.026** | 0.143 | 1.071 | 0.522 | 0.163 | | | | | | | | | | |
| Slope | (2.79) | (0.28) | (1.85) | (0.86) | (0.23) | | | | | | | | | | |
| $\beta_5$ | 0.061 | 4.520* | 4.263* | 5.775** | 5.098* | | | | | | | | | | |
| Slope × Post | (0.04) | (2.41) | (2.45) | (2.85) | (2.50) | | | | | | | | | | |
| $\beta_4$ | | | | | | 0.931*** | 0.796** | 1.328*** | 1.229*** | 1.021* | | | | | |
| Shock | | | | | | (4.44) | (3.22) | (4.53) | (4.07) | (2.10) | | | | | |
| $\beta_5$ | | | | | | -3.584** | -3.790* | -2.710 | -3.609 | -3.567* | | | | | |
| Shock × Post | | | | | | (-2.99) | (-2.35) | (-1.58) | (-1.86) | (-1.97) | | | | | |
| $\beta_4$ | | | | | | | | | | | 0.269*** | 0.290*** | 0.363*** | 0.331*** | 0.291** |
| Return | | | | | | | | | | | (4.25) | (4.33) | (4.57) | (3.60) | (2.62) |
| $\beta_5$ | | | | | | | | | | | -0.353* | -0.855*** | -0.969*** | -1.074*** | -0.965*** |
| Return × Post | | | | | | | | | | | (-2.41) | (-4.45) | (-4.65) | (-4.02) | (-4.05) |
| $\beta_6$ | 0.122 | 0.0450 | 0.115 | 0.150 | 0.125 | 0.017 | -0.175 | -0.184 | -0.141 | -0.127 | -0.250* | -0.590* | -0.489* | -0.354 | -0.349 |
| Credit | (1.65) | (0.43) | (0.96) | (1.23) | (0.91) | (0.18) | (-1.13) | (-1.17) | (-0.88) | (-0.70) | (-2.24) | (-2.56) | (-2.32) | (-1.84) | (-1.33) |
| $\alpha$ | -0.001 | 0.000 | -0.001 | -0.003 | -0.005* | -0.002 | -0.001 | -0.001 | -0.003 | -0.005* | 0.000 | 0.002 | 0.001 | -0.002 | -0.002 |
| | (-0.75) | (0.01) | (-0.66) | (-1.28) | (-2.19) | (-1.19) | (-0.27) | (-0.49) | (-1.22) | (-2.03) | (0.28) | (1.27) | (0.40) | (-0.36) | (-1.24) |
| Observations | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 |
| Adj. $R^2$ | 0.702 | 0.659 | 0.642 | 0.640 | 0.648 | 0.706 | 0.664 | 0.649 | 0.644 | 0.651 | 0.711 | 0.684 | 0.663 | 0.654 | 0.659 |

Note: t statistics in parentheses, * p<0.05 ** p<0.01 *** p<0.001, see Note in Table 5A.

stock returns of small size bank portfolios as equally as it does to stock returns of large size bank portfolios.

By extending the time horizon in Gandhi and Lustig (2014)[4] from 1970-2013 to 1975-2018, our results regarding Return factor and its corresponding dummy variable reveal how 2008 financial crisis has affected the effects of this interest risk measurement on banks' stock returns. In Gandhi and Lustig (2014), the coefficients of the interest risk factor, which is similar to the Return factor, are negative but not significant for small size bank portfolios, while the coefficients are positive and significant for large size bank portfolios, from which it is not clear whether the coefficients have changed after financial crisis. Table 5A and Table 5B show that coefficients of Return factor are positive and significant, while coefficients of Return dummy variable are negative and significant for all size sorted bank portfolios, suggesting that 2008 financial crisis has inversed the relations between banks' stock returns and long-term government bond returns. Our coefficients of Market, SMB, HML factors and adjusted R squares are close to those in Gandhi and Lustig (2014) for large size bank portfolios, but are different for small size bank portfolios.

The interpretations of the coefficients of Slope, Shock and Return factors and their corresponding dummy variables for size sorted bank portfolios are similar to the analysis regarding overall banking industry. Considering the nature of banking business, banks of all size are affected by interest risks in similar ways, but with different magnitudes.

We now take four steps to extend model (3) and model (4) in order to further examine the effects of size and 2008 financial crisis on interest risk factor coefficients. First, we extend model (3) and model (4) by adding post financial crisis dummy variables to all explanatory factors in the model. Second, we run the models for the post financial crisis period 2010-2018. Third, we orthogonalize Market factor for period 2010-2018, as the correlations between Market factor and other risk factors are relatively large during this time. Fourth, we add value (BE/ME) sorted bank portfolios to construct 25 bank portfolios, similar to the 25 stock portfolios in Fama and French (1993), to study whether value (BE/ME) plays similar roles as size does with regard to affect interest risk factor coefficients.

[4] Table I Panel A in Gandhi and Lustig (2014)

STEP ONE – In Table 6A and 6B (see Appendix) we add post financial crisis dummy variables to all explanatory factors and focus our analysis on the changes of coefficients of Interest risk factor dummy variables ($\beta_4$). Compared to Table 5A, Table 6A shows that the Slope dummy variable coefficients are not significant for Size1 and Size2 bank portfolios, the Shock dummy variable coefficients are larger in magnitude, while Slope and Return factor dummy variable coefficients do not change much. Table 6B shows more differences. The coefficients of Slope and Shock dummy variable ($\beta_8$) are not significant for all size bank portfolios, challenging the argument that Slope factor can explain the variations in bank stock returns after 2008 financial crisis.

Regarding other explanatory factors, the coefficients of Market and HML factor dummy variables are generally small and non-significant, suggesting the effects of Market and HML factors on banks' stock returns do not change after financial crisis. The coefficients of SMB factor dummy variables are generally positive and significant, except for size5 bank portfolio where the coefficients are all non-significant. The coefficients of the constant variable and its corresponding dummy variable are generally close to zero and non-significant, but Size1 bank portfolio has small but significant coefficients for all three measurements of interest risk factors, shown in Table 6B.

STEP TWO – In Table 7A and 7B (see Appendix), the time horizons of model (3) and model (4) are from 2010 to 2018. We have two motivations. First, as shown in Table 1, although we orthogonalize the credit risk factor with respect to each interest risk factor for the period 1975-2018, the orthogonalized credit risk factors present larger correlations with corresponding interest risk factors for the period 2010-2018. For example, the correlation between credit risk factor and Slope factor is negligible for 1975-2018 while it is -0.65 for 2010-2018. Hence, we process the orthogonalization method to credit risk factor for subperiod 2010-2018. Second, regressions for 2010-2018 may show more details about the effects of size and financial crisis than only using the post financial crisis dummy variables (Post).

The results are presented in Table 7A and 7B. While the coefficients are not exactly same, as expected, as those corresponding numbers in Table 6A and 6B, the patterns are similar, except for the Slope factor. In Table 7B, the Slope factor coefficients are significant for Size3, Size4 and Size5 bank portfolios, suggesting the Slope factor indeed explains the variations in larger size bank stock returns after financial crisis, compared to results in STEP ONE.

STEP THREE – As shown in Table 1, the Market factor has higher correlations with Interest risk factors in subperiod 2010-2018 than in period 1975-2018. For example, the correlation between Market factor and Slope factor is 0.504 for 2010-2018, but it is only 0.081 for 1975-2018. The correlation between Market factor and Return factor is -0.476 for 2010-2018, but it is only 0.075 for 1975-2018. Motivated by the treatment in Fama and French (1992), we regress the Market factor on all other explanatory factors in model (3) and model (4) for 2010-2018. The results are shown below.

$$Market = \underset{(3.05)}{0.008} + \underset{(7.43)}{10.11} \cdot Slope + \underset{(5.58)}{1.721} \cdot Credit + \varepsilon \qquad Adj.R^2\ 0.436$$

$$Market = \underset{(-1.74)}{-0.017} - \underset{(-2.44)}{11.28} \cdot Shock + \underset{(1.87)}{0.639} \cdot Credit + \varepsilon \qquad Adj.R^2\ 0.098$$

$$Market = \underset{(2.75)}{0.007} - \underset{(-7.30)}{1.043} \cdot Return + \underset{(6.80)}{2.39} \cdot Credit + \varepsilon \qquad Adj.R^2\ 0.516$$

$$Market = \underset{(2.94)}{0.008} + \underset{(4.26)}{0.410} \cdot SMB - \underset{(-2.83)}{0.392} \cdot HML + \underset{(7.02)}{10.87} \cdot Slope + \underset{(6.34)}{1.777} \cdot Credit + \varepsilon \qquad Adj.R^2\ 0.528$$

$$Market = \underset{(-1.39)}{-0.012} + \underset{(3.46)}{0.537} \cdot SMB + \underset{(0.58)}{0.090} \cdot HML - \underset{(-1.89)}{8.333} \cdot Shock + \underset{(2.33)}{0.718} \cdot Credit + \varepsilon \qquad Adj.R^2\ 0.188$$

$$Market = \underset{(2.58)}{0.006} + \underset{(4.08)}{0.374} \cdot SMB - \underset{(-2.92)}{0.361} \cdot HML - \underset{(-7.08)}{1.095} \cdot Return + \underset{(7.38)}{2.435} \cdot Credit + \varepsilon \qquad Adj.R^2\ 0.593$$

The t-statistics are in parentheses below the coefficients. Note that the adjusted R squares are small when Shock factor is used as interest risk factor measurement. As argued in Fama and French (1992), the Market factor shares much variations with other explanatory factors. Extracting common variations from the Market factor could reflect the explanation power of other factors. The sum of intercept and residual is an orthogonalized Market factor RMO. The results are presented in Table 8A and Table 8B (see Appendix).

As expected, the magnitudes of interest risk factor coefficients all increase in Table 8B, compared to those in Table 7B. The Slope and Return factor coefficients are significant for all size sorted bank portfolios, and the Shock factor coefficients are significant for Size1 and Size5 bank portfolios. The positive and negative signs of the coefficients are in line with our previous analysis. Compared to those in Table 7B, the SMB coefficients in Table 8B increase for all three interest risk measurements, while the HML coefficients increase when Shock factor is used but decrease when Slope and Return factors are used. The credit factor coefficients are significant and positive when Slope and Return factors are used for all size sorted bank portfolios. An increase of the credit risk factor, measured by monthly returns on a portfolio that is long on US investment grade corporate bond index, means a decrease in the yield to maturity and hence, a decrease of borrowing cost for companies. The reasons could be an increase in overall corporate credit rate, or a decrease in overall interest rate. Considering the economic and business environment in 2010-2018, the former reason is more likely, as companies recover from the financial crisis, which is positive to banks' stock returns.

STEP FOUR − We add value (BE/ME) sorted bank portfolios to construct 25 bank portfolios so that we can further explore if value affects the coefficients in similar ways as size does. Considering time horizon, because we are more interested in the interest risk factor coefficients after 2008 financial crisis than the period 1975-2018, we run model (3) and model (4), omitting the dummy variables, on 25 size and value sorted bank portfolios for 2010-2018. The results are presented in Table 9A and Table 9B (see Appendix).

Table 9A shows the overall monotonic increase of the Slope factor coefficients with the growth of bank portfolios' size and value. Such overall monotonic increase also presents for the Return factor coefficients in magnitudes. Shock factor coefficients present less monotonic increasing pattern and they are not significant for all size and value sorted bank portfolios.

Table 9B presents the results when SMB and HML factors are added to the regression. The overall monotonic increase of the Slope factor coefficients with size and value is now less obvious, and coefficients are significant only in 6 of 25 bank portfolios. The coefficients within the same size group could increase, decrease then increase again as value grows (size3) or decrease then increase (size5). However, in general, as size and value increase, the Slope factor coefficients tend to increase. On the other hand, there are no clear patterns suggesting which categories of bank portfolios have significant Slope factor coefficients.

In Table 9B the Shock coefficients are not significant for all size and value sorted bank portfolios and most of coefficients are negative. The trends of decrease or increase with size and value seem random for Shock coefficients, compared to other two interest risk factors. In addition, Shock coefficients are not all negative. There are 7 in 25 bank portfolios show positive Shock coefficients, most of them in Value4 and Value5 groups, suggesting these bank portfolios' stock returns tend to rise when Shock factor increases, i.e. a negative unanticipated short-term interest rate change.

In Table 9B the Return coefficients present the overall monotonic increase in magnitudes as size or value grows. For example, in the Size5 (Big) group, the magnitudes of Return coefficients monotonically increase from negative 0.445 to negative 1.976 as value grows from low to high. In the Value5 (High) group, the magnitudes of Return coefficients increase from negative 0.083 to negative 1.976 as size grows from small to big, though such increase is not strictly monotonic. Regarding significances, all bank portfolios in Size4 and Size5 groups and most bank portfolios in the Value5 group have significant Return coefficients. As size grows, Return coefficients are more likely to be significant. This is consistent with the results in Table 7B, where the Return coefficients are significant for Size3, Size4 and Size5 bank portfolios but are not significant for smaller size bank portfolios. On the other hand, Return coefficients are not necessarily become significant as value grows. Only the highest value (Value5) groups show significant Return coefficients.

### IV.4. A Closer Look at Interest Risk Factors

Analysis in section IV.2 and section IV.3 shows 2008 financial crisis has changed the associations between banks' stock returns and interest risk measurements. Such changes of associations vary across different sizes of bank portfolios. For example, the changes of Return coefficients because of financial crisis are bigger for larger size bank portfolios, as shown in Table 5B and Table 6B. Meanwhile, the impact of 2008 financial crisis on such changes of associations affects overall banking industry, no matter how small or big the bank portfolios' sizes are. For example, the Return coefficients change from positive to negative for all five size sorted bank portfolios.

In this section, we employ three visual approaches to take a closer look at the interest risk factors. In the first approach, we look at the dynamic changes of interest risk factor coefficients every year from 1975 to 2018. In the second approach, we look at the dynamic changes of interest risk factors themselves, i.e. Slope, Shock and Return factors, every year from 1975 to 2018. In the third approach, we compare the dynamic changes of interest risk factor coefficients with the dynamic changes of Fama-French stock market factors coefficients. We will show that while the coefficients of interest risk factor and HML factor present apparent changes after 2008 financial crisis, the coefficients of the Market factor and SMB factor do not present obvious changes because of the financial crisis. Compared to analysis in section IV.2 and section IV.3, the dynamic changes of Market factor and interest risk factor coefficients are in line with expectations, but the dynamic changes of SMB factor and HML factor show a different picture.

FIRST APPROACH − We run regressions to obtain coefficients for Slope, Shock and Return factors each year for the period 1975-2018. Until now, our analysis is based on monthly data of all variables. As a result, the number of observations is limited to 12 for each regression when running regressions each year. We take two further steps to overcome the drawbacks of limited number of observations for the regressions. First, we calculate daily value weighted average stock returns for size sorted bank portfolios and daily Slope factor from 1975 to 2018. We also obtain daily Fama-French factors from WRDS. As the daily credit risk factor is currently not available to us, it is omitted here. We run the following two models to obtain the yearly Slope coefficients. The data in model (5) and model (6) is daily basis.

(5) $$\text{Bank}_i(t) = \alpha + \beta_1 \cdot \text{Market}(t) + \beta_2 \cdot \text{Slope}(t) + \varepsilon$$

(6) $$\text{Bank}_i(t) = \alpha + \beta_1 \cdot \text{Market}(t) + \beta_2 \cdot \text{SMB}(t) + \beta_3 \cdot \text{HML}(t) + \beta_4 \cdot \text{Slope}(t) + \varepsilon$$

Second, since the daily data on US government bond returns is also currently not available to us, we run model (4), omitting the dummy variable, each year and each rolling three-year to obtain yearly Shock and Return coefficients. The three-year rolling regressions have 36 observations each time, providing a better view on the coefficient changes over time than one-year regressions with only 12 observations each time.

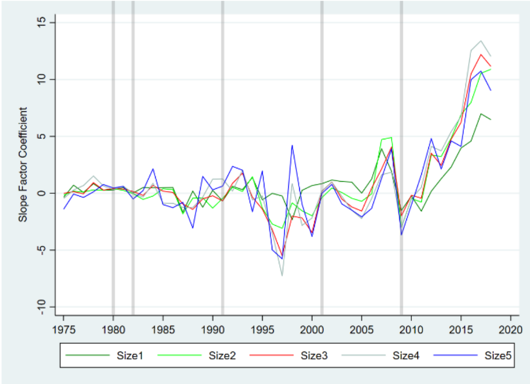
The results are shown in Figure 2. The gray lines are years in which NBER (National Bureau of Economic Research) announced a trough in business activity. In general, the coefficients change during and after troughs. The 2009 trough shows the most dramatic changes of interest risk factor coefficients.

Figure 2(1) and Figure 2(2) show results of Slope coefficients from model (5) and model (6). As shown in Figure 2(1), the Slope coefficients are close to zero from 1975 to 1982. They become more volatile since the 1982 trough. From 1982 to 2009, the Slope coefficients of five size sorted bank portfolios tend to move in similar directions, rising and falling around the x-axis. The Slope coefficients of five size sorted bank portfolios reach relatively low points at the same time in 2009, then keep rising until around 2016. Adding SMB and HML factors, as shown in Figure 2(2), the dynamic patterns of Slope coefficients are similar to those in Figure 2(1), but the magnitudes are reduced after 2008 financial crisis.

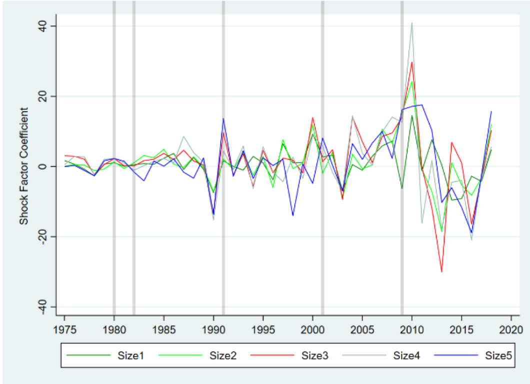
Figure 2(3) and Figure 2(4) show the yearly changes of Shock coefficients from model (4), omitting the dummy variable. The results of three-year rolling regressions in Figure 2(4) show clearer trends than those from one-year regressions in Figure 2(3), especially about the effects of 2008 financial crisis. In Figure 2(4), the Shock coefficients of five size sorted bank portfolios generally rise and fall together until 2008 financial crisis. There is an obvious rise of Shock coefficients starting from 2000 for Size3, Size4 and Size5 bank portfolios and starting from 2005 for Size1 and Size2 bank portfolios. This may correspond to the argument that after the repeal of Glass-Steagall Act in 1999 large banks are more involved in trading assets and interest rate derivatives (Begenau et al., 2015), hence have increased their sensitivity to the short-term interest rate shocks. On the other hand, small banks are generally not or at a later time involved in such business, hence the rise of the coefficients begins several years later. After 2008 financial crisis, the Shock coefficients of all five size sorted bank portfolios drop quickly around 2010, with larger size bank portfolios drop more than smaller size portfolios. After 2015, the Shock coefficients begin moving back to x-axis, with larger size bank portfolios moving earlier than smaller size bank portfolios.

Figure 2(5) and Figure 2(6) show the yearly change of Return coefficients from model (4), omitting the dummy variable. Similar to Shock coefficients, the results for Return factor from three-year rolling regression in Figure 2(6) show patterns more clearly than those from one-year regressions in Figure 2(5). The Return coefficients of all five size sorted bank portfolios

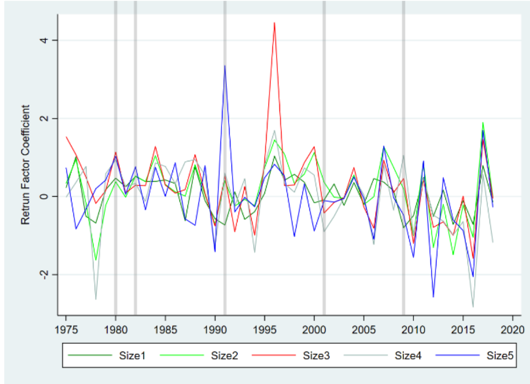
# Figure 2. Yearly Changes of Interest Risk Factor Coefficients 1975-2018



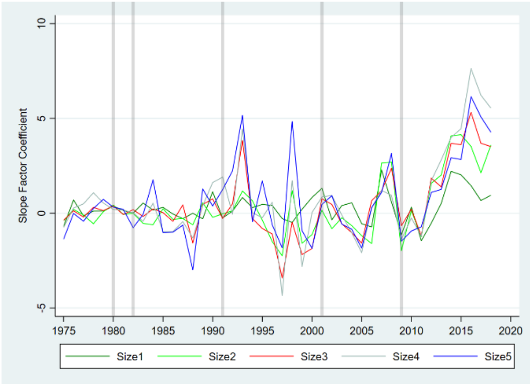

(1)



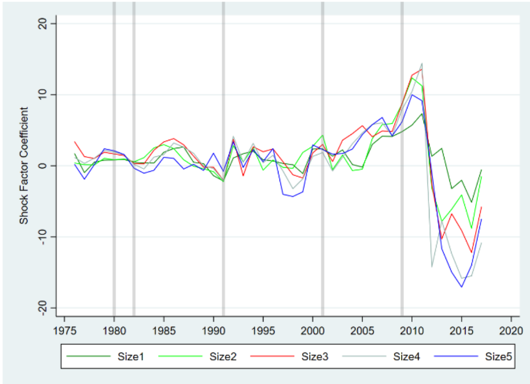

(3)




(5)




(2)




(4)


(6)

Note: Figure (1) shows the estimated coefficients of Slope factor by regressing daily stock excess returns of each size sorted bank portfolio (Size1 to Size5) on daily Market, Slope and Credit factors each year. Figure (2) shows the same coefficients but adding SMB and HML as additional explanatory factors. Figure (3) shows the estimated coefficients of Shock factor by regressing monthly stock excess returns of each size sorted bank portfolio on monthly Market, SMB, HML, Shock and Credit factors each year. Figure (4) shows the Shock coefficients by implementing the regression in Figure (3) each rolling three-year. For example, the Shock coefficient in year 2000 in Figure (4) is the estimated coefficient by regression for 1999-2001. Figure (5) shows the estimated coefficients of Return factor by regressing monthly stock excess returns of each size sorted bank portfolio on monthly Market, SMB, HML, Return and Credit factors each year. Figure (6) shows the Shock coefficients by implementing the regression in Figure (5) each rolling three-year. Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Then, Banks are sorted to five portfolios by monthly market equity values in each June using NYSE breakpoints. Market, SMB and HML are monthly Fama-French stock factors. Slope is the monthly changes of the spread between ten-year and one-year Treasury yields. Shock is the residuals of third-order autoregressive model (AR(3)) of one-year Treasury monthly excess return. Return is the ten-year Treasury monthly excess return. Credit is the monthly return on a portfolio that is long on US investment grade corporate bond index and is orthogonal to each measurement of interest risks from 1975 to 2018. Risk-free rate is one-month Treasury bill rate. The gray vertical lines are years in which NBER Business Cycle Dating Committee announced a trough in business activity. These years are 1980, 1982, 1991, 2001 and 2009. https://www.nber.org/cycles.html shown in Figure 2(6) have been decreasing since 1975, i.e. the coefficients are positive from 1975 to late 1980s, they move around x-axis in 1990s until 2008 financial crisis, then they drop to negative. The Return coefficients of Size4 and Size5 bank portfolios move more volatility than smaller size bank portfolios.

The results shown in Figure 2 are consistent with other researches, as well as our findings in section IV.2 and section IV.3. For example, the average Shock coefficients of five size sorted bank portfolios from 1976 to 1981 is 0.304 in Figure 2(3) and is 0.914 in Figure 2(4). In Flannery and James (1984a) when regressing banks' stock returns on overall market returns and a similar interest risk measurement from 1976 to 1981, the Shock coefficient is 0.515. The rises of Slope coefficients and the drops of Shock and Return coefficients after 2010 are corresponding to the coefficients of interest risk factor dummy variables in Table 5A ($\beta_3$) and Table 5B ($\beta_5$).

SECOND APPROACH – We plot the dynamic changes of interest risk factors each year from 1975 to 2018. We have also calculated the summary statistics of these factors. As shown in Table 10, the means of interest risk factors – Slope, Shock and Return – are close to zero. The standard deviations are also small. The Return factor has the largest standard deviations in both period 1975-2018 and subperiod 2010-2018. Figure 3 presents the time-series data of the three interest risk measurements from 1975 to 2018. It is easy to observe the changes of Return factor across the time period, whereas the changes of Slope and Shock factors are relatively small. As shown in Figure 3, the Slope factor is more volatile after financial crisis than Shock factor while it is on the contrary before the crisis. This is supported by the numbers in Table 10, where the standard deviation of Slope factor (0.002) is bigger than that of Shock factor (0.001) for 2010-2018, while it is smaller for 1975-2018 (0.003 compared to 0.005). Note that the large changes (relatively high volatility) of Slope and Shock factors happen in period 1979-1983 when interest rates were at the highest levels.

Figure 4 shows the time-series monthly data of one-year and ten-year Treasury yields, Spread and Slope factor from 1975 to 2018. After 2008 financial crisis, as shown in Figure 4, one-year Treasury yield is close to zero. As a result, the Spread, defined as ten-year Treasury yield minus one-year Treasury yield, is close to ten-year Treasury yield after financial crisis. Consequently, the Slope, which is the change of Spread, is close to the change of ten-year Treasury yield. Since the change of ten-year Treasury yield can be seen as a proxy of the Return factor with

**Table 10. Summary Statistics of Monthly Interest Risk Factors**

| Factor | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| | | 1975-2018 | | |
| Slope | 0.000 | 0.003 | -0.015 | 0.028 |
| Shock | 0.000 | 0.005 | -0.024 | 0.051 |
| Return | 0.002 | 0.022 | -0.075 | 0.094 |
| | | 2010-2018 | | |
| Slope | 0.000 | 0.002 | -0.005 | 0.005 |
| Shock | -0.002 | 0.001 | -0.004 | 0.002 |
| Return | 0.003 | 0.017 | -0.041 | 0.047 |

Note: Slope, Shock and Return are measurements of interest risks. Slope is the monthly changes of the spread between ten-year and one-year Treasury yields. Shock is the residuals of third-order autoregressive model (AR(3)) of one-year Treasury monthly excess return. Return is the ten-year Treasury monthly excess return. Risk-free rate is one-month Treasury bill rate.

some calculations, e.g. the correlation between the Return factor and the change of ten-year Treasury yield is -0.96 for 1975-2018 and is -0.99 for 2010-2018, it is not surprising to see the high correlation between Return factor and Slope factor for 2010-2018, which is -0.922 (see Table 1).

In addition, regressing Slope factor on the Return factor reveals the numeric relations between these two factors. The results of regressions are shown below.

1975-2018 $$\text{Slope} = -\,0.000 + 0.001 \cdot \text{Return} + \varepsilon$$
$$(-0.01)\quad (0.05) \qquad \text{Adj.}R^2\ -0.002$$

2010-2018 $$\text{Slope} = -\,0.000 - 0.101 \cdot \text{Return} + \varepsilon$$
$$(-0.17)\quad (-23.81) \qquad \text{Adj.}R^2\ 0.849$$

The t-statistics are in parentheses below the coefficients. Indeed, the loading on Return factor is non-significant and the adjusted R squared is negligible for period 1975-2018. On the contrary, the loading on Return factor is significant and the adjusted R squared is high for period 2010-2018. If we divide Return coefficients by Slope coefficients for each size sorted bank portfolio in Table 7A ($\beta_2$ Return / $\beta_2$ Slope) and Table 7B ($\beta_4$ Return / $\beta_4$ Slope), the results are on average -0.116 in Table 7A and -0.126 in Table 7B. These are close to -0.101,

**Figure 3. Monthly Interest Risk Factors 1975-2018**

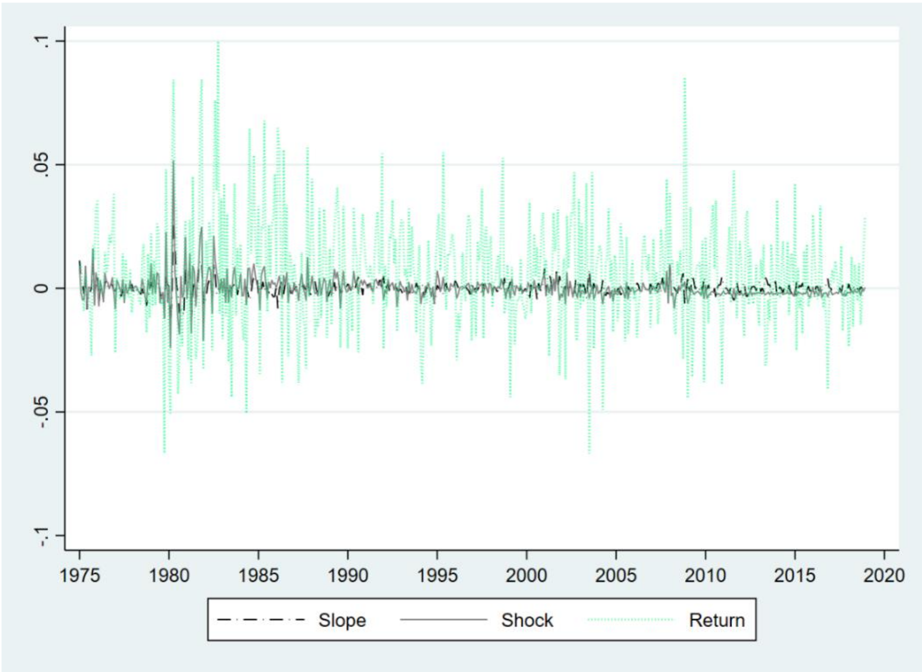



**Figure 4. Daily Treasury Yield and Slope Factor 1975-2018**


Note: Figure 3 is the monthly data of three measurements of interest risks, i.e. Slope, Shock and Return, from 1975 to 2018. Slope is the monthly changes of the spread between ten-year and one-year Treasury yields. Shock is the residuals of third-order autoregressive model (AR(3)) of one-year Treasury monthly excess return. Return is the ten-year Treasury monthly excess return. Risk-free rate is one-month Treasury bill rate. Figure 4 is a daily presentation of the Slope factor and the components for its calculation. 1Y Yield is daily one-year Treasury bond yield. 10Y Yield is daily ten-year Treasury bond yield. Spread is defined as 10Y Yield minus 1Y Yield, i.e. Spread (t) = 10Y Yield (t) – 1Y Yield (t). Slope is the daily change of Spread, i.e. Slope (t) = Spread (t) – Spread (t-1). The monthly and daily ten-year and one-year Treasury yields come from Federal Reserve Bank of St. Louis – FRED. The monthly ten-year and one-year Treasury returns come from CRSP US Treasury and Inflation Indexes on WRDS.

the loading on Return factor for 2010-2018, further proving a strong relation between these two factors post-crisis.

THIRD APPROACH – We compare the dynamic changes of Interest risk factor coefficients with the changes of Fama-French stock market factors' coefficients. We study whether the coefficients are obviously different after 2008 financial crisis and across different size groups. We use a proxy for the Return factor on daily basis in the third approach to overcome some concerns raised by using Slope, Shock or Return factor. One concern is that if we run model (6) on daily basis, the Slope coefficients are mostly not significant, especially for years before 2010. For example, for the five size sorted bank portfolios in 44 years from 1975 to 2018, the Slope coefficients are significant in 43 of 220 cases[5], with 23 cases after 2010. Another concern is that if we run model (4) each year and each rolling three-year with Return factor, the number of observations for each regression is still limited.

In this approach, we deal with these concerns by introducing a proxy to the Return factor on daily basis. It is the daily change of ten-year Treasury yield, for which the daily data is available. As we have shown in the second approach, the correlation between the proxy and the Return factor is high, i.e. -0.96 for 1975-2018 and -0.99 for 2010-2018 on monthly basis. We modify model (4) by employing the daily change of ten-year Treasury yield as a proxy to Return factor and omitting the credit risk factor to obtain the yearly coefficients of Market, SMB, HML and Interest risk factor.

(7) $$\text{Bank}_i(t) = \alpha + \beta_1 \cdot \text{Market}(t) + \beta_2 \cdot \text{SMB}(t) + \beta_3 \cdot \text{HML}(t) + \beta_4 \cdot \text{Yield}(t) + \varepsilon$$

Yield – daily changes of ten-year Treasury yield

Table 11 presents summary statistics of risk factor coefficients. From 1975 to 2018, the means of Market coefficients monotonically increase as size grows. This pattern is similar to results in section IV.2 and section IV.3. The Market coefficient means of Size1, Size2 and Size3 bank portfolios are smaller than one, while the means of Size4 and Size5 bank portfolios are larger than one. The Market coefficient standard deviations of Size4 and Size5 bank portfolios are

[5] In 43 of 220 cases, the Slope factor coefficients are significant in 6 years for Size1 bank portfolio, 8 years for Size2, 9 years for Size3, 9 years for Size4, and 11 years for Size5.

## Table 11. Summary Statistics of Risk Factor Coefficients 1975-2018

$$Bank_i(t) = \alpha + \beta_1 \cdot Market(t) + \beta_2 \cdot SMB(t) + \beta_3 \cdot HML(t) + \beta_4 \cdot Yield(t) + \varepsilon$$

| Banks | Market | SMB | HML | Yield | Alpha | Adj.$R^2$ | Market | SMB | HML | Yield | Alpha | Adj.$R^2$ | Market | SMB | HML | Yield | Alpha | Adj.$R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1975-2018 | | | | | | 1975-2009 | | | | | | 2010-2018 | | | | | |
| | Mean | | | | | | Mean | | | | | | Mean | | | | | |
| Size1 | 0.687 | 0.707 | 0.464 | -0.037 | 0.000 | 0.700 | 0.684 | 0.660 | 0.406 | -0.319 | 0.000 | 0.668 | 0.696 | 0.887 | 0.691 | 1.063 | 0.000 | 0.824 |
| Size2 | 0.850 | 0.686 | 0.613 | 0.100 | 0.000 | 0.719 | 0.828 | 0.621 | 0.500 | -0.539 | 0.000 | 0.697 | 0.932 | 0.937 | 1.050 | 2.584 | 0.000 | 0.808 |
| Size3 | 0.958 | 0.461 | 0.697 | -0.068 | 0.000 | 0.689 | 0.962 | 0.411 | 0.609 | -0.822 | 0.000 | 0.662 | 0.942 | 0.653 | 1.043 | 2.866 | 0.000 | 0.791 |
| Size4 | 1.123 | 0.165 | 0.754 | 0.220 | 0.000 | 0.695 | 1.140 | 0.135 | 0.673 | -0.711 | 0.000 | 0.670 | 1.056 | 0.281 | 1.067 | 3.839 | 0.000 | 0.790 |
| Size5 | 1.227 | -0.135 | 0.751 | 0.108 | 0.000 | 0.697 | 1.251 | -0.139 | 0.658 | -0.626 | 0.000 | 0.661 | 1.134 | -0.121 | 1.115 | 2.963 | 0.000 | 0.837 |
| | Standard Deviation | | | | | | Standard Deviation | | | | | | Standard Deviation | | | | | |
| Size1 | 0.127 | 0.189 | 0.232 | 0.926 | 0.001 | 0.152 | 0.137 | 0.171 | 0.198 | 0.482 | 0.001 | 0.152 | 0.083 | 0.150 | 0.223 | 1.382 | 0.000 | 0.059 |
| Size2 | 0.181 | 0.275 | 0.402 | 1.713 | 0.001 | 0.107 | 0.194 | 0.265 | 0.351 | 0.723 | 0.001 | 0.106 | 0.087 | 0.135 | 0.274 | 2.195 | 0.000 | 0.055 |
| Size3 | 0.201 | 0.309 | 0.400 | 2.105 | 0.000 | 0.106 | 0.217 | 0.323 | 0.389 | 1.090 | 0.000 | 0.100 | 0.130 | 0.132 | 0.216 | 2.567 | 0.000 | 0.059 |
| Size4 | 0.240 | 0.323 | 0.454 | 2.695 | 0.000 | 0.107 | 0.261 | 0.346 | 0.466 | 1.427 | 0.000 | 0.104 | 0.116 | 0.177 | 0.210 | 3.445 | 0.000 | 0.056 |
| Size5 | 0.229 | 0.296 | 0.594 | 2.382 | 0.000 | 0.132 | 0.247 | 0.324 | 0.603 | 1.467 | 0.000 | 0.122 | 0.100 | 0.165 | 0.400 | 3.133 | 0.000 | 0.045 |

Note: Bank is daily value weighted average stock returns minus risk-free rate for each size sorted bank portfolio (Size1 to Size5, as index i in the model). Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Then, Banks are sorted to five portfolios by monthly market equity values in each June using NYSE breakpoints. Market (market excess return), SMB (small minus big) and HML (high minus low) are daily Fama-French stock factors. Yield is daily changes of ten-year Treasury yield. The regression is run each year from 1975 to 2018 for each size sorted bank portfolio. Risk-free rate is one-month Treasury bill rate. The mean is the simple average of yearly coefficients for each risk factor and of yearly adjusted R squares in each period for each portfolio. The Standard Deviation is calculated accordingly.

larger than those of smaller size bank portfolios. The means of SMB and HML coefficients also shows similar patterns as in section IV.2 and section IV.3, i.e. smaller SMB coefficient means and larger HML coefficient means as size grows. The standard deviations of SMB and HML coefficients generally increase as size grows. On the other hand, from 1975 to 2018, the means of Yield coefficients do not show obvious patterns as those of Market, SMB and HML do. For Size1 and Size3 bank portfolios, the Yield coefficient means are negative and close to zero. Size4 bank portfolio has the largest Yield coefficient mean. The standard deviations of Yield coefficients generally increase as size grows.

Comparing coefficients before and after financial crisis reveals more about the change of Yield coefficient after 2008 financial crisis and its differences from other factor coefficients. The Yield coefficient means of five size sorted bank portfolios all change from negative for period 1975-2009 to positive for period 2010-2018. The magnitudes of such changes are generally bigger as size grows. Size4 bank portfolio has the largest change, i.e. from -0.711 (1975-2009) to 3.839 (2010-2018), suggesting that 1 percentage increase of absolute value in daily ten-year Treasury yield is on average associated with 3.839 percentage increase of Size4 bank portfolio's stock returns for the period 2010-2018, while such an increase in the Treasury yield is on average associated with 0.711 percentage decrease for the period 1975-2009. This is consistent with our findings in Table 5B and Table 6B, where the coefficients of Return dummy variable ($\beta_5$ in Table 5B and $\beta_8$ in Table 6B) are negative, and larger size bank portfolios having relatively bigger Return dummy variable coefficients in magnitude. Changing from negative to positive for Yield coefficient means after financial crisis is corresponding to the negative coefficients of Return dummy variable in Table 5B and Table 6B, because the correlation between Yield factor and the Return factor is close to -1. Also note that the standard deviations of Yield coefficients increase after 2008 financial crisis. Size4 bank portfolio has the largest increase, i.e. from 1.427 (1975-2009) to 3.445 (2010-2018).

Other risk factor coefficients do not have such obvious changes before and after financial crisis. The means of Market coefficients slightly increase for Size1 and Size2 bank portfolios, but the means slightly decrease for Size3, Size4 and Size5 bank portfolios. This is consistent with findings in Table 6B, where the coefficients of Market factor dummy variable ($\beta_2$) are negative and significant for Size4 and Size5 bank portfolios when Return factor is used as interest risk measurement. Different from Market coefficients, the means of SMB and HML coefficients all increase for five size sorted bank portfolios after financial crisis. Furthermore, the standard deviations of Market, SMB and HML coefficient means all decrease after financial crisis except that the standard deviation of HML coefficient means of Size1 bank portfolio increase. Note that regarding Yield coefficient means, the standard deviations all increase for five size sorted bank portfolios.

The alphas and their standard deviations are negligible for all five size sorted bank portfolios before and after financial crisis. The adjusted R squares (Adj.$R^2$) is about 0.7 for all five size sorted bank portfolios for 1975-2018. It is higher after financial crisis (about 0.8 for 2010-2018, compared to about 0.7 for 1975-2009). The adjusted R squares for different size bank portfolios do not increase or decrease monotonically. This is contrary to our findings in Table 5B and Table 6B, where the adjusted R squares generally decrease as size grows.

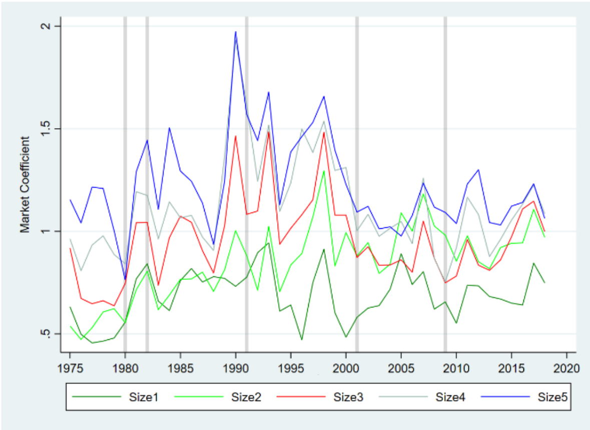
Figure 5 shows the yearly changes of risk factor coefficients from 1975 to 2018. There are apparent differences among different size groups with regard to Market and SMB coefficients, as shown in Figure 5(1) and Figure 5(2), while the differences with regard to HML and Yield coefficients are less obvious overall and are subject to specific time period, as shown in Figure 5(3) and Figure 5(4). Figure 5 reveals some characters of risk factor coefficients not shown previously, either in section IV.2 and section IV.3 or in Table 11.

The results shown in Table 6B, where the coefficients of Market factor dummy variable ($\beta_2$) are significant and negative for Size4 and Size5 bank portfolios, seemly obscure the truth. As shown in Figure 5(1), the Market coefficients of Size4 and Size5 bank portfolios reach the high levels in the 1990s, i.e. 1.931 for Size4 bank portfolio and 1.974 for Size5 bank portfolio in 1990, 1.518 for Size4 bank portfolio and 1.679 for Size5 bank portfolio in 1993, 1.537 for Size4 bank portfolio and 1.658 for Size5 bank portfolio in 1998. Then the Market coefficients of Size4 and Size5 bank portfolios decrease. The coefficients are closer to one after 2000, compared to those before 2000. The seemingly decrease of Market coefficients for Size4 and Size5 bank portfolios after financial crisis is affected by the high levels in 1990s. Generally speaking, the Market coefficients for these two size bank portfolios, as well as other size portfolios, do not change after 2008 financial crisis.

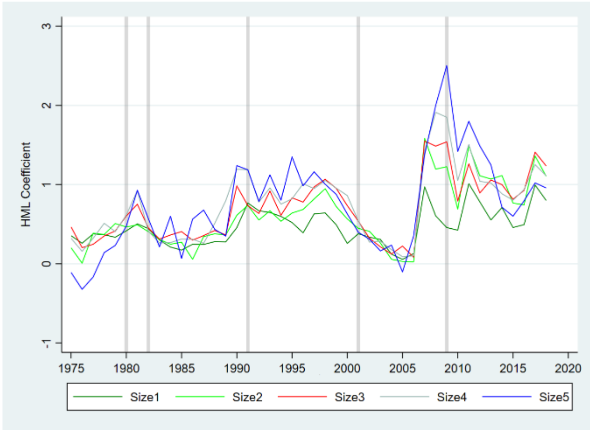
Figure 5(3) shows details about HML coefficients. Although the differences among five size sorted bank portfolios regarding HML coefficients are not obvious overall, as shown in Table 5B where HML coefficients of all five size sorted bank portfolios are close to 0.8 when Return

**Figure 5. Yearly Changes of Risk Factor Coefficients 1975-2018**

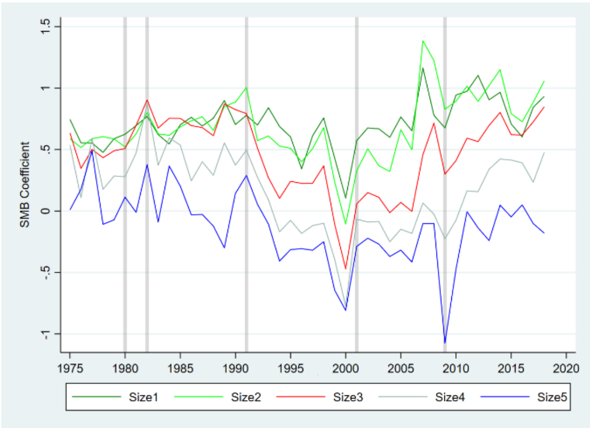
$$\text{Bank}_{i}\,(t) = \alpha + \beta_1 \cdot \text{Market}\,(t) + \beta_2 \cdot \text{SMB}\,(t) + \beta_3 \cdot \text{HML}\,(t) + \beta_4 \cdot \text{Yield}\,(t) + \varepsilon$$



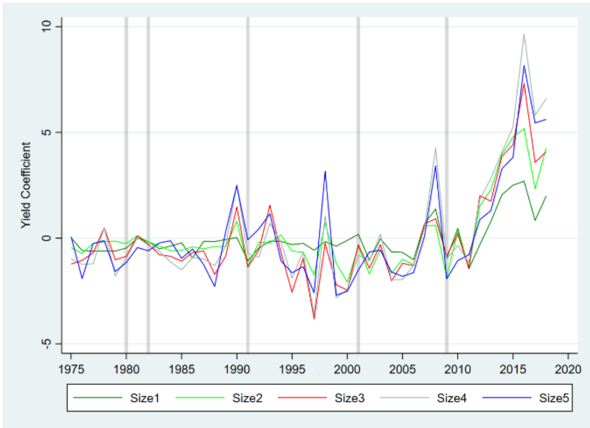

(1)




(3)




(2)




(4)

Note: Figure (1) shows yearly coefficients of Market factor from 1975 to 2018 by regressing daily stock excess returns of each size sorted bank portfolio (Size1 to Size5, as index i in the model) on daily Market, SMB, HML and Yield factors each year. Figure (2) to Figure (4) show the coefficients of SMB, HML and Yield factors respectively. Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Then, Banks are sorted to five portfolios by monthly market equity values in each June using NYSE breakpoints. Market, SMB and HML are daily Fama-French stock factors. Yield is daily changes of ten-year Treasury yield. Risk-free rate is one-month Treasury bill rate. The data to calculate daily stock returns of bank portfolios comes from Compustat and CRSP. Fama-French stock factors and risk-free rates come from WRDS. The daily ten-year Treasury yields come from Federal Reserve Bank of St. Louis – FRED. The gray vertical lines are years – 1980, 1982, 1991, 2001 and 2009 – in which NBER Business Cycle Dating Committee announced a trough in business activity. https://www.nber.org/cycles.html

factor is used as the interest risk measurement, the differences exist for some specific time period, such as between 1991 trough and 2001 trough, during and after 2008 financial crisis. HML coefficients of all five size sorted bank portfolios move together downward starting from the 2001 trough to near x-axis in 2005 and 2006, then increase dramatically in 2007, e.g. Size1 bank portfolio's HML coefficient increase from 0.128 in 2006 to 0.972 in 2007, Size5 bank portfolio's HML coefficient increase from 0.349 in 2006 to 1.376 in 2007. Moreover, Size1 and Size2 bank portfolios' HML coefficients reach the peaks in 2007 then decrease, Size3 and Size4 bank portfolios' HML coefficients remain at high levels until 2009, while Size5 bank portfolios' HML coefficient continuously rise until the peak in 2009. The HML coefficient of Size5 bank portfolio in 2009 is 2.502.

As Figure 5(4) shows, the Yield coefficients reach the relatively high points in 2008, then drop quickly to the relatively low points in 2009, and begin to rise starting from 2012 until the next relatively high points in 2016. Although movements of the Yield coefficients of five size sorted bank portfolios are not identical, they tend to reach the relatively high and low points in the same year. The magnitudes of the increase of the Yield coefficients after 2010 for all five size sorted bank portfolios are unprecedented, showing the impacts of the financial crisis. For example, Size5 bank portfolios' Yield coefficient increase from -1.922 in 2009 to 8.165 in 2016, implying that one percentage increase of absolute value in daily ten-year Treasury yield is on average associated with 1.922 percentage decrease of Size5 bank portfolio's stock returns in 2009 while it is associated with 8.165 percentage increase in 2016.

Note that Figure 5(4) is similar to Figure 2(2). Such similarity becomes stronger in more recent years. For example, after the 2009 trough the plots in Figure 5(4) and Figure 2(2) are very close. This is not surprising. As Figure 6 (see Appendix) shows, the correlations between Slope factor and Yield factor have been increasing. The correlations are close to 1 from 2011 to 2015. Accordingly, Slope factor and Yield factor may contain very similar interest risk information for that period. However, Yield coefficients may provide a better measurement of how banks' stock returns respond to interest rate changes for two reasons. First, Yield coefficients have more significant results, being significant in 81 of 220 cases for the five size sorted bank portfolios in 44 years from 1975 to 2018, with 25 cases after 2010. This is compared to 43 of 220 cases regarding Slope factor. Second, Figure 5(4) displays a pattern that troughs usually appear in the years when or shortly after Yield coefficients reach the relatively low points, such as the troughs in 1982, 1991, 2001 and 2009. Such pattern is not easily observed in Figure 2(2) before 2008 financial crisis.

### IV.5. Interest Risk and Income Structure

The dynamic changes of Yield coefficients behave differently from the changes of other risk factors, i.e. Market, SMB and HML. As banks generally borrow in short-term and lend in long-term, the changes of interest rate directly affect the cost and income of banking business. The changes of interest rate also reflect the economic environment, but the impacts to banking business and banks' stock returns require different ways to make judgements. Using the yearly Yield coefficients from section IV.4 and additional accounting data from Compustat Bank Fundamentals Annual dataset, we test a hypothesis that the variations in Yield coefficients can be explained by the variations in size sorted bank portfolios' income structure measured by interest related accounting numbers.

We construct two factors to measure the income structure. The first factor is to divide aggregated total interest income of each size sorted bank portfolio in fiscal year t by aggregated total interest expense in the same fiscal year. We call it Interest Margin factor. The second factor is to divide aggregated total non-interest income of each size sorted bank portfolio in fiscal year t by aggregated income before extraordinary items in the same fiscal year. We call it Non-Interest Proportion factor. These accounting data is missing for most banks before fiscal year 1993, hence our accounting data for the two factors, Interest Margin and Non-Interest Proportion, is from fiscal year 1993 to 2018.

The model is presented below.

(8)
$$\text{Yield Coefficient}_i\,(t) = \alpha + \beta_1 \cdot \text{Interest Margin}_i\,(t\text{-}1) + \beta_2 \cdot \text{Non-Interest Proportion}_i\,(t\text{-}1) + \varepsilon$$

Yield Coefficient $_i$ (t) – Yield Coefficient of each size sorted bank portfolio in year t

Interest Margin $_i$ (t-1) – Aggregated Total Interest Income of each size sorted bank portfolio in fiscal year t-1 divided by Aggregated Total Interest Expense in the same fiscal year

Non-Interest Proportion $_i$ (t-1) – Aggregated Total Non-Interest Income of each size sorted bank portfolio in fiscal year t-1 divided by Aggregated Income Before Extraordinary Items in the same fiscal year

## Table 12. Yield Coefficient and Income Structure 1994-2018

Yield Coefficient $_i$ (t) = $\alpha + \beta_1 \cdot$ Interest Margin $_i$ (t-1) + $\beta_2 \cdot$ Non-Interest Proportion $_i$ (t-1) + $\varepsilon$

| | Size1 | Size2 | Size3 | Size4 | Size5 |
|---|---|---|---|---|---|
| $\beta_1$ Interest Margin | 0.404*** (5.45) | 0.807*** (6.64) | 0.958*** (7.23) | 1.102*** (6.36) | 1.314*** (5.98) |
| $\beta_2$ Non-Interest Proportion | 0.179 (1.21) | -0.044 (-0.89) | 0.010 (0.09) | 0.023 (0.10) | -0.481* (-2.14) |
| $\alpha$ | -1.333*** (-4.68) | -2.519*** (-5.56) | -3.368*** (-6.33) | -3.366*** (-5.14) | -2.820* (-2.77) |
| Observations | 25 | 25 | 25 | 25 | 25 |
| Adj. $R^2$ | 0.555 | 0.717 | 0.734 | 0.657 | 0.591 |

Note: t statistics in parentheses, * p<0.05 ** p<0.01 *** p<0.001. The dependent variable yearly Yield coefficients are obtained by regressing daily stock excess returns of each size sorted bank portfolio (Size1 to Size5, as index i in the model) on daily Market, SMB, HML and Yield factors each year from. Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Then, Banks are sorted to five portfolios by monthly market equity values in each June using NYSE breakpoints. Market, SMB and HML are daily Fama-French stock factors. Yield is daily changes of ten-year Treasury yield. Risk-free rate is one-month Treasury bill rate. The Yield coefficients in year t are then regressed on two income structure factors – Interest Margin and Non-Interest Proportion – in fiscal year t-1 for each size sorted bank portfolio from 1994 to 2018. Interest Margin is aggregated Total Interest Income of each size sorted bank portfolio divided by aggregated Total Interest Expense in the same fiscal year. Non-Interest Proportion is aggregated Total Non-Interest Income of each size sorted bank portfolio divided by Aggregated Income Before Extraordinary Items in the same fiscal year. The data to calculate daily stock returns of bank portfolios comes from Compustat and CRSP. Fama-French stock factors and risk-free rates come from WRDS. The daily ten-year Treasury yields come from Federal Reserve Bank of St. Louis – FRED. The accounting numbers come from Compustat Bank Fundamentals Annual database.

We regress the Yield coefficient in year t on Interest Margin and Non-Interest Proportion for fiscal year t-1 for each size sorted bank portfolio. The reason for the one yar lag is that accounting information of fiscal year t-1 would be probably reflected in the stock prices in year t, instead of year t-1. This is consistent with the method to construct Fama-French stock market factors, where the book equity value (BE) in fiscal year t-1 is used to form the portfolio from July year t to June year t+1.

Table 12 presents the results from model (8). The loadings on Interest Margin ($\beta_1$) are significant for all five size sorted bank portfolios. The positive loadings suggest that increasing the ratio of interest income divided by interest expense is associated with higher Yield Coefficients. The loadings on Interest Margin increase monotonically from 0.404 (Size1) to 1.314 (Size5) as size grows, suggesting that if everything else remain unchanged, Yield

Coefficients of larger size bank portfolios increase more than those of smaller size bank portfolios for the same increase in the Interest Margin.

The loadings on Non-Interest Proportion ($\beta_2$) is only significant for Size5 bank portfolio. The negative loading suggests that if the proportion of non-interest income in total income increases, the Yield Coefficient tends to decrease. Hence, for the Size5 bank portfolio, stock returns would be less sensitive to interest risks if the proportion of non-interest income increases relative to total income. The loadings on Non-Interest Share do not display monotonic increase or decrease as size grows.

The intercepts ($\alpha$) are significant for all five size sorted bank portfolios. The negative intercepts suggest if there is no interest income or the Interest Margin is low, the Yield Coefficients would be negative. When interest rate rises, bank stock returns would fall if not enough interest income can offset the rise of interest cost.

By studying the yearly changes of Interest Margin, which presents significant loadings for all size sorted bank portfolios. we further interpret the three loadings $\alpha$, $\beta_1$ and $\beta_2$ in a more coherent way.

Figure 7 (see Appendix) shows the dynamic changes of Interest Margins from 1993 to 2017. There are two NBER announced trough during this period. The Interest Margins are close to 2 from 1993 to 2001 trough, suggesting negative Yield Coefficients of five size sorted bank portfolios. This is consistent with the on average below x-axis plots from 1993 to 2001 in Figure 5(4) except that the plots in Figure 5(4) are much more volatile. The Interest Margins then rise to about 3 then drop back to about 2 right before the financial crisis in 2007, suggesting the rise and fall of Yield Coefficients. On the other hand, the plots in Figure 5(4) do not show such patterns of rise and fall. The Interest Margins rise again from about 2 in 2007 to high levels around 2015. The highest Interest Margins of each size sorted bank portfolio are 7.838 in 2014 (Size1), 9.255 in 2015 (Size2), 8.698 in 2016 (Size3), 9.435 in 2016 (Size4) and 7.226 in 2015 (Size5).

The sharply rise and high levels of Interest Margins after 2008 financial crisis can help to explain the high Yield Coefficients of five size sorted bank portfolios. For example, the estimated Yield Coefficient of Size5 bank portfolio in 2017 is 4.794 from model (12) and Table

12, and it is 5.450 in Figure 5(4). However, it is less obvious to use Interest Margin to explain the high levels of Yield Coefficients in 1998 and 2008, the low points in 1997 and 1999. There are certainly other factors affect Yield Coefficients, such as the Asian financial crisis in 1997 and the collapse of Long-Term Capital Management in 1998.

The monotonic rise of loadings on Interest Margin, shown in Table 12, can help explain the differences in Figure 7 and Figure 5(4) for the period 2010-2018. In Figure 7, the Interest Margins of Size1 bank portfolio are higher than Interest Margins of Size5 bank portfolio in most years from 2010 to 2018. On the other hand, the Yield Coefficients of Size1 bank portfolio are generally below the Yield Coefficients of Size5 bank portfolio in Figure 5(4). Considering that the Interest Margin loading of Size5 bank portfolio is nearly three times of the number of Size1 bank portfolio, such differences are justifiable.

Note that the shapes of Interest Margins from 1993 to 2007 in Figure 7 are similar to the shapes of Spread in Figure 4. While Interest Margins are close to 2 from 1993 to 2001, rise and then fall from 2001 to 2007, the Spread is close to x-axis from 1993 to 2001, then rise and then fall from 2001 to 2007. Such similarity changes after 2008 financial crisis, i.e. the Interest Margins keep rising to high levels around 2015 whereas the Spread reach the high levels in 2011.

## V. Conclusion

In this thesis, we have shown that 2008 financial crisis has changed the relations between US banks' stock returns and interest rate changes. The effect of financial crisis is consistent with various interest risk measurements we have used and applies to different sizes of bank portfolios, large and small. We show how the interest risk factor coefficients evolve every year and how they are different from coefficients of other risk factors. More importantly, we show that bank's sensitivity to interest rate changes relates to its income structure. When banks are sorted to different groups by size, all sorted bank portfolios show similar relations between stock returns and interest rate changes. The effects of size reflect the magnitude of bank's sensitivity to interest risks.

Our thesis has several useful implications for investors and regulators. First, the effects of interest rate changes on banks' stock returns have changed due to financial crisis. The interpretation of interest risks requires us to examine specific economic environment after financial crisis and make decisions accordingly. Second, among different types of interest rate changes, simple measurements such as changes of long-term Treasury returns or changes of long-term Treasury yields have consistent, statistically significant effects on US banks' stock returns, compared to other measurements such as unanticipated shocks in short-term interest rates. Third, the degrees of how interest rate changes would affect banks' stock returns are related to (1) how much banks' market equity value is and (2) how much interest income could be earned from one-unit interest expense. Fourth, the coefficients of Yield factor change periodically in line with business cycles. The rapid changes of Yield factor loadings could either be a predictor or be an indication of recessions.

Our thesis also reveals some interesting findings worth further examinations. First, the dynamic interest risk factor coefficients, as shown in Figure 2 and Figure 5, rise and fall cyclically with economic activities. Beginning around 2015 the interest risk factor coefficients generally have been returning toward the historical average levels, short-term interest rate has been rising, and yield spread has been falling. Future researches can examine whether the trend that bank stock return's sensitivity to interest rate changes moving toward zero continues after 2018, especially as the short-term interest rate again drops to near zero in the first half of 2020. Second, the relations between banks' interest risk factor coefficients and income structure can be further studied by extending the annual accounting data to quarterly data. Increasing the number of observations could improve the estimation by time-series regressions. For the same reason, further study can obtain daily or weekly data on Treasury returns and test different measures of interest risk factors.

In conclusion, our thesis suggests that size and 2008 financial crisis indeed play a role in determining the relations between banks' stock returns and interest rate changes. Moreover, income structure could be a link from the effects of size and 2008 financial crisis to banks' stock prices. As economic conditions and banks' business structures are continuously changing, when we monitor banks' exposure to interest risks, attention should be taken on how the exposure evolves overtime.

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## VII. Appendix

### Table 6A. Bank Excess Return on Full Factors, 5 Size Groups, 1975-2018

$$\text{Bank}_i(t) = \alpha_1 + \alpha_2 \cdot \text{Post} + \beta_1 \cdot \text{Market}(t) + \beta_2 \cdot (\text{Market}(t) \times \text{Post}) + \beta_3 \cdot \text{Interest}_k(t) + \beta_4 \cdot (\text{Interest}_k(t) \times \text{Post}) + \beta_5 \cdot \text{Credit}_k(t) + \beta_6 \cdot (\text{Credit}_k(t) \times \text{Post}) + \varepsilon$$

| Coefficient | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\beta_1$ | 0.701*** | 0.722*** | 0.800*** | 0.911*** | 1.012*** | 0.704*** | 0.734*** | 0.822*** | 0.934*** | 1.033*** | 0.702*** | 0.746*** | 0.827*** | 0.941*** | 1.040*** |
| Market | (11.16) | (12.29) | (12.22) | (13.90) | (14.08) | (10.59) | (12.03) | (12.22) | (14.24) | (14.72) | (10.85) | (12.02) | (12.33) | (14.49) | (14.56) |
| $\beta_2$ | 0.062 | 0.317* | 0.122 | -0.0164 | -0.0659 | 0.206* | 0.492*** | 0.347** | 0.269* | 0.222 | 0.0563 | 0.300* | 0.0560 | -0.176 | -0.225 |
| Market × Post | (0.53) | (2.29) | (0.84) | (-0.09) | (-0.50) | (2.05) | (4.19) | (3.08) | (2.45) | (1.92) | (0.46) | (2.11) | (0.38) | (-1.05) | (-1.69) |
| $\beta_3$ | 1.884** | 0.949 | 1.723** | 1.013 | 0.627 | | | | | | | | | | |
| Slope | (3.17) | (1.57) | (2.65) | (1.51) | (0.75) | | | | | | | | | | |
| $\beta_4$ | 3.495 | 5.298 | 7.207* | 11.50** | 11.13*** | | | | | | | | | | |
| Slope× Post | (1.42) | (1.62) | (2.08) | (2.65) | (3.60) | | | | | | | | | | |
| $\beta_3$ | | | | | | 0.857** | 0.942** | 1.577*** | 1.624*** | 1.547** | | | | | |
| Shock | | | | | | (2.99) | (3.07) | (4.73) | (4.74) | (2.92) | | | | | |
| $\beta_4$ | | | | | | -3.804 | -3.845 | -5.090 | -7.905 | -6.228 | | | | | |
| Shock× Post | | | | | | (-1.02) | (-0.75) | (-0.92) | (-1.06) | (-1.44) | | | | | |
| $\beta_3$ | | | | | | | | | | | 0.201* | 0.287** | 0.392*** | 0.414*** | 0.412** |
| Return | | | | | | | | | | | (2.30) | (3.26) | (4.34) | (4.16) | (3.25) |
| $\beta_4$ | | | | | | | | | | | -0.933*** | -1.294*** | -1.479*** | -1.619*** | -1.690*** |
| Return× Post | | | | | | | | | | | (-3.86) | (-4.66) | (-5.45) | (-5.62) | (-6.10) |
| $\beta_5$ | 0.172 | 0.169 | 0.251 | 0.317* | 0.350* | 0.150 | 0.0507 | 0.0404 | 0.0849 | 0.136 | 0.141 | -0.237 | -0.213 | -0.174 | -0.124 |
| Credit | (1.64) | (1.28) | (1.93) | (2.50) | (2.22) | (1.01) | (0.25) | (0.21) | (0.47) | (0.59) | (0.70) | (-0.71) | (-0.75) | (-0.74) | (-0.34) |
| $\beta_6$ | -0.426 | -0.678 | -0.468 | -0.115 | -0.334 | -0.933** | -1.229** | -1.138** | -0.983* | -1.221** | -0.252 | -0.154 | 0.364 | 1.212 | 0.966 |
| Credit × Post | (-1.13) | (-1.37) | (-0.89) | (-0.18) | (-0.73) | (-2.77) | (-3.02) | (-2.86) | (-2.41) | (-2.81) | (-0.57) | (-0.26) | (0.61) | (1.90) | (1.62) |
| $\alpha_1$ | 0.002 | 0.003 | 0.001 | -0.001 | -0.004 | 0.002 | 0.003 | 0.002 | -0.000 | -0.003 | 0.002 | 0.005 | 0.004 | 0.001 | -0.001 |
| | (1.04) | (1.20) | (0.59) | (-0.41) | (-1.24) | (1.02) | (1.34) | (0.91) | (-0.02) | (-0.89) | (0.95) | (1.65) | (1.28) | (0.48) | (-0.41) |
| $\alpha_2$ | 0.004 | 0.002 | 0.001 | 0.004 | 0.007 | 0.001 | 0.000 | -0.003 | -0.007 | -0.000 | 0.004 | -0.000 | -0.001 | 0.002 | 0.005 |
| Post | (1.08) | (0.46) | (0.22) | (0.83) | (1.50) | (0.13) | (0.00) | (-0.30) | (-0.46) | (-0.01) | (0.92) | (-0.05) | (-0.32) | (0.33) | (0.97) |
| Observations | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 |
| Adj. $R^2$ | 0.487 | 0.487 | 0.508 | 0.527 | 0.521 | 0.474 | 0.484 | 0.505 | 0.524 | 0.517 | 0.476 | 0.493 | 0.515 | 0.541 | 0.532 |

Note: t statistics in parentheses, * p<0.05 ** p<0.01 *** p<0.001. Bank is monthly value weighted average stock returns of each size sorted bank portfolio (Size1 to Size5, as index i in the model) minus risk-free rate. Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Then, Banks are sorted to five portfolios by market equity values in each June using NYSE breakpoints. Market, SMB (in Table 6B) and HML (in Table 6B) are monthly Fama-French stock factors. Post equals to 0 from 1970 to 2009 and equals to 1 from 2010 to 2018. Interest is the interest risk factor. The index k in the model indicates each measurement of Interest, i.e. Slope, Shock and Return. Slope is the monthly changes of the spread between ten-year and one-year Treasury yields. Shock is the residuals of third-order autoregressive model (AR(3)) of one-year Treasury monthly excess return. Return is the ten-year Treasury monthly excess return. Credit is the monthly return on a portfolio that is long on US investment grade corporate bond index and is orthogonal to each measurement of interest risks from 1975 to 2018. The index k in the model indicates the Credit factor that is orthogonal to the specific Interest. Risk-free rate is one-month Treasury bill rate.

# Table 6B. Bank Excess Return on Full Factors, 5 Size Groups, 1975-2018

$$\text{Bank}_i(t) = \alpha_1 + \alpha_2 \cdot \text{Post} + \beta_1 \cdot \text{Market}(t) + \beta_2 \cdot (\text{Market}(t) \times \text{Post}) + \beta_3 \cdot \text{SMB}(t) + \beta_4 \cdot (\text{SMB}(t) \times \text{Post}) + \beta_5 \cdot \text{HML}(t) + \beta_6 \cdot (\text{HML}(t) \times \text{Post}) +$$
$$\beta_7 \cdot \text{Interest}_k(t) + \beta_8 \cdot (\text{Interest}_k(t) \times \text{Post}) + \beta_9 \cdot \text{Credit}_k(t) + \beta_{10} \cdot (\text{Credit}_k(t) \times \text{Post}) + \varepsilon$$

| Coefficient | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\beta_1$ | 0.767*** | 0.854*** | 0.960*** | 1.102*** | 1.242*** | 0.778*** | 0.869*** | 0.981*** | 1.123*** | 1.260*** | 0.786*** | 0.889*** | 0.993*** | 1.133*** | 1.270*** |
| Market | (17.48) | (15.66) | (15.37) | (16.18) | (18.18) | (18.00) | (15.77) | (16.34) | (17.29) | (19.36) | (18.31) | (16.35) | (16.92) | (18.29) | (19.00) |
| $\beta_2$ | -0.119 | 0.0634 | -0.125 | -0.196 | -0.155 | -0.104 | 0.100 | -0.040 | -0.069 | -0.0528 | -0.128 | 0.0530 | -0.185 | -0.357* | -0.307* |
| Market × Post | (-1.36) | (0.50) | (-0.89) | (-1.01) | (-1.19) | (-1.65) | (1.08) | (-0.44) | (-0.63) | (-0.50) | (-1.54) | (0.44) | (-1.41) | (-2.09) | (-2.37) |
| $\beta_3$ | 0.473*** | 0.219** | 0.0224 | -0.183* | -0.276*** | 0.492*** | 0.231** | 0.0507 | -0.164* | -0.264*** | 0.514*** | 0.271*** | 0.086 | -0.134 | -0.236** |
| SMB | (7.08) | (3.07) | (0.28) | (-2.29) | (-3.75) | (7.17) | (3.17) | (0.63) | (-2.04) | (-3.59) | (7.11) | (3.78) | (1.01) | (-1.62) | (-3.11) |
| $\beta_4$ | 0.369** | 0.687*** | 0.748*** | 0.601*** | 0.231 | 0.351** | 0.676*** | 0.709*** | 0.554*** | 0.199 | 0.326** | 0.631*** | 0.688*** | 0.571*** | 0.209 |
| SMB × Post | (3.25) | (5.06) | (5.53) | (3.59) | (1.51) | (3.09) | (5.01) | (5.27) | (3.34) | (1.31) | (2.81) | (4.67) | (5.04) | (3.53) | (1.38) |
| $\beta_5$ | 0.727*** | 0.799*** | 0.753*** | 0.714*** | 0.809*** | 0.738*** | 0.803*** | 0.767*** | 0.722*** | 0.812*** | 0.753*** | 0.830*** | 0.793*** | 0.744*** | 0.832*** |
| HML | (11.67) | (8.85) | (8.36) | (7.69) | (8.23) | (11.96) | (9.16) | (9.10) | (8.17) | (8.47) | (12.31) | (10.07) | (10.15) | (9.12) | (8.65) |
| $\beta_6$ | 0.016 | 0.004 | 0.0413 | 0.109 | 0.056 | 0.0212 | 0.038 | 0.118 | 0.243 | 0.164 | -0.002 | -0.002 | -0.006 | 0.003 | -0.045 |
| HML × Post | (0.13) | (0.02) | (0.26) | (0.59) | (0.34) | (0.19) | (0.26) | (0.79) | (1.38) | (1.09) | (-0.02) | (-0.02) | (-0.04) | (0.02) | (-0.28) |
| $\beta_7$ | 1.047** | 0.205 | 1.132 | 0.573 | 0.168 | | | | | | | | | | |
| Slope | (2.78) | (0.40) | (1.92) | (0.93) | (0.23) | | | | | | | | | | |
| $\beta_8$ | -0.750 | 0.535 | 2.159 | 5.504 | 4.068 | | | | | | | | | | |
| Slope× Post | (-0.36) | (0.17) | (0.66) | (1.20) | (1.27) | | | | | | | | | | |
| $\beta_7$ | | | | | | 0.908*** | 0.774** | 1.291*** | 1.200*** | 1.012* | | | | | |
| Shock | | | | | | (4.31) | (3.14) | (4.32) | (3.91) | (2.06) | | | | | |
| $\beta_8$ | | | | | | 0.062 | 0.608 | -0.685 | -3.874 | -2.967 | | | | | |
| Shock× Post | | | | | | (0.03) | (0.16) | (-0.15) | (-0.55) | (-0.76) | | | | | |
| $\beta_7$ | | | | | | | | | | | 0.264*** | 0.285*** | 0.348*** | 0.320*** | 0.286* |
| Return | | | | | | | | | | | (4.13) | (4.18) | (4.32) | (3.44) | (2.55) |
| $\beta_8$ | | | | | | | | | | | -0.428** | -0.670*** | -0.855*** | -1.018*** | -1.099*** |
| Return× Post | | | | | | | | | | | (-2.91) | (-3.49) | (-4.53) | (-4.19) | (-4.63) |
| $\beta_9$ | 0.155* | 0.087 | 0.134 | 0.163 | 0.160 | 0.048 | -0.085 | -0.103 | -0.067 | -0.041 | -0.189 | -0.548* | -0.480* | -0.387 | -0.347 |
| Credit | (1.98) | (0.71) | (1.06) | (1.28) | (1.09) | (0.45) | (-0.48) | (-0.59) | (-0.39) | (-0.20) | (-1.50) | (-2.12) | (-2.00) | (-1.80) | (-1.17) |
| $\beta_{10}$ | -0.342 | -0.525 | -0.330 | -0.087 | -0.465 | -0.321 | -0.535 | -0.453 | -0.345 | -0.661 | -0.025 | 0.034 | 0.474 | 1.138 | 0.660 |
| Credit × Post | (-1.40) | (-1.36) | (-0.78) | (-0.14) | (-1.08) | (-1.58) | (-1.89) | (-1.72) | (-1.08) | (-1.85) | (-0.09) | (0.08) | (1.02) | (1.94) | (1.20) |
| $\alpha_1$ | -0.002 | -0.001 | -0.002 | -0.003 | -0.006* | -0.002 | -0.000 | -0.001 | -0.002 | -0.005 | -0.001 | 0.002 | 0.001 | -0.001 | -0.004 |
| | (-1.69) | (-0.57) | (-0.73) | (-1.37) | (-2.34) | (-1.43) | (-0.23) | (-0.37) | (-1.00) | (-1.96) | (-0.69) | (0.68) | (0.30) | (-0.41) | (-1.36) |
| $\alpha_2$ | 0.009*** | 0.006 | 0.004 | 0.006 | 0.008* | 0.011* | 0.0106 | 0.006 | 0.001 | 0.006 | 0.007** | 0.003 | 0.002 | 0.004 | 0.006 |
| Post | (3.62) | (1.90) | (1.21) | (1.40) | (2.15) | (2.28) | (1.37) | (0.69) | (0.06) | (0.75) | (2.98) | (1.05) | (0.48) | (0.95) | (1.64) |
| Observations | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 | 528 |
| Adj. $R^2$ | 0.709 | 0.675 | 0.654 | 0.646 | 0.649 | 0.710 | 0.680 | 0.661 | 0.650 | 0.652 | 0.715 | 0.697 | 0.672 | 0.661 | 0.659 |

Note: t statistics in parentheses, * p<0.05 ** p<0.01 *** p<0.001, see Note in Table 6A.

## Table 7A. Bank Excess Return on Full Factors, 5 Size Groups, 2010-2018

$$\text{Bank}_i(t) = \alpha + \beta_1 \cdot \text{Market}(t) + \beta_2 \cdot \text{Interest}_k(t) + \beta_3 \cdot \text{Credit}_k(t) + \varepsilon$$

| Coefficient | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\beta_1$ Market | 0.763***<br>(7.69) | 1.039***<br>(8.19) | 0.922***<br>(7.07) | 0.895***<br>(5.33) | 0.946***<br>(8.57) | 0.911***<br>(11.96) | 1.227***<br>(12.09) | 1.169***<br>(12.77) | 1.203***<br>(13.54) | 1.254***<br>(13.48) | 0.758***<br>(7.18) | 1.046***<br>(8.10) | 0.883***<br>(6.76) | 0.764***<br>(4.86) | 0.815***<br>(7.16) |
| $\beta_2$ Slope | 6.512***<br>(3.63) | 8.515***<br>(3.94) | 9.898***<br>(4.75) | 11.62***<br>(4.84) | 11.68***<br>(5.50) | | | | | | | | | | |
| $\beta_2$ Shock | | | | | | -4.044<br>(-1.07) | -4.555<br>(-0.87) | -5.051<br>(-0.89) | -7.540<br>(-0.99) | -6.203<br>(-1.42) | | | | | |
| $\beta_2$ Return | | | | | | | | | | | -0.705***<br>(-3.41) | -0.910***<br>(-3.83) | -1.124***<br>(-4.80) | -1.459***<br>(-5.84) | -1.484***<br>(-6.04) |
| $\beta_3$ Credit | -0.254<br>(-0.69) | -0.509<br>(-1.05) | -0.217<br>(-0.42) | 0.202<br>(0.32) | 0.0157<br>(0.04) | -0.782*<br>(-2.57) | -1.178**<br>(-3.30) | -1.097**<br>(-3.10) | -0.898*<br>(-2.44) | -1.085**<br>(-2.92) | -0.111<br>(-0.28) | -0.391<br>(-0.79) | 0.151<br>(0.28) | 1.038<br>(1.73) | 0.842<br>(1.76) |
| $\alpha$ | 0.006<br>(1.87) | 0.005<br>(1.25) | 0.002<br>(0.64) | 0.003<br>(0.72) | 0.003<br>(0.93) | 0.003<br>(0.41) | 0.003<br>(0.33) | -0.001<br>(-0.09) | -0.007<br>(-0.46) | -0.003<br>(-0.30) | 0.006<br>(1.76) | 0.004<br>(1.14) | 0.002<br>(0.54) | 0.003<br>(0.73) | 0.003<br>(0.94) |
| Observations | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 |
| Adj. $R^2$ | 0.570 | 0.632 | 0.640 | 0.645 | 0.697 | 0.550 | 0.614 | 0.605 | 0.591 | 0.644 | 0.566 | 0.627 | 0.640 | 0.670 | 0.722 |

Note: t statistics in parentheses, * p<0.05 ** p<0.01 *** p<0.001. Bank is monthly value weighted average stock returns of each size sorted bank portfolio (Size1 to Size5, as index i in the model) minus risk-free rate. Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Then, Banks are sorted to five portfolios by market equity values in each June using NYSE breakpoints. Market, SMB (in Table 7B) and HML (in Table 7B) are monthly Fama-French stock factors. Interest is the interest risk factor. The index k in the model indicates each measurement of Interest, i.e. Slope, Shock and Return. Slope is the monthly changes of the spread between ten-year and one-year Treasury yields. Shock is the residuals of third-order autoregressive model (AR(3)) of one-year Treasury monthly excess return. Return is the ten-year Treasury monthly excess return. Credit is the monthly return on a portfolio that is long on US investment grade corporate bond index and is orthogonal to each measurement of interest risks from 2010 to 2018. The index k in the model indicates the Credit factor that is orthogonal to the specific Interest. Risk-free rate is one-month Treasury bill rate.

## Table 7B. Bank Excess Return on Full Factors, 5 Size Groups, 2010-2018

$$Bank_i(t) = \alpha + \beta_1 \cdot Market(t) + \beta_2 \cdot SMB(t) + \beta_3 \cdot HML(t) + \beta_4 \cdot Interest_k(t) + \beta_5 \cdot Credit_k(t) + \varepsilon$$

| Coefficient | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\beta_1$ Market | 0.649*** (8.46) | 0.917*** (7.78) | 0.835*** (6.48) | 0.906*** (4.91) | 1.087*** (9.68) | 0.673*** (14.31) | 0.970*** (12.67) | 0.942*** (13.60) | 1.054*** (11.69) | 1.207*** (14.26) | 0.658*** (9.04) | 0.942*** (8.65) | 0.808*** (6.75) | 0.776*** (4.79) | 0.963*** (8.53) |
| $\beta_2$ SMB | 0.842*** (9.05) | 0.906*** (7.71) | 0.770*** (6.89) | 0.418** (2.79) | -0.045 (-0.33) | 0.843*** (9.17) | 0.907*** (7.85) | 0.760*** (6.91) | 0.390** (2.64) | -0.065 (-0.48) | 0.841*** (9.10) | 0.902*** (7.76) | 0.774*** (7.11) | 0.437** (3.09) | -0.027 (-0.20) |
| $\beta_3$ HML | 0.742*** (7.09) | 0.803*** (6.06) | 0.794*** (5.83) | 0.823*** (5.01) | 0.865*** (6.52) | 0.760*** (7.84) | 0.842*** (7.13) | 0.886*** (7.04) | 0.965*** (6.20) | 0.976*** (8.29) | 0.751*** (7.51) | 0.827*** (6.37) | 0.787*** (5.90) | 0.747*** (4.61) | 0.787*** (5.93) |
| $\beta_4$ Slope | 1.129 (0.76) | 2.694 (1.35) | 4.164* (2.28) | 5.741* (2.37) | 5.594** (2.76) | | | | | | | | | | |
| $\beta_4$ Shock | | | | | | 0.587 (0.25) | 0.513 (0.13) | -0.174 (-0.04) | -3.251 (-0.45) | -2.939 (-0.75) | | | | | |
| $\beta_4$ Return | | | | | | | | | | | -0.112 (-0.84) | -0.258 (-1.41) | -0.506** (-2.72) | -0.88*** (-3.72) | -0.89*** (-3.85) |
| $\beta_5$ Credit | -0.187 (-0.80) | -0.439 (-1.18) | -0.196 (-0.48) | 0.0756 (0.13) | -0.305 (-0.74) | -0.273 (-1.55) | -0.620** (-2.75) | -0.556** (-2.74) | -0.412 (-1.51) | -0.702* (-2.38) | -0.214 (-0.82) | -0.515 (-1.38) | -0.006 (-0.01) | 0.751 (1.35) | 0.312 (0.66) |
| $\alpha$ | 0.006** (3.18) | 0.005 (1.92) | 0.003 (0.96) | 0.003 (0.73) | 0.002 (0.81) | 0.009 (1.91) | 0.010 (1.34) | 0.005 (0.60) | -0.002 (-0.11) | 0.001 (0.13) | 0.006** (3.21) | 0.005 (1.96) | 0.002 (0.96) | 0.003 (0.87) | 0.003 (0.95) |
| Observations | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 |
| Adj. $R^2$ | 0.830 | 0.818 | 0.803 | 0.736 | 0.770 | 0.831 | 0.819 | 0.800 | 0.726 | 0.763 | 0.830 | 0.818 | 0.804 | 0.752 | 0.783 |

Note: t statistics in parentheses, * p<0.05 ** p<0.01 *** p<0.001. See Note in Table 7A.

## Table 8A. Bank Excess Return on Full Factors, 5 Size Groups, 2010-2018

$$\text{Bank}_i(t) = \alpha + \beta_1 \cdot \text{RMO}_k(t) + \beta_2 \cdot \text{Interest}_k(t) + \beta_3 \cdot \text{Credit}_k(t) + \varepsilon$$

| Coefficient | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\beta_1$ RMO | 0.763*** | 1.039*** | 0.922*** | 0.895*** | 0.946*** | 0.911*** | 1.227*** | 1.169*** | 1.203*** | 1.254*** | 0.758*** | 1.046*** | 0.883*** | 0.764*** | 0.815*** |
| | (7.69) | (8.19) | (7.07) | (5.33) | (8.57) | (11.96) | (12.09) | (12.77) | (13.54) | (13.48) | (7.18) | (8.10) | (6.76) | (4.86) | (7.16) |
| $\beta_2$ Slope | 14.25*** | 19.07*** | 19.26*** | 20.70*** | 21.29*** | | | | | | | | | | |
| | (8.72) | (9.66) | (10.39) | (10.08) | (11.70) | | | | | | | | | | |
| $\beta_2$ Shock | | | | | | -14.23*** | -18.27*** | -18.12** | -20.99** | -20.23*** | | | | | |
| | | | | | | (-3.78) | (-3.56) | (-3.20) | (-2.67) | (-4.75) | | | | | |
| $\beta_2$ Return | | | | | | | | | | | -1.497*** | -2.004*** | -2.047*** | -2.258*** | -2.336*** |
| | | | | | | | | | | | (-7.79) | (-8.65) | (-8.96) | (-8.98) | (-11.04) |
| $\beta_3$ Credit | 1.079*** | 1.308*** | 1.395*** | 1.766*** | 1.669*** | -0.199 | -0.393 | -0.349 | -0.128 | -0.282 | 1.699*** | 2.106*** | 2.260*** | 2.863*** | 2.787*** |
| | (3.70) | (3.48) | (3.78) | (4.27) | (4.69) | (-0.69) | (-1.16) | (-1.05) | (-0.37) | (-0.79) | (5.76) | (5.62) | (6.43) | (8.25) | (8.10) |
| $\alpha$ | 0.006 | 0.005 | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | -0.001 | -0.007 | -0.003 | 0.006 | 0.004 | 0.002 | 0.003 | 0.003 |
| | (1.87) | (1.25) | (0.64) | (0.72) | (0.93) | (0.41) | (0.33) | (-0.09) | (-0.46) | (-0.30) | (1.76) | (1.14) | (0.54) | (0.73) | (0.94) |
| Observations | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 |
| Adj. $R^2$ | 0.570 | 0.632 | 0.640 | 0.645 | 0.697 | 0.550 | 0.614 | 0.605 | 0.591 | 0.644 | 0.566 | 0.627 | 0.640 | 0.670 | 0.722 |

Note: t statistics in parentheses, * $p<0.05$ ** $p<0.01$ *** $p<0.001$. Bank is monthly value weighted average stock returns of each size sorted bank portfolio (Size1 to Size5, as index i in the model) minus risk-free rate. Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Then, Banks are sorted to five portfolios by market equity values in each June using NYSE breakpoints. RMO is the orthogonalized market factor by first regressing Market factor on Interest and Credit factors each month and second adding the residuals and intercepts. Market is the monthly market excess return in Fama-French stock factors. The index k in the model indicates the RMO factor that is corresponding to the specific Interest factor. Interest is the interest risk factor. The index k in the model indicates each measurement of Interest, i.e. Slope, Shock and Return. Slope is the monthly changes of the spread between ten-year and one-year Treasury yields. Shock is the residuals of third-order autoregressive model (AR(3)) of one-year Treasury monthly excess return. Return is the ten-year Treasury monthly excess return. Credit is the monthly return on a portfolio that is long on US investment grade corporate bond index and is orthogonal to each measurement of interest risks from 2010 to 2018. The index k in the model indicates the Credit factor that is orthogonal to the specific Interest. Risk-free rate is one-month Treasury bill rate.

## Table 8B. Bank Excess Return on Full Factors, 5 Size Groups, 2010-2018

$$\text{Bank}_{i}(t) = \alpha + \beta_1 \cdot \text{RMO}_{k}(t) + \beta_2 \cdot \text{SMB}(t) + \beta_3 \cdot \text{HML}(t) + \beta_4 \cdot \text{Interest}_{k}(t) + \beta_5 \cdot \text{Credit}_{k}(t) + \varepsilon$$

| Coefficient | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 | Size1 | Size2 | Size3 | Size4 | Size5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\beta_1$ | 0.649*** | 0.917*** | 0.835*** | 0.906*** | 1.087*** | 0.673*** | 0.970*** | 0.942*** | 1.054*** | 1.207*** | 0.658*** | 0.942*** | 0.808*** | 0.776*** | 0.963*** |
| RMO | (8.46) | (7.78) | (6.48) | (4.91) | (9.68) | (14.31) | (12.67) | (13.60) | (11.69) | (14.26) | (9.04) | (8.65) | (6.75) | (4.79) | (8.53) |
| $\beta_2$ | 1.103*** | 1.276*** | 1.107*** | 0.783*** | 0.393** | 1.202*** | 1.424*** | 1.262*** | 0.952*** | 0.579*** | 1.083*** | 1.250*** | 1.072*** | 0.723*** | 0.328** |
| SMB | (12.56) | (12.27) | (11.59) | (6.05) | (3.20) | (13.75) | (12.92) | (12.32) | (7.22) | (4.75) | (12.30) | (11.98) | (11.12) | (5.75) | (2.75) |
| $\beta_3$ | 0.547*** | 0.527*** | 0.543*** | 0.551*** | 0.538*** | 0.854*** | 0.978*** | 1.019*** | 1.114*** | 1.146*** | 0.549*** | 0.538*** | 0.539*** | 0.508** | 0.492*** |
| HML | (5.30) | (4.10) | (4.13) | (3.49) | (4.10) | (8.92) | (8.35) | (8.19) | (7.23) | (9.83) | (5.44) | (4.19) | (4.09) | (3.15) | (3.79) |
| $\beta_4$ | 8.037*** | 12.46*** | 13.06*** | 15.39*** | 17.17*** | | | | | | | | | | |
| Slope | (7.18) | (7.97) | (10.25) | (8.63) | (9.73) | | | | | | | | | | |
| $\beta_4$ | | | | | | -4.801* | -7.248 | -7.712 | -11.69 | -12.60** | | | | | |
| Shock | | | | | | (-2.04) | (-1.90) | (-1.67) | (-1.57) | (-3.19) | | | | | |
| $\beta_4$ | | | | | | | | | | | -0.837*** | -1.297*** | -1.396*** | -1.736*** | -1.950*** |
| Return | | | | | | | | | | | (-7.49) | (-7.60) | (-8.52) | (-7.41) | (-9.68) |
| $\beta_5$ | 0.943*** | 1.160*** | 1.259*** | 1.655*** | 1.590*** | 0.226 | 0.0984 | 0.142 | 0.370 | 0.193 | 1.354*** | 1.731*** | 1.920*** | 2.600*** | 2.608*** |
| Credit | (5.15) | (4.36) | (4.98) | (4.67) | (4.99) | (1.30) | (0.46) | (0.74) | (1.46) | (0.69) | (6.86) | (6.39) | (8.24) | (8.73) | (7.77) |
| $\alpha$ | 0.006** | 0.005 | 0.003 | 0.003 | 0.002 | 0.009 | 0.010 | 0.005 | -0.002 | 0.001 | 0.006** | 0.005 | 0.002 | 0.003 | 0.003 |
| | (3.18) | (1.92) | (0.96) | (0.73) | (0.81) | (1.91) | (1.34) | (0.60) | (-0.11) | (0.13) | (3.21) | (1.96) | (0.96) | (0.87) | (0.95) |
| Observations | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 |
| Adj. $R^2$ | 0.830 | 0.818 | 0.803 | 0.736 | 0.770 | 0.831 | 0.819 | 0.800 | 0.726 | 0.763 | 0.830 | 0.818 | 0.804 | 0.752 | 0.783 |

Note: t statistics in parentheses, * $p<0.05$ ** $p<0.01$ *** $p<0.001$. Bank is monthly value weighted average stock returns of each size sorted bank portfolio (Size1 to Size5, as index i in the model) minus risk-free rate. Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Then, Banks are sorted to five portfolios by market equity values in each June using NYSE breakpoints. RMO is the orthogonalized market factor by first regressing Market factor on SMB, HML, Interest and Credit factors each month and second adding the residuals and intercepts. Market (market excess return), SMB (small minus big) and HML (high minus low) are monthly Fama-French stock factors. The index k in the model indicates the RMO factor that is corresponding to the specific Interest factor. Interest is the interest risk factor. The index k in the model indicates each measurement of Interest, i.e. Slope, Shock and Return. Slope is the monthly changes of the spread between ten-year and one-year Treasury yields. Shock is the residuals of third-order autoregressive model (AR(3)) of one-year Treasury monthly excess return. Return is the ten-year Treasury monthly excess return. Credit is the monthly return on a portfolio that is long on US investment grade corporate bond index and is orthogonal to each measurement of interest risks from 2010 to 2018. The index k in the model indicates the Credit factor that is orthogonal to the specific Interest factor. Risk-free rate is one-month Treasury bill rate.

## Table 9A. Interest Risk Factor Coefficients of Size and Value Sorted Bank Portfolios 2010-2018

$$\text{Bank}_i(t) = \alpha + \beta_1 \cdot \text{Market}(t) + \beta_2 \cdot \text{Interest}_k(t) + \beta_3 \cdot \text{Credit}_k(t) + \varepsilon$$

| | Book-to-Market Equity Ratio | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Size | Low | 2 | 3 | 4 | High | Low | 2 | 3 | 4 | High |
| | | Slope Coefficient $\beta_2$ | | | | | | t statistics | | |
| Small | 6.796*** | 5.525** | 5.340** | 7.279*** | 7.466*** | (3.43) | (2.99) | (2.74) | (4.37) | (3.57) |
| 2 | 7.965*** | 7.103** | 8.718*** | 9.679*** | 10.96*** | (3.39) | (2.90) | (3.60) | (3.53) | (3.43) |
| 3 | 9.717*** | 11.00*** | 8.036*** | 13.43** | 16.10*** | (3.70) | (4.91) | (3.80) | (3.15) | (4.73) |
| 4 | 8.993*** | 10.34*** | 8.997*** | 14.49*** | 15.60*** | (4.67) | (4.68) | (3.75) | (4.53) | (3.58) |
| Big | 8.086*** | 6.637** | 9.539*** | 13.29*** | 18.87*** | (3.90) | (3.36) | (4.33) | (4.14) | (3.99) |
| | | Shock Coefficient $\beta_2$ | | | | | | t statistics | | |
| Small | -5.900 | -5.618 | -4.619 | -1.285 | -1.360 | (-1.52) | (-1.61) | (-1.27) | (-0.32) | (-0.28) |
| 2 | -7.147 | -5.131 | -3.993 | 0.060 | -6.445 | (-1.54) | (-1.01) | (-0.65) | (0.01) | (-1.24) |
| 3 | -7.265 | -4.738 | -4.891 | 6.693 | -1.908 | (-1.37) | (-0.87) | (-0.92) | (0.42) | (-0.23) |
| 4 | -7.126 | -12.14 | -11.37 | -1.965 | -6.860 | (-1.66) | (-1.91) | (-1.95) | (-0.19) | (-0.53) |
| Big | -9.790 | -8.436 | -5.900 | -4.879 | -12.77 | (-1.60) | (-1.28) | (-1.00) | (-1.00) | (-1.40) |
| | | Return Coefficient $\beta_2$ | | | | | | t statistics | | |
| Small | -0.795*** | -0.659** | -0.566* | -0.758*** | -0.780** | (-3.42) | (-3.11) | (-2.58) | (-4.14) | (-3.34) |
| 2 | -0.817** | -0.759** | -0.994*** | -0.935*** | -1.404*** | (-2.98) | (-2.88) | (-3.72) | (-3.42) | (-4.63) |
| 3 | -1.135*** | -1.168*** | -0.854*** | -1.166*** | -2.078*** | (-3.70) | (-4.39) | (-3.66) | (-3.72) | (-5.32) |
| 4 | -1.129*** | -1.497*** | -1.211*** | -1.629*** | -2.115*** | (-5.01) | (-5.72) | (-4.77) | (-5.61) | (-5.25) |
| Big | -0.900*** | -0.880*** | -1.185*** | -1.843*** | -2.500*** | (-3.99) | (-4.15) | (-4.66) | (-5.09) | (-4.92) |

Note: * $p<0.05$ ** $p<0.01$ *** $p<0.001$. Bank is monthly value weighted average stock returns of each size and value sorted bank portfolio (as index i in the model) minus risk-free rate. Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Then, Banks are sorted to five portfolios by market equity values and are independently sorted to five portfolios by Book-to-Market Equity Ratios in each June using NYSE breakpoints, to form 25 size and value sorted portfolios. Market, SMB (in Table 9B) and HML (in Table 9B) are monthly Fama-French stock factors. Interest is the interest risk factor. The index k in the model indicates each measurement of Interest, i.e. Slope, Shock and Return. Slope is the monthly changes of the spread between ten-year and one-year Treasury yields. Shock is the residuals of third-order autoregressive model (AR(3)) of one-year Treasury monthly excess return. Return is the ten-year Treasury monthly excess return. Credit is the monthly return on a portfolio that is long on US investment grade corporate bond index and is orthogonal to each measurement of interest risks from 1975 to 2018. The index k in the model indicates the Credit factor that is orthogonal to the specific Interest. Risk-free rate is one-month Treasury bill rate.

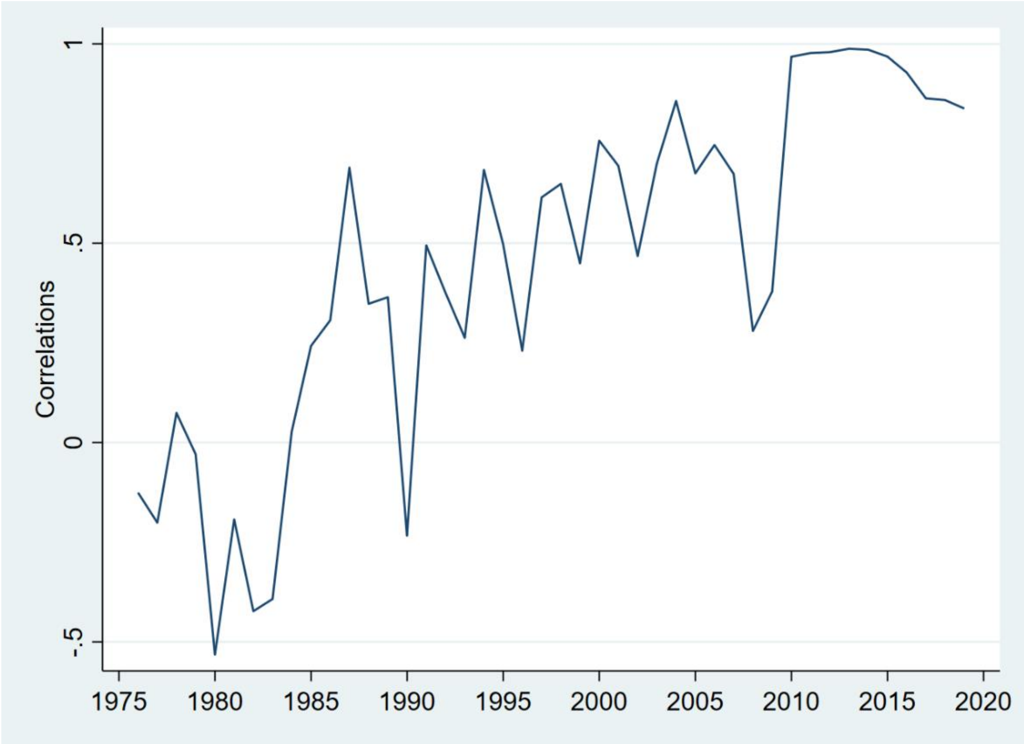
## Table 9B. Interest Risk Factor Coefficients of Size and Value Sorted Bank Portfolios 2010-2018

$$Bank_i(t) = \alpha + \beta_1 \cdot Market(t) + \beta_2 \cdot SMB(t) + \beta_3 \cdot HML(t) + \beta_4 \cdot Interest_k(t) + \beta_5 \cdot Credit_k(t) + \varepsilon$$

| | | | | | Book-to-Market Equity Ratio | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Size | Low | 2 | 3 | 4 | High | Low | 2 | 3 | 4 | High |
| | | | Slope Coefficient $\beta_4$ | | | | | t statistics | | |
| Small | 1.607 | 0.205 | 0.289 | 2.545 | 1.094 | (0.94) | (0.12) | (0.17) | (1.72) | (0.45) |
| 2 | 2.904 | 1.299 | 1.769 | 3.744 | 4.179 | (1.36) | (0.50) | (0.78) | (1.42) | (1.47) |
| 3 | 2.611 | 6.380** | 3.051 | 4.241 | 12.94** | (1.24) | (2.90) | (1.45) | (0.91) | (3.33) |
| 4 | 5.331* | 4.911* | 4.591 | 7.491* | 5.851 | (2.51) | (2.19) | (1.74) | (2.44) | (1.30) |
| Big | 3.912 | 2.728 | 4.051 | 5.816 | 12.97* | (1.62) | (1.32) | (1.69) | (1.64) | (2.59) |
| | | | Shock Coefficient $\beta_4$ | | | | | t statistics | | |
| Small | -1.132 | -1.239 | -0.184 | 3.031 | 3.518 | (-0.45) | (-0.55) | (-0.08) | (1.08) | (0.93) |
| 2 | -2.268 | -0.343 | 1.527 | 5.599 | -1.285 | (-0.69) | (-0.09) | (0.33) | (0.85) | (-0.28) |
| 3 | -2.040 | -0.037 | -0.589 | 14.26 | 1.947 | (-0.48) | (-0.01) | (-0.14) | (0.94) | (0.24) |
| 4 | -3.949 | -8.471 | -8.092 | 2.929 | -0.294 | (-1.05) | (-1.34) | (-1.47) | (0.29) | (-0.02) |
| Big | -7.610 | -6.297 | -2.484 | -1.230 | -7.816 | (-1.21) | (-0.95) | (-0.42) | (-0.27) | (-0.95) |
| | | | Return Coefficient $\beta_4$ | | | | | t statistics | | |
| Small | -0.236 | -0.088 | -0.003 | -0.230 | -0.083 | (-1.41) | (-0.56) | (-0.02) | (-1.85) | (-0.35) |
| 2 | -0.231 | -0.105 | -0.243 | -0.248 | -0.726** | (-1.02) | (-0.42) | (-1.16) | (-1.09) | (-2.75) |
| 3 | -0.387 | -0.639** | -0.288 | -0.183 | -1.834*** | (-1.61) | (-2.72) | (-1.36) | (-0.58) | (-4.02) |
| 4 | -0.767*** | -1.026** | -0.799** | -0.887*** | -1.202** | (-3.42) | (-3.23) | (-2.95) | (-3.49) | (-3.21) |
| Big | -0.445 | -0.508* | -0.630* | -1.161** | -1.976*** | (-1.90) | (-2.12) | (-2.17) | (-2.97) | (-3.76) |

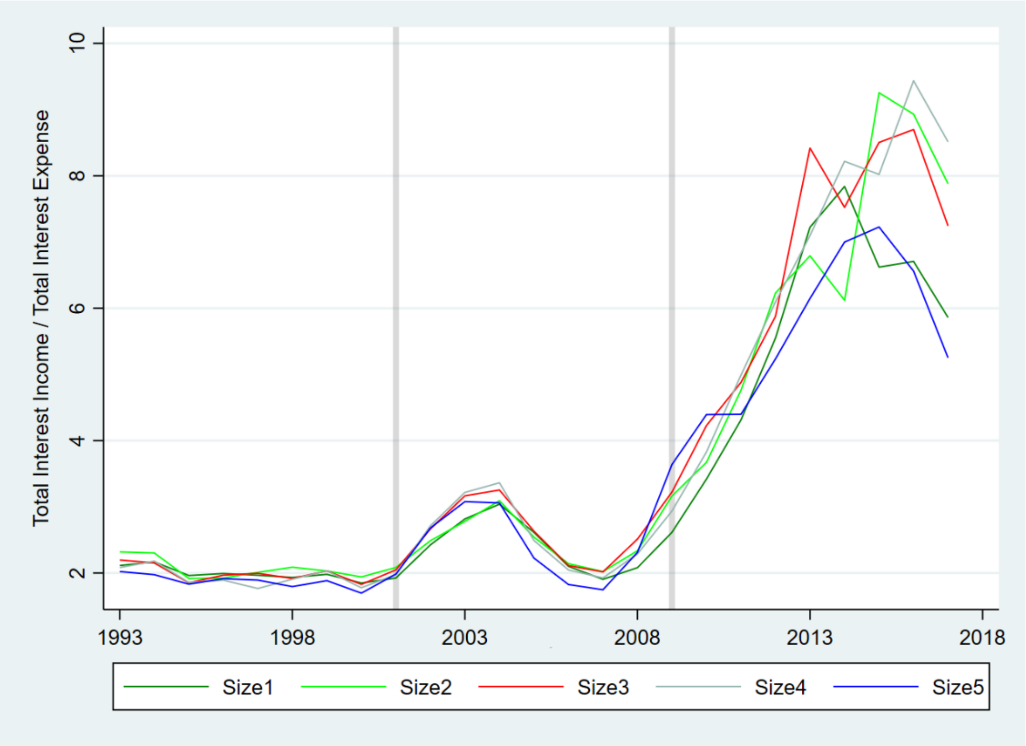
Note: * p<0.05 ** p<0.01 *** p<0.001. See Note in Table 9A.

**Figure 6. Yearly Changes of Correlations of Slope and Yield Factors 1975-2018**




Note: Correlations of Slope and Yield Factors each year are based on daily Slope factor and Yield factor. Slope is daily changes of the spread between ten-year and one-year Treasury yields. Yield is daily changes of ten-year Treasury yield. The daily one-year and ten-year Treasury yields come from Federal Reserve Bank of St. Louis – FRED.

**Figure 7. Yearly Interest Margin of Size Sorted Bank Portfolios 1993-2017**




Note: The Figure shows the yearly ratios of aggregated Total Interest Income of each size sorted bank portfolio divided by aggregated Total Interest Expense in the same fiscal year. Banks must be included in Compustat Bank Fundamentals Annual and must be qualified for calculating Fama-French factors, i.e. with CRSP share code 10 or 11, etc. Then, Banks are sorted to five portfolios by monthly market equity values in each June using NYSE breakpoints. For each size bank portfolio in each fiscal year, we aggregate Total Interest Income and Total Interest Expense in the same portfolio. The data Total Interest Income and Total Interest Expense comes from Compustat Bank Fundamentals Annual database. The vertical gray lines are years – 2001 and 2009 – in which NBER Business Cycle Dating Committee announced a trough in business activity. https://www.nber.org/cycles.html