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Size, leverage, and risk-taking of financial institutions

Sanjai Bhagat [a,*], Brian Bolton [b], Jun Lu [c]

[a] University of Colorado at Boulder, United States
[b] Portland State University, United States
[c] Central University of Finance and Economics, Beijing, China

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ABSTRACT

We investigate the link between firm size and risk-taking among financial institutions during the period of 2002 to 2012 and find size is positively correlated with risk-taking measures. Second, a decomposition of the primary risk measure, the Z-score, reveals that financial firms engage in excessive risk-taking mainly through increased leverage. Third, banks that enjoy better corporate governance engage in less risk-taking. Fourth, investment banks engage in more risk-taking compared to commercial banks. Finally, the positive relation between bank size and risk is present in the pre-crisis period (2002–2006) and the crisis period (2007–2009), but not in the post-crisis period (2010–2012).

> "Too-big-to-fail policies offer systemically important firms the explicit or implicit promise of a bailout when things go wrong. These policies are destructive, for several reasons. First, because the possibility of a bailout means a firm's stakeholders claim all the profits but only some of the losses, financial firms that might receive government support have an incentive to take extra risk. The firm's shareholders, creditors, employees, and management all share the temptation. The result is an increase in the risks borne by society as a whole." – French et al. (2010), The Squam Lake Report.

> "But giant banks, operating on the belief that they are backed by government, turn these otherwise manageable episodes into catastrophes. Is there a better alternative? Yes, reducing the size and complexity of the largest banks." – Richard Fisher, President and CEO of the Federal Reserve Bank of Dallas.

1. Introduction

Are large banks riskier? Some argue that governments have to bail out a large failing financial institution because its failure may present a threat to the proper functioning of the financial intermediation process and cause severe disruption to the economy.[1] When firms are perceived to be too big to fail (TBTF), they have a propensity to assume excessive risks to profit in the short term. Indeed, TBTF policy has been blamed by many as one of the main factors causing distortion in financial firms' risk-taking incentives; for example, see Boyd et al. (2009).

In turn, researchers and policymakers have proposed an array of regulations. Limiting the size of financial institutions is a frequent suggestion.[2] On the other hand, many concerns are associated with this proposed reform to limit bank size. First, it is difficult to determine the correct size threshold. Second, this simple size metric will miss many small firms that perform critical payment processing and pose significant systemic risk, even if the first issue can be solved (see, Stern and Feldman (2009)). In addition, opponents of such a proposal often cite the literature on scale economies; they are concerned such

* Corresponding author. Tel.: +1 303 492 7821.
E-mail address: Sanjai.bhagat@colorado.edu (S. Bhagat).

[1] For example, see the recent book by former Treasury Secretary, Timothy Geithner (2014).

[2] For example, the SAFE Banking Act of 2012 was introduced in the U.S. Senate on May 9, 2012. Among other restrictions, it proposes a strict 10% cap on any bank's share of the total amount of deposits of all insured banks in the U.S., and a limit of 2% of the U.S. GDP of the non-deposit liabilities of a bank holding company. The SAFE Banking Act was not enacted, however.

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restraint could weaken the global competitiveness of the U.S. financial firms and cause loss of market share. Further, Dermine and Schoenmaker (2010) argue that capping the size is not the best tool, based on the finding that countries with relatively small banks faced large bailout costs; in addition, they caution that capping the size can have unintended effects, such as lack of credit risk diversification.

Is size the problem? This paper sheds light on the issue by studying the size effect on the risk-taking of U.S.-based financial institutions, including commercial banks, investment banks and life insurance companies. Using data on the size and risk-taking of financial institutions from 2002 to 2012, we investigate whether cross-sectional variation in the size of firms is related to risk-taking. Our measures of risk-taking are comprehensive. They include two model-based measures (namely, the *Z-score*, and Merton's Distance to Default (Merton DD)), a market-based measure (volatility of stock returns), and an accounting-based measure (write-downs). We focus primarily on *Z-score* and Merton DD; the other risk measures serve as robustness checks.

If size does affect risk-taking as measured by *Z-score*, then an interesting question is how does size affect the components of *Z-score*? Focusing on the components of *Z-score* – namely, leverage, return on assets, and volatility of earnings – allows policymakers to target the risk-taking problem of financial institutions more directly.

We establish the following findings. First, firm size is positively correlated with risk-taking, even when controlling for observable firm characteristics such as market-to-book ratio and corporate governance structure. The relationship between bank size and risk is plagued by endogeneity concerns. Banks are more likely to pursue riskier activities (even if they are negative net present value) as they get bigger because of TBTF regulatory bias and the increasing likelihood of a government bailout if things go bad; however, it is also possible that risky banks strive to grow in size to obtain TBTF status; for example, see Brewer III and Jagtiani (2009), and Molyneux et al. (2010). It is unclear whether large banks undertake riskier activities, or whether an omitted variable impacts both risk and size. To account for this, we adopt an instrumental variables approach. We consider three instruments for bank size: the bank's number of employees, the bank's net plant, property and equipment (PP&E), and an indicator variable for whether a firm is incorporated in Delaware. We utilize a battery of robustness tests to verify the validity and strength of our instruments.

Our second finding: the decomposition of *Z-score* reveals that firm size has a consistent and significant negative impact on the capital asset ratio; we do not find a consistent relation between firm size and return on assets or earnings volatility. These findings suggest that financial firms engage in excessive risk-taking mainly through increased leverage. On the other hand, they also suggest that economies of scale do not exist for banks. Regressions with volatility of stock return as the dependent variable indicate that size-related diversification may not exist in the financial sector since size is positively associated with return volatility.

Third, we find that Bhagat and Bolton's (2008) newly developed corporate governance measure, calculated as median director dollar stockholding, is negatively associated with risk-taking. This has important policy implications, to wit, policy-makers interested in discouraging banks from engaging in excessive risk should focus on bank director compensation and stock ownership.

Fourth, we find that investment banks, but not insurance companies, engage in more risk-taking compared to commercial banks. Finally, we document that the positive relation between bank size and risk is present in the pre-crisis period (2002–2006) and the crisis period (2007–2009), but not in the post-crisis period (2010–2012). Perhaps the intense scrutiny put on bank risk-taking by the bank regulators, senior policy-makers, and the media in the post-crisis period may have curbed the appetite and ability of large banks to engage in high-risk investments.

Our analysis is critical from a public policy perspective because the risk-taking behavior of financial institutions affects financial and economic fragility, as well as economic growth – see Bernanke (1983), Calomiris and Mason (1997, 2003a, 2003b), and Keely (1990). Our findings have important policy implications that are particularly relevant today, as the calls for tougher restrictions and reinforcement of corporate governance on the financial sector accelerate. First, they suggest that instead of just limiting firm size, it may be more effective for regulators to strengthen and enhance regulations on equity capital requirements for all financial institutions. This suggestion regarding increased bank equity capital requirements is consistent with the recent recommendations of Admati and Hellwig (2013), Bhagat and Bolton (2014), and Fama (2010). Also, in recent op-eds, the *Wall Street Journal* has recommended significantly higher equity capital requirements for banks. Second, our finding on corporate governance indicates that median director dollar stockholding can be used as an effective internal corporate risk control mechanism.

The paper is organized as follows. In the next section we briefly review the extant literature. Section 3 describes the data. Section 4 presents core results. The final section concludes with policy implications.

2. Literature review

While there is a substantial literature that examines the risk-taking behavior of financial institutions (see Saunders et al., 1990; Demsetz and Strahan, 1997; Stiroh, 2006; Laeven and Levine, 2009; Houston et al., 2010; Demirguc-Kunt and Huizinga, 2011)), to our knowledge, we are the first to focus exclusively on the relation between size and risk-taking of financial institutions (see Table 1 for a summary of other studies). While Boyd and Runkle (1993) is the closest to this study, there are significant differences. First, the scope of their study is limited by focusing on only large bank holding companies (BHCs), while our sample includes commercial banks, investment banks and insurance companies which have a larger variation in size. We argue that, since the recent financial crisis was not caused by BHCs alone, excluding non-BHCs will not provide a complete picture about risk-taking in the financial industry. Second, Boyd and Runkle (1993) is a univariate analysis between size and risk. We consider covariates which, in theory, might affect bank risk-taking. Another paper which is close to ours is Demsetz and Strahan (1997) who focus on BHC diversification and size. They conclude that BHC size-related diversification does not translate into reductions in risk since size is uncorrelated or positively correlated with stock return variance in many years of their sample period. In their regression analysis, however, they find that firm size has a significant effect in reducing firm-specific risk for their sample period (1980–1993).

The recent financial crisis has generated tremendous interest in the study of risk-taking of financial institutions. Laeven and Levine (2009) consider a sample of the largest 270 banks in 48 countries. They find a significant positive relation between the cash flow rights of the largest shareholder of the bank and bank risk measured as *Z-score*. They also document a positive relation between bank size and bank risk. Beltratti and Stulz (2012) exploit variation in the cross-section of performance of 164 large banks (defined as banks with total assets greater than $50 billion) across the world during the period of the financial turmoil (2007–2008). They document that smaller banks with concentrated ownership and more non-interest income are associated with higher idiosyncratic risk. Consistent with our results, they document a negative relation between bank size and *Z-score*. However, their relation is statistically not significant – possibly due to the limited cross-sectional variation in their bank size measure since they only consider banks

Table 1
Comparison with extant literature.

Study	Sample period & size	Data source & screens	Dependent variable (Risk)	Firm size	Sign of risk and size relation	Variable of interest	Other independent variables
Saunders et al. (1990)	1978–1985 38	Call Report Bank holding company only	Standard deviation of daily stock return	Total Assets	+	Insider ownership	Insider ownership Capital asset ratio Operating leverage
Boyd and Runkle (1993)	1971–1990 122	Annual COMPUSTAT data Bank holding company only Total asset > $1 billion Require 5 consecutive years	Z-score Standard deviation of ROA Equity to assets ratio	Log of Total Assets	–	Size	
Demsetz and Strahan (1997)	1980–1993 134	Bank holding companies only Y-9C Report & CRSP Trading weeks > 30	Firm-specific risk ($\sigma(\varepsilon)$)	Log of Total Assets	–	Size	Capital asset ratio squared Loan characteristics
De Nicolo (2000)	1988–1998 419	Worldscope Bank holding company only Require at least 3 year data	Z-score Volatility of ROA Equity to assets ratio ROA	Log of Total Assets	–	Size	Asset growth rate
Boyd et al. (2006)	June, 2003 2500	Small banks Operate only in rural non-Metropolitan Statistical Areas	Z-score Equity to assets ratio	Log of Total Assets	–	Bank competition	Bank Competition Country controls
Stiroh (2006)	1997–2004 400	Y-9C Bank holding companies only	Standard deviation of weekly stock return	Log of Total Assets	–		Log of equity asset ratio Loan & income controls
Laeven and Levine (2009)	1996–2001 270	BankScope & Bankers Almanac 10 largest public banks in each country	Z-score	Log of Total Assets	–	Cash flow rights	Country controls
Houston et al. (2010)	2000–2007 2400	BankScope Banks only Cross-country study	Z-score ROA Capital asset ratio Volatility of ROA	Log of Total Assets and TBTF dummy	–	Creditor rights	Log of Total Assets square Country controls
This paper	2002–2012 7095	Compustat & Proxy statement Commercial bank, investment bank and insurance	Z-score, Merton Distance to Default Volatility of stock return Write-downs	Log of Total Assets	–	Size Corporate governance	Market to book CEO ownership

greater than $50 billion in assets. Berger and Bouwman (2013) consider a comprehensive sample of U.S. banks during 1984–2010 and document a positive relation between bank size and bank credit risk (defined as the bank's Basel I risk-weighted assets divided by total assets). Based on a U.S. sample of financial institutions, Cheng et al. (2010) investigate whether compensation structure contributes to excessive risk-taking. They find that risk-taking, measured as firm beta and return volatility, is correlated with short-term pay such as options and bonuses. Bolton et al. (2010) propose addressing the excessive risk-taking by tying executive compensation to both stock and debt prices. Baker and McArthur (2009) estimate that the gap of funding costs between small and TBTF firms averaged 0.29 percentage points in the period 2000 through 2007, and that this gap widened to an average of 0.78 percentage points from 2008 through 2009. Rime (2005) finds that the TBTF status has a significant positive impact on bank issuer ratings. Lastly, using an international sample of banks, Demirguc-Kunt and Huizinga (2011) find that systemically large banks achieve lower profitability and without a clear impact on risk. Their results suggest that it is not in the bank shareholders' interests but that it is in managers' interests (via higher pay and status) for a bank to become large relative to its national economy.

The role of corporate governance in coping with risk is not obvious. Standard theory on corporate governance predicts that firms with better governance increase firm value by adopting projects with positive net present value (NPV). However, it does not preclude the possibility of the firm investing in projects with risky cash flows. Therefore, it might be in the interest of shareholders to take risky projects as long as they are value-enhancing. In addition, option theory (Black and Scholes, 1973; Merton, 1974) suggests that, all else being equal, the value of an option increases with volatility of the underlying asset.[3] Since a company's shareholders are essentially holding a call option with the total value of the company as the underlying asset, and the face value of debt as the exercise price, it follows that the more volatile the company's cash flow is, the more valuable the call option. Thus, the value of common stock increases with the volatility of the company's cash flow. Based on these arguments, we might expect a positive association between effective corporate governance and risk-taking.

This relation, however, can go in the opposite direction. As Rajan (2006) and Diamond and Rajan (2009) point out, the compensation structure is different in the finance industry in that the performance of CEOs is evaluated based in part on the earnings the CEOs generate relative to their peers. With this pressure, executives have incentives to take excessive risk to profit in the short run even if they are not truly value-maximizing. As noted in Diamond and Rajan (2009), "even if managers recognize that this type of strategy is not truly value-creating, a desire to pump up their stock prices and their personal reputations may nevertheless make it the most attractive option for them" (p.607). If this argument is correct, we would expect financial institutions with better governance to set incentives and controls to avoid taking risks that do not benefit shareholders. Thus, we should see a negative relation between effective corporate governance and risk-taking. Because of these two countervailing arguments, the impact of corporate governance on risk-taking in the financial industry remains an empirical question. To the extent there is a negative relation between good corporate governance and bank-risk, this would be an important tool for policy-makers to focus on.

[3] Flannery (2014) and Pennacchi (1987a, 1987b) argue that adequacy of bank capital depends on both portfolio risk and the period of time for which that bank capital must protect liability-holders from loss.

3. Sample and variable construction

Our main sources of data are Compustat, the Center for Research in Security Prices (CRSP), RiskMetrics, and Bloomberg, supplemented by hand-collected data from companies' SEC filings on EDGAR. We define the financial industry as all financial institutions consisting of commercial banks, investment banks, and life insurance companies, as classified by their 4-digit standard industrial classification (SIC). Specifically, firms with the 4-digit SIC codes of 6020, 6211 and 6311 are identified as commercial banks, investment banks and life insurance companies, respectively; this classification is similar to Cheng et al. (2010). We use this narrower classification on the grounds that it greatly reduces unobservable heterogeneity among firms within each category, thus it alleviates omitted variable bias and enhances comparability.

The starting point for the sample selection is Compustat, where we collect annual accounting data on all U.S. commercial banks, investment banks and life insurance companies. Our sample spans the period 2002 to 2012. Following Boyd and Runkle (1993) and John et al. (2008), we require that firms have at least five consecutive years of data on key accounting variables over the period to be included in the sample. This process yields an initial sample of 702 unique financial institutions or an unbalanced panel of 6277 firm-year observations, comprising 599 commercial banks, 60 investment banks, and 43 life insurance companies. In our sample, insurance companies include firms such as AIG, Prudential Financial, and Lincoln National Corp, while investment banks include firms such as Bear Stearns, Lehman Brothers, and Goldman Sachs.

We utilize a stratified sampling process to avoid selection bias when dealing with governance and CEO ownership data. The governance data are available through RiskMetrics and the CEO ownership data are available through RiskMetrics and Compustat's Execucomp. However, RiskMetrics only provides data for S&P 1500 companies, which includes around 10% of financial firms; Execucomp covers slightly more, but still not nearly all of our sample financial institutions. Due to this, we took a random sample of 250 commercial banks (from the full sample of 599 commercial banks), plus all of the 60 investment banks and 43 life insurance companies from those available in Compustat. From this sample, we hand-collected data on governance and ownership from companies' proxy statement for firms that are not covered by RiskMetrics and Execucomp. The advantage of this stratified sampling process is that it avoids the problem of selection bias on observables (specifically, firm size) since firms in the S&P 1500 are, by definition, relatively large, whereas the Compustat database that we begin with includes financial institutions of all sizes.

3.1. Definition of variables

3.1.1. Risk-taking

One of our two primary measures for firm risk-taking is the *Z-score*, which equals the average return on assets (ROA) plus the capital asset ratio (CAR), divided by the standard deviation of asset returns (σ(ROA)):

$$\textit{Z-score} = \frac{(\mathrm{ROA} + \mathrm{CAR})}{\sigma(\mathrm{ROA})}$$

Following Laeven and Levine (2009), and Houston et al. (2010), we calculate CAR as total assets minus total liabilities, divided by total assets. *Z-score* has been widely used in the recent literature as a measure of bank risk. The *Z-score* measures the distance from insolvency. A higher value of *Z-score* indicates less risk-taking. Since the *Z-score* is highly skewed, we follow Laeven and Levine (2009) and Houston et al. (2010), and use the natural logarithm of the *Z-score* as the risk measure. In calculating *Z-score*, annual values of ROA and CAR are used and σ(ROA) is the standard deviation of annual ROA calculated over the preceding five year period for each firm-year observation. For more on *Z-score* as a measure of risk-taking, see Boyd and Runkle (1993), Boyd et al. (2006) or Beltratti and Stulz (2012).

Our second measure of risk-taking is Merton distance to default (Merton DD) with a high value indicating less risk-taking. Merton DD has been used in the literature to forecast bankruptcy. Merton DD builds on Merton (1974) where firm equity is modeled as a call option on the underlying value of the firm with an exercise price equal to the face value of the firm's liabilities.[4] Similar to *Z-score* as a measure of risk-taking, the Merton DD measure also attempts to gauge the probability that a firm will go bankrupt over the forecasting horizon. Unlike *Z-score*, which is based solely on accounting information, the Merton DD measure is based on market and accounting data. We follow the iterative procedure described in Bharath and Shumway (2008) to calculate the value of the monthly distance to default for each firm in our sample and then aggregate them into yearly DD by taking a simple average of the monthly DD value. For more on Merton DD as a measure of risk-taking, see Duffie et al. (2007), and Bharath and Shumway (2008).

While Merton DD has been used as a measure of risk-taking in general, there is a growing literature that successfully employs Merton-like models, or more generally structural credit risk models, in quantifying bank risk. There are a number of examples of this approach in the recent literature. Anginer and Demirguc-Kunt (2014) apply the Merton (1974) contingent claim model to measure default risk and credit-risk co-dependence for a sample of banks in over 65 countries. Calice et al. (2012) use the Merton model in examining the relationship between the volatility in the credit default swap markets and valuation of the assets of 16 large complex financial instituions. Chen et al. (2014) incorporate Merton's idea to construct a lattice-based multi-period structural credit risk model to analyze default risk. Lastly, Jessen and Lando (2015) demonstrate the robustness of Merton distance-to-default (as a measure of default risk) to model misspecifications.

As a robustness check, we consider additional risk-taking measures including standard deviation of stock returns and accounting write-downs.[5] The standard deviation of stock returns indicates the market's perception about firms' risk-taking and the accounting write-downs reflect ex-post realization of the firms' tail risk. For equity volatility, we use the standard deviation of daily stock returns within each sample year. For write-downs for each firm, we follow Vyas (2011) and define write-downs as the net credit losses recognized by financial institutions through accounting treatments, which include fair value adjustments, impairment charges, loan loss provisions, and charge-offs during 2007 and 2008.

3.1.2. Firm size

The potential candidates for measuring firm size include accounting-based measures such as total assets and total revenue, and market based measures such as market capitalization. Following the existing literature, we focus primarily on total assets and use total revenue as a robustness check. We consider bank size as a continuous variable. We considered a binary dummy variable for too big to fail banks. However, correctly identifying the size threshold when a financial institution becomes too big to fail is not obvious especially over our entire sample period that includes an expansion and a recession. More importantly, as we show later in the paper, although we do observe a positive association between firm size and risk-taking, this relation is driven not only by size per se but also by the unusually high leverage of the larger banks. This suggests that regulations designed to rein in the risk-taking of financial firms should focus more on capital requirements, rather than on bank size alone.

3.1.3. Corporate governance

We employ a new measure of corporate governance, the median director dollar stockholding, developed by Bhagat and Bolton (2008). This variable is motivated by the idea that directors, as economic agents, will be more likely to fulfill their monitoring and advising duties when they have 'skin in the game' (that is, holding stocks of the companies where they serve on the board). This is consistent with the industry practice that many firms either require or encourage directors to own certain number of shares in the company (for example, non-employee directors at Nike are required to own Nike stock valued at five times their annual cash retainer – which was around $100,000 in 2013 – or more while they are on the Nike board[6]). Therefore, the functioning of corporate boards will be affected by directors' stock ownership. This variable could potentially be a measure of overall good governance because it is the corporate boards that ultimately make, or at least, approve all important corporate decisions, which ultimately affect firm performance. The most significant advantage of this governance measure over other commonly used governance measures such as the G-index (Gompers et al. (2003)), and the E-index (Bebchuk et al. (2009)), comes from its simplicity, and, thus, it is less susceptible to measurement errors (Bhagat et al. (2008)). Constructing governance indices inevitably involves measuring and summing up a multitude of governance attributes such as governance processes, compensation structure, and charter provisions – and thereby ascribing weights to the various governance factors in the index. If the weights assigned to each of these attributes are not consistent with those used by informed market participants, then incorrect inferences would be drawn regarding the relationship between governance and performance.

Bhagat and Bolton (2008) consider the dollar value of stock ownership of the median director as the measure of stock ownership of (non-employee) board members. Their focus on the median director's ownership, instead of the average ownership, is motivated by the political economy literature on the median voter; see Murphy and Shleifer (2004), and Milanovic (2004). Also, directors, as economic agents, are more likely to focus on the impact on the dollar value of their holdings in the company rather than on the percentage ownership. As mentioned earlier, RiskMetrics provides limited data on financial firms (177 out of 702 firms), so we supplement it by hand-collecting director ownership information from proxy statements.[7]

3.1.4. CEO ownership

Risk-averse managers are inclined to take on less than optimal firm risk in order to protect their firm-specific human capital because their employment income is usually tied to changes in firm value. This is an agency problem, in essence, as described in Jensen and Meckling (1976), Amihud and Lev (1981), and Smith and Stulz (1985). However, stock-ownership by managers may be used to

[4] Merton (1974) builds on the Black and Scholes (1973) option pricing model to value corporate bonds. Another area where Merton (1974) framework is widely applied is the pricing of deposit insurance; see Merton (1977), Pennacchi (1987a,b), and Ronn and Verma (1986).

[5] See Chesney et al. (2010) for a discussion of the rationale underlying this risk-taking variable.

[6] See Nike, Inc.'s 2013 DEF 14A proxy statement for details.

[7] As a robustness check, we consider alternative measures of corporate governance, such as the G-index (Gompers et al. (2003)), and the E-index (Bebchuk et al. (2009)) in our analysis. Governance, as measured by these indices, is not related to firm risk-taking; the relationships between all other explanatory variables and risk-taking are qualitatively similar to our main results and are available from the authors upon request.

Table 2
Summary statistics.

	Number of Observations	Mean	Median	Standard Deviation
Z-score	7095	46.36	32.98	49.73
Merton Distance-to-Default	4756	4.46	3.59	3.81
Naïve Distance-to-Default	4756	3.72	3.86	4.41
Probability-of-Default (Merton)	4756	10.98%	0.01%	26.47%
σ(RET)	5599	0.48	0.35	0.31
Total Assets	7095	33,605	1572	174,486
Total Revenue	7095	3531	101	13,268
ROA	7095	1.07%	0.79%	3.07%
CAR	7095	13.81%	10.57%	14.05%
σ(ROA)	7095	1.15%	0.37%	1.95%
Tier 1 Capital Ratio	5344	11.94%	11.18%	3.59%
Market-to-Book	7002	1.08	1.00	0.29
Director Ownership ($000)	1622	1759	841	3317
CEO Ownership (%)	2205	2.30%	1.01%	3.56%
Firm Age	7095	16.61	13.00	10.44

This table reports summary statistics of the main variables for U.S. financial institutions during the period 2002–2012. See Section 3 for sample construction. *Z-score* is firm's return on assets plus the capital asset ratio divided by the standard deviation of return on assets. *Merton Distance-to-Default* is the Merton-KMV Distance-to-Default measure of credit risk. *Naïve Distance-to-Default* is the distance to default measure from Bharath and Shumway (2008). *Probability-of-Default (Merton)* is the estimated probability of default using the *Merton Distance-to-Default* variable and a cumulative normal distribution. *σ(RET)* is the standard deviation of daily stock returns for each firm-year. *Total Assets* is the book value of total assets in millions. *ROA* is the return on assets, or net income divided by total assets. *CAR* is the capital-to-asset ratio, or total equity divided by total assets. *σ(ROA)* is the volatility of the firm's return on assets (net income divided by total assets), calculated over the previous 5 years. *Tier 1 Capital Ratio* is the ratio of tier 1 capital to assets. *Director Ownership* is the median dollar value of stock owned by the members of the board of directors, in thousands of dollars. *CEO ownership* is percentage of stock owned by the CEO in each firm-year. *Firm Age* is the calculated based on when the firm first appears in the CRSP monthly stock returns database. Mean and median values are given, along with the standard deviations of each variable.

induce them to act in a manner that is consistent with the interest of shareholders. Thus, we expect to see a positive relation between CEO ownership and risk-taking. Researchers have documented the impact of ownership structure on firm risk-taking. For instance, in analyzing nonfinancial firms, Agrawal and Mandelker (1987) find a positive relation between stock holdings of managers and the changes in firm variance, while John et al. (2008) find that managers enjoying large private benefits of control select suboptimally conservative investment strategies. Saunders et al. (1990) find that stockholder controlled banks exhibit higher risk-taking behavior than manager controlled banks. Demsetz et al. (1997) document that the significant relationship between ownership structure and risk-taking exists only at low franchise value banks. Laeven and Levine (2009) find that bank risk is generally higher in banks that have controlling shareholders. We use CEO ownership percentage as our measure for bank ownership structure. Like the governance variable, we hand-collect CEO ownership data from companies' proxy statements in addition to the data provided by RiskMetrics and Execucomp for firms that are not covered by those two sources.

3.1.5. Market-to-book ratio and age

Market-to-book value ratio, has been identified as an important risk factor in the asset pricing literature. For instance, Fama and French (1992) point out that firms with high ratios of book-to-market value (or low market-to-book) are more likely to be in financial distress. We compute this variable by dividing the market value of equity by the book value of equity for each firm and year.

In the banking literature, market-to-book value ratio has often been used as a proxy for bank charter value; see Demsetz et al. (1997) and Goyal (2005). A charter has value because of barriers to entry into the industry and usually it is defined as the discounted stream of future profits that a bank is expected to earn from its access to protected markets. Since loss of charter imposes substantial costs, it is argued that charter value can incentivize banks to adopt prudent decision-making; see Keely (1990) and Carletti and Hartmann (2003). Empirical models of bank risk have focused on this disciplinary role of charter value. Based on a sample of 367 bank holding companies from 1991–1995, Demsetz et al. (1997) found that charter value is negatively associated with bank risk-taking. Galloway et al. (1997) also found that banks with low charter value assumed significantly more risk.

Finally, we use firm age to control for firm experience, and we expect that more experienced firms are better at handling risk than less experienced firms.

3.1.6. Financial institution and financial crisis specific variables

We include three indicator variables to capture the unique characteristics of both different types of financial institutions and the unique characteristics of our 2002–2012 time period. We use an Investment Bank indicator if the firm is an investment bank to capture how a non-depository institution might differ from a commercial bank. We use an Insurance Company indicator if the firm is an insurance company to capture the restrictions imposed by insurance regulations. And, we use a Financial Crisis indicator if the observation occurred during 2007–2009 to capture the uniqueness of this three-year period.

3.2. Summary statistics

Table 2 presents the summary statistics for all key variables. The variable definitions and the data sources are described in Appendix A. The *Z-score* has a mean of 46.4 and a standard deviation of 49.7. This fairly high standard deviation and the wide range in *Z-scores* suggest a considerable cross-sectional variation in the level of firm risk. Consistent with Laeven and Levine (2009) and Houston et al. (2010), our *Z-score* measure is right-skewed and we use the log of *Z-score* in our analysis which is more normally distributed. Our sample statistics of the Probability-of-Default (Merton) are consistent with reported sample statistics in Bharath and Shumway (2008). Table 3 presents the correlation among the key variables. As expected, all three risk measures (*Z-score*, Merton DD, and equity volatility) are highly correlated.

4. Empirical results

4.1. Baseline regression

Our primary measures of risk-taking (*Bank Risk*) are *Z-score* and Merton DD with a higher *Z-score* and a higher Merton DD

Table 3
Correlation coefficients. Pearson below the diagonal; Spearman nonparametric above the diagonal.

	Z-score	Merton Distance-to-Default	Naïve Distance-to-Default	Probability-of-Default (Merton)	σ(RET)	Total Assets	Total Revenue	ROA	CAR	σ(ROA)	Tier 1 Capital Ratio	Market-to-Book	Director Ownership ($000)	CEO Ownership (%)	Firm Age
Z-score	–	0.500	0.554	−0.320	0.567	0.061	0.050	−0.256	0.005	0.553	0.107	0.012	−0.214	0.033	0.064
Merton Distance-to-Default	0.542	–	0.873	−0.914	0.680	−0.044	−0.034	−0.485	−0.329	0.087	0.241	−0.334	−0.081	−0.083	−0.053
Naïve Distance-to-Default	0.424	0.950	–	−0.806	0.773	−0.051	−0.046	−0.583	−0.334	0.080	0.223	−0.326	−0.070	−0.086	−0.042
Probability-of-Default (Merton)	−0.260	−0.945	−0.844	–	−0.768	0.042	0.037	0.629	0.382	−0.059	−0.197	0.174	0.083	0.058	0.050
σ(RET)	0.554	0.702	0.703	−0.371	–	−0.112	−0.087	−0.378	−0.137	0.211	0.036	−0.150	−0.057	−0.019	−0.052
Total Assets	0.071	−0.051	−0.060	0.066	−0.113	–	0.772	0.004	−0.033	−0.031	0.241	−0.052	0.087	−0.247	0.599
Total Revenue	0.054	−0.054	−0.043	0.029	−0.092	0.789	–	0.004	−0.027	−0.034	0.187	−0.056	0.094	−0.252	0.526
ROA	−0.220	−0.507	−0.502	0.620	−0.384	0.004	0.004	–	0.618	0.188	−0.016	0.796	0.139	0.160	0.075
CAR	0.006	−0.377	−0.389	0.373	−0.126	−0.028	−0.022	0.721	–	0.523	−0.084	0.566	0.001	0.077	0.053
σ(ROA)	0.538	0.082	0.066	−0.076	0.247	−0.030	−0.035	0.190	0.499	–	0.038	0.356	−0.104	0.047	0.014
Tier 1 Capital Ratio	0.087	0.270	0.317	−0.367	0.033	0.280	0.229	−0.016	−0.096	0.043	–	0.011	0.246	−0.005	0.110
Market-to-Book	0.015	−0.302	−0.227	0.247	−0.140	−0.048	−0.059	0.768	0.560	0.397	0.010	–	0.210	0.156	0.054
Director Ownership ($000)	−0.211	−0.092	−0.092	0.078	−0.047	0.081	0.069	0.139	0.001	−0.123	0.207	0.210	–	0.098	−0.070
CEO Ownership (%)	0.038	−0.079	−0.098	0.116	−0.019	−0.254	−0.194	0.154	0.091	0.053	−0.005	0.191	0.112	–	−0.105
Firm Age	0.057	−0.061	−0.067	0.035	−0.053	0.592	0.639	0.071	0.051	0.015	0.103	0.048	−0.067	−0.112	–

This table reports the correlation coefficients for the main regression variables; Pearson correlation coefficients are below the diagonal and Spearman non-parametric correlation coefficients are above the diagonal. The sample consists of U.S. financial institutions during the period 2002–2012. All variables are as defined in Table 2 and Appendix A.

associated with less risk-taking. We begin by examining whether larger size is associated with greater risk. For brevity, we use the label 'size' in referring to the natural logarithm of size in the remainder of the paper; in our primary analyses we measure size by the firm's Total Assets.

Our baseline model is as follows:[8]

$$\begin{aligned} Bank\ Risk_i = \alpha &+ \beta_1 Total\ Assets_i + \beta_2 Market-to-Book_i \\ &+ \beta_3 Director\ Ownership_i + \beta_4 CEO\ Ownership_i \\ &+ \beta_5 Firm\ Age_i + \beta_6 Investment\ Bank_i \\ &+ \beta_7 Insurance\ Company_i \\ &+ \beta_8 Financial\ Crisis\ dummy_i + \varepsilon_i \end{aligned} \quad (1)$$

Table 4, Panel A, presents the results of the regression analysis with log *Z-score* as the dependent variable. Table 4, Panel B, presents the results of the regression analysis with Merton Distance to Default as the dependent variable. They are estimated using robust regressions to minimize the influence of outliers in the data. To control for unobserved differences among individual banks, we also use the fixed effects (FE) estimator. Size enters negatively and is significant at conventional levels in most models: larger firms are riskier.

The governance variable enters positively and is significant at the 1% level in most regressions, meaning better governance as measured by median director dollar stockholding is associated with less risk-taking. This result provides evidence that the conjecture based on Diamond and Rajan (2009) is correct.[9] Investment banks are significantly riskier than commercial banks; coefficients on the Investment Bank dummy are negative and significant at the 1% level. Also, as expected, the crisis period dummy variable indicates that bank risk was high during 2007–2009. CEO ownership has a positive correlation with bank risk, but enters insignificantly in the fixed effects model. As expected, the sign of firm age is positive.

To summarize our results so far: bank size is positively correlated with risk-taking. Better governance is associated with reduced risk-taking.

4.2. Endogeneity of firm size

Empirical corporate finance research is plagued by the problem of endogeneity, and this research is no exception. Specifically, we are concerned about the joint determination of risk-taking and firm size. Previous research has identified that banks are willing to pay a large premium to make acquisitions that will make them sufficiently large and TBTF (Brewer III and Jagtiani (2009)). Therefore, although firms are more likely to pursue risk-taking activities when they become larger, it is also likely that high-risk firms have the incentives to increase their sizes to achieve TBTF status. To address this issue, we use the identification strategy of instrumental variables (IV). In particular, we use three different instrumental variables: whether or not the firm is incorporated in Delaware, the natural logarithm of the number of employees at the firm, and the natural logarithm of the net plant, property and equipment.

[8] Implicit in this specification is that the relation between size and risk is linear. We prefer the linear specification because a simple t-test in an unreported regression fails to reject the null hypothesis that the coefficient on variable size-squared is not significantly different from zero.

[9] However, it is in sharp contrast to Cheng et al. (2010), who use alternative governance measures such as G-index and E-index and find that these governance indices have no effect on financial firms' risk-taking. We also find that governance measures such as G-index and E-index have no effect on financial firms' risk-taking (in untabulated results); a possible reason is that these indices are mostly measures of anti-takeover provisions. Theoretically, it is difficult to make a direct connection between anti-takeover provisions and bank risk-taking. Results using the G-Index and the E-Index as measures of corporate governance are available upon request.

Table 4
Firm size (total assets) and risk-taking.

	Dependent Variable: *ln (Z-score)*		
	Robust (1)	Robust (2)	FE (3)
Panel A: Z-score as measure of risk-taking, Assets as measure of size			
Assets (ln)	−0.027*	−0.033*	−0.613***
	(*−0.018*)	(*−0.017*)	(*−0.211*)
Market-to-Book	0.112*	0.118*	0.248
	(*−0.066*)	(*−0.07*)	(*−0.216*)
Director Ownership (ln)	0.158***	0.187***	0.213***
	(*−0.052*)	(*−0.056*)	(*−0.057*)
CEO Ownership	−1.918***	−1.986**	−1.044
	(*−0.617*)	(*−0.816*)	(*−0.873*)
Firm Age	0.025**	0.028**	–
	(*−0.01*)	(*−0.01*)	–
Investment Bank	–	−0.144***	–
	–	(*−0.033*)	–
Insurance Company	–	0.088	–
	–	(*−0.143*)	–
Crisis Period dummy	−1.025**	−1.588***	−0.833***
	(*−0.437*)	(*−0.04*)	(*−0.111*)
Constant	2.758***	2.869***	7.631***
	(*−0.378*)	(*−0.391*)	(*−1.813*)
Year Controls	Yes	Yes	Yes
Sample Period	2002–2012	2002–2012	2002–2012
# of Observations	1427	1427	1427
R-Squared	0.267	0.298	0.291
	Dependent Variable: ln (Merton Distance to Default)		
	Robust (1)	Robust (2)	FE (3)
Panel B: Merton Distance to Default as measure of risk-taking, Assets as measure of size			
Assets (ln)	−0.079**	−0.081**	−0.277***
	(*−0.035*)	(*−0.036*)	(*−0.078*)
Market-to-Book	0.341*	0.355*	0.156
	(*−0.18*)	(*−0.19*)	(*−0.114*)
Director Ownership (ln)	0.103***	0.101***	0.020*
	(*−0.025*)	(*−0.021*)	(*−0.013*)
CEO Ownership	−1.106*	−1.007	−0.243
	(*−0.573*)	(*−0.661*)	(*−0.855*)
Firm Age	0.055**	0.059**	–
	(*−0.027*)	(*−0.024*)	–
Investment Bank	–	−1.758***	–
	–	(*−0.151*)	–
Insurance Company	–	0.994	–
	–	(*−0.826*)	–
Crisis Period dummy	−1.252**	−1.296***	−0.576***
	(*−0.501*)	(*−0.486*)	(*−0.168*)
Constant	1.448***	1.401***	4.008***
	(*−0.2*)	(*−0.207*)	(*−0.089*)
Year Controls	Yes	Yes	Yes
Sample Period	2002–2012	2002–2012	2002–2012
# of Observations	1219	1219	1219
R-Squared	0.367	0.578	0.477

This table presents the regression results analyzing Eq. (1) on the relationship between firm size and risk-taking. Robust regressions are estimated. In Panel A the dependent variable is natural logarithm of *Z-score*; in Panel B the dependent variable is the natural logarithm of *Merton Distance to Default*. The sample consists of U.S. financial institutions during the period 2002–2012. The measure of firm size is the natural log of Total Assets. Robust regressions (Robust) estimation is used in models (1)–(2) and Fixed Effects (FE) estimation is used in model (3). *Z-score* is defined in Appendix A; *Merton Distance to Default*, are calculated as described in Appendix B. *Market-to-Book* is the market-to-book ratio. *Director Ownership* is the dollar value of the median director stock ownership in natural logarithm form. *CEO Ownership* is the percent of stock owned by the CEO. *Firm Age* is the age of the firm in each year. *Investment Bank* is an indicator variable equal to 1 if the firm is an investment bank and 0 otherwise. *Insurance Company* is an indicator variable equal to 1 if the firm is an insurance company and 0 otherwise. *Crisis Period dummy* is an indicator variable equal to 1 if the observation occurs during 2007–2009 and 0 otherwise. Coefficients are provided with standard errors below in parenthesis. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.
Italic values are standard errors associated with coefficient estimates.

We make use of variation in whether or not a firm incorporates in Delaware as an instrument for firm size because when a company decides to go public, the decision where to incorporate, while not random, should be exogenous to the unobservable factors that affect firms' risk-taking as induced by moral hazard of TBTF. The validity of an instrument critically hinges on this exclusion restriction. Empirical legal and financial studies have investigated extensively why a firm would choose Delaware as its domicile. For example, Daines (2001) finds there is a wealth effect associated with Delaware incorporation, due to the fact that Delaware corporate law encourages takeover bids and facilitates the sale of public firms by reducing the cost of acquiring a Delaware firm. Conceptually, this wealth effect should have nothing to do with a firm's risk-taking. Bebchuck and Cohen (2003) identify that favorable anti-takeover protections are important for a state to attract out-of-state incorporation. Romano (1985) argues that Delaware's large store of legal precedent reduces transaction costs and uncertainty about legal liability. Lastly, Fisch (2000) notes the peculiar role of the Delaware judiciary in corporate lawmaking, arguing that Delaware lawmaking offers Delaware corporations a variety of benefits, including flexibility, responsiveness, insulation from undue political influence, and transparency. While these factors affect a firm's domicile decision, all of them appear centered around the legal environment of Delaware. In addition, other researchers have argued that a firm's choice of domicile is unimportant and trivial (Black (1990)). This literature suggests that our instrumental variable, dummy for Delaware incorporation, does not belong to the structural equation; we thus expect that it is a valid instrument.

The other two instrument variables, number of employees at the firm and net plant, property and equipment, are likely correlated with bank size. However, given the recent banking literature (for example, see Berger and Bouwman (2013), Laeven and Levine (2009), and Vallascas and Keasey (2012)), it is not obvious why these two variables would be systematically related to the bank's risk taking.[10]

While the three instrument variables have ex ante theoretical plausibility, we conduct a battery of specification tests to validate the strength and relevance of these instrument variables. We consider Hausman's endogeneity test, and the following instrument strength and validity tests: Stock and Yogo weak instrument test (2005), Hahn and Hausman instrument validity test (2002), Hansen-Sargan overidentification test, and Anderson-Rubin joint significance test.[11]

The Two-Stage Least Squares IV approach involves estimating the following second-stage structural model using the predicted values from the first-stage instrumental variables equation:

$$\begin{aligned} Bank\ Risk_i = {} & \alpha + \beta_1 Total\ Assets_i + \beta_2 Market-to-Book_i \\ & + \beta_2 Director\ Ownership_i + \beta_4 CEO\ Ownership_i \\ & + \beta_5 Firm\ Age_i + \beta_6 Investment\ Bank_i \\ & + \beta_7 Insurance\ Company_i \\ & + \beta_8 Financial\ Crisis\ dummy_i + \varepsilon_i \end{aligned} \tag{2}$$

[10] We considered state bank merger restrictions as another instrument variable. The Interstate Banking and Branching Efficiency Act of 1997 allowed banks to expand across state lines, but also allowed states to make such expansion difficult; see Rice and Strahan (2010). However, the Stock and Yogo weak instrument test (2005) and the Hahn and Hausman instrument validity test (2002) indicate this is not an appropriate instrument.

[11] Conceptually, there may be concerns about using Delaware as an instrument, especially since it is a binary indicator variable. Using the battery of specification tests as noted in Appendix D, it proves to be a strong instrument. Therefore, we leave it in the primary specifications to have as much power as possible. However, in untabulated analyses, when we exclude the Delaware instrument and only include the number of employees and PP&E, the primary results are qualitatively similar; results are available from the authors upon request.

Table 5
Two-Stage Least Square (2SLS) IV regression of firm size on risk-taking.

	Dependent Variable: *ln (Assets)* (1)	(2)	(3)	(4)
Panel A: First-stage regression, predicting firm size using Total Assets				
Delaware	1.418***	–	–	1.055***
	(*0.284*)	–	–	(*0.020*)
Number of Employees	–	1.026***	–	1.001***
	–	(*0.014*)	–	(*0.017*)
PP & E	–	–	2.367***	2.349***
	–	–	(*0.028*)	(*0.026*)
Market-to-Book	−0.277*	−0.258	−0.269*	−0.255*
	(*0.154*)	(*0.219*)	(*0.151*)	(*0.014*)
Director Ownership (ln)	0.481***	0.479***	0.466***	0.477***
	(*0.102*)	(*0.094*)	(*0.087*)	(*0.091*)
CEO Ownership	−2.553**	−2.310**	−2.448**	−2.471**
	(*1.094*)	(*0.938*)	(*1.020*)	(*1.031*)
Firm Age	0.071***	0.066***	0.072***	0.074***
	(*0.007*)	(*0.007*)	(*0.008*)	(*0.008*)
Investment Bank	1.561***	1.546***	1.618***	1.627***
	(*0.043*)	(*0.040*)	(*0.044*)	(*0.043*)
Insurance Company	1.857***	1.951***	2.003***	1.918***
	(*0.055*)	(*0.051*)	(*0.056*)	(*0.054*)
Crisis Period dummy	1.387*	1.366*	1.391*	1.388*
	(*0.077*)	(*0.074*)	(*0.074*)	(*0.072*)
Constant	−3.279***	−3.010***	−3.155***	−3.338***
	(*0.081*)	(*0.089*)	(*0.087*)	(*0.084*)
Year Controls	Yes	Yes	Yes	Yes
Sample Period	2002–2012	2002–2012	2002–2012	2002–2012
# of Observations	1483	1483	1483	1483
R-Squared	0.682	0.863	0.857	0.893
First-Stage *F*-statistic	19.34	18.76	20.07	34.61
Stock and Yogo (2005) Weak Instrument Test Critical Value	16.38	16.38	16.38	22.30
Instruments Strong?	Yes	Yes	Yes	Yes

	Dependent Variable:			
	ln (Z-Score) Robust (1)	*ln (Z-Score)* FE (2)	*ln (Merton Distance to Default)* Robust (3)	*ln (Merton Distance to Default)* FE (4)
Panel B: Second-stage regression, predicting risk-taking, Assets as measure of size				
Assets (ln)	−0.025***	−0.042*	−0.055**	−0.072**
	(*0.008*)	(*0.026*)	(*0.024*)	(*0.036*)
Market-to-Book	0.153*	0.217	0.595*	0.448*
	(*0.086*)	(*1.035*)	(*0.366*)	(*0.261*)
Director Ownership (ln)	0.078***	0.279***	0.158**	0.187*
	(*0.015*)	(*0.092*)	(*0.071*)	(*0.118*)
CEO Ownership	−1.001	−1.307	−1.769	−1.639
	(*0.955*)	(*1.128*)	(*1.800*)	(*1.299*)
Firm Age	0.012*	–	0.054**	–
	(*0.006*)	–	(*0.021*)	–
Investment Bank	−0.082***	–	−0.066***	–
	(*0.014*)	–	(*0.061*)	–
Insurance Company	0.088	–	0.311	–
	(*0.076*)	–	(*0.901*)	–
Crisis Period dummy	−1.366***	−0.701***	−1.854***	−2.244***
	(*0.351*)	(*0.069*)	(*0.218*)	(*0.315*)
Constant	3.681***	5.873***	6.251***	9.021***
	(*0.269*)	(*1.066*)	(*0.856*)	(*1.344*)
Year Controls	Yes	Yes	Yes	Yes
Sample Period	2002–2012	2002–2012	2002–2012	2002–2012
# of Observations	1421	1421	1202	1202
R-Squared	0.354	0.328	0.618	0.663

	Dependent Variable:			
	Stock Volatility Robust (1)	*Stock Volatility* FE (2)	*ln (Write-downs)* Robust (3)	*Write-downs/Assets* Robust (4)
Panel C: Second-stage regression, alternate measures of risk-taking, Assets as measure of size				
Assets (ln)	0.005*	0.127*	1.225***	0.009**
	(*0.003*)	(*0.071*)	(*0.252*)	(*0.004*)
Market-to-Book	0.199**	0.360*	0.203*	0.044*
	(*0.089*)	(*0.199*)	(*0.125*)	(*0.025*)
Director Ownership (ln)	−0.843**	−0.786***	−1.235***	−0.055*
	(*0.336*)	(*0.225*)	(*0.264*)	(*0.032*)
CEO Ownership	0.254	0.174	0.674	0.266
	(*0.361*)	(*0.182*)	(*0.499*)	(*0.423*)

Table 5 (*continued*)

	Dependent Variable:			
	Stock Volatility Robust (1)	*Stock Volatility* FE (2)	*ln (Write-downs)* Robust (3)	*Write-downs/Assets* Robust (4)
Firm Age	−0.036*	–	−0.872	−0.497
	(*0.019*)	–	(*0.971*)	(*0.879*)
Investment Bank	1.255**	–	1.597***	1.224**
	(*0.523*)	–	(*0.344*)	(*0.542*)
Insurance Company	0.699	–	0.672	0.231
	(*0.601*)	–	(*0.489*)	(*0.693*)
Crisis Period dummy	2.364***	1.855***	–	–
	(*0.249*)	(*0.239*)	–	–
Constant	−4.236***	−5.276***	−0.966***	−1.233*
	(*1.010*)	(*1.168*)	(*0.244*)	(*0.685*)
Year Controls	Yes	Yes	No	No
Sample Period	2002–2012	2002–2012	2008	2008
# of Observations	1435	1435	94	94
R-Squared	0.816	0.798	0.638	0.203

	Dependent Variable:			
	ln (Naïve Distance to Default) Robust (1)	*ln (Naïve Distance to Default)* FE (2)	*Probability of Default (Merton)* Robust (3)	*Probability of Default (Merton)* FE (4)
Panel D: Second-stage regression, alternate measures of risk-taking, Assets as measure of size				
Assets (ln)	−0.031*	−0.106**	0.015**	0.024***
	(*0.019*)	(*0.048*)	(*0.007*)	(*0.007*)
Market-to-Book	0.232*	0.373*	−0.043**	−0.049
	(*0.142*)	(*0.238*)	(*0.020*)	(*0.047*)
Director Ownership (ln)	0.112***	0.401**	−0.031***	−0.025*
	(*0.032*)	(*0.198*)	(*0.009*)	(*0.013*)
CEO Ownership	−1.048*	−1.926*	0.096*	0.167
	(*0.635*)	(*1.184*)	(*0.052*)	(*0.130*)
Firm Age	0.017	–	−0.007***	–
	(*0.014*)	–	(*0.002*)	–
Investment Bank	−0.100**	–	−0.013***	–
	(*0.037*)	–	(*0.004*)	–
Insurance Company	0.124*	–	−0.029	–
	(*0.073*)	–	(*0.055*)	–
Crisis Period dummy	−2.611***	−1.402***	0.306***	0.298***
	(*0.768*)	(*0.417*)	(*0.042*)	(*0.051*)
Constant	2.005***	3.286***	−0.302***	−0.573***
	(*0.392*)	(*1.153*)	(*0.051*)	(*0.103*)
Year Controls	Yes	Yes	Yes	Yes
Sample Period	2002–2012	2002–2012	2002–2012	2002–2012
# of Observations	1202	1202	1202	1202
R-Squared	0.198	0.279	0.237	0.327

This table presents the two-stage least squares (2SLS) regression analysis estimating Eqs. (2) and (3) on the relationship between firm size and risk-taking. The sample consists of U.S. financial institutions during the period 2002–2012. All variables are as defined in Table 2 and Appendix A. In Panel A, the first-stage estimation of Eq. (3) is presented, using the first-stage instruments to obtain the predicted value of firm size using *Total Assets*. In the estimation of the first-stage Eq. (3), three different instrumental variables for firm size are considered: *Delaware*, an indicator variable equal to 1 if the firm is incorporated in Delaware and 0 otherwise, *Number of Employees*, the natural logarithm of the total number of employees at the institution in each year, and *PP & E*, the natural logarithm of net plant, property and equipment at the institution in each year. Model (4) includes all three instrumental variables. In Panels B, C and D the estimation of the structural Eq. (2) is presented, using the predicted values of size from the first-stage to estimate the relationship between firm size and risk-taking. Robust regressions (Robust) and Fixed-Effects (FE) estimation are used. The natural logarithm of *Total Assets* is the measure of size based on the first-stage analysis in Panel A. In Panel B the dependent variables are *Z-score* and *Merton Distance to Default;* in Panel C the dependent variables are the standard deviation of daily stock returns in each year, the natural logarithm of the cumulative accounting write-downs during 2007–2008 and the ratio of cumulative accounting write-downs to total assets; and, in Panel D, the dependent variables are *Naïve Distance to Default* and *Probability of Default (Merton). Market-to-Book* is the market-to-book for the year. *Director Ownership* is the dollar value of the median director stock ownership in natural logarithm form. *CEO Ownership* is the percentage of stock owned by the CEO. *Firm Age* is the age of the firm in each year. *Investment Bank* is an indicator variable equal to 1 if the firm is an investment bank and 0 otherwise. *Insurance Company* is an indicator variable equal to 1 if the firm is an insurance company and 0 otherwise. *Financial Crisis dummy* is an indicator variable equal to 1 if the observation occurs during 2007–2009 and 0 otherwise. In Panel A, the partial *F*-statistic on the instrument is provided along with the relevant critical value from the Stock and Yogo (2005) weak instruments test using 5% relative bias tolerance. Appendix D presents and explains more thorough tests of endogeneity. Coefficients are provided with standard errors below in parenthesis. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.
Italic values are standard errors associated with coefficient estimates.

First-stage instrumental variables model:

$$\begin{aligned} Total\ Assets_i = \alpha &+ \beta_1 Delaware_i + \beta_2 Employees_i + \beta_3 PP\&E_i \\ &+ \beta_4 Director\ Ownership_i + \beta_5 CEO\ Ownership_i \\ &+ \beta_6 Firm\ Age_i + \beta_7 Investment\ Bank_i \\ &+ \beta_8 Insurance\ Company_i \\ &+ \beta_9 Financial\ Crisis\ dummy_i + \varepsilon_i \end{aligned} \tag{3}$$

where $Delaware_i$ is a dummy variable which equals one if firm i is Delaware incorporated, $Employees_i$ is the natural logarithm of employees at the firm, and $PP\&E_i$ is the natural logarithm of net plant, property and equipment at the firm; the rest of the variables are defined as in Eq. (1).

Identification of the IV model requires a strong correlation between the instruments (Delaware dummy, Employees, and PP&E) and firm size. Results from the first-stage regression on size (ln (Assets)) are presented in Table 5, Panel A. We perform a weak instrument test as proposed by Stock and Yogo (2005); if the *F*-statistic from the first-stage regression exceeds the critical value (using 5% bias), the instrument is deemed to be valid. The critical

Table 6
Size and risk-taking across financial crisis periods.

	Dependent Variable: *ln (Z-score)*		
	Pre-Crisis 2002–2006 (1)	Crisis 2007–2009 (2)	Post-Crisis 2010–2012 (3)
Panel A: Size and risk-taking across financial crisis periods, Second-stage regression predicting risk-taking, Z-score as measure of risk-taking, Assets as measure of size			
Assets (ln)	−0.021**	−0.035*	−0.012
	(*0.009*)	(*0.021*)	(*0.016*)
Market-to-Book	0.156*	0.166*	0.143
	(*0.087*)	(*0.094*)	(*0.186*)
Director Ownership (ln)	0.059***	0.093***	0.085*
	(*0.011*)	(*0.014*)	(*0.055*)
CEO Ownership	−1.055	−1.036	−0.641*
	(*0.863*)	(*0.710*)	(*0.397*)
Firm Age	0.019*	0.010*	0.004
	(*0.011*)	(*0.006*)	(*0.008*)
Investment Bank	−0.097***	−0.080**	−0.054
	(*0.018*)	(*0.034*)	(*0.049*)
Insurance Company	0.054	0.087	0.099*
	(*0.061*)	(*0.073*)	(*0.061*)
Constant	2.369***	3.774***	4.427***
	(*0.355*)	(*0.366*)	(*0.856*)
Year Controls	Yes	Yes	Yes
Sample Period	2002–2006	2007–2009	2010–2012
# of Observations	625	409	387
R-Squared	0.511	0.298	0.183
	Dependent Variable: ln (Merton Distance to Default)		
	Pre-Crisis 2002–2006 (1)	Crisis 2007–2009 (2)	Post-Crisis 2010–2012 (3)
Panel B: Size and risk-taking across financial crisis periods, Second-stage regression predicting risk-taking, Merton Distance to Default as measure of risk-taking. Assets as measure of size			
Assets (ln)	−0.068***	−0.077***	−0.029*
	(*0.012*)	(*0.019*)	(*0.180*)
Market-to-Book	0.663*	0.563*	0.488
	(*0.385*)	(*0.311*)	(*0.401*)
Director Ownership (ln)	0.144*	0.169**	0.153**
	(*0.092*)	(*0.081*)	(*0.073*)
CEO Ownership	−1.257*	−1.965	−2.066
	(*0.696*)	(*1.660*)	(*1.364*)
Firm Age	0.043**	0.061*	0.064*
	(*0.019*)	(*0.381*)	(*0.388*)
Investment Bank	−0.063***	−0.074**	−0.055***
	(*0.013*)	(*0.034*)	(*0.019*)
Insurance Company	0.363	0.300	0.245
	(*0.436*)	(*0.499*)	(*0.277*)
Constant	5.239**	7.144***	7.003***
	(*2.193*)	(*1.364*)	(*1.554*)
Year Controls	Yes	Yes	Yes
Sample Period	2002–2006	2007–2009	2010–2012
# of Observations	536	344	322
R-Squared	0.628	0.476	0.287
	Dependent Variable: ln (Naïve Distance to Default)		
	Pre-Crisis 2002–2006 (1)	Crisis 2007–2009 (2)	Post-Crisis 2010–2012 (3)
Panel C: Size and risk-taking across financial crisis periods, Second-stage regression predicting risk-taking, Naïve Distance to Default as measure of risk-taking, Assets as measure of size			
Assets (ln)	−0.020***	−0.037**	−0.016
	(*0.007*)	(*0.017*)	(*0.014*)
Market-to-Book	0.137*	0.159*	0.137
	(*0.073*)	(*0.092*)	(*0.192*)
Director Ownership (ln)	0.061***	0.098***	0.089*
	(*0.012*)	(*0.016*)	(*0.051*)
CEO Ownership	−0.925	−1.004	−0.672*
	(*0.766*)	(*0.763*)	(*0.401*)
Firm Age	0.019**	0.009*	0.004
	(*0.009*)	(*0.005*)	(*0.009*)
Investment Bank	−0.102***	−0.092***	−0.051
	(*0.022*)	(*0.028*)	(*0.054*)
Insurance Company	0.047	0.078	0.102*
	(*0.072*)	(*0.070*)	(*0.063*)

Table 6 (*continued*)

	Dependent Variable: ln (Naïve Distance to Default)		
	Pre-Crisis 2002–2006 (1)	Crisis 2007–2009 (2)	Post-Crisis 2010–2012 (3)
Constant	2.134***	3.634***	4.341***
	(*0.422*)	(*0.415*)	(*0.902*)
Year Controls	Yes	Yes	Yes
Sample Period	2002–2006	2007–2009	2010–2012
# of Observations	536	344	322
R-Squared	0.532	0.302	0.191
	Dependent Variable: Probability of Default (Merton)		
	Pre-Crisis 2002–2006 (1)	Crisis 2007–2009 (2)	Post-Crisis 2010–2012 (3)
Panel D: Size and risk-taking across financial crisis periods, Second-stage regression predicting risk-taking, Probability of Default (Merton) as measure of risk-taking. Assets as measure of size			
Assets (ln)	0.002***	0.004***	0.002
	(*0.001*)	(*0.001*)	(*0.002*)
Market-to-Book	−0.015*	−0.015*	−0.013
	(*0.006*)	(*0.009*)	(*0.020*)
Director Ownership (ln)	−0.007***	−0.010***	−0.010**
	(*0.002*)	(*0.002*)	(*0.004*)
CEO Ownership	0.088	0.096	0.071*
	(*0.081*)	(*0.078*)	(*0.038*)
Firm Age	−0.002**	−0.001*	−0.001
	(*0.001*)	(*0.001*)	(*0.001*)
Investment Bank	0.011***	0.010***	0.005
	(*0.003*)	(*0.003*)	(*0.007*)
Insurance Company	−0.005	−0.008	−0.011*
	(*0.006*)	(*0.008*)	(*0.007*)
Constant	−0.224***	−0.352***	−0.425***
	(*0.041*)	(*0.049*)	(*0.069*)
Year Controls	Yes	Yes	Yes
Sample Period	2002–2006	2007–2009	2010–2012
# of Observations	536	344	322
R-Squared	0.548	0.328	0.232

This table shows the relationship between firm size and risk-taking before, during and after the 2007–2009 financial crisis. The sample consists of U.S. financial institutions during the period 2002–2012. All variables are as defined in Table 2 and Appendix A. The 2SLS results from estimating Eq. (3) are presented; the first-stage regression includes all three instrumental variables. Panel A presents the results using *Z-score* as the dependent variable measure of risk-taking; Panel B presents the results using *Merton Distance to Default* as the dependent variable measure of risk-taking; Panels C and D present the results using *Naïve (Distance to Default)* and *Probability of Default* as the dependent variable measure of risk-taking. Panels A, B, C and D present the results using *Total Assets* as the measure of firm size. Model (1) considers only the observations from 2002–2006; Model (2) considers only the observations during 2007–2009; and Model (3) considers only the observations during 2010–2012. The predicted value of firm size obtained in the first-stage regression is the measure of firm size. *Market-to-Book* is the market-to-book for the year. *Director Ownership* is the natural logarithm of the dollar value of median director stock ownership. *CEO Ownership* is the percentage of stock owned by the CEO. *Firm Age* is the age of the firm in each year. *Investment Bank* is an indicator variable equal to 1 if the firm is an investment bank and 0 otherwise. *Insurance Company* is an indicator variable equal to 1 if the firm is an insurance company and 0 otherwise. Robust regressions estimation is used in the second-stage regressions. Coefficients are provided with standard errors below in parenthesis. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.
Italic values are standard errors associated with coefficient estimates.

value is 16.38, which is less than the *F*-statistic; hence we conclude that the instruments are not weak. Appendix D contains details on additional tests regarding the validity of our instruments.

Results from IV estimates for risk-taking, as measured by *Z-score* and Merton DD are reported in Table 5, Panel B. After controlling for the endogeneity between firm size and risk, we find that larger firms are associated with greater risk-taking, as measured by *Z-score* and Merton DD; specifically, a 1% increase in total assets decreases *Z-score* by 0.042% (Column 2), and decreases Merton DD by 0.072% (Column 4).[12] Well-governed financial institutions, as measured by director ownership, are correlated with less risk-taking. The size of the coefficient on director ownership is also economically consequential. A 1% increase in director ownership is associated with a 0.279% (Column 2) increase in *Z-score*, and a 0.187% (Column 4) increase in Merton DD. Investment banks and the crisis period (2007–2009) are associated with greater risk-taking.

Table 5, Panel C, highlights results with alternative methods of measuring risk-taking, namely, bank stock volatility, write-downs and write-downs-to-assets. We find a positive, though statistically only marginally significant, relation between firm risk as measured by stock volatility and size. We find a positive, and statistically significant, relation between bank risk as measured by bank write-downs and write-downs-to-assets, and bank size. The findings on our governance variable, and the crisis period are consistent with previous findings. Specifically, well-governed banks, as measured by director ownership, are correlated with less risk-taking by banks; the crisis period (2007–2009) is associated with greater risk-taking by banks.

4.3. Robustness check: Alternative measures of Distance to Default

Bharath and Shumway (2008) propose a more robust way of measuring Distance to Default based on Merton (1974). They call their estimator Naïve Distance to Default (*Naïve DD*), and show that while it retains the structure of Merton DD it is easier to compute; more importantly, Naïve DD has better out-of-sample prediction properties than Merton DD. The second-stage regression estimates of the relation between bank size and Naive DD are presented in Table 5, Panel D. Results considering Naïve DD as a measure of bank risk are consistent with earlier results: Smaller and

[12] Coefficients in the regressions for bank total assets and director ownership can be interpreted as elasticities since *Z-score*, Merton DD, bank total assets and director ownership are included in the regression as their natural logarithm.

Table 7
Decomposition of Z-score.

	CAR (1)	ROA (2)	σ(ROA) (3)
Panel A: Robust regressions in 2nd stage regression			
Assets (ln), predicted	−0.012***	0.002	−0.005***
	(*0.002*)	(*0.002*)	(*0.000*)
Market-to-Book	0.044**	0.024*	0.009*
	(*0.021*)	(*0.015*)	(*0.005*)
Director Ownership (ln)	0.023**	0.148***	−0.003***
	(*0.011*)	(*0.023*)	(*0.000*)
CEO Ownership	−0.445*	0.087*	−0.008*
	(*0.271*)	(*0.050*)	(*0.004*)
Firm Age	−0.766*	−0.002	0.015
	(*0.408*)	(*0.041*)	(*0.056*)
Investment Bank	−1.244*	−0.694	1.334**
	(*0.689*)	(*0.601*)	(*0.490*)
Insurance Company	0.033	0.048	0.431
	(*0.478*)	(*0.079*)	(*0.407*)
Constant	1.329**	−0.108**	0.058**
	(*0.526*)	(*0.042*)	(*0.025*)
Year Controls	Yes	Yes	Yes
Sample Period	2002–2012	2002–2012	2002–2012
# of Observations	1421	1421	1421
R-Squared	0.623	0.745	0.316
Panel B: Fixed effects in 2nd stage regression			
Assets (ln), predicted	−0.054***	−0.024***	−0.005*
	(*0.015*)	(*0.005*)	(*0.003*)
Market-to-Book	0.034	0.077*	0.000
	(*0.084*)	(*0.040*)	(*0.015*)
Director Ownership (ln)	0.055*	0.099***	−0.002***
	(*0.034*)	(*0.015*)	(*0.000*)
CEO Ownership	−0.331	0.144**	−0.115*
	(*0.752*)	(*0.054*)	(*0.607*)
Firm Age	−0.441	0.344	0.881
	(*0.369*)	(*0.869*)	(*0.977*)
Investment Bank	−1.880*	−1.075	−0.446
	(*1.035*)	(*0.866*)	(*0.894*)
Insurance Company	0.077*	0.166	0.330
	(*0.046*)	(*0.244*)	(*0.476*)
Constant	1.004***	0.344***	0.099***
	(*0.301*)	(*0.092*)	(*0.016*)
Year Controls	Yes	Yes	Yes
Sample Period	2002–2012	2002–2012	2002–2012
# of Observations	1421	1421	1421
R-Squared	0.194	0.366	0.201

This table presents the 2SLS results from estimating Eq. (1) using the components of *Z-score* as the dependent variables. The sample consists of U.S. financial institutions during the period 2002–2012. All three instruments are used to predict *Assets* in the first-stage. Panel A presents the results using Robust Regressions estimation in the second-stage structural regression; Panel B presents the results using Fixed Effects estimation in the second-stage structural regression. In model (1), the dependent variable is *CAR*, or capital to assets ratio, measured as the ratio of total equity to total assets. In model (2), the dependent variable is *ROA*, or return on assets, measured as net income divided by total assets. In model (3), the dependent variable is the standard deviation of annual *ROA*. *Assets(ln)* is the predicted value of Total Assets for the firm-year. *Market-to-Book* is the market-to-book ratio. *Director Ownership* is the natural logarithm of the dollar value of median director stock ownership. *CEO Ownership* is the percentage of stock owned by the CEO. *Firm Age* is the age of the firm. *Investment Bank* is an indicator variable equal to 1 if the firm is an investment bank and 0 otherwise. *Insurance Company* is an indicator variable equal to 1 if the firm is an insurance company and 0 otherwise. Coefficients are provided with standard errors below in parenthesis. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.
Italic values are standard errors associated with coefficient estimates.

well governed banks (as measured by director ownership) are correlated with less risk-taking; investment banks and the crisis period (2007–2009) are associated with greater risk-taking.

We also compute the probability of default based on Merton DD; the estimation procedure is described in Bharath and Shumway (2008). The second-stage regression estimates of the relation between bank size and probability of default based on Merton DD are presented in Table 5, Panel D. Results considering the probability of default based on Merton DD are consistent with earlier findings: Smaller and well governed banks (as measured by director ownership) are correlated with less risk-taking; investment banks and the crisis period (2007–2009) are associated with greater risk-taking.

4.4. Robustness check: Alternative measure of bank size

Most of the banking literature considers asset size as the primary measure of bank size (for example, see Laeven and Levine (2009)); hence, in our analysis so far, we have used assets as a measure of bank size. However, total revenue is often used as a measure of size in the corporate finance literature (for example, see Eckbo and Thorburn (2012)). Hence, as a robustness check, we use the bank's total revenue as its measure of size. The results are consistent with those reported earlier in Table 5 where total assets is used as the measure of bank size; these results are available from the authors upon request.

4.5. Robustness check: Larger sample size but without director and CEO ownership as a control variable

We have far fewer observations on director ownership (1622) compared to the other variables; see Table 2. The reason is our data source for director ownership, RiskMetrics, covers only a subset of our sample firms. While we augmented this with hand-collected data (see Section 3 above) we still have far fewer observations on director ownership. As a robustness check, we consider the relation between bank size and risk for a much larger sample, but without director and CEO ownership as a control variable. The results, summarized in Appendix C, using this larger sample confirm our earlier findings, in particular, on the negative relation between bank size and risk-taking.

4.6. Financial crisis time period effects

The 2002–2012 time period is unique in that it contains data before, during and after the largest financial crisis in recent history. As such, it is possible that different sub-periods within our sample may have different relationships between bank size and risk-taking. For example, the intense scrutiny put on bank risk-taking by the bank regulators, senior policy-makers, and the media in the post-crisis period may have curbed the appetite and ability of large banks to engage in high-risk investments. To address this, we consider three sub-periods: the pre-crisis period of 2002–2006, the crisis period of 2007–2009 and the post-crisis period of 2010–2012. We estimate Eq. (2) using 2SLS during each of these periods, with both *Z-score* and Merton Distance to Default as our measures of risk-taking. The results are presented in Table 6. The strong relationships we observed earlier between firm size-and risk-taking are most pronounced in the pre-crisis and crisis periods for both measures of risk-taking. In the post-crisis period, there is no consistent significant relation between bank size and risk-taking[13]; this is consistent with the argument that the intense public scrutiny put on bank risk-taking in the post-crisis period may have curbed the appetite and ability of large banks to engage in high-risk investments.[14]

[13] We conducted econometric testing and confirmed for a structural break in the model from the crisis period (2007–2009) to the post-crisis period (2010–2012). The Chow Tests reported p-values of 0.030 to 0.077, suggesting that there was a structural break and a different relationship between firm size and risk-taking after 2009. We thank the referee for this suggestion.

[14] Additionally, for robustness, we consider these same three sub-periods using total revenues as the measure of bank size rather than using total assets; the results are qualitatively similar and are available from the authors upon request. We also consider three alternative time periods: the pre-crisis period of 2002–2005, the crisis period of 2008 and the post-crisis period of 2010–2012. Using both total assets and total revenues as the measures of bank size, these results are qualitatively similar to the results in Table 6 and are available from the authors upon request.

4.7. Decomposition of Z-score

Z-score has three components – ROA, CAR, and σ(ROA). A higher level of ROA and higher capital asset ratios (CAR) translate into higher *Z-scores*, while a larger standard deviation of ROA translates into lower *Z-scores*. Thus, when we find a positive relation between size and risk-taking, it may be attributable to a lower ROA, a lower capital ratio (CAR), and/or a higher standard deviation. Therefore, it is possible that size may not necessarily increase the risk of assets, but rather the drop in *Z-score* may instead be attributed to a decline in the average bank capital ratio or return on assets. To further explore how the various components of *Z-score* are correlated with size, we run regressions treating each of these *Z-score* components as a separate dependent variable. The empirical results are reported in Table 7.

We see that an increase in size is associated with a decrease in capital asset ratio at the 1% significance level. As for the economic effect, on average, a 1% percent increase in size translates into a 0.012% to 0.054% reduction in capital asset ratio. We do not find a consistent significant relation between size and ROA or earnings volatility. These results indicate that the lower *Z-score* for large banks is driven primarily by a reduction in capital asset ratio. This is consistent, with some of the conclusions drawn by the aforementioned studies that use structural credit risk models to analyze financial institution risk. For instance, Calice et al. (2012), Flannery (2014), and Chen et al. (2014) find, within the context of Merton-like models, that the financial system was undercapitalized and required massive capital infusions to stabilize the financial system during the crisis. Specifically, on the basis of simulation results, Calice et al. (2012) document that, even under favorable asset volatility scenarios, there is a substantial need for capital injections for a sample of 16 large complex financial institutions from around the world. Applying a lattice-based multi-period credit risk model to the case of Lehman Brothers, Chen et al. (2014) show that there is a substantial increase in default probability during the first few months of 2008; and, in a hypothetical exercise, they also show that Lehman would have needed an equity capital infusion of $15 billion in order to reduce probability of default below 5%, given the market conditions of March 2008. Flannery (2014) documents substantial market value of the government guarantees against bank insolvency – in the order of 30% of bank capitalization for the largest 25 U.S. bank holding companies during 2007–2011.

Corporate governance (director ownership) is positively associated with ROA and negatively associated with earnings volatility. These results suggest better governance enhances firm performance (ROA), consistent with Bhagat and Bolton (2008) who note a significant and positive relationship between director ownership and contemporaneous and next year's ROA. The risk-reducing mechanism of corporate governance appears to work its way through an increase in ROA and a reduction in earnings volatility.

5. Conclusion

The recent financial crisis of 2008, and policies that will prevent it in the future, continues to occupy policymakers at the highest levels. The consensus has been that TBTF financial firms took too much risk prior to the crisis. Regarding remedies, some have suggested capping the size of banks. However, given the difficulty of correctly identifying the size threshold when a financial institution becomes too big to fail, concerns have been raised regarding implementation of "capping the size." Although we do observe a positive association between firm size and risk-taking, this relation is driven not only by size per se but also by the unusually high leverage of the larger banks. This suggests that regulations designed to rein in the risk-taking of financial firms should focus more on capital requirements, rather than on bank size alone. This suggestion regarding increased bank capital requirements is consistent with the recent recommendations of Admati and Hellwig (2013), Bhagat and Bolton (2014), and Fama (2010). Also, in several recent op-eds, the *Wall Street Journal* has recommended significantly higher equity capital requirements for banks.

Also, we find that the newly developed corporate governance measure, calculated as median director dollar stockholding, is significantly negatively associated with risk-taking. This has important policy implications: policy-makers interested in discouraging banks from engaging in excessive risk should also focus on bank director compensation and stock ownership.

Additionally, we find that investment banks, but not insurance companies, engage in more risk-taking compared to commercial banks. Finally, we document that the positive relation between bank size and risk is present in the pre-crisis period (2002–2006) and the crisis period (2007–2009), but not in the post-crisis period (2010–2012). Perhaps the intense scrutiny put on bank risk-taking by the bank regulators, senior policy-makers, and the media in the post-crisis period may have curbed the appetite and ability of large banks to engage in high-risk investments. We think the inter-temporal variation in the relation between bank size and risk is a fruitful topic for future research.

Appendix A

Variable definitions and data sources

Variable	Definition	Original sources
Risk measures		
Z-score	Equals (ROA+CAR)/σ(ROA), where ROA = π/A is return on assets and CAR = E/A where E equals (Total Assets – Total Liabilities) divided by Total Assets. Higher *Z-score* implies more stability	Compustat
Merton Distance to Default	The market value of the firm minus the face value of the firm's debt divided by the volatility of the firm value. The estimates of firm value and volatility are obtained by applying the Merton (1974) option valuation model (see Appendix B for details). Higher Merton DD implied more stability	
ROA	Return on assets, Net Income divided by Total Assets. Higher value implies more stability	Compustat
CAR	Capital asset ratio, Equity divided by Total Assets. Higher value implies more stability	Compustat
σ(ROA)	Equals standard deviation of ROA, rolling five-year periods	Compustat

(*continued on next page*)

Appendix A (*continued*)

Variable	Definition	Original sources
σ(RET)	Equals standard deviation of daily stock returns	CRSP
Write-Down	Equals the sum of accounting write-down for 2007 and 2008	Bloomberg and 10-K, 10-Q
Controls		
Size	Equals the natural logarithm of Total Assets	Compustat
Revenue	Equals the natural logarithm of Total Revenue	Compustat
Market-to-Book	Equals the market value of equity divided by the book value of equity	Compustat
Director Ownership	Equals the natural logarithm of the median director dollar stockholding as of the beginning of the year	RiskMetrics and proxy statement
CEO Ownership	Equals the percentage of CEO stock ownership as of the beginning of the year	RiskMetrics and proxy statement
Firm Age	Firm age, calculated as the difference between the sample year and the year that firm's first appearance in the CRSP monthly stock return database	CRSP, Compustat
Leverage	Equal Total Liabilities divided by Total Assets	Compustat
Investment Bank	A dummy variable that equals 1 if investment bank and 0 otherwise	Compustat
Insurance Company	A dummy variable that equals 1 if insurance company and 0 otherwise	Compustat
Crisis Period dummy	A dummy variable that equals 1 if the observation occurs during the financial crisis years of 2007, 2008 or 2009 and 0 otherwise	Compustat

Appendix B

Estimation of Merton's distance to default

According to Duffie et al. (2007), the distance to default is defined (DD) as:

$$DD = \frac{\ln\left(\frac{V}{F}\right) + (\mu - 0.5\sigma_V^2)T}{\sigma_V\sqrt{T}}$$

where V is the current firm value, F, known as the default point in practice, is the face value of the firm's debt, μ and σ_V are expected annual return and volatility of the firm's assets, respectively, T is forecast horizon. Calculation of DD would be straightforward if V and σ_V were known. Instead they are estimated using the following two equations. The first equation is the call option pricing formula based on Merton (1974):

$$E = VN(d_1) - e^{-rT}FN(d_2)$$

where E is the value of equity and r is the risk-free rate and N is the cumulative density function of the standard normal distribution; d_1 and d_2 are defined as the following:

$$d_1 = \frac{\ln\left(\frac{V}{F}\right) + (r + 0.5\sigma_V^2)T}{\sigma_V\sqrt{T}}$$

$$d_2 = d_1 - \sigma_V\sqrt{T}$$

The second equation relates the volatilities of firms' assets to equity using Ito's formula:

$$\sigma_E = \left(\frac{V}{F}\right)N(d_1)\sigma_V$$

Following Duffie et al. (2007) and Bharath and Shumway (2008), the default point F is measured as the short term debt plus one half of its long-term debt, based on the quarterly Compustat data file. The forecast horizon T is measured as one year. The risk-free rate is measured as the one-year T-bill rate. Equity value E is measured as the number of shares outstanding times daily stock price based on CRSP database. We utilize an iterative procedure described in Bharath and Shumway (2008) to calculate the value of the monthly DD for each firm in our sample and then aggregate them into yearly data by taking a simple average of the monthly DD value.

Appendix C

Two-Stage Least Square (2SLS) IV regression of firm size on risk-taking, Larger sample without Director Ownership as control

This table presents the two-stage least squares (2SLS) regression analysis estimating Eqs. (2) and (3) on the relationship between firm size and risk-taking. Robust Regressions estimation is used in the second stage analyses. In Panel A the natural logarithm of *Total Assets* is the measure of size; in Panel B the natural logarithm of *Total Revenue* is the measure of size. The models do not include *Director Ownership* and *CEO Ownership* variables in order to increase the usable sample size. *Market-to-Book* is the market-to-book for the year. *Firm Age* is the age of the firm in each year. *Investment Bank* is an indicator variable equal to 1 if the firm is an investment bank and 0 otherwise. *Insurance Company* is an indicator variable equal to 1 if the firm is an insurance company and 0 otherwise. *Financial Crisis dummy* is an indicator variable equal to 1 if the observation occurs during 2007–2009 and 0 otherwise. Coefficients are provided with standard errors below in parenthesis. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

	Dependent Variable:			
	ln (*Z-Score*)	ln (Merton Distance to Default)	ln (Naïve Distance to Default)	Probability of Default (Merton)
	Robust	Robust	Robust	Robust
	(1)	(2)	(3)	(4)
Panel A: Second-stage regression, predicting risk-taking, Assets as measure of size, Larger sample without Director Ownership as control				
Assets (ln)	−0.017*	−0.085**	−0.047**	0.026***
	(*0.009*)	(*0.040*)	(*0.022*)	(*0.008*)
Market-to-Book	0.172**	0.726*	0.268*	−0.055**
	(*0.079*)	(*0.401*)	(*0.153*)	(*0.022*)
Firm Age	0.024**	0.031*	0.024	−0.008**
	(*0.010*)	(*0.018*)	(*0.200*)	(*0.004*)
Investment Bank	−0.070***	−0.054***	−0.125***	0.017***
	(*0.012*)	(*0.010*)	(*0.043*)	(*0.005*)
Insurance Company	0.104*	0.418	0.137*	−0.026
	(*0.062*)	(*0.689*)	(*0.075*)	(*0.057*)
Crisis Period	−2.0455***	−1.522***	−2.869***	0.0358***
dummy	(*0.351*)	(*0.224*)	(*0.802*)	(*0.061*)
Constant	4.075***	6.703***	2.134***	−0.278***
	(*0.428*)	(*0.925*)	(*0.429*)	(*0.064*)
Year Controls	Yes	Yes	Yes	Yes
Sample Period	2002–2012	2002–2012	2002–2012	2002–2012
# of Observations	6273	4359	4359	4359
R-Squared	0.292	0.528	0.187	0.205
	Dependent Variable:			
	ln (Z-Score)	ln (Merton Distance to Default)	ln (Naïve Distance to Default)	Probability of Default (Merton)
	Robust	Robust	Robust	Robust
	(1)	(2)	(3)	(4)
Panel B: Second-stage regression, predicting risk-taking, Revenue as measure of size, Larger sample without Director Ownership as control				
Revenue (ln)	−0.048**	−0.072*	−0.041**	0.029***
	(*0.021*)	(*0.045*)	(*0.019*)	(*0.010*)
Market-to-Book	0.414*	0.325	0.277**	−0.051
	(*0.269*)	(*0.418*)	(*0.133*)	(*0.062*)
Firm Age	0.027**	0.070**	0.026*	−0.010**
	(*0.013*)	(*0.034*)	(*0.015*)	(*0.005*)
Investment Bank	−0.128***	−0.152***	−0.130***	0.024***
	(*0.032*)	(*0.041*)	(*0.049*)	(*0.007*)
Insurance Company	0.144*	0.287	0.112*	−0.046*
	(*0.083*)	(*0.598*)	(*0.060*)	(*0.030*)
Crisis Period	−2.661***	−3.074***	−2.451***	0.253***
dummy	(*0.721*)	(*0.482*)	(*0.908*)	(*0.071*)
Constant	2.089***	3.071***	2.439***	−0.418***
	(*0.417*)	(*0.568*)	(*0.711*)	(*0.086*)
Year Controls	Yes	Yes	Yes	Yes
Sample Period	2002–2012	2002–2012	2002–2012	2002–2012
# of Observations	6273	4359	4359	4359
R-Squared	0.198	0.197	0.175	0.227

Italic values are standard errors associated with coefficient estimates.

Appendix D

Endogeneity and instrument validity tests

Hausman (1978) test for endogeneity – This tests for differences between the OLS (or one-stage robust regressions) and IV estimates. The test statistic normalizes the differences in coefficients by the differences in standard errors. Large differences between OLS and IV will result in large test statistics and low p-values, suggesting that endogeneity is a problem and that the IV results are more consistent than OLS results.

Stock and Yogo (2005) test for weak instruments – This test evaluates the strength of the first stage regression by considering the *F*-statistic of the reduced form first stage regression of excluded instruments. High *F*-statistics and low p-values suggest strong instruments. (This test was derived from the Cragg and Donald (1993) test. The two tests are the same when there is only one endogenous regressor, as is the case in our study.)

Hahn and Hausman (2002) test for instrument validity – This test is a variation of the Hausman (1978) test for endogeneity, applied to the instruments rather than the specification. This test compares the 'forward' and 'reverse' IV estimates. If the instruments are valid, the difference between the 'forward' and the inverse of the 'reverse' estimates should be small, leading to large test statistics and small p-values.

Hansen-Sargan – This is a test for overidentifying restrictions, testing the joint significance of the set of endogenous variables in the system of equations. It has a Chi-square distribution (with degrees of freedom equal to the number of instruments minus the number of parameters), and the null hypothesis is that the instruments are valid. Large p-values suggest that the instruments are valid.

Anderson-Rubin – This is a test of the joint significance of a set of endogenous variables in a system of equations. It tests for the joint significance of the excluded instruments by essentially substituting the first-stage reduced-form equations into the second-stage structural equations. The test statistic has a Chi-square distribution; large test statistics and small p-values suggest instrument validity and joint significance of the system.

Shea (1997) Partial R^2 – This test provides the partial R^2 for the excluded instruments on the fitted value of the endogenous regressors. Higher partial R^2 values are deemed to represent valid instruments, although there is no formal test statistic.

Instruments: In our instrumental variables tests, we use 3 instruments for firm size: *Delaware,* a dummy variable equal to 1 if the firm is incorporated in Delaware, and equal to 0 otherwise, *Number of Employees,* the natural logarithm of the total number of employees at the institution in each year, and *PP & E*, the natural logarithm of net property, plant and equipment at the institution in each year.

The following table presents the results from performing our endogeneity and weak instruments tests in estimating Eq. (1) with two-stage least squares analysis (2SLS). Brief descriptions of each test are given above. In the first stage, fitted values of firm size (*ln(Assets)*) are obtained; in the second stage, those fitted values are regressed on five different risk measures: *ln(Z-score)*, *ln (Merton Distance to Default)*, standard deviation of daily stock returns (*σ(RET)*), the natural logarithm of the cumulative accounting write-downs during 2007–2008, and the ratio of cumulative accounting write-downs to total assets. The Hausman (1978) is a test for endogeneity, comparing the one-stage robust regression estimation and 2SLS results; the other tests in this table are various tests of evaluating the strength and/or relevance of the instruments used in the instrumental variables analyses. The far right column, General Inference, provides a qualitative assessment of the findings from each test. For the Stock and Yogo (2005) test, the first-stage *F*-statistic is given. For the Shea Partial R^2, the *p*-value is given for the first-stage equation. For the other tests, the *p*-value is given for the second stage equation.

	Risk Measure					Inference
	ln (Z-Score)	ln (Merton Distance to Default)	Stock Volatility	ln (Write-downs)	Write-downs/Assets	
Endogeneity Test						
Hausman Test	0.943	0.973	0.936	0.940	0.981	High *p*-values. No measurement error. Endogeneity is not affecting the model
Instruments Tests						
Stock & Yogo	20.630	20.630	20.630	20.630	20.630	First-stage *F*-statistic higher than Stock & Yogo critical value. Instruments are strong
Hahn & Hausman	0.003	0.002	0.003	0.002	0.004	Low *p*-values. There is little difference between the 'forward' and 'reverse' IV estimates. Instruments are valid
Hansen-Sargan	0.991	0.920	0.938	0.968	0.908	High *p*-values. Instruments are valid
Anderson-Rubin	0.030	0.025	0.026	0.021	0.022	Low *p*-values on excluded instruments. Instruments are significant
Shea Partial R^2	0.089	0.089	0.089	0.089	0.089	Relatively low R^2 but high *t*-statistics on instruments. Instruments deemed adequate

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