Journal of Financial Stability 12 (2014) 26–36

Contents lists available at ScienceDirect

Journal of Financial Stability

journal homepage: www.elsevier.com/locate/jfstabil

# Distance to default and the financial crisis

Alistair Milne *

*School of Business and Economics, Loughborough University, UK*

ARTICLE INFO

*Article history:*
Received 24 September 2012
Received in revised form 23 May 2013
Accepted 23 May 2013
Available online 17 June 2013

*JEL classification:*
G01
G21
G28

*Keywords:*
Bank default
Bank moral hazard
Bank regulation
Bank safety net
Contingent claims
Early warning systems
Global financial crisis
Market-based risk measurement
Systemic risk
Risk shifting

ABSTRACT

This paper analyses contingent-claims based measures of distance to default (D2D) for the 41 largest global banking institutions over the period 2006H2 to 20011H2. D2D falls from end-2006 through to end-2008. Cross-sectional differences in D2D prior to the crisis do not predict either bank failure or bank share prices decline, but D2D measured in mid-2008 does have some predictive value for failure by end-year. The 'option value' of the bank safety net remains small except at the height of the crisis and there is little indication of bank shareholders consciously using the safety net to shift risk onto taxpayers.



## 1. Introduction

More than five years have passed since August of 2007, when problems in US sub-prime mortgage lending first spread internationally and initiated the global financial crisis. A large and growing body of subsequent research has examined the reasons for this sudden and unexpected emergence of systemic risk. Contributory factors have been identified amongst individual institutions, in specific markets and at the level of the system as a whole.

This paper uses data from the crisis on the largest 41 global banks, documenting the evolution of one standard market-based risk measure – 'distance to default' – through the crisis and examining its performance in cross-sectional econometric models of bank share price performance and for the prediction of bank failure.

The central questions addressed here are far from new: these are (i) whether this particular market based measure of risk provide useful information on the likelihood of future bank failure; (ii) whether it can perform better as a forecasting indicator than regulatory and accounting based measures of prudential risk; and (iii) what does the contingent-claims analysis that underpins the measurement of distance to default tell us about the value of the put option embedded in the bank safety net and the extent to which bank shareholders exploit the bank safety net in order to shift risk onto tax payers?

The global financial crisis provides a strong motivation for revisiting these questions. It is possible, had regulators paid greater attention to market based signals of risk such as the 'distance to default' on which this paper focuses, that they might have done more and earlier to mitigate the extent and impact of the crisis. Better understanding of what drove events during the crisis should also help identify how financial regulation and supervision could have been better designed so as to more effectively incentivize banks to behave in prudent manner.

This paper addresses these key questions by applying a standard one-period contingent-claims model of bank debt and equity pricing to data from the crisis period. This standard model allows calibration of the distance between the current market-implied value of bank assets and the level which would trigger bank failure.

* Tel.: +44 1509 222718.
*E-mail address:* a.k.l.milne@lboro.ac.uk

1572-3089/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jfs.2013.05.005

It also allows calculation of the value of the put-option offered to bank shareholders by the bank safety net, since distance to default provides a measure of the extent to which this put option provided to shareholders by the bank safety net is 'out of the money' (when distance to default is many standard deviations) or 'on the money' (when distance to default falls close to zero).

Doing this it turns out that, while distance to default is a convenient and intuitive risk measure, it was of only of very limited value as a forward looking predictor of bank share price performance and failure during the crisis. It is only with the full onset of the crisis, for relatively short six month ahead prediction window from 2008H1 to the end of the year, that a low value of distance to default had value as a signal of future financial failure.

This investigation of 'distance to default' also offers some insight into the extent to which bank shareholders were able to exploit the put option created by the bank safety net, taking the opportunity to create value for themselves by shifting risk onto tax payers through increased leverage and risk-taking. This mechanism has been proposed as the major driver of the recent crisis, for example by (Sinn, 2010) page 87[1]:

> "It cannot be stressed enough that the explanation of the banks' gambling is not primarily the false incentives of the bank executives but the false incentives of shareholders. After all, it is the shareholders who benefit from limited liability. They demand from their banks risky and profitable business models that only function because they entail the advantage of socializing the risk of losses that exceed equity. The problem was not that bank managers did not act in the interest of shareholders, but that shareholders gambled with the money of creditors and taxpayers."

Despite this strong claim, it is far from clear that bank shareholders did in fact recognise the scale of risk to which they were exposed or that they deliberately courted large scale risk prior to the crisis in order to maximise the value of tax payer support. Virtually all reports in the financial press suggest that the scale of losses during the crisis has been very much greater than either bank management or bank investors had conceived possible prior to the event. In short, in remains an open issue as to whether a major cause of the crisis was indeed pressure by shareholders on banks to take large risks with their solvency.

It is true that prior to the crisis banks did enjoy very low funding spreads (relative to risk free government securities) in both money and long term debt markets. These low spreads are consistent with the 'Sinn hypothesis', they indicate that banks were not being penalised by investors (in terms of higher funding costs) for the degree of risk they were taking on. But these low levels of spreads are equally consistent with an alternative: that banks and other market participants were simply unaware of the level of risks they were taking. In particular that bank management, bank shareholders and other investors may simply have grossly underestimated the shortcomings of their own risk models and of their processes of internal control; or of the potential for 'endogenous' magnification of risk as investors withdrew from markets and reduced available credit and liquidity.[2]

The results reported here help distinguish these two hypotheses. They reveal that the Sinn hypothesis is inconsistent with the standard one-period contingent claims analysis of bank liabilities. The implied value of the put option held by bank shareholders prior to the crisis has been far too small to compensate for the losses subsequently experienced by shareholders. If shareholders were deliberately 'risk shifting' the risks they were transferring to tax-payers were not the normal business and financial risks that materialise gradually over time and hence can be measured by observations on fluctuations of bank share prices over a horizon of a few months.

It may of course be that this simple one-period contingent claims model is itself not appropriate for capturing risk shifting. A different model – for example one in which risk materialises suddenly and catastrophically rather than gradually over time – might be consistent with risk-shifting by banks prior to the crisis. But this in turn suggests that to contain bank risk shifting, regulators should focus their attention not on containing normal business and market risks (the focus of both Basel II and subsequently of Basel III) but on addressing the readiness of banks to withstand sudden catastrophe.

The paper is organised as follows. Section 2 reviews prior literature. Many previous studies have explored the analogy between put option and the bank safety net. Indeed this analogy is one of the major insights offered by economists into the design of banking regulation. There certainly are circumstances where the provision of tax payer support creates an opportunity to take risk, for example in the 'gamble for resurrection' undertaken by many US Savings and Loans in the 1980s once their solvency had been undermined by their exposures to interest rate risk. But there are other offsetting incentives that can lead banks to limit their risk taking, most notably the loss of franchise or charter value in the event of bank failure. There is also a substantial econometric literature, some of which employs a similar contingent claims framework as that used in the present paper, considering how market based information can be a used as an indicator of bank fragility and for quantifying the incentives for risk shifting.

Section 3 examines the behaviour of distance to default for the largest global banks during the crisis. It first describes the calculation of distance to default, and the data based used for this purpose covering the 41 largest global banks and credit institutions, as of end-2006. It then presents a summary descriptive analysis of the resulting measures of distance to default, considering how it evolved over the years of the crisis, and reporting the value of the 'put option' as implied by the contingent claims model.

Section 4 presents some simple econometric tests of the ability of distance to default to predict problems during the crisis. This finds that, based on information available in 2006 or in 2007, distance to default has little forecasting value in cross-sectional regressions of either share price declines or of bank failure. But using more recent information from the first half of 2008 then distance to default is a significant predictor of default in the second half of the year. Section 5 draws conclusions, arguing that attributing the global financial crisis to incentives on shareholders is an oversimplification. A full account of the crisis cannot of course ignore incentives on bank managers and shareholders, but it also has to take account of the system wide interactions which so unexpectedly magnified the crisis and which, inevitably, are not included in a single bank risk measure such as distance to default.

## 2. Market based measures of bank risk: theory, evidence and relevance to the recent crisis

This section reviews the literature on the contingent claims model of bank assets and liabilities and of the use of market based indicators of bank risk, in particular distance to default, as a measure of bank risk exposure and a predictor of financial distress.

[1] Sinn (2010) also attributes the crisis to other causes, notably to poor standards of credit assessment in US sub-prime mortgage lending and to failures of both regulators and rating agencies to identify the scale of prospective risks.

[2] Such mechanisms are stressed in other accounts, for example (Brunnermeier, 2009; Milne, 2009).

It relates these earlier contributions to more recent research that seek to understand the determinants of bank failure in the crisis of 2007–2008.

The contingent claims model of corporate assets and liabilities, introduced by Merton (1974), has been widely applied in both corporate finance and banking research. Banking applications follow Merton (1977) by interpreting a bank's shareholders as holding a put option ultimately underwritten, explicitly or implicitly, by the bank safety net. As with other contingent claims analysis, this option can be modelled using standard option-pricing models, including Black-Scholes and variants that allow for infinite horizon with random audit, for correlation between interest rates and asset values, and for other generalizations.

Several papers have examined the use of distance to default and other 'market based' measures of bank risk as tools for both regulation and supervision and also for predicting corporate and bank failure.[3] Particular attention has been paid to the use of credit spreads on subordinated debt, as a tool of bank supervision (see Evanoff and Wall, 2002; Flannery, 1998). Subordinated debt has been seen as desirable form of financing because it imposes an additional market discipline, with any increase in bank risk taking resulting in increased spreads on subordinated debt and, if banks must fact higher costs of refinancing, lowering the value of equity; and also for its potential use as a trigger for supervisory intervention in a regulated institution.

There have been comparatively few studies of distance to default as a predictor of bank failure. One exception is (Gropp et al., 2006) who investigate the use of both distance to default and subordinated bond spreads in predicting the downgrading of banks to a C-rating, i.e. close to failure, with a sample of between 59 and 86 US and European banks, finding that distance to default has some forecasting power at a horizon of 12–18 months and subordinated bond spreads have forecasting power over a shorter time horizon and can improve forecasts relative to using bank accounting variables alone. However, many of their coefficients are only moderately significant (at 10 per cent level). Other evidence from the case studies of failure of eight Japanese banks reported by (Harada et al., 2010), suggests that distance to default appears not to have much predictive power, only increasing markedly relative to previous values or to other banks in the final month before default. Another alternative market based indicator, examined by (Coffinet et al., 2010) using data from the recent crisis period, is implied volatility revealed by traded option prices. Consistent with the short term finding of short term predictive power for distance to default in the present paper, they find that implied volatility has short-term predictive power for the occurrence of financial distress using a quarterly sample of 255 large US banks and financial services firms during the period 1995–2008.

There are now several papers looking at the determinants of bank default in the current global financial crisis, although none (to the knowledge of this author) have examined the usefulness of distance to default as a predictor of bank failure. The finding of the present paper that distance to default for global banking institutions rose only comparatively late in the crisis is reported also by Castrén and Kavonius (2009), but they do not test the forecasting power of distance default, instead exploring how distance to default measures can be adapted to capture systemic interlinkages between banks. Ratnovski and Huang (2009) find that high ratios of equity to assets and high proportions of deposits in total funding, had an economically and statistically significant positive impact on share price performance; and on the probability of avoiding extreme stress, for a sample of 72 of OECD banks over the period beginning of 2007 to beginning of 2009. They interpret this as evidence that liquidity and funding problems played a major role in the crisis and that this protected Canadian banks, in particular, because of their strong deposit base.

Beltratti and Stulz (2009), obtain similar findings for a sample of 98 banks and also find that banks whose share prices rose the most prior to the crisis also suffered the largest falls during the crisis (consistent with the evidence reported in this paper that banks with the highest distance default in 2006 were more likely to fail in 2008). They further report weak and sometimes negative relationship between measures of corporate governance and share price performance. Their interpretation of the crisis is that many banks were encouraged by shareholders to pursue business models that performed well during the prior period of rapid credit expansion, but were then revealed to be flawed in the crisis. Fahlenbrach et al. (2011) find further evidence for this "flawed business model" interpretation, from their finding that banks that performed poorly during the market crisis triggered by the default of Russia and near failure of LTCM in 1997, also performed badly during the current crisis.

Altunbas et al. (2011) also investigate the role of bank balance sheet variables on bank risk in the current crisis, for a much larger sample of between 546 and 842 European and US banks (the number depending on the variables included in their models). They do not directly look at share price performance, but instead examine the impact on the probability of requiring liquidity support and of solvency support, and also the impact on the beta of the bank with the market, i.e. the systematic risk of bank equity. They find consistent results across all their specifications, in that a large number of variables are associated with greater probability of support or greater systematic risk, including low levels of equity or Tier 1 capital, rapid credit growth, and reliance on wholesale funding. They also find, using quantilie regressions, that these impacts are strongest in for the riskiest banks. Finally, as in Beltratti and Stulz (2009) they find that banks with a high market to book ratio before the crisis, and suggest that this is due to the pursuit of 'false alpha', i.e. increasing market returns simply by taking on more risk.

The one period contingent claims model of banking employed in this paper is a natural formalisation of the bank moral hazard stressed by Sinn (2010) and many others. According to this view the bank safety net encourages banks to take greater risk in order to increase the value of this put option. Such incentives are especially strong for banks that are already close to failure, leading them to 'gamble for resurrection' knowing that only a very large increase in asset values will allow them to avoid closure. The extensive literature on the US Savings and Loans crisis of the 1980s reveals such a gamble for resurrection amongst US thrifts, once their solvency was undermined by rising short term interest rates and their poor management of interest rate risk.[4] Many then turned to large scale risky investments in high yield 'junk bonds', in commercial property, and to outright fraud. Regulatory forbearance allowed such massive risk taking to continue and was a principal cause of the eventual 2.25% of US GDP needed to resolve the failed thrifts. Subsequently Congress passed the 1991 FDICIA act, with the intention that prompt corrective action, requiring supervisors to intervene in banks as capitalization measures declined, would prevent such massive losses recurring.

[3] This framework is widely used by practitioners for predicting non-financial corporate default, in the proprietary implementation by KMV. See Crosbie (2000) for detail and how they correct for bias by matching default frequency to their corporate default database.

[4] See for example Benston (1986) and White (1991).

While bank moral hazard can provide powerful incentives for risk-taking, there can be other offsetting incentives. For example bank managers may seek to limit risk if they are averse to the possibility of losing their jobs. Similarly shareholders may not wish to increase risk if the bank has a substantial charter or franchise value from its continued future operation, a value which would be lost in the event of failure (Keeley, 1990; Marcus, 1984). Demsetz and Strahan (1996) find that banks with higher charter value both took less risk and were less leveraged (and thus by implication should have much greater distance from default). Milne and Whalley (2002) demonstrate how these incentives can switch from limiting risk, when banks operate with more than minimum capital, to maximisation of risk should regulatory forbearance allows banks to continue in operation with less than minimum capital.

One strand of this literature uses distance to default, and the associated measure of the expected risk of default, to investigate whether FDIC deposit insurance is actuarially fair. Marcus and Shaked (1984) find, on a sample of 40 US banks in the years 1979 and 1980, that distance to default was relatively high and hence default probabilities were comparatively low. They conclude that US deposit insurance was mostly overpriced. Ronn and Verma (1986) using a slightly different calculation, and a somewhat larger sample of banks, report considerable cross-sectional variation in actuarially fair deposit premia, with a small number of risky banks benefitting from underpricing and the expense of other safer banks. Pennacchi (1987) implements an infinite horizon option model, finding that the large majority of US banks benefit from underpricing of deposit insurance.

A related line of enquiry has used the same analytical framework to investigate the extent to which banks have opportunities for 'risk shifting', i.e. increasing the actuarially fair level of deposit insurance by increasing their asset risk; or whether this opportunity is constrained by market and regulatory disciplines that force riskier banks to operate with higher capital ratios. This approach was pioneered by Duan et al. (1992) who report only limited opportunities for risk shifting in their sample of 43 US banks. But this contrasts with the results of Hovakimian and Kane (2000), who, using panel estimation on data set of US banks that extends into the mid-1990s, find a substantial and positive relationship between asset risk and the fair value of deposit insurance. In particular they find that weaker banks, closer to default, have somewhat larger opportunities for risk-shifting, suggesting that despite the passage of FDICIA regulatory and market disciplines are ineffective in controlling risk-taking by banks close to failure.

## 3. The calculation of distance to default and its behaviour through the crisis

### 3.1. Calculation method

Distance to default is not measured directly. Rather it is recovered implicitly from observed measures of bank liabilities and of the market prices of those liabilities. This process can be most easily understood from writing the value of bank equity using a Black-Scholes formulation, in terms of the underlying assets of the bank and the debt issued by the bank, i.e. as:

$$E = A * N(d_1) - De^{-r(T-t)} * N(d_2) \tag{1}$$

where $A$ is the value of bank assets, $T$ is the time until the debt matures, $D$ is the debt's face value and $d_1$ and $d_2$ are given by:

$$d_1 = \frac{\ln(A/D) + (r + (\sigma^2/2))(T-t)}{\sigma\sqrt{(T-t)}} \tag{2}$$

$$d_2 = d_1 - \sigma\sqrt{(T-t)} \tag{3}$$

Default takes place when asset values $A$ fall to below the value of debt $D$. This 'put option' interpretation of default is especially applicable to banks, because (in contrast to non-financial corporates) the presence of the bank safety net means that the costs of deposits and other debt can be insensitive to the risk of default, so the interest rate $r$ can be measured by a constant risk-free rate.

The observed volatility of bank equity can be related to the unobserved volatility of bank assets using

$$\sigma_E = N(d_1)\frac{A}{E}\sigma_A \tag{4}$$

The two unobserved 'latent' variables, $A$ and $\sigma_A$, cannot be directly observed, but can be recovered by inverting the two relationships for the value and volatility of equity.

Using this model to quantify distance to default requires some practical compromises. Real debt contracts are not all written with a single terminal date. What then about debt of longer maturity? At longer time horizons, if there is trend asset growth, default becomes relatively unlikely. So this suggests that longer term debt should not have such a big impact on default probabilities. A common procedure, used by Moody's KMV and also employed here, is to adopt a one year horizon $T$, but to weight longer term debt of maturity of greater than one year at only 50% of face value.

Inversion of the Black-Scholes model in this way is an appealing way of using market prices to quantify default risk (even though the resulting default probabilities must be interpreted with care since, being 'risk-neutral', they are lower than actual probabilities of default). The question remains how useful distance to default was as a risk measure in the crisis.

### 3.2. Data

The calculation of distance to default requires data on both bank share prices and accounting information. The banks chosen were the largest in the world at end 2006, those which most obviously benefited from safety net protection. The selection was made beginning initially with the largest 100 institutions, by total assets, as reported in BankScope at end 2006 (early 2006 for the Japanese banks which traditionally report in March). 59 institutions were then eliminated (subsidiaries of other banks on the list, co-operative or state owned, pure insurance companies or subsidiaries of non-financial companies.) This left 41 banks comprising the large US housing finance institutions (Fannie and Freddie), commercial banks, investment banks and bank-assurers. Of these, the breakdown by jurisdiction of their headquarters is as follows: 11 in US, 5 in the UK, 4 in France, 3 in Japan, 3 in Germany, 3 in China, 3 in Belgium, 2 in Switzerland, 2 in Italy, 2 in Spain, 1 in the Netherlands, 1 in Sweden, and 1 in Denmark.

Of these 41 banks, 11 are deemed to have failed in the autumn of 2008, either because they were acquired by government or were supported with a substantial injection of government equity or were the subject of forced takeover by another bank with a payment to shareholders considerably less than book value. The list of banks in the sample, and the indication of whether they survived or failed, is provided in Appendix A.

In order to have access to sub annual data, interim reports were taken from Thomson Banker Worldscope, in their bank format. These were found for 38 of the 41 institutions. The exceptions are Wachovia Corporation (missing from database), Dresdner Bank (a subsidiary of Allianz SE insurance since 2001, so we do not get customer deposit data), and Halifax Bank of Scotland Group (missing from database). This missing data was hand collected directly from these banks accounting statements. The accounting data was

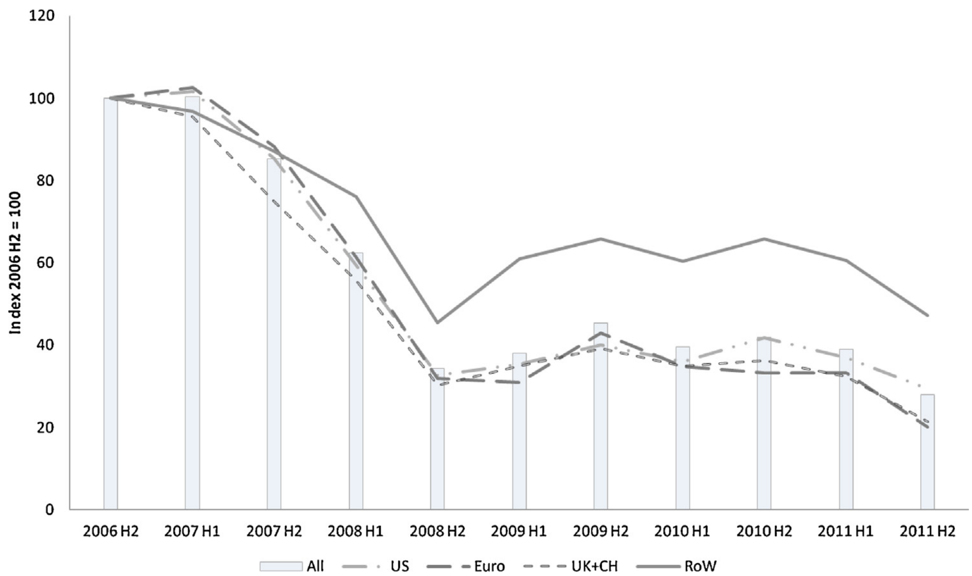


**Fig. 1.** Global bank share prices.

scrutinised carefully, and on a number of other occasions, where the reporting was not consistent from one period to the next, they were supplemented by hand collected data from published financial accounts.

Debt was calculated as 100% of deposits and short term debt and 50% of long term debt. This meant that insurance liabilities and also trading liabilities (other than short term unsecured and repo funding) had a zero weighting. Two of the banks (Dresdner and KBC) were part of large banking and insurance groups in which the insurance activities contributed substantially to overall profits, thus reducing debt relative to total assets. Daily shareprice data was downloaded for all 41 institutions from DataStream, and used to compute market capitalisation and the volatility of daily equity returns for the past 66 trading days (3 months) prior to each accounting date. Shareprices and interest rates were all downloaded in the currency used by each bank for its reporting.

Calculations of distance to default were made on a half yearly basis, for the nearest accounting period to end-Dec and end-June. While all US banks and a number of others report quarterly, many other institutions only reported on a half-yearly basis for most of the period 2006–2012. The inversion of the equations to obtain the value of assets $A$ and the volatility of assets $\sigma_A$, were made using the Excel Solver routine, implemented in Visual Basic. Distance to default was calculated for all 41 banks and from 2006H2 until 2011H2 or the date of closure of those banks in this sample that did not survive the crisis.

### 3.3. *Share prices and distance to default during the crisis*

Figs. 1–3 summarise the behaviour of share prices and of distance to default during the crisis. Bank share prices have fallen very substantially since the first half of 2007, much more than

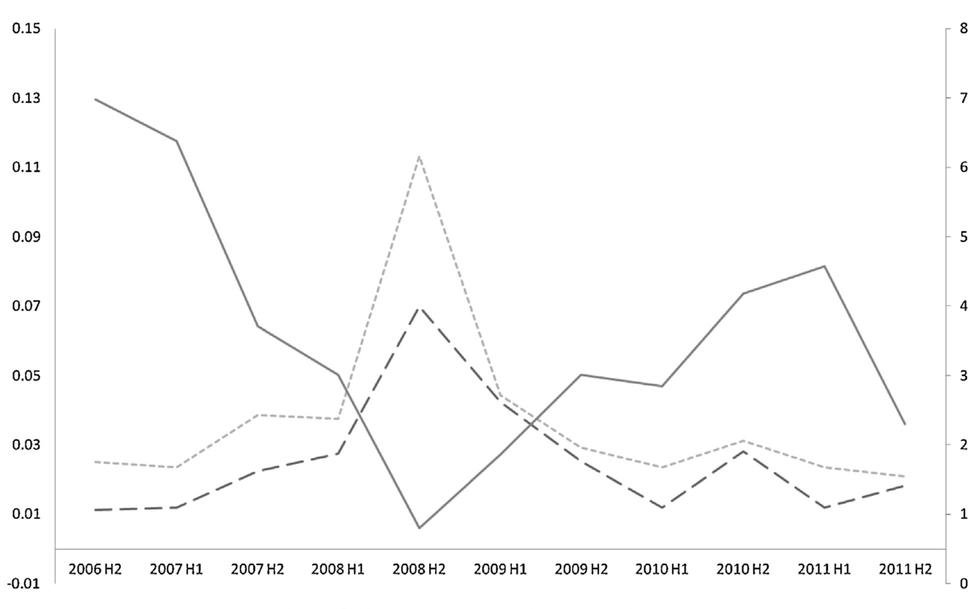


**Fig. 2.** Volatility (lhs%) and distance to default (rhs).

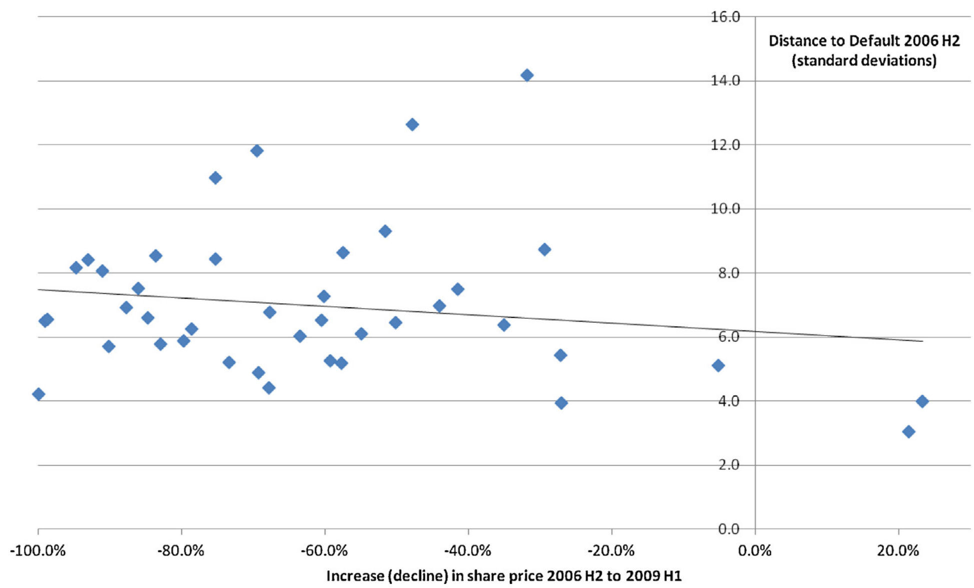


**Fig. 3.** Scatter plot and trend line.

stock markets as a whole, with average share prices of large global banks at less than 30% of their end-2006 values at end 2011 (Fig. 1). Most of this decline had already taken place by end-2008. A modest recovery in bank share prices was reversed with the onset of the periphery Euro-area crisis in early 2010. This decline in share prices has been of a similar magnitude for banks in different regions: the US, the UK and Switzerland and in the Euro area. The share prices of some banks in the rest of the world, notably the three Chinese banks with a large global presence, have performed somewhat better.

Amongst the 41 banks, 11 either failed outright or which were unable to continue without being taken over or receiving very substantial government support. With one exception these were all banks that suffered a 90% or more fall in share price before their situation was resolved.[5]

Fig. 2 presents unweighted sample averages of equity price volatility $\sigma_E$, of computed asset volatility $\sigma_A$, and of distance to default. The changes in $\sigma_A$ over time are largely driven by changes in $\sigma_E$, i.e. during periods of market volatility is when implied underlying asset volatility is also at its highest. This is most noticeable in 2008H2 when the crisis was at its height. Fig. 2 also shows unweighted sample average distance to default. Broadly this behaves in the opposite manner to volatility declining especially fast in 2008H2. However subsequently, from 2009H1 to 2011H2, distance to default rises rather more than might be expected, given the observed behaviour of equity and asset market volatility. The break in this relationship can be explained by the substantial equity capital injections provided to many banks across Europe and in the US.

Distance to default is a potential indicator of future financial distress. Fig. 3 examines this possibility, presenting a scattergram (and associated statistical regression line) comparing the fall in share price from 2006H1 to 2009H1 with distance to default. As this makes clear there was no direct and obvious prediction of vulnerability to the crisis from distance to default prior to the crisis. If anything the relationship between distance to default and share price declines seems to be negative, with banks with a high value of distance to default experiencing a relatively large fall of share price during this period.

For a subset of the banks in this sample – including Fannie Mae, Freddie Mac, Lehman Brothers, Royal Bank of Scotland, UBS – distance to default fell especially sharply between 2006H2 and 2008H1. In the case of Lehman Brothers distance to default was negative by end-June 2008, a little more than two months prior to its eventual failure, while the distance to default of Freddie Mac had fallen to 0.6 standard deviations. At this point market investors were getting a better understanding of the risk exposures of the world's largest banks, and this was reflected in share prices and share price volatility. It appears that, once the crisis had begun, distance to default may have been a useful indicator of those banks at immediate risk of failure.

As well as providing a potential market-based indicator of risk of financial distress, distance to default can also be used to calculate the value provided to shareholders by the presence of the bank safety net. This calculation follows directly from the contingent claims model, according which in the absence of the bank safety net the value of bank equity is:

$$E_{0=A} = A \times N(d_1) - De^{-r(T-t)} \times N(d_2) \quad (5)$$

so the subsidy provided by the bank safety net can be expressed as:

$$E_{0=A} = A \times [N(d_1) - 1] - De^{-r(T-t)} \times [N(d_2) - 1] \quad (6)$$

This expression varies according to whether the put option is out or on-the-money. When distance to default is very large then the put option is out of the money, $N(d_1) \approx N(d_2) \approx 1$ and the additional value created for shareholders by the bank safety net is close to zero. When distance to default is small or negative then the put option is on or in the money and the additional value created for shareholders by the bank safety net is comparatively large.

Table 1 shows the unweighted sample averages of this put option from 2006H2 to 2011H2, expressed as a percentage of bank equity value in 2006H2, for banks in different regions (the reason for expressing as a percentage of beginning of sample value is to screen out large rises in the percentage value of the put option when equity values fall). The table reveals that during most of the

[5] The exception is Halifax: Bank of Scotland also known as HBOS whose share prices seem to have been supported by the generous terms of takeover offered by Lloyds TSB This takeover resulted in the creation of Lloyds Banking Group and the necessity for substantial UK government share purchase to prevent the failure of the combined group.

**Table 1**
Implied value of the "put option" provided by the bank safety net.

| % of 2006 market capitalisation | All banks | US banks | Euro area banks | UK and Swiss banks | Other banks |
|---|---|---|---|---|---|
| 2006H2 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2007H1 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2007H2 | 0.4% | 1.1% | 0.0% | 0.1% | 0.2% |
| 2008H1 | 1.4% | 3.6% | 0.0% | 1.3% | 0.2% |
| 2008H2 | 21.9% | 52.1% | 13.3% | 14.8% | 7.2% |
| 2009H1 | 2.3% | 5.7% | 1.9% | 1.2% | 0.5% |
| 2009H2 | 0.2% | 0.0% | 0.3% | 0.0% | 0.1% |
| 2010H1 | 0.3% | 0.0% | 0.6% | 0.1% | 0.1% |
| 2010H2 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2011H1 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2011H2 | 0.3% | 0.4% | 1.2% | 0.2% | 0.2% |

*Notes*: Unweighted average of put option, calculated from the Merton-Black-Scholes contingent claims model with a one year time horizon to default and expressed as a percentage of 2006H2 market capitalisation. The average is reported for 11 US banks, 17 Euro area banks, 7 UK and Swiss banks and 6 banks in the rest of the world.

sample the average value of the put option is a very small percentage of total equity value. Until 2007H2 the average put value is less than 0.05% of equity value. In 2008H1, when the crisis had intensified, the average value of the put option had only risen to an average of 1.4% of equity value. But by end-year the average value of the put option, for surviving banks, had jumped dramatically to 21.9% of their 2006 equity market valuations. Thereafter, as the crisis subsided, this put value also fell declined sharply to an average of only 2.0% at end 2009H1. Thereafter the value of the put value remains fairly low, with the partial exception of Euro area banks because of the impact of the sovereign and banking problems in the Euro area.

These comparatively low values for the put option reported in Table 1 for most time periods are a direct consequence of the relatively large distances to default reported in Fig. 2. In every period of this sample except 2008H2 the distance to default is two or more standard annual deviations and so the probability of a decline in asset values within a single year remains small. These low values of the put option are calculated using the relatively simple Black-Scholes option pricing framework with a one-year horizon. Alternative modelling assumptions, for example allowing for the possibility of default over a multi-year period or for time varying volatility, could result in higher calculations of the value of the bank safety net. Nonetheless the calculations reported in Table 1 do suggest that in most periods of the sample the volatility of bank equity values is simply too small to be consistent with a very large value for the bank safety net.

A final conclusion that can be drawn, from this summary of the behaviour of distance to default through the crisis period offered is that the standard contingent claims model of bank debt and equity is inconsistent with the Sinn hypothesis that shareholders were encouraging banks to take risks with their own solvency. This is for two distinct reasons.

The high average values of distance to default and low values for the put option (Fig. 2 and Table 1), prior to the crisis, indicating a relatively low perceived benefit to shareholders from 'risk shifting'.

The absence of any obvious association between low distance to default and falling share price (Fig. 3) or subsequent financial distress suggests that the banks which shareholders regarded as higher risk did not in fact turn out to be the banks that performed poorly in the crisis.

The data reviewed here offers little support for the Sinn hypothesis. They are consistent with the alternative hypothesis that shareholders and bank management were over confident, taking high risks not as a deliberate choice but because they did not understand their own exposures, the limitations of their risk models and risk governance, or the extent to which they were exposed to system-wide problems.

## 4. Econometric results

This section reports the results of an investigation of the predictive power of distance to default, for the share prices and failure (or survival) of banks in the crisis. Because of the small sample only simple econometric specifications merit investigation. All estimates are cross-sectional regressions that seek to explain bank performance until 2009H1, either the decline in share price or whether the bank survived or failed. In each case the measure of distance to default is used together with a set of other variables, of the kind adopted in recent investigations of bank failures in the crisis. These additional explanatory variables are:

- *sratio*: a measure of the ratio of short term wholesale funding to total short term and long term debt
- *eratio*: the ratio of book value of equity to total short term and long term debt, i.e. an inverse leverage ratio.
- *bderatio*: this is *eratio* for US broker dealers. It is included because there is no measure of Tier1 capital ratio for these banks and when included in regressions always accompanied by a (1,0) dummy indicating whether a bank is a US broker dealer (i.e. Lehman Brothers, Goldman Sachs, Merrill Lynch, Morgan Stanley) or not.
- *mbratio*: the ratio of the market value of equity to the book value of equity
- *tier1ratio*: the Basel II tier 1 ratio (this is available for all banks in the sample except the four US broker dealers)
- *fsup:* the Fitch IBCA bank support ratio, a judgemental assessment varying from values of 1 (a high likelihood of government providing financial support to a bank) to 5 (a low likelihood of government support). In practice for the 41 banks in this sample *fsup* is more like a dummy variable with only two extreme values, of 5 for all UK and US institutions (with the exception of Fannie and Freddie for which *fsup* = 1), and 1 for all other banks in all other countries (with the sole exceptions of Credit Suisse for which *fsup* = 5 and Intesa San Paulo for which *fsup* = 2 in 2006 before being reduced to 1 in 2007).

The estimation strategy pursued and reported here has been to estimate two regressions:

(a) the first a bivariate regression against distance to default *d2d*
(b) The second a multivariate regression obtained by testing down from a general specification including all the explanatory variables in the data-set. Variables were included only if their *p*-value was less than 10% (with the exception of *d2d* and *tier1ratio*, which because of their central importance as measures of financial risk are always retained).

**Table 2**
Regression results: end-2006 distance to default as a predictor of share price fall 2008–2009.

Dependent variable: ploss (% loss of share price 2006H2 to 2009H1)

| Regression | All banks | | | | | | Excluding Chinese banks | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | | | (2) | | | (3) | | | (4) | | |
| | Coeff | s.e. | *p*. val (%) | Coeff | s.e. | *p*. val (%) | Coeff | s.e. | *p*. val (%) | Coeff | s.e. | *p*. val (%) |
| *d2d* | −0.021 | 0.021 | 39.5 | −0.019 | 0.006 | 5.0 | 0.141 | 0.015 | 41.2 | −0.012 | 0.012 | 40.8 |
| *sratio* | | | | −0.836 | 0.280 | 5.9 | | | | −0.225 | 0.108 | 12.9 |
| *tier1ratio* | | | | 0.087 | 0.029 | 5.8 | | | | 0.011 | 0.010 | 35.2 |
| *eratio* | | | | | | | | | | 3.122 | 0.672 | 1.9 |
| *bderatio* | | | | 8.729 | 1.999 | 2.2 | | | | | | |
| nobs | 41 | | | 41 | | | 38 | | | 38 | | |
| $R^2$ | 0.03 | | | 0.55 | | | 0.02 | | | 0.16 | | |

*Notes and variable definitions*: Linear regression. Standard Errors Cluster adjusted by region (US, Euro, UK/CH, RoW), constant and also (in regression (2)) dummy for the four US broker-dealers are included but not reported. All independent variables are dated 2006H1. *d2d* is distance to default, *sratio* is the ratio of short term wholesale funding to total debt and deposits, *tier1ratio* is the Basel tier 1 capital ratio, *eratio* is the ratio of book equity to total debt and deposits (inverse unweighted leverage), *bderatio* is eratio for the four US broker dealers only. Regressions (2) and (4) are the result of a general to specific elimination of insignificant variables, but retaining *d2d* and *tier1ratio*; the original general equation also included *m2b* the market to book ratio, and *f2sup* the Fitch IBCA bank support ratio.

As a test of robustness *fsup* is included as an additional explanatory variable in both specifications. The reported results include or exclude *fsup* depending on whether it turns out to be significant at the 10% level or not. In addition all regressions were estimated both on the full sample of 41 banks and on a smaller sample of 38 that excluded the three Chinese banks.

Table 2 reports estimated regressions based on information available at the end of 2006H2, i.e. before the onset of the crisis. The dependent variable is the percentage fall in bank share price between end 2006H2 and 2009H1. If the bank failed then the price is the acquisition price – if any – in 2008H2. Regression (1) is the full sample bivariate regression in which *d2d* is the only explanatory variable. This has an unexpected negative sign (indicating, as illustrated in Fig. 2, that banks with higher distance to default before the crisis suffered a larger fall in share price) but is statistically insignificant. Restricting the sample to non-Chinese banks (regression (3)) *d2d* has the anticipated positive sign but again is again statistically insignificant.

Regression (2) reports the outcome, using the same 2006 explanatory data, when testing down from a general regression. Four variables are now significant at the 5% or 10% level: *d2d* with the unanticipated negative sign, *sratio* with the anticipated negative sign (banks that relied more on short term funding suffered greater fall in share price); *tier1ratio* and *bderatio* indicating that banks with a higher Basel II capitalization or (amongst US broker dealers) a higher equity to asset (inverse leverage) ratio suffered a smaller fall in share price. But when the three Chinese banks are excluded from the sample (regression (4)) only the unweighted equity ratio *eratio* is significant, with the anticipated positive sign, at the 2% significance level. These results show that for the major global banks in this sample *d2d* was of no value at all in predicting share price performance during the crisis.

A more direct test of the contingent claims model and the value of *d2d* as a predictor of default comes from estimating logit regressions for bank failure. These are reported in Table 3 (using information available in 2006) and in Table 4 (using information available in 2007H2 and 2008H1). Regression (1) of Table 3 reports the regression in which *d2d*, *fsup* and a constant are the explanatory variables (these bivariate regressions for bank failure using 2006 explanatory data were the only ones where *fsup* proved to be significant, in all other specifications it was insignificant and is dropped from the reported regression results). In this bivariate regression *d2d* is now statistically significant with the anticipated negative sign (higher distance to default means it is less likely that a bank will fail). When this specification is re-estimated excluding the Chinese banks then the results are similar (regression (3) of Table 3).

**Table 3**
Regression results: end-2006 distance to default as a predictor of failure 2008–2009.

Dependent variable: failure dummy (1 = failed or forced acquisition in 2008–2009; 0 otherwise)

| Regression | All banks | | | | | | Excluding Chinese banks | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | | | (2) | | | (3) | | | (4) | | |
| | Coeff | s.e. | *p*. val (%) | Coeff | s.e. | *p*. val (%) | Coeff | s.e. | *p*. val (%) | coeff | s.e. | *p*. val (%) |
| *d2d* | −0.182 | 0.092 | 4.8 | −0.025 | 0.161 | 87.7 | −0.241 | 0.115 | 3.7 | −0.016 | 0.199 | 93.7 |
| *Sratio* | | | | 2.43 | 0.93 | 0.9 | | | | 2.066 | 1.070 | 5.4 |
| *tier1ratio* | | | | −0.166 | 0.112 | 13.8 | | | | −0.146 | 0.127 | 24.9 |
| *fsup* | 0.410 | 0.171 | 1.7 | | | | 0.380 | 0.190 | 4.5 | | | |
| *n-obs* | 41 | | | 41 | | | 38 | | | 38 | | |
| *log-likelihood* | −20.8 | | | −20.7 | | | −19.98 | | | −20.4 | | |

*Notes and variable definitions*: Logit regression. Standard Errors Cluster adjusted by region (US, Euro, UK/CH, RoW), constant is included but not reported. All independent variables are dated 2006H1. *d2d* is distance to default, *sratio* is the ratio of short term wholesale funding to total debt and deposits, *tier1ratio* is the Basel tier 1 capital ratio, *eratio* is the ratio of book equity to total debt and deposits (inverse unweighted leverage), *fsup* is the Fitch-IBCA bank support ratio, for all US and UK banks and US broker-dealers and also Credit-Suisse *fsup* = *5* (implying low level of support), for all other banks *fsup* = 1 or 2 (implying a high level of support). Regressions (2) and (4) are the result of a general to specific elimination of insignificant variables, but retaining *d2d* and *tier1ratio*; the original general equation also included *eratio* the unweighted inverse leverage ratio, *m2b* the market to book ratio and *bderatio* which is eratio for US broker dealers together with an accompanying US broker dealer dummy.

**Table 4**
Regression results: end-2007 and mid-2008 distance to default as a predictor of failure.

| Dependent variable: failure dummy (1 = failed or forced acquisition in 2008–2009; 0 otherwise) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Regression | All banks–2007H2 information | | | | | | All banks–2008H1 information | | | | | |
| | (1) | | | (2) | | | (3) | | | (4) | | |
| | Coeff | s.e. | *p*. val (%) | Coeff | s.e. | *p*. val (%) | Coeff | s.e. | *p*. val (%) | coeff | s.e. | *p*. val (%) |
| *d2d* | −0.525 | 0.470 | 26.3 | −0.559 | 0.492 | 25.6 | −1.374 | 0.352 | 0.00 | −1.414 | 0.688 | 4.0 |
| *sratio* | | | | 7.656 | 1.240 | 0.0 | | | | 7.591 | 2.642 | 0.4 |
| *tier1ratio* | | | | −0.456 | 0.621 | 46.3 | | | | −0.400 | 0.577 | 48.9 |
| *bderatio* | | | | −54.12 | 5.74 | 0.0 | | | | −33.17 | 12.38 | 0.7 |
| *N-obs* | 41 | | | 41 | | | 41 | | | 41 | | |
| *Log-likelihood* | −20.9 | | | −16.4 | | | −16.5 | | | −14.35 | | |

*Notes and variable definitions*: Logit regression. Standard Errors Cluster adjusted by region (US, Euro, UK/CH, RoW), constant and also (in regressions (2) and (4)) dummy for the four US broker-dealers are included but not reported. All independent variables are dated 2007H2 or 2008H1. *d2d* is distance to default, *sratio* is the ratio of short term wholesale funding to total debt and deposits, *tier1ratio* is the Basel tier 1 capital ratio, *bderatio* is eratio for the four US broker dealers only. Regressions (2) and (4) are the result of a general to specific elimination of insignificant variables, but retaining *d2d* and *tier1ratio*; the original general equation also included *eratio* the ratio of book equity to total debt and deposits (inverse unweighted leverage), *m2b* the market to book ratio, and *f2sup* the Fitch-IBCA bank support ratio.

Regression (2) of Table 3 report the results of testing down from a general regression including all the available explanatory variables, again with 2006 explanatory variables. Now a very different picture emerges, *d2d* is no longer a significant predictor of failure in 2008 and instead the short term funding *sratio* is highly statistically significant at the 1% level. The key regulatory ratio, the Basel II Tier 1 capital ratio *teir1ratio* is not significant (although it has the correct sign in the reported regression) and neither are any of the inverse leverage ratios (*eratio, bderatio*) which are both eliminated when testing down. The results are similar when excluding Chinese banks from the sample (regression (4)) although now *sratio* is only significant at just over the 5% level.

Table 4 reports further logit regressions for bank failure, using end-2007 and mid-2008 information. The results when excluding the Chinese banks are very similar and are not reported in this table. When using end-2007 data *d2d* is no longer significant in either the bivariate specification (regression (1)) or the general-to-specific specification (regression (2)). *sratio* and the inverse leverage ratio for US broker dealers *bderatio* are both highly significant (regression (2)). Once again the Tier 1 Basel ratio *tier1ratio* has no predictive value for default.

It is only when using mid-year information for the prediction of bank failure during the second half of 2008 that *d2d* has any significant explanatory power for predicting default. In the bivariate specification it is significant at less than the 0.05% level (regression (3)). In the general-to-specific specification it remains highly significant at the 1% level and the short term funding ratio *sratio* and the inverse leverage ratio for US broker dealers *bderatio* remain highly statistically significant (regression (4)).

## 5. Conclusions

This paper has looked at the role of 'distance to default', a measure of the number of standard deviations underlying assets of a bank are away from default, in the global financial crisis that erupted in 2007. It uses a standard one period contingent claims framework to measure distance to default for the 41 largest global banks over the period 2006H2 to 2011H2 and investigates its association with bank performance during the crisis, both the substantial fall in the share price of most banks (Fig. 1) and the failure of 11 of these 41 global institutions.

Over this period distance to default (Fig. 2) falls in every successive half year through the crisis, from 2007H1 to 2008H2, before recovering, confirming the finding of (Castrén and Kavonius, 2009) that distance to default only provided any indication of problems well after the crisis had begun. These falls are driven in particular by increased equity volatility and, at the later stages of the crisis, by falling market valuations. Despite these falls the value of the protection offered to equity holders by the bank safety net – as measured by the standard contingent claims model with a one year horizon – remains low through most of the crisis (Table 1), rising sharply to above 2 per cent of pre-crisis equity valuations only in the second half of 2008 when the crisis reached its climax, and falling back again once financial markets stabilised in the first half of 2009.

How did distance to default serve as a market-based signal of bank risk? The answer is that it performed poorly. During the crisis share valuations fells very substantially for almost all of the world's largest 41 banks (the exceptions are the three global banks from China) and eleven of these banks failed. Since these share price falls and bank failures are a result of excessive risk exposure and consequent financial distress it might have been thought that the apparently riskiest banks, i.e. those banks with the smallest values of distance default, would have experienced the largest share price falls and have been most likely to fail. Instead it turns out that amongst these 41 banks there is no statistically significant correlation of the expected sign between distance to default prior to the crisis (measured at end 2006) and bank share price performance (Fig. 3 and Table 2) and a weak association with bank failure disappears with the inclusion of other explanatory variables (Table 3). If anything the relationship with share price performance seems to go in the opposite direction to that anticipated, with banks with higher values of distance to default in 2006 having somewhat larger falls in share prices; although this surprising finding is not usually statistically significant when Chinese banks are excluded from the sample.

Even when later information is available, up to end 2007, distance to default does not perform at all well as a predictor of subsequent failure (Table 4). It only begins to be of some value over a very short term horizon, when it is calculated using information available at mid-2008 to predict bank failure by end-year. Even then, consistent with the results of (Ratnovski and Huang, 2009) using a larger sample of global banks, the ratio of short term funding to total assets and the inverse leverage ratio (i.e. book equity divided by total assets) seem to be more important predictors of bank failure. The Basel II tier 1 risk weighted capital ratio is never useful for default prediction.

To conclude, there are several reasons for considering market based measures of risk alongside standard regulatory measures. These include their ease of calculation, the fact that they respond quickly to new information, and most importantly and unlike regulatory ratios, they are not subject to distortion by 'regulatory arbitrage'. But it turns out that the particular market based measure of risk investigated in this paper – distance to default – while attractive on all these grounds, performed if anything rather worse than traditional accounting measures as a predictor of default or financial distress during the crisis.

There is some indication from the results reported here that distance to default can be useful as an indicator of imminent failure. If more attention had been paid to the warning given by the negative value of distance to default at end June 2008, then the authorities might then been able to do a little more to prepare for very difficult circumstances of September and October that year. Still the real lesson from these estimation results is that prediction of bank failure or survival is extremely difficult. This implies that regulation should focus not so much on intervening to prevent failure as on ensuring that it is manageable if and when it does occur.

The results of this paper point to one further conclusion. This finding of a low value to shareholders of the protection provided by the bank safety net, together with the lack of any obvious association between risk as measured by distance to default and subsequent share price falls or bank failure, indicates that the standard contingent-claims model is inconsistent with what is referred to here as the 'Sinn hypothesis'. This is the view, asserted by Sinn (2010), that shareholders in the major global banks were consciously exploiting the bank safety net prior to the global crisis of 2007–2008, in the knowledge that they would be protected from extreme downside losses. The calculations of the value of the safety net reported here are far too small to justify this view and the failure of distance to default as a predictor of bank share price falls or bank failure suggests that bank shareholders were largely unaware of the level of risk to which they were exposed.

Some version of the Sinn hypothesis might yet be rescued, by developing a more sophisticated version of the contingent claims model, for example one allowing for the possibility of default over many periods or for dynamic evolution of asset prices uncertainty. Still, the analysis provided here for the 41 largest global banks, indicates that the data are much more easily explained by the alternative viewpoint, that banks shareholders and management did not understand the risks they were taking. In particular, as suggested by Turner (2009), it suggests that the crisis was so unexpectedly serious because of interconnections amongst firms in the financial system, risk exposures that only became fully apparent at the height of the crisis in the second half of 2008.

## Acknowledgements

I am grateful to comments from Sheri Markose and from an anonymous referee. Remaining errors and omissions are my responsibility alone.

## Appendix A. List of banks

| Name | Failure: 1 = yes, 0 = no |
|---|---|
| Dresdner | 0 |
| Bank Of America Corporation | 0 |
| Bank Of China Limited | 0 |
| Barclays Plc | 0 |
| BBVA | 0 |
| BNP Paribas | 0 |
| China Construction Bank Corporation | 0 |
| Citigroup Inc. | 1 |
| Commerzbank | 0 |
| Credit Agricole | 0 |
| Credit Suisse Group Ltd | 0 |
| Danske Bank | 0 |
| DE Bank | 0 |
| Dexia S.A. | 0 |
| Federal National Mortgage Association (Fannie Mae) | 1 |
| Fortis Bank | 1 |
| Federal Home Loan Mortgage Corporation (Freddie Mac) | 1 |
| The Goldman Sachs Group, Inc. | 0 |
| Halifax Bank Of Scotland | 1 |
| HSBC Holdings Plc | 0 |
| Industrial And Commercial Bank Of China Limited | 0 |
| ING Groep N.V. | 0 |
| Intesa Sanpaolo | 0 |
| JPMorgan Chase & Co. | 0 |
| KBC Groupe S.A. | 0 |
| Lehman Brothers Holdings Inc. | 1 |
| Lloyds Banking Group Plc | 0 |
| Merrill Lynch & Co., Inc. | 1 |
| Mitsubishi UFJ Financial Group, Inc. | 0 |
| Mizuho Financial Group, Inc. | 0 |
| Morgan Stanley | 0 |
| Nordea Bank Ab | 0 |
| Natixis Fr | 1 |
| The Royal Bank Of Scotland Group | 1 |
| Banco Santander | 0 |
| Societe Generale S.A. | 0 |
| Sumitomo Mitsui Financial Group, Inc. | 0 |
| UBS Inc. | 1 |
| Uni Credit | 0 |
| Wachovia Corporation | 1 |
| Wells Fargo & Company | 0 |

## References

Altunbas, Y., Manganelli, S., Marques-Ibanez, D., 2011. Bank Risk during the Financial Crisis: Do Business Models Matter? European Central Bank, Working Paper Series 1394.
Beltratti, A., Stulz, R.M., 2009. Why did some banks perform better during the credit crisis? A cross-country study of the impact of governance and regulation. SSRN Electronic Journal.
Benston, G., 1986. Perspectives on Safe and Sound Banking: Past, Present and Future (MIT Press Series in Artificial Intelligence). MIT Press, Cambridge, MA.
Brunnermeier, M.K., 2009. Deciphering the liquidity and credit crunch 2007–2008. Journal of Economic Perspectives 23, 77–100.
Castrén, O., Kavonius, I., 2009. Balance Sheet Interlinkages and Macro-Financial Risk Analysis in the Euro Area. European Central Bank, Working Paper Series 1124.
Coffinet, J., Pop, A., Tiesset, M., 2010. Predicting Financial Distress in a High-Stress Financial World: The Role of Option Prices as Bank Risk Metrics. Banque de France Working Papers 311.
Crosbie, P., 2000. Modelling default risk. In: Das, S. (Ed.), Credit Derivatives: Trading and Management of Creidt and Default Risk. Wiley, Frontiers of Finance, London, UK, pp. 369–410.
Duan, J.-C., Moreau, A.F., Sealey, C.W., 1992. Fixed-rate deposit insurance and risk-shifting behavior at commercial banks. Journal of Banking and Finance 16, 715–742.
Evanoff, D., Wall, L., 2002. Measures of the riskiness of banking organizations: subordinated debt yields, risk-based capital, and examination ratings. Journal of Banking and Finance 26, 989–1009.
Fahlenbrach, R., Prilmeier, R., Stulz, R., 2011. This Time Is the Same: Using Bank Performance in 1998 to Explain Bank Performance During the Recent Financial Crisis, SSRN eLibrary 1779406.
Flannery, M., 1998. Using market information in prudential bank supervision: a review of the U.S. empirical evidence. Journal of Money, Credit and Banking 30, 273–305.
Gropp, R., Vesala, J., Vulpes, G., 2006. Equity and bond market signals as leading indicators of bank fragility. Journal of Money, Credit, and Banking 38, 399–428.
Harada, K., Ito, T., Takahashi, S., 2010. Is the Distance to Default a Good Measure in Predicting Bank Failures? Case Studies. National Bureau of Economic Research Working Paper 16182.
Hovakimian, A., Kane, E.J., 2000. Effectiveness of capital regulation at U.S. commercial banks, 1985 to 1994. Journal of Finance 55, 451–468.
Keeley, M.C., 1990. Deposit insurance, risk, and market power in banking. American Economic Review 80, 1183–1200.
Marcus, A.J., 1984. Deregulation and bank financial policy. Journal of Banking and Finance 8, 557–565.
Marcus, A.J., Shaked, I., 1984. The valuation of FDIC deposit insurance using option-pricing estimates. Journal of Money, Credit and Banking 16, 446–460.
Merton, R.C., 1974. On the pricing of corporate debt: the risk structure of interest rates. Journal of Finance 29, 449–470.
Merton, R.C., 1977. An analytic derivation of the cost of deposit insurance and loan guarantees. An application of modern option pricing theory. Journal of Banking and Finance 1, 3–11.

Milne, A., Whalley, A.E., 2002. Bank Capital and Incentives for Risk Taking, SSRN eLibrary 299319.
Milne, A., 2009. The Fall of the House of Credit. Cambridge University Press, Cambridge, UK.
Pennacchi, G.G., 1987. A reexamination of the over- (or under-) pricing of deposit insurance. Journal of Money, Credit and Banking 19, 340–360 (CR – Copyright © 1987 Ohio State Univ.).
Demsetz, R.M.S., Strahan, P., 1996. Banks with something to lose: the disciplinary role of franchise value. Federal Reserve Bank of New York Economic Review, 1–14.
Ratnovski, L., Huang, R., 2009. Why Are Canadian Banks More Resilient?, IMF Working Paper WP/09/152.
Ronn, E.I., Verma, A.K., 1986. Pricing risk-adjusted deposit insurance: an option-based model. Journal of Finance 41, 871–895.
Sinn, H.-W., 2010. Casino Capitalism: How the Financial Crisis Came About and What Needs to be Done Now. Oxford University Press (Google eBook).
Turner, A., 2009. The Turner Review: A Regulatory Response to the Global Banking Crisis. The Financial Services Authority, Canary Wharf, London.
White, L.J., 1991. S. & L. Debacle: Public Policy Lessons for Bank and Thrift Regulation. Oxford University Press, Inc., Oxford, UK.