



Information about bank risk in options prices

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Abstract

The volatility of its share price reflects the volatility of the market value of a bank's assets. We present data for the volatilities of individual banks' shares that are implied by the prices of options on the banks' shares. We present evidence that implied volatilities (IV's) better forecast actual, future volatilities of share prices than historical volatilities do. Banks' IV's are correlated with marketwide volatility, with the levels of their own share prices, with their own subordinated debt yield spreads, and with other banks' IV's. Bank capital reduces the response of IV's to market volatility. IV's are likely to add information about bank risk that is timely, cheap, objective, and useful. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Bank supervisors, investors, depositors, and even bank borrowers are interested in estimates of the likelihood that a bank will become insolvent. The likelihood that a bank will become insolvent rises with its expected losses relative to its total of equity capital and reserve for losses. The likelihood also rises as the variance of its unexpected losses rises relative to its net capital.¹ To offset the former effect, bank supervisors intend that a bank's reserves for loan and lease losses rise as a bank's expected losses rise. To at least partially offset an increase in the variance of a bank's unexpected losses, bank supervisors might also intend that a bank hold more capital,

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¹ We assume that the estimation risk associated with the moments of the loss distributions can be ignored here.

ceteris paribus. Bank capital regulations require that a bank hold more capital as conditions at the bank warrant. How much more, then, presumably reflects, among other things, the bank's supervisors' view about the expected variability of the value of the bank's assets.

Judgments about the likelihood of a bank (holding company) becoming insolvent are typically based on both on-site and off-site surveillance.² On-site surveillance takes place through bank examination. To assist in off-site surveillance, financial statements and government-mandated and other reports that contain accounting and other data are reviewed and tracked. For decades, analysts inside and outside bank supervisory agencies have used financial statements and reports to help assess the likelihood that a bank would become insolvent. Book values of capital, earnings, loan charge-offs and provisions, loans disaggregated by category of borrower, and other variables have been mainstays in these efforts.

Over the past few decades, more and more of the assets and liabilities of large US banks have come to be traded in financial markets. This enables bank supervisors and other analysts to monitor the market prices and quantities of the assets and liabilities of a bank. Bank supervisors in the US, for example, sometimes monitor yield spreads on a bank's subordinated (sub) debt for signals about its financial outlook. They can also monitor the prices and issuance of shares of stock in a bank. In general, we expect that the market prices of these traded, longer-term financial assets will be more sensitive barometers of expected future values than most accounting measures that banks report for past periods.

Empirical work that addresses the relations between market information and banks' current and expected future conditions focuses on the prices of subordinated debt and equity. For example, Flannery and Sorescu (1996), Jagtiani et al. (2000), Sironi (2000) and De Young et al. (2001) find that sub debt yields incorporate accounting information about the bank. Sironi (2000) notes that the sub debt yields of European banks increasingly reflect those banks' risks over the 1990s.

Recent studies by Evanoff and Wall (2000) and by Hancock and Kwast (2001) lay out some of the potential benefits and pitfalls of using sub debt yields to evaluate the conditions of banks. A joint study conducted by the Board of Governors of the Federal Reserve System and US Department of the Treasury (2000) notes that the sub debt yield spread seemed not to bear a consistent relation to the likelihood of banks' financial distress. In general, prior studies also conclude that yield spreads at issuance during 1986–1987 and before then do not reflect risks, while spreads during 1988–1991 do reflect banks' risks. The Fed–Treasury study concludes that the spreads between yields on banks' subordinated debt and Treasury bond yields change with changes in liquidity, in the supply and demand for specific issues of sub debt, and in the characteristics of specific issues. The report finds that since the late 1980s the sub debt yield spread responds to changes in banks' risks when banks are in distress or in turmoil. De Young et al. (2001) present similar findings.

² For simplicity, although we use data that pertain to bank holding companies, we refer to these companies as banks.

They conclude that sub debt yield spreads respond less to changes in presumed risk measures at banks that are regarded as being healthier.

The Fed–Treasury study also notes that sub debt yield spreads differ importantly from the KMV estimates of the expected default frequencies (EDFs) over the 1995–2000 period. More recently, Gropp et al. (2001) reported that yield spreads and equity-based distance-to-default measures both help to explain a bank's financial fragility. They concluded that regulators should use both of these market-based signals.

The correlations between yield spreads and many proxy measures for bank volatility or probability of failure perhaps should not be expected to be very high. It may well be that the relations between yield spreads and many proxy measures will be nonlinear. The relations might also be altered, as suggested above, by changes in liquidity and other idiosyncratic factors. Other more systematic factors, like changes in expected tax impacts and changes in the prices of various risks, may also be expected to shift yield spreads by important amounts, quite apart from any changes in the condition or outlook for a bank. Indeed, it may well be that such shifts in yield spreads would occur particularly, but not only, during times when information from market prices would have been most helpful to bank analysts. For example, the financial turmoil of the late 1990s might well have shifted yield spreads on banks' sub debt by far larger amounts than would be warranted by the shifts in banks' riskiness.

A good case can be made that no single proxy should be expected to perfectly signal banks' volatility or risk of failure. Any measure might dominate others as indicators of specific aspects of bank conditions. Consider signals about the variability of the market value of a bank's assets and equity. The standard deviation, or volatility, of equity share returns is typically thought of as a measure of the firm's equity risk. As such, the market's implied assessment of the second moment of the distribution of share returns is likely to provide a ready supplement to the levels of share prices. Implied volatilities (IV's) may better signal volatility of the market value of bank equity and assets, quite apart from the probability that a bank will fail, which will be affected by a bank's capital and other factors. Because they are affected so much less by capital and other factors, IV's may be one of the few proxy measures that would signal, following a run of unusually good luck that increased the bank's net worth, that a bank remains volatile. In that regard, IV's might be of special interest to a bank supervisor seeking to require more capital in the face of increases in the volatility of the value of a bank's assets.

Here we analyze the movements of the expected volatilities of banks' share prices that are implied by the transactions prices for their exchange-listed options. We compare IV to other commonly used measures of bank risk including the historical volatility (HV) of bank share prices. We show how the IV's move through time, how they differ across banks, and how they co-vary across banks through time. We then show that IV's have lower root-mean-squared-error (RMSE) forecasts of banks' future share price volatility than HV's do and significantly improve forecasts based on HV's.

We also estimate how much individual banks' IV's co-vary with the volatility of a broad index of share prices and present evidence that this covariance changes as a

function of a bank's condition. More specifically, we show that the covariance depends systematically on the leverage (or capital ratio) of a bank.

We find that the correlations between various proxy measures of bank volatility and of probability of failure are appreciably above zero and below one. Our results suggest that a bank's IV moves partly sympathetically and partly independently of movements in shares prices as well as in its sub debt yields. This suggests that data for IV's are likely to have different noise and thus different signals than those that are readily extracted from share prices and sub debt yield spreads. At the same time, any measure of IV's is also subject to difficulties. In our case, we use time-varying measures of IV that are derived from the constant-volatility, Black–Scholes option pricing framework. Although the procedure for deriving estimates of IV's seeks to reduce the effects of the volatility of volatility on the estimates, estimation errors likely remain.

Below we indicate how a regression framework can help choose the combination of HV's and IV's that best forecasts actual, future bank share price volatility. If bank analysts are willing to construct a measure that quantifies or at least categorizes, however precisely, the risk of bank failure, then regression or various categorical methods such as factor analysis can be used to identify the signals offered by the various proxies for bank risk of failure. We suggest that such indicators of bank risk be constructed and if the ensuing tests point to its signaling value, add IV to the menu of market-based risk measures that they monitor.

2. Risk measures and implied volatility

IV's do not inform us completely about bank risk in the sense of probability of default. Rather they are better understood as reflecting the market's view about the volatility of the market value of a bank's equity, which in turn reflects the market's view primarily about the market value of a bank's assets. Nevertheless, since asset volatility is directly related to default risk, it follows that IV is an important dimension of a bank's default risk.

We examine estimates of a bank's IV that are calculated from exchange-traded option prices. IV has the advantage that it brings to bear whatever information from the past and present the market deems to be relevant to form views about the future volatility of a bank's share price.³ Thus, IV is forward looking; in that regard, IV may be superior to historically based volatility estimates.

As Mayhew (1995) points out, changes in IV are frequently thought of as the market's response to news that affects the future volatility of the underlying share price. He documents that studies based on 1970s data tend to find that IV's are superior to HV's in forecasting share price volatility. Research since that period has tended to confirm that conclusion, but the evidence is not universal.

³ It may well be that bank supervisors are more interested in downside rather than upside volatility. Nevertheless, put–call parity ensures that both put and call options yield price information about the entire distribution of the share's returns.

A number of studies show that useful information about market expectations can be extracted from the prices of options. For example, Patell and Wolfson (1979) suggest that options prices reflect investors' opinions concerning the information in public announcements. Patell and Wolfson (1981) examine option prices around earnings announcements and find that IV's fall subsequent to the news release, presumably due to the resolution of the uncertainty about what the announcements would say. Cornell (1978) documents that IV's respond to announcements about the macroeconomy. Buttner and Swidler (1998) examine the effect of the Mexican peso devaluation during the 1990s on the IV of foreign share prices, while Chu and Swidler (in press) illustrate how the expected distribution of future exchange rates can be extracted from option prices.

In examining option prices, it is important to note that the derivatives market may offer relative transactional efficiencies over both equity and bond markets. Because options represent highly leveraged equity positions that lower the cost of speculation, trading in options increases market liquidity, which in turn increases the informational efficiency of the option market. Consider, for example, an unanticipated negative earnings announcement for a bank. Investors wishing to trade on the news may decide to write call options or buy put options on the bank shares. However, Figlewski and Webb (1993) point out that after an investor buys a put from a market maker, the market professional will likely hedge by shorting the share and buying the call option. Thus, the market maker transforms the original put trade into a short sale at a lower cost than that of the retail investor. Ultimately this increase in transactional efficiency should produce a gain in informational efficiency as well and provides further motivation for investigating the informational content of bank option prices.

3. Data

The Berkeley Options Data Base (BODB) and the CRSP dividend database contain data that permits estimating the IV's of bank share prices. The BODB contains the second in time at which each option trade takes place on the CBOE, as well as pertinent information about the strike price, time until expiration, and so on.

Stewart Mayhew graciously provided us with his estimates of IV's for each bank in our sample.⁴ To compute IV's, Mayhew follows the procedure used by the CBOE to calculate the VIX, a measure of the IV of the S&P 100 index of share prices.⁵ He

⁴ These data are part of a larger data set used by Dennis and Mayhew (2001). The data set contains only options that were listed on the CBOE. Thus, several large banks with options listed on other exchanges during the 1986–1997 period are not part of our data set.

⁵ The Dennis and Mayhew (2001) methodology for extracting IV's is consistent with the CBOE's calculation of VIX. Their methodology also indirectly captures changes in higher moments of the expected return distribution. A negative skew in the expected distribution of share prices, for example, will cause the price of the in-the-money put (out-of-the-money call) to be greater than the price of the out-of-the-money put (in-the-money call). The effect of the skew then will be to affect the interpolated value of the at-the-money IV.

chooses the in-the-money put and out-of-the-money call with a strike price nearest to the underlying share price. Mayhew next averages their IV's to produce the IV for options with the strike price just above the bank share price. He repeats this procedure for the out-of-the-money put and in-the-money call with strike prices closest to the share price and averages their IV's. Mayhew then interpolates between the two averages to calculate an estimate of the IV for a hypothetical at-the-money option.

The result is a hypothetical, at-the-money, IV for the two option maturities greater than one week but closest to 22 business days (roughly one calendar month).⁶ A linear interpolation/extrapolation of the two at-the-money IV's produces an estimate of an at-the-money option that matures in 22 days.

Mayhew uses a 100 step binomial tree to compute the IV for each individual stock option. This process accounts for discrete dividend payments and the possibility of early exercise. The T-bill yield serves as a proxy for the risk-free rate. Option prices are bid/ask averages that are matched with synchronous (in time) share prices reported in the BODB (Cornell, 1978).

We use estimates of IV's for each business day during the period January 2, 1986 through July 31, 1997.⁷ This period contains a large number of banking events and is rich in information about risk in the banking industry generally as well as at several individual banks. During the period around 1990 bank failures were numerous, and a number of large and smaller banks encountered difficulties. Important events that occur during the 1986–1997 period include: the oil and agricultural market difficulties of the latter 1980s, the stock market drop of October 1987, the commercial real estate loan difficulties around 1990, the introduction of the Basel capital standards around 1990, the 1990–1991 oil price shocks, the recession of 1990–1991, and the long and eventually vigorous economic recovery of banking and the macro-economy during the middle and latter 1990s.

European-style S&P 500 index options began trading in 1986. Trading of these options spurred a dramatic increase in option market liquidity and in the number of companies whose options are traded. Moreover, the CBOE's calculation of the VIX, a measure of the volatility of the S&P 100 index of share prices, also began in 1986. The end of our sample period reflects the last full month for which the BODB contains data for a large number of the banks in our sample. The CBOE has not provided options data to the BODB for the period since August 1997.

We find 33 banks that both have options that are traded on the CBOE and have SIC codes of 6712 or 6021 through 6029. Options for three banks trade for virtually the entire 1986–1997 period: Bank of America (options ticker symbol: BAC), Citicorp (CCI) and Great Western Financial (GWF).⁸ The 33 banks, their options

⁶ Thus, IV may be thought of as incorporating the market's expectation on day t of share price movement over the next month. Future research might examine longer-term equity options to extract market expectations of bank risk for horizons as long as three years.

⁷ For various technical reasons, some business days in our data set have no IV data. One such reason is that we omitted estimated IV's that are negative. In a few cases, extrapolation of the two IV's yields a negative value. We delete these observations from our sample.

⁸ This is the San Francisco-headquartered BankAmerica prior to its acquisition by NationsBank.

Table 1
Banks, option ticker symbols, and sample periods

Bank	Option ticker symbol (1)	Sample period	
		Began (2)	Ended (3)
Astoria Financial Corp.	AQR	8/9/1994	8/29/1997
Advanta Corp CL. A	AVQ	5/8/1992	8/29/1997
BankAmerica Corp	BAC	1/2/1986	8/20/1997
BayBanks, Inc.	BBQ	4/17/1990	8/28/1997
Bank of New York Company, Inc.	BK	12/20/1988	8/29/1997
Bank South Corp.	BKQ	2/18/1993	1/8/1996
Boatmen's Bancshares	BTQ	12/5/1990	1/7/1997
California Federal Bank, Inc.	CAL	5/3/1993	7/30/1996
Continental Bank Corp.	CBK	12/1/1989	8/19/1994
Citicorp	CCI	1/2/1986	8/29/1997
Capital One Financial Corp	COF	4/11/1995	8/29/1997
Coast Savings Financial, Inc.	CSA	4/1/1993	8/29/1997
City National Corp	CYN	10/10/1994	8/29/1997
First Chicago NBD Corp	FCN	12/5/1995	8/29/1997
First Fidelity Bancorp	FFB	3/8/1990	12/28/1995
First Chicago Corp	FNB	1/2/1986	11/30/1995
Firststar Corp	FSR	3/6/1995	6/20/1997
Greater New York Savings Bank	GQR	8/9/1994	8/29/1997
Great Western Financial Corp	GWF	1/2/1986	7/1/1997
Homefed Corp./Home Federal S&L	HFD	11/24/1987	3/20/1991
Hibernia Corp	HIB	11/10/1993	8/27/1997
Huntington Bancshares, Inc	HQB	6/3/1994	8/29/1997
First Interstate Bancorp	I	7/7/1986	3/28/1996
MBNA Corp	KRB	7/26/1991	8/29/1997
Long Island Bancorp. Inc	LBQ	9/17/1994	8/29/1997
MNC Financial, Inc.	MNC	4/8/1992	9/21/1993
Old Kent Financial Corp	OQH	9/5/1995	2/29/1996
People's Bank-Bridgeport, Conn.	PQY	11/4/1994	8/27/1997
Reliance Bancorp, Inc	RLQ	8/31/1995	8/29/1997
Standard Federal Bancorporation	SFB	7/10/1995	1/14/1997
St Paul Bancorp. Inc	SQU	6/1/1994	10/3/1996
Southeast Banking Corp	STB	4/9/1990	5/6/1991
Summit Bancorp	SUB	3/1/1996	8/29/1997

ticker symbols, and the sample period for which we have options prices for these banks appear in Table 1.

4. Implied volatilities: Summary statistics and patterns

Table 1 lists the 33 banks and the time periods for which we have daily estimates of IV's. Column 1 lists the CBOE ticker symbol for the options on the shares of each bank. Columns 2 and 3 show the first and last days for which we have IV data for each bank. For eight of the 33 banks, we have options prices before 1990. We have options prices for 17 of the 33 banks in August 1997; for 16 of the banks, options

trading ceased before then due to failure, merger, or other reasons. Because it is the last full month for which IV's have been calculated, we impose a common ending date of July 1997 for the sample period.

Table 2 lists summary statistics for the 33 banks in our sample. Column 1 shows the numbers of days during 1986–1997 for which we have price data for the shares of common stock for each bank. Column 2 lists the mean, annualized, decimal return on the shares of common stock for each bank for the observations noted in column 1. For example, shares of the common stock of Astoria Financial Corp (options ticker symbol: AQR) has a 36% mean, annualized return over the 755 days for which we have share price data for the period August 9, 1994 through August 29, 1997. For each bank, column 3 lists the standard deviation of its annualized, daily returns calculated from the number of observations identified in column 1. Columns 4 and 5 list the skewness and kurtosis of the daily returns on the shares of common stock for each bank.

Column 6 shows the numbers of days for which we have data for the IV for each bank. Column 7 shows the mean of the IV's for the observations identified in column 6. Column 8 lists the standard deviation, column 9 the minimum, and column 10 the maximum of the IV's for each bank.

The bottom row of Table 2 shows the simple averages of the data reported in each column. Note that each average is calculated from data that in turn pertains to different time periods. For example, we calculate the mean return for Southeast Banking Corp in row 32 over the 1990–1991 period and we calculate the mean return for Summit Bankcorp in row 33 over the 1996–1997 period.

HV often serves as an empirical proxy for the future volatility of a bank's equity returns.⁹ HV can, for example, be calculated as the standard deviation of the daily returns over the past month or year on shares of common stock. The standard deviation of the return on the share prices shown in column 3 is one measure of the average HV of the share price of each bank. The mean of the IV's shown in column 7 is a measure of the average ex ante volatility. Thus, for BAC, we see that its mean IV of 0.37 considerably exceeds its 1986–1997 standard deviation of returns of 0.29.

The bottom row of Table 2 shows that the mean (across banks) of IV (0.39) is higher than the mean of the full-sample-based standard deviation (0.32). Indeed, for 29 of 33 banks, the mean IV's in column 7 are larger than the HV's in column 3. At the same time, the correlation between the volatilities in columns 3 and 7 is quite high and approximately equals 0.80.

Figs. 1–3 plot the IV's for BankAmerica, Citicorp, and Great Western for each day from January 1986 through July 1997. Each figure also plots VIX, the IV of the S&P 100. Not surprisingly, the IV for each individual bank is higher than VIX, which is based on options on an index of the share prices for 100 companies. Fig. 1 shows that the IV for BAC, IV(BAC), tends to rise and fall with the VIX. IV(BAC) also tends to have some idiosyncratic movements. During the 1986–1988 period, in particular, the mean of IV(BAC) is much higher than the mean of VIX.

⁹ This occurs despite the drawback that HV is based, in part, on dated information.

Table 2
Summary statistics

Option ticker symbol	Actual returns					Implied volatility				
	Observations	Mean	Std. dev.	Skewness	Kurtosis	Observations	Mean	Std. dev.	Minimum	Maximum
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AQR	755	0.36	0.21	0.29	2.15	625	0.34	0.09	0.15	0.59
AVQ	1324	0.21	0.44	-0.41	7.37	1214	0.48	0.13	0.21	0.92
BAC	2929	0.19	0.29	-0.44	8.91	2733	0.37	0.12	0.17	1.38
BBQ	1588	0.31	0.35	0.48	6.74	1575	0.50	0.23	0.21	1.57
BK	2178	0.23	0.30	0.47	4.89	1921	0.30	0.08	0.15	0.74
BKQ	730	0.30	0.28	0.34	3.03	657	0.42	0.06	0.24	0.66
BTQ	1538	0.27	0.22	2.51	36.58	1292	0.25	0.07	0.11	1.79
CAL	821	0.14	0.37	0.46	6.21	763	0.49	0.11	0.16	0.85
CBK	1192	0.17	0.39	0.56	5.90	1153	0.44	0.14	0.16	1.01
CCI	2929	0.18	0.35	-1.03	25.97	2735	0.34	0.10	0.19	0.92
COF	585	0.27	0.37	0.10	2.49	506	0.45	0.10	0.29	1.01
CSA	1097	0.23	0.32	0.62	3.30	1046	0.51	0.09	0.33	0.96
CYN	712	0.36	0.31	0.50	2.35	552	0.40	0.08	0.21	0.74
FCN	420	0.40	0.28	-0.03	0.75	339	0.32	0.04	0.25	0.46
FFB	1469	0.23	0.30	1.11	10.34	1373	0.34	0.12	0.08	0.73
FNB	2507	0.13	0.32	-0.68	17.77	2271	0.32	0.08	0.14	0.81
FSR	582	0.53	0.18	0.18	1.74	388	0.25	0.04	0.18	0.36
GQR	755	0.26	0.33	0.12	1.70	555	0.48	0.09	0.25	1.06
GWF	2907	0.17	0.38	-0.93	37.37	2710	0.37	0.10	0.15	1.18
HFD	782	-0.47	0.55	-2.03	22.59	684	0.49	0.26	0.17	1.76
HIB	942	0.21	0.29	0.49	2.48	712	0.43	0.08	0.17	1.00
HQB	801	0.20	0.21	0.36	3.98	624	0.31	0.07	0.17	0.65
I	2461	0.14	0.34	1.02	21.05	2112	0.35	0.14	0.14	1.06
KRB	1523	0.40	0.34	-0.16	2.38	1351	0.35	0.06	0.20	0.65
LBQ	735	0.31	0.27	0.81	5.49	571	0.40	0.09	0.25	0.99
MNC	368	0.51	0.27	1.01	10.13	325	0.33	0.23	0.04	0.95
OQH	124	0.15	0.15	-0.12	1.35	98	0.28	0.02	0.21	0.35
PQY	693	0.45	0.28	0.51	3.35	540	0.39	0.08	0.23	0.84
RLQ	486	0.42	0.27	0.40	0.81	323	0.39	0.09	0.19	0.84
SFB	385	0.34	0.20	0.21	1.79	314	0.37	0.07	0.12	0.55
SQU	594	0.11	0.26	1.35	10.32	524	0.39	0.07	0.25	0.68
STB	182	-1.38	0.70	-0.07	1.37	201	0.81	0.22	0.35	1.38
SUB	2929	0.12	0.31	0.19	4.86	305	0.30	0.10	0.17	0.67
Mean	1213	0.20	0.32	0.25	8.41	1003	0.39	0.10	0.19	0.91

Fig. 2 shows that the IV for CCI, $IV(CCI)$, follows a somewhat different path. Until the early 1990s, $IV(CCI)$ is not much larger than VIX. In the first half of the 1990s, by contrast, $IV(CCI)$ exceeds VIX by considerable amounts. The spikes in $IV(CCI)$ near the end of 1990 and the end of 1992 are particularly large. As the 1990s continue, the spread between $IV(CCI)$ and VIX continues to narrow. By the middle of 1997, the spread drops to amounts similar to those we observe in the 1980s.

Fig. 3 shows that the IV's for GWF, $IV(GWF)$, are considerably above VIX during 1988 and 1989. The spreads of $IV(GWF)$ above VIX rise to quite high levels

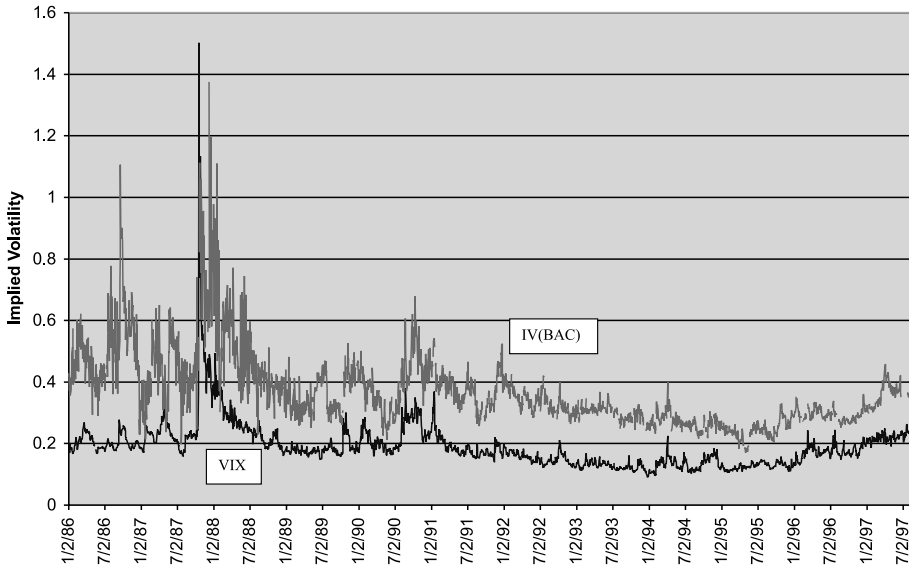


Fig. 1. IV's for BankAmerica and for the stock market sample period: 1986–1997, daily.

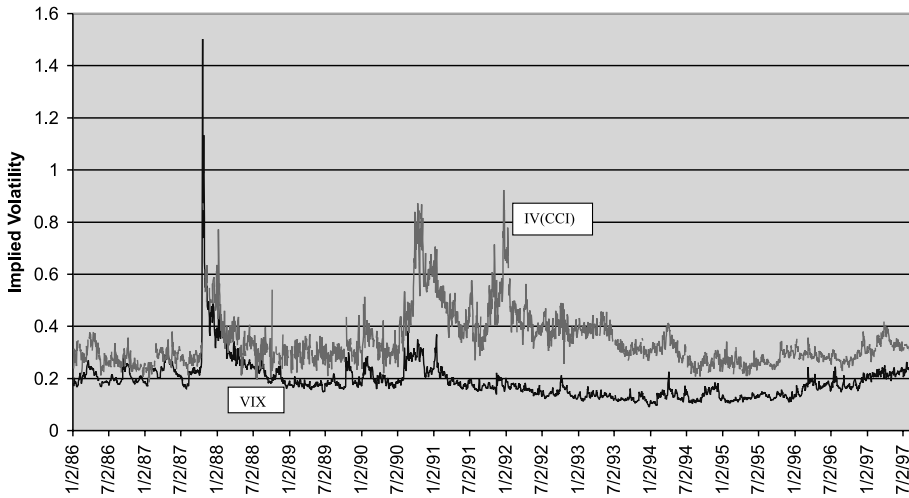


Fig. 2. IV's for Citicorp and for the stock market sample period: 1986–1997, daily.

during the 1990–1991 recession and remain high until well into the late 1990s, finally shrinking near the end of our sample in July 1997.

Table 3 shows the extent to which the IV's for these three banks tended to move with each other and with the VIX. Several notable patterns emerge from the correlation coefficients in Table 3. First, each bank's correlation is far enough below one

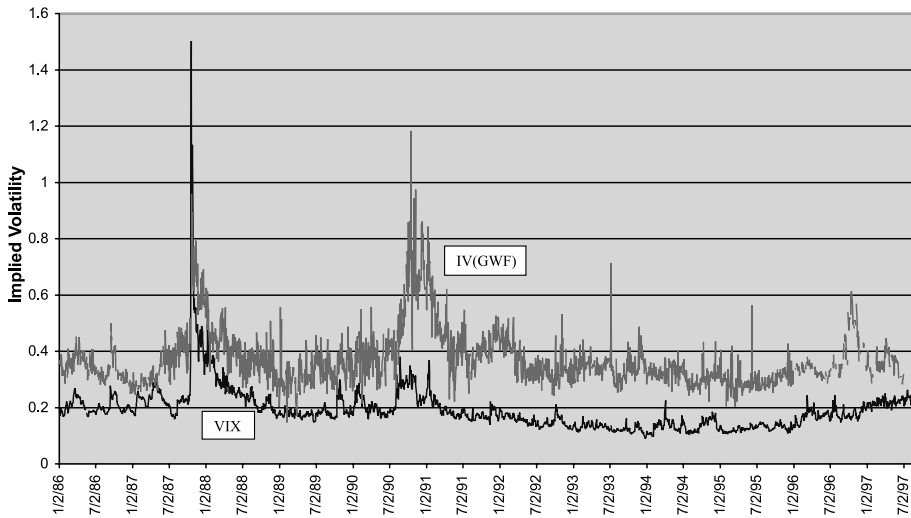


Fig. 3. IV's for Great Western Financial and for the stock market sample period: 1986–1997, daily.

Table 3
Correlation coefficients between IV's (sample period: 1986–1997, daily)

Option ticker symbol	Option ticker symbol			
	BAC (1)	CCI (2)	GWF (3)	VIX (4)
BAC	1.00			
CCI	0.34	1.00		
GWF	0.49	0.70	1.00	
VIX	0.72	0.39	0.60	1.00

to indicate important idiosyncratic movement in each bank's IV. Second, each bank's IV is significantly and positively correlated over the entire period with the IV for the other two banks – the average correlation is about 0.5. That suggests to us that important industrywide forces affected these banks during this period. Third, each bank's IV is importantly correlated with VIX – the average correlation is even a bit higher than the correlations between banks' IV's. This suggests that common, marketwide forces affected each bank.

5. Historical volatility and implied volatility

Measures of HV and of IV can each be used to measure the total risk of equity. Because HV is calculated from a sample of past observations, it is constrained from reacting quickly to new information. Thus, the predictive power of measures of HV is enhanced by return distributions that are less variable over time.

By construction, IV is a forward-looking measure of expected future volatility. An advantage of IV measures is that they can respond rapidly and completely to any innovation in the conditional (on current information), expected distribution of share prices. On the other hand, measures of IV necessarily reflect the assumptions of the option pricing model used to derive IV. Violations of those assumptions in practice may produce biased or imprecise estimates of realized future volatility.

No single measure of bank volatility is likely to always dominate all others. Rather than being regarded purely as substitutes, these two measures of expected future volatility, HV and IV, might better be regarded as complements. One reason is that we cannot be sure which sets of information and assumptions will be most relevant for the upcoming period. IV and HV are based on different information sets and different assumptions. As a result, they are, of course, not perfectly correlated. For BAC, CCI, and GWF, respectively, the correlations between HV and IV were 0.44, 0.65, and 0.58.

Bank supervisors might take account of the extent to which the two measures simultaneously indicate increases in bank risk. The greater the coherence of the signals being sent by the different measures, presumably the greater the supervisor's confidence that bank risk has increased. The confidence of the supervisor ought further be enhanced if other market-based risk measures, such as KMV's EDFs and yield spreads on the bank's debts indicate similar increases in the direction and size of changes in bank risk.

One way to estimate, ex post, the optimal average linear combination of HV and IV to forecast actual future, or realized, volatility (RV) is to use regression coefficients. Here we investigate the performance of HV and IV as predictors of RV for the three large banks for which we have data for the 1986–1997 sample period. To obtain the results shown in Table 4, we regressed HV and IV on RV. Each of these variables was calculated as described above. We used daily observations over the entire 1986–1997 sample period.

Table 4

Estimated relation of realized future volatility to IV and HV (dependent variable: Realized future volatility; sample period: 1986–1997, daily)

Option ticker symbol	Independent variables			R^2 (4)	RMSE (5)
	Constant (1)	IV (2)	HV (3)		
BAC	0.17 (26.85)	0.27 (16.71)		0.0937	0.1717
BAC	0.14 (30.34)		0.46 (27.89)	0.2126	0.1128
BAC	0.12 (18.68)	0.11 (6.92)	0.40 (21.52)	0.2265	
CCI	0.05 (5.80)	0.77 (30.75)		0.2612	0.0823
CCI	0.21 (34.08)		0.33 (18.99)	0.1112	0.1264
CCI	0.05 (5.83)	0.80 (24.37)	-0.04 (-1.56)	0.2619	
GWF	0.10 (9.06)	0.65 (22.09)		0.1536	0.1577
GWF	0.25 (35.86)		0.28 (15.79)	0.0800	0.1997
GWF	0.10 (9.19)	0.57 (16.07)	0.07 (3.45)	0.1573	

Note: *t*-statistics in parentheses.

Table 4 shows that, taken individually, HV and IV are each positively and statistically significantly correlated with RV. The estimated IV coefficients are about 0.8 for CCI and GWF, but only about 0.3 for BAC. The estimated HV coefficients averaged a bit over 0.3. Thus, taken individually, IV tended to be more highly correlated and have larger estimated coefficients than HV.

Another piece of evidence about the forecasting abilities of IV and HV individually appears in column 5 of Table 4, which reports the RMSE for HV and for IV for each of the three banks. Based on the RMSE of HV relative to the RMSE of IV for each bank, IV has smaller forecast errors than HV for CCI and GWF, but not for BAC. These results are consistent with the bivariate regression results.

When both HV and IV are included, coefficients on both are positively and statistically significant, with the exception of the HV coefficient for CCI. These three regressions suggest that using both dominates using either alone.¹⁰ (Even including HV, since it has a *t*-statistic over one in absolute value, to forecast RV for CCI would reduce the corrected *R*-squared.) Thus, forecasts of future volatility here are improved by taking a linear combination of the two imperfect and imperfectly correlated measures of bank risk, HV and IV. It would certainly not be surprising if EDFs and yield spreads on bank's debts further improved forecasts. In that regard, bank supervisors could benefit from using the separate signals from each of these measures to derive their forecasts and the confidence with which they hold those forecasts.

6. Options on bank shares as compound options

In this section, we demonstrate how IV's relate to a bank's financial condition. Consider a bank with assets that exceed its liabilities. The resulting, positive net worth, or capital, make it likely that its shareholders will retain ownership of the bank rather than abandon their shares. If the market value of the assets of the bank falls sufficiently below its liabilities, rather than retain ownership of a negative net worth enterprise, the shareholders may instead at negligible cost to shareholders close the bank. In that sense, bank shares inherently are a call option on the bank's assets with a strike price equal to the value of its liabilities.

This option to put a firm into insolvency is not unique to banks. The limited liability of nonfinancial corporations in general confers an option to "put" those firms into bankruptcy. In the case of banks, their shareholders can put the bank to the FDIC. Alternatively, only when assets exceed liabilities will shareholders exercise their call option to own the bank; otherwise, they cede it to the FDIC.

When the market value of a bank's assets equals the market value of its liabilities (and thus its capital is zero), the bank is "at the money". In contrast, a bank with a

¹⁰ Hansen et al. (2001) find that for index options, IV subsumes the information contained in HV once adjustments are made for overlapping data. In light of their results, our finding that IV is superior to HV for predicting future volatility is all the more impressive.

high, positive capital ratio is deep in the money – its assets exceed its liabilities by the amount of its capital. A share, which is a call option, is then said to have more “moneyness”.

Since bank shares are a call option on the bank’s assets, then options on bank shares can be regarded as options on options, or compound options. It follows that IV’s represent equity risk rather than bank asset risk. Because asset risk is a principal determinant of a bank’s default probability, it is important to delineate the relation between a bank’s equity risk and its asset risk.

Jarrow and Rudd (1983) show that the variance of a call option is equal to the variance of the underlying share price times η^2 , where η is the call option’s price sensitivity to changes in the share price. Moreover, since normally η is greater than 1, the call’s risk is greater than the share’s risk. Given that an option on a bank’s shares can be thought of as a compound option, $\eta > 1$ implies that bank equity risk, σ_c^2 , is greater than its asset risk, σ_a^2 :

$$\sigma_c^2 = \eta^2 \sigma_a^2 > \sigma_a^2. \quad (1)$$

Therefore, any change in IV (which measures σ_c), overstates any change in the bank’s asset volatility, σ_a .

Eq. (1) shows that the ratio of equity variance (and thus volatility) to asset variance (and thus volatility) depends upon the value of η . Consider the extreme case where the leverage of the bank approaches zero and thus the bank’s equity becomes deeper in the money. In the limit, bank equity and assets are virtually the same and η declines toward one. This suggests that η varies with leverage: For a given change in a bank’s asset volatility, the change in its equity volatility rises with the bank’s leverage (or the inverse of its capital ratio).

Banks typically are quite highly levered. Under the Basel Accord, banks are expected to hold capital equal to at least 8% of risk-weighted assets and the larger banks are likely to have capital ratios that reflect Basel and other regulations. Even if all of a bank’s assets had 100% risk weights, a bank would be allowed leverage ratios that are high relative to the leverage ratios at most other corporations. Because bank leverage varies widely (both over time at a given bank and across banks at any given time), it is an important variable to consider when examining the relation between bank equity risk and asset risk. Nevertheless, leverage is generally difficult to measure precisely on a daily basis.

Asset risk or volatility is also difficult to observe; however, insights may be derived from the preceding leverage argument. The reasoning may be extended to the responses of the market value of a bank’s assets, which primarily consist of the loans that it extends. A bank’s market value will be more volatile when the borrowers’ own assets are close to their liabilities in market value. When borrowers have higher ratios of market value assets to liabilities, the volatility of the market values of their loans will be lower. Thus, we expect that the better capitalized are bank’s (solvent) borrowers, the less volatile the market value of banks’ loans.

Here we take VIX to be a proxy for the volatility of bank assets. Since movements in VIX should incorporate changes in the leverage of bank borrowers, we have made no additional allowance for the degree to which bank borrowers are “in the money”.

For the large banks in our sample, changes in the market value of their assets are likely to be dominated by changes in the market value of claims that are the liabilities of relatively large businesses. We have assumed that the distribution of expected future changes in the S&P 100 index is reasonably highly correlated with that for the companies that actually borrow from these banks.

To investigate the relation between the volatility of bank equity and the volatility of bank assets, we regress the log of each bank's IV on a constant term and on the log of VIX:

$$\ln(\text{IV}) = \beta_0 + \beta_1 \ln(\text{VIX}). \quad (2)$$

We estimate a separate, simple regression for each year and for each bank. The estimated elasticities of IV's to VIX, β_1 , appear in Table 5. Given the considerable extent to which bank capital ratios (on a market value basis) vary across banks and across time in our sample, and mindful of the leverage argument, we expect that the estimated elasticities in Table 5 will vary widely too.

Table 5 illustrates that, indeed, the estimated elasticities of IV's to VIX do vary considerably both across banks and across time. First, reading down the columns, we see a wide variation of the estimates in any given year across banks. In most years, the estimates range from near zero to well over 0.5. Second, reading across columns, the estimates for any given bank vary noticeably across the years. In general, the estimated elasticities tend to be higher in the period before 1992 than after 1992.

The mean estimated elasticity for the three banks whose data is available for the entire sample period (BAC, CCI, and GWF) for the 1986 through 1992 period is about 0.65. Their joint mean for the 1993 through 1997 period is a little less than 0.20. In addition, in years when the mean estimated elasticity across all banks is relatively high, most banks are estimated to have high elasticities, and conversely for years with low mean estimated elasticities. Thus, there is some tendency for the individual banks' estimates to rise and fall together over time.

Next we ask whether the elasticities at a given bank are higher when the bank's capital ratio is lower. To investigate this hypothesis, we examine the three banks (BAC, CCI, and GWF) for which we have data for the entire 1986–1997 sample period. Table 6 presents the results of regressing a bank's estimated elasticity on a constant term and on $(A - L)/L$, where $A - L$ is each bank's market value equity and L is each bank's book value of its liabilities. The ratio is a proxy for each bank's market value equity (or capital) ratio, or inverse of its leverage.¹¹ Because of data limitations, we use the book value of liabilities instead of market value. Given the short-term and adjustable rate nature of many liabilities at these very large banks, the difference between book and market values of liabilities may not be particularly large.

The estimates in Table 6 support the hypothesis that volatility of a bank's share price falls the better capitalized is the bank. The estimated coefficients on $(A - L)/L$ for both Citicorp and Great Western are negative and clearly significant at the 5%

¹¹ It is inconsequential whether we express a bank's equity ratio to liabilities or to the more commonly used denominator, assets.

Table 5
Estimated elasticities of IV with respect to stock market volatility

Option ticker symbol	Year											
	1986 (1)	1987 (2)	1988 (3)	1989 (4)	1990 (5)	1991 (6)	1992 (7)	1993 (8)	1994 (9)	1995 (10)	1996 (11)	1997 (12)
AQR									0.26	−0.80	0.76	−1.26
AVQ							−0.07	0.05	0.06	−0.79	0.16	0.43
BAC	0.85	0.60	0.65	0.41	0.86	0.58	0.46	0.42	0.22	0.40	0.15	0.51
BBQ					0.70	0.60	0.27	0.04	0.04	0.11	2.23	−0.28
BK			−0.43	0.42	0.92	0.45	0.39	0.13	0.26	0.16	0.35	−0.17
BKQ								0.30	−0.06	0.92	−0.19	
BTQ					0.23	0.18	0.45	−0.43	0.10	0.91	0.02	−0.21
CAL								−0.36	0.15	−0.37	−0.15	
CBK				−0.49	1.02	0.29	0.61	0.51	−0.14			
CCI	0.59	0.79	0.56	0.33	1.22	0.56	0.68	0.67	0.29	0.21	0.19	0.17
COF										−0.08	−0.47	1.38
CSA								0.20	0.09	0.35	−0.39	0.35
CYN									−0.21	0.19	−0.07	0.42
CCN										0.05	0.08	0.26
FFB					0.56	0.92	0.29	0.05	−0.35	−2.94		
FNB	0.49	0.56	0.53	0.16	0.92	0.60	0.39	0.33	0.17	−0.05		
FSR										0.14	−0.10	0.17
GQR									0.22	−0.14	−0.21	−1.38
GWF	0.62	0.61	0.52	0.32	0.96	0.96	0.62	0.12	0.13	0.00	0.10	−0.31
HFD		0.12	0.69	0.57	1.38	0.79						
FIB								−0.13	−0.29	0.25	−0.13	−0.25

HQB									0.06	−0.16	−0.24	−0.52
I	−0.05	0.62	0.36	0.76	0.98	0.45	0.55	0.34	0.16	1.47	0.18	
KRB						1.11	0.54	−0.10	−0.03	0.09	0.29	0.01
LBQ									0.41	0.51	−0.75	0.07
MNC							−0.12	−0.32				
OQH										−0.08	−0.04	
PQY									0.32	−0.25	−0.33	−0.01
RLQ										−0.16	−0.11	0.59
SFB										−0.24	−0.43	
SQU									−0.14	0.43	−0.52	
STB					0.79	0.21						
SUB											0.20	0.45
<i>Means</i>												
All 33 banks	0.50	0.55	0.41	0.31	0.88	0.59	0.39	0.11	0.08	0.00	0.02	0.02
BAC, CCI, GWF only	0.69	0.67	0.58	0.35	1.02	0.70	0.59	0.40	0.21	0.20	0.15	0.12
Market volatility	0.02	0.29	0.25	0.18	0.23	0.19	0.15	0.13	0.13	0.13	0.17	0.22

Table 6

Estimated relation of IV elasticity to bank capitalization (dependent variable: Elasticity of IV to VIX; sample period: 1986–1997, annually)

Option ticker symbol	Independent variables		R^2	F	SEE
	Constant (1)	$(A - L)/L$ (2)			
BAC	0.54 (5.37)	-0.30 (1.64)	0.21	2.69	0.13
CCI	0.26 (5.49)	-0.24 (3.00)	0.47	9.02	0.08
GWF	0.23 (11.57)	-0.10 (2.86)	0.45	8.20	0.05

Note: t -statistics in parentheses.

level. The significance level of the estimated coefficient on moneyness at BankAmerica is somewhat above 10%. However, the estimated coefficient on moneyness for BankAmerica and its significance level would have been about the same as those for the other two banks had the estimated 1997 elasticity for BAC in Table 5 been similar to its recent levels. The 1997 estimated elasticity for BAC is 0.51, while it averaged about half of that over the 1994–1996 period. Since the 1997 estimate is based on data only through July, we have less confidence in that point estimate than for the other years, for which we have nearly twice as many observations. Taken together, the three rows of Table 6 suggest that bank leverage raises the response of IV's to stock market volatility.¹²

7. Implied volatilities and share prices

The previous section made the case that as a bank's leverage increases the volatility of (the market value of) its equity also increases. In this section, we look at the relation between the volatility of a bank's equity and the level of its equity. There are reasons to think that a causal relation between the volatility and the level of equity may be either negative or positive. In the asset-pricing branch of the finance literature, a negative relation is often noted: higher share prices seem to be associated with lower volatility of those share prices.

Various reasons have been given for this observation. One of the better known is that when a firm's share price rises, it becomes less levered, and therefore its share price is less volatile. On the other hand, in the banking and especially in the thrift literature, it is sometimes argued that we should see a positive causal relation: Unless they are prevented by their government supervisors, deposit-insured institutions will maximize equity by taking on more risk than they would in the absence of deposit

¹² Crouhy (2002) reports that he did not find a positive relation between leverage and a bank's elasticity of volatility with respect to overall market volatility. Crouhy's analysis differs from ours in two ways. First, he uses HV instead of IV. Second, his Eq. (2) regression uses end of month data rather than the daily data that we use to obtain our estimates. We prefer the specification shown in Eq. (2), in part, because of our finding that IV is a better forecaster of realized volatility than HV is. Using each day's data rather than only the end of month data would likely reduce the estimated standard errors of the estimated coefficients.

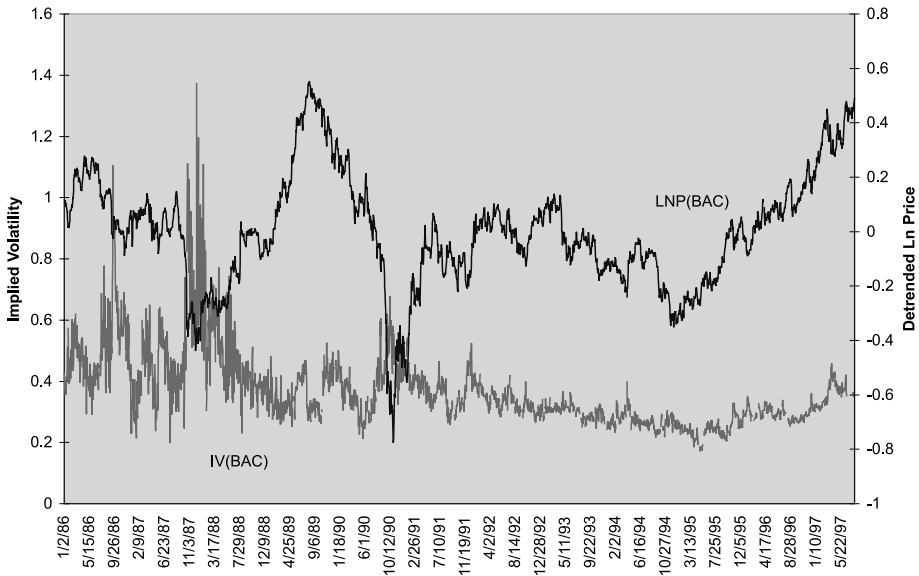


Fig. 4. IV and detrended log of share prices for BankAmerica sample period: 1986–1997, daily.

insurance that is not fairly priced. This suggests that higher volatility of asset values and of share prices may be associated with a higher level of share prices.

Here we do not present evidence on the causal, *ceteris paribus* relation between IV and the level of equity. To do so would require specification of a complete model of the determination of equity values. Even if banks did increase equity value by taking on more asset volatility, one impediment to observing this positive correlation may be that bank supervisors effectively prevent banks from exercising that option.

A second impediment might be that, in practice, many of the shocks that lead to higher asset and share price IV's simultaneously reduce the expected profitability of banks. Unless volatility shocks can be identified, estimates might reflect the combination of volatility and changed profitability on share prices. As an example, consider the 1990–1991 period, when IV's for bank share prices rose appreciably. That period of increased IV coincided with a national recession, which is very likely to have affected expectations about bank profits. Thus, we have the more modest goal of documenting the simple correlation between IV and the level of share prices.

In Figs. 4–6, we plot the IV's and (detrended) logs of share prices for BAC, CCI, and GWF for the 1986–1997 period.¹³ For each of these banks, higher volatility generally coincides with lower share prices. Fig. 4 shows that the IV for BAC is highest

¹³ The detrended log of each share price series was the residual series obtained by regressing the log of each share price series on a constant term and a linear time trend. General patterns and conclusions based on share prices that were not detrended are similar to those we report here based on detrended share prices.

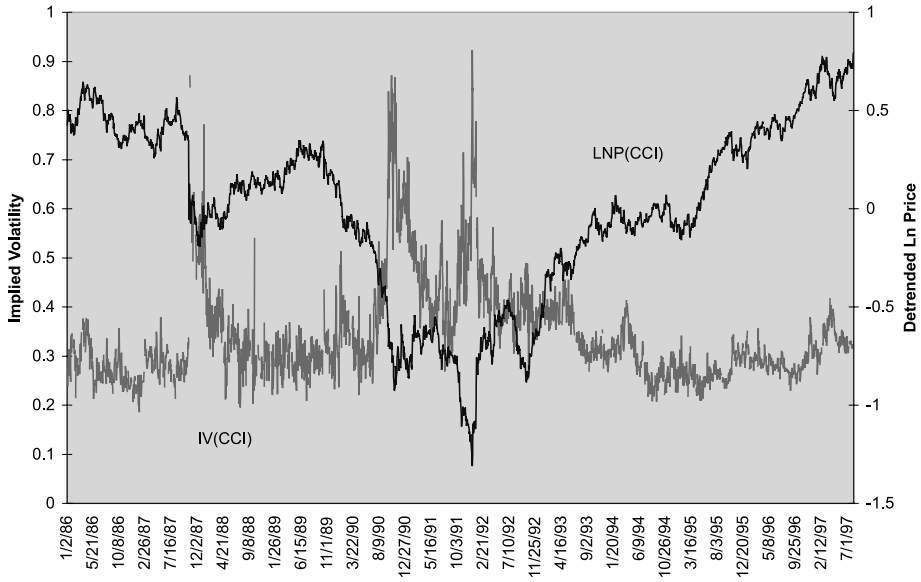


Fig. 5. IV and detrended log of share prices for Citicorp sample period: 1986–1997, daily.

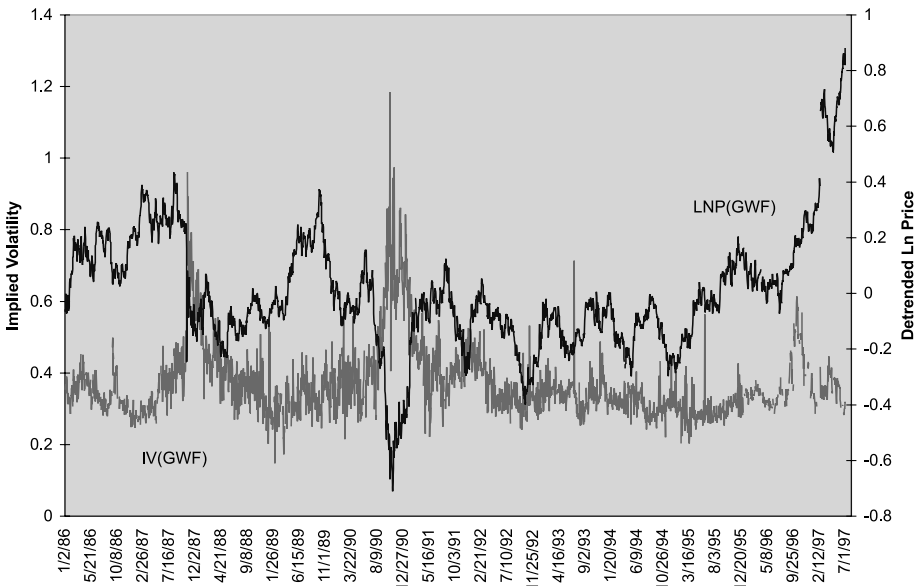


Fig. 6. IV and detrended log of share prices for Great Western Financial sample period: 1986–1997, daily.

until the middle of 1988, when the Third World debt crisis remains unresolved, and during the second half of 1990, when war loomed and recession was underway. The

Table 7

Correlation coefficients between IV's and (detrended) logs of share prices (sample period: 1986–1997, daily)

	IV(BAC) (1)	LNP(BAC) (2)	IV(CCI) (3)	LNP(CCI) (4)	IV(GWF) (5)	LNP(GWF) (6)
IV(BAC)	1.00					
LNP(BAC)	-0.13	1.00				
IV(CCI)	0.34	-0.40	1.00			
LNP(CCI)	0.05	0.52	-0.67	1.00		
IV(GWF)	0.49	-0.40	0.70	-0.33	1.00	
LNP(GWF)	0.05	0.72	-0.44	0.72	-0.30	1.00

higher IV's during those periods coincide with lower share prices for BAC. Between those two periods and afterwards, the negative correlation also held, as share prices rose and IV's drifted downward. Furthermore, the longer-run increase in share prices through the 1990s coincides with a generally declining IV for BAC. Thus, the log of the share price for BAC is negatively correlated with its IV. Overall, while the correlation seems to be negative, the relation is noisy in that one series or the other sometimes moves by large amounts for long periods of time without much movement of the other.

In Fig. 5, we plot the same variables for Citicorp. The most notable decline in its share price occurs from about the middle of 1989 through the middle of 1992. That decline is accompanied by an erratic, but clear, rise in its average IV. The periods of the steepest share price declines also tend to be associated with the steepest increases in IV. An earlier episode during which the share price decline was negatively correlated with an increase in volatility takes place following the October 1987 stock market crash. During the long period in the 1990s when the Citicorp share price drifted upward, Fig. 5 shows that IV of CCI tended to drift downward.

Fig. 6 shows a similar pattern of an overall negative correlation, especially until the early 1990s. After the middle of the 1990s, the sharp, longer-run increase in the share price of Great Western tended to coincide with an upward drift in IV. During the last year of the sample period, however, the correlation between the level of the share price and IV again seems to be negative.

Table 7 supports these visual impressions with correlation coefficients.¹⁴ Table 7 shows the correlation between each of the IV and share price variables that appear in Figs. 4–6. The correlation coefficients between IV's and the (detrended) logs of share prices average nearly -0.4 . This suggests that while the overall relation is clearly negative, each series has considerable independent movements. Table 7 also shows that IV's across banks are strongly, positively correlated; the correlation coefficients average about -0.5 . Table 7 also shows that (detrended) share prices are strongly, positively correlated across banks; the correlation coefficients average about 0.5 .

¹⁴ Correlation coefficients provide a measure of the linear association between these variables. There may well be good reasons to expect tighter connections between nonlinear transformations of these variables.

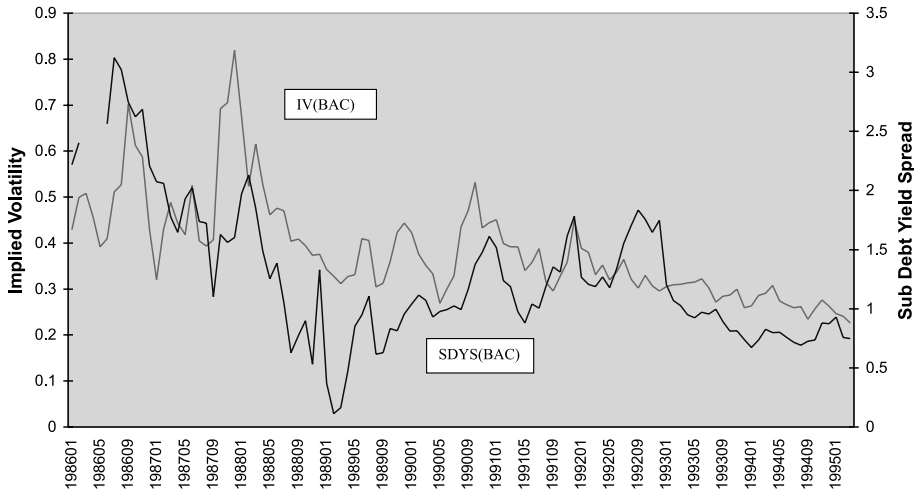


Fig. 7. IV and sub debt yield spread for BankAmerica sample period: 1986–1995, monthly.

8. Implied volatilities and sub debt yield spreads

Figs. 7 and 8 plot IV's and the spread between the yield on a bank's subordinated debt and Treasury yields for January 1988 through March 1995.¹⁵ We have yield-spread data only for two banks for which we also have IV's: BAC and CCI. Fig. 7 plots the IV's and yield spreads for BAC; Fig. 8 plots the IV's and yield spreads for CCI. Because we have monthly data for yield spreads, we plot the monthly averages of daily IV's.

Fig. 7 shows that both series for BAC trended downward over this period. Although they share that common feature, there are a number of periods during which they are much less correlated. In the aftermath of the October 1987 stock market decline and rise in VIX, IV(BAC) rises while the yield spread remains fairly low. During 1988 and 1989, the yield spread remains considerably below the overall pattern of IV's and spread. During 1992, on the other hand, yield spread is considerably above the overall pattern of IV and the spread. Fig. 8 shows that IV(CCI) and the yield spread on Citicorp's sub debt tend to track each other more closely. Especially noticeable are their similar spikes during 1991 and 1992. On the other hand, from the middle of 1987 through the middle of 1990, the two series showed little correlation in their movements. While IV(CCI) drifted little, the yield spread moved up by about 100 basis points over this period.

Although the IV's and yield spreads generally move together over longer periods, they also have important movements that are independent. Table 8 bears this out. The correlations between IV and the yield spread at each bank is a little over 0.6. The correlations across these two banks of their IV's and their yield spreads is in

¹⁵ De Young et al. (2001) provided the data for yield spreads on subordinated debt.

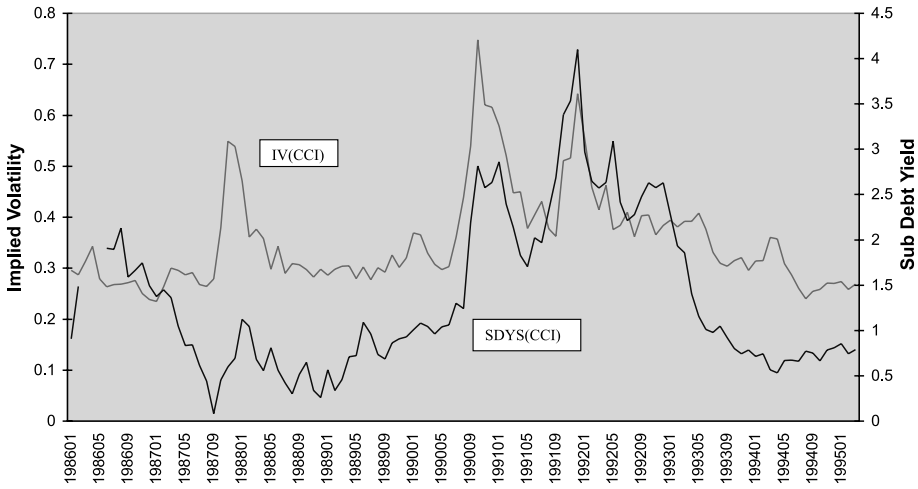


Fig. 8. IV and sub debt yield spread for Citicorp sample period: 1986–1995, monthly.

Table 8
Correlation coefficients between IV's and sub debt yield spreads (sample period: 1986–1995, monthly)

	IV(BAC) (1)	SDYS(BAC) (2)	IV(CCI) (3)	SDYS(CCI) (4)
IV(BAC)	1.00			
SDYS(BAC)	0.61	1.00		
IV(CCI)	0.27	0.06	1.00	
SDYS(CCI)	0.01	0.37	0.65	1.00

the neighborhood of 0.3, about half as large as the correlation of a bank's own IV and yield spread. Thus, data for IV's and for sub debt yield spreads seem to reflect both industrywide and bank-specific shocks, and they seem to respond differently at different times to those shocks.¹⁶

9. Summary and conclusions

As measured by the volatility of its share price, the risk of a bank reflects the volatility of the market value of its assets. Quite apart from its effect on the probability of bank failure, the risk of a bank is of independent interest. In the US context, bank

¹⁶ We also estimated a number of linear vector autoregressions using the data from Figs. 7 and 8. These VARs differed in variable ordering and in lag lengths. The estimated impulse response functions suggest that it is difficult to find significant generalizable patterns in the responses to various shocks. The lack of consistent responses is foreshadowed by the cross-correlograms, which implied that movements in the sub debt yield spread preceded those in IV for BAC while the opposite was true for CCI.

supervisors are concerned with bank safety and soundness. A concern with safety and soundness may encompass more than probability of failure. It might mean that bank supervisors would not accept a bank's having very high volatility of its market value, even though its capital ratios were sufficiently high to keep its probability of insolvency within the acceptable range. One reason for concern with volatility of bank equity and asset value may be that severity of loss may not also be tightly tied to probability of failure. Another may be that estimates of the volatility of assets may be a vital input in determining the amount of capital required above that implied by the Basel risk-weighted-assets formula.

Here we present measures of the volatilities of individual banks that are implied by the prices of options on the banks' shares. These data come from markets whose prices, and thus measures of IV, can be observed virtually continually at low cost. These prices come from markets that are widely regarded as being efficient and deep.

IV's contain both important common movements across banks and important bank-specific movements in banks' risks. We present evidence that the extent to which the riskiness of a bank's assets translate into IV of its share price depends positively on the leverage (or equivalently, the inverse of the capital ratio) of a bank. For two of the three banks we examined in detail, we show that the IV's have lower RMSE's in forecasting future volatility of bank share prices than HV's do.

We also show that banks' IV's share important common movements with their own share prices and with yield spreads on their subordinated debt. However, IV's also importantly diverge from the paths followed by share prices and yield spreads. Thus, IV's are likely to add information about bank risk that is timely, relatively cheap to acquire, objective, and useful.

Adding a measure of IV to the information that supervisors and others use to evaluate the volatility and failure probability of a bank can alter the point estimates and the confidence in those point estimates. We show that measures of IV are not perfectly, and sometimes not highly, correlated with HV, not to mention with signals from other models and the debt markets. At the same time, measures of IV tend to be significantly correlated with what it purports to forecast – actual, future volatility. These correlations suggest that using measures of IV in conjunction with other measures, such as measures of HV, EDFs, and yield spreads on bank debts, may well improve the accuracy of forecasts of bank outcomes. We discuss generally and show in a specific case how various measures might be combined to improve signals about the future of banks. This is not to suggest that this is the only or the best way to combine such signals. It will take further work to determine whether, for example, a more categorical approach would better forecast bank outcomes. An alternative to the regression approach that we show is to evaluate changes in risk by tallying how many separate signals from a bank point toward risk changing in the same direction.

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