A New Look at the Relationship Between Capital Constraints and Bank Lending

William Bassett and Francisco Covas*

Abstract: A central feature of the financial crisis of 2007 to 2009 was the erosion of the capital strength of numerous financial institutions. Policy responses focused on first on recapitalizing the financial system and then significantly increasing minimum capital requirements going forward. The collapse in intermediated credit that continued well after the most acute phase of the crisis ended suggests a strong link between lending and capital adequacy. However, capital adequacy is difficult for observers to assess and lending volumes reflect both supply of and demand for credit. This paper uses banks' own assessments of their capital adequacy and customer demand to study the link between capital and lending. We find significantly reduced loan growth at banks that tighten lending standards as a result of concerns about their current or future capital position relative to banks that do not report being capital constrained. The results suggest that efforts to significantly boost required capital levels during an economic downturn could adversely affect the strength and pace of recovery, and that efforts to recapitalize the financial system during the recent crisis likely boosted lending somewhat.

Preliminary

Please do not quote without permission of the authors.

*The analysis and opinions expressed herein are solely those of the authors and do not represent the views of the Federal Reserve Board, the Federal Reserve System, or any of our colleagues. We thank John Driscoll, William English, Diana Hancock, William Nelson, Gretchen Weinbach, and Egon Zakrajsek for helpful comments. Thomas Spiller provided excellent research assistance. Any errors remain the responsibility of the authors

1 Introduction

The steep declines in real output and employment that coincided with notable declines in household and business credit outstanding during and after the financial crisis of 2007 to 2009 strongly suggest important links between the effectiveness of financial intermediation and economic performance. The scope of the financial crisis of 2007 to 2009, in which several stalwart institutions either failed outright or merged under duress and several credit markets froze for a time, was much greater than any other episode in the U.S. since the Great Depression. Moreover, many of the large financial institutions that survived the crisis did so only with the benefit of extraordinary government support. While those institutions worked through substantial inventories of impaired assets that left them in danger of becoming undercapitalized, they were reluctant to grow their balance sheets. At the same time, demand for credit reportedly fell as sales of many nonfinancial businesses dried up and households experienced large negative shocks to their income and net worth. However, as in previous episodes of financial distress, the relative contributions of supply constraints and reduced demand for funds are difficult to disentangle.

Also, the slow and uneven recovery from the 2007-2009 crisis in the United States may be partly explained by the disruption to the bank lending channel of monetary policy while a large fraction of the banking system was capital constrained (Bernanke and Blinder (1988), Kashyap and Stein (1995), Kishan and Opiela (2006)). Peek and Rosengren (1995c) show that binding capital requirements make loan supply less responsive to a monetary policy regime that operates through bank reserves. Chami and Cosimano (2010) also find that binding capital constraints frustrate the goals of a more accommodating monetary policy because constrained banks opt to reduce deposit rates and increase loan spreads in order to boost profitability rather than expand lending.

Recognizing that banks and other financial institutions were not adequately capitalized to withstand the shocks of 2007-2009, the benefits of higher minimum capital requirements and meaningful capital buffers are potentially quite large (Basel Committee on Banking Supervision (2010a)). Relatedly, in December 2009, the Basel Committee on Banking Supervision (BCBS) proposed much more stringent capital and liquidity standards for all internationally active banks. The modified package was that finalized in September 2010 is commonly referenced as Basel 3. The new

rules restrict the definition of regulatory capital, increase the risk weights assigned to various asset classes, and boost the required ratios of capital to risk-weighted assets and total credit exposures (Basel Committee on Banking Supervision (2010b)).

Because capital adequacy is a determinant of banks' ability and willingness to extend credit, one risk of introducing tougher capital and liquidity requirements in the near term is that they could cause financial firms to maintain the restrictive credit policies adopted during the crisis for longer than they otherwise would, and thus impede the recovery. Although the stricter capital requirements phase in between 2013 and 2019, some banks still may restrain the growth of their balance sheet in order to meet them as quickly as possible, perhaps because of pressure from market participants or because they believe doing so will lessen the amount of regulatory scrutiny that they face during the transition. Indeed, prior to the financial crisis that began in 2007, such pressures led most commercial banks to actively manage their capital ratios well in excess of the levels required by regulators (Berger, DeYoung, Flannery, Lee, and Oztekin (2008)). Thus, the position of a bank relative to its internal target capital ratio likely impacts credit supply to a greater extent than its position relative to regulatory minimums. However, the size and composition of the internal target capital ratio is not known to researchers, making it difficult to ascertain the effect of changes in minimum capital ratios on bank lending using accounting measures of capital ratios.

This paper attempts to overcome those limitations, and control for the role of loan demand in loan growth, by exploiting the bank-level responses to the Federal Reserve's Senior Loan Officer Opinion Survey on Bank Lending Practices (SLOOS). In this survey, banks report changes over the previous three months in lending standards and terms, as well as changes in loan demand for most major categories of loans they hold. In addition, those banks that reported having changed their lending standards also indicated whether they have done so as a result of current or expected changes in their capital position. The survey responses generally are thought to align well with contemporary narratives of banking and broader economic conditions.

A challenge of using SLOOS responses to control for the effect of capital on loan supply is that the question in which a bank would report having tightened lending policies as a result of concerns about its capital position is asked only to a subset of respondents and is therefore subject to classification errors. In particular, the question on the survey that asks about reasons for tightening lending standards and

terms is asked only to banks that had tightened such lending policies on commercial and industrial (C&I) loans. Hence, a bank that had not changed its standards or terms for C&I loans (perhaps because they had an insignificant exposure to such loans) may still be tightening standards and terms to other types of borrowers due to concerns about its capital position, but they would not be asked that question in the SLOOS survey. To address this potential issue, we use the misclassification model of Keane and Sauer (2010) to model classification errors in tightening as a result of current or expected changes in capital position. We find that allowing for misclassification in the responses, leads to a much stronger economic and statistical effect of capital concerns on loan growth.

The results of this paper add to the evidence in prior research that capital constrained banks are likely to significantly restrict lending. After controlling for lagged loan growth, reported changes in standards and demand, and bank and time fixed effects, growth of core loans at banks that reported having tightened lending policies as a result of concerns about their capital position typically was about 4 percentage points (at an annual rate) lower in subsequent quarters than loan growth at banks that did not express such concerns as a reason for tightening standards and loan terms.[1] By comparison, average annual growth of core loans at commercial banks over the past two decades was about 8 percent. The results also imply that steps taken to recapitalize the banking sector in the wake of the financial crisis, such as the Treasury's Capital Purchase Program, by reducing the number of capital constrained banks, may have provided material support for lending.

The next section of the document reviews the existing literature on the relationship between capital and lending. Next, we discuss the changes in capital requirements under Basel 3 and the current distribution of tier 1 capital ratios. Then, we describe the data used in the analysis. The discussion then turns to a statistical analysis of the quality of the responses to the question about capital concerns. After that, we describe our examination of the relationship between capital constraints and lending activity. In the conclusion, we examine the ramifications of the change in capital requirements in light of the statistical results.

[1] Core loans are defined as loans to nonfinancial businesses and households.

2 Literature Review

Standard theoretical results imply that banks will respond to capital constraints by restricting the supply of loans; when those capital requirements are risk-based, some of that adjustment occurs by increasing the share of assets with low risk weights, such as government securities (Thakor (1996); Kopecky and VanHoose (2004); Jacques (2008)). Given the focus of policymakers on small business lending, it is important to note that higher capital requirements may also cause banks to tighten lending standards disproportionately for bank-dependent borrowers such as households and less established, growth-oriented businesses with lower cash flows (Thakor and Wilson (1995)). Moreover, the same mechanism reduces the quantity of loans demanded because established firms with access to capital markets substitute away from bank loans as a result of the higher costs.

The predictions of those models are consistent with a number of empirical studies that found capital-constrained banks restricted credit supply during the period after the implementation of the Basel Accord in 1988 (Lown, Morgan, and Rohatgi (2000); Hancock, Laing, and Wilcox (1995); Peek and Rosengren (1995b); Bernanke and Lown (1991)). Peek and Rosengren (1995c) and Hancock and Wilcox (1994) showed that a large share of the contraction occurred in loan categories with concentrations of bank-dependent borrowers. Moreover, Hall (1993) found that portfolio adjustments at banks in the early 1990s were consistent with changes that would be predicted based upon the risk-weights assigned in the 1988 Basel Accord. Using a dynamic structural model and panel data for the US between 1989 and 1997, Furfine (2001) finds that either stricter capital requirements or the related stepped up regulatory monitoring significantly affected lending in the early 1990s. An increasing number of paper focused on the recent crisis have shown that capital constrained banks reduced lending more than others (see, for example, Puri, Rocholl, and Steffen (2010)). Berrospide and Edge. (2010) and Kiley and Sim (2010) find modest effects on loan growth and GDP in the US of changes in aggregate bank capital ratios over the period 1990 to 2008.

When a capital shock is widespread, the constraints on lending will be greater due to the lack of alternative sources of funds. However, one of the impediments to raising outside capital in a crisis stems from the poor signal sent by a bank that is willing to dilute existing shareholders. So, it may be easier for banks to raise funds gradually in

response to an imposed higher minimum capital requirement such as Basel 3 than in response to a perceived erosion in their individual health. Consistent with this, Peek and Rosengren (1995a) found that banks under formal regulatory enforcement actions requiring them to build capital accounted for most of the supply-induced decline in lending during the early 1990s, whereas low-capital banks that were not subjected to additional scrutiny did not shrink significantly more than high-capital banks. In addition, Berger and Udell (1994) found no link between capital regulation and the adjustments in bank portfolios during the early 1990s.

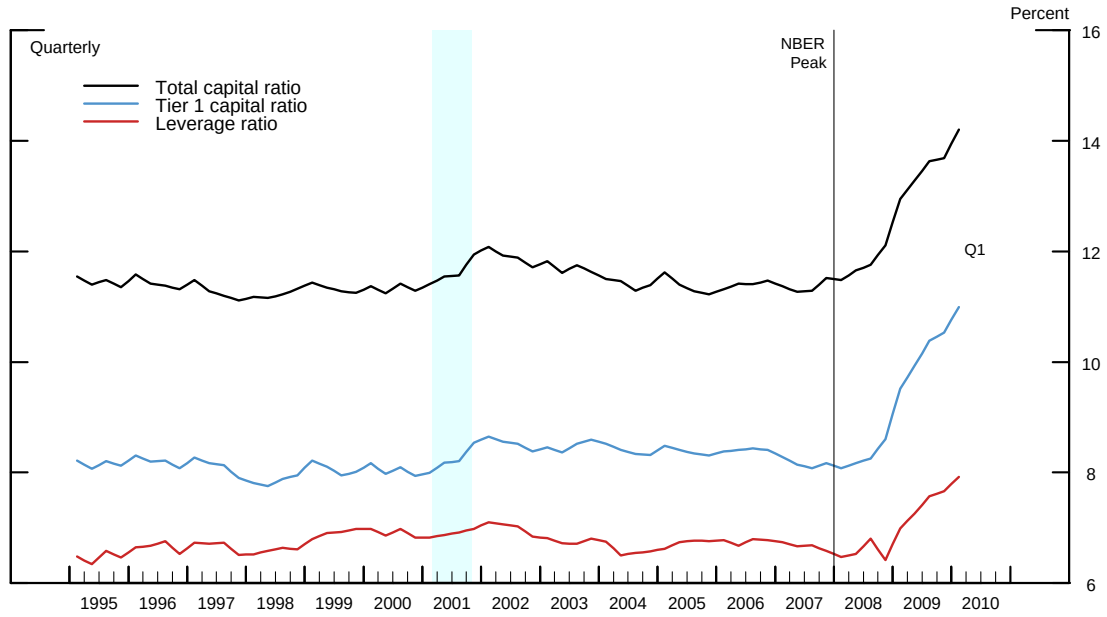
3 Basel 3 and the Distribution of Tier 1 Capital Ratios

The deterioration in asset quality that triggered the crisis placed substantial pressure on banks' capital adequacy. However, accounting measures of the industry average capital position showed little evidence of the stress during the crisis. As shown in figure 1, aggregate tier 1 capital, total capital and leverage ratios moved down only slightly in the early part of the crisis and have since climbed to record levels. The increase in aggregate ratios reflects about equally a reduction in assets and an increase in capital over the past two years. The increases in tier 1 capital are attributable to both privately raised equity and the Treasury's purchases of preferred stock, though as of this writing the latter has largely been repaid.

The Basel Committee on Banking Supervision finalized substantial changes in the regulatory capital regime in September 2010. The BCBS set a new minimum ratio of tangible common equity (TCE) to risk-weighted assets of 4.5 percent and raised the minimum ratio of tier 1 capital to risk weighted assets to 6 percent from 4 percent. In addition, the supervisors placed more restrictions on the instruments that will qualify as common equity and tier 1 capital. Lastly, the new rules significantly increased the risk weights associated with some assets and off-balance sheet exposures.

In addition to the minimums, banks will be required to hold a fixed "capital conservation buffer" of tangible common equity amounting to 2.5 percent of risk-weighted assets. Banks that breach the buffer will be subjected to supervisory restrictions on their earnings distributions and possibly other business practices, a penalty that is likely to make the top of the buffer range a de facto new well-capitalized standard.

Figure 1: Regulatory Capital Ratios



NOTES: Tier 1 is the ratio of tier 1 capital to risk-weighted assets. Total is the ratio of total capital to risk-weighted assets. Leverage is the ratio of tier 1 capital to average tangible assets. For definitions of tier 1 capital, total capital, risk-weighted assets, and average tangible assets, see Seung Lee and Jonathan Rose, "Profits and Balance Sheet Developments at US Commercial Banks in 2009" *Federal Reserve Bulletin* May 2010.

Because TCE is a subset of tier 1 capital, and Basel 3 risk-weights, especially for trading securities, are larger, the combined standards of 7 percent for TCE and 8.5 percent for tier 1 are substantially in excess of the current requirement to maintain well-capitalized status in the U.S. In many jurisdictions, national regulators are expected to establish even stricter requirements for systemically important financial institutions, and perhaps to require even larger buffers during economic expansions.

Because regulators recognize that higher capital requirements could restrict growth just as the world economy is emerging from the crisis, implementation of the new standards begins in 2013 and the ultimate levels are phased in over the following 6 years. The rationale for the phase in of capital requirements is that banks will be able to boost capital gradually through retained earnings over that period, reducing the extent of share dilution or the need to restrict balance sheet growth. However, it is not unlikely that market participants or ratings agencies would require banks to reach the fully phased-in thresholds faster than prescribed by regulators, or that banks would

seek to signal their strength to market participants and to supervisors by complying early.

The new restrictions on tier 1 capital instruments and the higher risk-weights on some financial instruments make it difficult to determine the capital ratios of banks using currently available public information. Nonetheless, it can be inferred that the current tier 1 capital ratios at commercial banks represent an upper bound on their ratios in the new regime. As shown in the first two columns of Table 1, most commercial banks in the United States would meet the new well capitalized threshold for tier 1 capital of 8.5 percent under the current configuration of the ratio.

Suppose, however, that banks continue to hold a discretionary buffer of 1 to 2 percentage points over the new well capitalized standard, so that the new target ratio for tier 1 capital is around 10 percent. As shown by the weighted percentiles in column 2, at that level, banks accounting for about 25 percent of industry assets would not be compliant as of the middle of 2010. Further, consider that the translation from a Basel 1 to Basel 3 basis to account for stricter definitions of capital and risk-weighted assets could add an additional 20 percent to banks' capital requirements, especially at larger banks with substantial trading assets and off-balance sheet exposures. In that scenario, those banks would need to target a tier 1 capital ratio equivalent to about 12 percent using the old definitions, a level that is substantially above the weighted median shown in column 2.

Columns 3 and 4 of Table 1 show the distribution of tier 1 capital ratios only for those banks that currently do not meet the hypothetical target tier 1 capital ratio of 12 percent. As shown in column 3, only about half of those banks had tier 1 capital ratios above 10.5 percent, a level about equal to the minimum plus the expected discretionary buffer. Moreover, as shown in column 4, about three-fourths of the assets held by banks below the hypothetical 12 percent threshold are held by banks with tier 1 ratios below 10.5 percent, meaning those banks may need to add substantially to capital or further restrict the size of their balance sheet to comply.

Moreover, national regulatory reforms and attempts by governments to recoup the costs of supporting financial institutions during the crisis may limit bank profitability and hence their ability to build capital by retaining earnings during the phase-in period. For instance, bank profitability in the US remains well below pre-crisis norms, and the Dodd-Frank financial reform package contains provisions that will reduce the profitability of many large banks going forward (such as limitations on fee income

Table 1: Distribution of Tier 1 Capital Ratios: Second Quarter of 2010

	All Banks		Tier 1 < 12 percent	
Moment	*Unweighted*	*Weighted*	*Unweighted*	*Weighted*
Mean	17.8	12.6	10.0	10.3
Standard deviation	26.9	9.0	2.2	1.1
5th percentile	8.8	9.2	4.9	7.8
25th percentile	11.3	10.0	9.7	10.2
Median	13.5	10.8	10.6	10.2
75th percentile	17.4	14.2	11.3	10.5
90th percentile	24.4	15.0	11.7	11.3

NOTES: The tier 1 capital ratio is the ratio of tier 1 capital to total risk-weighted assets as defined by the current Basel I standards in the United States. The current minimum for the tier 1 capital ratio is 4 percent and the threshold value for being considered well capitalized is 6 percent. Tier 1 capital consists primarily of common equity (excluding intangible assets such as goodwill and excluding net unrealized gains on investment account securities classified as available for sale) and certain perpetual preferred stock. Weighted values are calculated using total average assets from Schedule K of the Call Report as weights.

from debit cards, restrictions on proprietary trading, and prohibitions on certain high margin derivatives business lines). Those proposals to restrain bank profitability could reduce the effectiveness of the phase-in period in muting the contractionary effects of new capital requirements on bank credit.

4 Data and Methodology

The paper uses data from the SLOOS and the Report of Condition and Income (Call Reports) for commercial banks. The SLOOS is conducted quarterly with a sample of about 60 of the largest commercial banks in the United States. It has contained a standard set of questions about changes in lending policies since the second quarter of 1990 and about changes in loan demand since the second quarter of 1991. The question about the relationship between capital adequacy and changes in lending standards has been asked consistently in its current form since 1995. The Call Report provides quarterly, bank-level income and balance sheet data. The analysis covers all banks that participated in the SLOOS for a minimum of 8 quarters during the period between 1995 and the first quarter of 2010. The resulting sample is an unbalanced panel that has about 100 banks with a median tenure of 30 quarters and a median of

Table 2: Composition of the Sample

Sample period	1996:Q1–2010:Q4			
# of banks	75			
	Average	*Median*	*Minimum*	*Maximum*
# of banks per quarter	48.4	49	37	56
# of quarters per bank	29.6	30	8	58

49 banks in each quarter.

4.1 Senior Loan Officer Opinion Survey

The SLOOS queries banks about changes in standards and terms separately for each of seven major loan categories.[2] Banks respond by indicating whether they have tightened standards considerably, tightened standards somewhat, left standards unchanged, eased standards somewhat, or eased standards considerably. For purposes of this analysis, we collapse the five possible responses into three and assign a numerical value to each: tightened (1), stayed the same (0), and eased (-1). The responses across various categories of lending are then combined to create a composite index of changes in credit standards (ranging from -1 to 1) for each bank. The index is constructed by weighting the reported change in lending standards on each loan category by the amount of that type of loan in the bank's portfolio divided by the total loans held by the bank that are covered by the survey.

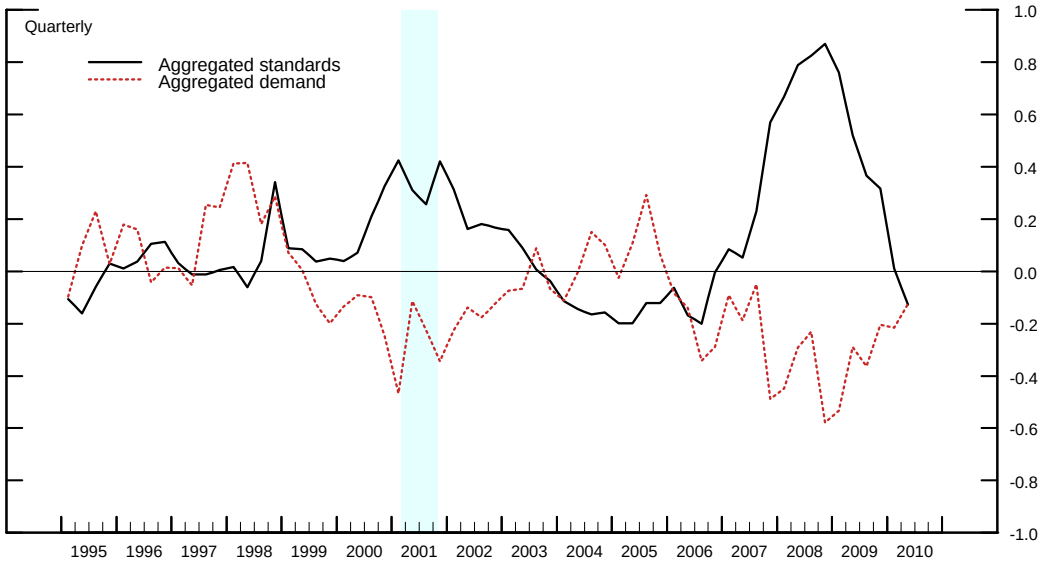
As in the case of changes in lending standards, respondents are asked to characterize the change in demand using a five point scale, with the answers ranging from "increased considerably" to "decreased considerably." Using the same method as was used to create the standards index, we create a bank-specific composite index for the reported changes in demand.

Figure 2 shows the average value of both the credit standards index and the demand index from 1990Q1 to 2010Q1.[3] During the mid-1990s, banks eased credit

[2]The seven categories are C&I loans to large and middle-market firms, C&I loans to small firms, commercial real estate loans, residential real estate loans, credit card loans, and other consumer loans.

[3]Note that the time reference for responses has been shifted back one quarter. The questions ask about changes in standards or demand *"over the past three months"*so responses to the second quarter survey, usually conducted in April, reference changes over the first quarter.

Figure 2: Reported Changes in Credit Standards and Loan Demand at U.S. Commercial Banks

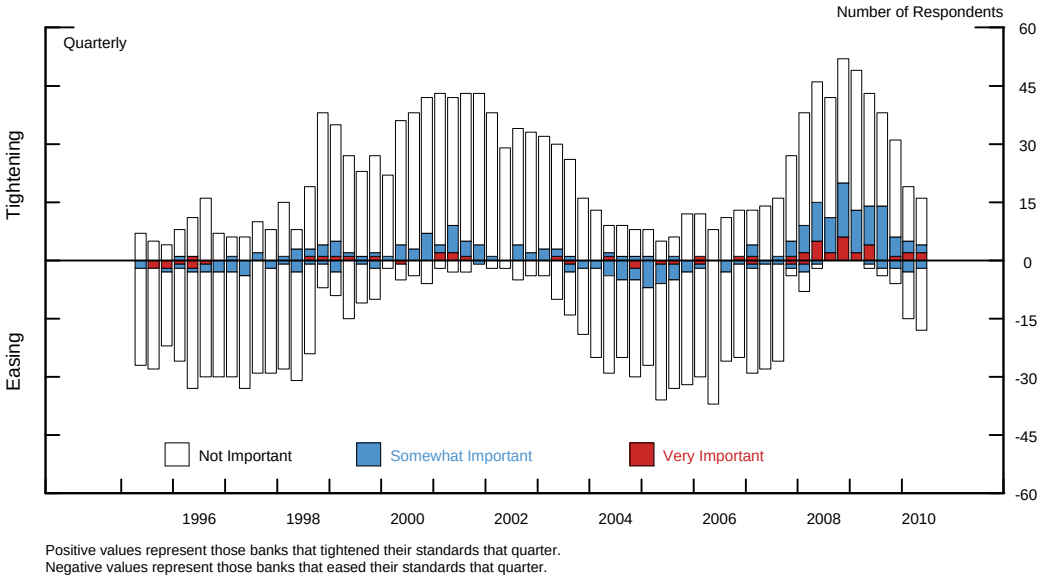


NOTES: The change in credit standards is an index of changes across loan categories surveyed in the Senior Loan Officer Opinion Survey, weighted by the share of each loan type relative to the bank's total loans in those same categories (see the text for more details). The change in demand is calculated using the same method.

standards, on net, as the economy generally performed well. The market disruptions of late 1998 generated a spike in the series until the uncertainty cleared. Banks tightened lending policies consistently from 2000 through 2002, as equity markets declined on balance, the economy entered recession, the 9-11 terrorist attacks eroded confidence, and corporate accounting scandals increased uncertainty. Banks eased their standards fairly broadly during the global credit boom of 2003-2006. Finally, the standards index reached record highs amid sustained tightening of credit conditions during the financial crisis that began in the second half of 2007. The tightening of lending standards during that period was more consistent and more widespread than even the early 1990s when banks implemented the first Basel accord and needed to repair their balance sheets after the Latin American debt crisis and shakeout in the commercial real estate sector.

The demand index largely mirrors the credit standards index. Banks generally reported increased loan demand during periods of sustained economic growth and decreased loan demand in the quarters surrounding the recessions of 2001 and 2007-

Figure 3: Reported Concerns about Capital Levels at U.S. Commercial Banks



NOTES: The fraction of respondents that cited concerns about their bank's capital position as a reason for tightening standards or terms on C&I loans

2008. The reported weakening of demand during the current crisis is about on par with the weakening reflected in the demand index during the 2000-2002 slow growth period. Despite the broad-based deterioration in the economy over 2008, banks, particularly at times of acute financial market stress, experienced significant draws on existing business credit lines. That demand, some of which was precautionary or represented substitution from other sources of credit, may have kept the demand index from falling further during the most recent recession.

If a respondent had tightened or eased standards or terms on commercial and industrial (C&I) loans, a subsequent question asked about the importance of several possible reasons for the changes.[4] However, the list of reasons and the way in which respondents indicated their importance has changed over time. From 1990 to 1994, respondents were asked to rank the importance of the listed reasons against each other, while from 1995 to present respondents indicate separately whether each reason

[4]This question is not asked as a follow up to questions about changes in standards and terms on other types of loans. If a bank kept its policies unchanged on C&I loans, but changed the lending standards on other types of loans, it will not have responded to this question. As a result, the fraction of banks reporting that they changed standards because of capital considerations is a lower bound.

was 1) not important, 2) somewhat important, or 3) very important. Because of the change in the list of responses and in the response method, many of the responses are not comparable. The paper presents a separate analysis of the data between 1990 and 1994, but limitations of the smaller sample make inference more difficult. The key results from 1995 to 2010 are not inconsistent with results from the earlier period.

One of the possible reasons for tightening lending policies that has been asked consistently since 1995 is, "A deterioration in your bank's current or expected capital position."Figure 3 shows the fraction of all banks responding to the survey for which capital adequacy was a factor in the decision to change credit standards. Very few banks indicated that reduced concern about their capital adequacy was a reason for easing lending standards during the sample period. In contrast, capital pressures have been an important reason for tightening at points corresponding to recessions and periods where banks suffered large, unexpected losses. The graph breaks out responses between those banks that indicated it was a very important reason or a somewhat important reason. A small but noticeable fraction of banks reported capital pressures in 2000 and 2001, probably stemming in part from increased uncertainty about losses on business loans in the wake of financial accounting scandals and the downturn in the economy. The fraction of banks that reported having tightened lending policies as a result of capital concerns rose to a high of 36 percent in the third quarter of 2008 amid the full blown financial panic. It has remained fairly elevated through 2009 even as industry-wide aggregate capital ratios reached record highs.[5]

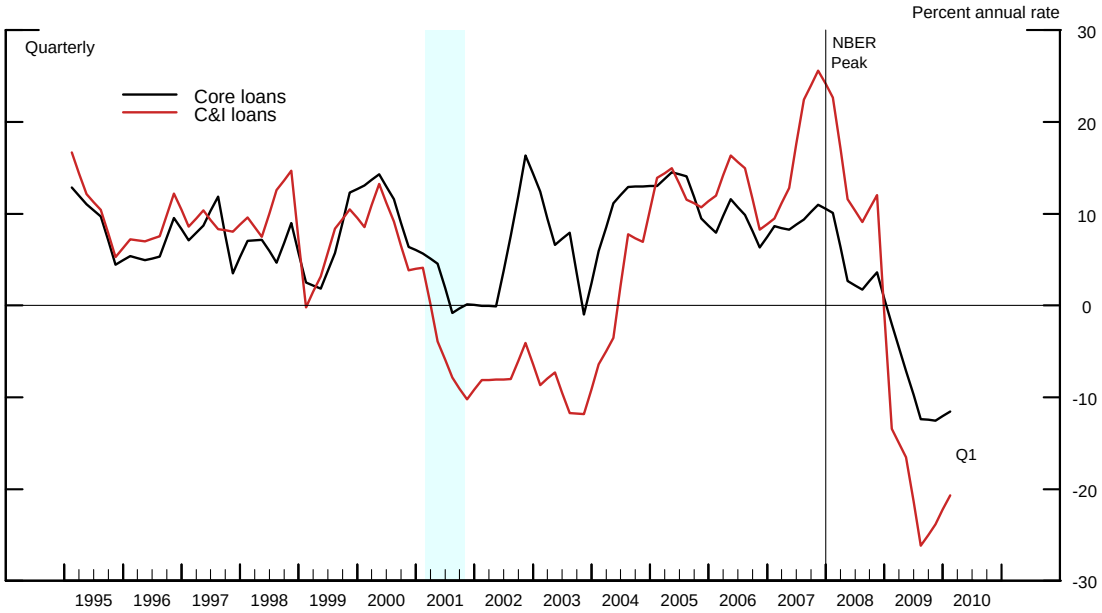
4.2 Call Report

Data from the Call Report are adjusted for mergers between commercial banks and then used to construct the growth rate of core loans.[6] Even after adjusting for mergers,

[5]Three other reasons for changing standards and terms are available for the entire 1995 to 2010 period: 1) changes in the economic outlook, 2) changes in tolerance for risk, and 3) changes in industry-specific conditions. These reasons are only loosely correlated with changes in capital concerns, and thus their exclusion from the regression does not materially change the magnitude or significance of the effect of capital position. In addition, whether they are added individually or in combination with other reasons to the single-stage regression specifications used for this paper, none of these reasons are estimated to have had significant effects on loan growth.

[6]Core loans are loans to nonfinancial businesses and households and correspond to the categories of lending included in the SLOOS on regular basis. The data consolidate information from foreign and domestic offices and have been adjusted to take account of mergers. For additional information on the adjustments to the data, see the appendix in William B. English and William R. Nelson, "Profits and Balance Sheet Developments at U.S. Commercial Banks in 1997," Federal Reserve

Figure 4: Growth of Core Loans at U.S. Commercial Banks, 1991 to 2010Q1



NOTES: Core loans are defined as loans to nonfinancial businesses and households.

some outliers exist for loan growth, and bank-quarter observations with growth that exceeds 20 percent in absolute value at quarterly rate are removed.

As shown in figure 4, core loans expanded briskly in the 1990s, averaging growth of about 8 percent at an annual rate, before stepping down during the period of slow economic growth in the early 2000s. In most of 2007 and 2008, growth was solid, in part reflecting categories of lending in which banks had made significant prior commitments–such as C&I loans, home equity loans, and credit cards–to which some customers may have turned when their access to other sources of credit dried up. Further, because of the disruptions in securitization markets, at times banks likely found themselves holding assets somewhat involuntarily. At the same time, the remaining unused portions of such credit lines decreased sharply beginning in the second half of 2008, a move that likely reflected supply constrains and presaged the steep decline in lending that started during the the first quarter of 2009 and continued through 2010.

Bulletin, vol. 84 (June 1997), p. 408.

5 Determinants of Capital Concerns

Although the variation across time in the fraction of banks that cited concerns about capital levels as a reason for tightening lending standards accords with narrative descriptions of the health of the banking sector during the survey period, a closer examination of the individual banks' responses seems prudent. Specifically, the degree of measurement error introduced by the survey design that asks the reason for tightening only after the section on C&I loan policies is an important caveat. In this section we estimate the degree of misclassification caused by the survey design and show that the responses covary in expected ways with observable characteristics of individual banks.

To study the bank's responses for tightening lending standards as a result of concerns about its capital position, we consider the following specification:

$$y_{it} = 1(X'_{it-1}\beta + \alpha y_{i,t-1} + \epsilon_{it} > 0) \quad (i = 1, \ldots, N; t = 1, \ldots, T), \tag{1}$$

where y_{it} denotes whether bank i tightened lending standards as a result of concerns about its capital position in period t. X_{it-1} is a vector of explanatory variables, which contains the capital buffer, loan loss provisions, return-on-assets, and a dummy variable that takes the value of '1' if a bank has publicly traded equity, and '0' otherwise. y_{t-1} indicates whether the bank also tightened lending standards in the previous period as a result of capital concerns and ϵ_{it} is an error term. A bank tightens its lending standards as a result of concerns about its capital position if the expression inside the parenthesis is true.

The error term, ϵ_{it}, can be further decomposed into the following structure:

$$\epsilon_{it} = \mu_i + \eta_{it}, \tag{2}$$

where μ_i is a bank-specific effect distributed $N(0, \sigma^2_\mu)$ to capture unobserved time-invariant bank factors; and η_{it} is a transitory error component, which is assumed to be uncorrelated and independent of μ_i and distributed $N(0, \sigma^2_\eta)$. Furthermore, in probit models with endogenous explanatory variables a normalization assumption is typically made in which $\sigma^2_\epsilon = \sigma^2_\mu + \sigma^2_\eta = 1$. Thus, we only need to estimate σ^2_μ and set $\sigma^2_\eta = 1 - \sigma^2_\mu$.

Following Keane and Sauer (2009) we nest the dynamic probit model defined

in (1) and (2) with a classification error model derived from a logit latent variable model:

$$l_{it} = \gamma_0 + \gamma_1 y_{it} + \gamma_2 y^*_{it-1} + \omega_{it}, \tag{3}$$

where the reported response by bank i in the survey conducted in quarter t, y^*_{it}, equals 1 if $l_{it} > 0$ and 0 otherwise. This specification includes both the current value of bank's i ("true") response, y_{it} and the lagged reported response, y^*_{it-1}. The latter captures persistence in misreporting. The error term ω_{it} is logistically distributed and independent of ϵ_{it}.

In dynamic probit models treating y_{i0} as exogenous may lead to a significant bias of the estimated coefficients, which leads to the so called initial conditions problem. In the technical appendix we outline the algorithm used to estimate the coefficients of the model, the derivation of the misclassification probabilities and the solution to the initial conditions problem.

Column 1 of Table 3 shows the coefficients and their significance for the model with no misreporting. Those estimates are fairly similar to the results in columns 2 and 3, which show the estimated coefficients and t-statistics in models allowing for misreporting. Nonetheless, standard likelihood ratio tests reject the assumption of no misclassification in Model 1 in favor of Model 2, which assumes no persistence in misreporting. The likelihood ratio test does not reject Model 2 in favor of Model 3, which allows for persistence in misreporting.

Both models with misreporting provide qualitatively similar results. They indicate that capital constraints are moderately underreported, likely as a result of survey design. As shown in Table 3, model 2 suggests that the fraction reporting concerns about capital levels should be about 45 percent greater than observed across the sample period, while Model 3 shows about a 75 percent gap.[7]

However, both models suggest that nearly all banks that report having tightened

[7]The probability a bank's true response is a "one" but the bank reports a "zero" for Model 2 (CE) is calculated as follows:

$$\hat{\pi}^{CE}_{10} = 1 - \frac{e^{-4.8676+5.0236}}{1+e^{-4.8676+5.0236}} = 0.4611.$$

For Model 3 (PCE) the misclassification probability also depends on the bank's previous quarter true response, captured by $\hat{\gamma}_2$, that is if last period's true response is a "zero" then,

$$\hat{\pi}^{PCE}_{10} = 1 - \frac{e^{-5.2399+4.0696}}{1+e^{-5.2399+4.0696}} = 0.7632,$$

Table 3: Dynamic Probit Model for Capital Concerns with Classification Error

	Model type		
Explanatory Variable	No CE	CE	PCE
WCM_{it-1}	-0.0038^{***}	-0.0037^{***}	-0.0011
	(.0014)	(.0015)	(.0014)
DEL_{it-1}	0.1334^{***}	0.1606^{***}	0.0550^{***}
	(.0140)	(.0181)	(.0161)
ROA_{it-1}	-0.8525^{***}	-0.8770^{***}	-1.2770^{***}
	(.0921)	(.0618)	(.0122)
RET_{it-1}	-0.4584^{***}	-0.4149^{***}	-0.5518^{***}
	(.0519)	(.0922)	(.0333)
NII_{it-1}	-0.0345^{***}	-0.0375^{***}	-0.1253^{***}
	(.0084)	(.0078)	(.0132)
CAPC_{it-1}	1.8345^{***}	2.4848^{***}	2.5025^{***}
	(.0084)	(.1115)	(.1037)
$\sigma(\mu_i)$	0.5300^{***}	0.6373^{***}	0.6143^{***}
	(.0202)	(.0196)	(.0176)
γ_0	—	-4.8676^{***}	-5.2399^{***}
		(.2683)	(.2907)
γ_1	—	5.0236^{***}	4.0696^{***}
		(.3522)	(.3211)
γ_2	—	—	1.5979^{***}
			(.2787)
Time Dummies	Yes	Yes	Yes
Obs.	2512	2512	2512
Log-likelihood	424.50	293.42	292.79

NOTE: The sample period is 1996:Q1–2010:Q4. Specifications: No CE = model without classification error; CE = model with classification error; and PCE = model with persistent classification error. Explanatory variables: WCM = well capitalized margin; DEL = delinquency rate; ROA = return-on-assets; RET = stock return indicator variable; NII = noninterest income; CAPC = capital concerns; σ_μ = standard deviation of random effects model; γ_0 = constant of classification error model; γ_1 = coeficient of reported choice of the classification error model; γ_2 = persistence in misclassification in the classification error model. All regressions include a constant and time dummies for each quarter (not reported). Heteroskesdasticy-consistent asymptotic standard errors are in parenthesis. * denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

instead, if last period's response was a "one" then the misclassification probability is calculated as

$$\hat{\pi}_{10}^{PCE} = 1 - \frac{e^{-5.2399+4.0696+1.5979}}{1+e^{-5.2399+4.0696+1.5979}} = 0.3947.$$

lending standards or terms as a result of capital pressures are accurately reflecting their reason for changing those policies. That asymmetric pattern of misclassification suggests that main reason for misreporting is likely that the question is only asked of banks that tightened policies on C&I loans. In our sample, on average 5.7 percent, or 3 banks per quarter, report tightening of lending standards on C&I loans as a result of concerns about its capital position. Based on Model 2's estimates of misclssification probabilities, the average number of banks that report tightening of lending standards on *all loan categories* as a result of concerns about its capital position is about 5.5 banks.

The coefficients and significance levels on the control variables suggest that banks respond appropriately to the capital concerns question. The lagged value of the dependent variable enters positively and is highly significant. This is expected, as adjusting capital is costly and therefore likely to be carried out gradually. The well capitalized margin–defined as the minimum buffer between the current value of the three regulatory capital ratios held by the bank and the corresponding minimum value required to maintain well capitalized status–has a significant negative coefficient, as expected.[8] Banks that are holding capital well in excess of a regulatory threshold are less likely to report concern about their capital levels. However, in Model 3, the well capitalized margin is not significant. Given the relatively small number of banks that tighten standards due to capital concerns we may not have a sufficient number of observations to distinguish between persistence in misreporting and the effect of some of the exogenous variables of the model. For this reason, in the analysis below we use the model without persistence in misreporting to estimate the impact of capital concerns on loan growth.

Banks with lower delinquency rates, are less likely to tighten due to concerns about its capital position as it reduces the need to provision for expected losses. Likewise, banks with publicly traded equity are less likely to report concern about their capital, probably because of the lesser difficulty in raising capital in a secondary

[8]In order to be considered well capitalized, an institution must maintain (1) a total risk-based capital ratio of at least 10 percent, (2) a tier 1 risk-based capital ratio of at least 6 percent, and (3) a leverage ratio of at least 5 percent. The average margin by which banks remained well capitalized was computed as follows. First, among the leverage, tier 1, and total capital ratios of each well-capitalized bank, the institution's tightest capital ratio is defined as the one closest to the regulatory standard for being well capitalized. The institution's margin is then defined as the percentage-point difference between its tightest capital ratio and the corresponding regulatory standard divided by the corresponding regulatory standard.

offering than through a private placement. As would be expected, banks with high profitability (measured by ROA) are less likely to be concerned about their capital position because retained earnings can be used rather seemlessly to build a larger buffer. Finally, banks with higher noninterest income are less likely to tighten due to capital concerns, as trading and investment banking income may provide a more diversifiable source of income.

The results for the well-capitalized margin suggest that a material change in required minimum capital levels would meaningfully increase the fraction of banks that tightened lending standards as a result of concerns about their capital. For instance, if the tier 1 ratio was the tightest ratio for all banks in the sample, then the recent change in the tier 1 capital requirement from 6 percent to 8.5 percent is similar to shrinking the average well-capitalized margin for banks in the sample from 94 percent to 28 percent. Based on the estimates in each of the 3 models considered here, the change raises the probability of tightening due to capital concerns by 1.0 percentage points to 2.5 percentage points. Compared to the average probability of tightening lending standards because of capital constraints in the sample, about 5.7 percent, this represents an increase of 20 to 40 percent.

We have further evaluated the results by restricting the sample to banks that have publicly traded equity and replaced the equity indicator variable with equity returns. We found that the estimates of the effect of the well-capitalized margin on the probability of tightening standards due to capital concerns was economically weaker (still statistically significant at 1 percent) and we have also obtained significantly lower estimates for the misclassification probabilities. The results are consistent with the ability of those firms to issue new equity relatively quickly.

6 Analysis of Capital and Loan Growth

To estimate the relationship between growth of core loans and capital constraints, we regress the bank's loan growth on lagged values of loan growth, the credit standards index, the demand index, a variable reflecting capital constraints, and other controls for profitability and the credit quality of the bank's loan portfolio.

$$y_{i,t} = y_{i,t-1}\beta_1 + x_{i,t-1}\beta_2 + \alpha_i + \delta_t + \epsilon_{i,t} \tag{4}$$

The specification also includes bank fixed effects, α_i, and time fixed effects δ_t. The error term, $\epsilon_{i,t}$, is assumed to have the usual properties for OLS regressions. In one set of regressions, we use the predicted value for the probability of having tightened standards as a result of capital constraints from the model with misclassification error in the previous section. In another specification, we simply use the indicator variable for whether the bank reported that it had tightened its C&I lending policies as a result of concerns about its capital position.

6.1 Estimation using predicted value of capital constraints

Table 4, reports the results of the loan growth regression using the reported value of the Call Report variables and the changes in standards and demand from SLOOS, along with the the predicted value from the misclassification model for the probability that the bank tightened lending policies because of capital concerns. All of the SLOOS variables are highly significant determinants of loan growth. The lagged values of the standards index, the demand index, and the capital concerns value have statistically significant coefficients with meaningful economic magnitudes. The R^2 values for equation 4 are generally between 15 percent and 20 percent.

Column I of table 4 shows a parsimonious specification with one lag of all of the control variables. The control variables are normalized by their standard deviation. The coefficient on the standards index is statistically significant with a value of about $\frac{1}{4}$ percent. Thus, a two-standard-deviation increase in the standards index (e.g., a fairly typical reading during the financial crisis that indicates a bank tightened standards on loan categories accounting for 50 percent of its core loans) is associated with a reduction of $\frac{1}{2}$ percentage point at a quarterly rate (or two percentage points at an annual rate) in the the one-period-ahead forecast of loan growth. Likewise, the first lag of the demand index has a statistically significant effect on core loans. The effect is positive and the coefficient suggests that a two-standard-deviation change in the demand index is associated with about a 3 percentage point change in loan growth during the subsequent quarter.

The regression analysis suggests that banks that are concerned about the level of their capital ratios likely will restrict lending further, ceteris paribus, than those that tightened standards but were not concerned about their capital position. The coefficient on the generated variable for the probability that capital concerns were a reason for tightening is negative and statistically significant. The coefficient estimate

Table 4: Determinants of Core Loan Growth

	Specification			
Explanatory Variable	(I)	(II)	(III)	(IV)
ΔL_{it-1}	0.1139**	0.1106**	0.0974**	0.1028**
	(.0446)	(.0460)	(.0456)	(.0439)
WCM_{it-1}	—	−0.1222	−0.1484	—
		(.1349)	(.1277)	
ROA_{it-1}	0.2030**	0.2117**	0.2070**	0.1914**
	(.0854)	(.0840)	(.0805)	(.0859)
STD_{it-1}	−0.2843***	−0.2894***	−0.1757*	−0.1744*
	(.1081)	(.1091)	(.1049)	(.1053)
STD_{it-2}	—	—	−0.1090	−0.1130
			(.0928)	(.0906)
STD_{it-3}	—	—	−0.2953**	−0.2911**
			(.1172)	(.1149)
STD_{it-4}	—	—	−0.3334***	−0.3354***
			(.0959)	(.0985)
DEM_{it-1}	0.3599***	0.3619**	0.3121***	0.3327***
	(.1028)	(.1028)	(.1015)	(.1048)
DEM_{it-2}	—	—	0.0248	—
			(.0834)	
DEM_{it-3}	—	—	−0.0192	—
			(.1137)	
DEM_{it-4}	—	—	0.1206*	—
			(.0724)	
BUF_{it-1}	0.0553	0.0515	0.0515	0.0554
	(.0808)	(.0805)	(.0814)	(.0792)
$\widehat{\text{CAPC}}_{it-1}$	−0.7468**	−0.7660**	−0.6824**	−0.0300
	(.3557)	(.3444)	(.3292)	(.6076)
$\widehat{\text{CAPC}}_{it-2}$	—	—	—	−0.8588
				(.6891)
$\widehat{\text{CAPC}}_{it-3}$	—	—	—	−0.2130
				(.5574)
$\widehat{\text{CAPC}}_{it-4}$	—	—	—	0.1160
				(.5574)
Sum of rows 4 and 13	−1.031***	−1.055***	−0.8581**	−0.2043
	(.3688)	(.1129)	(.3411)	(.6062)
Sum of rows 4-7	—	—	−0.9134***	−0.9138***
			(.1522)	(.1556)
Sum of rows 8-11	—	—	0.4383**	—
			(.1718)	
Sum of rows 13-16	—	—	—	−0.9857**
				(.4189)
Obs.	2516	2516	2516	2516
Within R^2	0.1897	0.1906	0.2040	0.2043

NOTE: The sample period is 1996:Q1–2010:Q4. Explanatory variables: ΔL = core loan growth; ROA = return-on-assets; STD = lending standards index; $\widehat{\text{CAPC}}$ = average number of times a banks tightens its lending standards as a results of concerns about its capital position (from the CE model); BUF = capital cushion indicator; and DEM = demand index. All regressions include a constant and time dummies for each quarter (not reported). Standard errors are obtained from 45 bootstrap samples (see appendix for details). *,** ,*** denotes significance at the 10% 5% and 1% level, respectively.

suggests that a one-standard-deviation increase in the probability that a bank tightened standards because it was concerned about its capital translates into about a 3 percentage point reduction in the annualized growth rate of loans over the subsequent quarter relative to a bank that also tightened standards but did not become more capital constrained. As shown in the first row memo section of the table, the point estimate for the combined effect of a one-standard-deviation increase in the lending standards index that coincides with a similar magnitude rise in the capital concerns variable is estimated to be 4 percentage points, with a 95 percent confidence interval of about 2 percentage points to 7 percentage points.

Banks that have eased standards or terms on C&I loans can specify less concern about their current or future capital position as a reason for having eased. These responses are recorded as the indicator variable, "BUF" or the "capital cushion," which takes the value 1 when a bank reports that it eased because it had become less concerned about its current or expected capital position.[9] As shown in Table 4, the coefficient estimates for the capital cushion variable are small and not statistically significant. Therefore, the results suggest that one-quarter-ahead loan growth is not statistically different at banks that ease standards or terms on C&I loans because they are less concerned about their capital position.

The simple specification neglects that changes in credit standards and loan demand may also affect loan growth at longer lags. As shown in column II of Table 4, the coefficients on the third and fourth lags of the standards index are individually statistically significant at traditional confidence levels, and the sum of the coefficients on the first four lags is economically meaningful and highly statistically significant. When banks are tightening credit standards, the persistent effect on loan growth at longer lags is partly explained by the prevalence of long-term lending commitments that are not easily cancelable. In addition to contractual restrictions, some banks likely are reluctant to disrupt relationships with existing customers that generate ancillary revenue by abruptly reducing such commitments. Those dynamics also suggest that a recovery in loan growth would lag behind a decision to ease lending policies, as banks require time to build new lending relationships. Indeed, as shown in column III of Table 4, only the first lag of the demand index is individually significant at standard statistical levels, and a test of joint significance of just the first and second lags is also not statistically significant. Moreover, the absolute values of the coeffi-

[9] In a future version, we will treat this variable analogously to the capital concerns variable.

cients on longer lags of the demand index are small and, in some specifications, have offsetting effects.

Furthermore, adding more lags of changes in standards and demand does not materially affect the magnitude or significance level of the coefficient on the first lag of capital concerns. Of note, the estimated effect of capital concerns on one-period ahead loan growth remains significant and decreases only slightly to about -2$\frac{3}{4}$ percent at an annual rate in these broader specifications.

Column IV of Table 4 reports a representative specification with longer lags using the predicted value of the capital concerns variable. None of the lags of capital concerns are statistically significant in this case, but the sum of the four coefficients remain significant and economically large in this specification. The reason why none of the lags are statistically significant is likely due to multicollinearity as the model generated capital concern variable and its lags are highly correlated.

The long period over which adjustments in standards generally affect lending may partly explain the strength of the effect of capital concerns. Because market participants or supervisors may require banks that are experiencing capital pressures to adjust standards more rapidly or, ceteris paribus, more forcefully, the effect on lending is pulled forward relative to a tightening cycle that is not spurred by capital constraints. Moreover, the asymmetric effect of capital concerns and capital cushion may result because easing of standards owing to an improvement in capital position does not reflect the same urgency as a deterioration in capital.

6.2 Estimation using reported value of capital constraints

Importantly, the conclusions drawn from the two-stage estimation procedure that accounts for misclassification are qualitatively similar to the results obtained using the single-stage, or indicator variable, approach. As shown in table 5 the coefficients on the variables indexing changes in standards and demand are nearly identical across the two specifications, as are the effects of lagged loan growth, ROA, and the capital cushion indicator.

The capital concerns indicator variable also remains statistically significant, economically meaningful, and negative in these specifications. As might be expected given the degree of misclassification in the capital concerns variable, however, the magnitude of the effect is quite a bit smaller.

Table 5: Determinants of Core Loan Growth in Single-Stage Regression

	Specification			
Explanatory Variable	(I)	(II)	(III)	(IV)
ΔL_{it-1}	0.1074**	0.1032**	0.0898*	0.0926*
	(.0510)	(.0513)	(.0509)	(.0510)
WCM_{it-1}	—	−0.1490*	−0.1716**	—
		(.0750)	(.0808)	
ROA_{it-1}	0.2142**	0.2261**	0.2177**	0.1879**
	(.0970)	(.0998)	(.0952)	(.0904)
STD_{it-1}	−0.2908**	−0.2962**	−0.1811	−0.1736
	(.1168)	(.1153)	(.1091)	(.1085)
STD_{it-2}	—	—	−0.1113	−0.1031
			(.1019)	(.1036)
STD_{it-3}	—	—	−0.3015***	−0.2872***
			(.1056)	(.1056)
STD_{it-4}	—	—	−0.3440**	−0.3393**
			(.1380)	(.1387)
DEM_{it-1}	0.3421***	0.3448***	0.2953***	0.3139***
	(.0916)	(.0921)	(.0804)	(.0857)
DEM_{it-2}	—	—	0.0064	—
			(.0809)	
DEM_{it-3}	—	—	0.0032	—
			(.1001)	
DEM_{it-4}	—	—	0.1228	—
			(.0903)	
BUF_{it-1}	0.0566	0.0520	0.0523	0.0587
	(.0749)	(.0756)	(.0765)	(.0755)
CAPC_{it-1}	−0.2071***	−0.2099***	−0.1990***	−0.1359*
	(.0626)	(.0620)	(.0620)	(.0705)
CAPC_{it-2}	—	—	—	−0.0929
				(.0961)
CAPC_{it-3}	—	—	—	−0.1195
				(.0981)
CAPC_{it-4}	—	—	—	−0.0679
				(.0942)
Sum of rows 4 and 13	−0.4978***	−0.5061***	−0.3801***	−0.3095***
	(.1147)	(.1129)	(.1065)	(.1022)
Sum of rows 4-7	—	—	−0.9380***	−0.9032***
			(.2233)	(.2227)
Sum of rows 8-11	—	—	0.4277**	—
			(.1639)	
Rows 13-16	—	—	—	−0.4162***
				(.1246)
Obs.	2512	2512	2512	2512
Within R^2	0.1797	0.1803	0.1922	0.1928

NOTE: The sample period is 1996:Q1–2010:Q4. Explanatory variables: ΔL = core loan growth; WCM = well capitalized margin; ROA = return-on-assets; STD = lending standards index; CAPC = capital concerns indicator; BUF = capital cushion indicator; and DEM = demand index. All regressions include a constant and time dummies for each quarter (not reported). Heteroskesdasticy-consistent asymptotic standard errors are in parenthesis. *, **, and *** denotes significance at the 10%, 5%, and 1% level, respectively.

6.3 Capital Concerns from 1990 to 1994

Between 1990 and 1994, the banking industry was building its capital position in response to the new Basel Accord and subsequent regulations contained in the Federal Deposit Insurance Corporation Improvement Act (FDICIA). Also, as noted earlier, banks were responding to loan losses on LDC loans and CRE loans. During this period, banks that reported in the SLOOS having changed their credit standards or terms for C&I loans were asked to rank several potential reasons for having made the changes. During the 1990 to 1994 period, respondents were asked to rank five or six reasons for tightening lending policies. A list of four reasons for easing lending policies first appeared in 1992Q2 (prior to that, only 3 banks had eased standards or terms in any quarter since 1990Q1), and the list was expanded to six reasons in 1994Q3 and 1994Q4. Moreover, because the questions about loan demand were not asked until 1991Q2, the bank-specific demand variation is not included in the analysis for this section.

As shown in table 6, banks were asked separately during this period about their current capital position and their expected future capital position, whereas those reasons were always combined in the post-1994 listings. Most of the banks that changed credit standards ranked concerns about their current or expected capital position below changes in the economic outlook or changes in industry-specific conditions. Only about 20 of the bank-quarter observations identify increased concerns about current or expected capital as one of the three most important reasons for tightening (ranks of 4, 5, or 6). About the same number identify reduced concerns about the bank's current or expected capital position as one of the two most important reasons for easing (not shown).

For the analysis in this section, the rankings of the reasons for tightening and easing credit standards and terms are translated into sets of indicator variables based on the ranks. In the simpler specification, two indicator variables are used to denote when capital concerns were ranked in the top half of the reasons given for changing lending standards. A variable "combine capital tight" takes the value 1 when either current or expected capital concerns are ranked as one of the three most important reasons for tightening lending policies and 0 otherwise. Analogously, "combine capital ease" takes the value 1 when a lessening of either current or expected capital concerns are ranked as one of the two most important reasons for easing lending policies and 0 otherwise. A finer split of the data into five separate indicator variables corresponding

Table 6: Rank of Reasons for Tightening Lending Policies: 1990Q2 to 1994Q4

	Ranking									
Reason for Tightening	*1*	*1.5*	*2*	*2.5*	*3*	*4*	*4.5*	*5*	*5.5*	*6*
Capital concerns	3	8	28	21	0	2	2	3	0	1
Expected capital concerns	1	6	27	21	1	2	1	5	0	4
Diminished economic outlook	0	0	4	3	0	5	2	11	1	42
Industry specific problems	1	6	11	19	2	2	2	18	1	6

NOTE: A higher rank means the reason was deemed more important. For the period 1990:Q2–1992:Q1 and 1994:Q3–1994:Q4 the maximum rank for a tightening reason was 6. For the period 1992:Q2–1994:Q2 the maximum rank for a tightening reason was 5. Only these four reasons were listed over the entire period. Reasons that were ranked equally important were assigned the average rank.

to paired ranks (first or second most important reason, third or fourth most important reason, etc.) is also presented.

The results of the regressions using the indicators of capital concerns as control variables are directionally similar to the results for 1995 to 2010 discussed above but lack statistical significance.[10] As displayed in table 7, the coefficient on the variable indicating that current or expected capital concerns rank high among the reasons for tightening is economically meaningful but very imprecisely estimated. The point estimate suggests that a bank that ranked capital concerns as one of the three most important reasons for tightening standards or terms can be expected to have a decline in loans in the subsequent quarter that is about $3\frac{1}{4}$ percentage points larger at an annual rate than a bank that did not tighten standards or terms on C&I loans or ranked capital concerns as a relatively unimportant reason for tightening those policies. That magnitude is about the same as the effect estimated in the 1995 to 2010 period. The results using a finer categorization of the ranked responses, shown in column II of the table, are not materially different.

[10]The regression results presented here are also hampered by the well-known bias in estimating dynamic panel models over short time horizons. The sample for this section includes only banks that have at least 13 quarters of data.

Table 7: Determinants of Core Loan Growth 1990:Q2 to 1994:Q4

	Specification	
Explanatory Variable	(I)	(II)
ΔL_{it-1}	-0.0468^{*}	-0.0402
	(.0262)	(.0288)
ROA_{it-1}	0.5518	0.4860
	(.7366)	(.7288)
STD_{it-1}	-0.0098	-0.0132
	(.0079)	(.0108)
Capital tight_{it-1}	-0.0082	—
	(.0126)	
Capital ease_{it-1}	0.0102	—
	(.0086)	
Capital very tight_{it-1}	—	-0.0050
		(.0133)
Capital somewhat tight_{it-1}	—	-0.0101
		(.0067)
Capital not tight_{it-1}	—	0.0030
		(.0117)
Capital somewhat ease_{it-1}	—	-0.0097
		(.0099)
Capital very ease_{it-1}	—	0.0036
		(.0090)
Memo:		
F(5,51) : lines 6-10	—	.85
Prob > F		.5187
F(3,51) : lines 6-8	—	.98
Prob > F		.4109
F(2,51) : lines 9-10	—	.54
Prob > F		.5878

NOTE: Heteroskedastic-consistent asymptotic standard errors are in parenthesis. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

6.4 Impact on Aggregate Lending

The macroeconomic impact of the new capital regulations would depend on the number and size of banks that tightened lending policies as a result of the new capital

requirements. Our estimates suggest that the requirements would increase the probability of that banks would tighten lending standards by about 1 percentage point. The upper end of that range represents about $\frac{1}{10}$ of a standard deviation of the probability of tightening because of capital constraints. We know from the loan growth equation that such a change translates to about a 30 basis point reduction in the annual rate of growth of total loans. Commercial banks currently hold $6.1 trillion of core loans. Thus, a reduction in the annual rate of growth of 30 basis points implies that loans to households and nonfinancial businesses would be reduced by about $20 billion for each year that the probability that banks tightened because of capital constraints remained elevated.

Total net borrowing by the private domestic nonfinancial sector averaged about $2 trillion per year from 2004 to 2007, of which about $700 billion was extended by commercial banks. So the restriction on bank credit due to capital constraints arising from the proposed Basel III standard amounts to about 1 percent of total annual credit flow and $2\frac{3}{4}$ percent of annual bank lending over that period. Although some substitution of nonbank credit for bank credit is possible, the continued strains in securitization and other capital markets represent an obstacle to such substitution. Moreover, large firms with access to bond and equity markets would be least affected, while bank-dependent smaller firms and households would bear the brunt of such restrictions.

7 Conclusion

During the financial crisis of 2007 to 2009, larger-than-normal fractions of SLOOS respondents reported having tightened lending standards because of capital constraints. Meanwhile, the growth of core loans held on banks' books contracted sharply in 2009 and continued to fall throughout 2010. This paper investigates the quality of the responses to the capital concerns question and the likely effect of Basel 3 on banks' lending policies. It then uses banks' own assessments of their capital position to evaluate the relationship between capital constraints and bank lending.

The fraction of banks in the SLOOS sample that reported having tightened lending policies as a result of capital concerns likely likely has been understated by about 45 percent (or, equivalently, 2 banks per quarter). The misclassification probably arises

in part because banks are only asked the reasons they tightened policies on C&I loans, and not when they tighten standards for other loan categories. Nonetheless, responses tend to covary in expected ways with explanatory variables, importantly including the size of the capital buffer that banks hold over the regulatory minimums. Given the average level of capital buffers over the sample, the increase in the regulatory minimum from 6 percent to a de facto value of 8.5 percent is associated with a 20 percent to 40 percent rise in the probability that a bank tightened lending standards as a result of capital concerns.

Over the period from 1995 to 2010, after controlling for changes in lending standards and loan demand, a one-standard-deviation increase in the probability that a bank would tighten lending standards because of capital pressures is associated with almost 3 percentage points slower annualized growth of core loans in the subsequent quarter. That translates into about 4 percent of overall bank lending flows during a typical year. A somewhat different version of the same question was asked between 1990 and 1994, and a similar analysis using data from that sample period yields a point estimate of the effect of tightening lending standards because of concerns about capital adequacy that is almost the same magnitude.

Basel 3 imposes a de facto well-capitalized standard consistent with a tier 1 capital ratio of at least 8.5 percent under current definitions. Moreover, changes in the definition of tier 1 capital and risk-weighted assets may result in large banks targeting a tier 1 capital ratio defined under current rules of 12 percent. As of the middle of 2010, a considerable fraction of the banking industry fell below that standard, including many of the largest banks. Thus, the combination of a weak economy, poor credit quality of existing bank portfolios, and the significantly higher capital requirements may have dampened bank lending and impeded economic recovery over the past few years. The early 1990s, the previous period of transition to a higher, uniform international capital standard was associated with a prolonged period of depressed lending activity. That period, often referenced as a "credit crunch," followed the much shallower recession of 1990 and recovery was not stifled by disruptions in nearly all other capital markets.

The analysis also bears on the effectiveness of the Capital Purchase Program and other steps taken to recapitalize the banking industry in the wake of the financial crisis. To the extent that those actions reduced the number of banks that tightened–or would have tightened–lending standards as a result of concern about their capital

levels, they probably supported additional lending. Indeed, the fraction of banks that reported tightening lending standards as a result of capital pressures fell from a high of about 35 percent in the third quarter of 2008 to about 20 percent after the distributions of CPP funds in 2008Q4 and 2009Q1. Such a decline in the fraction of banks reporting capital constraints would be associated with a 3 percentage point increase in the annualized growth rate of core loans in subsequent quarters.

Appendix: Econometric Framework for Evaluating the Capital Concerns Response

This section is divided in two subsections. In the first subsection, we describe the estimation of the model defined in expressions (1)-(3) using the method of simulated maximum likelihood as proposed by Keane and Sauer (2010). In the second subsection, we describe the bootstrap method used to deal with an endogeneous generated regressor in a linear panel regression with firm and time fixed effects.

Estimation of the Model with Misclassification

The simulated maximum likelihood (SML) estimator for the vector of parameters θ solves:

$$\hat{\theta}_{SML} = \arg\max_{\theta} \sum_{i=1}^{N} \ln[\hat{P}(Y_i^*|\theta, X_i)]. \tag{5}$$

where $Y_i^* = \{y_i^*\}_{i=1}^T$ is the history of reported answers to the question as recorded in the survey by bank i. Since there may be missing answers let $I(y_{it}^*$ observed) be an indicator that equals one if y_{it}^* is observed and zero otherwise. To calculate $\hat{P}(Y_i^*|\theta, X_i)$ we need to construct M simulated responses for each bank i in the following way:

1. Draw M sequences of errors from the joint distribution of $(\epsilon_{i1}, \ldots, \epsilon_{iT})$ to form $\left\{\left\{\{\epsilon_{it}^m\}_{t=1}^T\right\}_{i=1}^N\right\}_{m=1}^M$.

2. Given $\left\{\{X_{it}\}_{t=1}^T\right\}_{i=1}^N$ and the error sequences $\left\{\left\{\{\epsilon_{it}^m\}_{t=1}^T\right\}_{i=1}^N\right\}_{m=1}^M$, construct M simulated responses for each bank i, $\left\{\left\{\{y_{it}^m\}_{t=1}^T\right\}_{i=1}^N\right\}_{m=1}^M$ following equation (1).

3. Construct the conditional probabilities $\left\{\{\hat{\pi}_{jkt}^m\}_{t=1}^T\right\}_{m=1}^M$ for each bank i, where j denotes the simulated response and k denotes the reported response to the

survey question. In particular:

$$\begin{aligned}
\hat{\pi}_{01t} &= \frac{e^{\gamma_0+\gamma_2 y_{it-1}^{*(m)}}}{1+e^{\gamma_0+\gamma_2 y_{it-1}^{*(m)}}} \\
\hat{\pi}_{00t} &= 1-\hat{\pi}_{01t} \\
\hat{\pi}_{11t} &= \frac{e^{\gamma_0+\gamma_1+\gamma_2 y_{it-1}^{*(m)}}}{1+e^{\gamma_0+\gamma_1+\gamma_2 y_{it-1}^{*(m)}}} \\
\hat{\pi}_{10t} &= 1-\hat{\pi}_{11t}.
\end{aligned}$$

where π_{01t} is the probability a bank's true response is a "zero" but the bank reports a "one", and conversely, π_{10t} is the probability a bank's true response is a "one" but the bank reports a "zero".

If y_{t-1}^* is missing it needs to be simulated using equation (3), which is only necessary in the case of persistent misclassification.

4. Calculate the simulator of the likelihood contribution for each bank i as:

$$\hat{P}(Y_i^*|\theta, X_i) = \frac{1}{M}\sum_{m=1}^{M}\prod_{t=1}^{T}\left(\sum_{j=0}^{1}\sum_{k=0}^{1}\hat{\pi}_{jkt}^m I[y_{it}^m = j, y_{it}^* = k]\right)^{I(y_{it}^* \textit{ observed})}$$

Note that if y_{it}^* is not observed there is no contribution to the likelihood, that is the product is one in period t for bank i.

The simulated likelihood function is non-smooth so the simplex optimization method (Nelder-Mead) should be used. However, it is possible to use importance sampling techniques to smooth the likelihood and use a quasi-Newton optimization method. Dealing with the initial conditions problem is relatively simple in the context of this algorithm. Let $t = \tau_i$ be the first period in which the bank's response becomes available in the survey and $t = \tau_i - \tau_0$ be the first period in which call report data is observed. Thus, for each bank we can use τ_0 quarters to simulate the bank's responses and use the last period's response as the initial condition to the problem. Each m simulated reported choice will have its own initial response.

Bootstrap Algorithm

There are three steps in the bootstrap algorithm used to estimate the loan growth regression with an endogenous regressor. The bootstrap algorithm is based on Gonçalves and White (2004) and Gonçalves (2010) as described in step 2 and 3, respectively.

1. Generate a time sequence, $(\tau_1, \ldots, \tau_T)$, by bootstrapping from the original time-series.

2. Let $\hat{\theta}^*$ solve the following problem:

$$\hat{\theta}^* = \arg\max_{\theta} \sum_{i=1}^{N} \ln[\hat{P}^*(Y_i^*|\theta^*, X_i)], \tag{6}$$

   where

$$\hat{P}^*(Y_i^*|\theta^*, X_i) = \frac{1}{M} \sum_{m=1}^{M} \prod_{t=\tau_1}^{\tau_T} \left(\sum_{j=0}^{1} \sum_{k=0}^{1} \hat{\pi}_{jkt}^m I[y_{it}^m = j, y_{it}^* = k] \right)^{I(y_{it}^* \; observed)} \tag{7}$$

   Note that we bootstrap the contributions to the optimization problem constructed to estimate $\hat{\theta}^*$ by using the sequence of indexes $(\tau_1, \ldots, \tau_T)$.

3. Using the same sequence of time indexes as in the previous step solve for the bootstrap fixed effect OLS estimator:

$$\hat{\beta}^* = \left(\sum_{i=1}^{N} \sum_{t=\tau_1}^{\tau_T} (x_{it} - \bar{x}_i)(x_{it} - \bar{x}_i)' \right)^{-1} \sum_{i=1}^{N} \sum_{t=\tau_1}^{\tau_T} (x_{it} - \bar{x}_i)(y_{it} - \bar{y}_i) \tag{8}$$

4. Repeat steps 1-3 a large number of times (large in the paper means 50 in this version).

References

Basel Committee on Banking Supervision (2010a): "An assessment of the long-term economic impact of stronger capital and liquidity requirements," Bank for International Settlements.

Basel Committee on Banking Supervision (2010b): "Basel III: A global regulatory framework for more resilient banks and banking systems," Bank for International Settlements.

Berger, A. N., R. DeYoung, M. J. Flannery, D. K. Lee, and O. Oztekin (2008): "How Do Large Banking Organizations Manage Their Capital Ratios?," *Journal of Financial Services Research*, 34.

Berger, A. N., and G. F. Udell (1994): "Did risk-base capital allocate bank credit and cause a 'credit crunch' the US?," *Journal of Money, Credit and Banking*, 26, 585–628.

Bernanke, B. S., and A. S. Blinder (1988): "Credit, Money, and Aggregate Demand," *American Economic Review*, 78(2), 435–39.

Bernanke, B. S., and C. S. Lown (1991): "The Credit Crunch," *Brookings Papers on Economic Activity*, 2, 205–47.

Berrospide, J. M., and R. M. Edge. (2010): "The effects of bank capital on lending: What do we know? and, what does it all mean?," Unpublished working paper, Board of Governors of the Federal Reserve System.

Chami, R., and T. F. Cosimano (2010): "Monetary policy with a touch of Basel.," *Journal of Economics and Business*, 62, 161–75.

Furfine, C. (2001): "Bank Portfolio Allocation: The Impact of Capital Requirements, Regulatory Monitoring, and Economic Conditions," *Journal of Financial Services Research*, 20, 33.

Gonçalves, S. (2010): "The Moving Block Bootstrap for Panel Linear Regression Models with Individual Fixed Effects," forthcoming in *Econometric Theory*.

Gonçalves, S., and H. White (2004): "Maximum Likelihood and the Bootstrap for Nonlinear Dynamic Models," *Journal of Econometrics*, 119, 199–220.

Hall, B. J. (1993): "How has the Basle Accord affected bank portfolios?," *Journal of the Japanese and International Economies*, 7, 408–40.

Hancock, D., A. J. Laing, and J. A. Wilcox (1995): "Bank capital shocks: Dynamic effects on securities, loans, and capital," *Journal of Banking and Finance*, 19, 661–77.

Hancock, D., and J. A. Wilcox (1994): "Bank capital and the credit crunch: The roles of risk-weighted and unweighted capital regulations," *Journal of the American Real Estate and Urban Economics Association*, 22, 59–94.

Jacques, K. T. (2008): "Capital shocks, bank asset allocation, and the revised Basel Accord," *Review of Financial Economics*, 17, 79–91.

Kashyap, A. K., and J. C. Stein (1995): "The Impact of Monetary Policy on Bank Balance Sheets," *Carnegie-Rochester Conference Series on Public Policy*, 42, 151–95.

Keane, M. P., and R. M. Sauer (2009): "Classification Error in Dynamic Discrete Choice Models: Implications for Female Labor Supply Behavior," *Econometrica*, 77, 975–991.

——— (2010): "A Computationally Practical Simulation Estimation Algorithm for Dynamic Panel Data Models with Unobserved Endogenous State Variables," International Economic Review, forthcoming.

Kiley, M. T., and J. Sim (2010): "Technical background report: An assessment of the macroeconomic transition costs associated with higher levels of capital at financial institutions in the United States," Working Paper, Board of Governors of the Federal Reserve System.

Kishan, R. P., and T. P. Opiela (2006): "Bank capital and loan asymmetry in the transmission of monetary policy," *Journal of Banking and Finance*, 30(1), 259–285.

Kopecky, K. J., and D. VanHoose (2004): "A model of the monetary sector with and without binding capital requirements," *Journal of Banking and Finance*, 28, 633–46.

Lown, C., D. P. Morgan, and S. Rohatgi (2000): "Listening to Loan Officers: The Impact of Commercial Credit Standards on Lending and Output," *Federal Reserve Bank of New York Economic Policy Review*, 6.

Peek, J., and E. Rosengren (1995a): "Bank regulation and the credit crunch," *Journal of Banking and Finance*, 27, 679–92.

——— (1995b): "The Capital Crunch: Neither a borrower nor a lender be," *Journal of Money, Credit and Banking*, 19, 625–38.

——— (1995c): "Is bank lending important for the transmission of monetary policy: An overview," *New England Economic Review*, November-December, 3–10.

Puri, M., J. Rocholl, and S. Steffen (2010): "Global Retail Lending in the Aftermath of the US Financial Crisis: Distinguishing between Supply and Demand Effects," *Journal of Financial Economics*, forthcoming.

Thakor, A. V. (1996): "Capital Requirements, Monetary Policy, and Aggregate Bank Lending: Theory and Empirical Evidence," *Journal of Finance*, 51(1), 279–324.

Thakor, A. V., and P. F. Wilson (1995): "Capital requirements, loan renegotiation and the borrower's choice of financing source," *Journal of Banking and Finance*, 19(3-4), 693 – 711.