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Essays on Option Implied Volatility Risk Meausures for Banks

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Chapter I – Information on futures banks' stock returns in option's implied volatilities skews and spreads

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In this study we focus our attention on how volatility skew – measured as the difference between OTM put and ATM call – and volatility spread – measured as the difference between ATM call and ATM put – affect future equity returns for banking industry. In doing so, we perform two different techniques: a regression analysis and a portfolio analysis. With the regression analysis we find out that volatility skew is negative correlated with future equity returns, while volatility spread is positive correlated with future equity returns and that short time-to-maturity options are the most important contract for shaping future equity returns. In portfolio analysis we observe that investing in stock with lower values of volatility skew (spread) significantly underperforms a portfolio which invests in stock with higher values of volatility skew (spread).

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1. Introduction

This paper studies how volatility skews and spreads calculated from options implied volatilities influence future banks' stocks returns. The analysis exploits two different methods. As a leading method we perform a regression analysis on a dataset of weekly banks' stocks returns and their corresponding implied volatilities while as complementary method we perform a portfolio analysis using option implied volatility skews and spreads distributions' to identify banks that perform better across time.

As a robustness check we execute a model full of Fama French [1996] four factors model control variables and we use a multivariate regression analysis which has the entire term structure of volatility skews (spreads) as exogenous variables. A multivariate analysis which uses all time-to-maturity options cleanses volatility skews (spreads) coefficients from any correlation among each other, so that we can identify which volatility skew (spread) affects more next week returns. Lastly, we check life span of future returns predictability in skews (spreads) by performing a regression analysis comprehensive of lagged skew (spread). In doing so, we extend the array of exogenous variables up to 12 weeks lag.

Options market is a suitable environment for informed traders to operate. It offers high leverage, no constrains to short-selling and gives the opportunity but not the obligation to buy or sell a specific asset at a specific price within – or at – a specific point in time. Thanks to all their features option prices embody traders' expectations on future stock returns and represent a forward looking measure.

Traders operate in option market by quoting their implied volatilities for different maturities and different moneyness according to their view on future stock's returns. The result of this trading activity produces volatility skews, smirks and spreads which eventually get away from Black and Scholes [1973] environment of constant volatility and put-call parity equation.

Option implied volatilities risk measures and their role in forecasting future price movements has been already unfolded for stock indices and low regulated industries in recent literature.

Several papers use option implied volatilities skews, spreads and variance risk premia as risk measures to construct portfolios of low regulated stocks. In studying the relationship between option's market and firms' capital structure other papers rely on option implied volatility informational content to assess the flexibility of a firm in changing its capital structure and its financing sources only for non-financial industry but none, to the best of our knowledge, extended this analysis for financial industry.

On one hand banks and financial firms respond to the same profitability and economic laws of other industries. On the other hand they present a deeper bond with macroeconomic fundamentals and with central banks' monetary policy decisions as well as they operate in a high-regulated environment. Due to the nature of their business any association with other industries must be eluded and aware of this special requirement we perform the analysis only on banks' stocks and their option implied volatilities.

Our aim is to investigate whether volatility skews and spread are statistically and economically significant for banking industry future stocks returns as much as they are for other industries as previous studies highlighted. If this is the case, it means that traders convey their views about bank's economic and financial health in option markets prior to expressing it in the underlying asset market and option volatility skews analysis is a useful tool in gauge equity future movements.

In our study, regression analysis provides good evidence that volatility skew and volatility spread define future weekly returns and portfolio analysis supports this evidence.

Volatility skews regression analysis recognizes statistically significant and negative coefficients for all short term maturities options (from 1 to 3 months to maturity). Skew, which can be defined as the difference between out-of-the-money (OTM) put and at-the-money (ATM) call option, is negative correlated with next week stock return for option time to maturity from 1 up to 3 months, with a peak of significance at 2 months' time-to-maturity. This evidence suggests that the intent of traders to pay more for OTM put options is connected with a negative return in coming week.

Volatility spreads analysis offers clear results about the sign of the correlation but less straightforward evidence about which is the most important maturity to be considered. Spread can be defined as the difference between ATM call and ATM put option and it is statistically significant and positive correlated with next week stock return for options with time to maturity from 2 up to 12 months. When we consider a univariate model, spread tends to show a peak in statistical and economic significance for 6 and 12 months' time-to-maturity options. On the contrary, when we add control variables and perform a multivariate analysis using the entire spread's term structure, the relevant contracts are 1 and 2 months' maturity option. So we still identify short term maturities as leading contracts, but less certainly than we can state for skews. Considering the sign of the relationship a positive correlation between spread and future return witness that any positive upward departure from put-call parity conditions produces an increase in stock price.

Results from volatility skew and spread analysis are corroborated by our portfolio model. In our model we find that a portfolio which invests in banks' stocks with lower volatility skews (spread) significantly underperforms one investing in those with higher volatility skews (spread). In our portfolio analysis we rank banks on their option implied volatilities skews (spreads) and build portfolios of stocks according to it. For each skew (spread) we generate four portfolio, 1st and 5th quintile and 1st and 10th decile portfolios.

Portfolios based on left hand side distribution of implied volatility skew (spread) underperform those based on the right hand side distribution for all maturities and for all considered time frame. Average portfolio returns corroborate our findings in regression analysis but statistical significance arises irregularly among different portfolios and it is widespread only for 1st quintiles portfolios.

For 90% moneyness level, 1st quintile portfolios show statistically significant negative returns for 1, 2, 3 and 6 months maturity options, while for deciles portfolios, only those based on 2 months' time to maturity option implied volatility skew, produces statistically significant return of -0.168% per week.

Volatility spread analysis portfolio model shows strong statistically significance for both 1st quintile and 1st deciles, however fails to statistically support volatility spread as a measure for upside movement in stock prices and provides evidence only for downside movements. Portfolio of stocks which fall in the 1st quintile for option implied volatility spread with time to maturity equal to 1, 2, 3, 6 and 12 months show significant negative returns while those which fall in the 1st decile show significant negative returns for maturities equal to 3, 6 and 12 months.

Summing up, regression analysis highlights that volatility skew is negative correlated with future stock returns and portfolio analysis indicates a relative underperformance of stock with lower skew, supporting the theory that volatility skew absorbs traders' expectation on future drawdowns. Volatility spread regression analysis identifies a positive correlation with next week stock returns and portfolio analysis identifies a relative underperformance of stocks with lower volatility spreads. However, when asked to support volatility spread as a measure to capture traders' expectation for future upside returns, portfolio analysis partially succeeds in backing up our findings.

This paper is organized as follow, Section 1 is the introduction, Section 2 presents previous literature related to the topic, Section 3 describes the data and the methodology used in the analysis, Section 4 illustrates the results and robustness check analysis and Section 5 concludes.

2. Previous Literature

Bates [1991] states that the set of index call and put option prices across different moneyness levels give a direct indication of market participants' aggregate subjective distribution of future price realizations. Therefore, OTM puts become more expensive compared to ATM calls and volatility skews become more prominent before big negative jumps in price levels. In his paper shows that out-of-the money puts became unusually expensive during the year preceding the 1987 crash and by setting a model for pricing American option on jump-diffusion processes with systematic jump risk is shown that jump-diffusion parameters implicit in option prices indicate a crash was expected and that implicit distributions were negatively skewed in the year preceding 1987.

Pan [2002] documents that informational content of volatility smirk for an S&P 500 index option with 30 days to expiration is 10% on a median volatility day in his paper he incorporates both jump risk premium and volatility risk premium and shows that investors' aversion toward negative jumps is the driving force for volatility skew. For OTM put options the jump risk premium component characterizes 80% of total risk premium while the jump premium for OTM calls is just 30% of total risk premium.

Doran et al. [2007b] use a probit model for all options on S&P 100 from 1996 to 2002 to demonstrate that the shape of the skew can reveal with significant probability when the market will "crash" or "spike". Their findings suggest that there is predictive information content within volatility skew and put-only volatility skew has strong predictive power in forecasting short-term market declines.

Xing et al. [2010] show that implied volatility smirk (defined has the difference between the implied volatilities of OTM put options and the implied volatilities of ATM call options) is persistent and has significant predictive power for future equity returns. In their study stocks exhibiting the steepest smirks in their traded options tend to underperform stocks with least pronounced volatility smirks in their options by 10.9% per year on a risk-adjusted basis using the Fama and French [1996] three-factor model. They also find that predictability of the volatility skew on future stock returns last for at least six months and stocks with steepest volatility smirks are those stocks experiencing the worst earning shocks in the following quarter.

Cremers and Weinbaum [2010] find that deviations from put-call parity contain information about future stock prices. By comparing pairs of call and put they discover that stocks with relative expensive calls outperform stocks with relative expensive puts by at least 45 basis points per week.

Liu et al. [2014] further inspect option-implied volatilities informational content by investigate the industry effect of portfolio of stocks constructed according to implied volatility measure and comparing those portfolios with industry-neutral portfolios of stocks. They find that quintile portfolios constructed using volatility skew and volatility spread are subject to substantial industry effect and industry-neutral portfolio over perform.

Chen, Chung and Wang [2014] propose a forward-looking approach to estimate the individual stock moments from option prices and use them as inputs in determining optimal portfolios under the mean-variance framework proposed by Markowitz [1952]. They found that 80.77% of portfolios relying on option prices information outperform those built on stocks historical data and 58.97% of the differences are statistically significant at the 5% level, 75.64% of the optimization portfolios constructed with the forward-looking approach outperform the naïve diversification and 53.56% of the differences are statistically different from zero at the 5% significance level.

Borochin and Yang [2014] use forward looking risk estimates impounded into option prices to create market-based indices which explain the ability to change firm's capital structure more than traditional accounting-based measures. They also construct indices using implied volatility spread, implied volatility skew and volatility risk premium and perform a long-short trading strategy based on these indices which generates abnormal returns from 2.3% to 4.9% over one year.

Bollerslev, Tauchen and Zhou [2009] provide empirical evidence that stock market returns are predictable by the difference between implied volatilities and realized volatilities or variance risk premium. Moreover, stock returns are positively correlated with variance risk premium and the degree of predictability is the largest at quarterly horizons but the premium still explains observed return variation at monthly and annual horizons. Volatility risk premium captures risk premium for option sellers to bear losses on the underlying stock.

Goyal and Saretto [2009] study cross-section stock option returns by sorting stocks on the difference between historical realized volatility and at-the-money implied volatility and find that auto-financing trading strategy that is long (short) in the portfolio with a large positive (negative) difference between historical volatility and implied volatility produces economically and statistically significant monthly returns. They observe that deviations between historical volatility and implied volatility are transitory and indicative of option mispricing, hence future volatility will converge to its long-run historical volatility.

Zhou [2009] presents evidence of variance risk premium forecasting ability for financial market risk premia across equity, bond, currency and credit asset classes and this forecasting ability is maximum at one month horizon.

3. Data and Methodology

Banks are selected from STOXX Global 1800 Banks Index. Among 106 components of the index we exclude those banks with an incomplete or missing array of option prices. The resulting dataset comprehends daily observations from January 2005 to December 2014 for 72 banks. For each bank we collect option data for different moneyness level and different maturities. We relied on a broader dataset, with respect to previous studies, by collecting call and put options with moneyness (strike-to-spot ratio) from 0.90 to 1.10, by including option with time-to-maturity from 1 to 12 months and by performing the analysis separately for each time-to-maturity, instead of averaging across them all. Call and put option with moneyness close to 1 are defined ATM option, call (put) with moneyness equal or above 1.05 (equal or below 0.95) are defined OTM. The approach in selecting ATM and OTM moneyness levels is consistent with Ofek, Richardson and Whitelaw [2004]. Options and stocks data are obtained from Bloomberg and implied volatility prices represent daily average value of market trades.

Volatility skew is the difference between OTM put and ATM call option implied volatility and measures the excess premium paid for purchasing OTM put option with respect to ATM call option. Equation (1) defines volatility skew.

(1) $$skew_{i,t}^{m} = iv_{i,t}^{OTMP,m} - iv_{i,t}^{ATMC,m}$$

where $iv_{i,t}^{OTMP,m}$ is the implied volatility for an OTM put option, maturity *m* on stock *i* at time *t* and $iv_{i,t}^{ATMC,m}$ is the implied volatility for ATM call option with maturity *m* on stock *i* at time *t.* A negative and statistically significant coefficient for $skew_{i,t}^{m}$ over weekly stock returns would infer that traders use OTM put options to hedge for (invest in) those stocks willing to have a drawdowns in price in coming weeks. Different option maturities produce different skews and allow us to measure the informational content of skews among different time horizons.

The selected moneyness is 0.90 and the considered option time to maturity *m* are 1, 2, 3, 6 and 12 months, $skew$ is computed for each bank on a weekly basis by taking the difference between average daily OTM put and ATM call implied volatilities over a week (Tuesday close to Tuesday close). Weekly stock returns are calculated from Wednesday close to Wednesday close in order to avoid non-synchronous trading issues as pointed out by Battalio and Schultz [2006].[1]

Volatility spread is defined in Equation (2) as the difference between ATM call option implied volatilities and ATM put option implied volatilities of.

(2) $$spread_{i,t}^{m} = iv_{i,t}^{ATMC,m} - iv_{i,t}^{ATMP,m}$$

where *i* and *t* represent the same variables in Eq. (1) and the considered *m* maturities are 10 days, 1, 2, 3, 6 and 12 months. Volatility spread aims to capture any departure from put-call parity state due to current market condition. Positive values of $spread_{i,t}^{m}$ are manifestation of a more expensiveness of call option to put option, hence traders' expectation of future positive return on stock *i*. Positive and statistically significant coefficient for $spread_{i,t}^{m}$ in a regression analysis on weekly stock returns would suggest that $spread_{i,t}^{m}$ soaks up market expectations for upward movement in stock prices.

[1] Using same-day closing price may lead in non-synchronous issues since option market closes at 4:02 PM for individual stock options while equity market closes at 4:00 PM.

A. Regression Analysis

Regression analysis is performed on a panel dataset of 72 banks from 2005 to 2014 for a total of 30,000 weekly observations. Equation (3) presents the model for volatility skew analysis and Equation (4) presents the model for volatility spread analysis:

$$r_{i,t+1} = \beta_0\alpha_i + \beta_1 skew_{i,t}^m + \beta_2 crisis_t + \beta_3\mathbf{X}_t + \boldsymbol{\varepsilon}_{i,t} \quad (3)$$

$$r_{i,t+1} = \beta_0\alpha_i + \beta_1 spread_{i,t}^m + \beta_2 crisis_t + \beta_3\mathbf{X}_t + \boldsymbol{\varepsilon}_{i,t} \quad (4)$$

where $r_{i,t}$ represents the weekly log return for bank *i*, at time t, α_i is the constant, $skew_{i,t}^m$ represents the volatility skew as the difference between OTM put and ATM call volatility for bank *i* at time *t* and option's time to maturity *m*, $spread_{i,t}^m$ represents the volatility spread as the difference between ATM call and ATM put volatility for bank *i* at time *t* and option's time to maturity *m*, $crisis_t$ is a dummy variable equal to one if *t* happens during financial crisis (from Q3 2007 to Q1 2009) and zero otherwise, $crisis_t$ allows to clean our analysis from any misbehavior of dependent variable during the financial crisis and $\mathbf{X}_t$ is a vector of control variables from Fama French four factors model.

Once we studied different time-to-maturity option implied volatility skews (spreads) in separate models we perform a multivariate model which comprehends, as exogenous variables, the entire term structure of volatility skews (spreads). Multivariate analysis is carried out in order to verify which time-to-maturity skew (spread) affects the most future equity returns and if the results in previous analysis are somehow corrupted by correlation among exogenous variables. Equations (5) and (6) show the models.

(5) $$r_{i,t} = \beta_0\alpha_i + \beta_1\boldsymbol{SKEW}_{i,t-1} + \beta_2 crisis_t + \beta_3\mathbf{X}_t + \boldsymbol{\varepsilon}_{i,t}$$

(6) $$r_{i,t} = \beta_0\alpha_i + \beta_1\boldsymbol{SPREAD}_{i,t-1} + \beta_2 crisis_t + \beta_3\mathbf{X}_t + \boldsymbol{\varepsilon}_{i,t}$$

Where $\boldsymbol{SKEW}_{i,t}$ is a vector comprehensive of the entire volatility skew term structure and $\boldsymbol{SPREAD}_{i,t}$ is a vector comprehensive of the entire volatility spread term structure.

Finally, we focus on the persistency over time of volatility skew's (spread's) informational content about future returns. In order to verify how many weeks in the future will be affected by volatility skews (spreads) we perform a regression analysis with lagged values of skews (spreads) up to 12 weeks. Equations (7) and (8) show the model.

(7) $$r_{i,t} = \beta_0\alpha_i + \beta_1 skew^m_{i,t-1} + \sum_{j=2}^{n}\gamma_j skew^m_{i,t-j} + \beta_2 crisis_t + \beta_3\mathbf{X}_t + \boldsymbol{\varepsilon}_{i,t}$$

(8) $$r_{i,t} = \beta_0\alpha_i + \beta_1 spread^m_{i,t-1} + \sum_{j=2}^{n}\gamma_j spread^m_{i,t-j} + \beta_2 crisis_t + \beta_3\mathbf{X}_t + \boldsymbol{\varepsilon}_{i,t}$$

For values of *j* equal to 2, 3, 4, 5, 6, 8, 10 and 12 and where γ_j represents the coefficient for *j*-th lagged values of skews (spreads).

B. Portfolio Analysis

Portfolio analysis builds an investment strategy based on implied volatility skew distribution and implied volatility spread distribution by investing each week in those stocks which fall in lower (upper) section of the distribution. We create four portfolios: two for the lower tail of volatility skew distribution and two for the upper tail. For the left hand side of the distribution we choose 1st quintile and 1^{st} decile while for the right hand side we choose 5^{th} quintile and 10^{th} decile. The same procedure has been carried on for volatility spread.

In order to build a portfolio that invests in those stocks which fall in the 1^{st} quintile (1^{st} decile) of volatility skew distribution, every week we sort banks in quintiles (deciles) according to their average weekly volatility skew. Average volatility skew is computed from Tuesday close to Tuesday close. Banks with lower volatility skew will fall in the lower quintile (decile) and banks with higher volatility skew will fall in the upper quintile (decile). Then we compute our 1^{st} quintile (1^{st} decile) weekly return portfolio by averaging next week stocks' returns for all stocks belonging to that quintile (decile). Stock's weekly returns are calculated from Wednesday close to Wednesday close so that we have one entire trading day between the model set up and the performance analysis. The results is a portfolio which strategy is to buy each Wednesday the stocks that – in previous week – fall within the 1^{st} quintile (1^{st} decile) of volatility skew distribution of all 72 banks. In order to pick the stocks with higher volatility skews values this process is replicated for 5^{th} quintile and 10^{th} decile. The same procedure has been led for volatility spread.

For the analysis on volatility skew we generate a total of 40 portfolios by using two moneyness levels (90% and 95%), five different time-to-maturity options (1, 2, 3, 6 and 12 months) and four different sections of distribution (1^{st} quintile, 1^{st} decile, 5^{th} quintile and 10^{th} decile).

For volatility spread we generate a total of 20 portfolios by using only ATM levels, five different time to maturity options (1, 2, 3, 6 and 12 months) and four different sections of distribution (1^{st} quintile, 1^{st} decile, 5^{th} quintile and 10^{th} decile).

Finally, we find interesting to observe average returns for each of the 60 portfolios through four different time samples, in order to verify whether the results changes. The considered time samples are a full sample (from 2005 to

2014), one sample excluding the financial crisis (from Q1 2005 to Q2 2007 and from Q2 2009 to Q4 2014), one only considering the observations before the financial crisis (from Q1 2005 to Q2 2007) and another only the observations after the financial crisis (from Q2 2009 to Q4 2014).

4. Results

Table 1 shows the first two moments and the most relevant percentiles for volatility skew – over the entire sample – for 90% and 95% moneyness levels and through all options maturities. Table 2 shows the same statistical factors for a restricted sample which excludes the financial crisis period.

Skews exhibit an overall expensiveness of OTM put option compared to ATM call, for all levels of moneyness and for all options time to maturity. In specific lower levels of moneyness show larger skews and the shorter the maturity the larger the skew. Traders use lower moneyness option to hedge themselves against large drawdowns in stock’s price because of their relative cheapness and rely on shorter term options for liquidity reasons. For 90% moneyness, 1 month OTM put options are priced using an implied volatility 5.74 points higher than the one used in pricing ATM call options. For 95% moneyness this this overprice is equal to 2.27.

Table 1 — Volatility Skews (complete sample from Q1 2005 to Q4 2014)

	90% OTM put moneyness				
Maturity	1 month	2 months	3 months	6 months	12 months
Mean	5.74	3.62	2.95	1.97	1.18
Standard deviation	6.14	3.21	2.79	3.04	4.32
5th percentile	-0.06	-0.18	-0.37	-1.06	-3.16
25th percentile	3.10	2.23	1.85	1.11	0.55
50th percentile	5.34	3.64	3.02	2.14	1.55
75th percentile	7.60	4.97	4.12	2.92	2.20

	95% OTM put moneyness				
Maturity	1 month	2 months	3 months	6 months	12 months
Mean	2.27	1.53	1.25	0.70	0.17
Standard deviation	3.49	2.59	2.45	2.92	3.68
5th percentile	-0.95	-0.98	-1.20	-2.05	-4.05
25th percentile	1.05	0.77	0.57	0.13	-0.24
50th percentile	2.16	1.56	1.31	0.91	0.63
75th percentile	3.21	2.25	1.92	1.38	1.07

Table 2 — Volatility Skews (ex-Crisis sample from Q1 2005- Q2 2007 and from Q2 2009- Q4 2014)

	90% OTM put moneyness				
Maturity	1 month	2 months	3 months	6 months	12 months
Mean	5.67	2.20	3.57	1.51	2.93
Standard deviation	5.08	3.26	3.02	2.37	2.59
5th percentile	-0.09	-0.89	-0.17	-0.81	-0.33
25th percentile	3.07	1.04	2.23	0.81	1.88
50th percentile	5.30	2.12	3.61	1.56	3.02
75th percentile	7.57	3.14	4.91	2.22	4.08

	95% OTM put moneyness				
Maturity	1 month	2 months	3 months	6 months	12 months
Mean	0.78	2.02	0.78	1.30	0.30
Standard deviation	2.75	2.90	2.75	4.49	3.77
5th percentile	-1.66	-0.79	-1.66	-2.69	-3.62
25th percentile	0.28	1.21	0.28	0.75	-0.02
50th percentile	0.93	2.16	0.93	1.60	0.68
75th percentile	1.36	2.89	1.36	2.21	1.09

Table 3 shows the main statistical factors for volatility spreads. The spread, which is the difference between ATM call and ATM put option for the same maturity is minimal and non-homogenous among maturities.

TABLE 3 — VOLATILITY SPREADS

complete sample from Q1 2005 to Q4 2014

Maturity	10 days	1 month	2 months	3 months	6 months	12 months
Mean	-0.07	-0.04	0.02	0.10	0.37	0.69
Standard	3.37	2.45	2.21	2.27	2.70	3.53
5th percentile	-2.53	-2.12	-1.93	-1.87	-1.71	-1.75
25th	-0.07	-0.06	-0.02	0.00	0.00	0.00
50th	0.00	0.00	0.00	0.00	0.00	0.00
75th	0.11	0.13	0.20	0.32	0.66	0.99

ex-Crisis sample from Q1 2005- Q2 2007 and from Q2 2009- Q4 2014

Maturity	10 days	1 month	2 months	3 months	6 months	12 months
Mean	-0.10	-0.07	-0.04	0.02	0.24	0.55
Standard	3.22	2.12	1.94	1.98	2.48	3.54
5th percentile	-2.39	-2.04	-1.88	-1.81	-1.76	-1.84
25th	-0.08	-0.08	-0.06	-0.03	0.00	0.00
50th	0.00	0.00	0.00	0.00	0.00	0.00
75th	0.05	0.07	0.12	0.22	0.47	0.71

4.A. Regression Analysis Results

Table 4 illustrates the results from Eq. (3). Univariate model shows that volatility skew is statistically significant for options with maturity up to 3 months, with a peak of significance at 2 months maturity. Skew coefficient is always negative and any increase in volatility skew delivers negative stocks' returns in next week. A 1 basis point increase in current week average volatility skew (Tuesday close to Tuesday close) for 1 month OTM put option vs 1 month ATM call option produces a decrease in next week stock returns (Wednesday close to Wednesday close) by 1.37 bps. Options expiring in two months produce the greatest drawdown of -4.14 bps.

TABLE 4 — REGRESSION ANALYSIS ON VOLATILITY SKEWS

This table shows the main results from regression analysis of Eq. (3). The model measures the effect of implied volatility skew on next week banks stock' returns. Volatility skew is the difference between OTM put and ATM call and is computed for each time-to-maturity option. Panel A shows the univariate model comprehensive only of volatility skews, Panel B shows the full model with control variables. "Maturity" indicates the option's maturity, "Skew" is the associated volatility skew, "Crisis" is a dummy variable equal to 1 if the observation falls within Financial Crisis (form Q3 2007 to Q1 2009) and 0 otherwise, "MKT, SMB, HML and UMB" represent the Fama-French four factors model control variables for market returns, size, value and momentum. For each variable we report coefficient and t-stat. Coefficients (except for the dummy variable) represent the change in next week stock's prices when the considered variable increases by 100 bps. Bold figures represent coefficients statistically significant at a 5 or below percent level.

Panel A – Univariate Model

Maturity	1 month	2 months	3 months	6 months	12 months
Constant	-0.01%	0.06%	0.02%	-0.11%	-0.12%
	-0.30	1.23	0.45	**-2.75**	**-3.01**
Skew	-1.37%	-4.14%	-3.63%	0.80%	1.74%
	-2.47	**-3.82**	**-2.91**	0.70	1.81
R-squared	0.01	0.01	0.02	0.01	0.01
F-stat	6.12	14.55	8.48	0.49	3.17

Panel B – Full Model

Maturity	1 month	2 months	3 months	6 months	12 months
Constant	0.19%	0.25%	0.22%	0.11%	0.11%
	4.06	**4.73**	**4.31**	**2.55**	**2.61**
Skew	-1.27%	-3.58%	-3.35%	0.10%	0.96%
	-2.29	**-3.30**	**-2.69**	0.09	1.00
Crisis	-1.35%	-1.33%	-1.34%	-1.34%	-1.45%
	-15.94	**-15.62**	**-15.63**	**-15.15**	**-14.26**
MKT	0.16%	0.16%	0.16%	0.14%	0.14%
	7.93	**8.02**	**8.03**	**6.93**	**5.92**
SMB	-0.05%	-0.05%	-0.05%	-0.05%	-0.03%
	-1.25	-1.34	-1.31	-1.22	-0.76
HML	-0.21%	-0.21%	-0.21%	-0.20%	-0.23%
	-5.17	**-5.36**	**-5.34**	**-5.01**	**-4.95**
UMD	0.06%	0.06%	0.06%	0.05%	0.09%
	3.01	**2.89**	**2.91**	**2.56**	**3.61**
R-squared	0.05	0.05	0.06	0.05	0.05
F-stat	20.75	22.57	21.40	15.98	16.49

Table 5 illustrates our results from model presented in Eq. (4). In univariate model volatility spread is statistically significant for options with maturity from 2 to 12 months (with a peak of significance between 6 and 12 months) but when control variables are included, the model states that only 6 and 12 months' time-to-maturity options coefficients are statistically significant.

Spreads coefficient – when significant – is always positive, meaning that any increase in volatility spread delivers positive returns in next week. An increase of 1 bp in this week average volatility spread (Tuesday close to Tuesday close) for 6 months ATM options produces an increase in next week stock returns (Wednesday close to Wednesday close) by 5.78 bps in univariate model and by 3.57 bps in full model. Options expiring in twelve months produce the greatest increase of 6 bps in univariate model and 4.5 bps in full model.

TABLE 5 — REGRESSION ANALYSIS ON VOLATILITY SPREADS

This table shows the main results from regression analysis of Eq. (4). The model measures the effect of implied volatility spread on next week banks stock' returns. Volatility spread is the difference between ATM call and ATM put and is computed for each time-to-maturity option. Panel A shows the univariate model comprehensive only of volatility spreads, Panel B shows the full model with control variables. "Maturity" indicates the option maturity, "Spread" is the associated volatility spread, "Crisis" is a dummy variable equal to 1 if the observation falls within Financial Crisis and o otherwise "MKT, SMB, HML and UMB" represent the Fama-French four factors model control variables for market returns, size, value and momentum. For each variable we report coefficient and t-stat. Coefficients (except for dummy variable) represent the change in next week stock's prices when the considered variable increases by 100 bps. Bold figures represent coefficients statistically significant at a 5 or below percent level.

Panel A – Univariate Model

Maturity	10 days	1 month	2 months	3 months	6 months	12 months
Constant	-0.08%	-0.09%	-0.08%	-0.08%	-0.07%	-0.05%
	-2.56	**-2.75**	**-2.67**	**-2.45**	**-2.08**	-1.43
Spread	-0.32%	0.86%	4.22%	4.54%	5.78%	5.99%
	-0.33	0.66	**2.87**	**3.21**	**4.65**	**4.87**
R-squared	0.00	0.00	0.01	0.01	0.02	0.02
F-stat	0.11	0.43	8.21	10.31	21.66	23.67

Panel B – Full Model

Maturity	10 days	1 month	2 months	3 months	6 months	12 months
Constant	0.13%	0.12%	0.12%	0.12%	0.12%	0.15%
	3.52	**3.48**	**3.41**	**3.50**	**3.37**	**3.56**
Spread	0.06%	-0.16%	2.74%	2.65%	3.57%	4.54%
	0.06	-0.13	1.86	1.87	**2.85**	**3.66**
Crisis	-1.34%	-1.35%	-1.33%	-1.32%	-1.31%	-1.42%
	-15.53	**-15.89**	**-15.62**	**-15.63**	**-14.87**	**-14.00**
MKT	0.16%	0.16%	0.16%	0.16%	0.14%	0.14%
	8.01	**7.93**	**7.99**	**8.21**	**7.07**	**6.01**
SMB	-0.05%	-0.05%	-0.05%	-0.05%	-0.05%	-0.03%
	-1.33	-1.33	-1.42	-1.41	-1.30	-0.83
HML	-0.21%	-0.21%	-0.21%	-0.21%	-0.20%	-0.23%
	-5.16	**-5.20**	**-5.28**	**-5.40**	**-5.06**	**-4.95**
UMD	0.06%	0.06%	0.06%	0.06%	0.05%	0.09%
	2.74	**2.96**	**2.91**	**3.02**	**2.66**	**0.15%**
R-squared	0.04	0.05	0.05	0.05	0.05	0.06
F-stat	19.31	19.59	21.26	22.59	20.82	21.15

In order to verify which volatility skew (spread) leads in determining future equity returns and to cleanse the model from correlation between exogenous variables we perform a multivariate analysis, comprehensive of the entire term structure for volatility skews (spreads). Table 6 shows the model for volatility skews and volatility spreads. On volatility skew, exhibits from Table 6 confirm our findings in univariate analysis from Table 4 and 2 months volatility skew is the leading factor in conditioning future stock's returns. A 1 bp increase in 2 months volatility skew produces a negative return of 5 bps in next week. When volatility spread is considered results do confirm the positive correlation between spread and stocks' return but identifies 1 and 2 months' time-to-maturity options as the statistically significant ones instead of 6 and 12 months' time-to-maturity options highlighted in Table 5. Overall, when an the entire term structure of volatility skew and spread is considered more liquid options appear to be the most influencing ones.

TABLE 6 — MULTIVARIATE MODEL FOR SKEWS AND SPREADS

This table shows the main results from regression analysis of Eq. (5) and (6). The model measures how the entire term structure of skews and spreads volatility effects future equity returns of implied volatility. Volatility skews are obtained from Eq. (1) as the difference between OTM put and ATM call implied volatility. Volatility spreads are obtained from Eq. (2) as the difference between ATM call and ATM put option implied volatility. Volatility skews and spreads are computed for each time to maturity option covering the entire term structure. “Crisis” is a dummy variable equal to 1 if the observation falls within Financial Crisis and o otherwise “MKT, SMB, HML and UMB” represent the Fama-French four factors model control variables. For each variable is reported the coefficient and its t-stat. Coefficients (except for dummy variable) represent the change in weekly stock’s price when the considered variable increases by 100 bps. Bold figures represent coefficients statistically significant at a 5 or below percent level.

Maturity	Skew	Skew	Spread	Spread
Constant	0.12%	0.30%	-0.05%	0.15%
	1.69	**4.10**	-1.37	**3.50**
10 days			-2.71%	-3.60%
			-0.70	-0.93
1 month	-0.65%	-0.63%	11.46%	11.24%
	-0.90	-0.88	**2.02**	**1.99**
2 months	-5.72%	-4.99%	15.59%	15.60%
	-2.39	**-2.09**	**2.98**	**2.98**
3 months	-0.33%	0.62%	6.66%	8.15%
	-0.12	0.22	1.46	1.78
6 months	1.48%	1.08%	-4.27%	-2.35%
	0.88	0.64	-1.57	-0.86
12 months	2.23%	1.33%	-3.88%	-3.24%
	2.14	1.27	**-2.31**	-1.92
Crisis		-1.43%		-1.42%
		-14.00		**-13.57**
MKT		0.14%		0.14%
		5.94		**5.80**
SMB		-0.03%		-0.03%
		-0.76		-0.71
HML		-0.24%		-0.23%
		-5.03		**-4.77**
UMD		0.09%		0.08%
		3.58		**3.36**
R-squared	0.03	0.10	0.03	0.10
F-stat	4.55	29.92	5.68	26.69

4.B. Portfolio Analysis Results

Portfolios are built from weekly volatility skew distribution. Every week we rank all banks according to their volatility skew. Those banks with higher skews will have higher ranks while those with lower skews will have lower ranks. The result from this procedure is a time series of ranking values for each bank.

We build four portfolios by investing each week in those banks which fall in 1st and 5th quintiles and 1st and 10th deciles of the above illustrated ranking. By doing so, our 1st quintile and 1st decile portfolios will perform a strategy which is long stocks belonging to the lower-end of implied volatility skews distribution (hence those stocks with OTM put option far more expensive than ATM call option) and our 5th quintile and 10th decile portfolios will perform a strategy which is long those stocks belonging to the upper-end of volatility skews distribution. The procedure is repeated for different moneyness levels and different time-to-maturity options until we generate a total of 40 portfolios relying on volatility skew (since we selected two different moneyness levels, 0.90 and 0.95, five different time to maturity, 1 month and 2, 3 6 and 12 months, first and last quintiles and first and last deciles) and a total of 20 portfolios relying on volatility spread (since we select ATM level, five different time to maturity, 1 month and 2, 3 6 and 12 months, first and last quintiles and first and last deciles). All portfolios have approximately 500 observations.

Portfolio returns analysis supports our findings from regression analysis in section 4.A and the above mentioned literature. Quintiles portfolios are statistical significant and lower quintile (decile) portfolios underperform upper quintile (decile) portfolios for almost all time-to-maturities and all moneyness levels. Regarding volatility skew, a portfolio of stocks based on 1st decile, 90% moneyness, 2 months maturity options underperform its upper decile equivalent by 19 basis points per week. This underperformance is even bigger if we exclude the financial crisis from the dataset (24 basis points) or if we consider only the sample after the financial crisis (25 basis point).

Considering volatility spread, portfolio based on 1st decile, 3 months to maturity options underperform its equivalent upper decile by 19 basis points per week, by 29 basis points if we exclude the financial crisis from the sample and by 24 basis points if we consider only the sample after the financial crisis.

When we exclude financial crisis from our sample, all portfolio returns are shifted upward and almost all perform a positive return. Still, underperformance of left hand side skew distribution portfolios (1st quintile and 1st decile) with respect to right hand side distribution (5th quintile and 10th quintile) stands strong. Similar results are obtained for a pre-crisis sample (from Q1 2005 to Q2 2007) and for after crisis sample (from Q2 2009 to Q4 2014).

In Table 7 we consider two different volatility skews, one computed using 90% OTM put option and another computed using 95% put option. An overview on average weekly returns shows that 1st quintiles and 1st deciles portfolios always deliver returns significantly lower than 5th quintiles and 10th deciles portofolios. For 90% moneyness level of volatility skew, investing in a portfolio based on 1st decile implied volatility skews for an option expiring in 2 months delivers a negative return of -17 bps per week. For 95% moneyness level, investing in a portfolio based on 1st decile implied volatility skews for an option expiring in 1 month delivers a negative return of -21 bps per week.

TABLE 7 — PORTFOLIO ANALYSIS ON VOLATILITY SKEWS

This table shows the results from portfolio analysis on volatility skews for different time to maturity options. Portfolio of banks are built according to weekly volatility skew distribution. Each week a volatility skew distribution is computed and banks are ranked according to this distribution, higher values of skew have higher ranks while lower values of skew have lower ranks. For 90% and 95% moneyness levels four portfolios are computed using 1st and 5th quintiles and 1st and 10th deciles of the distribution. Bold figures represent coefficients statistically significant at a 5 or below percent level.

Skew for 90% OTM put option

Option time to maturity	Quintiles 1st	5th	5th – 1st (bps)	Deciles 1st	10th	10th – 1st (bps)
1 month	-0.17%	-0.01%	15.45	-0.11%	0.05%	16.07
	-2.04	-0.20		-1.35	0.74	
2months	-0.17%	0.02%	19.16	-0.17%	0.02%	18.83
	-2.12	0.28		**-1.98**	0.28	
3 months	-0.14%	0.02%	15.49	-0.12%	0.04%	16.08
	-1.74	0.26		-1.48	0.58	
6 months	-0.16%	-0.07%	9.39	-0.14%	-0.10%	4.24
	-2.10	-0.95		-1.83	-1.19	
12 months	-0.11%	-0.15%	-3.68	-0.12%	-0.08%	3.76
	-1.26	-1.74		-1.19	-0.79	

Skew for 95% OTM put option

Option time to maturity	Quintiles 1st	5th	5th – 1st (bps)	Deciles 1st	10th	10th – 1st (bps)
1 month	-0.21%	-0.01%	20.07	-0.24%	0.02%	26.08
	-2.53	-0.09		-1.93	0.18	
2months	-0.12%	-0.02%	10.23	-0.16%	-0.07%	8.85
	-1.46	-0.28		-1.32	-0.68	
3 months	-0.09%	-0.04%	4.85	-0.14%	-0.16%	-1.95
	-1.11	-0.53		-1.27	-1.54	
6 months	-0.14%	-0.12%	1.93	-0.16%	-0.21%	-4.99
	-1.78	-1.56		-1.57	-1.89	
12 months	-0.07%	-0.16%	-8.24	-0.09%	-0.24%	-14.87
	-0.84	-1.82		-0.75	-1.73	

Table 8 shows results for portfolio analysis on implied volatilities spreads. Portfolios are built using the same rationale in Table 7 although the rank is based on implied volatility spread, hence banks with higher spread receive a higher rank and banks with lower spread a lower rank. As for Table 7 deciles portfolio fail to deliver wide statistical significant return since only 1st deciles portfolio returns show stronger statistical significance. General results show that stocks with relative more expensive ATM put than ATM call will suffer from drawdown in future prices but there is no evidence supporting any informational content in spreads for upside movements. More in specific, 1st quintile portfolio based on 2, 3, 6 and 12 months' time to maturity options deliver significant negative weekly return. 1st decile portfolio based on volatility spread from 6 months' time to maturity option will deliver a negative weekly return of -32 bps, 18 bps lower than its 10th decile equivalent.

TABLE 8 — PORTFOLIO ANALYSIS ON VOLATILITY SPREADS

This table shows the results from portfolio analysis on volatility spreads for different time to maturity options. Portfolio of banks are built according to weekly volatility spread distribution. Each week a volatility spread distribution is computed and banks are ranked according to this distribution, higher values of spread have higher ranks while lower spread have lower ranks. Four portfolios are computed using 1st and 5th quintiles and 1st and 10th deciles of the distribution. Bold figures represent coefficients statistically significant at a 5 or below percent level.

Option time to maturity	Quintiles			Deciles		
	1st	5th	5th – 1st (bps)	1st	10th	10th – 1st (bps)
10 days	-0.04%	-0.08%	-4.31	-0.08%	-0.12%	-4.24
	-0.81	-1.04		-1.25	-1.06	
1 month	-0.15%	-0.05%	9.90	-0.06%	-0.13%	-6.40
	-2.90	-0.67		-0.99	-1.18	
2months	-0.22%	-0.11%	11.13	-0.12%	-0.05%	7.43
	-4.00	-1.34		-1.89	-0.45	
3 months	-0.22%	0.00%	21.82	-0.20%	-0.01%	19.36
	-3.92	-0.03		**-3.01**	-0.09	
6 months	-0.24%	-0.07%	17.47	-0.32%	-0.14%	18.25
	-4.58	-0.88		**-4.83**	-1.19	
12 months	-0.27%	-0.11%	16.16	-0.22%	-0.11%	11.17
	-4.89	-1.14		**-3.17**	-0.78	

Generally speaking we can conclude that volatility skew is strongly negative correlated with future equity returns and volatility spread is strongly positive correlated with future equity returns. But not all option contracts affect equity returns the same, the most active contracts, 2 and 3 months' time to maturity options, appear to be also the relevant ones.

C. Investment Horizon

In order to verify the lasting effect of implied volatility skews and spreads on future week stock returns we perform a regression analysis with lagged values of skew (spread) up to 12 weeks as exogenous variables.

General results show that, when lagged values of skew (spread) are considered, variables coefficient are affected by market microstructure noise. Although coefficients' sign mostly validate our findings from Eq. (3) and (4) adding lags brings a sort of correction effect in weekly returns. Table 9 shows the results from the model presented in Eq. (5) and (6).

TABLE 9 — STRETCHING THE INVESTMENT HORIZON FOR SKEW AND SPREAD

This table shows results from model presented in Eq. (7) and Eq. (8). The model performs a regression analysis on future equity returns using lagged values of volatility skew (spread) up to 12 weeks, for the entire term structure. The focus of this model is to estimate the persistency of skew (spread) in shaping future returns over time. Options expiring in one month present a series of lagged exogenous variables truncated to 4 weeks and options expiring in two months a series truncated to 8 weeks. Each regression present coefficient and t-stat for the considered lagged values of skew (spread). Coefficients represent the change in weekly stock's price when the considered variable increases by 100 bps. Bold figures represent coefficients statistically significant at a 5 or below percent level.

	Skew					Spread				
	1 month	2 months	3 months	6 months	12 months	1 month	2 months	3 months	6 months	12 months
1 week	-0.80%	-3.77%	-5.60%	-0.60%	0.71%	5.05%	9.49%	8.63%	5.32%	5.22%
	-1.29	**-2.45**	**-3.50**	-0.30	0.43	**2.74**	**4.21**	**3.67**	**2.43**	1.64
2 weeks	-0.27%	2.88%	2.80%	0.77%	4.12%	-3.54%	-3.75%	-2.40%	0.97%	8.06%
	-0.40	1.74	1.67	0.36	**2.25**	-1.84	-1.54	-0.92	0.40	**2.11**
3 weeks	-1.00%	-3.69%	-3.65%	2.06%	-0.75%	-4.79%	-5.43%	-3.78%	0.53%	-11.17%
	-1.52	**-2.22**	**-2.16**	0.94	-0.41	**-2.46**	**-2.19**	-1.43	0.21	**-2.91**
4 weeks	-0.62%	2.43%	2.61%	6.45%	3.45%	7.87%	9.01%	9.98%	9.81%	15.10%
	-1.00	1.49	1.55	**2.95**	1.93	**4.05**	**3.65**	**3.78**	**3.97**	**3.95**
5 weeks	-	-1.58%	-2.01%	-2.74%	-0.63%		2.39%	2.25%	4.03%	5.83%
		-0.96	-1.19	-1.25	-0.35		0.99	0.87	1.65	1.55
6 weeks	-	2.87%	1.55%	0.90%	-0.84%		-1.37%	-0.54%	0.97%	-1.15%
		1.73	0.96	0.42	-0.51		-0.59	-0.22	0.41	-0.33
8 weeks	-	-2.86%	0.18%	-2.34%	-2.88%		1.06%	3.90%	3.03%	5.56%
		-1.73	0.12	-1.13	-1.95		0.49	1.73	1.26	1.82
10 weeks	-	-	-2.40%	-2.59%	0.52%			3.97%	4.27%	3.08%
			0.10	-1.21	0.35			1.78	1.66	1.02
12 weeks	-	-	0.83%	0.23%	1.48%			-6.79%	-2.82%	-4.80%
			0.60	0.13	1.16			**-3.43**	-1.27	-1.92
R-squared	0.00	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.03
F-stat	3.15	5.91	4.22	1.65	2.72	6.15	6.37	6.19	6.97	10.77

5. Conclusions

In this paper we investigate how implied volatility skews and implied volatility spreads affect banks' stock performance. In order to do that, we perform a regression and a portfolio analysis. In the regression analysis we analyze next week stocks return over previous week volatility skew (spread). Regression is performed both in a univariate and multivariate framework. Multivariate analysis includes the entire term structure of volatility skews (spreads) and is useful to cleanse the model from any correlation among exogenous variables.

Our findings show a negative correlation between skew and future returns, suggesting that volatility skew capture traders' expectation about downfalls in future stock returns. Negative correlation is statistically significant only for short term time-to-maturity options and when we perform a multivariate analysis, 2 months to maturity options appear to be the leading contract in influencing future returns.

Volatility spread, on the other hand, appears to be positive correlated with next week stock returns, suggesting that an overprice in ATM call with respect to ATM put option delivers statistically significant positive returns in next week. When we perform univariate model, longer maturity options show statistically significant results, however when we implement a multivariate model, 2 months to maturity options is the only one with statistically significant positive coefficient.

In portfolio analysis we perform investment strategies based on lower and upper end of volatility skews distribution and volatility spreads distribution. For the lower end of the distribution we create two portfolios: one investing in the 1st quintile and another investing in the 1st decile. For the upper end of the distribution we create two portfolios: one investing in the 5th quintile and another investing in the 10th decile. We ran the procedure for the entire volatility term structure, resulting in 40 portfolios generated for volatility skew and 20 for volatility spread. Results show that investing in stocks which permanently falls within the 1st decile of volatility skew distribution underperforms those stocks which belong to the 10th decile up to 26 basis points when we consider the entire sample, and by 24 bps if we exclude the financial crisis from the considered time frame.

Volatility spread shows similar results, if we invest in stocks which fall within the 1st decile of volatility spread distribution we underperform those stocks which belong to the 10th decile up to 19 bps when we consider the entire sample, and 29 bps if we exclude the financial crisis.

Summing up we can conclude that skew is negative correlated with future equity returns and spread is positive correlated with future equity returns. Also, option contracts expiring in two months – which together with 3 months maturity are the most liquid contracts – seem to deliver most of the informational content about future returns. This paper expanded the field of study for option implied volatility informational content by analyzing the financial industry and splitting option informational content among different time to maturities and moneyness levels.

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APPENDIX

TABLE A.1 — PORTFOLIO ANALYSIS ON VOLATILITY SKEW AND SPREAD (EX-CRISIS)

This table shows the results from portfolio analysis on volatility skews and spread for different time to maturity options. Portfolio of banks are built according to weekly volatility skew (spread) distribution. Each week a volatility skew (spread) distribution is computed and banks are ranked according to this distribution, higher values of skew (spread) have higher ranks while lower values of skew (spread) have lower ranks. Four portfolios are computed using 1^{st} and 5^{th} quintiles and 1^{st} and 10^{th} deciles of the distribution. The considered time frame is from Q1 2005 to Q2 2007 and from Q2 2009 to Q4 2014, in order to exclude the financial crisis period from the sample. Bold figures represent coefficients statistically significant at a 5 or below percent level.

Skew for 90% OTM put option

Option time to maturity	Quintiles 1^{st}	Quintiles 5^{th}	5^{th} – 1^{st} (bps)	Deciles 1^{st}	Deciles 10^{th}	10^{th} – 1^{st} (bps)
1 month	0.10%	0.24%	14.28	0.087%	0.319%	23.26
	-2.04	-0.20		0.57	**2.56**	
2months	0.07%	0.19%	12.40	-0.009%	0.234%	24.30
	-2.12	0.28		-0.06	**1.74**	
3 months	0.10%	0.18%	7.78	0.120%	0.261%	14.14
	-1.74	0.26		0.75	**1.73**	
6 months	0.07%	0.11%	4.11	0.060%	0.097%	3.71
	-2.10	-0.95		0.37	0.58	
12 months	0.15%	0.03%	-11.85	0.092%	0.102%	1.04
	-1.26	**-1.74**		0.47	0.63	

Skew for 95% OTM put option

Option time to maturity	Quintiles 1^{st}	Quintiles 5^{th}	5^{th} – 1^{st} (bps)	Deciles 1^{st}	Deciles 10^{th}	10^{th} – 1^{st} (bps)
1 month	0.09%	0.22%	12.79	0.06%	0.27%	21.46
	-2.53	-0.09		**-1.93**	0.18	
2months	0.15%	0.15%	0.68	0.07%	0.16%	9.41
	-1.46	-0.28		-1.32	-0.68	
3 months	0.18%	0.15%	-3.22	0.17%	0.06%	-10.36
	-1.11	-0.53		-1.27	-1.54	
6 months	0.10%	0.07%	-3.24	0.06%	0.02%	-3.67
	-1.78	-1.56		-1.57	**-1.89**	
12 months	0.14%	0.03%	-11.52	0.14%	-0.02%	-16.36
	-0.84	**-1.82**		-0.75	**-1.73**	

Spread

Option time to maturity	Quintiles 1^{st}	Deciles 5^{th}	Quintiles 1^{st}	Deciles 5^{th}	Quintiles 1^{st}	Deciles 5^{th}
10 days	0.03%	0.23%	20.65	0.00%	0.21%	21.27
	-0.81	-1.04		-1.25	-1.06	
1 month	0.05%	0.22%	16.98	0.02%	0.14%	11.96
	-2.90	-0.67		-0.99	-1.18	
2 months	0.01%	0.20%	18.60	-0.01%	0.20%	20.97
	-4.00	-1.34		**-1.89**	-0.45	
3 months	0.04%	0.26%	22.10	-0.06%	0.23%	29.53
	-3.92	-0.03		**-3.01**	-0.09	
6 months	0.03%	0.19%	15.88	-0.04%	0.12%	16.16
	-4.58	-0.88		**-4.83**	-1.19	
12 months	0.03%	0.16%	12.76	0.01%	0.15%	14.36
	-4.89	-1.14		**-3.17**	-0.78	

TABLE A.2 — PORTFOLIO ANALYSIS ON VOLATILITY SKEW AND SPREAD (PRE CRISIS)

This table shows the results from portfolio analysis on volatility skews and spread for different time to maturity options. Portfolio of banks are built according to weekly volatility skew (spread) distribution. Each week a volatility skew (spread) distribution is computed and banks are ranked according to this distribution, higher values of skew (spread) have higher ranks while lower values of skew (spread) have lower ranks. Four portfolios are computed using 1^{st} and 5^{th} quintiles and 1^{st} and 10^{th} deciles of the distribution. The considered time frame is from Q1 2005 to Q2 2007. Bold figures represent coefficients statistically significant at a 5 or below percent level.

Skew for 90% OTM put option

Option time to maturity	Quintiles 1^{st}	Quintiles 5^{th}	Quintiles $5^{th} – 1^{st}$ (bps)	Deciles 1^{st}	Deciles 10^{th}	Deciles $10^{th} – 1^{st}$ (bps)
1 month	0.10%	0.24%	14.28	0.087%	0.319%	23.26
	-2.04	-0.20		0.57	**2.56**	
2months	0.07%	0.19%	12.40	-0.009%	0.234%	24.30
	-2.12	0.28		-0.06	**1.74**	
3 months	0.10%	0.18%	7.78	0.120%	0.261%	14.14
	-1.74	0.26		0.75	**1.73**	
6 months	0.07%	0.11%	4.11	0.060%	0.097%	3.71
	-2.10	-0.95		0.37	0.58	
12 months	0.15%	0.03%	-11.85	0.092%	0.102%	1.04
	-1.26	**-1.74**		0.47	0.63	

Skew for 95% OTM put option

Option time to maturity	Quintiles 1^{st}	Quintiles 5^{th}	Quintiles $5^{th} – 1^{st}$ (bps)	Deciles 1^{st}	Deciles 10^{th}	Deciles $10^{th} – 1^{st}$ (bps)
1 month	0.09%	0.22%	12.79	0.06%	0.27%	21.46
	-2.53	-0.09		**-1.93**	0.18	
2months	0.15%	0.15%	0.68	0.07%	0.16%	9.41
	-1.46	-0.28		-1.32	-0.68	
3 months	0.18%	0.15%	-3.22	0.17%	0.06%	-10.36
	-1.11	-0.53		-1.27	-1.54	
6 months	0.10%	0.07%	-3.24	0.06%	0.02%	-3.67
	-1.78	-1.56		-1.57	**-1.89**	
12 months	0.14%	0.03%	-11.52	0.14%	-0.02%	-16.36
	-0.84	**-1.82**		-0.75	**-1.73**	

Spread

Option time to maturity	Quintiles 1^{st}	Deciles 5^{th}	Quintiles 1^{st}	Deciles 5^{th}	Quintiles 1^{st}	Deciles 5^{th}
10 days	-0.81	-1.04		-1.25	-1.06	
	0.05%	0.22%	16.98	0.02%	0.14%	11.96
1 month	**-2.90**	-0.67		-0.99	-1.18	
	0.01%	0.20%	18.60	-0.01%	0.20%	20.97
2 months	**-4.00**	-1.34		**-1.89**	-0.45	
	0.04%	0.26%	22.10	-0.06%	0.23%	29.53
3 months	**-3.92**	-0.03		**-3.01**	-0.09	
	0.03%	0.19%	15.88	-0.04%	0.12%	16.16
6 months	**-4.58**	-0.88		**-4.83**	-1.19	
	0.03%	0.16%	12.76	0.01%	0.15%	14.36
12 months	**-4.89**	-1.14		**-3.17**	-0.78	
	-0.81	-1.04		-1.25	-1.06	

TABLE A.3 — PORTFOLIO ANALYSIS ON VOLATILITY SKEW AND SPREAD (POST CRISIS)

This table shows the results from portfolio analysis on volatility skews and spread for different time to maturity options. Portfolio of banks are built according to weekly volatility skew (spread) distribution. Each week a volatility skew (spread) distribution is computed and banks are ranked according to this distribution, higher values of skew (spread) have higher ranks while lower values of skew (spread) have lower ranks. Four portfolios are computed using 1st and 5th quintiles and 1st and 10th deciles of the distribution. The considered time frame is from Q2 2009 to Q4 2014. Bold figures represent coefficients statistically significant at a 5 or below percent level.

Skew for 90% OTM put option

Option time to maturity	Quintiles 1st	5th	5th – 1st (bps)	Deciles 1st	10th	10th – 1st (bps)
1 month	0.06%	0.22%	15.83	0.075%	0.335%	25.99
	-2.04	-0.20		0.33	**1.85**	
2months	0.02%	0.19%	16.87	-0.072%	0.180%	25.21
	-2.12	0.28		-0.31	0.92	
3 months	0.04%	0.17%	12.74	0.085%	0.244%	15.87
	-1.74	0.26		0.36	1.10	
6 months	0.01%	0.08%	7.28	-0.021%	0.039%	6.01
	-2.10	-0.95		-0.09	0.16	
12 months	0.11%	-0.01%	-11.37	0.097%	0.111%	1.42
	-1.26	**-1.74**		0.33	0.46	

Skew for 95% OTM put option

Option time to maturity	Quintiles 1st	5th	5th – 1st (bps)	Deciles 1st	10th	10th – 1st (bps)
1 month	0.05%	0.20%	15.18	0.02%	0.26%	24.11
	-2.53	-0.09		**-1.93**	0.18	
2months	0.12%	0.13%	0.62	0.04%	0.12%	8.11
	-1.46	-0.28		-1.32	-0.68	
3 months	0.16%	0.13%	-3.61	0.14%	0.01%	-12.38
	-1.11	-0.53		-1.27	-1.54	
6 months	0.06%	0.04%	-1.83	-0.02%	-0.02%	-0.16
	-1.78	-1.56		-1.57	**-1.89**	
12 months	0.11%	0.01%	-10.72	0.11%	-0.03%	-13.77
	-0.84	**-1.82**		-0.75	**-1.73**	

Spread

Option time to maturity	Quintiles 1st	Deciles 5th	Quintiles 1st	Deciles 5th	Quintiles 1st	Deciles 5th
10 days	-0.01%	0.19%	19.72	-0.01%	0.17%	18.23
	-0.81	-1.04		-1.25	-1.06	
1 month	0.02%	0.14%	12.68	0.00%	0.02%	1.19
	-2.90	-0.67		-0.99	-1.18	
2 months	-0.03%	0.14%	16.70	-0.02%	0.08%	10.91
	-4.00	-1.34		**-1.89**	-0.45	
3 months	-0.04%	0.21%	25.86	-0.12%	0.12%	24.76
	-3.92	-0.03		**-3.01**	-0.09	
6 months	-0.05%	0.13%	17.89	-0.10%	0.04%	14.03
	-4.58	-0.88		**-4.83**	-1.19	
12 months	0.00%	0.10%	10.01	-0.04%	0.08%	12.56
	-4.89	-1.14		**-3.17**	-0.78	

Chapter II – Volatility risk measures and banks' leverage

By GIULIO ANSELMI

In this paper we investigate how volatility risk may influence bank's capital structure when we allow for the possibility that bank's capital provisions depends from variables other than mandatory capital regulation. By identifying four volatility risk measure and regressing them over bank's market leverage we studied how banks adjust their balance sheet when they discount a risk premia from traders. The four volatility risk measures are volatility skew, volatility spread, variance risk premia and realized volatility. Among these four volatility skew, which is the difference between OTM put and ATM call implied volatility and absorb traders perceived tail risk delivers the strongest result if affecting bank's leverage. In particular as volatility skew increases – hence OTM put became more expensive than ATM call – banks deleverage their assets structure. One plausible explanation is connected to the higher costs which should face the bank when raises new equity during a period of distress. As bank faces the possibility to incur in expensive equity issuing deleverage its balance sheet and create a buffer.

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1. Introduction

In this paper we focus on the informational content of exchange-traded options to detect banks' capital structure adjustments and whether implied volatility can predict future changes in banks' capital structure.

Banks' minimum capital requirements work as a buffer in absorbing losses and in bounding risk taking and they also partially amend to the moral hazard resulting from deposit insurance. Although the need for capital requirements is not in discussion, their calibration is still a hot topic and fine tuning them is important to identify the right amount of cash to put aside for depositors' and other stakeholders' protection from financial crisis without compromising banks' efficiency.

Efficient asset allocation is vital for banking sector which invests depositors' money in borrowers' business and where any loan loss from banking activity may compromise bank's profitability and require an injection of additional capital, either in bail out or bail in form.

Recent financial crisis shed light on the misleadingness of existing capital provisions and how they are affected from mark-to-market of assets held for sales – such as sovereign bonds or other securities – or how they are undermined from losses on lending activity. This weakness opened some space for discussions on the efficiency of current capital ratios and buffers and which are the determinants of financial leverage. Is it solely dependent on capital regulation or relies also on other factors? In this framework previous literature, on non-financial corporates' capital structure and on the effectiveness of market signals in enhancing regulatory tools, may come in help in understanding the determinants for banks' financial leverage and how to fix it.

In order to investigate capital structure decision and which factors are crucial in determining it, we should first emancipate from the view that banks' capital – due to the high costs of holding it – is solely defined by capital requirements regulation and only this constraint justifies its departure from Modigliani and Miller [1958] proposition of irrelevance. Once we assume that capital structure is affected by some bank's specific features we are free to investigate balance sheet items as much as market variables in order to discover which factors are more critical and if the risk priced by investors plays a role in determining banks' financial leverage.

If traders' quote for risk premia on banks affects the financial leverage market discipline, which is defined as a series of corrective actions taken by authorities based on the screening of market prices, could represent an additional tool in reinforcing capital requirements efficiency.

When market discipline is the topic, previous studies offer a broad range of securities to focus on. While subordinated debt and credit default swaps have been already discussed by previous literature, we focus our attention on implied volatility derived from options and how this risk measure affects the dynamics of banks' capital structure.

Option-based risk measures deliver several advantages with respect to accounting measures. First of all, they are forward looking measure based on traders' expectations about equity future prices rather than accounting based measure which are backward looking and lagged indicators. Second, option prices are computed at much higher frequencies than traditional measures hence they adapt to changing market conditions quickly and can help delivering informational content about banks' capital structure. Third, by selecting different type of options and moneyness levels one can detect different kinds of risks.

Also, options market is a suitable environment for informed traders thanks to the high use of leverage, the asymmetric payoff and no constraint in short selling. Options give the opportunity but not the obligation to buy or sell a specific asset at a specific price within – or at – a specific point in time. Traders operate in option market by quoting their implied volatilities for different maturities and moneyness according to their view on future stock's returns. The result of this trading produces volatility skews, smirks and spreads which get away from Black and Scholes [1973] environment of constant volatility across all maturity and all moneyness.

By studying the effect of implied volatility measure on banks' leverage we want to investigate whether traders preemptively discount future changes in financial leverage and hence whether they account for any capital distress in banks. If a bank is expected to face assets' impairments will most probably put aside more capital as a buffer in order to face those losses without going through the costs from raising equity at short notice. By using a measure of equity-related risk we should be able to proxy asset risk which is critical for banks. Using equity-based data as proxy for asset-risk, among several studies and literatures, has been stressed out – for financial institutions – by Huang et al. [2009].

Our study is conducted via a regression analysis on a panel dataset of banks' balance sheets and their corresponding implied volatilities and is organized as follows: First, we investigates whether volatility risk measure affect banks market leverage then we add to the analysis control variables in order to evidence the second order importance of capital regulation in determining capital structure as already exposed by Gropp and Heider [2009]. In order to cope with heteroskedasticity and serial correlation issues standard errors are clustered at bank level as suggested by Peterson [2009]. As a robusteness check we run the analysis also on leverage and option-implied volatility risk measure changes.

As banks' leverage measure we identify a market-based measure denoted as $1 - \frac{market\ cap}{assets}$. Table 1 describes the main characteristics of banks' leverage.

As a risk measures we select three different option-based variables and one stock-based variable. Volatility skew, which can be shortly defined as the difference in implied volatility between out-of-the-money (OTM) put and at-the-money (ATM) call and should capture expectations about a left tail event in stock prices. Volatility spread, which is the difference between ATM call implied volatility and ATM put implied volatility and should capture expectations about future stock performance. Variance Risk Premia (VRP hereafter) as the difference between ATM call implied volatility and realized volatility from historical returns which captures changes in perceived riskiness of the bank. As stock-based risk measure we select realized volatility.

In our study we discovered that volatility skew negatively affects market leverage and hence any increase in trader's perceived downturn risk is translated into a reduction of market leverage in the next quarter. As pointed out by Gropp and Heider [2009] for non-financial firms, it seems that a perception of a riskier business leads to higher costs for raising more equity in case of needs for bank's recapitalization and henceforth banks which are interested in avoiding these costs conduct a deleverage in their capital structure.

On the other hand, volatility spread produces an increase in asset leverage as a better outlook for firm's business is translated into an increase of upward potential in stock markets. The same happens for VRP which delivers an increase in bank's leverage as the premium over past volatility levels increases. This relationship is somehow in opposition with what we found for volatility skew and what Borochin and Yang [2014] discovered for non-financial firms. Finally, realized volatility negatively affects bank's leverage.

This paper is organized as follow, Section 1 is the introduction, Section 2 presents previous literature related to the topic, Section 3 describes the data and the methodology used in the analysis, Section 4 illustrates the results and robustness check analysis and Section 5 concludes.

2. Previous Literature

Berger et al. [1995] investigate the role of capital for financial institutions and how a market-generated capital requirement differs from regulatory requirements and Santos [2001] reviews the literature on the design of the financial system and on bank capital regulation presenting as well a list of the market failures that justify banking regulation. Barth et al. [2005], Berger et al. [2008] and Brewer et al. [2008] observe that bank capital's levels are higher than what regulation dictates opening up for discussion about what determines this buffers. On non-binding capital requirements and banks' capital structure flexibility see Flannery [1994], Myers and Rajan [1998], Diamond and Rajan [2000] and Allen et al. [2009]. On the other hand Flannery and Nikolova [2004] and Gropp [2004] offer a survey on non-binding capital requirements in a market discipline framework.

Also, Gropp and Heider [2009] see capital regulation only as a second order factor in determining capital structure for large banks and capital buffers held to to avoid falls below minimum capital requirements also fail to explain the high levels of banks' discretionary capital detained. Instead, with exception for those banks whose capital ratio is close to regulatory minimum, market leverage is driven by market-to-book-ratio, bank's size, dividends and risk – where risk is defined as the annualized standard deviation of daily stock price returns adjusted by the market capitalization to total assets ratio. They investigate also whether macro variables affect book and market leverage and find out that inflation and stock markets' risk decrease market leverage while spread's term structure increases it. Brunnermeier et al. [2008] distinguish between regulatory and market based capital.

Chernyk and Cole [2014] test the predictive power of several alternative measures of bank capital adequacy in identifying US bank failures during the recent crisis period. They found out that non-performing asset coverage ratio

(NPACR) significantly outperforms Basel-based ratios throughout the crisis period by accounting for both banking risks and asset quality, aligning capital and credit risk, eliminating banking management incentives to mask capital deficiency and allowing to account for various time period and cross-country provisioning rules.

Sorokina and Thornton [2014] show that loan market competition and loan portfolio diversification reduce banks' leverage and excess leverage and short-term borrowing of banks increase in low market liquidity conditions. They also state that banks' capital structure significantly affects capital structure of non-financial firms since an increase in banks' holding of capital reduces firms' leverage.

Valencia [2011] explains how monetary policy rates affect bank risk-taking and its leverage by showing that under limited liability a decrease in interest rate produces an increase in banks profitability which could lead to take excessive risk and leverage.

On the relationship between market returns and capital ratios Demirguc-Kunt et al. [2010] use a multi-country panel of banks to study whether better capitalized banks experienced higher stock return during financial crisis. They find out that before the crisis differences in capital did not have much impact on stock returns while during the financial crisis a stronger capital position was associated with better stock market performance and relationship between stock returns and capital is stronger when capital is measured by Tier I capital to total asset leverage ratio.

Calem and Rob [1998] identify a U-shape relationship between bank capital and risk. As their capital increases banks first take less risk, then more risk. A deposit insurance premium surcharge on undercapitalized banks induces them to take more risk and an increased capital requirement, whether flat or risk-based, tends to induce more risk-taking by ex-ante well-capitalized banks that comply with the new standard.

Berger and Bouwman [2013] examine how capital affects a bank's performance and state that capital helps small banks to increase their profitability of survival and market share at all times while for large banks enhances performance primarily during banking crisis.

Previous literature on capital structure determinants mostly focus on non-financial firms and Frank and Goyal [2009] in examining which factors are relevant in capital structure decisions for American firms notice that the most reliable factors for explaining an increase in market leverage are median industry leverage, tangibility of assets, log of assets and expected inflation and for explaining a decrease in capital ratios are market-to-book ratio and firm's profits. Book leverage indicates similar results. While Welch [2004] and Lemmon et al. [2008] find out that risk significantly reduces leverage. Negative correlation between risk and leverage agrees with traditional corporate finance literature as well as with regulatory view, where, riskier banks are required to hold more equity in order to prevent any solvency or liquidity issues.

Regarding implied volatility risk measure and its application to firms, Bates [1991] states that the set of index call and put option prices across different moneyness levels gives a direct indication of market participants' aggregate subjective distribution of future price realizations. Therefore, OTM puts become more expensive compared to ATM calls and volatility skew increases before big negative jumps in price levels. In his paper shows that out-of-the money puts became unusually expensive during the year preceding the 1987 crash and by setting a model for pricing American option on jump-diffusion processes with systematic jump risk is shown that jump-diffusion parameters implicit in option prices indicate a crash was expected and that implicit distributions were negatively skewed in the year preceding 1987.

Pan [2002] documents that informational content of volatility smirk for the S&P 500 index option with 30 days to expiration is 10% on a median volatility day, in his paper he incorporates both jump risk premium and volatility risk premium and shows that investors' aversion toward negative jumps is the driving force for volatility skew. For OTM put options the jump risk premium component characterizes 80% of total risk premium, while the jump premium for OTM calls is just 30% of total risk premium.

Doran et al. [2006] use a probit model for all options on S&P 100 from 1996 to 2002 to demonstrate that the shape of the skew can reveal with significant probability when the market will "crash" or "spike". Their findings suggest that there is predictive information content in volatility skew and put-only volatility skew has strong predictive power in forecasting short-term market declines.

Xing et al. [2010] show that implied volatility smirk (defined has the difference between the implied volatilities of OTM put options and the implied volatilities of ATM call options is persistent and has significant predictive power for future equity returns. In their study stocks exhibiting the steepest smirks tend to underperform stocks with least pronounced volatility smirks by 10.9% per year on a risk-adjusted basis and using the Fama and French [1996] three-factor model. They also find that predictability of the volatility skew on future stock returns lasts for at least six months and stocks with steepest volatility smirks are those experiencing the worst earning shocks in the following quarter.

Cremers and Weinbaum [2010] find that deviations from put-call parity contain information about future stock prices. By comparing pairs of call and put they discover that stocks with relative expensive calls outperform stocks with relative expensive puts by at least 45 basis points per week.

Liu et al. [2014] further inspect option-implied volatilities informational content by investigate the industry effect of portfolio of stocks constructed according to implied volatility measure and comparing those portfolios with industry-neutral portfolios of stocks. They find that quintile portfolios constructed using volatility skew and volatility spread are subject to substantial industry effect and industry-neutral portfolio over perform.

Borochin and Yang [2014] analyze the relationship between option implied volatility measure and capital structure for non-financial firms. They say that option implied volatility is a good proxy for cash flow risk and as the latter grows also the likelihood of a firm entering in default increases, producing a rise in cost of debt and ultimate a decrease in firm's leverage. They also use forward looking risk estimates impounded into option prices to create market-based indices which explain the ability to change firm's capital structure more than traditional accounting-based measures. Finally they construct indices using implied volatility spread, implied volatility skew and volatility risk premium and perform a long-short trading strategy based on these indices which generates abnormal returns from 2.3% to 4.9% over one year.

Bollerslev, Tauchen and Zhou [2009] provide empirical evidence that stock market returns are predictable using the difference between implied volatilities and realized volatilities or variance risk premia. Moreover, stock returns are positively correlated with variance risk premium and the degree of predictability is as its largest at quarterly horizons but the premium still explains observed return variation at monthly and annual horizons. Volatility risk premium captures risk premium for option sellers to bear losses on the underlying stock.

Goyal and Saretto [2009] study cross-section stock option returns by sorting stocks on the difference between historical realized volatility and at-the-money implied volatility and find that auto-financing trading strategy that is long (short) in the portfolio with a large positive (negative) difference between historical volatility and implied volatility produces economically and statistically significant monthly returns. They observe that deviation between historical volatility and implied volatility are transitory and indicative of option mispricing, hence future volatility will converge to its long-run historical volatility.

Zhou [2009] presents evidence of variance risk premia forecasting ability for financial market risk premia across equity, bond, currency and credit asset classes and this forecasting ability is maximum at one month horizon.

3. Data and Methodology

We select banks from STOXX Global 1800 Banks Index. Among 106 components of the index we exclude banks with an incomplete or missing array of option prices and balance sheets information. The resulting dataset comprehends approximately 1,800 quarterly observations from January 2005 to December 2014 and 50 banks.

Financial leverage can be briefly summarized as the ratio between firm's borrowed capital and firm's own capital. For non-financial firms usually total debt over total equity is an appropriate measure, but for banks a more accurate measure is asset over equity ratio. As numerator we preferred to use total assets, instead of Basel regulation risk-weighting, as the former is a more comprehensive measure of bank's exposures. As a numerarie we rely on market capitalization since better approximates current equity fair value.

For each bank we collect option data for different moneyness level and different maturities. For moneyness levels (strike-to-spot ratio) we select call and put options from 0.80 to 1.20 and for maturities we chose options lasting from 3 month to 12 months. Call and put option with moneyness close to 1 are defined ATM option, call (put) with moneyness above 1.10 (below 0.90) are defined OTM. The approach in selecting ATM and OTM moneyness levels is consistent with Ofek, Richardson and Whitelaw [2004]. Options and stocks data are obtained from Bloomberg and implied volatility prices represent daily average value of market trades. After averaging across maturities we build quarterly observation by taking the mean value for implied volatility during the three months period so that we could compare market-based and balance sheet-based information.

Volatility skew is the difference between OTM put and ATM call option implied volatility and measures the excess premium paid for purchasing OTM put option with respect to ATM call option. Equation (2) defines volatility skew.

$$skew_{i,t} = iv_{i,t}^{OTM,put} - iv_{i,t}^{ATM,call} \tag{2}$$

where $iv_{i,t}^{OTM,put}$ is the implied volatility for an OTM put option, stock *i* at time *t* and $iv_{i,t}^{ATM,call}$ is the implied volatility for ATM call option on stock *i* at time *t*.

Volatility spread is defined in Equation (3) as the difference between ATM call option implied volatilities and ATM put option implied volatilities of.

$$spread_{i,t} = iv_{i,t}^{ATM,call} - iv_{i,t}^{ATM,put} \tag{3}$$

where *i* and *t* represent the same variables in Eq. (2). Volatility spread aims to capture departures from put-call parity state due to current market condition. Positive values of $spread_{i,t}$ depict a condition of more expensiveness call option to put option hence a traders' expectation of future positive return on the stock i, we are interested in how this excess premium interacts with bank's leverage.

Finally we identify Variance Risk Premia (VRP) in Eq. (4) as the difference between long-term ATM call implied volatility levels (computed as the average between 6 and 12 months to maturity options) and yearly historical realized volatility.

(4) $$vrp_{i,t} = iv_{i,t}^{ATM,call} - rv_{i,t}$$

Where $iv_{i,t}^{ATM,call}$ is the implied volatility for long term ATM call option on stock *i* at time *t* and $rv_{i,t} = \sqrt[4]{\sum_{j=1}^{60} r_{i,j}^2}$ is the realized volatility from daily log-returns for stock *i* and quarter *t.* Due to unavailability of vast intraday dataset on Bloomberg, computing realized volatility from intraday return – which is a better proxy of the integrated volatility – has been impossible. A positive VRP indicates that traders are pricing a premium on stock's volatility for the future with respect to the historical performance.

Regression analysis is performed on a panel dataset of 50 banks from 2005 to 2014 for a total of 1,800 quarterly observations. Equation (5) presents the general model for addressing the effect of option implied volatility risk measure on changes in bank's leverage.

(5) $$L_{i,t} = \beta_0 + \beta_1 risk_{i,t-1} + \beta_2 crisis_t + \beta_3 \mathbf{X}_t + \boldsymbol{\varepsilon}_{i,t}$$

where $L_{i,t}$ represents the leverage measure for bank *i*, in quarter *t*, and $risk_{i,t}$ is the option implied volatility risk measure (either skew, spread, VRP or realized volatility) for bank *i* at time *t*-1, $crisis_t$ is a dummy variable equal to one if quarter *t* happens during financial crisis (from Q3 2007 to Q1 2009) and zero otherwise, $crisis_t$ allows us to clean the analysis for any misbehavior of dependent variable during the Financial Crisis and $\mathbf{X}_t$ is a vector of control variables.

As a robusteness check we also controlled for contemporaneous effect by analyzing changes in leverage and in volatility measures, Equation (6) specifies the model.

(6) $$\Delta L_{i,t} = \beta_0 + \beta_1 \Delta \boldsymbol{risk}_{i,t} + \boldsymbol{\varepsilon}_{i,t}$$

Where $\Delta \boldsymbol{risk}_{i,t}$ is a vector of changes in volatility risk measure (skew, spread, VRP or realized volatility) for bank *i* at time *t*.

4. Results

Table 1 shows the descriptive statistics for the dataset of banks and their more relevant balance sheet items. Table 2 depicts the correlation among the considered variables.

TABLE 1 — SUMMARY OF BANKS

The dataset consists in quarterly observation on 50 publicly traded banks from STOXX GLOBAL 1800 Banks from 2005 to 2014. PBV is the price-to-book-value, ROA is the return on assets, NPA-to-assets is the ratio of non-performing assets over bank's total assets, Dyield is bank's dividend yield in % term, Market leverage is given by 1- asset-to-market-cap ratio, Book leverage is given by 1- asset-to-book-equity ratio and NPACR Leverage is a measure of leverage based on NPACR proposed by Chernykh and Cole [2014] and is given by 1-(equity + loan loss reserves- non-performing assets)/total assets.

	Mean	Median	St Dev	Min	Max
PBV	1.3111	1.1357	1.1517	0.2405	13.54
ROA	0.533	0.550	0.816	0.000	0.880
NPA-to-assets	2.30%	1.00%	3.13%	0.10%	34.19%
Dyield	3.91	3.36	3.35	0.13	9.37
Market leverage	91%	93%	9%	45%	99%
Book leverage	93%	94%	4%	85%	98.5%
NPACR Leverage	93%	95%	6%	86%	98%

Table 2 reports correlation among market and balance sheet variables for banks.

TABLE 2 — CORRELATIONS

The dataset consists in quarterly observation on 50 publicly traded banks from STOXX GLOBAL 1800 Banks from 2005 to 2014.

	Log(Assets)	Log(Deposits)	PBV	NPL/Assets	Mkt Leverage	Book Leverage	NPACR Leverage	Skew	Spread	RV	VRP	Loan Loss Res
Log(Assets)	1.000	0.941	-0.142	-0.051	0.384	0.328	0.235	0.104	0.039	0.086	-0.069	0.625
Log(Deposits)	0.941	1.000	-0.098	-0.041	0.389	0.151	0.081	0.132	0.036	0.059	-0.046	0.579
PBV	-0.142	-0.098	1.000	-0.596	-0.354	0.107	-0.019	0.076	-0.056	-0.438	0.383	-0.350
NPL/Assets	-0.051	-0.041	-0.596	1.000	0.239	-0.145	0.056	-0.045	-0.038	0.332	-0.313	0.341
Mkt Leverage	0.384	0.389	-0.354	0.239	1.000	0.217	0.263	0.026	0.057	0.283	-0.249	0.290
Book Leverage	0.328	0.151	0.107	-0.145	0.217	1.000	0.946	-0.007	-0.038	0.040	-0.035	0.145
NPACR Leverage	0.235	0.081	-0.019	0.056	0.263	0.946	1.000	0.007	-0.066	0.134	-0.136	0.128
Skew	0.104	0.132	0.076	-0.045	0.026	-0.007	0.007	1.000	0.270	0.155	-0.166	0.069
Spread	0.039	0.036	-0.056	-0.038	0.057	-0.038	-0.066	0.270	1.000	0.012	0.015	0.031
RV	0.086	0.059	-0.438	0.332	0.283	0.040	0.134	0.155	0.012	1.000	-0.983	0.200
VRP	-0.069	-0.046	0.383	-0.313	-0.249	-0.035	-0.136	-0.166	0.015	-0.983	1.000	-0.143
Loan Loss Res	0.625	0.579	-0.350	0.341	0.290	0.145	0.128	0.069	0.031	0.200	-0.143	1.000

Table 3 describes the principal statistics for all volatility risk measure. Skews exhibit an overall expensiveness of OTM put option compared to ATM call for all levels of moneyness and for all options time to maturity. In specific, the shorter is the option's maturity the larger is the skew. Traders use lower moneyness option to hedge themselves against large drawdowns in stock's price thanks to their relative cheapness and rely on shorter term options for liquidity reasons. Spread is generally shifted towards positive values, showing a relative more expensiveness for ATM call than for ATM put and as already pointed out for skew, shorter term options exhibit greater spreads.

TABLE 3 — VOLATILITY RISK MEASURES

			Skew		
Maturity	3 months	Short term	6 months	12 months	Long term
Mean	5.74	3.62	2.95	1.97	1.18
Standard deviation	6.14	3.21	2.79	3.04	4.32
5th percentile	-0.06	-0.18	-0.37	-1.06	-3.16
25th percentile	3.10	2.23	1.85	1.11	0.55
50th percentile	5.34	3.64	3.02	2.14	1.55
75th percentile	7.60	4.97	4.12	2.92	2.20
			Spread		
Maturity	3 months	Short term	6 months	12 months	Long term
Mean	2.27	1.53	1.25	0.70	0.17
Standard deviation	3.49	2.59	2.45	2.92	3.68
5th percentile	-0.95	-0.98	-1.20	-2.05	-4.05
25th percentile	1.05	0.77	0.57	0.13	-0.24
50th percentile	2.16	1.56	1.31	0.91	0.63
75th percentile	3.21	2.25	1.92	1.38	1.07

Maturity	VRP 6 months	VRP 12 months	RV
Mean	2.27	1.53	1.25
Standard deviation	3.49	2.59	2.45
5th percentile	-0.95	-0.98	-1.20
25th percentile	1.05	0.77	0.57
50th percentile	2.16	1.56	1.31
75th percentile	3.21	2.25	1.92

Table 4 illustrates results from Eq. (5). Univariate model shows that volatility skew is statistically significant and produces a reduction in banks' market leverage for next quarter. This means that an increase in perceived risk (given by an increase in OTM put option price without a corresponding increase in ATM call prices) envisages higher costs to raise equity in case of distress for the bank, hence force a deleverage in bank’s assets in order to avoid these costs. Realized volatility also produces a reduction in bank’s leverage. However when Skew and RV are both regressed on dependent variable, the former use to soak up all the negative effect on leverage. This inconsistency in RV’s sign forces us to declass the realized volatility measure as a driver for market leverage with respect to the other measure. On the other hand, any increase in volatility spread depicts a more flourishing business and delivers an increase in market leverage and VRP as well seems to drive an increase in market leverage. Finally, it is worth notice how running a regression with both Skew and Spread, as we did in model (7), increases the statistical significance for the latter variable, as if the tail risk component of Skew somehow mix up univariate Spread model (2).

TABLE 4 — REGRESSION ANALYSIS ON VOLATILITY RISK MEASURES

This table shows the main results from regression analysis of Eq. (5). The model measures the effect of implied volatility risk measures (volatility skew, volatility spread, realized volatility and variance risk premia) on next quarter banks' market leverage. Volatility skews are obtained from the difference between 80% OTM put implied volatility and ATM call implied volatility for a 3 months-to-maturity contract. Volatility spread is the difference between implied volatility for ATM call and ATM put for a 6 months-to-maturity option. RV (Realized Volatility) is the sum of squared daily stock returns and Variance Risk Premia is the difference between ATM call 6 months to maturity option implied volatility and annualized realized volatility. Market leverage is given by 1- market-capitalization-over-assets ratio. The dataset consists in quarterly observation on 50 publicly traded banks from STOXX GLOBAL 1800 Banks from 2005 to 2014 for a total of approximately 1,800 observations. In order to deal with heteroskedaticity and serial correlation issues standard errors are clustered at bank's level. Bold figures represent coefficients statistically significant at a 5 or below percent level.

	Market leverage						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Skew	-0.003				-0.003		-0.005
	-2.30				**-2.32**		**-2.59**
Spread		0.001				0.0015	0.004
		1.91				**1.98**	**2.75**
RV			-0.014		0.050	-0.010	0.04
			-4.65		**2.76**	**-3.69**	**2.06**
VRP				0.002			
				4.53			
R sq	0.05	0.04	0.05	0.05	0.05	0.05	0.05

Table 5 shows the model in Eq. (5) when all control variables are included. The selected control variable accounts for firm's size, profitability, dividend payout policy, reliance on short term borrowing as a source of financing, assets' quality and the Financial Crisis period. Adding control variables to the model does not change neither the statistical nor the economic significance of our volatility risk measures. Skew and RV still have a negative effect on next quarter market leverage whereas Spread and VRP have a positive effect. On the other hand, checking for control variable allow us to further investigate which factor ultimately affects banks' capital structure and to show how capital regulation plays a second order role in determining it. Beside $Log(Deposits)$ which collects the size effect and grows in line with banks' leverage, we see that profitability of the bank is somehow inversely related to leverage for different profitability ratios.[2] Other variables which positively affect banks' leverage are the dividend yields, the reliance on short term financing and the ratio of non-performing loans to total assets.

[2] by regressing bank's operating margin instead of Return on Asset we found the same negative relationship.

TABLE 5 —REGRESSION ANALYSIS ON VOLATILITY RISK MEASURES WITH CONTROL VARIABLES

This table shows the main results from regression analysis of Eq. (5). The model measures the effect of implied volatility risk measures (volatility skew, volatility spread, realized volatility and variance risk premia) on next quarter banks' market leverage. Volatility skews are obtained from the difference between 80% OTM put implied volatility and ATM call implied volatility for a 3 months-to-maturity contract. Volatility spread is the difference between implied volatility for ATM call and ATM put for a 6 months-to-maturity option. Realized volatility is the sum of squared daily stock returns and Variance Risk Premia is the difference between ATM call 6 months to maturity option implied volatility and annualized realized volatility. Market leverage is given by 1- market-capitalization-over-assets ratio. Crisis is a dummy which identifies whether the observation falls within Q3 2007 to Q1 2009 time frame. Log(deposits) is the logarithm of deposits in 2010 USD. ROA is return-on-asset ratio, Dyield represent the dividend yield, Log(St Borrow) is the logarithm of short term bank's financing operations and NPL-to-assets is the ratio of non-performing loans over bank's total assets. The dataset consists in quarterly observation on 50 publicly traded banks from STOXX GLOBAL 1800 Banks from 2005 to 2014 for a total of approximately 1,800 observations. In order to deal with heteroskedaticity and serial correlation issues standard errors are clustered at bank's level. Bold figures represent coefficients statistically significant at a 5 or below percent level.

	Market leverage					
	(8)	(9)	(10)	(11)	(12)	(13)
Skew	-0.0018					-0.0029
	-2.12					**-2.32**
Spread		0.0004				**0.0022**
		1.52				**2.43**
RV			**-0.0116**			0.001
			-4.45			1.08
VRP				0.017		
				4.45		
Crisis	0.0780	0.120	0.1080	0.1063	0.1200	0.0740
	2.20	**2.90**	**4.24**	**3.76**	**4.17**	**2.48**
Log(Deposits)	0.0271	0.0490	0.0416	0.0395	0.0430	0.0262
	2.10	**3.66**	**6.61**	**4.46**	**6.66**	**2.07**
ROA	-0.1296	-0.17	-0.021	-0.019	-0.2130	-0.0126
	-4.12	**-4.09**	**-5.23**	**-4.96**	**-4.64**	**-4.17**
Dyield	0.0019	0.0021	0.0017	0.0017	0.0017	0.0017
	4.87	**3.68**	**4.21**	**3.56**	**4.08**	**4.10**
Log(St Borrow)	0.0095	0.0041	0.0045	0.0048	0.0030	0.0092
	2.68	**1.16**	**1.97**	1.58	1.27	2.58
NPL-to-assets	0.2505	0.4107	0.3600	0.3878	0.3934	0.2613
	1.33	1.81	**3.04**	**2.28**	**3.14**	1.42
Constant	0.4014	0.2723	0.3660	0.3899	0.3566	0.4740
	2.62	1.48	**4.09**	**3.07**	**3.94**	**2.68**
R-sq	0.19	0.21	0.15	0.17	0.18	0.29

In Table 6 we conduct a robustness check to verify whether the effect of volatility risk measures on market leverage is somehow disproved when we deal with changes in variables rather than level (or logarithm). Evidences confirm what we already highlighted in Table 4 and Table 5. Table 6 confirms that changes in Skew (Spread) negatively (positively) affect future changes in market leverage and as we already discovered in model (7) when Skew and Spread are both in the regression – as in model (20) – the predictive power of these two increases.

On the other hand, changes in RV seems to produce a deleverage in firms assets and does not help in clarifying the effectiveness of this variable.

TABLE 6 — REGRESSION ANALYSIS FOR CHANGES IN VOLATILITY RISK MEASURES -

This table shows the main results from regression analysis of Eq. (6). The model measures the effect of changes in implied volatility risk measures (volatility skew, volatility spread, realized volatility and variance risk premia) on changes in current quarter banks' market leverage. Volatility skews are obtained from the difference between 80% OTM put implied volatility and ATM call implied volatility for a 3 months-to-maturity contract. Volatility spread is the difference between implied volatility for ATM call and ATM put for a 6 months-to-maturity option. Realized volatility is the sum of squared daily stock returns and Variance Risk Premia is the difference between ATM call 6 months to maturity option implied volatility and annualized realized volatility. Market leverage is given by 1- market-capitalization-over-assets ratio. The dataset consists in quarterly observation on 50 publicly traded banks from STOXX GLOBAL 1800 Banks from 2005 to 2014 for a total of approximately 1,800 observations. In order to deal with heteroskedaticity and serial correlation issues standard errors are clustered at bank's level. Bold figures represent coefficients statistically significant at a 5 or below percent level.

	ΔMarket leverage						
	(14)	(15)	(16)	(17)	(18)	(19)	(20)
ΔSkew	-0.080				-0.070		-0.140
	-2.26				**-2.21**		**-2.45**
ΔSpread		0.010				0.010	0.110
		0.57				0.56	**2.45**
ΔRealized			0.050		0.090	0.010	0.0100
			3.18		**4.57**	**3.04**	**4.52**
ΔVRP				-0.002			
				-1.08			
R-sq	0.04	0.01	0.04	0.02	0.05	0.03	0.10

5. Conclusions

In this paper we addressed how volatility risk measure from option prices influences banks' leverage. In order to do that, we assumed that banks' capital structure is driven by some balance sheet characteristic and not solely determined by capital regulation. The analysis is run using as exogenous variables volatility skew, spread, VRP and realized volatility and as endogenous variable banks' market leverage, which is defined as total assets over market capitalization. The model is performed both in univariate and multivariate regression fixed effect framework. In multivariate analysis we include different control variables from banks' balance sheet. Overall, the most effective implied volatility risk measure seems to be volatility skew, which negatively affects market leverage.

Our findings show a strong and significant negative relationship between skew and next quarter market leverage. This outcome suggests that, as perceived risk increases, the probability for banks to incur in higher refinancing costs when an additional raise in equity is needed increases as well. Hence, banks wisely deleverage their business and generate a safety buffer. On the other hand, volatility spread which captures any upside risk is positively related to bank's leverage however this relationship emerges clearly only when is regressed together with volatility skew. VRP and Spread are positively related to leverage while RV fails to deliver consistent estimates.

Our main conclusion is that banks' capital structure although different form non-financial firms and subject to strong regulation does not solely depends on mandatory minimum capital requirements. Actually, to the above mentioned risk measures are yet another determinant factor in shaping banks' market leverage and implied volatility measures due to their characteristics – first of all being a forward looking measure – suit well this role. Above all the analyzed volatility risk measure, skew is by far more closely related to bank's perceived risk and useful in determining next quarter leverage.

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Chapter III – Banks' liquidity ratio, credit risk and other market based risk measures in periods of financial distress

By GIULIO ANSELMI

In this paper we investigate the role of liquidity in banks lending activity and how liquidity provision is related to bank's credit risk and others macroeconomic and idiosyncratic market-based risk measures, such as bank's implied volatility skew from options traded on the market and realized volatility from futures contract on three months LIBOR, during periods of global financial distress. Credit risk is given by the ratio between loan loss reserves and total assets. We find that losses from lending activity forces banks to build up new liquidity provisions only during period of financial distress. On the other hand, during period of financial stability, new loans are crippled from losses, experienced by the bank, in the previous quarter. Regarding liquidity ratio, we discovered that, in good times, credit risk reduces liquidity ratio and do not trigger liquid asset demand for banks while, in bad times, this demand for liquid asset is suddenly switched on and the more reserves from loan losses the bank has, the more it cleans its balance sheet from long term commitments in order to replenish it cash and short term securities. When we control for market based risk measures we evidence that both implied volatility skew and LIBOR's realized volatility are negatively related with liquidity ratio and are useful in predicting a distress in bank's liquidity holdings.

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1. Introduction

In this paper we analyze the role of liquidity in banks' lending activity and how liquidity provision is related to bank's credit risk, as well as to others macroeconomic and idiosyncratic market-based risk measures, when we have liquidity issues in the inter-banking market and during periods of global financial distress. During 2007-2009 Financial Crisis banking sector froze its inter-banking activity experiencing a severe drawdown in banks' liquidity and some defaults. Since then, liquidity provisioning became a critical principle to account for by everyone involved in loans market, for commercial and investment banks, central banks and other regulators. In order to set thing back to normality central banking authorities implemented broad measure to provide liquidity to the commercial and non-commercial banking sector. Meanwhile regulators drafted a liquidity coverage criteria to prevent future liquidity distress – both in inter-banking activity and in customers' deposits – and to reinforce banking sector stability, supporting capital regulations standards where they are less effective.

To address the issue Basel Committee's presented the Liquidity Coverage Ratio (LCR) which has the objective to promote short-term resilience of the liquidity risk profile of banks. The principle behind LCR is that banks must hold a minimum high-quality liquid asset (HQLA) buffer portfolio that can be easily and immediately converted into cash in private markets to meet sudden liquidity needs for a 30 calendar day liquidity stress scenario. This 30-days window buffer gives banks, supervisors and central banks a sufficient amount of time to implement any corrective action needed to restore liquidity and refurbish a stable business environment. Liquid capital provisions may be useful for managing a bank run and address a deleveraging process by a bank's with excessive risk-taking activity and/or with a severe borrowers' insolvency, as we experienced during recent financial crisis. An over leveraged firm, which is suddenly exposed to an erosion in its asset quality, would incur in extremely high costs when raises more capital to offset the losses. By detaining a buffer of liquidity reserves the bank can cope with a short-term illiquidity phase derived from the losses without raising new – expensive – equity.

In this study we focus on cash and other marketable short term assets as a proxy for liquidity buffer and we investigate how these assets relate to other risk measure. Following Cornett et al. [2011] we broaden the analysis by controlling for credit risk measures and market based measures, while relying on a dataset of mostly Global SIFI rather than solely belonging to the US. By focusing on the main features that produces changes in liquidity provision and in lending activity they discovered that banks relying more on stable sources of financing, such as core deposit and equity capital financing, continued to lend relative to other banks with a less stable source of financing. Also, they found out that banks with more illiquid assets on their balance sheets increased their asset liquidity and reduced lending in the next quarter in order to balance out their asset structure and increase their liquidity provision.

First, we restate their model by adding as a new exogenous variable credit risk, than, we investigate how liquidity ratio is influenced by additional risk measures inherited by the market (such as option implied volatility skew, which captures trader's expectations about bank's idiosyncratic features and realized volatility on three months LIBOR futures, which reflects the general macroeconomic environment). If these market-based risk measures do influence banks' liquidity then future liquidity provisions could be eligible to play a part in a broader market discipline-based monitoring activity. As a robustness check on the efficiency of these market-based risk measure we implemented also a regression analysis having as a dependent variable bank's z-score, which is already identified by previous literature as a good risk measure to examine the effects of the financial assistance on banks' risk-taking behavior.

This paper is organized as follow, Section 1 is the introduction, Section 2 presents previous literature related to the topic, Section 3 describes the data and the methodology used in the analysis, Section 4 illustrates the results and robustness check analysis and Section 5 concludes.

2. Previous literature

On loans growth and liquidity issues, Ivashina and Scarfstein [2010] show that new loans to large borrowers fell by 37% during the peak period of the Financial Crisis relative to the prior three-month period and by 68% relative to the peak of the credit boom. New lending for real investment fell to the same extent as new lending for restructuring. Banks that have access to deposit financing cut their lending less than banks with less access to deposit financing.

Diamond and Rajan [2000] state that greater bank capital reduces liquidity creation but enables the bank to survive and to avoid distress. Also, banks with different amounts of capital extract different amounts of repayment from borrowers and the optimal bank capital structure trades off the effects of bank capital on liquidity creation, the expected costs of bank distress, and the ease of forcing borrower repayment.

Thakor [2014] highlights that in a cross-section analysis on banks higher capital is associated with higher lending activity, higher liquidity creation and higher probability of surviving the crisis. On the other hand, lower capital in banking leads to higher systemic risk and a higher probability of a government-funded bailout.

Calomiris [2012] states that cash reserves requirements could play a role of broader prudential tool than just for addressing liquidity risk. But focusing on cash ratios rather than capital ratio is subject to a tradeoff. By relying on cash ratios we deal with adverse-selection cost of raising equity, a limited verifiability of loan outcomes is limited, when and the moral-hazard resulting from costly or postponed loss recognition but we are subject to a higher opportunity cost by providing high cash ratio than our lending activity needs. Previous literature evidences the need also for non-financial firms to hold cash as a precautionary tools see Mortal and Reisel [2013].

Calomiris et al. [2015] further investigate cash reserve requirements and argue that, while during stable period just deposit insurance may be optimal, during liquidity shocks period a cash reserve requirement must exist to avoid free riding behavior in the interbank market.

Mandatory capital requirements provide capital buffer to absorb losses on banks' balance sheets and to limit risk taking in banking sector, but their restoration could be painful to achieve for a bank which faces high costs for raising new capital. This limitation could be amended, rather than from an increase in equity, by holding more liquid assets. On capital regulation Berger et al. [1995] investigate the role of capital for financial institutions and how market-generated capital requirements differ from regulatory requirements and Santos [2001] reviews the literature on the design of the financial system and bank capital regulation presenting a list of the market failures that justify banking regulation. Barth et al. [2005], Berger et al. [2008] and Brewer et al. [2008] observe that bank capital's levels are higher than what regulation dictates opening up for discussion about what determines this buffers. On non-binding capital requirements and banks' capital structure flexibility see Flannery [1994], Myers and Rajan [1998], Diamond and Rajan [2000] and Allen et al. [2011]. On the other hand Flannery and Nikolova [2004] and Gropp [2004] offer a survey on non-binding capital requirements in a market discipline framework.

Brunnermeier et al. [2008] propose some distinctions between regulatory and market based capital while Chernyk and Cole [2014] test the predictive power of several alternative measures of bank capital adequacy in identifying US bank failures during the recent crisis period. They found that the non-performing asset coverage ratio (NPACR) significantly outperforms Basel-based ratios throughout the crisis period by accounting for both banking risks and asset quality and aligning capital and credit risk, eliminating banking management incentives to mask capital deficiency and allowing to account for various time period and cross-country provisioning rules.

Sorokina and Thornton [2014] show that loan market competition and loan portfolio diversification reduce leverage of the banks and excess leverage, that short-term borrowing of banks increases in low market liquidity conditions and banks' capital structure significantly affects capital structure of the firms in the broad economy, since an increase in banks' holding of capital reduces firms' leverage.

Valencia [2011] focus on how monetary policy rates affect bank risk-taking and its leverage by showing that under limited liability a decrease in interest rate produces an increase in banks profitability which could lead to take excessive risk and leverage.

On the relationship between market returns and capital ratios during the financial crisis Demirguc-Kunt et al. [2010] study whether better capitalized banks experienced higher stock return. They find out that before the crisis differences in capital did not have much impact on stock returns while during the financial crisis a stronger capital position was associated with better stock market performance and relationship between stock returns and capital is stronger when capital is measured by Tier I capital to total asset leverage ratio.

3. Data and Methodology

We build the dataset from quarterly observations on 50 banks belonging to STOXX Global 1800 Banks Index for a total of approximately 1,800 observations from January 2005 to December 2014.

In order to capture how banks adjust their liquidity provisions and lending activity in next quarter we select as dependent variable changes in liquid assets and loans activity standardized by bank's total assets. In addition the interaction between exogenous variables and TED spread allows us to see how liquidity provisions and lending activity changes when inter-banking market is under stress. Equation 1 and 2 describe the model.

$$(1)\ \frac{\Delta liquid_{i,t}}{assets_{i,t-1}} = \beta_0 + \beta_1 \frac{illiquid_{i,t-1}}{assets_{i,t-1}} + \beta_2 \frac{illiquid_{i,t-1}}{assets_{i,t-1}} * TED_{i,t-1} + \beta_3 creditrisk_{i,t-1} + \beta_4 creditrisk_{i,t-1_{,t}} * TED_{i,t-1} + \beta_5 \frac{equity_{i,t-1}}{assets_{i,t-1}} + \beta_6 \frac{equity_{i,t-1}}{assets_{i,t-1}} * TED_{i,t-1} + \beta_5 \mathbf{X}_t + \boldsymbol{\varepsilon}_{i,t}$$

$$(2)\ \frac{\Delta loans_{i,t}}{assets_{i,t-1}} = \beta_0 + \beta_1 \frac{illiquid_{i,t-1}}{assets_{i,t-1}} + \beta_2 \frac{illiquid_{i,t-1}}{assets_{i,t-1}} * TED_{i,t-1} + \beta_3 creditrisk_{i,t-1} + \beta_4 creditrisk_{i,t-1_{,t}} * TED_{i,t-1} + \beta_5 \frac{equity_{i,t-1}}{assets_{i,t-1}} + \beta_6 \frac{equity_{i,t-1}}{assets_{i,t-1}} * TED_{i,t-1} + \beta_5 \mathbf{X}_t + \boldsymbol{\varepsilon}_{i,t}$$

Where, as liquid assets, we use cash and short term marketable securities, and as illiquid assets we use long term investments, $creditrisk_{i,t-1}$ is expression on the insolvency risk that bank is bearing and is given by the ratio between loan loss reserves and total assets, while $TED_{i,t-1}$ is the difference between 3 months LIBOR and the 3 months treasury bills yield rate for bank *i* at time *t*-1, and capture the stress on the interbank market. β_1 and β_3 tell us correspondingly how banks more exposed to illiquid assets and insolvencies adapt their liquidity holdings in next quarter when the inter-banking activity is normal, while β_2 and β_4 allow us to study the role of these variables when the inter-banking market is under stress. β_5 and β_6 focus on how better capitalized banks adjust their liquidity needs.

On the other hand, when we are not interested in changes, but we want to address overall levels of liquidity and lending and how they are affected from market volatility risk measures, we shift to levels. To measure banks' overall liquidity ratio we chose the ratio between liquid assets (which is given by the sum of cash, cash equivalents and short term assets) and total assets. Equation (3) presents the general model.

(3) $$Liq_{i,t} = \beta_0 + \beta_1 creditrisk_{i,t-1} + \beta_2 creditrisk_{i,t-1_{,t}} * TED_{i,t-1} + \beta_3 skew_{i,t-1} + \beta_4 RV^c_{LIBOR,t-1} + \beta_5 \mathbf{X}_t + \boldsymbol{\varepsilon}_{i,t}$$

where $Liq_{i,t}$ represents the liquidity ratio for bank *i*, in quarter *t*, which is equal the ratio between cash plus other short term securities assets and bank's total asset, $skew_{i,t-1}$ is the volatility skew and is equal to the difference between OTM put and ATM call option implied volatility and measures the over premium paid for purchasing OTM put option with respect to ATM call option. Equation (5) defines volatility skew.

(4) $$skew_{i,t} = iv_{i,t}^{OTM,put} - iv_{i,t}^{ATM,call}$$

where $iv_{i,t}^{OTM,put}$ is the implied volatility for an OTM put option, stock *i* at time *t* and $iv_{i,t}^{ATM,call}$ is the implied volatility for ATM call option on stock *i* at time *t*.

$RV^c_{LIBOR,t-1} = \sqrt[4]{\sum_{j=1}^{60} r^2_{LIBOR,j}}$ is the realized volatility from daily log-returns for futures contract on 3 months LIBOR for country *c* (whom bank *i* belongs to) and quarter *t*-1. Realized volatility calculated from futures contract on a interbank lending interest rate gives us several advantages in comparison to realized volatility on bank's *i* stocks: (i) it is not focused on bank's *i* idiosyncratic risks but rather captures banking sector's and macroeconomics' issues (ii) since derives from a quoted futures rather than inter-banking dealers average rate it means that is a direct expression of traders' sentiment about where will be the underlying LIBOR in three months' time and this forward looking relationship comes in our help when we have to weigh the forecasting ability of this variable.[3] Due to unavailability of vast intraday dataset on Bloomberg computing realized volatility from intraday return – which is a better proxy of the integrated volatility – was impossible.

Using option-based or futures-based risk measures to address the change in liquidity delivers several advantages with respect to accounting measures. First of all, they are forward looking measure based on traders' expectations on equity future prices rather than accounting based measure which are backward looking and lagged indicators. Second, prices are computed at much higher frequencies than traditional measures, hence they changes quickly as market conditions changes and can help in delivering informational content about banks' capital structure or about sudden fluctuations in macroeconomic environment. RV quickly absorbs any spikes in the quotation of the underlying market.

Also, options market is a suitable environment for informed traders thanks to the high use of leverage, the asymmetric payoff and no constraint in short selling. Options give the opportunity but not the obligation to buy or sell a specific asset at a specific price within – or at – a specific point in time. Traders operate in option market by quoting their implied volatilities for different maturities and moneyness according to their view on future stock's returns. The result of this

[3] To be more specific the measure is only partially forward looking since represents the sum of squared daily returns of the previous quarter instead a better forward looking measure would have been one based on implied volatility from option on LIBOR.

trading produces volatility skews, smirks and spreads which get away from Black and Scholes [1973] environment of constant volatility across all maturity and all moneyness.

As a robustness check we run the same model in Eq. (3) but selecting as dependent variable bank's z-score which is a measure of stability. The z-score is the sum of the quarterly ROA return-on-assets and equity to assets ratio, divided by the standard deviation of the return on assets, see Roy [1952] to measure bank solvency. The z-score indicates the number of standard deviations that a bank's rate of return on assets can fall in a single period before it becomes insolvent. A higher z-score signals a lower probability of bank insolvency.

OLS fixed effect regression analysis is performed on a panel dataset of 50 banks from 2005 to 2014 for a total of 1,800 quarterly observations. In order to cope with heteroskedasticity and serial correlation issues standard errors are clustered at bank level as suggested by Peterson [2009] and quarterly and bank's effect are implemented.

3. Results

Table 1 shows the descriptive statistics for the dataset describing the considered variables while Table 2 depicts the correlation for the very same variables.

TABLE 1 — SUMMARY OF BANKS

The dataset consists in quarterly observation on 50 publicly traded banks from STOXX GLOBAL 1800 Banks from 2005 to 2014. Balance sheet items are weighted over total assets.

	Obs	Mean	STD	Min	Max
Loans	1,915	0.582	0.412	0.091	0.860
Cash	1,976	0.026	0.035	0.000	0.302
Cash + ST securities	1,950	0.097	0.081	0.000	0.355
LT investments	1,743	0.082	0.169	0.001	0.377
Deposits	2,009	0.494	0.306	0.155	0.802
Loan Loss Reserves	1,888	0.014	0.015	0.001	0.343
Total equity	2,020	0.070	0.041	0.010	0.174
Interbank assets	1,869	0.060	0.062	0.005	0.272
Skew	1,342	-6.761	4.291	-33.789	9.844
ROA	1,950	0.533	0.816	0.000	0.880
ROA STD	1,667	0.255	0.370	0.006	5.352

Table 2 reports correlation among market and balance sheet variables for banks.

TABLE 2 — CORRELATIONS

The dataset consists in quarterly observation on 50 publicly traded banks from STOXX GLOBAL 1800 Banks from 2005 to 2014.

	Liquidity ratio	Credit risk	z-score	equity-to-asset	TED	Skew	LT invest	Loan Loss
Liquidity ratio	1.000							
Credit risk	0.208	1.000						
z-score	0.082	-0.257	1.000					
equity-to-asset	0.311	0.558	-0.026	1.000				
TED	-0.008	-0.067	-0.130	0.013	1.000			
Skew	-0.091	0.004	-0.047	-0.021	-0.033	1.000		
LT investment	0.293	0.387	-0.094	0.581	0.039	0.240	1.000	
Loan Loss	0.208	1.000	-0.257	0.558	-0.067	0.004	0.387	1.000

Table 3 illustrates the results from Eq. (1) and (2). As already stated by Cornett et al. [2011] banks with more long term investments are forced to build up their liquid assets both in period of financial distress and in normal times. Better capitalized banks also increase their liquid assets. Banks with higher credit risk are forced to dismiss long term securities and build up cash reserves only when we are in a period of inter-banking stress. Regarding new loans commitment we can state that banks with more illiquid investments tend to reduce their loans approval in next quarter when inter-banking market is working properly. We cannot infer the same thing during period of financial stress. Better capitalized bank continue their lending activity without any trouble and higher credit risk levels force banks to reduce the amount of lending.

TABLE 3 — ADDRESSING CREDIT RISK MEASURE EFFECTS FOR LIQUIDITY AND LOANS

This table shows the main results from regression analysis of Eq. (1) and (2). The model measures the effect of credit risk (measured as the ratio between loan loss reserves and total assets) on changes in next quarter banks' liquid assets in model (1) and in new loans in model (2). The dataset consists in quarterly observation on 50 publicly traded banks from STOXX GLOBAL 1800 Banks from 2005 to 2014 for a total of approximately 1,800 observations. In order to deal with heteroskedaticity and serial correlation issues standard errors are clustered at bank's level. Balance sheet items are weighted over total assets at t-1. Bold figures represent coefficients statistically significant at a 5 or below percent level.

	(1)	(2)
numeraire: assets (t-1)	Δliquidassets/assets (t-1)	Δloans/assets (t-1)
Illiquid assets (t-1)	0.5843	-0.1298
	2.79	**-2.89**
Illiquid assets*TED (t-1)	0.2913	-0.0596
	2.44	-1.25
Capital (t-1)	1.4432	0.4176
	2.22	**3.73**
Capital*TED (t-1)	-0.1984	0.2256
	-0.54	1.33
Credit risk (t-1)	0.7705	-0.5628
	1.07	**-3.41**
Credit risk*TED (t-1)	4.0917	-0.4835
	3.64	-1.48
Log(Assets) (t-1)	0.0393	-0.01627
	1.28	**-4.17**
Log(Assets)*TED (t-1)	-0.003	-0.0029
	-1.92	-1.09
R-squared	0.48	0.09
obs	1511	1665
F-stat	5.63	8.07

Table 4 focuses on the effect of credit risk and market risk measures on bank's overall liquidity ratio as presented in Eq. (3) and on bank's overall lending activity as presented in Eq. (4). As a robustness check model (5) depicts the same analysis on z-score. Regarding overall liquidity during period of financial stability high levels of loan loss reserves do not immediately bind the bank to provide new cash in order to increase liquidity provisions, actually the bank decreases their liquidity ratio since is not under pressure from either depositors, investors or other financial intermediaries. But, when though times come being overly exposed to loan losses forces the bank to liquidate other assets and replenish its liquidity provisions. Skew since measures traders' expectation on downward movement on bank's stock is negatively related with liquidity ratio. As the bank is expected to suffer from liquidity vanishing, traders expect a drop in stock's prices, hence OTM put option became severely more expensive than ATM call. Finally, LIBOR realized volatility captures distress in inter-banking market and hence is negatively related to liquidity ratio.

TABLE 4 —CREDIT RISK AND MARKET VOLATILITY RISK MEASURE

This table shows the main results from regression analysis of Eq. (3). The model measures the effect of credit risk (measured as the ratio between loan loss reserves and total assets), volatility skew derived from options on bank's stock and realized volatility from quotes on Libor 3 months futures on bank's liquid ratio (which is given by the cash and short term securities divided by total assets) in model (3) and(4) and on bank's z-score (given by the sum of ROA and equity-to-asset ratio standardized by ROA standard deviation) in model (5) and (6). As control variable we identified equity-to-asset ratio and Log(Assets). The dataset consists in quarterly observation on 50 publicly traded banks from STOXX GLOBAL 1800 Banks from 2005 to 2014 for a total of approximately 1,800 observations. In order to deal with heteroskedaticity and serial correlation issues standard errors are clustered at bank's level. Bold figures represent coefficients statistically significant at a 5 or below percent level.

all lagged at (t-1)	(3)	(4)	(5)	(6)
Credit risk	-0,7109		-2,2258	
	-3,5		**-3,41**	
Credit risk*TED	0,602		-0,7833	
	2,65		-1,63	
Skew	-0,0011	-0,001	-0,227	
	-2,11	-1,83	-1,64	-0,2196
LIBOR RV	-0,013	-0,00947	-1,5232	**-1,96**
	-3,66	**-2,16**	**-2,91**	-2,604
Leverage	0,5027		1,6074	**-3,51**
	2,07		**4,3**	
Leverage*TED	0,056		-0,8614	
	0,46		-2,71	
Log(Assets)	0,0379		0,0081	
	2,19		1,84	
Log(Assets)*TED	-0,001		0,0001	
	-1,36		0,83	
R-squared	0,13	0,09	0,16	0,04
F-stat	4,55	4,00	3,84	4,33

5. Conclusions

In this paper we studied how credit risk measure interacts with changes in liquidity provisions and new loans commitment during period of financial stability and financial distress. Losses from lending activity forces banks to build up new liquidity provisions only during period of financial distress and cripple lending activity during period of financial stability. Looking at the overall bank's liquidity ratio in addition to credit risk measure we implemented market-based risk measures such as implied volatility skew from options on bank's stock and realized volatility from LIBOR 3 months futures affect banks liquidity ratio.

These two measure enable us to capture market-based risk about bank's idiosyncratic features (with volatility skew) and macroeconomic environment (with realized volatility on LIBOR). We discovered that credit risk reduces liquidity ratio during stable times and do not trigger any liquid asset demand from banks. On the other hand, when we experience period of severe financial distress this demand for liquid asset is suddenly switched on and the more reserves from loan losses the bank has the more it cleans its balance sheet from long term commitments in order to replenish its cash and short term securities. Implied volatility skew in negatively related with liquidity ration and predicts a distress in bank's liquidity holdings as traders' future expectations are translated in OTM put option prices. Realized volatility on futures contract on 3 months LIBOR is also useful in predicting reduction in liquidity holdings. When we control whether these market based variable influence bank's z-score we find results in line with what we expected, credit risk, skew and LIBOR realized volatility all compromise bank's stability.

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