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Have big banks gotten safer?

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Abstract

Since the financial crisis, there have been major changes in the regulation of large financial institutions directed at reducing their risk. Measures of regulatory capital have substantially increased; leverage ratios have been reduced; and stress testing has sought to further assure safety by raising levels of capital and reducing risk taking. Standard financial theories would predict that such changes would lead to substantial declines in financial market measures of risk. For major institutions in the United States and around the world and midsized institutions in the United States, we test this proposition using information on stock price volatility, option-based estimates of future volatility, beta, credit default swaps, earnings-price ratios, and preferred stock yields. To our surprise, we find that financial market information provides little support for the view that major institutions are significantly safer than they were before the crisis and some support for the notion that risks have actually increased. This does not make a case against the regulatory approaches that have been pursued, but does caution against complacency.

We examine a number of possible explanations for our surprising findings. We conclude that financial markets may have underestimated risk prior to the crisis and that there may have been significant distortions in measures of regulatory capital. While we cannot rule out these explanations, we believe that our findings are most consistent with a dramatic decline in the franchise value of major financial institutions, caused at least in part by new regulations. This decline in franchise value makes financial institutions more vulnerable to adverse shocks. We highlight that the ratio of the market value of common equity to assets on both a risk-adjusted and risk-unadjusted basis has declined significantly for most major institutions. Our findings, if validated by others, may have important implications for regulatory policy.

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1. Introduction

It is widely believed that because of regulatory changes made in the wake of the Great Recession, major financial institutions in the United States and around the world are much safer and sounder today than they were prior to the financial crisis. This is a consequence of the landmark Dodd Frank legislation as well as major changes in regulatory policies. Among the changes made were higher capital requirements, particularly for systemically important firms; increases in bank liquidity; and required compliance with and passage of bank stress-tests to test banks' solvency in periods of crisis.[1]

The regulatory community believes that it has brought about large increases in capital. Mark Carney, the Governor of the Bank of England, observes that Tier-1 capital ratios for systemically important financial institutions have more than doubled since 2009 (Carney 2016a). And taking into account adjustments in the definition of bank risk in the aftermath of the crisis, key officials such as Carney and Jaime Caruana, the General Manager of the Bank for International Settlements, claim that properly risk-adjusted capital levels brought about by Basel III for systemically important financial institutions are seven times Basel II levels (Carney 2014, Caruana 2012).

Policymakers and political commentators alike have heralded Dodd-Frank and Basel III as ushering in a new era of financial security. President Obama proclaimed on the five-year anniversary of the crisis that "our financial system is safer...[We] put in place tough new rules on banks" (Obama 2013). Janet Yellen, Chairwoman of the Federal Reserve, concurs, noting that "we have put in place numerous steps and have more in the works that will strengthen these [financial] institutions, force them to hold a great deal of additional capital, and reduce their odds of failure. There will be much lower odds that a so-called systemic firm will fail, and should that occur we'll have better tools to deal with it" (Yellen 2014).

The view that banks are safer and less likely to fail is essentially an assertion that their market value is less likely to approach zero. This should be testable with

[1] Federal Reserve Chairwoman Janet Yellen discussed the success of Dodd Frank and these measures in a May 2015 speech at the Institute for New Economic Thinking.

information on bank security prices. Indeed, according to standard financial theories, the idea that banks are better capitalized and hold fewer risky assets has clear implications for the pricing of their securities. With less leverage, bank equity should be less volatile, and there should be less market expectation of future volatility. Bank stocks should also be less responsive to movements in overall economic conditions. As a consequence of reduced risk, the expected return on bank debt, bank preferred stock, and common stock should be reduced. This last idea, that reduced riskiness should translate into lower required returns on stock, is central to the influential arguments put forth by Admati and Hellwig (2014) that increasing capital requirements promotes safety without significantly raising overall capital costs.

In this paper we use a range of financial market data to examine the evolution of bank risk. Any individual indicator is an imperfect proxy for financial risk; however, looking at many different indicators enables an assessment of market risk judgments. In examining volatility, we focus on historical stock price volatility, expected volatility as implied by traded options, beta—the standard measure of comovement with the market, and a measure of contribution to systemic risk devised by Acharya et al. (2016). In investigating expected returns, we look at credit default swaps as a measure of the riskiness of unsecured bank debt, preferred stock yields, and earnings-price ratios as a proxy for expected stock market returns.

We look at data for the Big 6 US financial institutions (Bank of America, Citigroup, Goldman Sachs, JP Morgan, Morgan Stanley, and Wells Fargo) as well as the largest non-Chinese banks outside the United States. We also consider a broader range of domestic banks, analyzing the fifty largest US financial institutions outside of the Big 6 (as measured by total assets).

To our surprise, capital market information is at least superficially inconsistent with the view that banks are far safer today than they were before the crisis. If anything, measures of volatility appear to be higher post-crisis than they were pre-crisis and measures of expected return are higher as well. These tendencies are even stronger outside the US, perhaps reflecting greater regulatory progress in the US. They are about equally pronounced for the Big 6 institutions and for midsize institutions; and are strongest for the smallest institutions in our sample, a finding perhaps unsurprising given that much greater regulatory effort has gone into reducing risk in large institutions.

We examine a number of possible explanations for our anomalous findings. It is plausible that markets underestimated risks in the pre-crisis period, which explains the increase in banks' unsecured borrowing costs. It is harder, however, to attribute lower volatility and beta over a multiyear period to underestimation of risk. We suspect that measures of regulatory capital are flawed as measures of economic capital. Thus, properly measured capital may have increased less than regulatory capital measures and this may account for part of what we find.

Our primary explanation is that the franchise value of banks has substantially declined in the wake of the financial crisis. This is reflected in sharp declines in the ratio of price to book value for most institutions. Essentially equivalently, the ratio of the market value of equity to assets has declined on a risk-adjusted or risk-unadjusted basis for most institutions. With a lower level of equity relative to assets, it is not surprising that volatility has gone up or that the riskiness of bank debt has increased. Critically, a lower ratio of market value of equity to total assets means that the proportional losses on assets sufficient to cause the bank to fail have decreased.

Our results do not call into question the desirability of the increases in capital that have been mandated by post-crisis regulations. But they do counsel against complacency and highlight future policy challenges.

This paper is organized as follows. Section II motivates our risk measures and evaluates what the expected effect of a substantial increase in bank capital requirements on these measures. Section III discusses our data sources and presents results on these measures for the six major US financial institutions. Section IV considers a broader range of domestic banks. Section V presents corresponding results for international financial institutions. Section VI considers a number of possible explanations for our findings and focuses attention on the ratio of the market value of equity to assets as a crucial risk measure. Section VII concludes by discussing possible policy implications.

2. Review of Risk Measures

The standard frameworks used in bank regulation and supervision place little emphasis on the pricing of bank liabilities and bank equity in evaluating the riskiness of banks. These frameworks are the basis for assertions that the financial system has become far safer.

It is noteworthy that, as Bulow and Klemperer (2013, 2015) and Haldane (2013) point out, measures of regulatory capital have historically not had much predictive power for bank failures. Bear Stearns, Wachovia, Washington Mutual, Fannie Mae, and Freddie Mac were all seen by their regulators as well-capitalized immediately before their failures. In contrast, the pricing of their equity and debt securities was signaling distress.

It therefore seems worthwhile to use information on bank security prices in evaluating their safety. In this section we review the risk measures we use to evaluate the impact of regulatory changes on systemically important financial institutions. We also explain the anticipated impact of stricter regulation—as a result of increased capital requirements—on these measures. Since many things have changed in the economic environment alongside regulation, we look at a variety of risk measures.

2.1 Volatility

Banks fail when their equity value falls below zero or some threshold close to zero. The likelihood of reaching this threshold depends on their volatility. If one assumes that dollar volatility is constant as the value of equity declines (implying a proportional increase in percentage volatility) than the probability of the stock price reaching zero over a given interval is readily calculable. Suppose for example a bank has a 30 percent annualized volatility. Then, leaving aside expected appreciation in its stock, it would require a 3.33 standard deviation move in 1 year for its equity to go to zero or a 1.67 standard deviation move in 4 years. A major improvement in the safety of financial institutions should precipitate a reduction in their stock price volatility (or equivalently, an increase in the number of standard deviations required to get to zero over any given interval).

Standard financial theory holds that reductions in leverage or equivalently increases in capital should lead to declines in volatility. Schwert (1989) models the relationship between stock volatility and leverage. He notes that the variance of the return on assets of a firm is given by

$$\sigma_{vt}{}^2 = \left[\frac{S_{t-1}}{V_{t-1}}\right]^2 \sigma_{st}{}^2 + \left[\frac{B_{t-1}}{V_{t-1}}\right]^2 \sigma_{bt}{}^2 + 2\left[\frac{S_{t-1}}{V_{t-1}}\right]\left[\frac{B_{t-1}}{V_{t-1}}\right] \text{cov}(R_{st}, R_{bt})$$

with $\sigma_{vt}{}^2$ as the variance of the return on the assets of a firm, $\sigma_{st}{}^2$ as the variance of the returns on stock, and $\sigma_{bt}{}^2$ as the variance of the bond returns, and $\text{cov}(R_{st}, R_{bt})$ as the covariance of the bond and stock returns. Again assuming a firm with riskless debt, such that

$$\sigma_{bt}{}^2 = \text{cov}(R_{st}, R_{bt}) = 0$$

We are left with the standard deviation of stock returns as

$$\sigma_{st} = \sigma_{vt}\left[\frac{V_{t-1}}{S_{t-1}}\right]$$

V/S is the financial leverage ratio—the ratio of assets to equity. Thus, the relationship between stock volatility and leverage is linear, with a slope equal to the volatility of the return on firm assets. If effective leverage has been reduced by regulatory changes in a way that has not been offset by an increase in the volatility of bank assets, one would expect to see the volatility of bank equity go down.

In reality bank debt is not riskless and fluctuates in value with bank assets; and banks sometimes of their own volition or at the behest of regulators raise equity, creating a wedge between movements in stock prices and movements in the total market value of equity. For all these reasons the relationship between leverage and volatility is not likely to be perfectly linear. Nonetheless it is reasonable to expect that if banks have become materially safer and if they are less levered that their equity volatility should go down.[11]

Many will suspect that markets now expect that banks are less likely to be bailed out than previously. We are not sure whether this is a valid suspicion nor whether markets have it. But note that if it is true, it strengthens the prediction made here. If the likelihood of bailout has gone down, then debt should bear more risk and equity less as the value of bank assets fluctuate.

2.2 Implied Volatility

Volatility can be measured using historical stock price data or inferred from options data, and the latter exercise allows us to ascertain the market's expectation of future volatility. Christensen and Prabhala (1998) find that implied volatility outperforms historical volatility in predicting future volatility. And Cao et al. (2010) come to the same conclusion, noting that implied volatility is a better predictor of CDS spreads than realized volatility because information about the volatility risk premium is embedded in option prices. Thus, for completeness, we use both realized and implied volatility as risk measures in our forthcoming analysis and study their responsiveness to decreases in banks' leverage.

2.3 Put Option Delta

The absolute value of the delta of an option can be thought of as the probability of the option ending up in the money (Gunn 2009). As such, we calculate the delta on a one-year 50 percent out-of-the-money (OTM) put option to ascertain the probability of a major fall in stock price in the next calendar year and use this delta as a supplemental risk measure.

In order to calculate the delta of a 50 percent OTM put option, we take the most out-of-the-money put option (with more than two months to expiration) on each day in

[11] Equity represents a call option on the total assets of a firm with a strike price equal to the value of its debt. Debt can be thought of as safe debt less the writing of a put option on the assets of the firm with strike price equal to the value of the debt. As the firm becomes less levered, the delta of the equity option will rise and, given that it is in the money, its gamma will fall—implying a reduction in its volatility.

the pre- and post-crisis period.[12] We use the implied volatility on these far OTM options to calculate an annual average implied volatility[13] and follow the Black-Scholes model to compute a delta on an exactly 50 percent OTM option with one year to expiration.

Since a decrease in leverage should decrease the likelihood of default, we expect increased capital requirements to decrease (in absolute value terms) OTM put delta. More simply, if banks are safer the market assessment of the probability that they will lose half their equity value in the next year should have gone down.

2.4 Beta

One issue with volatility as a measure of bank risk it that it does not naturally benchmark relative to the market. For this reason, beta may be a preferred measure. Baker and Wurgler (2015) seek to understand the impact of stringent capital requirements on cost of capital. They focus on beta as a measure of equity risk and discuss how bank leverage impacts firm beta. We adopt their framework in considering the impact of a decrease in banks' leverage on equity betas. Arithmetically, we know that the following relationship holds for equity, debt, and asset beta:

$$\beta_a = e\beta_e + (1 - e)\ \beta_d$$

With β_a as asset beta, β_e equity beta, β_d debt beta, and *e* the ratio of equity to total assets.

1/e is the inverse capital ratio, equivalent to Schwert's V/S above. We again assume that the riskiness of bank assets is constant, that is, that β_a has not changed. When Baker and Wurgler (2015) rearrange the above and assume riskless debt, they conclude that, like volatility, the relationship between beta and leverage is linear, with a slope equal to the asset beta.

Baker and Wurgler verify that this relation holds true to a substantial extent in the cross-section.[14] We replicate their results using our data on large and mid-sized

[12] Volatility differs across different classes of options, and in this calculation we focus on the volatility of those far OTM put options that are related to the likelihood of a large decline in equity value.
[13] We use daily data on risk-free rates from a 12-month treasury bill, and add in dividend yield data for our banks to use Black Scholes to compute option deltas. Dividend yield data is available quarterly.

domestic financial institutions. We compute forward beta following their methodology, by regressing a minimum of 24 months and a maximum of 60 months of future holding period returns on the CRSP value-weighted market returns, both in excess of the riskless rate. As a measure of leverage, we use the quarterly Tier 1 leverage ratio from bank call reports. Figure 1 presents the relationship between bank beta and leverage in our cross-section.[17] Like Baker and Wurgler (2015), we see that this relationship is linear over most of the range of leverage, with a slight S-shape that Baker and Wurgler attribute to the inclusion of what they call "extreme levels" of leverage in the sample.

Based on these cross-sectional results we can expect that as capital requirements become more stringent, beta should decrease. We further hypothesize that, as is the case with volatility, we should see a linear relationship between beta and our leverage measures. We take this hypothesis to the data in the forthcoming analysis.

2.5 Credit Spread

The CDS spread is the annual cost of protection against a default by a company.

CDS spreads should rise with leverage, as the probability of default is increased as firms become more levered (see, e.g. Collin-Dufresne et al. 2001). Consequently, all else equal, the increased capital requirements in the wake of the financial crisis should have decreased CDS spreads.

More generally, if banks are now less likely to fail, their CDS spreads should be lower. There is of course the possibility that CDS spreads move not because of changes in bank riskiness but because of changes in the probability of government bailout. That is why we examine them as described above alongside option-based estimates of the probability of a large decline in bank stock prices. If CDS spreads were rising only

[14] Baker and Wurgler (2015) find an approximately linear relationship between leverage and bank beta using returns and capitalization data for nearly 4000 publicly traded banks or holding companies that appear in CRSP between 1970 and 2011.

[17] Although we present only the results for the local polynomial regression in Figure 1, we note that since our sample is much smaller than Baker and Wurgler (only around 6,000 bank-months versus their sample of over 74,000), nonparametric analysis may be ill-suited here. While we think this visual is powerful, we also run a basic regression of beta on leverage. The results show a positive and statistically significant relationship, and when we suppress the constant, which corresponds to the Baker and Wurgler assumption of riskless debt, we have a point estimate of 0.081 for asset beta, slightly higher than the Baker and Wurgler estimate of 0.074.

because of a reduction in the prospect of a government bailout, one would not expect to see increases in the probability of a large drop in stock prices.

2.6 Price-Earnings Ratio

Rajan (2005) compares the price-earnings (PE) ratios of banks in the US relative to the market and proposes that the declining PE ratios implied that the market was discounting bank earnings with an increasing risk premium. He suggests this as evidence that (at the time) banks had not become less risky as the result of global financial development in the prior three decades.

We follow Rajan (2005), but focus on a different epoch. We compare PE ratios in the pre- versus post-crisis period and expect that an increase in bank capitalization should decrease risk—and thus increase PE ratios.

2.7 Preferred Stock Price and Yields

Relatedly, we examine pricing of preferred stock both before and after the Great Recession. Preferred stock is a layer of capital that is junior to debt, and its holders are entitled to a fixed or floating (indexed to LIBOR) dividend whose payment takes priority over dividend payments to common shareholders. Preferred stock has a unique feature of being callable, meaning its holders can be bought out, if the firm decides that the payout (or stream of future payouts) is large relative to the value of the share.

Since preferred stock has debt-like features, we can infer from the price of these shares how the market perception of bank risk has evolved in the aftermath of the Great Recession. Given that long-term riskless rates have declined substantially since the pre-crisis period, we would expect that if banks are no riskier today (or even less risky, given the large influx of capital as a result of post-crisis regulation), preferred shares should be selling for substantially more today than they were in the pre-crisis period. We would also anticipate that yields on preferred stock should have declined in the aftermath of the crisis and that yields on new preferred stock issuances should be low.

2.8 Systemic Risk

Acharya et al. (2016) focus on a new definition of a firm's systemic risk. They define systemic risk not in terms of the likelihood of an individual financial firm's failure, but rather by the likely size of a firm's contribution to a system-wide failure. Their systemic risk measure is equal to the product of three components: 1) real social cost of a crisis per dollar of capital shortage; 2) probability of a crisis; and 3) expected capital shortfall of the firm in a crisis.

They compare their measure to standard measures of institution-level risk such as volatility and beta and find that while these standard measures do a relatively poor job predicting which institutions fare worst in crisis, the Acharya et al. systemic risk measure explains a high proportion of realized returns during the Great Recession. As an additional financial market indicator of bank stability, we examine whether the Acharya et al. measure reflects a decline in systemic risk since the financial crisis.

3. Results

3.1 Sources of Data

The data we use in this paper are derived from numerous financial databases.

3.1.a Domestic Data

We collect daily data on beta and historical volatility from Bloomberg. To compare historical volatility to market volatility, we divide by market volatility for each day.[20] Market volatility is given by the realized volatility of the S&P 500. To compute annual averages, we take the average of the prior 260 days' volatilities.

We collect daily data on implied volatility from Bloomberg as well. The implied volatility is the annualized volatility on the nearest contract, which generally will be expiring within the next thirty days. As with historical volatility, to compare implied volatility to market volatility, we divide by market volatility each day.[23] Market implied volatility is given by the CBOE Volatility Index (VIX), a measure of the implied volatility of S&P 500 stock index option prices.

[20] We also subtract out market volatility, yielding similar results.
[23] As above, results are comparable when we subtract out market volatility.

We collect CDS data from Capital IQ. We use price data for a five-year tenor. Acharya et al.'s (2016) systemic risk metric comes from the NYU Volatility Institute.

We compute our financial ratios using data from CRSP, Compustat, and Bloomberg. The price-earnings (PE) ratio is daily stock price (from CRSP) divided by earnings per share (from Compustat). Price-to-book (PTB) data comes from Bloomberg. The ratio of market value of equity to assets (MVE ratio) is computed as the multiple of price and shares outstanding (from CRSP) divided by assets data (from Bloomberg). Information on preferred stock offerings and daily price data comes from the New York Stock Exchange online database.

3.1.b International Data

We collect daily data on beta, CDS spreads, and price-to-book ratios from Thompson Reuters Datastream. We calculate international betas relative to the country index for each of our financial institutions. We get data on firm volatility and implied volatility from Bloomberg, and match this with country volatility[24] and country implied volatility indexes[25] also from Bloomberg.

Bloomberg LIVE provides us with implied volatility data for our international financial institutions. The LIVE calculator uses listed option market data to generate implied volatility figures. Specifically, it weighs the nearest two option series that are at-the-money, one above and one below the underlying price.[27]

3.2 Summary of Results

In Table I, we summarize the results for each of the risk measures. We compare the "pre-crisis" period (typically from 2002-2007) to the "post-crisis" period (typically from 2010-2015) and seek to determine how the risk profile of our financial firms has evolved in the aftermath of the crisis. We exclude 2008 and 2009 from our sample based

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[24] Because of data availability, we benchmark banks in the Netherlands, Sweden, and Denmark against European realized volatility indices rather than country-specific ones.

[25] Because Brazil, Canada, and Australia only recently added implied volatility indices, in these countries we benchmark against the US VIX. We benchmark banks in France, Spain, Switzerland, Italy, Denmark, Sweden, and the Netherlands against a European implied volatility index because country-specific data is unavailable. We believe this is a reasonable approach given the extremely high correlation between the various country-specific indices and regional ones. See Liu 2012.

[27] Reuters uses a similar methodology, and explains it as follows – "Example: if the underlying is 655 and the two closest ATM strikes are 650 and 700, the implied volatility of the 650 strike will be weighted 45/50 against the implied volatility 700 strike which is weighted 5/50." Datastream. Options User Companion. February 2008.

on the NBER's classification of the Great Recession, which officially began in December 2007 and ended in June 2009.[28] We begin our pre-crisis period in 2002 also following the NBER in efforts not to contaminate our pre-crisis period with previous cyclical downturns. Before the Great Recession, the last official recession began in March 2001 and ended in November 2001. Our estimates are robust to defining "crisis" as July 2007 to December 2008 following Acharya et al. (2010) or January 2007 to September 2008 following Erken et al. (2012), although past work has also used December 2007 as the start date for the Great Recession (see, e.g. Elbsy et al. 2010; Katz 2010). Panel A provides the results for the "Big 6" US financial institutions, Panel B provides the results for the midsize US financial institutions (by total assets, excluding the Big 6), and Panel C provides the results for the largest financial institutions outside of the US and China.

Figure II illustrates how several of our risk measures have evolved over time for the Big 6 financial institutions (Panel A), midsize domestic institutions (Panel B), and international institutions (Panel C). We see that while risk beta, volatility, and CDS spread peaked during the Great Recession, these measures remain elevated in the post-crisis period. Our preferred specification involves comparing the pre-period to the most recent 2015 crisis measures, where our baseline results continue to hold.

We find that, based on virtually all of our measures, firms have become more risky in the post-crisis epoch. At least superficially, capital market measures are inconsistent with the notion that banks have become safer as a result of enhanced regulation in the form of higher capital requirements. Below, we discuss specific results for each of our risk measures. We first provide results for the Big 6, and then look at a wider range of US financial institutions and international banks to further bolster our baseline results.

[28] We extend our "crisis" period through December 2009, but results are even stronger when the second half of 2009 is included in our "post-crisis" period as per the NBER's classification. We exclude the second half of 2009 from post-crisis because do not want to capture any of the residual impact of the Great Recession. We also favor a more conservative estimate of bank risk in the post-crisis period.

3.2.a Volatility

We expect that volatility decreases with decreased leverage, and consequently hypothesize that volatility is lower in the post-crisis period. However, looking at the Big 6 financial institutions, we find that this is not the case. Particularly, in Appendix A, Panel A1 we see that volatility has risen in the aftermath of the financial crisis, and this rise is not explained by the increased volatility of the market as a whole (see Panel A2 and discussion below). Although banks differ in their relative increases in volatility (with the most significant jumps for Wells Fargo, Citigroup, and Bank of America, which parallels the beta results described below), all six of our major institutions have experienced some increase in volatility in the post-crisis period.

It is perhaps more sensible, though, to compare volatility in 2015 to volatility in the pre-crisis period. If it is the case that it took time for capital to accumulate and the market to grasp the implications of the new wave of financial reforms; or if in 2010 the effects of the crisis were still weighing heavily on the financial sector then perhaps we should not be surprised that in the post-crisis period we see elevated volatility. Consistent with this hypothesis, volatility has been falling in the aftermath of the Great Recession, and the most recent average (20.67) is substantially below the pre-crisis estimate of 24.70. Note though that the most recent volatility measure for Bank of America (23.21) remains substantially above the pre-crisis estimate of 19.70.

Assuming riskless debt, the standard deviation of stock returns is given by

$$\sigma_{st} = \sigma_{vt}\left[\frac{V_{t-1}}{S_{t-1}}\right]$$

where V is the market value of assets, S is the market value of equity, and σ_{vt} is the volatility of the bank assets, which we assume has not changed from the pre- to post-crisis period. Our assumption of riskless debt is justified based on Baker and Wurgler (2015). Replicating their methodology for our sample, we estimate an asset beta of approximately 0.081 in our cross-section. Since asset beta must mechanically be higher than debt beta, like Baker and Wurgler, we conclude that the zero estimate for debt beta is a reasonable one.[29]

The average Tier-1 capital ratio for the Big 6 financial institutions has risen from 8.4 percent to 13.3 percent, so the inverse capital ratio (1/e) has fallen from 11.9 to 7.5. Average volatility for the Big 6 in the pre-period is 24.70. Thus, we would expect that average volatility in the post-period after Tier-1 ratios have increased should be 15.60. This is not what we observe. Volatility is still significantly higher in 2015 (Big 6 average of 20.67) than we would have predicted given the capital increases of these large financial institutions.

One possible explanation for our volatility results is that we are capturing changes in market volatility. That is, it is possible that bank volatility has not moved much despite increases in capital requirements, but bank volatility *relative* to market volatility reflects greater stability in the financial sector. This possibility explains why beta, which is a measure of volatility with respect to the market, is perhaps a more meaningful risk measure for our analysis.

If market volatility has increased but bank volatility has remained constant, then we would expect that when we net out the market effect, we should see a decrease in volatility. We test this hypothesis in Appendix A, Panel A2. In Panel A2, we divide bank volatility by the volatility of the S&P 500 by calculating the standard deviation of daily returns over the course of the year.

We see that pre-crisis volatility relative to the most recent 2015 measure has actually increased on average when we divide by the market. Big 6 volatility relative to the market averaged 1.55 in the pre-crisis period; now these banks are 1.71 times as risky as the market.

3.2.b Implied Volatility

Like historical volatility, we anticipate that future volatility, as implied by option prices, will decrease as a result of heightened bank regulations and particularly higher

[29] This is slightly above the Baker and Wurgler estimate of .074, which is likely related to the difference in our samples—BW consider all domestic bank-holding companies, we restrict our attention to the largest ones.

capital requirements. We find this too is not the case. In Appendix A, Panel 3 we see that implied volatility increases for all of the Big 6 financial institutions in the post-crisis period. Unfortunately our implied volatility data is available beginning only 2005, so we are not fully able to compare the pre- and post-crisis periods. Again, given the fact that (a) capital took time to accumulate and (b) 2010 was still fairly close to the financial crisis's conclusion, it is more sensible to benchmark against the most recent measure. However, when we compare 2005-2007 to the most recently available 2015 implied volatility data, we see that implied volatility is basically unchanged, moving from a pre-crisis average of 22.90 to a 2015 average of 22.96.

In Panel A4, we divide bank volatility by the VIX, which provides a measure of the implied volatility of S&P 500 index options.[30] Relative to the market, implied volatility has fallen when compared to the pre-crisis measure, from an average of 1.91 in the pre-crisis period to 1.61 in 2015. However, this decrease is not close to what standard theory would have predicted. Based on the corresponding decrease in leverage, we should have seen bank implied volatility divided by market volatility fall from 1.91 (pre-crisis) to 1.20. The actual drop was of less than half this magnitude.

Volatility provides us with a crude proxy for susceptible to bankruptcy a firm is. The implication of our volatility results is that default risk has not meaningfully changed in the pre-crisis relative to the post-crisis period. Specifically, in both the pre- and the post-crisis period our banks appear to be about a five-sigma move away from default in the next year based on implied volatility estimates.

3.2.c Out-of-the-Money Put Option Delta

To get a proxy for the likelihood of a major drop in stock price, we took the delta of a deep out-of-the-money option with one year to expiration.

If the financial system has become far safer then we would expect the probability of major declines in stock prices would have fallen after the Great Recession. Appendix A, Panel A5 makes clear that this is not the case. Before the crisis, the probability of a

[30] The results are similar when we subtract market volatility instead of dividing by it, and are available upon request.

50 percent fall in stock price in the next year was around 3.6 percent. In the post-crisis era, this has increased to an average of 7.4 percent. The same pattern remains when we look at the probabilities of a 25 percent fall in stock price by calculating the delta of a 25 percent OTM option (which has risen from an average of around 16 percent to an average of over 21 percent for the Big 6).[31] Deltas have fallen since the peak of the crisis, suggesting that the more stringent regulatory requirements are having an impact on market assessments of the likelihood of financial sector crashes; however, even comparing the pre-crisis period to the most recent measure, deltas remain elevated: the most recent value is 4.6 percent—relative to the pre-crisis mean of 3.6 percent.

These probabilities refer to the chance of a 50 percent decline over exactly one year. Option theory suggests that the probability of at least a 50 percent decline *at some point within the year* is twice as great. There is the further point that the chance of a large decline over a several year period is of course much greater.

3.2.d Beta

Although we attempt to capture the impact of the market on our volatility measures in our analysis above, this analysis is imperfect. As such, we also look to beta to help us understand how bank risk has evolved (relative to the market) after the financial crisis and the regulation that followed.

Using the logic of Baker and Wurgler (2015), we hypothesize that the decrease in leverage as a result of Dodd-Frank and other regulatory changes implemented in the aftermath of the crisis lowers bank betas. We know that this relationship between beta and leverage holds true in the cross-section for our financial institutions. However, in Appendix A, Panel A6 we see that for each of the six major US financial institutions, bank beta has actually increased in the aftermath of Great Recession. And this increase is not a byproduct of the "early" post-crisis period, before the impact of increased regulation was fully realized. Although bank betas have been falling since the crisis, they have yet to dip below the pre-crisis levels. In fact, average beta today for these banks is

[31] For brevity, we do not report the results for a 25 percent OTM option in our tables below; these results are available upon request.

1.23, slightly *above* the pre-crisis estimate of 1.18. For half of the Big 6 (Wells Fargo, Citigroup, and Bank of America), 2015 beta remains above the pre-crisis estimate.

To understand how these bank betas differ from our expectations, it is helpful to recall Baker and Wurgler (2015) who note that the relationship between leverage and beta is given by:

$$\beta_e = \frac{1}{e} \beta_a$$

For our domestic data, taking the average equity beta for the Big 6 in the pre-crisis period (1.18) based on the decrease in leverage, we can impute that our average beta in the post-period should have decreased to approximately 0.75. This is clearly not what we observe, as in 2015 average beta was 1.18.

3.2.e CDS Spread

CDS spread reflects the cost of insurance against a default. Hence, all else equal, CDS spread should fall as risk (and thus the probability of default) falls.

However, we find that CDS spreads have risen significantly in the aftermath of the crisis (Appendix A, Panel A7). Although the CDS spread for the S&P 500 has increased as well, the spread increase for each of the Big 6 firms is of a significantly higher magnitude. This increase is most pronounced for Citigroup and Bank of America. Even focusing on the most recent 2015 measure (rather than the post-crisis period) to allow for the impact of increased capital accumulation to be reflected in CDS spread, spreads today remain about three times higher than they were in the pre-crisis period.

Note though that it is not clear how we should think about CDS spreads in the context of concerns about too-big-too-fail and evolution of the government's bailout regime. It is possible that CDS spreads have risen because, although firms are better capitalized, they are less likely to be bailed out and thus probability of default has actually increased. We would hypothesize that CDS spreads should have decreased as leverage decreased; however, we think that option-based estimates of the probability of a large decline in stock price are perhaps better measures of risk because they do not force us to consider how the bailout regime has evolved and the impact of this evolution on our risk measure.

3.2.f Price-Earnings Ratio

Rajan (2005) in his contemplation of whether financial development had in fact made the world riskier presents as evidence for his thesis the fact that price-earnings ratios of banks in the United States relative to the market had declined since the 1980s. We perform his same analysis on a different period, looking to see (in Appendix A, Pane A8) how our Big 6 PE ratios (relative to the S&P 500 PE ratio) have evolved since the pre-crisis period. While the existence of the financial crisis and periods of incredibly low earnings makes these figures rather difficult to interpret, the overall picture for the Big 6 suggests that PE ratios have moved around very little since before the Great Recession (the mean in the pre-crisis period was 0.67, almost exactly equal to the post-crisis mean of 0.68).

For half of the Big 6 (Citigroup, JP Morgan, and Wells Fargo), PE ratios have decreased since the pre-crisis period, with the largest decrease for JP Morgan, which went from a PE ratio of 0.83 before the crisis to a PE ratio of 0.53 in 2015. The decline in PE ratio for these banks implies that the market is discounting earnings with increasing risk premium over time.[34] Given the new regulatory environment post-crisis and regulators' strong belief that the system is safer and better capitalized today than it was before the Great Recession, this is a surprising result, but consistent with our prior findings.

3.2.g Preferred Stock Prices and Yields on New Issuances

Another test to ascertain whether bank risk has moved in the aftermath of the Great Recession involves examining the price of preferred shares. Since our banks have very little preferred stock,[35] any losses to this class of shareholders will almost always also be borne by debt holders.[36]

[34] Rajan (2005) describes the relationship between PE ratios and market risk premium in great detail.

[35] Since 2000, preferred stock for our Big-6 banks has averaged on the low end 4.9 percent (Citigroup) and on the high-end only 10 percent (Bank of America, Morgan Stanley) of total equity.

[36] To understand this point, let us take a simple example. If a firm had $250 in regular equity and $125 in preferred, then a loss between 0-$250 would be absorbed totally by equity holders and a loss between $250-$375 would be absorbed totally by equity holders and preferred stockholders. There would be a large preferred stock buffer before debt holders would bear any losses. However, because preferred stock is a relatively thin layer of capital between debt and equity – averaging between 5% and 10% since 2000 for our Big-6 banks – this buffer is quite small. That is, any losses borne by preferred stock will most likely also hit debt holders.

Thus, anything we can learn about the risk premium of preferred stock and how it has evolved over time will shed light on the likelihood of a bank defaulting. This is perhaps a preferred metric to, for example, CDS spread which has embedded in it the likelihood of a bank being bailed out during crisis. Since preferred stock is unlikely to be bailed out (and indeed, preferred stockholders suffered losses during the Great Recession), by looking at preferred stock pricing we are able to hone in on the market's assessment of the likelihood of a major crash.

The price of a security is inversely related to its required rate of return. The required rate of return, in turn, is a function of (1) the riskless rate and (2) the product of a bank's beta and the market risk premium. Barring any change in the riskiness of banks, since the riskless rate has declined substantially in the post-crisis period, we would have expected that the required rate of return would have declined as well. Thus, we anticipate that the price of our preferred shares would have increased substantially in the post-crisis period. If bank betas had declined as our theory on the relationship between beta and leverage predicted, we would have expected that the required rate of return would be even lower (and thus, that prices would be even higher) for preferred stock in the post-crisis relative to the pre-crisis period.

There are two kinds of preferred stock: floating rate preferreds (whose dividends are indexed against LIBOR) and fixed rate preferreds (which pay, as their name implies, a fixed rate annually). We focus our analysis on the pre- relative to post-crisis prices of floating rate preferreds.[37]

The fact that prices of preferred stock are *lower* today than they were in the pre-crisis period suggests that banks have become riskier in the post-crisis period.

We turn to salient examples to illustrate this point in Figure 3. Goldman Sachs, Bank of America, and Morgan Stanley all have floating rate preferred shares that were

[37] The problem with looking at long-lived fixed rate preferred stock is that their prices are constrained by the fact that their dividends are paying a fixed rate. That is, since the dividend cannot adjust given changes in market conditions, price cannot move too far from par value for these securities.

first issued before the crisis period. As such, we can examine the pricing of these shares over time to learn about how the risk profile of these institutions has evolved.[38]

For Goldman, we look at Series D preferreds which became available in 2005 and which pay the greater of 0.67 percent above LIBOR or a minimum of 4.00 percent; for Bank of America, we look at Series E preferreds which started trading in 2006 and pay a rate per year equal to the greater of the three-month LIBOR plus 0.35 percent or 4.00 percent per annum; and for Morgan Stanley we look at Series A preferreds which pay the greater of the three-month LIBOR plus 0.70 percent, or 4.00 percent. In all three cases, we see that average price for these shares in the pre-crisis period (2007 and prior) is higher than the post-crisis price (24.26 vs. 20.11 for Bank of America; 25.12 vs. 20.66 for Goldman Sachs; and 25.36 versus 19.68 for Morgan Stanley). And while these preferreds have rebounded slightly since the Great Recession, prices in the last year remain lower than they were in the pre-crisis period for all three securities.

Since the risk-free rate has declined so much in this period, with a decrease in bank risk—or even with the same level of risk as in the pre-crisis period—preferred prices should be higher today than they were in the pre-crisis period. The fact that we see a decrease in price of these preferreds suggests that risk, at least for these three institutions, has increased over the same period that riskless rates have fallen.

Note that existence of long-lived preferred stocks that date back to the pre-crisis period is, in and of itself, a significant finding for our analysis. That is, we would anticipate that since interest rates decreased significantly, if bank risk stayed the same (or even declined), then Goldman, Bank of America, and Morgan Stanley would have been able to call these securities and issue replacement stock at a much lower yield.

A version of this same point can be made by looking to more recent preferred stock issuances by our Big-6 institutions. As we see in Table 2, in 2016 alone, Wells Fargo issued a preferred that is currently yielding 5.11 percent, Citigroup issued a preferred share that is yielding 5.81 percent, Bank of America a preferred that is

[38] Note that we use these three banks as examples because of limitations of the data. Our other three large financial institutions (JP Morgan, Wells Fargo, and Citigroup) do not have floating preferreds that date back to the pre-crisis period. We choose to avoid using fixed rate preferreds for this analysis because

yielding 5.64 percent, and Goldman a preferred that is yielding 5.73 percent. The fact that most recently issued preferred stock by these financial institutions is yielding between five and six percent suggests that these banks are far from safe, and holders of bank preferreds are being compensated for the risk that they are bearing.

3.2.h SRISK%

Using Acharya et al.'s (2016) systemic risk measure we can ascertain how each firm's contribution to systemic risk has evolved in the aftermath of the financial crisis. This measure is of special interest because it has been demonstrated to have predictive power in crisis when other measures have been lacking. We see in Appendix A, Panel A10 that the contribution of four of the six firms (Wells Fargo, Citigroup, Bank of America, and JP Morgan) to systemic risk has increased in the post-crisis period; while the relative contribution of Morgan Stanley and Goldman Sachs has declined. As a group, the SRISK% of the Big 6 has nearly doubled. Although SRISK% peaked in 2011, it remains well above pre-crisis levels today.

4. Midsize Domestic Institutions

We next extend our results to the largest financial institutions in the United States outside of the Big 6. We focus on the fifty largest institutions (by 2015 assets).[49] We exclude the Big 6 banks that have been our focus thus far from this analysis. These midsize banks differ vastly in size—with 2015 market capitalization ranging from over $78 billion (American Express) to barely over $2 billion (EverBank Financial Corporation).

We include data from the subset of banks for whom we are able to compile information on our risk measures, including bank beta, volatility, implied volatility, and CDS spread. This requires that we exclude those large financial institutions that are not publicly traded and that are subsidiaries of other publicly traded institutions (e.g. GE

[49] Note that we choose for our sample the fifty largest institutions by 2015 assets, so our results suffer from survivorship bias. This likely biases our results downward. Since bank risk strategies are persistent, we believe that the failed banks would have likely had higher risk measures in 2015 compared to those of an average survivor bank in the sample. For a discussion of persistence, see e.g. Fahlenbrach et al. (2012) who find that those banks that did worst in the 1998 crisis were most likely to fail during the Great Recession.

Capital). In our analysis, we present results for these midsize institutions by quintile, sorting them into five groups depending on their average market capitalization in the pre-, post, and 2015 period in turn. While most banks remain in the same quintile for these three distinct time periods, some shift by a quintile at different moments (e.g. Silicon Valley Bank, which is in the second quintile in the post-crisis period, with an average market capitalization of around $3.3 billion and in the third quintile in 2015, with a market capitalization of around $6.6 billion).

Our findings outside of the Big 6, presented in Appendix B, are largely consistent with our prior results. We see that volatility (Panel B1) has decreased when we compare the pre-crisis averages to the most recent 2015 measures. When we divide by market volatility (Panel B2), we see that volatility actually remains higher in 2015 than in the pre-crisis period. On many measures it appears large banks do better in the post-crisis period than their smaller counterparts, suggesting that at least to a certain extent, regulation aimed at lessening risk of large systemically important financial institutions is having the intended effect.

For example, looking to Appendix B, Panel B5 on beta of midsize banks and comparing pre-crisis to our 2015 measure, we see that for the smallest banks (those in the bottom three quintiles), beta is substantially higher in 2015 than it was in the pre-crisis period. For banks in the top two quintiles, beta has not moved much.

We can impute expected volatility and beta based on changes in leverage to give us a benchmark against which to measure the changes we observe. Outside of the Big 6, Tier-1 capital ratios for these banks increased from the pre-crisis to post-crisis period from 10.3 to 13.4 percent. Pre-crisis historical and implied volatility (for banks in all quintiles) averaged 25.54 for both of our measures and thus we would predict that volatility and implied volatility should have fallen to 19.63. Historical volatility remains above this at 21.58, and implied volatility has actually increased since the pre-crisis period to an average of 26.73 in 2015. And although Tier-1 ratios have increased by an average of 30%, betas have actually risen from 0.96 to 1.05 on average in 2015.

5. International Results

To supplement our main findings and in efforts to understand how bank risk has evolved for systemically important financial institutions across the globe, we next move to looking at the same risk measures documented above for large international financial institutions.

We restrict our study to the 30 largest banks in the world (ranked by market capitalization). We exclude from the international analysis US and Chinese banks.[50] We included data for the subset of banks for whom we are able to compile information on bank beta, volatility, implied volatility, CDS spread, and price-to-book ratios. We are left with 30 international institutions. We are not able to collect reliable options data for our international financial institutions to impute option deltas.

Rather than reporting bank averages for the 30 international banks in our sample individually, we group banks by country and report country averages in Appendix C.[51] This allows us to ascertain if banks in specific countries are driving the results that we document.

Our findings for international institutions are broadly consistent with those for the Big 6 and midsize domestic institutions reported above. Our results for volatility (Appendix C, Panel C1) and implied volatility (Appendix C, Panel) are more striking than our domestic findings. Our results outside of the US reflect roughly no change in volatility from the pre- to post-crisis period. Again, our results are not driven by the fact that (a) the post-crisis period includes 2010, when crisis shockwaves were still being felt or (b) that the impact of the new regulatory regime took time to be felt in

[50] We exclude Chinese banks from this analysis as state ownership involves different issues than the ones we are focused on.

[51] Australian banks include National Australia Bank, Australia and New Zealand Banking Company, and Westpac Banking. Brazilian banks include Banco de Brazil. Canadian banks include Toronto-Dominion Group, Royal Bank of Canada, Bank of Nova Scotia, and Bank of Montreal. Danske is the Danish bank in our sample and ING is the Netherlands bank. French banks are BNP Paribas, Credit Agricole Group, Societe Generale, and Natixis. German banks are Deutsche Bank and Commerzbank. Italian banks are Unicredit and Intesa Sanpaolo. Japanese banks are Mitsubishi, Mizuho, and Sumitomo. Santander is the Spanish bank in our sample. Nordea is the Swedish bank. UBS and Credit Suisse are the Switzerland banks. The UK banks are HSBC, Barclays, Lloyds, Royal Bank of Scotland, and Standard Chartered.

international financial institutions. 2015 volatility is basically identical to pre-crisis volatility – the average is 27.86 relative to the pre-crisis average of 28.67.

And, like for the midsize US banks, implied volatility has actually increased (from an average of 25.49 pre-crisis to 28.55 in 2015). This increase is concentrated in Italy, the Netherlands, and Spain. Although implied volatility relative to the home market indices has decreased on average, banks these three countries[52] have seen their implied volatility increase relative to the market (Appendix C, Panel C4).

Our results for international bank betas are similar to these volatility results. Bank betas have risen (Appendix C, Panel C5), not fallen, in the aftermath of the Great Recession, and this rise is even more pronounced for international banks, who went from a pre-crisis average beta of 0.82 to a 2015 beta of 1.01, than it is for the Big 6 (pre-crisis beta of 1.18, 2015 beta of 1.23). This increase in is quite pronounced for banks in Australia, Brazil, Canada, Denmark, France, Italy, and Sweden. Only Swiss banks have seen a substantial decline in beta since 2002, and most other countries have seen betas rise, except Japan and the UK where betas have roughly stayed the same.

CDS data is far from complete for international banks, and many are missing data for both the pre- and post-crisis period. For the few data points we have, we see in Appendix C, Panel 6 that international banks have experienced an even more dramatic rise in CDS spreads relative to US banks. However, this is driven substantially by the CDS spread of Banco de Brazil; when this bank is excluded from the sample we see that average CDS spread is 77.32 for 2015, below the Big 6 mean of 93.58. Both domestic and international banks have substantially higher CDS spreads today than before the crisis.

It is interesting to consider these results in the context of international financial regulators statements about the financial system. For example, Mark Carney remarked in 2014 that the increase in capital requirements had made banks safer – "Banks were woefully undercapitalized-many of the largest banks were levered 40 or 50 times. They

[52] The same is true in Australia, although we do not have an Australian implied volatility index and instead benchmark against the US VIX.

are now much more resilient."[53] And as recently as this summer, in response to the Brexit referendum results, Carney urged calm, noting that "The capital requirements of our largest banks are now ten times higher than before the crisis...This substantial capital and huge liquidity gives banks the flexibility they need to continue to lend to UK businesses and households, even during challenging times."[54]

And yet, the biggest UK banks (HSBC, Barclays, Lloyds, Royal Bank of Scotland, and Standard Chartered) which are in our sample of large international financial institutions look, based on measures like implied volatility and CDS spread, to be no safer in the pre-crisis relative to the post-crisis period. CDS spread in 2015 for the large UK institutions averaged 97.21 in 2015 relative to the pre-crisis average of 13.53 and implied volatility 27.02 in 2015 relative to the pre-crisis average of 23.04. And while betas have not increased (comparing 2015 to pre-crisis), they have not decreased either, and are stuck at around 0.85, exactly where they were before the Great Recession. It is hard to understand why, given the substantial increases in capitalization Carney oft highlights, we see no movement in our risk measures for the large institutions that were most impacted by the post-crisis reforms. Given the changes in the regulatory framework—and viewed through the lens of Carney's (and others')[55] statements on the impact of increased capital on bank stability—these are puzzling findings.

6. Discussion

The suite of measures considered in the previous sections taken together suggest to us that markets do not regard banks as substantially safer today than they were in the pre-crisis period. To be sure, the findings can be rationalized on an individual basis. It is logically possible for example that bank equities have become more volatile not because banks are more likely to fail, but because they are more likely to be forced into dilutive equity issuances in times of distress. But if this were true one would expect to

[53] Carney (2014).
[54] Carney, Mark. "Statement from the Governor of the Bank of England Following the EU Referendum Result." June 2016.
[55] See, e.g. "President Obama Marks the Five-Year Anniversary of the Financial Crisis."; Yellen, Janet L. "Finance and Society." *Federal Reserve Board*. Speech. May 2015.

see credit default spreads and preferred stock yields go down. It is possible that bank equity volatility has increased because of greater regulatory uncertainty. But this would not explain why the responsiveness of bank equity to overall market conditions has not decreased as banks have become better capitalized.

We envision three primary explanations for our findings, which we take up in the remainder of this section. First, the "market error" explanation holds that markets badly underestimated the risks associated with banking prior to the financial crisis and have adjusted their views in light of painful experience. If this were the case banks might be substantially safer today than they were prior to the crisis, but the difference is obscured by the excessive optimism that prevailed prior to the crisis. Implicitly, this is the view taken by the regulatory community.

Second, the "bank capital mismeasurement" explanation holds that regulatory bank capital measures may be highly flawed and may even have become more flawed over time as banks arbitrage regulatory rules. Andrew Haldane has made such an argument, pointing to the great increase in regulatory complexity, the use of internal models and declines in the ratio of risk weighted assets to total assets (Haldane 2013). In this case, banks have not become significantly safer than they were previously because regulation has been circumvented.

Third, the "declining franchise value" explanation recognizes that while *ceteris paribus* banks have become safer because of higher capital requirements other developments have eroded their franchise value thus increasing their effective leverage and riskiness. This hypothesis, which we find most plausible and important for explaining our findings, is suggested by very substantial declines in the price-book ratio for most major institutions and by international comparisons.

6.1 Market Error

One possible explanation for our findings is that in the pre-crisis period, the market failed to fully internalize the risks inherent in the financial sector. The dismal returns earned by investors in the financial sector during the crisis period demonstrate that this must have been the case to some extent.

Blanchard (2014) suggests that in the pre-crisis period bank runs, in which a small shock has ripple effects throughout the economy, and issues associated with banks' asset-liability liquidity mismatch were under-studied and thought of as relics of the past rather than considerations relevant to current macroeconomic policy discussions. He suggests that "we all knew that there were 'dark corners'—situations in which the economy could badly malfunction. But we [macroeconomists] thought we were far away from those corners, and could for the most part ignore them. Financial institutions and regulators also underestimated risks. The result was a financial structure that was increasingly exposed to potential shocks. In other words, the global economy operated closer and closer to the dark corners without economists, policymakers, and financial institutions realizing it."

It is easy to understand why excessive optimism about financial stability could have led to the overpricing of bank securities before the crisis. It is much less clear why it should have led to their being insufficiently volatile in response to daily news. If prior to the crisis there was a tendency for bank stock prices to underreact to news one would expect to see some evidence of positive serial correlation as underreactions were eventually corrected. One would expect this tendency to diminish or be eliminated in the post crisis period.

We follow Poterba and Summers (1988) and Lo and MacKinlay (1988) in computing variance ratios to test for autocorrelation in bank stock returns during the pre and post crisis period. To compute variance ratios, we begin with daily price data and compute (1) daily returns; (2) five-day returns (for non-overlapping five day intervals); (3) ten-day returns (for non-overlapping ten day intervals); (4) twenty-day returns (for non-overlapping twenty day intervals); and (5) fifty-day returns (for non-overlapping fifty day intervals).

We then compute the variance returns in each of these samples before and after the crisis and take the ratio of the variance for each interval relative to the variance of our daily (log) returns. Our goal is to ascertain whether (1) there is evidence of positive auto-correlation in the pre-crisis period and (2) there is more positive autocorrelation in the pre-crisis period relative to the post-crisis period (which would be an argument in favor of the market error hypothesis).

We report results in Table 3 only for the Big 6 financial institutions; however, these results are comparable for the rest of the large US financial institutions and are available upon request.

Variance ratios for the Big 6 banks provide no support for the view that there is significant positive serial correlation in returns during the pre-crisis period. Variance ratios are generally less than horizon length suggesting modest negative rather than positive autocorrelation. While variance ratios are slightly higher in the pre-crisis period, the difference is statistically insignificant for all 6 institutions.

As a final bit of evidence on the market error theory, we look to analyst estimates of future bank earnings in the United States in the pre- and post-crisis period. If beta and volatility were low in the pre-crisis period because the market failed to understand the risks banks faced, then we would anticipate that analyst forecasts would be more accurate in the post-crisis period (when market understanding has grown).

We test this theory directly by using data from Thompson Reuters Institutional Brokers' Estimate System (IBES). We pull all quarterly analyst forecasts for our largest US banks (both the Big 6 and midsize institutions) made from 2002 to present. We then measure average deviation[56] from actual earnings and do a basic t-test to see if pre-crisis deviations differ from post-crisis deviations in a statistically significant way. Our results are reported in Table 4. We find pre-crisis deviations differ from those that analysts make post-crisis, but our results do not support market misunderstanding of risk as the explanation for these differences. We find that (1) deviations are larger (in absolute value) in the post-crisis period and (2) that the sign of the deviations switches; specifically that analysts are on average overly optimistic post-crisis and overly pessimistic pre-crisis.

[56] We measure deviation first as the ratio of earnings: average analyst predictions (scaled by earnings+analyst predictions to give us more sensible values). Then, we consider the absolute value of these deviations. And finally, we follow Khan, Rozenbaum, and Sadka (2013) and measure average deviation from actual earnings scaled by price on the day earnings are announced. We report t-tests for all three of these measures of analyst deviations.

Perhaps the most important point to make regarding the market error hypothesis is of a different sort. Regardless of whether excess market complacency can or cannot explain the low level of market risk measures pre-crisis, current market indicators of risk are not encouraging. Table 1 notes that the average option implied probability of a 50% decline in stock price for major banks is 4.6 for one year. It is 11.4 percent for four years.[57] These estimates understate the risk of a major decline because it focuses only on option end dates not on the whole price path and because it ignores the likely tendency for volatility of bank assets to rise as their value declines.[58] As we noted in Section 3.2.e, the level of preferred yields also suggests grounds for concern about the health of major institutions.

6.2 Bank Capital Mismeasurement

Another possible explanation for the bank capital volatility puzzle we document is that bank capital (as calculated) is so distorted as a measure of capital in an economic sense that measures to raise regulatory capital have not in fact had large impacts on economic capital. Calculations of bank capital are very sensitive to procedures for valuing loans and other illiquid assets. As Haldane (2013) explains, there are also a variety of ways in which capital requirements can be gamed.

Bulow and Klemperer (2013) provide a dramatic illustration of the imperfection of regulatory capital measures. They note that if the 413 banks that failed between 2008-2011 (when 6% core Tier-1 equity was required to be classified as "well capitalized") had each held an additional 14% of assets in cash, this infusion would have covered losses in less than 10% of these failures. In other words most failed banks are found ex-post to have a capital gap of more than 14 percent of assets.[59]

It is plausible that the increase in Tier-1 capital as a consequence of a more stringent regulatory framework in the post-Recession period has done relatively little to stabilize the financial sector. Relatedly, it is possible that although banks are being forced to hold more capital (and have higher Tier-1 ratios), they are finding ways to

[57] Results available upon request.
[58] Think of a mortgage on a building. It will not move much with the price of the building until the building's value has declined to close to the value of the mortgage.
[59] In fact, Indy Mac cost an amount equal to 42 percent of assets to resolve.

increase risk that game the current risk weighted asset rules and the existing stress tests.

We are not sure how to evaluate this possibility. The observation discussed below—that the ratio of the market value of bank equity to book value has declined substantially between the pre- and post-crisis period—is consistent with an increasing gap between the reported and economic value of bank capital. But as we discuss in the next subsection, it can also be explained by declines in the franchise value of banks.

The evidence from Baker and Wurgler (2015) discussed in Section 2 that bank betas and capital ratios are negatively related in the cross section provides some suggestion that there is in fact information value in capital ratios. While very much aware of the infirmities of capital ratio measures, we find it implausible that ceteris paribus more capital as measured is not associated with reduced failure risk, and we do not find the bank capital mismeasurement hypothesis persuasive as a dominant explanation for our findings.

6.3. Declining Franchise Value

Table 5, which provides information on banks' price to book ratios, price to tangible book ratios,[60] and the ratio of the market value of equity to total assets on a risk-adjusted and risk-unadjusted basis, is key to understanding our findings. Even though book value measures suggest that banks are much less levered than previously, the declines in market valuation of banks have been so large that *measured on a market basis banks have less equity relative to assets than they did previously.*

This observation rationalizes all our findings. If banks have less equity relative to their assets, they are in a sense more levered. So one would expect more volatility, a higher probability of a major stock price decline, riskier debt, higher yields on preferred stock, and higher expected returns on common stock. This is exactly what we observe.

The question then becomes why has there been so substantial a change in the market value of banks relative to their book value. In 2006, the total market value of the big 6 US institutions exceeded their total book value by over 100 percent of book

[60] Tangible book value removes goodwill and other intangible assets from the basic book value measure.

value, or 492 billion dollars. By 2015, the gap had fallen to around 1 percent of book value, or 13.2 billion dollars.[61]

As we noted in the previous subsection, one possible explanation for the decline in price-book ratios is increasing mismeasurement of assets. We find it highly implausible that bank assets were highly undervalued in the pre-crisis period when price-book ratios averaged close to two.[62] It seems more plausible to explain declines in price-book ratios and consequent declines in the ratio of the market value to assets in terms of reduced franchise values for banks.

A variety of factors have impinged on bank franchise values in recent years to the point where the decline can be over-explained. These include the consequences of low interest rates and a relatively flat yield curve for bank profitability, regulatory restrictions on a range of allegedly unlawful profitable practices ranging from proprietary trading to credit card interchange to overdraft fees, substantial financial penalties for past practices, increased competition from shadow banks and an overhang of likely future regulatory actions.

Calomiris and Nissim (2014) systematically examine declines in price-book ratios for a large sample of banks and reject the view that their decline reflects unmeasured losses in favor of the view that it reflects the erosion of intangible assets for the reasons suggested in the previous paragraph. They do not estimate how much of the decline is due to regulatory changes and much is due to changed economic conditions, but suggest both are important factors.

Canada is often highlighted as the G-7 country that came through the financial crisis without great damage to its financial system or the need for large-scale public interventions. It is noteworthy that its banks have been consistently able to maintain a price-book ratio that is high by international standards. A similar observation holds for Australia, which is also thought to have come through the financial crisis well. This

[61] These numbers fluctuate annually but are well below the 2006 estimate – in 2014, the gap was 10% of book value, or about 92 billion dollars.
[62] And price-tangible book ratios close to three.

tends to support the idea that franchise value in a financial system is stabilizing and to confirm the idea that substantial losses in franchise value can be destabilizing.

7. Conclusions

As Haldane and Madouros (2012) point out, market measures of risk are invaluable in assessing banks' ability to withstand adverse shocks. They note that in a horse-race between the simplest market measure of risk (the market value of equity relative to unweighted assets) and the most complex regulatory measure (the Basel Tier 1 ratio), the explanatory power of the simple measure in predicting bank failure is about 10 times greater than the complex one. As such, we feel our focus on market measures of bank risk is a sensible one.

We find that these measures are in the same range that they were prior to the financial crisis. This suggests cause for concern that there is a nontrivial probability of at least a major loss in equity value by a major institution sometime in the next few years. In fact, the ratio of market value of equity to assets preferred by Haldane and Madouros (2012) has actually decreased since the pre-crisis period. There is little if any evidence in data on bank stock prices, options prices, bond prices or preferred stock prices of the kinds of declines in risk that might be expected from dramatic regulatory actions to increase capital and reduce risk taking.

None of this suggests to us that the broad approach taken by the regulatory community in the wake of the 2008 financial crisis of increasing capital and seeking to contain risk taking was inappropriate. Indeed we have no doubt that but for Dodd Frank and regulatory actions, the financial system today would be much more fragile. However, if our findings stand up to the scrutiny of others, we believe they should be uncomfortable for most participants in debate about the future of financial regulation and supervision. They clearly call into question the view of many officials and financial sector leaders who believe that large banks are far safer today than they were a decade ago. It is certainly possible that markets were unduly complacent before the crisis and are excessively alarmed today. But given that market risk measures functioned much more effectively as canaries in the coal mine during the 2008 crisis than did regulatory risk measures, we would caution against complacency.

While pushing against complacency, our results do not go so far as to support ever-heavier regulation of large banks. We find that a substantial part of the reason banks have become riskier and effectively more leveraged is a decline in their franchise value. And while we do not study the question in any depth it appears plausible that a large part of the reason for declines in franchise value is regulatory activity and the prospect of future regulation. There is a possibility that by further eroding bank franchise value, further regulatory actions could actually increase systemic risk.

Our emphasis on market values also raises questions about stress testing methodologies. US regulators carry out stress tests using very draconian scenarios. As Bulow and Klemperer note one year's stress test involved a stock market decline of nearly 60 percent and an increase in unemployment to 13 percent. All the major banks passed the test with relatively little estimated diminution in capital.

Yet, we believe that in such a scenario it is a near certainty that absent government support or new capital raising, bank equities would fall to zero. Applying the average post crisis beta for the big 6 banks of 1.59, just over a 60 percent decline in the market would wipe out its equity. This calculation substantially underestimates the risk because it ignores the increase in equity beta that would result as banks lost equity value and so became more levered and also ignores the fact that as the economy turns down bank assets become volatile. This latter effect occurs because for example mortgages become claims on real estate.

What does all of this imply for financial regulatory policy? We agree with Bulow and Klemperer (2015) that the essential largely unmet challenge in financial regulation and supervision is ensuring that institutions raise equity capital when necessary. This protects both debt holders, deposit insurers, and taxpayers more generally. It also protects against the risk of bank runs, contagion, and financial distress. The high yields currently paid on preferred stock demonstrate that market participants are not confident that in times of distress common equity will be raised on a sufficient scale.

And there are good reasons for their concern. Bank accounting can lead to delays in the recognition of problems. There are strong reasons to delay raising capital for fear of damaging confidence. While there is great political resistance to bailouts, there are strong political pressures for forbearance.

While it is tempting to believe that policy can compensate for inevitable delays in capital mobilization with large capital buffers[63] and restrictions on risk taking, experience and our results suggest that this may be an illusion. Consideration needs to be given to approaches such as those suggested by Bulow and Klemperer (2015) and King (2016) that give more weight to market prices as indicators of asset values and that bring automaticity to the restoration of bank capital when it starts to decline.

[63] Bulow and Klemperer (2013) discuss a variety of reasons why capital buffers are not enough. They point out that 90% of the banks in their sample that failed during the crisis would still have failed had they been "well-capitalized" by regulatory measures.

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Table 1: Summary of Bank Data

This table summarizes characteristics of the “Big Six” financial institutions (Bank of America, Goldman Sachs, Wells Fargo, Morgan Stanley, Citigroup, and JP Morgan) in Panel A; and the top-50 largest US financial institutions excluding these six in Panel B; and the largest non-US and non-Chinese financial institutions in Panel C. We compare pre-crisis to the most recent measure.

Panel A: Big 6

Measure	Pre–crisis average	Post–crisis average	2015 average
Volatility	24.70	33.07	20.67
Bank volatility/market volatility+	1.55	1.80	1.71
Implied volatility++	22.90	30.84	22.96
Implied bank volatility/market implied	1.91	2.13	1.61
Option delta+++	0.036	0.074	0.046
Beta	1.18	1.59	1.23
CDS spread++++	31.85	139.04	93.58
PE/market PE+++++	0.67	1.22	0.68
Preferred stock price++++++	24.91	20.15	20.74
SRISK%	5.76	10.44	10.18

Panel B: Midsize Domestic Financial Institutions

Measure	Pre–crisis average	Post–crisis average	2015 average
Volatility	25.54	29.89	21.58
Bank volatility/market volatility+	1.68	1.68	1.78
Implied volatility++	25.54	32.06	26.73
Implied bank volatility/market implied	2.13	2.28	1.90
Beta	0.96	1.27	1.05
CDS spread++++	23.20	94.52	68.11
PE/market PE+++++	0.79	0.75	0.73

Panel C: International Institutions

Measure	Pre–crisis average	Post–crisis average	2015 average
Volatility	28.67	33.81	27.86
Bank volatility/market volatility+	1.51	1.67	1.43
Implied volatility++	25.49	32.57	28.55
Implied bank volatility/market implied	1.51	1.52	1.36
Beta	0.82	1.05	1.01
CDS spread++++	14.18	142.21	111.85

+For domestic volatility/market comparisons, we used the market return of the S&P 500. We used the standard deviation of the daily return over 260 trading days to best approximate an annual average. For international comparisons, we use local indices except for banks in the Netherlands, Sweden, and Denmark. We benchmark volatility of banks in these countries against a European index.
++Earliest implied volatility data available in 2005. For domestic implied volatility/market comparisons, we use the US VIX. For international comparisons, implied volatility country indices are rather scarce. As such, we benchmark against a European implied volatility index except for Australian, Brazilian, and Canadian banks, which we compare to the US VIX.
+++ Delta on a one-year, 50% out-of-the-money put option. Option data dates back to June 2015, so we use 2014 average as most recent measure.
++++Earliest CDS data available is 2/04. This is the data for a five-year tenor.
+++++ We follow Rajan (2005) and examine bank PE ratio as a percentage of S&P 500 PE ratio.
++++++There are only three banks in our sample (Bank of America, Goldman Sachs, and Morgan Stanley) with floating rate preferred stock dating back to the pre-crisis period.

Table 2: Big 6 Recent Preferred Stock Issuances[1]

Bank	Date of Most Recent Issue	Par Value	Current Price	Current Yield
Bank of America	Apr–16	25	26.60	5.64%
Citigroup	Jan–16	25	27.12	5.81%
Goldman	Apr–16	25	27.48	5.73%
JP Morgan	Apr–14	25	27.49	5.73%
Morgan Stanley	Apr–14	25	27.59	6.00%
Wells Fargo	Jun–16	25	26.91	5.11%

[1] These yields are all for recently issued fixed rate preferreds, except for Morgan Stanley. MS issued a fixed rate preferred for 5.375% annually that will convert to a floating rate in five years.

Table 3: Variance Ratio for Big 6 Banks

Bank	Five day ratio		Ten day ratio		Twenty day ratio		Fifty day ratio	
	Pre–crisis	Post–crisis	Pre–crisis	Post–crisis	Pre–crisis	Post–crisis	Pre–crisis	Post–crisis
Bank of America	5.00	4.67	8.96	9.1	18.08	18.11	41.78	41.62
Citigroup	5.14	4.96	8.78	9.39	22.82	18.70	55.65	43.89
Goldman Sachs	4.82	4.83	8.32	9.09	17.53	19.51	33.16	45.77
JP Morgan	4.43	4.59	8.80	8.99	21.86	17.83	54.05	39.49
Morgan Stanley	5.09	4.49	8.09*	8.57	18.36	14.94	40.15	44.66
Wells Fargo	4.51	4.06**	8.60	7.09**	17.00	14.93	41.5	25.17
No. Banks Post–crisis < Pre–crisis	4		1		4		4	

Table 4: T-Test for Difference in Means in Analyst Report Deviations

	Pre–crisis	Post–crisis
Deviation from EPS	-0.0083	0.0404***
	(0.1849)	(0.4739)
Absolute Value of Deviation from EPS	0.0517	0.1193***
	(0.1777)	(0.4605)
Deviation from Earnings Price Ratio	-0.0001	0.0007***
	(0.0049)	(0.0065)
Absolute Value of Deviation from Earnings Price Ratio	0.0015	0.0028***
	(0.0047)	(0.0059)

[1] Asterics denote significance for t-test for difference in means.

Table 5: Price–to–Book Ratio, Price–to–Tangible–Book Ratio, Ratio of Market Value of Equity/Total Assets, and Ratio of Market Value of Equity/Risk–Adjusted Assets

Panel A: Big 6

Bank	Pre–crisis average				Post–crisis average				Recent (12/31/2015)			
	PTB	PTTB	MVE/A	MVE/RA	PTB	PTTB	MVE/A	MVE/RA	PTB	PTTB	MVE/A	MVE/RA
Bank of America	2.15	3.55	0.15	0.22	0.63	1.01	0.03	0.10	0.63	1.12	0.09	0.11
Citigroup	2.31	3.78	0.16	0.28	0.70	0.85	0.06	0.12	0.64	0.91	0.09	0.13
Goldman Sachs	2.14	2.78	0.11	N/A	1.04	1.13	0.04	0.15	0.87	1.16	0.09	0.13
JP Morgan	1.42	2.27	0.08	0.16	0.98	1.34	0.09	0.14	1.05	1.41	0.10	0.17
Morgan Stanley	1.84	2.02	0.07	N/A	0.83	1.04	0.05	0.13	0.78	1.23	0.08	0.16
Wells Fargo	2.77	3.99	0.22	0.29	1.44	1.90	0.10	0.18	1.45	2.06	0.15	0.22
Mean	2.11	3.06	0.13	0.24	0.93	1.21	0.06	0.14	0.90	1.32	0.10	0.15
Median	2.14	3.17	0.13	0.25	0.90	1.09	0.06	0.14	0.82	1.20	0.09	0.15

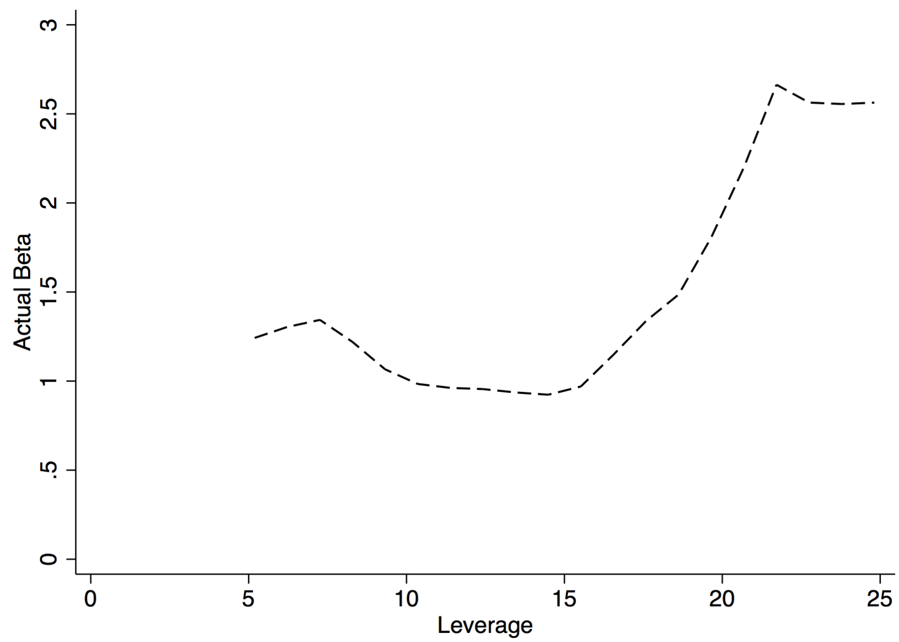
Panel B: Midsize Financial Institutions

Bank	Pre–crisis average				Post–crisis average				Recent (12/31/2015)			
	PTB	PTTB	MVE/A	MVE/RA	PTB	PTTB	MVE/A	MVE/RA	PTB	PTTB	MVE/A	MVE/RA
Low MVE	1.94	3.10	0.19	0.43	1.20	1.61	0.12	0.37	1.12	1.49	0.11	0.20
Quintile 2	2.45	2.90	0.22	0.30	1.40	1.78	0.13	0.27	1.31	1.83	0.15	0.28
Quintile 3	2.33	3.18	0.20	0.27	1.18	1.73	0.15	0.30	1.14	1.83	0.17	0.20
Quintile 4	2.26	3.23	0.21	0.27	1.20	1.46	0.13	0.17	1.19	1.48	0.13	0.18
High MVE	2.86	4.05	0.28	0.29	1.86	2.71	0.18	0.35	1.74	2.61	0.20	0.31
Mean	2.25	3.10	0.21	0.32	1.25	1.65	0.13	0.28	1.19	1.66	0.14	0.21
Median	2.33	3.18	0.21	0.29	1.20	1.73	0.13	0.30	1.19	1.83	0.15	0.20

Panel C: International Institutions

Bank	Pre–crisis average				Post–crisis average				Recent (12/31/2015)			
	PTB	PTTB	MVE/A	MVE/RA	PTB	PTTB	MVE/A	MVE/RA	PTB	PTTB	MVE/A	MVE/RA
Australia	2.44	3.34	0.10	0.15	1.71	2.41	0.11	0.24	1.74	2.40	0.08	0.19
Brazil	1.75	3.19	0.05	0.14	1.22	1.51	0.04	0.07	0.72	0.82	0.01	0.01
Canada	2.43	3.45	0.09	0.27	1.89	2.64	0.09	0.25	1.67	2.26	0.06	0.16
Denmark	1.66	1.77	0.01	0.02	0.87	1.06	0.01	0.02	1.19	1.39	0.01	0.03
France	1.44	1.81	0.06	0.22	0.59	0.83	0.03	0.11	0.73	0.98	0.03	0.12
Germany	1.14	1.44	0.04	0.16	0.48	0.73	0.02	0.09	0.49	0.62	0.02	0.07
Italy	1.55	2.48	0.11	0.20	0.57	0.81	0.05	0.11	0.87	1.05	0.06	0.14
Japan	1.77	2.54	0.00	0.02	0.72	0.84	0.00	0.05	0.74	0.82	0.00	0.05
Netherlands	N/A	1.88	0.06	0.26	N/A	0.74	0.04	0.14	N/A	1.09	0.06	0.17
Spain	1.66	2.56	0.12	0.23	0.90	1.42	0.07	0.16	0.92	1.39	0.05	0.12
Sweden	1.57	1.96	0.09	0.43	1.27	1.46	0.07	0.27	1.46	1.67	0.07	0.31
Switzerland	2.13	3.99	0.05	0.38	1.14	1.43	0.04	0.20	1.10	1.36	0.03	0.08
UK	2.16	3.06	0.12	0.20	0.91	1.35	0.06	0.17	0.84	1.21	0.07	0.18
Mean	1.81	2.57	0.07	0.21	1.02	1.33	0.05	0.14	1.04	1.31	0.04	0.13
Median	1.70	2.54	0.06	0.20	0.91	1.35	0.04	0.14	0.90	1.21	0.05	0.12

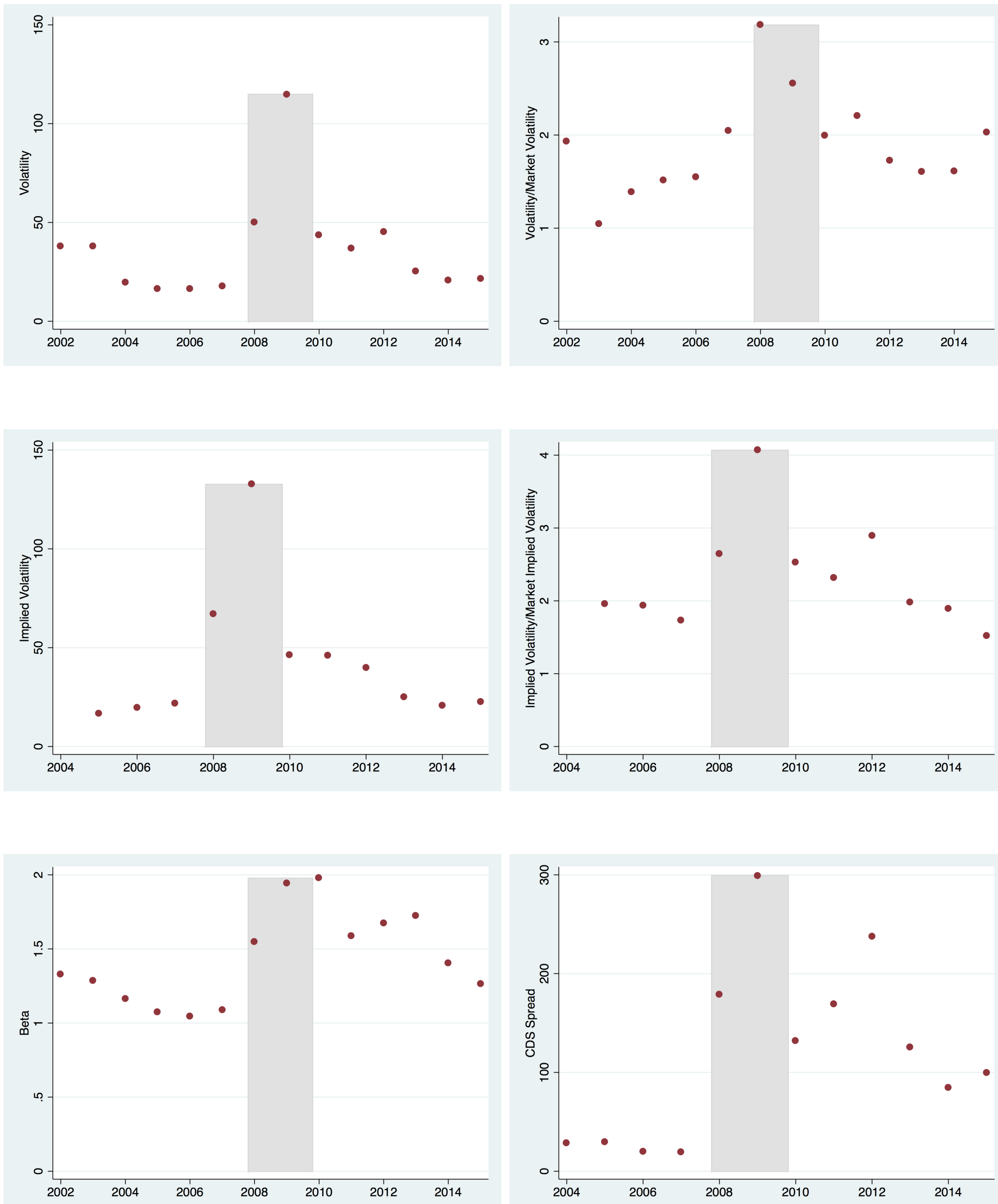
Figure 1: Beta and Bank Leverage



Like Baker and Wurgler (2015), the dependent variable here is forward beta and our independent variable is the ratio of total risk-based capital to Tier 1 capital. We have just over 6,000 bank-months in our dataset. We report results from local polynomial regressions using an Epanechnikov kernel with 20 bins and a smoothing interval of 0.1.

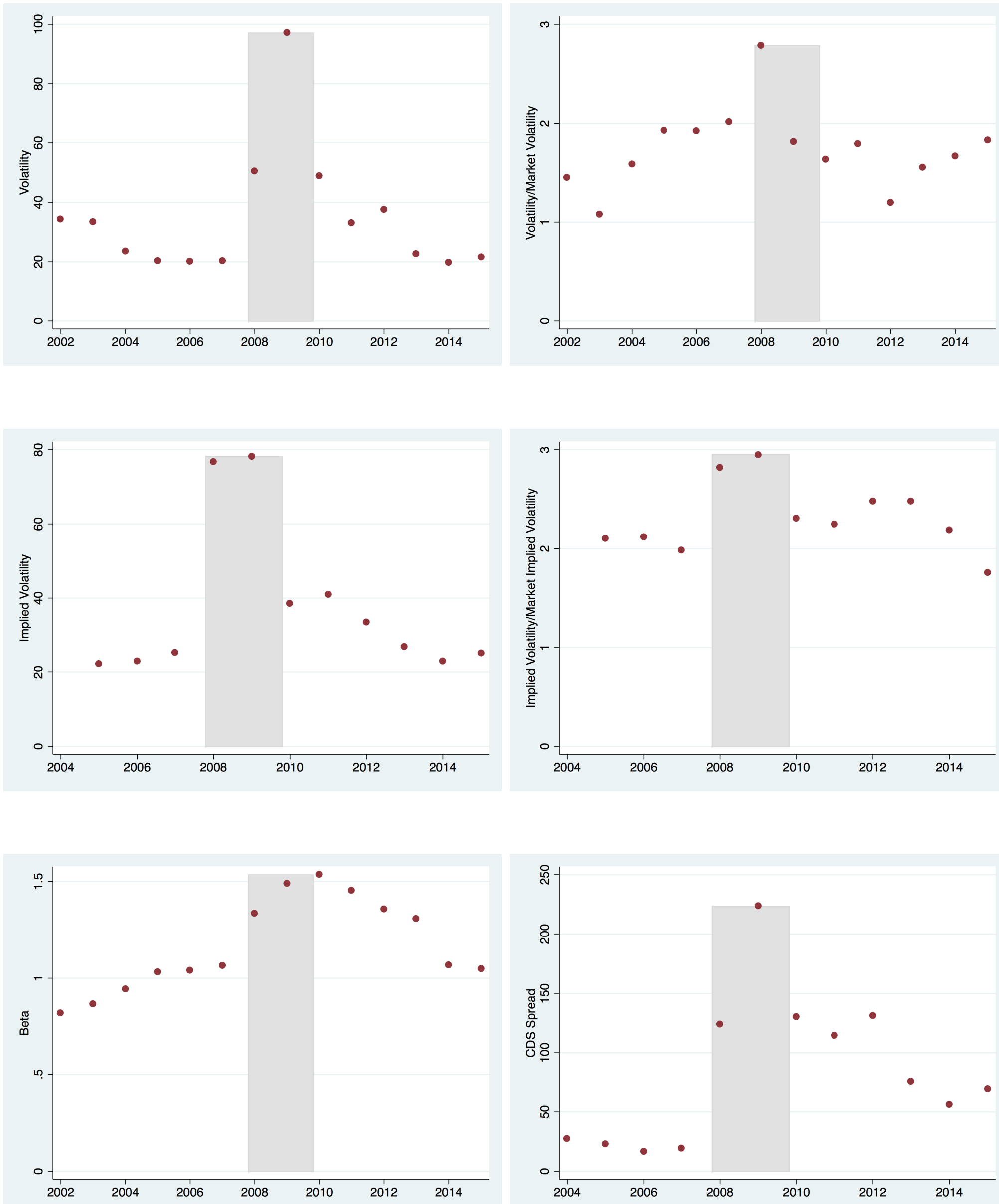
Figure 2: Changes in Risk Measures Over Time[1]

Panel A: Big 6 Institutions



[1]Shaded region indicates crisis years, 2008 and 2009 in our sample.

Panel B: Midsize Domestic Financial Institutions



Panel C: International Institutions

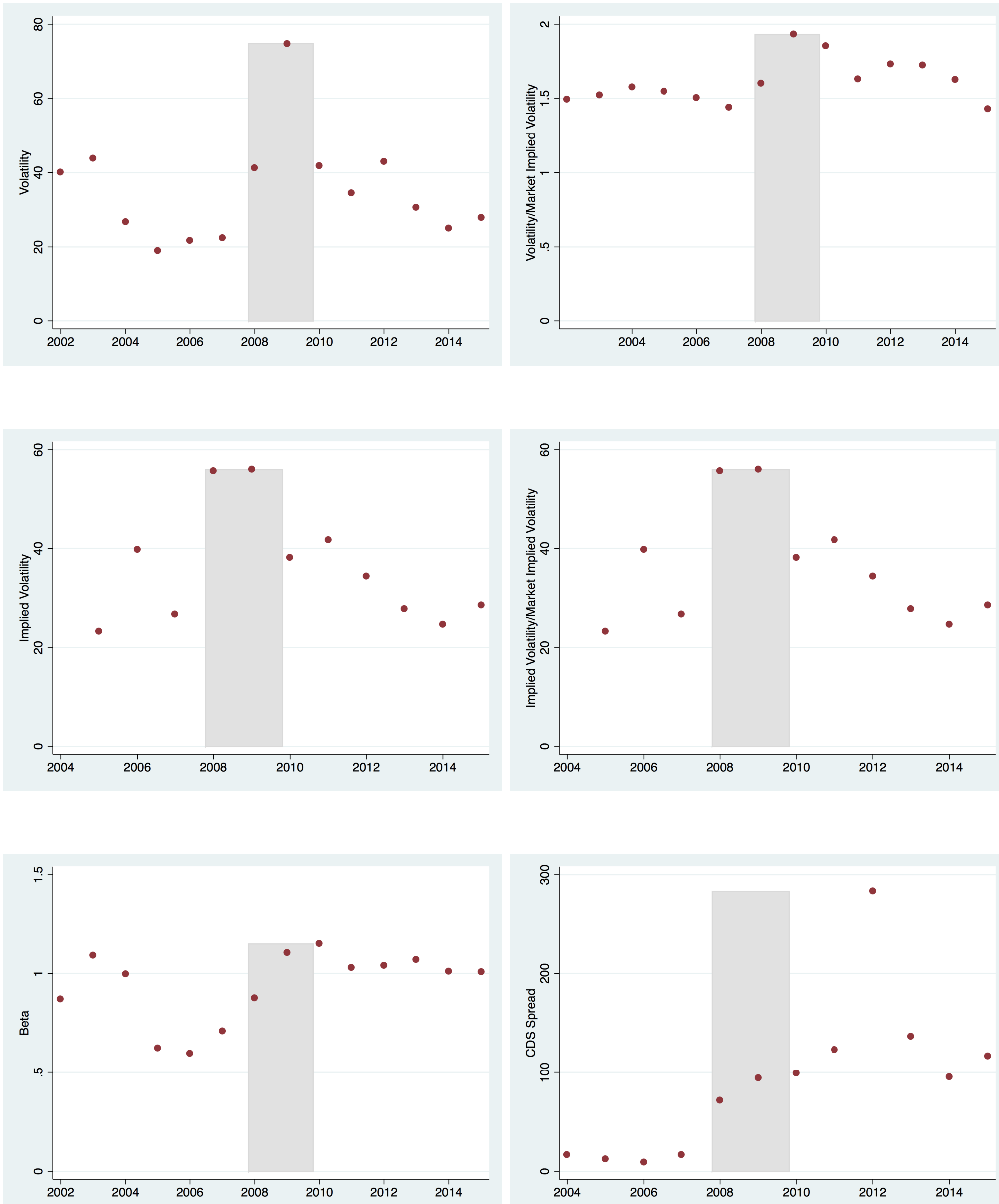
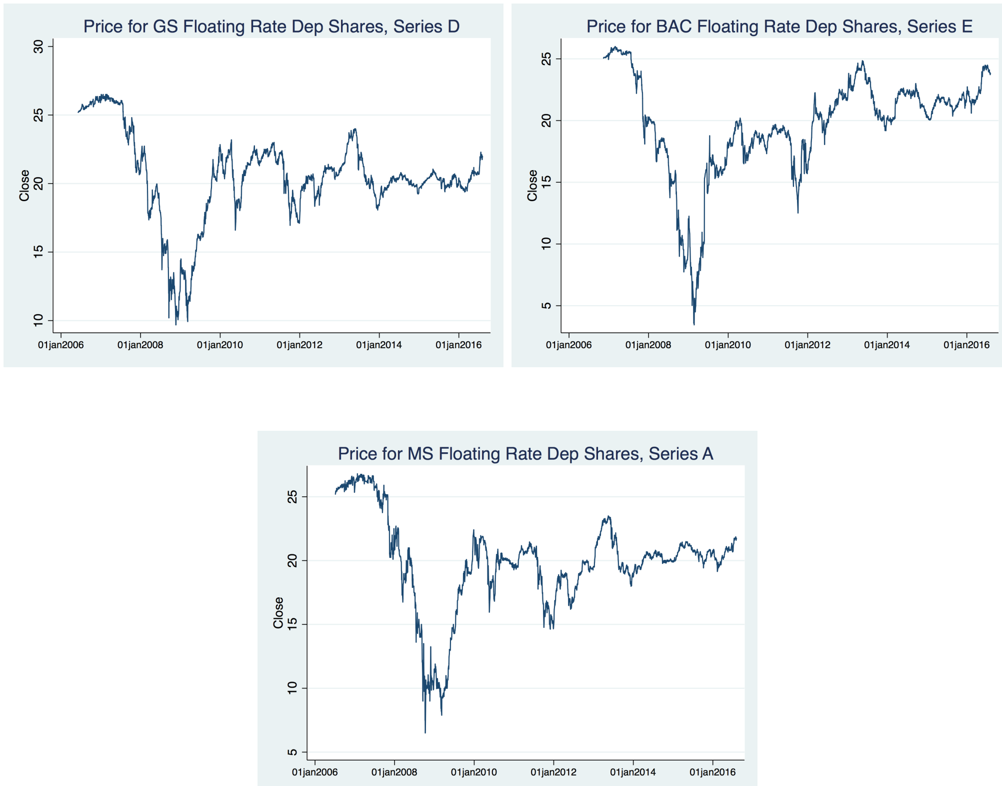


Figure 3: Preferred Stock Prices Over Time



Appendix A: Big 6 Banks

Panel A1: Big 6 Volatility

Bank	Pre–crisis average	Post–crisis average	2015 average
Bank of America	19.70	38.42	23.21
Citigroup	24.51	37.51	21.75
Goldman Sachs	26.92	28.04	19.35
JP Morgan	28.01	29.28	20.17
Morgan Stanley	31.75	36.80	22.60
Wells Fargo	17.29	28.34	16.94
Mean	24.70	33.07	20.67
Median	25.71	33.04	20.96

Panel A2: Big 6 Volatility/Market Volatility[1]

Bank	Pre–crisis average	Post–crisis average	2015 average
Bank of America	1.21	2.04	1.88
Citigroup	1.48	1.97	1.80
Goldman Sachs	1.81	1.62	1.62
JP Morgan	1.64	1.62	1.64
Morgan Stanley	1.99	2.09	1.89
Wells Fargo	1.18	1.47	1.44
Mean	1.55	1.80	1.71
Median	1.56	1.80	1.72

[1] For domestic volatility/market comparisons, we used the market return of the S&P 500. We used the standard deviation of the daily return over 260 trading days to best approximate an annual average.

Panel A3: Big 6 Implied Volatility

Bank	Pre–crisis average[1]	Post–crisis average	2015 average
Bank of America	18.55	35.51	25.42
Citigroup	21.00	33.60	24.68
Goldman Sachs	27.37	28.05	22.79
JP Morgan	22.53	27.02	21.47
Morgan Stanley	27.90	35.98	24.86
Wells Fargo	20.06	24.88	18.56
Mean	22.90	30.84	22.96
Median	21.76	30.82	23.74

[1] Earliest implied volatility data is available in 2005, so we begin our pre-crisis period then.

Panel A4: Big 6 Implied Volatility/Market Implied Volatility

Bank	Pre–crisis average	Post–crisis average	2015 average
Bank of America	1.56	2.46	1.78
Citigroup	1.73	2.30	1.73
Goldman Sachs	2.29	1.95	1.59
JP Morgan	1.88	1.86	1.49
Morgan Stanley	2.34	2.52	1.74
Wells Fargo	1.66	1.69	1.29
Mean	1.91	2.13	1.61
Median	1.81	2.12	1.66

Panel A5: Big 6 Option Delta[1]

Bank	Pre–crisis average	Post–crisis average	2014 average[2]
Bank of America	0.025	0.078	0.044
Citigroup	0.033	0.071	0.059
Goldman Sachs	0.040	0.075	0.047
JP Morgan	0.044	0.071	0.045
Morgan Stanley	0.049	0.081	0.040
Wells Fargo	0.028	0.069	0.043
Mean	0.036	0.074	0.046
Mean	0.038	0.073	0.047

[1] Delta is computed on one-year, 50% out–of–the–money put options.
[2] Delta data only through June 2015, so we use 2014 average as our most recent measure

Panel A6: Big 6 Betas

Bank	Pre–crisis average	Post–crisis average	2015 average
Bank of America	0.88	1.76	1.22
Citigroup	1.19	1.76	1.32
Goldman Sachs	1.33	1.32	1.21
JP Morgan	1.35	1.45	1.20
Morgan Stanley	1.56	1.82	1.40
Wells Fargo	0.77	1.41	1.04
Mean	1.18	1.59	1.23
Median	1.26	1.60	1.22

Panel A7: Big 6 CDS Spread[1]

Bank	Pre–crisis average[2]	Post–crisis average	2015 average
Bank of America	18.99	141.75	89.64
Citigroup	22.50	133.59	90.30
Goldman Sachs	47.47	161.26	117.04
JP Morgan	21.80	103.27	80.69
Morgan Stanley	65.29	226.15	136.07
Wells Fargo	15.02	68.19	47.73
Mean	31.85	139.04	93.58
Median	22.15	137.67	89.97
Median of S&P 500[3]	33.44	50.59	57.32

[1] Price data for a five–year tenor.
[2] Earliest CDS data is available in February 2004, so we begin our pre-crisis period then.
[3] Note that there is no S&P 500 CDS index, so median was calculated from CDS data for all companies now in the index.

Panel A8: Big 6 Price–Earnings Ratio Relative to Market[1]

Bank	Pre–crisis average	Post–crisis average	2015 average
Bank of America	0.56	1.90	0.81
Citigroup	0.73	0.19	0.67
Goldman Sachs	0.57	0.71	0.59
JP Morgan	0.83	0.60	0.53
Morgan Stanley	0.63	3.22	0.85
Wells Fargo	0.69	0.70	0.63
Mean	0.67	1.22	0.68
Median	0.66	0.70	0.65

[1] We follow Rajan (2005) and examine bank PE ratio as a percentage of S&P 500 PE ratio.

Panel A9: Big 6 Preferred Stock Price[1]

Bank	Pre–crisis average	Post–crisis average	2015 average
Bank of America	24.26	20.11	21.33
Citigroup	N/A	N/A	N/A
Goldman Sachs	25.12	20.66	20.21
JP Morgan	N/A	N/A	N/A
Morgan Stanley	25.36	19.68	20.68
Wells Fargo	N/A	N/A	N/A
Mean	24.91	20.15	20.74
Median	25.12	20.11	20.68

[1] Note there are only three banks in our sample (Bank of America, Goldman Sachs, and Morgan Stanley) with floating rate preferred stock dating back to the pre-crisis period, the rest are reported as N/A.

Panel A10: Big 6 Systemic Risk Percentage[1]

Bank	Pre–crisis average	Post–crisis average	2015 average
Bank of America	0.85	15.96	15.86
Citigroup	3.62	14.70	13.89
Goldman Sachs	5.95	6.01	6.21
JP Morgan	10.27	16.46	16.52
Morgan Stanley	13.80	7.79	8.20
Wells Fargo	0.05	1.73	0.37
Mean	5.76	10.44	10.18
Median	4.79	11.24	11.05

[1] SRISK is defined as the capital that a firm is expected to need if we have another financial crisis. SRISK% is SRISK divided by the sum of SRISK for all firms with positive SRISK in the relevant period.

Appendix B: Midsize Domestic Financial Institutions[1]

Panel B1: Midsize Domestic Volatility

Bank	Pre–crisis average	Post–crisis average	2015 average
Low MVE	26.56	29.79	22.58
Quintile 2	21.73	28.73	20.63
Quintile 3	25.86	30.98	22.64
Quintile 4	25.07	31.39	21.77
High MVE	28.50	28.56	20.30
Mean	25.54	29.89	21.58
Median	25.86	29.79	21.77

Panel B2: Midsize Domestic Volatility/Market Volatility[1]

Bank	Pre–crisis average	Post–crisis average	2015 average
Low MVE	1.81	1.71	1.82
Quintile 2	1.47	1.66	1.69
Quintile 3	1.73	1.70	1.89
Quintile 4	1.64	1.72	1.80
High MVE	1.73	1.60	1.70
Mean	1.68	1.68	1.78
Median	1.73	1.70	1.80

[1] For domestic volatility/market comparisons, we used the market return of the S&P 500. We used the standard deviation of the daily return over 260 trading days to best approximate an annual average.

[1] Quintile ranking based on market capitalization in each period. In the pre-crisis period, the mean market cap in the bottom quintile was slightly over $1B, and the mean in 2015 was around $2.7B. For the top quintile, the pre-crisis mean was $312B, and in 2015 it was around $488B.

Panel B3: Midsize Domestic Implied Volatility

Bank	Pre–crisis average[1]	Post–crisis average	2015 average
Low MVE	25.34	36.62	28.62
Quintile 2	24.38	36.19	31.66
Quintile 3	28.41	30.85	26.25
Quintile 4	24.91	29.78	25.25
High MVE	24.65	26.86	21.85
Mean	25.54	32.06	26.73
Median	24.91	30.85	26.25

[1] Earliest implied volatility data is available in 2005, so we begin our pre-crisis period then.

Panel B4: Midsize Domestic Implied Volatility/Market Implied Volatility

Bank	Pre–crisis average	Post–crisis average	2015 average
Low MVE	2.03	2.67	2.06
Quintile 2	2.10	2.60	2.27
Quintile 3	2.36	2.18	1.86
Quintile 4	2.08	2.07	1.80
High MVE	2.08	1.88	1.54
Mean	2.13	2.28	1.90
Median	2.08	2.18	1.86

Panel B5: Midsize Domestic Betas

Bank	Pre–crisis average	Post–crisis average	2015 average
Low MVE	0.85	1.21	0.99
Quintile 2	0.79	1.16	0.99
Quintile 3	0.99	1.31	1.14
Quintile 4	1.10	1.38	1.04
High MVE	1.08	1.32	1.11
Mean	0.96	1.27	1.05
Median	0.99	1.31	1.04

Panel B6: Midsize Domestic CDS Spread[1]

Bank	Pre–crisis average[2]	Post–crisis average	2015 average
Low MVE	18.15	76.37	61.79
Quintile 2	19.31	76.74	52.14
Quintile 3	24.65	106.38	72.03
Quintile 4	24.95	97.99	80.42
High MVE	28.94	115.14	74.18
Mean	23.20	94.52	68.11
Median	24.65	97.99	72.03

[1] Price data for a five–year tenor.
[2] Earliest CDS data is available in February 2004, so we begin our pre-crisis period then.

Panel B7: Midsize Domestic Price–Earnings Ratio Relative to Market[1]

Bank	Pre–crisis average	Post–crisis average	2015 average
Low MVE	0.89	0.96	0.78
Quintile 2	0.90	0.94	0.90
Quintile 3	0.51	0.61	0.64
Quintile 4	0.89	0.45	0.58
High MVE	0.76	0.82	0.75
Mean	0.79	0.75	0.73
Median	0.89	0.82	0.75

[1] We follow Rajan (2005) and examine bank PE ratio as a percentage of S&P 500 PE ratio.

Appendix C: International Institutions[2]

Panel C1: International Bank Volatility

Country	Pre–crisis average	Post–crisis average	2015 average
Australia	17.28	21.33	18.10
Brazil	43.80	35.36	51.84
Canada	17.49	16.61	14.45
Denmark	23.28	32.27	21.82
France	26.56	42.95	29.73
Germany	33.36	39.95	28.66
Italy	27.39	46.08	36.26
Japan	36.68	29.98	24.70
Netherlands	34.61	43.21	29.29
Spain	27.84	34.88	30.66
Sweden	29.67	28.54	24.90
Switzerland	29.46	32.70	27.39
UK	25.32	35.67	24.31
Mean	28.67	33.81	27.86
Median	27.84	34.88	27.39
Big 6 Mean	24.70	33.07	20.67
Big 6 Median	25.71	33.04	20.96

[2]Australian banks include National Australia Bank, Australia and New Zealand Banking Company, and Westpac Banking. Brazilian banks include Banco de Brazil. Canadian banks include Toronto-Dominion Group, Royal Bank of Canada, Bank of Nova Scotia, and Bank of Montreal. Danske is the Danish bank in our sample and ING is the Netherlands bank. French banks are BNP Paribas, Credit Agricole Group, Societe Generale, and Natixis. German banks are Deutsche Bank and Commerzbank. Italian banks are Unicredit and Intesa Sanpaolo. Japanese banks are Mitsubishi, Mizuho, and Sumitomo. Santander is the Spanish bank in our sample. Nordea is the Swedish bank. UBS and Credit Suisse are the Switzerland banks. The UK banks are HSBC, Barclays, Lloyds, Royal Bank of Scotland, and Standard Chartered.

Panel C2: International Volatility/Market Volatility[1]

Country	Pre–crisis average	Post–crisis average	2015 average
Australia	1.60	1.43	1.31
Brazil	1.56	1.52	1.99
Canada	1.34	1.21	1.17
Denmark	1.16	1.48	1.06
France	1.40	1.98	1.52
Germany	1.48	1.98	1.43
Italy	1.58	1.73	1.44
Japan	1.86	1.36	1.26
Netherlands	1.57	1.95	1.43
Spain	1.46	1.43	1.48
Sweden	1.45	1.30	1.21
Switzerland	1.64	2.11	1.54
UK	1.59	2.22	1.73
Mean	1.51	1.67	1.43
Median	1.56	1.52	1.43
Big 6 Mean	1.55	1.80	1.71
Big 6 Median	1.56	1.80	1.72

[1] For international market comparisons, we use local indices except for banks in the Netherlands, Sweden, and Denmark. We benchmark volatility of banks in these countries against a European index. We used the standard deviation of the daily return over 260 trading days to best approximate an annual average.

Panel C3: International Implied Volatility

Country	Pre–crisis average[1]	Post–crisis average	2015 average
Australia	15.91	18.87	20.71
Brazil	66.25	37.83	39.26
Canada	17.22	18.41	16.90
Denmark	21.74	31.87	22.48
France	23.72	41.91	31.88
Germany	25.66	40.10	33.08
Italy	20.54	41.24	34.61
Japan	29.00	28.46	28.49
Netherlands	20.84	38.49	30.95
Spain	22.47	36.68	35.25
Sweden	23.05	26.15	23.52
Switzerland	21.92	30.49	27.00
UK	23.04	32.93	27.02
Mean	25.49	32.57	28.55
Median	22.47	32.93	28.49
Big 6 Mean	22.90	30.84	22.96
Big 6 Median	21.76	30.82	23.74

[1] Earliest implied volatility data is available in 2005, so we begin our pre-crisis period then.

Panel C4: International Implied Volatility/Market Implied Volatility

Country	Pre–crisis average	Post–crisis average	2015 average
Australia	1.10	1.06	1.27
Brazil	3.63	2.23	2.44
Canada	1.23	1.02	1.04
Denmark	1.32	1.36	0.95
France	1.41	1.79	1.33
Germany	1.48	1.88	1.40
Italy	1.22	1.76	1.44
Japan	1.51	1.22	1.31
Netherlands	1.23	1.62	1.29
Spain	1.34	1.56	1.46
Sweden	1.38	1.11	0.99
Switzerland	1.28	1.30	1.13
UK	1.55	1.88	1.66
Mean	1.51	1.52	1.36
Median	1.34	1.56	1.31
Big 6 Mean	1.91	2.13	1.61
Big 6 Median	1.81	2.12	1.66

Panel C5: International Betas

Country	Pre–crisis average	Post–crisis average	2015 average
Australia	0.50	0.70	0.75
Brazil	0.73	0.85	1.28
Canada	0.41	0.58	0.69
Denmark	0.58	1.00	0.82
France	0.79	1.35	1.27
Germany	1.01	1.14	1.08
Italy	0.86	1.30	1.28
Japan	1.36	1.31	1.35
Netherlands	N/A	N/A	N/A
Spain	1.03	1.07	1.12
Sweden	0.57	0.80	0.88
Switzerland	1.10	1.27	0.73
UK	0.86	1.25	0.85
Mean	0.82	1.05	1.01
Median	0.82	1.11	0.98
Big 6 Mean	1.18	1.59	1.23
Big 6 Median	1.26	1.60	1.22

Panel C6: International CDS Spread[1]

Country	Pre–crisis average[2]	Post–crisis average	2015 average
Australia	11.76	103.44	70.86
Brazil	N/A	321.50	422.65
Canada	N/A	56.42	59.44
Denmark	N/A	N/A	N/A
France	11.74	139.48	75.13
Germany	N/A	N/A	N/A
Italy	16.09	208.35	93.20
Japan	N/A	N/A	N/A
Netherlands	11.89	116.01	62.30
Spain	14.77	203.43	103.46
Sweden	N/A	82.99	62.66
Switzerland	19.48	99.85	71.60
UK	13.53	90.67	97.21
Mean	14.18	142.21	111.85
Median	13.53	109.72	73.37
Big 6 Mean	31.85	139.04	93.58
Big 6 Median	22.15	137.67	89.97

[1] Price data for a five–year tenor.
[2] Earliest CDS data is available in February 2004, so we begin our pre-crisis period then.