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The Risk Sensitivity of Capital Requirements: Evidence from an International Sample of Large Banks

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Abstract

Using an international sample of large banks between 2000 and 2010, we evaluate the risk sensitivity of minimum capital requirements. Our results show that risk-weighted assets (the regulatory measure of portfolio risk which determines minimum capital requirements) are ill-calibrated to a market measure of bank portfolio risk. We show that this low-risk sensitivity of capital requirements permits banks to build up capital buffers by underreporting their portfolio risk and undermines banks' ability to withstand adverse shocks. While the risk sensitivity of capital requirements is higher for banks that have adopted Basel II, it remains low across banks and countries.

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1. Introduction

This paper explores a simple and yet unanswered question. To what extent are minimum capital requirements sensitive to the portfolio risk of banks? Risk-sensitive capital requirements are a keystone of international capital regulation. Their purpose is to prevent bank shareholders from investing in risky assets in order to capitalize on underpriced government bailout guarantees (Kim and Santomero, 1988; Rochet, 1992). However, the effectiveness of risk-based capital regulation in preventing shareholders from taking excessive risks rests on the extent to which capital requirements are an accurate reflection of the portfolio risk of each bank. Discrepancies between capital requirements and bank portfolio risk allow banks to game the system by investing in assets which maximize returns while reducing capital requirements in favor of more levered activities (Jones, 2000; Acharya, Schnabl and Suarez, 2013; Hellwig, 2010).

The financial crisis that started in 2007 illustrates that, despite numerous refinements and revisions over the last two decades, capital adequacy rules have failed to ensure that regulatory capital requirements are in line with the riskiness of bank assets. From the onset of the financial crisis, fears that banks hold insufficient capital have raised doubts over bank solvency and critically undermined the functioning of interbank markets.[*] Some commentators argue that one reason why banks held insufficient capital as they entered the crisis was because regulatory capital requirements were insufficiently attuned to the riskiness of bank activities (Acharya and Richardson, 2009; Basel Committee, 2009; 2011; Hellwig, 2010). When banks are not subject to regulatory capital requirements which are commensurate with their portfolio risk, bank solvency is likely to be at stake during adverse shocks to the value of bank asset portfolios.

In this paper, we empirically assess the risk sensitivity of capital requirements to bank portfolio risk. Our empirical strategy is to estimate the extent to which increases in risk-weighted

[*] See for example, 'Basel Accord sits at the root of the ongoing banking crisis', *Financial Times* (7 November 2007); 'Turmoil reveals the inadequacy of Basel II, *Financial Times* (27 February 2008); 'Basel: the mouse that did not roar', *Financial Times*, (15 September 2010).

assets (RWA)—the regulatory measure of bank portfolio risk which determines minimum capital requirements—are linked to increases in a market measure of portfolio risk. The main market measure of portfolio risk we use is the standard deviation of bank asset returns derived from option pricing theory (Ronn and Verma, 1986; Flannery and Rangan, 2008). Since we contrast RWA (via its implications for minimum capital requirements) with asset volatility, our paper effectively contrasts the regulatory and the market perception of bank portfolio risk.

Our sampling period includes banks that report RWA according to both the original Basel Accord on capital requirements and the Basel II revisions (effective from 2007 in many countries), but ends before additional revisions (Basel III) will have been fully implemented by 2018. Still, our paper has important implications for Basel III for two reasons. First, the Basel III proposals are motivated by the perceived failings of capital regulations with respect to their risk sensitivity before the financial crisis (Basel Committee, 2009; 2010). As our paper focuses on Basel I and II, we can shed light on the extent to which such criticisms are justified. Second, because Basel III maintains many of the defining features of the previous Accords (see Hellwig, 2010), intrinsic flaws in the risk sensitivity of Basel I and II, which we study in this paper, are bound to carry over and will also be present under Basel III. The Basel Committee (2011, pg. 31) estimates that RWA under Basel III will increase by no more than 23 percent for large banks relative to Basel II. Whether this increase in RWA is likely to be sufficient (or, alternatively, whether substantially larger increases in RWA are warranted; see Admati, DeMarzo, Hellwig, and Pfleiderer, 2010; Miles, Marcheggiano and Yang, 2012) will depend on the risk sensitivity of capital requirements under Basel I and Basel II.

By way of preview, we start the analysis by examining the risk sensitivity of capital requirements for an international sample of large banks between 2000 and 2010. We demonstrate that capital requirements are only loosely related to our market measure of the portfolio risk of banks. Owing to this weak risk calibration, even pronounced increases in portfolio risk generate almost negligible increases in capital requirements. To illustrate this, we show that when annual portfolio risk increases nearly threefold (from 2.1 percent to 6.2 percent), the average bank in our sample faces additional capital requirements of 0.78 percentage points (assuming capital requirements of 8 percent of RWA).

Next, we inspect the annual reports of each sample bank to identify banks that report RWA according to Basel II. Our results show that under Basel II banks display only a marginal improvement in the risk sensitivity of their capital requirements. Most importantly, however, the internal ratings-based (IRB) approach under Basel II has introduced asymmetric risk elasticities for low- and high-risk bank portfolios. While banks with low-risk portfolios reduce their capital requirements when adopting the IRB approach, banks with high-risk portfolios are not required to hold significantly more capital. This implies that banks with the riskiest asset portfolios are particularly at risk of holding insufficient capital under Basel II.

Asset volatility is affected by many factors external to bank management. Therefore, we do not intend to suggest that RWA should exactly track a market measure of bank portfolio risk. However, our results clearly show that the risk sensitivity of capital requirements is very weak and that this has undesirable consequences. First, we show the capital buffers which banks typically hold above regulatory requirements partly result from capital arbitrage. We show this by demonstrating that banks with higher capital buffers report lower amounts of RWA per unit of assets for a given level of portfolio risk. As a result, banks may be undercapitalized in spite of holding capital well above the minimum regulatory requirements (Allen, Carletti and Marquez, 2011). Second, we show that capital arbitrage diminishes banks' ability to withstand adverse shocks. We show that banks that increased their capital buffers markedly during 2008 and 2009 and did so relying at least in part on government support displayed a particularly low risk sensitivity of their capital requirements between 2000 and 2007.

Our paper contributes to previous studies on capital and risk in banking. First, our analysis provides the first empirical investigation which links international capital adequacy rules to a market measure of bank portfolio risk. Previous work on capital and risk has not examined whether international capital requirements are in line with bank risk. Instead, extant empirical work has focused on whether the amount of capital which banks *hold* is in line with bank risk (e.g., Shrieves and Dahl, 1992; Jacques and Nigro, 1997; Calem and Rob, 1999; Peura and Keppo, 2006; Flannery and Rangan, 2008).

Second, our results help explain the repeatedly reported finding that regulatory capital ratios perform poorly in predicting bankruptcy and distress more generally in the banking industry (e.g., Estrella, Park and Peristiani, 2000; IMF, 2009). In essence, our results show that before 2008 banks built up regulatory capital buffers via capital arbitrage, which allowed them to hold sizable capital buffers and yet remain intrinsically undercapitalized (see Allen et al., 2011) .

Finally, our results can be used as a benchmark for impending Basel III capital adequacy rules and, therefore, contribute to work which examines the effects of ongoing revisions of the Basel Accord (Feess and Hege, 2011; Kashyap, Stein and Hanson, 2010; Admati et al., 2010). Based on the projected 23 percent increase in risk-weighted assets for large banks under Basel III relative to Basel II (Basel Committee, 2011, pg. 31), we estimate that Basel III will require banks in our sample to hold, on average, no more than 1.20 percent of additional capital per unit of assets under a minimum regulatory capital ratio of 8 percent (and no more than 1.94 percent if the minimum capital ratio is 13 percent).[†] This shows that Basel III hardly represents a systemic overhaul in terms of capital regulation. From the results reported in this paper, it is therefore questionable whether the targeted increases in the risk sensitivity of capital requirements will be sufficient to ensure that capital requirements will become commensurate with bank portfolio risk under Basel III.

We organize the paper as follows. The next section describes the background and conceptual framework of our study. Sections 3 and 4 explain our sampling and our methodological approaches respectively. Section 5 reports the main results on the risk sensitivity of capital requirements. We examine whether Basel II has improved the risk sensitivity of capital requirements in Section 6.

[†] We derive these figures by adjusting the values of RWA for each bank to a 23 percent increase in RWA. We then compute the difference in minimum capital requirements per unit of assets relative to the original values of RWA.

Section 7 examines whether bank capital buffers above minimum regulatory requirements influence the risk sensitivity of capital requirements. Section 8 presents the results of additional anlyses and the final section concludes.

2. Background and Conceptual Framework: How Risk-Sensitive are Regulatory Capital Requirements?

Capital regulation has been designed to improve the safety and soundness of banks. Its theoretical foundations rest on the view that absent minimum regulatory requirements for capital banks will hold insufficient capital to absorb losses. In essence, bank shareholders will take on high portfolio risks in an attempt to maximize the value of deposit insurance and other implicit or explicit government guarantees. Capital regulation may offset incentives for bank shareholders to shift risk. If banks are required to hold capital as an increasing function of portfolio risk, shareholders will be forced to absorb the losses linked to bank risk taking (e.g., Sharpe, 1978; Furlong and Keeley, 1989; Calem and Rob, 1999). However, Kim and Santomero (1988) and Rochet (1992) show that if capital requirements do not accurately reflect portfolio risk, they distort a bank's risk choices towards more risky assets. This is because shareholders seek to offset the negative effect of additional capital holdings on expected returns by making riskier portfolio choices.[‡]

It follows from this that if capital regulation is to prevent banks from holding excessively risky asset portfolios, regulatory capital requirements ought to be highly calibrated to the riskiness of

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[‡] Arguably, weak risk calibration is only one of several aspects of capital regulation which can cause banks to shift risk. Various authors have examined other behavioral implications of capital regulation which could also encourage Risk-shifting. For instance, Furlong and Keeley (1989) and Calem and Rob (1999) argue whether capital regulations ensue risk-taking depends on the overall capital holdings of a bank (generally, lower holdings generate gambling-type risky behaviour). Repullo and Suarez (2004), and Kopecky and VanHoose (2006) look at the effect that capital regulations have on loan rationing (and therefore indirectly at the composition of a bank's asset portfolios). Repullo (2004) looks at the role of competition and Peura and Keppo (2006) and Flannery and Rangan (2008) at market discipline in affecting the effect of capital rules on bank risk-taking.

bank assets. To this end, the Basel Committee of Banking Supervision recommended common risk-based bank capital adequacy rules across most countries. The Basel Accord of 1988 introduced minimum standards for capital as a fixed proportion of the risk exposure of a bank, which is measured using the volume of risk-weighted assets (RWA).[§] RWA are the weighted sum of various on- and off-balance sheet exposures which, owing to revisions to the Accord in the mid-nineties, also include market risk.

The Basel II revisions introduced important changes to the algorithm used to determine a bank's risk exposures to make 'the Framework more risk-sensitive than the 1988 Accord' (Basel Committee, 2006a, pg. 17). The primary mechanisms used to enhance the sensitivity of capital requirements to bank portfolio risk was the introduction of more granular risk weights (which also included operational risk) and to grant banks some choice over the risk weights they apply.

Critical for our paper is the notion that under capital adequacy rules, the risk weights assigned to each asset class reflect a regulatory assessment of the economic risks associated with this type of asset. From its inception, the risk-weighting methodology has been criticized as insufficiently fine-tuned to distinguish between the riskiness of different portfolio choices of banks in an accurate manner (Avery and Berger, 1991; Jones, 2000; Hellwig, 2010).[**] Indeed, a number of studies have confirmed the existence of conceptual weaknesses in the Basel risk-weighting approach. For instance, Jacques and Nigro (1997) observe that the proportion of risk weighted to total assets is negatively

[§] The Basel Accord also defines the types of assets which qualify as capital. While national regulators may draw up slightly different rules, generally a distinction is made between Tier 1 capital (which is largely restricted to equity) and Tier 2 capital (mainly in the form of loan loss allowances and subordinated debt). National regulators will require banks to hold capital as a fixed percentage of risk-weighted assets, the sum of which is typically no less than 8 percent of RWA.

related to the capital holdings of U.S. banks in the first year that the Basel Accord took effect. Estrella, Park and Peristiani (2000) show that risk-adjusted capital ratios did not outperform simple capital to (unweighted) asset ratios when predicting U.S. bank failures in the early 1990s. An IMF (2009) study shows that banks in Europe and the U.S. that received capital assistance from governments during 2008–09 displayed *higher* regulatory capital ratios over the preceding decade than banks that were not in need of government assistance.

Discrepancies between the regulatory assessment and the economic risks of bank assets incentivize banks to engage in capital arbitrage which will further corrode the sensitivity of capital requirements with respect to portfolio risk (Merton, 1995; Jones, 2000). Capital arbitrage is particularly advantageous for banks that view raising capital as expensive and that will, therefore, seek to avoid holding capital above levels they deem optimal. Ultimately, such arbitrage activities will result in a riskier banking sector where capital requirements bear little relation to the economic risks of bank portfolios.

In response to these criticisms, additional revisions to the capital adequacy Framework (Basel III), which will gradually be phased in until 2018, have recently been proposed (see Basel Committee, 2009; 2010).[††] However, Basel III will maintain many of the defining features of the previous Basel Accords, above all the general risk-weighting approach (Hellwig, 2010; Admati et al., 2010). The

[**] Concerns over the accuracy of the risk weights and capital arbitrage which will result have accompanied both Basel I and Basel II. See for instance, 'Thank Basel for Credit Crunch', *Wall Street Journal*, 4 November 1992; 'Basel II under Fire - Further Revisions to the New Bank Capital Accord Are Needed', *Financial Times*, 21 August 2003; 'How Banks Learned to Play the System', *Financial Times*, 7 May 2009.

[††] Basel III will introduce important changes with potential consequences for the risk-sensitivity of capital requirements. Inter alia, Basel III will introduce higher risk weights for securitizations and off-balance sheet activities and, more generally, mandate increases in both the quantity and quality of capital requirements (for instance, Tier 1 capital will increase from 4 percent to 6 percent of RWA). Also, the Basel rules will require non-U.S. banks to maintain a non-risk-based leverage ratio for the first time (this ratio will be limited to 3 percent of total assets and it will be netted against risk-based capital requirements).

extent to which regulatory capital requirements reflect the portfolio risk of a bank, therefore, remains an important issue—not only against the background of the apparent failings of risk-based capital rules in the recent past, but also because risk-based capital requirements will continue to play a key role in international capital regulation.

3. The Sample

To analyze the risk sensitivity of capital requirements, we build a cross-country sample of large listed banking organizations. We focus on large banks, because the systemic relevance of large banks makes it particularly advantageous for them to make risky asset choices in order to maximize the value of the safety net.

We start by collecting the 650 largest banks (by USD assets) listed on Datastream on a yearly basis between 2000 and 2010.[‡‡] In order to implement the Generalized Method of Moments (GMM) systems estimator described in Section 4.2, we require that sample banks have at least five consecutive years of equity return data on Datastream and five years of accounting data on Bureau van Dijk's Bankscope database. Applying these sample criteria yields an initial sample of 4,575 observations.

Next, we exclude cooperative banks, government-owned institutions, long-term credit banks and Islamic banks, because the risk choices and capital management decisions at these institutions are less likely to be driven by shareholder value considerations. Finally, we omit regional banks in Japan, because, in contrast to the rest of the sample, the regulatory capital requirements of these institutions

[‡‡] Our sample therefore excludes pure investment banks that are not consistently (across time and countries) subject to the Basel Accord.

are not stipulated by the Basel Accord.[§§] The application of these selection criteria reduces the sample size by more than 1,000 observations.

*******TABLE 1 HERE******

Furthermore, since some capital management decisions are likely to be made at the level of the holding company rather than at subsidiary-level, we omit banks that are subsidiaries of other banking firms from our sample. We obtain data on the ownership structure as of the last fiscal year from Bankscope to identify a bank as a subsidiary if a single shareholder directly or indirectly holds a majority (>50 percent) of the voting equity. Since Bankscope does not provide ownership data before the last fiscal year for which data are reported, we inspect banks that Bankscope identifies as having a majority shareholder to determine how long the majority shareholding has existed.[***] We use Thomson Ownership as well as 13f filings (for U.S. banks) to retrieve historical ownership data. We augment this with acquisition data from Thomson Financial Mergers and Acquisitions (M&A) database, because M&A are the most frequent mode by which independent banks in our sample become subsidiaries. If we are still unable to determine the fiscal year in which a bank became a subsidiary, we run news searches using LexisNexis and Factiva. Finally, we hand-collect missing data on regulatory capital and RWA from annual reports to recover a total of 348 bank-year observations.

Table 1 reports the distribution of the final sample by country and year. Panel A shows that the sample consists of 246 unique banks chartered in 41 countries. The total number of observations

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[§§] The capital adequacy rules pertaining to regional banks in Japan differ in the way that risk-weighted assets are computed. Also, regional banks in Japan are subject to a reduced minimum regulatory capital ratio of 4 percent. The lower regulatory capital requirements may affect capital management practices at Japanese regional banks, for instance by reducing banks' incentives to engage in regulatory capital arbitrage.

[***] If we were to omit all banks that have a majority shareholder in the last fiscal year for the duration of the entire sample period, this could introduce a serious selection bias. For instance, by doing so, we might well exclude many underperforming and distressed institutions which had become acquisition targets earlier in the sampling period.

equals 2,272 with the average bank entering the sample for approximately nine years. Panel B shows that the yearly number of unique banks ranges between 178 (in 2000) and 236 (in 2005).

4. Methods

4.1 REGULATORY AND MARKET ASSESSMENT OF BANK PORTFOLIO RISK

To examine the degree to which risk-based capital requirements are reflective of the portfolio risk of a bank, we compare the bank risk assessment undertaken by regulators with a market-based measure of portfolio risk.

Following Avery and Berger (1991), Shrieves and Dahl (1992), Berger (1995) and others, the bank risk assessment undertaken by regulators, RWATA, is computed as the proportion of risk-weighted assets in total assets (TA). Under the original Basel Accord, this ratio reflects credit risk and market risk exposures as follows:

$$RWATA = (RWA_{CR} + 12.5*C\_RWA_{MR})/TA = (RWA_{CR}+RWA_{MR})/TA \qquad (1)$$

where RWA_{CR} is the volume of risk-weighted assets linked to a bank's credit risk exposure (based on the risk weights for on- and off-balance assets). C_RWA_{MR} is the amount of capital required for market risk exposure which is converted into the equivalent amount of risk-weighted assets by multiplying it by 12.5 $\left(\text{i.e. } \frac{1}{8}\%\right)$.

Basel II introduces a different weighting system for credit risk by giving banks the possibility to opt either for the standardized approach or for the internal rating-based (IRB) approach when determining capital adequacy. Further, Basel II introduces capital requirements for operational risk. Thus, under Basel II the ratio of RWA to total assets can be expressed as follows:

$$RWATA = [RWA_{CR\_SD(IRB)} + 12.5*(C\_RWA_{MR} + C\_RWA_{OR})]/TA = (RWA_{CR} + RWA_{MR} + RWA_{OR})/TA, \qquad (2)$$

where $RWA_{CR\_SD(IRB)}$ is the volume of risk-weighted assets linked to a bank's credit risk exposure (based on either the standardized [SD] or the IRB approach), and C_RWA_{MR} and C_RWA_{OR} are the amount of capital required for market risk and operational risk exposure respectively. As under Basel I, C_RWA_{M} and C_RWA_{OR} are then converted into the equivalent amount of risk-weighted assets by multiplying them by 12.5. In Equations (1) and (2), RWA will be mostly driven by credit risk exposure if banks have a strong lending focus.

In this paper, we contrast the regulatory risk assessment underlying capital requirements with a market measure of each bank's asset volatility. We follow Ronn and Verma (1986), Flannery and Sorescu (1996) and Flannery and Rangan (2008) and derive a bank's asset volatility by using the market value of equity to solve the asset value and its volatility. Asset volatility is a suitable measure for portfolio risk, because it reflects both asset and liability returns as well as changes in off-balance items and operating efficiencies. By contrast, other market measures of bank risk (most notably, measures of bank default risk) are less suited to capture portfolio risk not least because these indicators are themselves functions of bank capital strength.[†††]

We infer asset volatility ($\sigma_{A,t}$) using an iterative process based on the Black-Scholes-Merton pricing model. We express the market value of a bank's equity ($V_{E,t}$) as a function of the (unobservable) market value of assets ($V_{A,t}$) by solving the following system of nonlinear equations:

$$V_{E,t} = V_{A,t} N(d_{1,t}) - L_t e^{-r_f T} N(d_{2,t}) \tag{3}$$

$$\sigma_{E,t} = \left(\frac{V_{A,t}}{V_{E,t}} \right) N(d_{1,t}) \sigma_{A,t} \tag{4}$$

[†††] The default risk of a bank is not only determined by the riskiness of its assets, but also by the amount of capital that banks hold against their asset portfolios. Consequently, two banks with identical portfolio risk may display very different levels of default risk if their capital holdings are different (see Nier and Baumann, 2006; Flannery and Rangan, 2008).

Equation (3) defines $V_{E,t}$ as a call option on the market value of the bank's total assets, where $N(\cdot)$ is the cumulative normal distribution, L_t is total liabilities, $d_{1,t} = \dfrac{\ln\left(V_{A,t} / L_t\right) + \left(r_{f_t} + 0.5\sigma_{A,t}\right)T}{\sigma_{A,t}T}$ and $d_{2,t} = d_{1,t} - \sigma_{A,t}T$. Equation (3) is the optimal hedge equation that relates the standard deviation of daily equity returns in a given year to the standard deviation of daily asset returns (both expressed on an annualized basis with T=1).

To solve this system of equations and to extract $\sigma_{A,t}$ for each bank at yearly intervals, we employ as starting values for $\sigma_{A,t}$ the historical annualized yearly standard deviation of equity returns multiplied by the ratio of the market value of equity to the sum of the market value of equity and the book value of total liabilities, i.e. $\sigma_{A,t} = \sigma_{E,t}V_{E,t} / \left(V_{E,t} + L_t\right)$. Finally, a Newton search algorithm identifies the yearly values for $V_{A.t}$ and $\sigma_{A,t}$ in an iterative process. The resulting portfolio risk measure ($\sigma_{A,t}$) is expressed in percentage terms and shows a positive correlation with the regulatory risk assessment (RWATA). Over the full sample period, the correlation is 26.7 percent (significantly different from zero).

Table 2 presents univariate tests on the relationship between the risk assessment underlying regulatory capital requirements and the market measure of portfolio risk (σ_A). Panel A presents the mean and median values of RWATA by different levels of asset volatility. We distinguish between banks with a low portfolio risk (where asset volatility is below the median of the sample distribution) and banks with a high portfolio risk (where asset volatility is above the median of the sample distribution). Two main findings become obvious. First, the two groups differ markedly in terms of the market assessment of the riskiness of their asset portfolios. Average asset volatility in the high-volatility group is 6.2 percent, which is almost three times higher than the average asset volatility of 2.1 percent reported for low-volatility banks (mean and median differences are statistically significant at 1 percent according to a *t*-test and z-test respectively). Second, when we compare the regulatory risk exposure based on capital requirements across the two groups, we find that the average RWATA in high-volatility banks is higher than in low-volatility banks (69.9 percent compared to 60.1 percent; the difference is statistically significant at the 1 percent level).

*******TABLE 2 HERE******

However, it would be misleading to infer from the finding that banks with higher asset volatility hold more RWA, that RWATA are related to asset volatility in a meaningful way. Under the assumption that the minimum regulatory capital ratio is fixed at 8 percent of RWA, an increase in RWATA of nearly 10 percentage points (i.e. the difference in RWATA between banks with low and high portfolio risk) causes regulatory capital to increase by less than 0.8 percentage points. In other words, banks that triple their asset volatility are required to hold less than 0.8 percentage points of additional capital in order to comply with risk-based capital regulations. Evidently, regulatory capital requirements are very weakly related to bank portfolio risk.[‡‡‡]

During 2007–2010, our sample includes banks that report RWA based on either Basel I or Basel II.[§§§] We inspect banks' annual reports to identify the capital regime under which banks report RWA in each bank-year observation. Panel B of Table 2 reports RWA for low- and high-risk portfolios for banks under Basel I and Basel II from 2007–2010. The results show that while highly volatile portfolios are associated with higher values of RWA under both capital regimes (significant at

[‡‡‡] In fact, so low is the risk sensitivity of capital requirements during the sample period that even under the proposed Basel III revisions which are designed to be more risk-sensitive than previous capital adequacy regimes, our overall conclusion of weak risk sensitivity is unlikely to be significantly affected. The Basel Committee (2011) estimates Basel III is expected to increase RWA by 23 percent for the average large bank. Therefore, it appears unlikely that under Basel III, banks that move from a low- to a high-risk portfolio will face increases in regulatory capital requirements which are aligned with the riskiness of their assets.

[§§§] Most banks in our sample, which have adopted Basel II, did so in 2007. However, there are some noticeable exceptions. Some Japanese banks adopted Basel II in 2006 and some banks in Kuwait adopted Basel II as early as 2005.

the 1 percent level), any increases in capital requirements as banks move from low- to high-risk portfolios remain marginal.

Panel B of Table 2 also offers some indications that the risk sensitivity of capital requirements differs across bank capital regimes. First, banks face higher increases in minimum capital requirements under Basel II than Basel I if they move from low- to high-risk portfolios (the average increase is 0.85 percent under Basel II compared with 0.47 percent under Basel I; difference significant at the 1 percent level). Second, banks report lower values of RWATA (statistically significant at the 1 percent level) under Basel II than Basel I especially when banks hold low-risk portfolios. The latter finding is consistent with a cross-country Quantitative Impact Study conducted by the Basel Committee (2006b), which predicts a decrease in minimum capital requirements for banks adopting Basel II relative to Basel I for a given level of portfolio risk.

The results in Table 2 can only be seen as preliminary and as motivating additional analyses. This is because the proportion of RWA to total assets depends on several bank and environmental factors such as the composition of a bank's asset portfolio (e.g. the volume of RWA is a function of credit risk exposure). We discuss these and other factors in the next subsection, which develops an informal model of the various factors which may affect the sensitivity of capital requirements to the asset volatility of banking firms.

4.2 ECONOMETRIC MODEL

This section describes the baseline specification that we employ to estimate the relationship between RWATA and asset volatility as well as a set of control variables. To study the sensitivity of regulatory capital requirements to the market assessment of a bank portfolio risk exposure, we employ the following baseline model:

$$\mathrm{RWATA}_{i,t} = \alpha_0 + \beta_1 \times \mathrm{RWATA}_{i,t-1} + \beta_2 \times \text{asset volatility}_{i,t} + \delta' \mathbf{CONTROLS} + \varepsilon_{i,t} \tag{5}$$

where RWATA are risk-weighted assets scaled by total assets, asset volatility is the volatility of bank assets (see Section 4.1) and CONTROLS is a vector of control variables which includes bank, country characteristics and time dummies. The key coefficient for our analysis is β_2 which represents the first derivative of RWATA with respect to asset volatility. Thus, β_2 captures the sensitivity of RWATA to changes in our market measure of portfolio risk.

Equation (5) suffers from potential endogeneity of several right-hand side variables. Endogeneity concerns are particularly pressing considering that the market assessment of a bank's portfolio risk (asset volatility) may in part be determined by the regulatory assessment of portfolio risk (as embodied in RWATA). For instance, persistent growth in RWATA may cause market investors to upwardly adjust their assessment of a bank's portfolio risk. Likewise, there are endogeneity issues amongst some of the explanatory variables. For instance, it is well-documented that banks adjust capital buffers and risk weighted assets simultaneously (Shrieves and Dahl, 1992; Rime, 2001).

The system Generalized Method of Moments (GMM) estimator proposed by Blundell and Bond (1998) is suited to deal with endogeneity issues by means of appropriate instruments. This is achieved by combining the moment conditions from the first-differenced and the levels equations.[****] To choose the appropriate instruments, we follow an identification strategy similar to Delis and Staikouras (2011). Specifically, instruments are chosen with two objectives in mind.

The first objective is that one set of instruments needs to comply with the identification of the GMM estimation method. We achieve this by exploiting the first lag difference of bank characteristics as instruments in the level equation and second and third lags of bank characteristics as instruments in

[****] The Blundell and Bond (1998) system estimator we employ has two advantages over other dynamic panel data methods, most notably, the difference-in-difference estimator proposed by Arellano and Bond (1991). First, as long as the instruments are valid, the GMM estimator exhibits higher levels of both consistency and efficiency. Second, unlike the difference estimator, the system GMM estimator permits the use of time-invariant (or highly persistent) variables in our specifications. This will be particularly useful when we estimate the impact of the Basel II Accord or regulatory characteristics (both show little variation over time) on the risk sensitivity of regulatory capital requirements.

the difference equation. This approach means that we treat all bank characteristics as endogenous covariates, while treating the country and macro controls as strictly exogenous.

We verify that the instruments are statistically valid using a Hansen *J* test of over-identifying restrictions. Equally, it is economically valid to instrument asset volatility using Δasset volatility$_{t\text{-}1}$ (in the level equation), and asset volatility$_{t\text{-}2}$ and asset volatility$_{t\text{-}3}$ (in the difference equation). Δasset volatility$_{t\text{-}1}$ can be understood as reflecting changes in the economic environment. In the level equation, Δasset volatility$_{t\text{-}1}$ therefore affects the contemporaneous level of asset volatility, but not RWATA.[††††] By the same token, changes in RWATA react slowly to changes in the market assessment of portfolio risk in the difference equation.[‡‡‡‡] The slow response of RWATA to changes in the economic environment could be due to two main reasons. First, the risk weighting embedded in the Basel Framework (especially under Basel I and the standardized approach) is based on fixed weights that do not vary over the business cycle. Second, banks can engage in capital arbitrage by lowering the reported value of RWATA relative to their portfolio risk, thus reducing the link between RWATA and economic fundamentals.

The second objective when choosing instruments is to identify two additional instruments that are correlated with asset volatility but not with RWATA. Given the slow response of RWATA to the business cycle, this is achieved by using the level (first difference) of two country-level variables as instruments in the level (difference) equation: (i) the volatility of the annualized daily yield on one-

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[††††] The correlation between Δasset volatility$_{t\text{-}1}$ and asset volatility (RWATA) is 0.22 (-0.04). Further, in the difference equation, changes in RWATA respond slowly to changes in the market assessment of portfolio risk as indicated by low correlations between ΔRWA and asset volatility$_{t\text{-}2}$ (r=0.06) and ΔRWATA and asset volatility$_{t\text{-}3}$ (r=0.12).

[‡‡‡‡] These instruments show a much higher (negative) correlation with Δasset volatility at -0.34 and -0.18 respectively. The change in asset volatility is more correlated with closer lags. Further, the correlation is negative suggesting banks that are perceived as riskier by the market tend to reduce their risk exposure in future years, possibly in an effort to preserve their competitive position.

year government bonds, computed during the preceding quarter, and (ii) the yearly volatility of the domestic stock market (based on local Datastream market indices). Flannery and Rangan (2008) use a similar set of instruments and argue that these variables capture the external economic conditions that shape the market perceptions of bank portfolio risk. The validity of the additional instruments can be confirmed with reference to correlations. Both the government bond yields and stock market volatility correlate highly with asset volatility (the correlation coefficients, r, are 0.30 and 0.39 respectively), but not with RWATA (r=0.03 and r=-0.08).

The vector CONTROL in Equation (5) includes bank-specific variables and country characteristics. We discuss both of these groups of variables in the following two subsections.

Finally, system GMM specifications may be estimated either via a one-step or a two-step approach. While the one-step estimation produces unbiased standard errors, it is not asymptotically efficient in the estimation of the coefficients. The asymptotically more efficient two-step estimator, on the other hand, tends to bias the estimated standard errors downwards (Blundell and Bond, 1998). In this study, we employ the asymptotically efficient two-step GMM system and use the Windemeijer (2005) procedure to lower the bias and correct the standard errors.

4.2.a Bank-Specific Controls

We include a number of bank-specific control variables. The effect of these variables on RWATA may be due to two reasons. The variables either capture bank incentives to circumvent capital requirements via capital arbitrage (when capital regulations permit banks to underreport the riskiness of their portfolios), or alternatively the variables capture differences in the regulatory treatment of banks' activities (essentially, because the risk weights linked to different bank assets vary).

A first set of variables describes a bank's opportunities and incentives to affect the risk-weighted assets they report by means of capital arbitrage. First, we control for bank size using the log of total assets (in thousands of U.S. dollars). We hold no expectations regarding the effect of bank size on RWATA. On the one hand, large banks may report lower values of RWATA as they may attract a lower regulatory risk assessment of their asset portfolios owing to their ability to engage in capital arbitrage. On the other hand, large banks might be subject to closer regulatory scrutiny due to the negative systemic externalities produced by their failure. As a result, larger banks may find it more difficult to engage in regulatory arbitrage meaning that larger banks display higher values of RWATA for a given level of asset volatility. We also control for bank profitability via return on assets (ROA; defined as net income over total assets). We expect to find a positive relationship between ROA and RWATA, because more profitable banks face fewer incentives to understate the value of risky assets and to engage in regulatory arbitrage more generally.

We also control for the percentage capital buffer (the difference between a bank's regulatory capital ratio and the regulatory minimum). We expect that, after controlling for the level of asset volatility, capital buffers exert a negative effect on RWATA. A negative coefficient on capital buffers is consistent with the view that as capital buffers increase, banks are more prone to engage in capital arbitrage, partly because highly-capitalized banks tend to receive lower levels of regulatory scrutiny (Calem and Rob, 1999). Therefore, we expect higher capital buffers to be associated with lower RWATA as highly-capitalized banks are in a better position to shift more of their activities outside the scrutiny of the Basel Accord.

We control for bank funding using the ratio of total deposits to total liabilities. We expect a positive relationship between deposits and RWATA because deposits pose a relatively stable and cheap form of funding to banks. Banks with a larger deposit base are, therefore, more likely to be accepting of the higher regulatory capital requirements which result from higher values of RWATA and less likely to engage in capital arbitrage.

A second set of variables captures differences in the regulatory treatment of bank activities on RWATA. For instance, we control for a bank's asset composition by including the ratio of net customer loans to total assets. Under the Basel guidelines, the risk weights assigned to customer loans are higher than those applied to other forms of lending such as interbank lending.[§§§§] As a result, we expect that banks with a higher share of loans in their asset portfolio show higher values of RWATA. By the same token, we control for fee-based activities via the proportion of non-interest income in total operating income. Since higher values of this ratio indicate that banks engage in more non-lending or off-balance sheet activities, we expect that non-interest income attracts lower regulatory risk weights (and enters with a negative sign).[*****]

******TABLE 3 HERE******

Finally, to account for differences in the capital adequacy rules followed by banks, we introduce three bank-level indicators to capture if and how banks report RWATA under the Basel II guidelines. These indictors are constructed by inspecting the annual reports of sample banks to determine which of our sample banks have adopted Basel II[†††††] (and which banks continue to report RWATA according to Basel I). The first indicator is a simple binary variable which equals 1 if a bank has adopted Basel II in a given year and 0 otherwise. In a Quantitative Impact Study based on 29 countries, the Basel Committee (2006b) reports that banks that have adopted Basel II have seen minimum capital requirements decrease relative to Basel I for a given level of portfolio risk. We therefore expect that Basel II exerts a negative effect on the risk assessment underlying capital regulations.

[§§§§] The correlation between RWATA and loans in our sample is 51 percent indicating that, while loans are an important component of RWATA, the two variables capture different aspects. Unlike loans, RWATA captures the riskiness of a bank's lending book (by applying different risk weights to different types of loans) and, depending on the capital regime in place, also some off-balance sheet assets. A complete correlation matrix is available from the authors upon request.

[*****] While both loans and non-interest income capture bank business models, they are not highly correlated in our sample (r= 0.386).

[†††††] Overall, there are 401 observations in our sample where the value of risk-weighted assets has been computed on the basis of Basel II.

The other two Basel II indicators control for differences in the approaches banks employ to calculate their risk exposure under Basel II. We construct two binary variables which indicate if a bank has adopted the internal rating-based approach (IRB) or the standardized approach in a given year. Banks may either adopt the standardized approach (with a more granular regulatory definition of risk weights and the external use of ratings for rated borrowers, but no changes for loans to unrated borrowers) or, alternatively, the internal ratings-based approach. The IRB approach relies on a bank's internal risk measures of credit risk to determine regulatory capital requirements. Under the IRB approach, which is believed to be the most risk-sensitive of the Basel II approaches (Basel Committee, 2006b; Hakenes and Schnabel, 2011), banks estimate credit risk based on model estimates of the probability of default using their internal data. These estimates will then serve as inputs for the risk weighting function specified by the Basel Accord. Repullo and Suarez (2004) and Hakenes and Schnabel (2011) argue that the relatively more advantageous treatment of low-risk lending under the IRB approach means that banks with low-risk loans are more likely to adopt the IRB approach. We therefore expect IRB to exert a negative effect on RWATA.

4.2.b Country-Specific Controls

The final group of controls refers to country characteristics. First we control for the size of the shadow banking sector by calculating the value of outstanding securitized assets scaled by GDP. Following an aggregation method described in IMF (2009), we obtain data on the issue date, value and maturity date of all asset-backed securities (ABS) and mortgage-backed securities (MBS) from the SDC New Issues database. Where maturity dates are missing (this affects two percent of all issues), we assume a maturity of thirty years. Values are aggregated as the total principal amount of the entire transaction (across various tranches). We use the data to calculate the sum of all outstanding issues at the end of each calendar year and divide this amount by total GDP.

We expect the size of the shadow banking sector to reduce the proportion of RWATA on a bank's balance sheet. A larger shadow banking system should offer more opportunities for banks to engage in capital arbitrage and to move credit risk exposure out of the reach of capital adequacy regulations. For instance, Acharya and Richardson (2009) argue that under the Basel rules it is more advantageous for U.S. banks to transform loans into highly-rated bonds via securitization and to hold on to these securitized assets than to hold on to the underlying loans. On the other hand, if banks face more opportunities to offload credit risk under capital adequacy rules when the shadow banking system is large, it is conceivable that banks invest in loans which attract higher regulatory risk-weight. Consistent with this, Vo and Le (2011) show that following securitization issues, U.S. banks invest in riskier loans and experience a subsequent increase in RWATA. If larger shadow banking systems lead to banks assuming additional credit risk in their loan portfolios, we expect to find a positive relationship between the scale of shadow banking and RWATA.

Further, regulatory practices and the disciplinary powers at the disposal of regulators may also impact upon banks' incentives to undertake regulatory capital arbitrage. We rely on the Barth, Caprio and Levine (2004) database[‡‡‡‡‡] to construct two measures which capture the stringency of capital requirements and the availability of regulatory powers to enforce these. First, we use an index of capital regulation as used in Laeven and Levine (2009) to describe the regulatory approaches to assessing and verifying the amount of capital at risk in a bank.[§§§§§] Second, we expect that in regulatory environments in which stricter capital stringency and more regulatory powers prevail, banks will have fewer opportunities to engage in capital arbitrage to understate the value of their

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[‡‡‡‡‡] Updated values are available from the World Bank website, http://go.worldbank.org/SNUSW978P0.

[§§§§§] The index values are based on the following questions (yes = 1; no = 0). (1) Is the minimum capital asset requirement risk weighted in line with the Basel guidelines? (2) Does the minimum ratio vary as a function of market risk? (3) Are market value of loan losses not realized in accounting books deducted from capital? (4) Are unrealized losses in securities portfolios deducted? (5) Are unrealized foreign exchange losses deducted? (6) What fraction of revaluation gains is allowed as part of capital? (7) Are the sources of funds to be used as capital verified by regulatory or supervisory authorities? (8) Can the initial disbursement or subsequent injections of capital be done with assets other than cash or government securities? (9) Can the initial disbursement be done with borrowed funds? We construct the index such that we use the last available year for which data are available for each year.

RWATA for a given level of portfolio risk. Hence, we expect to observe a positive relationship between RWATA and the regulatory variables.

Finally, in some specifications, we control for the business cycle (expressed by the real GDP growth rate in U.S. dollars). Several papers emphasize the procyclical effects of risk-based capital regulation especially in the context of Basel II (see Repullo and Suarez, 2004; Feess and, 2011). Under procyclicality, we expect regulatory measures of credit risk to increase during an economic downturn. Therefore, we expect to find a negative relationship between GDP growth and RWATA.

Table 3 offers an overview and selected summary of statistics of the variables employed in the empirical analysis.

5. Empirical Results: The Market Assessment of Portfolio Risk and Capital Requirements

In this section, we analyze our main research question. We examine whether changes in the market assessment of bank portfolio risk lead to changes in the regulatory assessment of bank risk (RWATA), which determines minimum capital requirements. Table 4 reports the regression results of the baseline model on the relationship between asset volatility and RWATA using a dynamic GMM estimator.

*******TABLE 4 HERE******

Panel A of Table 4 reports the estimation results for different model specifications. In Column 1, we employ a parsimonious model which includes only basic firm characteristics and regulatory control variables. Next, in Column 2 we remove the regulatory characteristics and include additional firm characteristics. We then estimate the model control for the full range of bank characteristics and regulatory controls (Column 3), with the addition of the GDP growth rate (Column 4), and the variables indicating whether the IRB or standardized approach has been adopted (Columns 5–9). In all specifications, the coefficients assigned to asset volatility enter with a positive and significant coefficient (at the 1 percent level) indicating a positive association between regulatory risk assessment (RWATA) and market assessment of portfolio risk.[******]

Panel B of Table 4 estimates the additional capital requirements per unit of assets linked to increases in asset volatility (based on 1 percent and 5 percent increases in asset volatility). The results show that even substantial increases in the market assessment of bank portfolio risk cause only small increases in capital requirements. Depending on the model specification, a five-percentage point increase in portfolio risk (which in our sample distribution corresponds to approximately a 1.5 standard deviation increase in asset volatility) leads to additional capital holdings of between 0.171 and 0.189 percentage points. This confirms the results of the univariate analysis presented in Table 2, which also shows that the relationship between RWATA and asset volatility is very weak in economic terms. Jointly, these results raise doubts over the ability of bank capital regulation to capture the market perception of portfolio risk in an economically meaningful way.

In terms of the control variables, we observe that RWATA increases in loans (significant at 10 percent). This confirms that a bank's lending activities attract high regulatory risk weights under Basel rules on capital adequacy. Furthermore, RWATA is positively associated with both ROA and deposits (at the 1 percent level). These findings are consistent with the notion that both higher profitability and more deposit-based funding reduce a bank's incentives to engage in capital arbitrage by reporting lower values of RWATA. Further, for a given level of asset volatility, increases in capital buffers are negatively related to RWATA (significant at 1 percent). Consequently, banks with higher capital buffers exhibit a lower risk exposure based on capital adequacy rules. The negative coefficient on capital buffers pinpoints to deficiencies in the regulatory risk assessment, because it suggests that capital regulations permit banks to boost capital by letting them underreport their portfolio risk when

[******] Overall, the results we report confirm the validity of adopting a system GMM estimator. First, the lagged values on RWATA enter the regression analysis consistently with a positive and highly significant coefficient. Second, both the m_2 and the Hansen *J*-statistic are insignificant. This confirms, respectively, that there is no second-order serial correlation in the first-difference residuals and that our instruments are valid.

they hold regulatory capital above minimum requirements. We will revert to this issue in Section 7 where we examine whether the risk sensitivity of minimum capital requirements varies with the level of capital buffers which banks maintain.

As regards country characteristics, our findings suggest that RWATA is higher when banks operate in countries with a larger shadow banking system and in more stringent regulatory regimes (both the capital regulation and the regulatory strength index enter significantly and with a positive sign). The former result is consistent with banks engaging in riskier activities under capital adequacy rules when the shadow banking sector is large and when banks boast more opportunities to offload credit risk into the shadow banking system (see Vo and Le, 2011). The latter result is consistent with more stringent regulatory environments preventing banks from engaging in capital arbitrage. Finally, the results do not provide clear evidence on whether the adoption of Basel II affects RWATA, although we find a significant decline in RWATA for banks that have opted for the IRB approach in Columns 5 and 7 to 9.

6. Basel II, Capital Requirements and the Market Assessment of Portfolio Risk

This section analyzes whether the introduction of Basel II has modified the relationship between RWATA and asset volatility. The primary mechanisms by which Basel II seeks to enhance the sensitivity of capital requirements to bank portfolio risk is the introduction of more granular risk weights to calculate RWATA as well as the acceptance of internally developed credit risk models by regulators for eligible banks. Basel II therefore abandons the one-size-fits-all approach in terms of determining a bank's risk exposure and gives some banks the right to choose between different risk aggregation methods (the standardized or IRB approach). If Basel II is effective in improving the sensitivity of capital requirements with respect to portfolio risk, it should curb bank incentives for capital arbitrage and lead to a convergence in the regulatory and market assessment of banks' portfolio risk.

Furthermore, we expect that the moderating effect of Basel II on the risk sensitivity of capital requirements varies with the type of risk weighting approach which banks adopt. Repullo and Suarez (2004) and Hakenes and Schnabel (2011) argue that banks eligible for the IRB approach are likely to focus on low-risk lending (because the more risk-sensitive IRB approach leads to lower capital requirements for these banks), while banks not eligible for the IRB approach are likely to focus on high-risk lending (because the standardized approach leads to lower capital requirements for risky banks). Evidently, it will be more advantageous for banks that employ the standardized approach to engage in capital arbitrage than for banks that employ the more risk-sensitive IRB approach.

*******TABLE 5 HERE******

To test whether Basel II has modified the relationship between RWATA and asset volatility, we introduce interaction terms between asset volatility and the Basel II dummies. To avoid multicollinearity between the interaction terms and their constituent variables, we mean-center asset volatility before adding it to the regression models. Mean-centering, which involves transforming the values of asset volatility into deviations from their mean, also eases the interpretation of the results. The coefficient of Basel II can be interpreted as capturing the effect of this capital regime for a bank with an average value of asset volatility (namely, when the interaction term is equal to zero). Further, significantly positive coefficients on the Basel interaction terms indicate that increases in asset volatility are associated with a higher value of RWATA (and, thus, higher capital requirements) under Basel II than under the Basel I rules. While we expect that both the IRB and the standardized approach to improve the risk sensitivity of capital requirements, we also expect that the moderating effect of IRB on RWATA will be of a higher magnitude.

The results in Panel A of Table 5 suggest that Basel II has improved the risk sensitivity of regulatory capital requirements, as indicated by a significant interaction term between Basel II and asset volatility, especially in banks that have adopted the IRB approach as demonstrated by the results from Columns 3 to 8. However, when we compute the additional capital requirements which result from changes in asset volatility under Basel II, the results indicate that, similar to Basel I, increases in portfolio risk under Basel II have a near negligible impact on capital requirements. Even when the minimum capital ratio equals 13 percent, an increase in asset volatility of five-percentage points (the equivalent of a 1.5 standard deviation increase in the sample distribution of asset volatility) under the IRB approach translates into additional capital requirements of only 0.70 p.p. per unit of assets.

Panel B of Table 5 explores whether the impact of Basel II on the relationship between risk and capital requirements depends on how risky a bank's asset portfolio is. Panel B reports changes in RWATA when banks that adopt Basel II display asset portfolios which can be classified as either low risk (asset volatility=1 percent) or high risk (asset volatility=5 percent). We compute the minimum capital requirements which result when low-risk and high-risk portfolios are assessed under Basel II (assuming capital requirements are 8 percent of risk-weighted assets). The results show that banks with low-volatility portfolios hold significantly lower RWATA (and, thus, benefit from lower capital requirements) when adopting Basel II. By contrast, banks with high- volatility portfolios do not increase RWATA when adopting Basel II. This result is driven by banks adopting the IRB approach. Consequently, the increased risk sensitivity of capital requirements under the IRB approach is highly asymmetric. For low-volatility portfolios, capital adequacy requirements are lower, but the equivalent is not true for banks with high-volatility portfolios which do not see an increase in RWATA. We therefore conclude that the adoption of the IRB approach under Basel II rewards banks with less risky asset portfolios without penalizing banks with highly risky asset portfolios.

In summary, we show that Basel II is marginally more risk-sensitive than its predecessor. However, the increase in risk sensitivity only applies to banks with low-risk portfolios that adopt the IRB approach. High-risk institutions and institutions adopting the standardized approach do not experience an increased risk sensitivity of capital requirements.

7. Capital Buffers, Capital Requirements and the Market Assessment of Portfolio Risk

We next examine whether the risk sensitivity of capital requirements varies across banks depending on the amount of capital which banks hold above minimum regulatory requirements. It is a widelydocumented empirical fact that banks hold capital above minimum regulatory requirements (e.g., Brewer, Kaufman and Wall, 2008; Flannery and Rangan, 2008; Gropp and Heider, 2010). In our sample, the mean (median) buffer above capital requirements is 4.56 percent (3.90 percent) between 2000 and 2007 and slightly higher if we consider the full sample period (4.88 percent and 4.22 percent respectively). The higher capital buffers over the entire sample period are probably due to the recapitalization efforts undertaken by banks during the financial crisis.

Given that capital requirements are weakly related to our market measure of the portfolio risk of banks, this leaves two explanations for why banks maintain buffers. Both explanations have implications for the risk sensitivity of capital requirements. First, banks may boost their capital buffers via arbitrage, essentially because capital regulations permit them to underreport the portfolio risks they undertake. According to this explanation, banks may lower risk-weighted assets while maintaining a constant proportion of excess capital to total assets on their balance sheet. This can be demonstrated when we decompose a bank's capital buffer as follows:

$$\frac{\text{EXCESS\_REGUL\_CAPITAL}}{\text{RWA}} = \frac{\text{EXCESS\_REGUL\_CAPITAL}}{\text{TA}} \times \frac{\text{TA}}{\text{RWA}} \qquad (5)$$

Second, if buffers are not due to capital arbitrage, they may be the result of banks with riskier asset portfolios maintaining larger buffers. These larger buffers would then serve as a cushion against an increased probability that adverse shocks cause capital to fall below the minimum regulatory capital ratio. If this is the case, we expect buffers to interact with portfolio risk in shaping the value of RWA which banks report.

*******TABLE 6 HERE******

In this section, we test which explanation prevails (that is, are buffers the product of capital arbitrage or, alternatively, higher capital holdings against riskier bank portfolios?) by examining whether the risk sensitivity of capital requirements differs by the size of capital buffers that banks maintain. As previously, we mean-center asset volatility and buffer before multiplying the adjusted variables to produce an interaction term between asset volatility and buffer, which we add to the baseline specification. Initially, we focus on the period prior to the financial crisis before we extend the analysis to include the entire sample period. This allows us to isolate the potential impact of bank recapitalization strategies (including the effects of governments providing capital assistance [e.g., CPP in the U.S.]). Therefore, differences in our findings between the two time periods provide an indication of how any crisis-related recapitalization strategies have influenced the link between RWATA, asset volatility and buffer.

*******TABLE 7 HERE******

The findings for the pre-crisis period (2000–2007; reported in the first four columns of Panel A of Table 6) show that there is no evidence that the risk sensitivity of capital requirements changes as capital buffers increase. The interaction term between asset volatility and buffer is not significant at customary levels. However, we continue to observe that banks with higher capital buffers report lower RWATA before the crisis. This suggests that pre-2008 banks boost their regulatory capital ratios to levels above minimum requirements by exploiting deficiencies in the regulatory risk assessment underlying capital adequacy rules. Interestingly, this yields an explanation for why high regulatory capital ratios have been found to be unreliable signals of the capital strength of a bank (IMF, 2009; Allen et al., 2011).

When we examine the full sample period, the interaction term between asset volatility and buffer enters with a negative sign (significant at the 1 percent level). Consequently, higher capital buffers are associated with a weaker relationship between RWATA and asset volatility. One explanation for this result is that marked increases in buffer during the crisis period are particularly pronounced for banks that were most engaged in capital arbitrage in the pre-crisis period. Put differently, the banks most involved in arbitrage pre-2008 saw rapid increases in their capital holdings during the crisis in order to bring capital levels more in line with the economic risk of their asset portfolios.

We offer some support for this conjecture in Table 7 where we gauge whether capital arbitrage in the run-up to the financial crisis can be linked to government-aided recapitalizations during the financial crisis. We identify banks that increased their capital buffers markedly during the recent crisis in 2008–2009 (defined as banks located in the top quartile of the annual distribution of capital increases, namely 2.10 percent per annum on average) and build two binary variables for this group. The first variable takes a value of 1 for banks when some or all of the recapitalization is government-funded (usually when governments purchase participation capital in a bank).[††††††] The second variable takes a value of 1 for recapitalizations via bank funding markets. We introduce these two binary variables along with their interactions with mean-centered asset volatility (between 2000 and 2007) to the model specifications reported in Panel A of Table 7.

The results show that the interaction term between asset volatility and government recapitalizations enters all specifications with a negative and significant coefficient. Accordingly, the pre-crisis risk sensitivity of capital requirements at banks that engaged in large recapitalizations during the financial crisis that were at least in part financed by governments was significantly lower than that of the rest of the sample. Furthermore, as reported in Panel B, the risk sensitivity of capital requirements of these 'bailed-out' banks (the sum of the coefficients on asset volatility and asset volatility*government recapitalization) is not significantly different from zero in most specifications. By contrast, banks that increase their regulatory capital ratios during the crisis without government support display a risk sensitivity which is not significantly different from the rest of the sample.

In summary, the results of this section provide additional evidence that the risk assessment underlying the Basel capital rules does not sufficiently reflect the actual risk of bank portfolios. On the contrary, before the financial crisis, banks with larger buffers report lower values of RWATA for a given level of portfolio risk. While the risk sensitivity of capital requirements of well capitalized banks are not significantly different from those of less well capitalized banks before 2008, we observe a negative link between buffer and the risk sensitivity of capital requirements when the full sample

[††††††] We collect data on government-funded recapitalizations from ProPublica (http://projects.propublica.org/bailout/list) for U.S. banks, Petrovic and Tutsch (2009) for European banks, and annual reports as well as bank websites for the remainder of the sample.

period is considered. We argue that the latter result is due to the effect of bank recapitalization strategies during 2008 and 2009, which were disproportionately undertaken by banks characterized by the weakest risk sensitivity of capital requirements in the run-up to the financial crisis due to regulatory capital arbitrage. In line with this argument, we show that before 2008 banks that boosted their regulatory capital ratio during the crisis partly via government-aided recapitalization programs did not exhibit any measurable risk sensitivity in the capital requirements.

8. Additional Analysis

We perform additional tests that examine whether our results are robust to changes in the econometric techniques used, our market measure of risk or the composition of the sample. None of the changes outlined below cause us to observe material changes to the results reported in the previous sections. We report the results of these additional tests in full in the online appendix to this paper.

First, we assess the sensitivity of our results to an alternative econometric specification which does not rely on a dynamic GMM estimator, but uses a relatively simple and static two-stage least squares instrumental variable (2SLS-IV) model with macro variables as instruments for asset volatility. While the coefficient on asset volatility is somewhat higher, it remains economically weak and therefore in line with the previous results we report. Second, we follow Flannery and Rangan (2008) and we employ an alternative risk measure defined as the unlevered bank equity volatility (equity volatility multiplied by the ratio of the market value of equity to the quasi-market value of bank total assets). Third we run estimations only for banks that report risk-weighted assets under Basel I. Fourth, we sequentially exclude U.S. banks, banks based in developing countries, banks based in countries with only a single bank in the sample, and all observations after 2007 (to rule out explanations that the financial crisis has affected the results we report). Fifth, we include additional macro controls such as interest rates (e.g., banks may face incentives to take on additional risk in a low interest rate environment, see Delis and Kouretas, 2011) and the value of domestic credit relative to the size of the economy.

Finally, we examine whether the size of the shadow banking sector affects the relationship between asset volatility and RWATA. If securitization lowers capital requirements without a commensurate transfer in asset risk (Merton, 1995; Jones, 2000), a larger shadow banking sector will widen discrepancies between the regulatory and market indicators of portfolio risk. We mean-center asset volatility and the shadow banking variable and add an interaction term based on the multiplication of the two mean-centered variables to the baseline specification. The results show that the interaction terms between securitization and asset volatility enter the regression models with the expected negative coefficient (significant below the 5 percent level) while asset volatility continues to enter significantly. Thus, the larger the size of the shadow banking system in a country, the lower the sensitivity of capital requirements with respect to portfolio risk.

9. Conclusions

We examine if the minimum regulatory capital requirements as stipulated by the Basel Accord are sensitive to a market measure of the portfolio risk of banks. Based on an international sample of banks between 2000 and 2010, we assess to what extent increases in bank portfolio risk, measured in terms of asset volatility, affect the volume of risk-weighted assets (RWA) which determines the minimum amount of capital banks are required to hold against their asset portfolios.

The effectiveness of risk-based capital requirements is based on the extent to which the regulatory definition of each bank's risk exposure is an accurate reflection of bank portfolio risk. If regulatory capital requirements are ill-calibrated to portfolio risk, capital regulation will incentivize banks to invest in assets which attract a low risk-weighting even if these assets are highly risky. If the risk sensitivity of capital requirements is low, banks with riskier asset portfolios will not be subject to sufficiently higher capital requirements than banks with less risky portfolios.

Our results show that the calibration of regulatory capital requirements to portfolio risk is very weak. The adoption of Basel II has only marginally increased the risk sensitivity of capital requirements and has introduced an asymmetric treatment of low-risk portfolios (which lower regulatory requirements as banks adopt the IRB approach) and high-risk portfolios (for which banks do not face additional capital requirements under IRB). Further, before 2008 banks with larger buffers report lower values of risk-weighted assets over total assets for a given level of asset volatility suggesting that Basel has allowed banks to underreport the risk of their asset portfolios in the run-up to the financial crisis. In line with this argument, we also show that banks that substantially boosted their regulatory capital ratio during the crisis period via recapitalizations programs that were in part government-financed displayed particularly risk-insensitive capital requirements before 2008. Finally, as the size of the shadow banking sector grows, the link between risk and capital requirements further weakens.

Our analysis is not intended to suggest that it would be desirable if RWA were to exactly track our market measure of the volatility of bank assets. Asset volatility is affected by many factors external to bank management. Instead, our results uncover large discrepancies between the regulatory and the market perception of bank portfolio risk and demonstrate that this discrepancy has caused both a steady decline in the volume of risk-weighted assets and undermined the ability of banks to withstand large adverse shocks to the value of their asset portfolios. In other words, while our analysis does not allow us to identify the correct level of risk sensitivity, our results show that the existing risk sensitivity of capital requirements is clearly too low.

Our results raise doubts over whether the type of revisions to capital requirements which are in the processes of being implemented will be sufficient to ensure that banks are required to hold capital in line with their portfolio risk. The Basel III revisions are designed to increase both the quantity and quality of minimum capital holdings by further enhancing the risk sensitivity of capital requirements. As regards increases in RWA relative to Basel II, the Basel Committee (2011, pg. 31) reports that ‘a 1.23 factor is a rough approximation based on the average increase in risk-weighted assets associated with the enhancements to risk coverage in Basel III relative to Basel II’. However, as long as the regulatory concept of risk exposure which underlies the computation of RWA remains only weakly related to risk, the type of increases in the percentage of capital requirements which are proposed are unlikely to align capital holdings with the effective riskiness of bank asset portfolios. More precisely, the risk sensitivity of capital requirements we report in this paper is of such a low magnitude that this questions whether Basel III will improve the relationship between capital requirements and risk in an economically meaningful way. The projected increase in RWA under Basel III suggests that, even under a minimum capital ratio of 13 percent, banks in our sample will only be required to hold, on average, 1.94 percent of additional capital per unit of assets. Such an increase is unlikely to cause minimum capital requirements to be more reflective of bank portfolio risk in an economically meaningful way.

Our findings support a much more profound overhaul of capital adequacy rules than currently proposed. In line with our findings, Hellwig (2010) and Admati et al. (2010) call for an increase in capital requirements (based on unweighted assets) well into double-digit territory to improve the safety of the financial system. However, critics point out that the increasing cost of financial intermediation that could result from stricter capital requirements may cause a contraction in the level of debt-financed investment and consumption. Some evidence consistent with this view has been found following the introduction of the first Basel Accord (Peek and Rosengren, 1995; Chiuri, Ferri and Majnoni, 2002) and similar concerns have been voiced ahead of the Basel III revisions becoming effective (see Sironi, 2010). In contrast to this view, other work suggests that the costs which banks incur to comply with higher capital requirements may well be modest, because a bank's overall funding costs are likely to decrease as bank leverage decreases (Hellwig, 2010, Miles et al, 2012). Nonetheless, concerns over bank lending mean that the phasing in of higher capital requirements will have to be carefully managed by policymakers and complemented by tight and efficient supervision that minimizes banks' ability to game the system.

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Table 1: Sample Distribution by Country and Year

	Banks		Observations	
	Number	**Percentage**	**Number**	**Percentage**
Panel A: Sample Distribution by Country				
Australia	8	3.24	77	3.39
Austria	5	2.02	49	2.16
Belgium	2	0.81	22	0.97
Brazil	2	0.81	14	0.62
Canada	8	3.24	83	3.65
China	2	0.81	15	0.66
Colombia	1	0.40	7	0.31
Denmark	4	1.62	44	1.94
France	2	0.81	22	0.97
Germany	4	1.62	31	1.36
Greece	4	1.62	34	1.50
Hong Kong	4	1.62	39	1.72
Hungary	1	0.40	10	0.44
India	2	0.81	16	0.70
Ireland	3	1.21	28	1.23
Israel	5	2.02	54	2.38
Italy	6	2.43	57	2.51
Japan	15	6.48	141	6.21
Rep. of Korea	2	0.81	22	0.97
Kuwait	2	0.81	12	0.53
Liechtenstein	1	0.40	8	0.35
Malaysia	6	2.43	56	2.46
Mexico	1	0.40	6	0.26
Netherlands	1	0.40	7	0.31
Norway	2	0.81	14	0.62
Pakistan	1	0.40	6	0.26
Portugal	3	1.21	33	1.45
Qatar	2	0.81	13	0.57
Russia	1	0.40	6	0.26
Saudi Arabia	6	2.43	46	2.02
Singapore	3	1.21	33	1.45
South Africa	3	1.21	26	1.14
Spain	9	3.64	94	4.14
Sweden	3	1.21	33	1.45
Switzerland	3	1.21	31	1.36
Taiwan	1	0.40	6	0.26
Thailand	3	1.21	33	1.45
Turkey	2	0.81	15	0.66
United Arab Emirates	1	0.40	6	0.26
United Kingdom	9	3.64	84	3.70
USA	103	41.70	939	41.33
Total	246	100.00	2,272	100.00
Panel B: Sample Distribution by Year				
2000			178	7.83
2001			195	8.58
2002			207	9.11
2003			219	9.64
2004			229	10.08
2005			236	10.39
2006			226	9.95
2007			214	9.42
2008			198	8.71
2009			190	8.36
2010			180	7.92
Total			2,272	100.00

Table 2: Risk-Weighted Assets over Total Assets (RWATA) and the Market Assessment of Bank Portfolio Risk

The table presents univariate tests. RWATA is risk-weighted assets (RWA) scaled by total assets. Asset volatility captures the market assessment of bank portfolio risk and is estimated using option pricing theory. Banks are classified as low and high portfolio risk relative to the sample median. *t*- (z-)tests on the equality of mean (median) values of RWATA between high- and low-risk groups are reported. Minimum capital requirements are assumed to be 8 percent of RWA.

	LOW asset volatility	**HIGH asset volatility**	**(2) *minus* (1)**	**Δ min capital requirements due to (3)**
	(1)	**(2)**	**(3)**	**(4)**
Panel A: Full Sample				
Mean asset volatility	2.1%	6.2%		
Mean RWATA	60.13	69.87	9.74*** (14.23)	0.78%
Median RWATA	60.12	70.82	10.70*** (14.46)	0.86%
N	1,136	1,136		
Panel B: Basel I vs. Basel II (2007─2010)				
Mean asset volatility	2.2%	7.2%		
Basel I				
Mean RWATA *(a)*	67.00	72.83	5.83*** (3.863)	0.47%
Median RWATA *(b)*	66.91	73.98	7.07*** (3.571)	0.57%
N	144	259		
Basel II				
Mean RWATA *(c)*	54.16	64.73	10.57*** (4.973)	0.85%
Median RWATA *(d)*	51.89	64.70	12.81*** (5.663)	1.02%
N	247	132		
Basel I vs. Basel II				
(a) minus (c) = 0 ?	12.84*** (6.190)	8.10*** (5.157)		
(b) minus (d) = 0 ?	15.02*** (7.492)	9.18*** (4.737)		

*** significant at 1 percent.

Table 3: Descriptive Statistics

		N	Mean	Median	St. Dev.	1 Pctile	99 Pctile
RWATA	Risk-weighted assets over total assets (percent)	2,272	65.00	65.79	17.02	18.99	103.41
Asset volatility	Market assessment of bank portfolio risk estimated via option pricing theory (percent)	2,272	4.16	3.30	3.29	0.68	16.37
Size	Log of total assets in thousands of U.S. dollars	2,272	17.56	17.26	1.63	15.13	21.46
ROA	Net income over total assets (percent)	2,272	0.83	0.86	0.95	-3.00	3.07
Buffer	Bank regulatory capital ratio minus minimum required capital ratio (percent)	2,272	4.88	4.22	3.23	0.30	16.80
Deposits	Customer deposits over total liabilities (percent)	2,272	66.58	69.13	18.90	20.53	95.88
Loans	Net loans over total assets (percent)	2,272	60.84	61.91	13.45	21.77	90.41
Non-interest income	Non-interest income over total operating income (percent)	2,272	34.65	34.13	14.91	2.75	75.52
Basel II	Dummy variable which equals 1 if a bank adopted the Basel II capital standards (and 0 otherwise)	2,272	0.176	0.000	0.381	0.000	1.000
IRB	Dummy variable which equals 1 if a bank has adopted the internal ratings-based (IRB) approach (0 otherwise)	2,272	0.092	0.000	0.288	0.000	1.000
Standardized	Dummy variable which equals 1 if a bank adopted the standardized approach (0 otherwise)	2,272	0.086	0.000	0.280	0.000	1.000
Shadow banking	Total value of securitized assets over total GDP (percent)	2,272	36.32	37.92	16.46	0.00	97.56
Capital regulation	Yearly index which captures the regulatory approach to assessing and verifying the degree of capital at risk in a bank. The index ranges from 0 to 9 with higher values indicating increased strictness. From Barth et al. (2004) with updated values from the Worldbank website	2,272	5.19	5.00	1.28	2.00	8.00
Regulatory strength	Yearly index which assesses general regulatory strength at country level. The index ranges from 0 to 10 with higher values indicating increased strictness. From Barth et al. (2004) with updated values from the Worldbank website	2,272	8.12	9.00	1.44	4.00	10.00
GDP growth	Real GDP growth rate in (U.S. dollars)	2,256	2.54	2.67	2.88	-5.33	9.82

Table 4: The Market Assessment of Bank Portfolio Risk and RWATA

Panel A shows regression results on the ratio of risk- weighted assets to total assets (RWATA). The models are estimated via the two-step GMM estimator proposed by Blundell and Bond (1998). Asset volatility captures the market assessment of bank portfolio risk and is measured as the value of asset volatility estimated via option pricing theory, Size is the log of total assets, ROA is the ratio of net income to total assets, Buffer is the percent difference between the regulatory capital ratio and the required capital ratio, Deposits is customer deposits over total liabilities, Loans is the ratio of net loans to total assets and Non-interest income is the ratio of non-interest income to total operating income, Basel II is a dummy which equals 1 if a bank complies with the Basel II capital standards in a given year, IRB is a dummy which equals 1 if a bank adopts the internal rating-based approach to compute RWA, Standardized is a dummy which equals 1 if a bank has adopted the standardized approach, Shadow banking is the ratio of outstanding securitized assets to GDP, Capital regulation is an index of the regulatory approach to assessing and verifying the degree of capital at risk in a bank, Regulatory strength is an index of general regulatory strength, GDP growth is the real GDP growth rate (measured in U.S. $). Standard errors are adjusted via the finite sample correction derived by Windemeijer (2005), robust Z statistics are reported in round brackets. All specifications control for time dummies. Panel B computes increases in capital per unit of assets implied by a 1percent (5 percent) increase in asset volatility under a minimum capital ratio of 8 percent. This is calculated as the estimated coefficient on asset volatility*Δasset volatility*0.08*100.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Regression Analysis									
Lagged RWATA	0.821***	0.822***	0.808***	0.799***	0.800***	0.804***	0.802***	0.790***	0.811***
	(23.62)	(25.95)	(24.74)	(23.77)	(24.34)	(23.83)	(24.21)	(23.39)	(23.03)
Asset volatility	0.447***	0.430***	0.427***	0.459***	0.426***	0.465***	0.441***	0.473***	0.453***
	(4.06)	(4.15)	(4.34)	(4.67)	(4.24)	(4.37)	(4.30)	(4.66)	(4.10)
Size	-0.000	-0.004	-0.002	-0.002	-0.002	-0.001	-0.002	-0.002	0.000
	(0.03)	(1.19)	(0.70)	(0.64)	(0.79)	(0.41)	(0.59)	(0.49)	(0.06)
ROA	1.109***	0.950***	0.825**	0.738**	0.897***	0.671**	0.855***	0.791**	1.093***
	(3.18)	(2.98)	(2.54)	(2.34)	(2.79)	(2.08)	(2.63)	(2.37)	(3.04)
Buffer	-0.721***	-0.536***	-0.569***	-0.582***	-0.586***	-0.549***	-0.572***	-0.582***	-0.710***
	(4.36)	(4.29)	(4.72)	(4.76)	(4.62)	(4.16)	(4.46)	(4.31)	(4.53)
Deposits	0.082***	0.062*	0.058*	0.067*	0.061*	0.062*	0.057*	0.066*	0.079***
	(3.23)	(1.81)	(1.77)	(1.83)	(1.74)	(1.76)	(1.72)	(1.78)	(3.21)
Loans		0.022	0.022	0.019	0.020	0.024	0.018	0.016	
		(0.91)	(0.87)	(0.80)	(0.78)	(0.94)	(0.72)	(0.62)	
Non-interest income		0.057**	0.060***	0.062***	0.059***	0.064***	0.059**	0.060**	
		(2.46)	(2.64)	(2.66)	(2.58)	(2.79)	(2.55)	(2.47)	
Basel II	-0.007	-0.006	-0.007	-0.004					
	(1.22)	(1.00)	(1.31)	(0.73)					
IRB	0.016**				-0.016**		-0.016**	-0.013*	-0.017**
	(2.28)				(2.54)		(2.35)	(1.90)	(2.32)
Standardized	-0.003					0.011	0.002	0.007	0.002
	(0.63)					(1.54)	(0.34)	(0.93)	(0.33)
Shadow banking		0.011**	0.010*	0.013**	0.012*	0.016**	0.013**	0.017**	0.020***
		(2.04)	(1.70)	(2.08)	(1.96)	(2.46)	(2.01)	(2.40)	(2.71)
Capital regulation			0.004**	0.003**	0.003**	0.003**	0.003**	0.003*	0.004***
			(2.36)	(2.12)	(2.08)	(2.19)	(2.00)	(1.83)	(2.63)
Regulatory strength			0.004***	0.004***	0.004***	0.004***	0.004***	0.004***	0.002
			(2.88)	(3.03)	(3.00)	(3.08)	(3.02)	(3.19)	(1.25)
GDP growth				0.180**				0.154*	
				(2.01)				(1.71)	
Constant	0.022	0.097	0.031	0.021	0.044	0.003	0.033	0.023	0.028
	(0.36)	(1.27)	(0.40)	(0.27)	(0.59)	(0.04)	(0.44)	(0.29)	(0.47)
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	2,015	2,015	2,015	1,996	2,015	2,015	2,015	1,996	2,015
Number of banks	246	246	246	243	246	246	246	243	246
m2 Statistic (p-value)	0.179	0.163	0.164	0.170	0.163	0.152	0.160	0.162	0.173
Hansen J statistic (p-value)	0.219	0.415	0.501	0.473	0.488	0.482	0.468	0.391	0.274
Panel B: Capital Injections in % of Total Assets Linked to Increases in Asset Volatility (Min Capital Ratio = 8%)									
1%-increase in asset volatility	0.036	0.034	0.034	0.037	0.034	0.037	0.035	0.038	0.036
5%-increase in asset volatility	0.179	0.172	0.171	0.184	0.171	0.186	0.176	0.189	0.181

***significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.**

Table 5: Basel II and the Relationship between the Market Assessment of Bank Portfolio Risk and RWATA

This Table shows the regression results for the dynamic panel data model presented in Section 4.1, controlling for the impact of Basel II. The models are estimated via the two-step GMM estimator proposed by Blundell and Bond (1998). RWATA is the ratio between risk-weighted assets (RWA) and total assets, asset volatility captures the market assessment of bank portfolio risk and is measured as the value of asset volatility estimated via option pricing as discussed in section 3 (asset volatility has been mean-centered to avoid multicollinearity with its interactions), Size is the log of total assets, ROA is the ratio between net income and total assets, Buffer is the difference between the regulatory capital ratio and the required capital ratio, Deposits is computed as customer deposits over total liabilities, Loans is the ratio between net loans and total assets and Non-interest income is the ratio of non-interest income to total operating income, Basel II is a dummy equal to 1 if a bank complies with the Basel II capital standards in a given year, IRB is a dummy equal to 1 if a bank adopts the Internal Rating-Based Approach to compute RWA, Standardized is a dummy equal to 1 if a bank adopts the Standardized Approach, Shadow banking is the ratio between the outstanding value of securitized assets and GDP, Capital regulation is an index of the regulatory approach to assessing and verifying the degree of capital at risk in a bank, Regulatory strength is an index that assesses the general regulatory strength at the country level, GDP growth is the real GDP growth rate (measured in U.S. $). Standard errors are adjusted via the finite sample correction derived by Windemeijer (2005). Panel B shows the impact of Basel II on RWATA and on the value of capital per unit of assets for banks with low and high volatile portfolios based on the regression results reported in Columns 2 and 8 of Table 5. Low (High) risk portfolios are defined as banks with asset volatility equal to 1 percent (5 percent). Changes in minimum capital requirements per unit of assets (ΔCap / TA) are calculated assuming a minimum capital ratio of 8 percent (13 percent) of changes in RWA. The last row of Panel A and B shows the result of a Wald test on the equality between the effect produced by the IRB and the Standardized Approach of calculating RWA. robust Z statistics are reported in round brackets. All specifications control for time dummies. * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent

Table 5 (cont'd)

Panel A: Regression Analysis

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
β_1	Lagged RWATA	0.791***	0.784***	0.802***	0.794***	0.789***	0.777***	0.791***	0.781***
		(24.63)	(23.43)	(24.35)	(23.13)	(23.00)	(21.38)	(23.95)	(22.05)
β_2	Asset volatility	0.412***	0.392***	0.405***	0.432***	0.457***	0.443***	0.405***	0.406***
		(4.19)	(4.25)	(4.15)	(4.49)	(4.48)	(4.42)	(4.18)	(4.13)
β_3	Size	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.003	-0.002
		(0.78)	(0.49)	(0.68)	(0.57)	(0.66)	(0.66)	(0.89)	(0.67)
β_4	ROA	0.617**	0.610*	0.765**	0.763**	0.517*	0.518*	0.633**	0.611*
		(2.05)	(1.94)	(2.37)	(2.34)	(1.65)	(1.67)	(2.04)	(1.88)
β_5	Buffer	-0.586***	-0.558***	-0.543***	-0.576***	-0.591***	-0.560***	-0.565***	-0.547***
		(4.18)	(4.80)	(4.60)	(4.54)	(4.26)	(4.75)	(4.29)	(4.70)
β_6	Deposits	0.062***	0.064***	0.062***	0.063***	0.063***	0.066***	0.062***	0.064***
		(2.87)	(2.91)	(2.97)	(2.83)	(2.72)	(2.74)	(2.95)	(2.88)
β_7	Loans	0.056	0.064*	0.058*	0.061*	0.068*	0.073**	0.055	0.064*
		(1.64)	(1.79)	(1.75)	(1.78)	(1.89)	(2.01)	(1.57)	(1.79)
β_8	Non-interest income	0.024	0.019	0.017	0.011	0.026	0.021	0.018	0.012
		(0.91)	(0.68)	(0.71)	(0.45)	(1.03)	(0.84)	(0.82)	(0.48)
β_9	Basel II	-0.005	-0.003						
		(0.96)	(0.52)						
β_{10}	Basel II*asset volatility	0.492**	0.446**						
		(2.36)	(2.06)						
β_{11}	IRB			-0.009	-0.009			-0.007	-0.007
				(1.19)	(1.09)			(0.93)	(0.92)
β_{12}	IRB*asset volatility			0.703**	0.677*			0.773**	0.665**
				(2.04)	(1.88)			(2.28)	(2.03)
β_{13}	Standardized					0.011	0.014*	0.003	0.007
						(1.52)	(1.92)	(0.49)	(1.06)
β_{14}	Standardized*asset volatility					0.400	0.288	0.363	0.294
						(1.59)	(1.12)	(1.44)	(1.14)
β_{15}	Shadow banking	0.010*	0.013**	0.011*	0.011*	0.016**	0.018**	0.012*	0.015**
		(1.65)	(2.07)	(1.72)	(1.86)	(2.25)	(2.55)	(1.94)	(2.36)
β_{16}	Capital regulation	0.004***	0.004***	0.004***	0.004***	0.004***	0.004***	0.004***	0.005***
		(2.93)	(3.22)	(2.95)	(3.13)	(3.01)	(3.60)	(3.03)	(3.47)
β_{17}	Regulatory strength	0.004***	0.004**	0.003**	0.003**	0.004**	0.003**	0.004**	0.003**
		(2.62)	(2.54)	(1.98)	(1.99)	(2.57)	(2.14)	(2.20)	(2.11)
β_{18}	GDP growth		0.144		0.127		0.156*		0.120
			(1.49)		(1.40)		(1.68)		(1.29)
	Constant	0.061	0.037	0.053	0.049	0.042	0.042	0.072	0.055
		(0.80)	(0.45)	(0.80)	(0.66)	(0.52)	(0.47)	(0.98)	(0.70)
	Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
	Observations	2,015	1,996	2,015	1,996	2,015	1,996	2,015	1,996
	Number of banks	246	243	246	243	246	243	246	243
	m2 Statistic (p-value)	0.202	0.196	0.167	0.177	0.182	0.170	0.190	0.185
	Hansen J statistic (p-value)	0.728	0.758	0.599	0.611	0.631	0.698	0.818	0.846

Panel B: Changes in RWATA and Adoption of Basel II, by Asset Volatility

	ΔRWATA (%)		**ΔCap/TA (%)**	
	Low-risk	**High-risk**	**Low-risk**	**High-risk**
ΔRWATA= ($\beta_9 + \beta_{10} \times$ asset volatility)	-2.07***	-0.11	-0.17***	-0.00
	(3.05)	(3.05)	(3.05)	(0.16)
IRB: ΔRWATA= ($\beta_{11} + \beta_{12} \times$ asset volatility)	-2.77***	-0.10	-0.22***	-0.00
	(2.92)	(0.11)	(2.92)	(0.11)
Standardized: ΔRWATA= ($\beta_{13} + \beta_{14} \times$ asset volatility)	-0.20	0.98	-0.02	-0.08
	(0.20)	(0.20)	(0.20)	(0.20)
H_0: *IRB = Standardized*	4.70**	0.91	4.70**	0.91
	(0.03)	(0.34)	(0.03)	(0.34)

Table 6: The Market Assessment of Bank Portfolio Risk, RWATA and Capital Buffers

Panel A shows the regression results for the dynamic panel data model as presented in Section 4.1 which controls for the interaction between capital buffer and portfolio volatility (asset volatility). The models are estimated via the two-step GMM estimator proposed by Blundell and Bond (1998). RWATA is the ratio between risk-weighted assets (RWA) and total assets, asset volatility captures the market assessment of bank portfolio risk and is measured as the value of asset volatility estimated via option pricing, Size is the log of total assets, ROA is the ratio of net income to total assets, Buffer is the difference between the bank regulatory capital ratio and the required capital ratio in the country the bank is chartered in, Deposits is computed as customer deposits over total liabilities, Loans is the ratio of net loans to total assets, Non-interest income is the ratio of non-interest income to total operating income, Basel II is a dummy equal to 1 if a bank complies with the Basel II capital standards in a given year, IRB is a dummy which is equal to 1 if a bank adopts the Internal Rating Based Approach to compute RWA, Standardized is a dummy which is equal to 1 if a bank adopts the Standardized Approach, Capital regulation is an index of the regulatory approach to assessing and verifying the degree of capital at risk in a bank, Regulatory strength is an index that assesses the general regulatory strength at the country level, GDP growth is the real GDP growth rate (measured in U.S. $). asset volatility and Buffer have been mean-centered. Standard errors are adjusted via the finite sample correction derived by Windemeijer (2005); robust z-statistics are reported in round brackets. All specifications control for time dummies. Panel B shows how the impact of asset volatility on RWATA varies with different values of Buffer. * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

	2000–2007				**Full Sample Period**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
					Panel A: Regression Analysis			
Lagged RWATA	0.799***	0.795***	0.794***	0.789***	0.809***	0.798***	0.802***	0.785***
	(16.20)	(16.34)	(15.72)	(16.39)	(24.08)	(23.24)	(24.42)	(23.11)
Asset volatility	0.615***	0.645***	0.610***	0.644***	0.515***	0.516***	0.547***	0.544***
	(4.01)	(4.19)	(4.08)	(4.35)	(4.12)	(4.19)	(4.50)	(4.35)
Size	-0.000	0.001	-0.000	0.002	-0.001	-0.001	-0.001	-0.001
	(0.01)	(0.26)	(0.03)	(0.50)	(0.51)	(0.53)	(0.27)	(0.43)
ROA	-0.359	-0.467	-0.389	-0.472	0.750**	0.806**	0.615*	0.765**
	(0.67)	(0.87)	(0.71)	(0.86)	(2.09)	(2.31)	(1.80)	(2.14)
Buffer	-0.393**	-0.391***	-0.402***	-0.400***	-0.467***	-0.478***	-0.440***	-0.499***
	(2.54)	(2.58)	(2.73)	(2.70)	(4.21)	(4.23)	(3.85)	(3.86)
Buffer*asset volatility	-1.206	-0.854	-0.885	-0.927	-4.716**	-5.132**	-4.657**	-4.568**
	(0.53)	(0.37)	(0.40)	(0.39)	(2.18)	(2.40)	(2.22)	(2.09)
Deposits	0.094***	0.098***	0.091***	0.103***	0.071***	0.069***	0.074***	0.071***
	(3.11)	(3.27)	(2.77)	(3.30)	(3.02)	(2.95)	(3.17)	(2.93)
Loans	0.087**	0.091**	0.084**	0.092**	0.066**	0.070**	0.069**	0.071*
	(2.25)	(2.30)	(2.03)	(2.32)	(1.96)	(2.05)	(2.07)	(1.95)
Non-interest income	0.051	0.049	0.046	0.046	0.029	0.029	0.033	0.023
	(1.41)	(1.32)	(1.27)	(1.36)	(1.26)	(1.20)	(1.36)	(1.02)
Basel II	-0.021***				-0.008			
	(2.73)				(1.33)			
IRB		-0.035***		-0.034***		-0.018***		-0.016**
		(3.48)		(3.35)		(2.58)		(2.16)
Standardized			-0.010	-0.011			0.011	0.006
			(1.24)	(1.35)			(1.53)	(0.72)
Shadow banking	0.019*	0.022**	0.022**	0.025**	0.006	0.007	0.012*	0.012*
	(1.88)	(2.14)	(2.23)	(2.34)	(0.92)	(1.18)	(1.86)	(1.79)
Capital regulation	0.004**	0.004**	0.004**	0.004**	0.004***	0.004***	0.004***	0.004***
	(2.17)	(2.37)	(2.44)	(2.36)	(2.91)	(2.99)	(3.19)	(3.19)
Regulatory strength	0.002	0.002	0.003	0.002	0.003*	0.003*	0.003*	0.003
	(1.17)	(1.05)	(1.27)	(1.04)	(1.94)	(1.78)	(1.90)	(1.63)
GDP growth				0.261**				0.136
				(2.14)				(1.50)
Constant	-0.032	-0.055	-0.031	-0.077	-0.006	0.005	-0.025	0.002
	(0.43)	(0.74)	(0.39)	(0.95)	(0.09)	(0.08)	(0.35)	(0.03)
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Observations	1,386	1,386	1,386	1,386	2,015	2,015	2,015	1,996
Number of banks	220	220	220	220	246	246	246	243
m2 Statistic (p-value)	0.247	0.252	0.250	0.273	0.188	0.193	0.174	0.190
Hansen J Statistic (p-value)	0.365	0.322	0.430	0.373	0.784	0.826	0.842	0.859
				Panel B: Coefficient on (Asset Volatility + Buffer*Asset Volatility), by Different Values of Buffer				
Buffer = 0%	0.615***	0.645***	0.610***	0.644***	0.515***	0.516***	0.547***	0.544***
	(4.01)	(4.19)	(4.08)	(4.35)	(4.12)	(4.19)	(4.50)	(4.35)
Buffer = 3%	0.579***	0.619***	0.583***	0.616***	0.374**	0.362***	0.407***	0.407***
(25th percentile)	(4.62)	(4.90)	(4.86)	(5.12)	(3.75)	(3.68)	(4.16)	(4.17)
Buffer = 6%	0.543***	0.594***	0.557***	0.588***	0.232**	0.208*	0.268**	0.270**
(75th percentile)	(4.14)	(4.42)	(4.49)	(4.50)	(2.06)	(1.87)	(2.41)	(2.46)

Table 7: The Market Assessment of Bank Portfolio Risk and RWATA: Government vs. Market-financed Recapitalizations

Panel A shows the regression results for the dynamic panel data model as presented in Section 4.1 which controls for the interaction between changes in capital buffers in 2008–2009 and portfolio volatility (asset volatility) before the crisis (2000–2007). The models are estimated via the two-step GMM estimator proposed by Blundell and Bond (1998). RWATA is the ratio between risk-weighted assets (RWA) and total assets, asset volatility captures the market assessment of bank portfolio risk and is measured as s the mean-centered value of asset volatility estimated via option pricing, Size is the log of total assets, ROA is the ratio of net income to total assets, Buffer is the difference between the bank regulatory capital ratio and the required capital ratio in the country the bank is chartered in, Deposits is computed as customer deposits over total liabilities, Loans is the ratio of net loans to total assets, Non-interest income is the ratio of non-interest income to total operating income, Basel II is a dummy equal to 1 if a bank complies with the Basel II capital standards in a given year, IRB is a dummy which is equal to 1 if a bank adopts the Internal Rating-Based Approach to compute RWA, Standardized is a dummy which is equal to 1 if a bank adopts the Standardized Approach, Capital regulation is an index of the regulatory approach to assessing and verifying the degree of capital at risk in a bank, Regulatory strength is an index that assesses the general regulatory strength at the country level, GDP growth is the real GDP growth rate (measured in U.S. $). Government recapitalization (Market recapitalization) is a dummy equal to 1 for banks in the highest quartile of the distribution of capital buffer increases in 2008 and 2009, which were at least in part financed via government purchases of participation capital (market sources of capital). Panel B shows the risk sensitivity of capital requirements for banks which have increased their capital buffers during the crisis due to government support. Standard errors are adjusted via the finite sample correction derived by Windemeijer (2005); robust z-statistics are reported in round brackets. All specifications control for time dummies. *significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Regression Analysis							
Lagged RWATA	0.808***	0.805***	0.802***	0.807***	0.803***	0.803***	0.800***
	(15.20)	(15.56)	(14.50)	(15.01)	(14.76)	(15.54)	(15.39)
Asset volatility	0.693***	0.761***	0.720***	0.689***	0.711***	0.789***	0.813***
	(4.52)	(4.69)	(4.64)	(4.62)	(4.78)	(4.94)	(5.31)
Size	0.001	-0.002	0.003	0.001	0.002	-0.001	0.001
	(0.38)	(0.61)	(1.09)	(0.39)	(0.80)	(0.35)	(0.23)
ROA	-0.345	-0.401	-0.403	-0.361	-0.409	-0.486	-0.721
	(0.72)	(0.77)	(0.82)	(0.71)	(0.84)	(0.93)	(1.37)
Buffer	-0.402***	-0.449***	-0.360***	-0.405***	-0.372***	-0.432***	-0.396***
	(3.22)	(3.60)	(2.72)	(3.11)	(2.84)	(3.35)	(3.08)
Deposits	0.088***	0.083***	0.098***	0.085**	0.096***	0.091***	0.094***
	(2.70)	(2.89)	(2.94)	(2.41)	(2.91)	(3.18)	(3.19)
Loans	0.106**	0.109***	0.109**	0.104**	0.108**	0.110***	0.116***
	(2.51)	(2.67)	(2.49)	(2.37)	(2.53)	(2.73)	(2.90)
Non-interest income	0.045	0.060*	0.038	0.037	0.042	0.058*	0.056*
	(1.33)	(1.89)	(1.15)	(1.07)	(1.28)	(1.83)	(1.78)
Basel II	-0.019***	-0.022***					
	(2.60)	(2.84)					
IRB			-0.037***		-0.036***	-0.034***	-0.034***
			(3.92)		(3.87)	(3.76)	(3.52)
Standardized				-0.008	-0.010	-0.014*	-0.013*
				(1.06)	(1.32)	(1.71)	(1.67)
Shadow banking	0.019*	0.017*	0.023**	0.022**	0.021**	0.017*	0.022**
	(1.94)	(1.86)	(2.24)	(2.15)	(2.03)	(1.91)	(2.18)
Capital regulation	0.004**	0.003**	0.005***	0.004***	0.004**	0.003**	0.003**
	(2.46)	(1.97)	(2.66)	(2.74)	(2.54)	(2.04)	(2.13)
Regulatory strength	0.002	0.002	0.002	0.002	0.002	0.002	0.001
	(1.18)	(1.23)	(0.82)	(1.17)	(0.98)	(1.03)	(0.67)
Government recapitalization	0.003	0.004	0.004	0.004	0.004	0.005	0.006
	(0.68)	(0.99)	(0.83)	(0.79)	(0.83)	(1.13)	(1.26)
Asset volatility*government recapitalization	-0.441**	-0.415*	-0.504**	-0.413*	-0.487**	-0.432*	-0.493**
	(2.05)	(1.85)	(2.39)	(1.87)	(2.26)	(1.84)	(2.10)
Market recapitalization		0.000				-0.000	-0.002
		(0.04)				(0.07)	(0.44)
Asset volatility*market recapitalization		-0.302				-0.331	-0.302
		(1.24)				(1.42)	(1.34)
GDP growth							0.288***
							(2.77)
Constant	-0.050	0.006	-0.083	-0.051	-0.070	-0.012	-0.047
	(0.75)	(0.10)	(1.34)	(0.67)	(1.14)	(0.23)	(0.80)
Time fixed effects	YES	YES	YES	YES	YES	YES	YES
Observations	1,386	1,386	1,386	1,386	1,386	1,386	1,386
Number of banks	220	220	220	220	220	220	220
m2 Statistic (p-value)	0.230	0.205	0.243	0.238	0.237	0.205	0.220
Hansen J Statistic (p-value)	0.628	0.613	0.713	0.673	0.712	0.638	0.599
Panel B: asset volatility Sensitivity of Capital Requirements (2000–2007) where Government Recapitalizations Occurred (2008–2009)							
asset volatility+ asset volatility	0.251	0.346*	0.216	0.276	0.224	0.357*	0.321
*government recapitalization	(1.42)	(1.78)	(1.19)	(1.43)	(1.19)	(1.71)	(1.48)