Journal of Financial Stability 19 (2015) 22–30

Contents lists available at ScienceDirect

Journal of Financial Stability

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

How banks respond to Central Bank supervision: Evidence from Brazil

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ARTICLE INFO

Article history:
Received 30 June 2014
Received in revised form 2 November 2014
Accepted 4 May 2015
Available online 21 May 2015

JEL classification:
G21
G28

Keywords:
Bank regulation
Regulatory capital
Asset risk

ABSTRACT

Central Bank supervision is one of the pillars of capital regulation. Based on a unique database built using supervision data from the Central Bank of Brazil, we evaluate the effectiveness of the Central Bank's supervision over banks given the Central Bank's proprietary credit rating and signaling requests for higher capital buffers. We also examine the main determinants of capital buffer management in addition to supervision. We find evidence that (i) Brazilian Central Bank supervision imposes excess capital buffer needs on banks, especially small and midsize banks; (ii) market discipline may play no role in driving capital ratios; and (iii) the business cycle has a negative influence on bank capital cushions, suggesting pro-cyclical capital management. We conclude that supervision plays a major role in markets where market discipline is weak and for smaller banks which act on pro-cyclical way.

1. Introduction

Although banks play a key role in allowing efficient resource allocation in the economy, banks also inherently carry a fragility and opacity that may cause instability to the financial system with high costs to society. As a result, the banking industry is heavily regulated. In particular, capital regulations require the holding of a minimum level of equity in the business that is proportional to asset risk to minimize opportunistic behavior and protect banks from shocks that may affect the value of their assets. Bank equity holders, in turn, generally choose their stakes such that they can maintain a safety margin over the regulatory capital limit and simultaneously meet the expectations and pressures from the market. Thus, beyond regulatory constraints, other factors may influence the so-called capital buffer implied by the capital adequacy ratio, i.e., the holding of additional equity beyond the minimum capital required by regulations.

To a certain degree, international regulatory standards, which are dictated by the Basel Accord (BCBS, 1988, 2004), address these risk factors and ultimately aim toward financial system soundness. In addition to the minimum risk-adjusted capital requirement, a financial authority also monitors banks and requires appropriate risk management from them in accordance with the complexity of the business and appropriate disclosure to enable market monitoring. Specifically, the Basel II structure defines three pillars of regulation: Pillar 1 addresses capital requirement models and banks' capital/risk management, Pillar 2 addresses supervisory monitoring, and Pillar 3 addresses market discipline.

The Basel Committee has recently worked to redesign the regulatory model by strengthening capital requirements, increasing standardization in financial transactions, and adding a macro-prudential scope to regulation that includes additional capital buffer requirements in accordance with economic cycles (BCBS, 2010). This is informally referred to as the Fourth Pillar of prudential regulation.

In view of the discussion above, our contribution focuses on how Central Bank supervision can influence the adjustment process toward an adequate capital adequacy ratio. Using a comprehensive dynamic empirical model with bank-level panel data in which all of the Basel Pillars are controlled for, we analyze the behavior of bank capital buffers in Brazil and find that supervisory monitoring has a positive effect on solvency ratios, especially among less capitalized banks. This finding is of special interest because capital management practices are likely to be positively correlated with the economic cycle. In addition, markets seem to play no role in disciplining banks, partly because the yields to benchmark the risk profile are not available for most banks in Brazil. Our argument is based on our findings that in economies with pro-cyclical financial systems and less-developed capital markets, market discipline seems to play a minor role, whereas the role of Central Bank supervision is stronger. This result is stronger when we control for the

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http://dx.doi.org/10.1016/j.jfs.2015.05.001
1572-3089/

level of bank capitalization: the less capitalized banks, the stronger seem to be supervision of the Central Bank. Hence, the monitoring that is conducted by the supervisory authority contributes to curbing the risky behaviors of less solvent banks. This result contributes to the literature because, to our knowledge, this is the first study to rely on a unique database from a Central Bank and to focus on an emerging market in which market discipline seems to have no role.

The paper has the following structure. Section 2 provides some historical aspects of the implementation of the Basel Accord and trends in local prudential regulation and supervision in Brazil. Section 3 reviews banking theories regarding capital buffer management and some related empirical results in the literature. Section 4 presents the empirical model for the determinants of banks' solvency cushions based on capital buffer theories. Section 5 describes the database, highlighting the characteristics of the local market. Section 6 presents the econometric approach and robustness tests and analyzes the empirical results. Section 7 concludes the paper.

2. Prudential regulation and supervision in Brazil

Following international regulatory standards, Basel I risk-adjusted capital rules were introduced in Brazil under Resolution 2099 on August 17, 1994. Accordingly, the document stipulated that banks must maintain a solvency ratio of at least 8% that is calculated as the ratio of capital to risk-weighted assets. In the same year, a new economic plan – the Plano Real – was introduced and decreased hyperinflation from four digits to one by the end of the following year. Prior to the introduction of the Plano Real, most bank profits came from arbitrage opportunities between low-interest bank deposits and high-interest government bonds rather than from credit transactions. A few banks had to be acquired and others were liquidated because they were not able to perform typical credit activities at a profit (Alves and Alves, 2010).

To strengthen the supervision power of the Central Bank, a new law was introduced allowing the Central Bank to intervene in banks with solvency problems and/or to proffer market solutions, such as mergers or acquisitions or even liquidation. As a result of the Asian crisis in 1997, the minimum capital adequacy ratio was increased from 8% to 11%.

The first test of the new 11% capital adequacy ratio took place in 1999, when Brazil suffered a major exchange rate crisis. Gruben and Welch (2001) argue that an important reason that Brazil exited this crisis more rapidly than other countries in similar situations was the stability of the post-restructuring banking system. Strong prudential regulation and supervision, historical macroeconomic volatility, and a tight monetary policy that encouraged banks to expand holdings of high-yield government securities made Brazil's commercial banks financially sound, with high capitalization ratios and liquidity. By contrast, the stability of the banking system may have also contributed to curbing banks' loan supply and, consequently, economic growth.

Brazil serves as an interesting setting to examine the role of supervision in determining the capital buffer. First, the Brazilian requirement is higher (11%) than the minimum standard set by BIS (8%). In the period from 2003 to 2010, the aggregated capital adequacy ratio (CAR) of commercial banks varied between 16% and 19%, well above the limit of the 11% requirement. Second, the role of supervision should be more important in an economy with fewer funding options due to the minor role played by debt and equity capital markets and – as we will provide evidence for – where market discipline seems to play a minor role. We would expect the first factor to contribute to weakening the role of supervision, whereas the second factor may contribute to strengthening the role of supervision.

3. Review of capital buffer decisions

Given anecdotal evidence that banks present capital ratios well above regulatory requirements, a recent line of work has explored this notion by investigating the major drivers of bank capital buffers. As argued by Dewatripont and Tirole (1994), the theory states that banks balance costs and benefits across the entire balance sheet when subject to capital regulation because responsibility is shifted to the regulator when the bank's solvency falls below a threshold. Basically, the capital level should be set as an endogenous response to (i) penalties and other types of distress related to a breach of the regulatory minimum, including supervision pressure, (ii) the cost of capital surpluses, and (iii) the costs and time constraints for adjusting capital levels.

Milne and Whalley (2001) and Milne (2004) model the dynamics in banks' capital decisions as a continuous-time inventory problem. The manager must determine the level at which he must issue new capital or wait until the supervisory authority forces him to do so, giving the supervisor the important role of examining the bank's equity, as in Marcus (1984). In addition to balancing the costs and benefits of the capital surplus, the key point is that banks with high charter values have more to lose if they breach the regulation and thus have greater incentive to maintain extra capital. The models have important implications for the effects of capital regulation and supervision on bank risk taking. According to the authors, in the short term, the bank's risk aversion is a positive function of supervisory monitoring and the incentives of banks to take risks decrease as their capital levels approach the regulatory minimum.

Estrella (2004) aggregates cyclical shocks in a dynamic model in which forward-looking banks choose their capital levels subject to adjustment costs and to capital requirements on the basis of value-at-risk (VaR) models. He shows that over the cycle, the optimum capital level is negatively related to the period-dependent VaR capital constraint, such that, the difference between them – the optimal capital buffer – assumes a cyclical pattern. The results suggest that the regulatory capital requirement would be loose in phases of gains and binding on banks' capital structures during periods of loss, increasing the likelihood of reductions in the credit supply. The model also provides some useful insights regarding possible bank conduct and its implications for financial stability. In business cycle upturns, the gap between optimal and regulatory capital may be so large that banks may follow the temptation of opportunistically burning their buffer to increase short-term profits, hence ignoring possible future needs for capital. Ayuso et al. (2004) define such shortsighted behavior as pro-cyclical capital management, as they showed for the Spanish financial system through a dynamic econometric model.

In fact, the majority of empirical research has focused on dynamic models, the basis for the construction of capital buffer theories. In this regard, there are two approaches in the literature, which differ only in how they treat endogeneity in the capital-risk decision. The first approach separates capital and risk, so variables are simultaneously estimated, providing additional insights about the coordination between these two variables, as in Rime (2001) for the Swiss financial system and Jokipii and Milne (2011) for US banks[1]. The second approach directly models the dynamic

[1] For the first approach, a fairly common strategy is to use least squares estimators in two or three stages (2SLS/3SLS); however, this methodology does not address eventual unobserved bank heterogeneity (fixed effects), which can lead to biased estimations. Further, even approaches that specifically address the fixed effect issue should be sources of bias in the case of dynamic panels because the within-group

Table 1
Explanatory variables and expected signs.

Stimulus	Variable	Definition	Rationale	Expected sign
Capital requirement and capital management	BUF_{t-1}	Lagged capital buffer.	- Proxy for adjustment costs. Higher capitalization costs are associated with lower adjustment speeds.	+
	ROE	Return on equity.	- Higher costs of capital (trade-off theory).	–
			- Retained earnings as an important source of capitalization (pecking order).	+
	VOL	Return on equity volatility.	- Proxy for a firm's risk profile. Higher cost of failure (bankruptcy or violation of the capital minimum requirement).	+
	NPL	Non-performing loans.	- Proxy for a firm's risk exposure.	–
	SIZE	Total assets.	- Broader access to capital markets.	–
			- Higher diversification and better investment opportunities.	
			- Opportunistic behavior of those perceived as "too big to fail."	
	LIQUID	Liquid assets.	- Lower liquidation costs.	
Supervisory pressure	$SUPERV_{t-1}$	Supervisory CAMEL ratings.	- Supervisory monitoring effect.	+
Market pressure	*SUBORD*	Subordinated debt.	- Market discipline effect.	+
	BANKDEP	Uninsured bank deposits.	- Market discipline effect.	+
	PEER	Buffer average of the peer group.	- Peer group pressure.	+
Economic environment	*GDPG*	GDP growth.	- Prudent capital management.	+
			- Shortsighted capital management.	–
	LOANG	Loan growth.	- Control individual credit demand changes.	–

Explanatory variables and their expected signs in the presented capital buffer econometric model. The time dummies and the variable *DModel* – which defines change from Basel I to Basel II – are not included in the table. *K* in Eq. (3) is the intercept.

of capital asset ratios, i.e., the relation between capital and risk-weighted assets, and endogeneity issues are addressed through specific estimation techniques. Authors who have adopted the second approach include Alfon et al. (2004), who test bank behavior in Spain; Francis and Osborne (2009), who assess the determinants of bank capital in the UK; Wong et al. (2005), who test the banking industry in Hong Kong; and Lindquist (2004), Stolz (2007), and Jokipii and Milne (2008), who undertake similar studies in Norway, Germany, and Europe, respectively[2].

A common result for all studies is the persistence in the series of capital ratios in various jurisdictions, indicating that capital adjustment costs significantly influence banks' choices to hold capital in excess. In general, researchers note the prevalence of capital management based on the trade-off between the cost of capital and the cost of failures, with the exception of Alfon et al. (2004), who verify the predominance of a pecking order in the capital decisions of banks.

Another line of research examining capital buffers is related to bank cyclicality. Most researchers (e.g., Ayuso et al., 2004; Alfon et al., 2004; Francis and Osborne, 2009; Wong et al., 2005; Lindquist, 2004; Stolz, 2007; Jokipii and Milne, 2008) test the influence of business cycles on bank behavior and provide evidence that capital buffers may be pro-cyclical, with banks shrinking balance sheets in bad times and enlarging them in good times. By contrast, Jokipii and Milne (2008) find that banks from countries that have recently joined the European Union exhibit counter-cyclical behavior. A similar result is found by Francis and Osborne (2009) for the UK when testing for an alternative former period shortly after the implementation of Basel I capital regulations. These results suggest that legal and regulatory pressures can induce increases in the capital levels of banks despite the countervailing influence of the business cycle.

Market discipline can also determine bank capital buffers. The argument is that investors in subordinated positions may require additional discipline from banks, implying a higher capital buffer. Wong et al. (2005) and Francis and Osborne (2009) find that the wholesale funding market and subordinated debtholders both have positive effects on capital ratios. Nier and Baumann (2006) provide interesting cross-country market discipline evidence by showing that uninsured deposits held by banks prompt decreases in bank leverage. Blum (2002) provides some insights on the limitation of subordinated debt, which may induce banks to choose even higher risks than an absence of market discipline. As a result of market discipline, banks with capital buffers that are smaller than those of their peers may send negative signals to the market, such that a certain positive coordination among similar banks is expected. A positive sign is observed by Lindquist (2004), Alfon et al. (2004), and Wong et al. (2005) for different countries, whereas Fonseca and González (2010) find evidence of market discipline for several countries.

In light of the literature review, we believe that there is an opportunity for research to be conducted on the influence of supervision on capital ratios. Furfine (2001) provides evidence that tighter supervisory monitoring may influence a bank's balance-sheet decisions, and Lindquist (2004) finds a positive relationship between capital ratios and supervisory efforts, but his results are not significant. Our work contributes by examining how banks under supervision pressure may adjust to a faster speed. We benefited from a unique Central Bank database and examine an environment in which market discipline may not function in the same manner as in developed countries with strong capital markets.

4. Modeling capital buffer dynamics

We follow closely the partial adjustment model proposed by Francis and Osborne (2009) in which the empirical approach is developed in two steps. First, we concentrate on the relationship between risk and target capital ratio. Bank-specific risk indicators are used to estimate a target capital ratio for each bank while controlling for the bank's capacity to generate income and to

transformation ignores the correlation between the lagged dependent variable and the regression error term (Nickell, 1981).

[2] For the second approach, a common strategy is that proposed by Arellano and Bond (1991): a generalized method of moment (GMM) estimator to correct the bias in dynamic panels, as we describe in Section 6.

account for some structural characteristics, such as size, management, market discipline, supervisor monitoring and the economic environment. To account for risk, both market evaluation and bank accounting items are considered. Based on the estimated parameters, a bank's time-varying capital gap between the desired target capital ratio and the actual capital ratio is then computed for each time period. In the second step, the adjustment of the capital buffer is explained by using the estimates of the bank's capital gap and the previously mentioned variables.

Specifically, we test the determinants of bank capital buffer behavior based on a dynamic empirical model by including the costs of capital adjustments and regulations. Under this rationale, Eq. (1) considers that capital adjustments, $\Delta BUF_{i,t}$, are not instantaneous. Hence, bank i only partially reaches its optimal buffer, $BUF^*_{i,t}$, during the period between $t-1$ and t. The proportion or speed of adjustment, θ, will be greater with lower adjustment costs. In the case of zero adjustment costs, capital is fully adjusted ($\theta = 1$), and the observed buffer, $BUF_{i,t}$, is equivalent to the optimum one plus an exogenous error component, $u_{i,t}$[3].

$$\Delta BUF_{i,t} = \theta\left(BUF^*_{i,t} - BUF_{i,t-1}\right) + u_{i,t} \quad \text{or} \quad BUF_{i,t} = \left(1-\theta\right)BUF_{i,t-1} + \theta\, BUF^*_{i,t} + u_{i,t} \tag{1}$$

In turn, the theoretical optimum buffer is modeled as a function of four fundamental sources of influence on banks' decisions, as noted in the above literature discussion and presented in Eq. (2): First, the influence of capital requirements on banks' management model (*MNG*); second, the pressure of supervision (*SUP*); third, market pressure (*MKT*); and finally, the economic environment (*CYCLE*).

$$BUF^*_{i,t} = f\,(MNG, \quad SUP, \quad MKT, \quad CYCLE) \tag{2}$$

The first three sources of incentives to the optimal solvency cushion correspond to the three regulation pillars of Basel II, and the fourth source is the base of the macro-prudential requirement of the new Basel Accord. Therefore, the variables capturing each of those stimuli define the full specifications of the capital buffer empirical model in the following equation:

$$\begin{aligned} BUF_{i,t} &= \left(1-\theta\right)BUF_{i,t-1} + \alpha_1 ROE_{i,t} + \alpha_2 NPL_{i,t} + \alpha_3 VOL_{i,t} + \alpha_4 SIZE_{i,t} + \alpha_5 LIQUID_{i,t} \\ &\quad + \beta_1 SUPERV_{i,t-1} + \gamma_1 SUBORD_{i,t} + \gamma_2 PEER_{i,t} + \mu_1 GDPG_t + \mu_2 LOANG_{i,t} \\ &\quad + DModel + TimeDummies + K + \eta_i + \varepsilon_{i,t} \end{aligned} \tag{3}$$

From Eq. (3), we derive our main empirical hypothesis regarding the effect of supervisory solvency evaluations on the capital choices of banks, Basel Pillar 2, represented by the variable *SUPERV*, after controlling for the remaining three Basel-based stimuli. The corresponding explanatory variables are listed in Table 1.

Banking supervision can influence the decisions of banks, even those apparently compliant with capital regulations. Each bank is periodically evaluated in accordance with quantitative and qualitative criteria that cover broad definitions of economic and financial banking conditions, governance, risk profiles, and efficiency. A poorly rated institution, captured by the variable *SUPERV*, is more likely to incur direct action from supervision. In this case, a bank may compensate for its deficiencies by increasing its solvency ratio in the short term (Alfon et al., 2004). In addition, a more intense indirect effect of supervision is expected for banks that are closer to the regulatory capital limit. As supervisory evaluations worsen, the scores increase; thus, the expected sign of the variable *SUPERV* is positive.

Regarding capital management strategy and the influence of capital requirements (Basel Pillar 1), the three main drivers of capital buffers are adjustment costs, capital profitability, and bank risk appetite. If it is costly to increase capital, persistence in the variable *BUF* will be observed, implying that theta will have a positive value close to zero.

Like any other corporation, a profit-maximizing bank may balance the costs of holding capital surplus to the extent of the likelihood of confronting costs associated with failure. A banker may maintain a lower capital ratio when the opportunity cost of capital is high. By contrast, as argued by capital buffer theory, the banker may decide on a higher capital standard with a higher probability of breaching the regulation, which should increase the probability of bankruptcy; thus, as intended by regulators, banks with riskier portfolios should hold larger capital buffers. Therefore, under the trade-off perspective, return on equity, *ROE*, may be used as a proxy for the cost of remunerating the equity, with a negative expected sign[4]. Regarding the cost of failure, because measuring the riskiness of banks is a complex task, we combine two variables that are commonly adopted in the banking and corporate finance empirical literature: nonperforming loans, *NPL*, and the volatility of return on equity, *VOL*[5], which are expected to have positive signs.

With regard to ROE, although it can be negative from the trade-off perspective, the expected sign for the *ROE* variable should also be positive, especially in markets in which asymmetric information can significantly increase the costs of external capital, making retained earnings the main source of recapitalization, which is consistent with pecking order theory (Myers and Majluf, 1984). Indeed, Berger (1995) distinguishes three main reasons for the positive relationship between banks' profits and capital ratios. First, given a multi-period framework, higher profitability leads to increases in capital, provided that the marginal profits are not fully distributed as dividends. Second, if investors are risk averse and markets are incomplete, then increases in capital reduce bankruptcy costs and may lower the market's expected rate of return, thereby leading to increases in expected earnings. Finally, given information asymmetries, banks that expect better performance may signal that information through higher capital ratios (Leland and Pyle, 1977). We also control for size (Bank size, *SIZE*) and liquidity, as evidenced by the ratio of liquid assets to total assets (*LIQUID*).

Regarding market pressure, following Francis and Osborne (2009), we measure the amount of uninsured bank funding by the total subordinated debt, *SUBORD*. The effect of market discipline may strengthen as the amount of uninsured funding increases. Alternatively, because some banks may not have access to the

[3] We assume that the exogenous shocks to buffer adjustments (i.e., the error term u_{it}) consist of two orthogonal components, which are independent and identically distributed: a bank-specific effect (η_i) and a white noise (ε_{it}). Effects that are not directly observable (e.g., managerial attitudes, corporate strategy, and the instability of deposits) remain stable over time for a given bank but change from firm to firm justify the fixed effects assumption. Additionally, Hausman tests reject the use of random effects.

[4] The definition of equity profitability as a proxy for the cost of equity is based on the comparable accounting earnings model (Green et al., 2003), which is widely used because of its practicality. Roughly speaking, the methodology begins with the principle that shareholders may expect returns based on past earnings; thus, each dollar invested as capital must perform according to this target.

[5] Some related empirical studies (e.g., Ayuso et al., 2004) argue that nonperforming loans are an ex post measurement of the risks assumed by an institution and should therefore have a negative expected sign; however, Brazilian regulation demands that credit classification initially be conducted under prospective criteria and that such classification should subsequently be reviewed based on the credit past-due status (Resolution 2682 on December 19, 1999).

Table 2
Descriptive statistics.

Variable	Unit	Mean	Std. Dev.	Min.	Max.
BUF	(%)	17.4	23.4	−8.1	195.2
ROE	(%)	3.8	10.1	−77.2	309.9
VOL	(%)	4.4	7.7	0.1	167.7
NPL	(% Total credit)	5.4	7.1	0.0	84.0
SIZE	(Millions R$)	14,500	50,300	18	565,000
LIQUID	(%)	17.7	16.0	0.0	95.5
SUBORD	(% Total liability)	0.6	1.8	0.0	25.4
BANKDEP	(% Total deposit)	13.9	26.2	0.0	100.0
PEER	(%)	12.8	8.9	−2.0	46.1
LOANG	(%)	7.6	29.8	−98.8	554.4

Summary statistics for the variables that represent specific characteristics of the banks in the sample on a quarterly basis.

subordinated debt market, we also test the amount of interbank deposits, *BANKDEP*, following Wong et al. (2005) and Nier and Baumann (2006). Both variables are expected to present positive signs. The behavior of competition should also put pressure on banks' capital buffers. The variable *PEER* is defined by the average capital buffer of similar institutions, so it is expected to have a positive sign.

Regarding the economic environment, we add a variable for gross domestic product growth, *GDPG*, whose negative sign may indicate shortsighted management because negative co-movements between banks' capital buffers and variables of economic growth in several banking systems suggest that business cycles may significantly influence the behavior of banks. We also include the variable *LOANG* as a proxy for variations of bank-specific credit demand. Ayuso et al. (2004) argue that because the credit supply is rarely constrained by the capital requirement, credit growth may be primarily driven by demand.

Finally, we include the indicator dummy variable *DModel* to control for the mid-2008 changes in the regulatory models of capital requirements, and quarter and year dummies (time dummies) to capture possible quarterly seasonality and the specificities of each year in the sample.

5. Database

The database consists of quarterly information from banks alone and banking holding companies with commercial portfolios operating in Brazil between the first quarter of 2001 and the fourth quarter of 2009. Development banks and those whose main activities were investment banking or treasury operations are excluded from the sample. Institutions subject to government intervention or liquidation processes and those with fewer than five observations[6] during the period are also excluded.

After data cleaning, some banks presented regulatory capital in an amount more than 80 times greater than required, such as certain small foreign subsidiaries whose main function is to provide credit lines and export-import foreign exchange contracts to companies of their nationality conducting business in Brazil. Because their banking activity varies according to the business activity of related firms, in some downturn periods, the loan portfolio is replaced by government securities, making their solvency ratio extremely high and defining an accentuated cyclical pattern. Therefore, we remove those extreme outliers by eliminating observations with capital ratios above the sample's 99th percentile[7]. The final data set consists of an unbalanced panel with 3806 observations of 112 banks distributed in 36 quarters.

The firm-specific data include descriptive information on the institutions, accounting information from balance sheets and financial statements, and operational limits that are periodically sent to the Central Bank.

The bank's capital buffer, *BUF*, is calculated as excess regulatory capital over the risk-weighted assets as a percentage[8]. The value can also be calculated in terms of the CAR as the actual CAR minus the minimum required CAR. The capital ratios of Brazilian banks are well above the limit of 11% required by regulation, with the sample mean capital buffer at approximately 17%.

ROE is calculated as the quarterly net income over the average net book value. The volatility of this variable in the last four quarters, measured by the standard deviation, defines the risk variable *VOL*. The average equity profitability in the sample is 3.8% per quarter, and the average variability for this variable is 4.4%. Complementing the bank risk profile, *NPL* is defined as non-performing loans over total loans. A loan is considered non-performing when payments of interest and principal are past due by 90 days or more.

Bank size, *SIZE*, is defined as the net total assets of the amounts related to financial intermediation. The six largest banks account for more than 70% of the sample's total assets in the last quarter of 2009. Banco do Brasil alone accounted for approximately 565 billion BRL in assets in that period.

The amount of uninsured funding is measured first as the ratio of subordinated debt to total liabilities, *SUBORD*, and second as the amount of interbank deposits to total deposits, *BANKDEP*.

The peer group capital buffer, *PEER*, is calculated as the weighted average of the buffers of institutions with close business strategies and similar sizes. With regard to strategies, banks are divided into four groups according to the cluster analysis methodology adopted by the Central Bank of Brazil (Capelletto, 2006): (i) companies specializing in retail loans, (ii) banks of corporate credit, (iii) complex institutions with multiple strategies, and (iv) banks related to the automotive industry. In the sample, approximately 37% of banks are aimed at retail transactions, 41% are focused on corporations, 10% are multi-strategies banks, and the remaining are banks

[6] We do not expect survivorship bias because we have excluded five financial institutions. First, of the five banks, three banks had already been under a special regime by the Central Bank prior to 2001. Second, one bank entered into a special regime in the second semester of 2001, so the Central Bank had this bank under surveillance prior to 2001. Finally, the fifth bank was liquidated because of fraud, so the balance sheet would not reflect the risk profile of the bank and was excluded to prevent bias.

[7] To handle these types of extreme events in the regressions, three alternative treatments have been applied in the data set. First, the estimations were conducted with the entire sample. Second, the observations with capital buffers higher than the 99th percentile in the sample, equivalent to a CAR value of 211 %, were excluded. Third, the maximum buffer value was limited to the 99th percentile, such that any observation with a higher buffer had its value changed to the defined ceiling. In all three cases, the results and diagnostic tests of the models showed no significant changes.

[8] Resolution 3444 of February 28, 2007 amended the regulatory capital definition (*Patrimônio de Referência*—PR). In parallel, Resolution 3490 of August 29, 2007, which took effect in June 2008, provided new models for calculating the minimum capital requirement (*Patrimônio de Referência Exigido*—PRE).

Table 3
Correlation matrix.

	BUF	BUF_{t-1}	*ROE*	*VOL*	*NPL*	*SIZE*	*LIQUID*	*SUBORD*	*BANKDEP*	*PEER*	*LOANG*	*SUPERV*
BUF	1											
BUF_{t-1}	0.78*	1										
ROE	−0.09*	−0.10*	1									
VOL	−0.03	−0.04*	0.30*	1								
NPL	0.14*	0.09*	−0.12*	0.15*	1							
SIZE	−0.14*	−0.12*	0.05*	−0.05*	0.00	1						
LIQUID	0.44*	0.37*	−0.04*	0.04*	0.23*	−0.03	1					
SUBORD	−0.11*	−0.10*	0.00	−0.03	0.00	0.29*	−0.09*	1				
BANKDEP	−0.19*	−0.16*	−0.04*	−0.05*	−0.07*	−0.11*	−0.03*	0.08*	1			
PEER	0.40*	0.33*	−0.07*	0.03	0.13*	−0.23*	0.10*	−0.17*	−0.23*	1		
LOANG	−0.01	0.12*	0.01	−0.03*	−0.14*	0.01	0.05	−0.04*	0.02	−0.01	1	
SUPERV	0.04	0.02	0.01	0.01	0.04*	−0.01	−0.05*	−0.01	0.02	−0.01	0.03	1

Correlations among the variables in the sample on a quarterly basis. The index * represents a significance level of at least 5%.

focusing on the automobile industry. With regard to size, each strategy group is ordained as the individual total assets and then segmented into three subgroups with an equal number of banks.

The liquidity cushion, *LIQUID*, is defined by the ratio of liquid assets to total assets. A strict definition for liquid assets has been chosen to include only cash and government bonds held in portfolios. Brazilian banks commonly invest a considerable portion of their assets in government bonds, which can be explained by the low liquidity in the secondary credit market in addition to the historically high macroeconomic volatility and high interest rates.

The bank individual total loan growth, *LOANG*, has also been considered. The growth of individual credit portfolios is significant; in the sample, the loan volume increased an average of 7.7% per quarter.

Table 2 summarizes the basic statistics for the variables described, and Table 3 presents the correlations among those variables.

The data set also contains data on bank-specific supervisory ratings regarding banks' overall solvency conditions. The variable *SUPERV* is constructed from the average of the scores given to the institution by the supervisory authority on a quarterly basis. We use the local supervisor's proprietary assessment criteria, which involve evaluations of capital adequacy, asset quality, management, earnings, and liquidity, in a CAMEL style[9]. Poor results of supervisory evaluation are indicated by relatively higher scores.

Regarding the macroeconomic data, the variable *GDPG* is formed by real GDP growth in a quarter versus the same quarter a year earlier. This variable represents the Brazilian business cycle.

Finally, as is common in econometric analysis to address asymmetry issues in the data, we transformed the variables into their logarithmic forms.

6. Methodology and econometric analysis

The empirical problem in Eq. (3) has the structure of a dynamic unbalanced panel with fixed effects. Given the high amount of temporal information concerning the amount of cross-sectional data ($N = 112$ and $T = 36$), the panel is at the borderline between classical macro- and micro-panel data; therefore, we aim to explicitly consider the asymptotic properties of the series involved to avoid the problem of spurious regression among non-stationary variables that are not cointegrated. Thus, we employ the Fisher-type statistic proposed by Maddala and Wu (1999) to test for unbalanced panel unit roots and do not reject the assumption that our panel is stationary.

We estimate the regressions through the two-step generalized method of moments system developed by Arellano and Bover (1995) and Blundell and Bond (1998). The robustness is then verified by the bounding procedure proposed by Bond (2002), which compares the performance of the system GMM estimator with alternative estimators with known properties in dynamic panel applications. The results are presented in Table 4.

The first bounding procedure estimation (model I in Table 4) is performed by pooled ordinary least squares (POLS), in which the dependent and explanatory variables are defined in levels. The main problem is that the predetermined variable (lagged dependent) is endogenous to the omitted fixed effect term, violating a necessary condition for OLS consistency. Consequently, the coefficient estimate appropriates predictive power from the firm's fixed effects embedded in the error term. Because the estimate is positively biased, it sets the upper boundary for this coefficient.

The second bounding procedure estimation (model II in Table 4) addresses the endogeneity problem by removing the fixed effects through the least square dummy variable estimator (LSDV). However, because the within-group transformation is still biased because it ignores the correlation between the lagged dependent variable and the error term, the estimated coefficient of the predetermined variable becomes downward biased and thus defines the lower boundary.

Although the estimation bias decreases as the panel temporal dimension increases (Nickell, 1981), the problem may persist even for samples longer than 30 time units (Judson and Owen, 1999). One means of addressing this short panel issue would be to use instrumental variables (IVs), but reliable instruments for application in micro-finance panels are rare, and weak instruments can also result in biased estimates.

Arellano and Bond (1991) apply a generalized method of moments to construct efficient instruments. After taking first differences to remove the time-invariant heterogeneity effect, the authors demonstrate that the lagged variables are valid instruments for the predetermined variable in the first difference, provided that the residuals do not have second-order serial correlation. The weakness of the "difference GMM" methodology is the small correlation between first differences and the lagged levels of these variables, especially if the series is time-persistent. To address the potential problem, Arellano and Bover (1995) and Blundell and

[9] There is a low correlation between SUPERV and the other variables. This is mainly due to the fact that the SUPERV variable is not simply a composite of the basic variables described in the model. In fact, SUPERV includes variables that are treated and adjusted to better reflect each dimension of CAMEL. Some examples related to SUPERV include the following: (1) the bank capital includes not only the required regulatory capital but also the adjusted capital due to tax and other intangibles, which better captures the quality of the bank and the capacity to absorb losses (as defined by Basel III), (2) the earnings variable is not an accounting figure but an operational result that excludes non-recurrent income, (3) the liquidity component is composed of not only liquid assets but also the capacity to honor short-term liabilities under the stress condition (as per the Basel III definition—liquidity coverage ratio). In addition, we apply the IV for the variables by applying their lag, which would also mitigate this potential problem of multicollinearity. We thank the referee for noting this point.

Table 4
Capital buffer model specifications.

	POLS	FE-DVLS	Sys. GMM	Sys. GMM	Sys. GMM
	I	II	III	IV	V
BUF_{t-1}	0.901***	0.756***	0.818***	0.809***	0.830***
	(137.35)	(74.46)	(23.87)	(23.34)	(25.35)
ROE	0.282***	0.294***	0.306***	0.291***	0.297***
	(8.24)	(8.44)	(2.87)	(2.68)	(2.83)
VOL	0.157***	0.166***	0.190***	0.190***	0.180***
	(3.71)	(3.54)	(2.87)	(2.82)	(2.61)
NPL	0.000	0.001	−0.001	−0.001	−0.001
	(0.18)	(1.18)	(−0.68)	(−0.67)	(−0.74)
SIZE	−0.009***	−0.041***	−0.019***	−0.020***	−0.020***
	(−3.50)	(−5.28)	(−3.11)	(−2.96)	(−3.23)
LIQUID	0.009***	0.024***	0.025***	0.022***	0.024***
	(3.91)	(5.68)	(3.50)	(3.12)	(3.34)
SUBORD	0.376**	0.618***	0.436		0.444*
	(2.03)	(2.66)	(1.64)		(1.75)
BANKDEP				−0.069	
				(−1.41)	
PEER	0.031**	0.076***	0.058*	0.046	0.059**
	(2.12)	(3.72)	(1.78)	(1.29)	(2.05)
$SUPERV_{t-1}$	0.016	0.044***	0.056*	0.053*	
	(1.09)	(2.60)	(1.80)	(1.70)	
$DBuf_L .SUPERV_{t-1}$					0.070**
					(2.12)
$DBuf .SUPERV_{t-1}$					0.049*
					(1.71)
$DBuf_H .SUPERV_{t-1}$					0.016
					(0.33)
LOANG	−0.307***	−0.268***	−0.262***	−0.265***	−0.271***
	(−23.41)	(−20.51)	(−6.30)	(−6.25)	(−7.65)
GDPG	−0.311**	−0.218	−0.328**	−0.338**	−0.305**
	(−1.98)	(−1.43)	(−2.04)	(−2.03)	(−2.03)
K	0.228***	0.971***	0.487***	0.525***	0.487***
	(3.69)	(5.87)	(3.24)	(3.05)	(3.36)
R^2	**0.895**	**0.879**			
AR(1)			**0.000**	**0.000**	**0.000**
AR(2)			**0.670**	**0.688**	**0.700**
Hansen			**0.347**	**0.244**	**0.516**

The dependent variable is the bank's capital buffer, which is calculated as the natural logarithm of capital over the minimum required by regulation. In addition to the lagged dependent variables, the explanatory variables include firm-specific and macroeconomic factors. Specification I is estimated by pooled OLS. Specification II is a fixed effects panel model (FE) estimated by LSDV. Specifications III to V are estimated by system GMM; the endogenous variables are instrumented with one to five lags, and the instruments are collapsed. In all models (I to V), quarter and year dummies are included, but their coefficients are omitted. Indexes *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively, and *z*-statistics (Specification I) and *t*-statistics (Specifications II to V) are reported in parentheses. The Hansen test refers to the test for over-identification restrictions, and tests AR (1) and AR (2) refer to tests of the first- and second-order autocorrelations. For those tests, *p*-values are reported.

Bond (1998) propose a methodology known as system GMM, which combines a system of regressions in differences with a regression in levels and considerably increases the statistical efficiency of the estimator.

Therefore, the remaining estimations (models III–V in Table 4) are performed through the system GMM. With the aim of removing the unobserved idiosyncratic effects, we apply orthogonal deviations rather than first differences because first difference transformations may increase the gaps in unbalanced panels. We also use the two-step process, which is asymptotically more efficient than the estimator of the first stage. Because it may produce inconsistently smaller standard errors, especially in cases of short samples and a large number of instruments, we employ two corrective measures. First, we apply the Windmeijer (2005) method for finite samples to correct the variances and co-variance matrix. Second, we control the number of instruments by initially reducing the number of lags and then combining (collapsing) those instruments into smaller sets[10]. The optimal number of instruments is defined by the downward testing procedure for dynamic panels proposed by Andrews and Lu (2001), which consists of progressively testing combinations of moments to reduce the over-identification restrictions until the significance of the Hansen test increases. As a result, the endogenous variables considered are instrumented with one to five lags[11].

6.1. Empirical results

Table 4 shows that the GMM estimation results are robust to the bounding procedure. As expected, model I, estimated by POLS, presents the highest coefficient estimate on the lagged dependent variable (positive bias); the fixed effects model, model II, has the lowest estimate (negative bias); and models III–V, based on GMM instrumentation, encompass intermediate values. Notably, the coefficient estimates on the other explanatory variables do not change signs, and their values and significance levels generally remain similar, regardless of the method adopted. Moreover, the autocorrelation tests for the instrumented models suggest that

[10] Generally, the procedure reduces the moment conditions by creating, for each variable, one instrument for each lag distance rather than one for each period and lag distance. It is worth noting that in addition to the standard error bias, the excess of instruments may overfit endogenous variables and undermine identification tests, especially the *J* test of Hansen (Roodman, 2009).

[11] As a robustness check, all models were reestimated by considering only those banks with complete observations during the period of analysis (90 institutions) in a balanced panel. The results remained robust, with no significant differences from those presented.

the condition of the absence of second-order serial correlation is fulfilled, and the Hansen tests do not indicate over-identification restrictions on the estimated equations. The consistency of both tests is also observed in model V in Table 4.

6.1.1. Results for firms' capital management strategy

The estimated coefficient of the lagged dependent variable, BUF_{t-1}, has a positive sign at the 1% level in all models. The positive values close to one (approximately 0.83) indicate that the variable is persistent; that is, the adjustment of the buffers is fairly slow ($0 < \theta < 1$). Comparatively, the estimated adjustment speeds are close to those of other jurisdictions, such as England (Francis and Osborne, 2009) and Hong Kong (Wong et al., 2005). The results support the buffer capital theories regarding the influence of adjustment costs on the decisions of banks.

Contrasting the typical findings in the literature, the coefficient for the variable *ROE*, although significant at the 1% level, has a positive sign in all models ($\alpha_1 > 0$), supporting the hypothesis regarding earnings as a source of recapitalization. In fact, a high rate of earnings retention, which exceeds 50% on average, has been observed in the Brazilian banking industry. Retained earnings may be the main source of capital increases, confirming Myers and Majluf's (1984) pecking order theory. This result may be related to some combined characteristics of the Brazilian banking industry, such as the highly concentrated ownership structure, the limited access to external capital sources for the majority of banks, and the high profitability, which may also increase banks' charter value.

The coefficient for the variable *VOL* is positive and significant ($\alpha_2 > 0$) at the 1% level in all models, which shows that institutions with greater earnings instability may have higher levels of capital ratios to avoid eventual breaches of the capital limits. However, non-performing loans, *NPL*, which are also part of the risk profiles of firms, are not significant in all specifications, and their signal is undefined ($\alpha_3 = 0$).

Bank size, *SIZE*, presents a significant coefficient at the 1% level with a negative sign in all models. As expected, larger banks appear to hold less capital. Economies of scale, greater diversification, and especially public perceptions of safety nets for large banks may permeate this result. This evidence contributes to the discussion of different prudential rules for systemically important institutions.

Conversely, the coefficient for the variable *LIQUID* is positive and significant at the 1% level in all models, indicating that banks with larger liquid asset cushions also have higher capital buffers. It appears that the most prominent effect of this variable is the reduction in the value of risk-weighted assets, as most of the assets compounding the variable have zero risk weight. One reason for such an unexpected result is that the variable, as it was constructed, does not fully capture the underlying liquidity of bank portfolios; however, we reestimated the model by including other riskier liquid assets (stocks, quotes of investment funds, and other securities) in the liquidity proxy, and the signal remained significantly positive. Another explanation may be related to strategies for longer-term investments. Because the profitability of government bonds is high as a result of high interest rates, some banks may decide to hold capital and liquidity in excess to remain flexible to take advantage of growth opportunities.

6.1.2. Results pertaining to supervisory pressure

The variable $SUPERV_{t-1}$ is positive and becomes significant ($\beta_1 > 0$) at the 1% level when it is taken as endogenous in the instrumented models III and IV. After controlling for the level of capitalization (BUF_{t-1}), we find that a bad rating may cause subsequent positive adjustments in the capital ratio. One possible interpretation is that less efficient institutions and, consequently, poorly evaluated banks use capital as a means of compensating for their deficiencies and avoiding increases in supervisory monitoring. The result indicates a beneficial influence of supervisory evaluations over firms' management and solvency; firms would respond by either increasing the proportion of capital or reducing risk exposures.

6.1.3. Results pertaining to market discipline and competition pressure

Regarding the influence of subordinated debtholders on capital buffers, the coefficient of the variable *SUBORD* is positive; however, when instrumented, it loses significance. This coefficient is not significant in model III. Moreover, the interbank market appears to have no disciplinary effect on the capital ratios of banks, as model IV unexpectedly shows a non-significant negative relationship between *BANKDEP* and capital buffers ($\gamma_1 = 0$)[12]. These results indicate that uninsured debtholders may not play a significant role in disciplining banks, consistent with the recent tests performed by Mendonça and Loures (2009), who find no empirical evidence that reveals market discipline through subordinated debt spreads in Brazil. One reason for those findings may be the lack of a developed and transparent financial system.

By contrast, competition among banks appears to be a significant factor in defining the behavior of banks. As expected, the signal of the *PEER* variable is positive and significant ($\gamma_2 > 0$). As in other jurisdictions, there is evidence that banks are influenced by the behavior of their peer group. Overall, the evidence indicates that market discipline may arise from competitors rather than from debtholders, as in Lindquist (2004), Alfon et al. (2004), and Wong et al. (2005).

Nevertheless, peer group pressure may also have negative consequences for financial stability if banks begin decreasing their capital ratios. Hence, disclosure rules and market discipline should be an important part of the regulation agenda, as the recent accelerated growth in the credit and capital markets in Brazil may provide incentives for banks to migrate toward riskier investments.

6.1.4. Results on business cycle effects

Economic growth has a negative effect on capital buffer adjustments. Even when we control for individual loan portfolio growth (*LOANG*), the variable *GDPG* has a negative coefficient ($\mu_1 < 0$) and shows a significance level of 5% in all instrumented models (models III to V). The results provide evidence that banks act in coordination with economic cycles, suggesting pro-cyclical capital management. These results are in line with previous works by Ayuso et al. (2004), Alfon et al. (2004), Wong et al. (2005), Lindquist (2004), and Stolz (2007). These results are important primarily for the new macro-prudential regulation debate because the observed behavior may initially destabilize the banking system following loss periods and subsequently accentuate downturns in the real economy. Some macro-prudential measures have been discussed, such as additional time-varying capital requirements and dynamic credit loss provisions, such as that adopted in Spain.

6.1.5. Results of bank size and capital buffer requirements

As expected, the marginal effect of supervisory assessments is more pronounced for banks that are closer to the regulatory limit. In model V, the variable $SUPERV_{t-1}$ is interacted with dummies that separate three levels of capitalization in each quarter of the sample: (i) $DBuf_L$, considering the lowest 10% of capital buffers; (ii) *DBuf*, for banks with buffers between the 10th and 90th percentiles of the sample; and (iii) $DBuf_H$, for the highest 10% of capital buffers. For the group of less capitalized banks, the coefficient is positive and significant at the 5% level. To a lesser extent, the supervision

[12] The variable *BANKDEP* was tested within other specifications but remained negative and non-significant in all specifications.

evaluation effect is also positive for the intermediate group, with a coefficient that is significant at the 10% level. For the third group, the coefficient is not significant, suggesting that scores do not affect the capital structure of overly capitalized banks. Hence, the monitoring that is conducted by the supervisory authority appears to contribute to curbing the risky behaviors of less solvent banks.

7. Conclusion

In this study, we use a dynamic empirical model to link the supervision role to the monitoring of capital buffer requirements. Using a comprehensive dynamic empirical model with bank-level panel data, in which all of the Basel Pillars are controlled for, we analyze the behavior of bank capital buffers in Brazil and find that supervisory monitoring has a positive effect on solvency ratios, especially among less capitalized banks. This finding is of particular interest because capital management practices are likely to be positively correlated to the economic cycle. In addition, markets seem to play a minor role in disciplining banks. Our argument is based on our finding that in less developed capital markets, market discipline plays no role, whereas the role of Central Bank supervision is stronger. This result contributes to the literature because, to our knowledge, this is the first study to rely on a unique database from a Central Bank and focus on an emerging market in which market discipline seems to be weak.

In concluding, supervision plays a major role in markets, such as in Brazil, where market discipline is weak and the pro-cyclicality of banks is confirmed. In these cases, supervision may increase the resilience of the banking system with special focus on smaller banks.

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