Linkages between the Financial and Real Sectors: Bank Credit and Capital over the Crisis*

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October 16, 2009

Abstract

Motivated by the recent importance of the issue of how bank capital-to-asset ratios influence the extension of bank credit, this paper first applies models that were developed in the early-to-mid 1990s by Bernanke and Lown (1991) and Hancock and Wilcox (1993,1994) to address precisely this question to more current data on bank lending. This analysis, which uses panel regression techniques to study the lending of large institutions, finds relatively small effects of BHC capital-to-asset ratios on their lending. This result stands in marked contrast with current perceptions of the effect of bank capital-to-asset ratios on bank lending, which appear to be largely informed by a scatter plot of asset growth against leverage growth for commercial banks that was contained in a paper—not actually about this topic—by Adrian and Shin (2007). Specifically, the scatter plot reported by Adrian and Shin gives the strong impression that banks very actively maintain constant leverage—and thereby bank capital-to-assets ratios—thus suggesting that changes in bank capital-to-assets ratios have very large effects on bank lending as banks attempt to adjust their assets so as to reverse capital-ratio changes. Since our panel regression results conflict so sharply with those of Adrian and Shin we perform additional analysis so as to investigate our results further. Here we consider the effects of capital ratios on lending using macroeconomic time series and aggregate commercial bank balance-sheet data in a modified variant of one of the extended versions of Lown and Morgan's (2006) vector autoregression (VAR) model, which includes as one of its variables the bank capital-to-assets ratio. Again, we find relatively modest effects of bank capital ratio changes on lending, albeit slightly larger effects than in the panel regressions.

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The size of the effect of changes in bank capital-to-asset ratios (hence forth bank capital ratios) on the extension of bank credit has been one of the most important questions of the current financial crisis. For example, very early in the crisis—when the question of whether a credit crunch would obtain was still an issue for debate—the size of the effect of bank capital ratios on bank credit was central to any consideration of how losses in banks' subprime or other mortgage-related portfolios would impact lending and thereby economic activity. Likewise, about a year later, when the Troubled Asset Relief Program (TARP) became primarily one of injecting capital into banks via the Captial Purchase Program (CPP), the size of the effect of increases in bank-capital ratios on the extension of bank credit was again central to any consideration of how the CPP would likely bolster bank lending and thereby economic activity.

Economic theory gives a very wide range of possible values for the size of the impact of a bank's capital ratio on its assets and thereby its lending. Representing one extreme is the possibility that a decline in a bank's capital ratio, which results from a capital loss, can be accommodated without any change in bank assets—and therefore any change in bank lending—likely because the bank is well capitalized both before and after the loss and because the capital loss can be offset by alternative sources of funding. Thus a \$1 reduction in capital results in a \$0 reduction in bank assets. Representing the other extreme is the possibility that banks very actively maintain a constant bank capital ratio and are very limited in their ability to raise equity to offset declines in capital. In this case, a bank's only option for maintaining a constant bank capital ratio is to reduce its asset levels, whereby the amount by which its asset levels must decrease is equal to the size of its capital loss scaled up by the inverse of the bank's capital ratio—that is, its leverage ratio. Since bank capital ratios are on the order of about 0.08 to (for convenience) 0.125, leverage ratios are on the order of 8 (= 1/0.125) to 12.5 (= 1/0.08). This means that a \$1 reduction in capital results in a \$8 to \$12.5 reduction in bank assets.[1] Clearly, therefore, the size, rather than just the sign, of the effect of changes in bank capital ratios on bank credit is an empirical question.

A paper that provides one perspective on this question is that of Adrian and Shin (2007). Among other considerations, this paper takes data from the Federal Reserve Board's Flow of Funds Accounts for several classes of financial and non-financial institutions and uses scatter plots to consider the relationship between quarterly growth rates of each class of institutions' assets and leverage. For commercial banks, the authors find that leverage growth rates are concentrated quite closely around zero and that this is the case independent of the value of asset growth. The relevant figure from Adrian and Shin is inserted as the top panel of Figure 1. The lower panel of the figure is our attempt to replicate this figure, which we can do reasonably closely, according to the authors

[1] An even more extreme scenario is one in which asset levels and bank capital ratios are negatively correlated; that is, as balance sheets expand, leverage ratios also increase. In this case the reduction in bank assets associated with a \$1 reduction in capital would generate a greater than \$8 to \$12.5 reduction in bank assets.

descriptions.[2]

This result of Adrian and Shin gives the strong impression that banks very actively maintain constant leverage—and thereby bank capital—ratios, thus suggesting that changes in bank capital ratios have very large effects on bank lending as banks attempt to adjust their assets so as to reverse capital-ratio changes. Indeed, the scatter plots reported by Adrian and Shin have been very influential over the crisis in shaping forecasters and policymakers views on the size of the effect of bank capital ratio changes on lending. For example, Hatzius (2007) in a mid-November Goldman Sachs U.S. Daily note written fairly early in the crisis, used these results of Adrian and Shin as the basis of his estimates of the lending impact of banks' losses in their subprime or other mortgage-related portfolios. More recently, it appears—although it has not been explicitly stated—that Adrian and Shin's results have also had a strong influence on U.S. Department of Treasury estimates of the effect of bank capital injections made under the TARP on bank lending. For example, in recent testimony U.S. Treasury Secretary, Timothy Geithner, has stated that $1 invested in capital generates between $8 to $12 dollars of lending capacity.[3]

While the scatter plot approach used by Adrian and Shin represents one way to consider the effect of bank capital on lending, other more focused approaches also exist. In particular, in the early- to mid-1990s, when the U.S. economy was growing fairly sluggishly out of the 1990:Q3 to 1991:Q1 recession, an active area of research was on the question of whether newly introduced bank-capital regulations, associated with the adoption of Basel I, were inhibiting bank-lending activity and thereby acting as a headwind on the economic recovery. Although this debate did not yield a decisive answer on whether a bank-capital induced credit crunch was hindering the recovery, it did result in the development of empirical models that expressly addressed the question that again confronts forecasters and policymakers; specifically, the size of the effect of bank capital ratios on bank lending. For example, Hancock and Wilcox (1993, 1994) in a pair of papers that documented support for a bank-capital induced credit crunch in the early 1990s (specifically over 1991), developed and estimated models that related changes in the lending of individual banks to measures of loan demand and bank shortfalls/surpluses in actual relative to (modeled) target level. Likewise, Berger and Udell (1994) specified an equation relating the growth rate of individual banks' various asset-side balance-sheet variables to differently defined capital-asset ratios and argued against the presence of an early 1990s bank-capital headwind. Rather, they suggest that the

[2] The two series used to generate the cross plot shown in the lower panel of Figure 1 are the growth rate of the commercial banking sector's total financial assets (series FL764090005.Q from the Flow of Funds Accounts) and the growth rate of commercial banking sector's overall leverage ratio, which Adrian and Shin measure as the ratio of total financial assets (series FL764090005.Q) divided by commercial bank equity, that is total financial assets (series FL764090005.Q) less total liabilities (series FL764190005.Q).

[3] See, Treasury Department Press Release (TG-95) "Treasury Secretary Timothy Geithner, Opening Remarks As Prepared for Delivery to the Congressional Oversight Panel," April 21, 2009 for the quoted lending capacity estimates.

decline in bank credit between 1990 and 1991 was the result of asset reallocations from loans and to securities, encouraged by the implementation of risk-based capital requirements associated with Basel I. Another paper from this era to argue against the restraining influence of bank capital on lending was that of Bernanke and Lown (1991) who using equations linking bank lending to capital ratios and employment (all at the state level) found bank capital to be a less notable influence on bank lending than economic activity. That said their analysis was based on data ending in the first quarter of 1991, which is before when even the proponents of the credit-crunch view would argue it was occurring in its strongest form.[4]

Clearly, the models developed in this early- to mid-1990s literature could be applied to more recent data so as to estimate the effects of bank capital on lending that now obtain and thereby address policy and economic-outlook questions of critical importance. To our knowledge, however, these models have not been applied to inform the current debate and so the first part of this paper fills this gap by performing exactly this exercise.[5] In particular, using large bank holding company (BHC) balance-sheet data and some macroeconomic data as controls, which we discuss in section two, we consider variants of two of the models and approaches developed in this literature; specifically, the model developed by Hancock and Wilcox (1993, 1994) and the model developed by Bernanke and Lown (1990). These are both presented in section three. In brief, these models, use bank level data in panel regressions, which control for heterogeneous bank behavior, and find relatively small effects of BHC capital ratios on BHC lending. Since this finding conflicts quite sharply with the impression drawn from Adrian and Shin's scatter plots, we perform additional analysis so as to investigate our results further. Some of this analysis is undertaken by performing robustness analysis on the estimates derived from the Hancock and Wilcox and Bernanke and Lown models. Some analysis—conducted in section four—is, however, also undertakenby following a more aggregative approach, which given that the original scatter plot reported by Adrian and Shin (2007) used aggregate data seems instructive. Here we consider the effects of capital ratios on lending using macroeconomic time series and aggregate commercial bank balance-sheet data in a modified variant of one of the extended versions of Lown and Morgan's (2006) vector autoregression (VAR) model, which includes as one of its variables the bank capital ratio. This model allows us to investigate the dynamic effect of an exogenous impulse in the bank capital ratio on bank lending as well as the influence of bank capital ratios on fluctuations in bank lending over the model's sample

[4]Peek and Rosengren (1995) is another notable paper in this literature, which, using data for New England, found, like Hancock and Wilcox (1993, 1994), support for the existence of a early 1990s capital-induced credit crunch. In contrast to the above-mentioned papers, however, Peek and Rosengren approached the question from the liabilities side of banks' balance sheets and as a result their modeling specification does not lend itself as directly as the other papers to studying the effect of bank capital on lending.

[5]The Hancock and Wilcox (1993, 1994) approach has, however, been applied by Francis and Osborne (2009) for the U.K. to address the implications of changes to the design and calibration of capital requirements for lending.

period and during specific episodes. Again, and even using this very different approach, we find relatively modest effects of bank capital ratio changes on lending.

The rest of the paper is organized as follows. We describe the data and sources used in our two approaches in Section 1. Section 2 contains the empirical results of the link between bank capital and bank lending at the institutional level. Section 3 discusses our results using aggregate data. Section 4 concludes the paper.

1 Data

The paper employs a wide range of data sources as a result of its use of panel, cross-sectional, and timeseries methods. We discuss these data sources in this section.

1.1 Institution-level Data

For the empirical analysis that we conduct at the institution level we use bank holding company (BHC) data rather than the lending of individual commercial banks within the BHC. This decision reflects the fact that evidence suggests that many decisions are taken for the activities of the BHC as a whole rather than on a component by component basis. Of course, another—equally valid—approach is to use only the commercial banking activities of BHCs, which involves rolling up the balance sheets of all commercial banks within a BHC to the high-holder level and conducting our empirical analysis on this data. We do this as a robustness exercise and discuss the results in section 2.5.

Institution-level data are taken from the Consolidated Financial Statements for Bank Holding Companies (FR-Y9C) over the period 1994 to 2008.[6] Our sample consists of 165 large BHCs, all with total assets in excess of $3 billion as of 2008:Q4, which represent approximately 85 percent of the total assets in the banking sector.

Table 1 reports the summary statistics for the variables used in the panel estimation. Although the sample is based on a panel of large BHCs, there is a large variation in the distribution of total assets. The median BHC in the sample has assets above $3 billion. However, the standard deviation of $133 billion is consistent with the fact that the four largest institutions in the sample have assets above $1 trillion, whereas total assets for the smallest ones are below $1 billion. Quarterly growth in total loans and C&I loans averages 3 percent across all BHCs and over time. The

[6]We exclude institutions with missing observations in total assets, loans, and capital, and also BHCs that remain in the sample for less than 30 quarters. In order to minimize the influence of extreme outliers, we remove observations with more than 50 percent growth in total assets over a single quarter and winsorize the remaining variables at the 1 percent and 99 percent levels. The final sample consists of about 10860 bank-quarter observations for 141 institutions out of the 165 BHCs.

distribution of variables scaled by assets such as capital, securities and net charge-offs exhibit smaller variances. Both the mean and the median values for the equity-to-assets (leverage) ratio is about 8%. Interestingly, throughout most of the sample period, in terms of the mean and the median values, large BHCs in the sample hold capital positions significantly above the well-capitalized regulatory minima.[7] Finally, the Tangible Common Equity (TCE) ratio, measured as tangible common equity over tangible assets for the mean and median BHC is about 7 percent.

Figure 2 depicts the evolution of the average of different capital ratios over our sample period. As seen from the figure, there seems to be a distinctive behavior among them. While risk-based capital ratios exhibit a downward trend after 2004, the equity-to-assets ratio remains trending up until mid 2007. This different behavior could partly reflect increasing risk-taking on the side of banks during the last 5 years, which could have made risk-weighted assets increase faster than total assets.

As expected, the leverage ratio and the regulatory capital ratios all jump in 2008:Q4 after the implementation of the Treasury's capital injection program. The TCE ratio is unaffected by the capital infusions and seems to exhibit a downward trend that started around 2003.[8] Adverse market risk perceptions are more evident after the beginning of the financial crisis, which also explains a deeper contraction in the average TCE ratio after the second half of 2007.

Figure 3 plots the quarterly growth rate of total loans for all and large commercial banks, as well as the BHCs in our sample. As seen from the table, the lending growth patterns for BHCs and large commercial banks are similar and show a large volatility, especially around 1998, after the East Asian and the Russian crises, and the LTCM near-collapse episode. The figure also shows a rapid recovery of bank lending after the 2001 recession, with the average quarterly growth rate hoovering around 3% until 2007. Total growth in bank lending exhibits a severe contraction after the second half of 2007, with a significant slow down in growth rates following further deterioration in credit conditions during 2008, and negative growth rates over the first two quarters of 2009.

1.2 Aggregate data

Our panel regressions include a number of macroeconomic data series which we will discuss first before moving on to note those included in the VAR model. Specifically, our panel regression lending equations include real GDP growth, as measured by the NIPA, inflation, as measured by the CPI, the Federal funds rate, and (aggregate) net tightening of C&I lending standards, as reported by the

[7]Among other criteria, a BHC is considered well-capitalized if it has a total risk-based capital ratio of at least 10 percent, and a Tier 1 risk-based capital ratio of at least 6 percent.

[8]The capital injections did not affect the TCE ratio because the Treasury injected capital through purchases of preferred stock with warrants rather than common equity.

Federal Reserve Board's Senior Officer Opinion Survey (SLOOS). All other variables in our panel regressions are institution-level variables (discussed above).

A large fraction of the aggregate variables that are included in the paper's panel regressions are also included in the VAR model that we move onto consider in section 4. Indeed our panel equation for lending growth has a broadly similar specification to our lending equation in the VAR, albeit without the institution-specific variables that the former equation has. Our VAR model for example includes real GDP growth, which is measured as in the panel regression. Our VAR model also includes inflation, although here a different measure—specifically, the GDP deflator excluding food and energy—is used. Our reason for using different inflation measures in our panel regression and VAR model is largely due to our analysis following equation specifications that were set out by previous authors. Specifically, the equation used in the panel lending regression follows that of Kashyap and Stein (1995, 2000), who used the CPI, whereas our VAR model follows Lown and Morgan (2006) who use the GDP deflator as their price measure. We diverge from Lown and Morgan and use the GDP deflator excluding food and energy due to some very large swings in overall GDP prices (causes solely by energy prices) at the end of our sample. While these swings were not important for our impulse response functions, they were tending to influence (in an implausible way) the composition of estimated nonfinancial structural shocks being derived from our model over the 2008 to 2009 period, which was in turn affecting our conclusions regarding the influence of difference nonbanking shocks on economic developments.[9]

Like the panel regression, our VAR model also includes the Federal Funds rate and the net tightening in C&I lending standards from the SLOOS. Our measure of the aggregate capital-asset ratio is for commercial banks and is taken from the Call Reports. Finally, for lending we use bank and thrift depository lending as reported by the Flow of Funds accounts. Our principal motivation for using commercial bank and thrift lending in the VAR rather than just commercial bank lending—which may seem more sensible given that all other banking-sector variables pertain only to commercial banks—arises from some very sharp spikes in the latter series caused by purchases of large thrifts by commercial banks, such as Bank of America's purchase of Countrywide and JP Morgan's purchase of WaMu. Using the aggregate bank and thrift data eliminates these swings and does not greatly alter the VAR's impulse response functions, although clearly it does allow a more plausible historical sequence of structural shocks estimated by the model.

[9]Specifically, when our model included the GDP deflator we were finding that the most important nonfinancial shock accounting for movements bank and thrift lending over 2008 and 2009 was price shocks, which seemed somewhat counterintuitive. However, using the GDP deflator excluding food and energy eliminated this problem.

2 Bank Capital and Bank Lending at the Institution Level

In this section we use BHC insttution level data and panel regression techniques to study the effects of bank capital on lending. Our principal approach to doing this is to model the lending growth of our panel of banks as functions of supply and demand factors, with one of our supply factors being bank capital. Because in our lending growth regressions we control for the effects of other supply and demand variables we can interpret the coefficient on bank capital as its effect on lending growth. We consider two possibilities regarding the way that bank capital affects lending growth. In the first case we assume that it is the divergence between a bank's actual and target capital that is important for determining its lending growth. In the second case we assume that it is a bank's capital-to-assets ratio that influences its lending growth. We also try to use our models to address various developments of current policy interest. Specifically, we use our models to understand the factors underlying recent reductions in bank lending as well as to to estimate the expected impact of recent capital injections on bank lending.

2.1 Bank Capital Shortfalls/Surpluses and Bank Lending

The first model from the early 1990s credit-crunch literature that we use to study the effect of changes in bank capital on bank lending is that developed by Hancock and Wilcox (1993, 1994). In this model, bank's lending growth is influenced by the deviation of bank capital from its desired or target level. Implementing this model therefore first requires the estimation of target capital. This is done by estimating individual bank-specific capital *ratio* targets, from which bank-specific capital *level* targets can then be derived. These level targets then enter the model's lending growth equation as a percent deviation from actual capital levels.

2.1.1 Estimation of the target capital ratio

We estimate individual bank-specific capital targets with a partial-adjustment model of actual capital holdings toward a desired, or long-run, target ratio as in Hancock and Wilcox (1993, 1994), and more recently in Flannery and Rangan (2008). The target capital ratio, $k^*_{i,t}$, is modeled as a linear function of a vector of control variable $X_{i,t}$, which include bank-specific characteristics as well as institutional and aggregate determinants; specifically, we have $k^*_{i,t} = \theta \cdot X_{i,t}$. Based on the rationale that costs of altering bank capital in practice prevent banks from taking their holdings of capital to their target levels immediately, the actual bank capital ratio $k_{i,t}$ is assumed to follow a partial-adjustment process of the form:

$$k_{i,t} - k_{i,t-1} = \lambda \cdot (k^*_{i,t-1} - k_{i,t-1}) + \epsilon_{i,t}.$$

Substituting in our expression for $k^*_{i,t-1}$, re-arranging terms, and adding a constant yields our estimation equation:

$$k_{i,t} = \alpha + (1-\lambda) \cdot k_{i,t-1} + \lambda \cdot \theta \cdot X_{i,t-1} + \epsilon_{i,t}. \tag{1}$$

The bank-specific variables in $X_{i,t}$ include the log of total assets, the return on assets, and the net charge-off rate; these are intended as proxies for size, earning, and risk, respectively. Size captures the fact that larger banks are likely to face lower risks (due, for example, to greater diversification) and better access to sources of funding (thereby requiring less capital). Earnings are included because dividend payments are often slow to adjust, resulting in an accumulation of retained earnings and bank capital. Risk captures the fact that markets require more capital to be held against riskier assets. We also include the loan/security composition of bank assets, which reflects the differential risk exposures implied by different types of assets, and the composition of bank loans, which for similar reasons could also affect target capital ratios.[10] The institutional variable, called regulatory pressure, is a dummy variable that equals unity if the BHC's equity capital ratio is less than 1.5 percentage points above the minimum of 5 percent.[11] We also include aggregate variables such as a measure for stock-market volatility and the aggregate net charge-off rate.

Table 2 provides the estimation results for equation (1) under two different specifications of the $\theta \cdot X_{i,t-1}$ term. Other than the coefficients on bank size and aggregate stock-market volatility, most of the coefficients reported in Table 2 are close to what might be expected *a priori*. In both specifications, there is a positive and significant coeeficient on size, which suggests that larger BHCs hold higher capital ratios. Our evidence seems to contradict previous findings that larger BHCs hold lower capital ratios. We interpret the positive effects of size on capital as indication of some economies of scale at larger institutions. We also find that larger shares of loans and securities (relative to assets) are associated with lower capital ratios, which means that these forms of bank credit may be also controlling for risk associated with higher leverage. The coefficient on stock-market volatility appears to result from the counter-cyclical nature of volatility and the pro-cyclicality of bank capital. Both, individual and aggregate net charge-off rates are associated with higher capital ratios. These two variables control for bank risks and suggest that BHCs hold additional capital during bad times, when the credit quality of loans deteriorate. Finally, BHCs with higher profits and those facing higher regulatory pressure tend to hold more capital, but these result appear to be statistically weak.

In addition to the typical determinants of the target capital ratio, the regression equation

[10] All composition variables, such as the security and loan composition variables, are calculated in terms of their share of bank assets.

[11] 5 percent is approximately the level below which regulators in the U.S. would have concerns about the capital adequacy of BHCs.

includes bank-specific fixed effects to control for possible omitted variables and to capture heterogeneous characteristics such as different risk preferences, governance structures, and managerial skills. The fixed effects explain a large fraction of the cross-sectional variation in target capital ratios without affecting the statistical significance of the other time-varying, firm-specific characteristics in the regression equation.[12] Interestingly, the coefficient on the lagged capital ratio implies an estimated speed of adjustment of 40 percent per year, which is somewhat slower than the 60 percent per year rate found by Flannery and Rangan (2008).

As in Hancock and Wilcox (1993, 1994), the estimates of the coefficients in equation (1) are used to calculate a time-series for each BHC's target capital ratio, $k^*_{i,t}$. These estimated target capital *ratios* are then used to construct target capital *levels* $K^*_{i,t}$. Capital surpluses, denoted by $Z_{i,t}$, are calculated as deviations of actual capital relative to target; that is, $Z_{i,t} = (K_{i,t} - K^*_{i,t})/K^*_{i,t}$.

Figure 4 plots the average actual and average target capital ratios—that is, $\bar{k}_t$ and $\bar{k}^*_t$—over our estimation period. Differences between the average actual and average target capital ratio appear quite pronounced and quite persistent; nonetheless they do appear to conform with certain aspects of the conventional wisdom concerning movements in these series. In particular, in line with the findings of the literature on bank capital management, we find that BHCs operated with significant capital surpluses over the late 1990s.[13]

2.1.2 Estimation of the effect of capital shortfalls on lending

To gauge the effects of capital shortfalls on bank lending we include our estimates of bank capital surpluses $Z_{i,t}$ in a regression similar in spirit to Bernanke and Lown (1991) who studied the link between bank capital and bank lending, and Kashyap and Stein (1995, 2000) who modeled the growth rate of bank lending as a function of supply and demand factors. Specifically, we model the growth rate of BHC loans ($\Delta\%LOAN_{i,t}$) as a function of its own lags, lags of economic growth ($\Delta\%GDP_t$), lags of the CPI inflation rate ($\Delta\%INF_t$), and lags of the change in the federal funds rate (ΔRFF_t), and lags of lending standards (STD_t). In addition, we also include lagged BHC-specific characteristics such as a control for bank liquidity ($LIQU_{i,t}$), which is measured by the ratio of securities to total assets, and the ratio of net charge-offs to total assets ($CHG_{i,t}$). The last term is our estimates of bank capital surpluses $Z_{i,t}$, which is the main variable of interest. Thus,

[12] Although the presence of fixed effects in dynamic panel data estimation can lead to biased OLS estimates, simulations by Judson and Owen (1999) suggest that the the bias is minor in panels with more than 30 observations. Given that our panel uses 59 periods of data and the minimum number of quarters for any BHC in our sample is 30, we make no correction for short-panel bias.

[13] For example, Flannery and Rangan (2008), and Berger, De Young, Flannery, Lee and Oztekin (2008) document the build-up of capital cushions for large banks, substantially above the "well-capitalized"regulatory minima, during the 1990s and mid 2000s, a period of unusual profitability for the banking sector.

the following panel regression equation is estimated:

$$
\begin{aligned}
\Delta\%LOAN_{i,t} = & \sum_{s=1}^{4} \alpha_s \cdot \Delta\%LOAN_{i,t-s} + \sum_{s=1}^{4} \gamma_s \cdot \Delta\%GDP_{t-s} + \sum_{s=1}^{4} \delta_s \cdot INF_{t-s} \\
& + \sum_{s=1}^{4} \beta_s \cdot \Delta RFF_{t-s} + \sum_{s=1}^{4} \zeta_s \cdot STD_{t-s} + \phi \cdot LIQU_{i,t-1} \\
& + \chi \cdot CHG_{i,t-1} + \psi \cdot Z_{i,t} + \epsilon_{i,t}, \qquad (2)
\end{aligned}
$$

Note that the specification of this equation is broadly similar to the lending equation estimated in our VAR.

The model is specified in growth rates to deal with non-stationary variables and uses four lags. To avoid potential endogeneity issues, only lags of explanatory variables are used. We also include quarterly dummies to control for potential seasonality in the data. In this specification, economic growth is included to control for changes in loan demand; lending standards are used to control for credit supply changes that arise from more conservative lending behavior; and the federal funds rate is included to control for monetary policy changes. Regarding controls for firm characteristics, the liquidity variable is intended to capture the extent to which BHCs use their stock of securities to adjust their lending growth, all other things equal; and the fraction of charge-offs to total assets is a proxy for BHC risks. Equation (1) is estimated with bank fixed effects in order to allow for potential omitted factors that vary across BHCs and are constant over time.

Table 3 presents the estimation results for equation (2).[14] The first pair of columns presents results when total bank loans are used as the dependent variable, while the second pair of columns presents results when C&I loans are used as the dependent variable. For both total bank loans and C&I loans there is a positive and significant coefficient on capital surpluses, indicating that the growth rate of both total and C&I bank loans is larger for banks with greater amounts of excess capital. The effects seem small, however: The long-run impact of a capital shortfall (surplus) on both total and C&I BHC lending is roughly to reduce (increase) lending growth by 0.1 percentage point when capital falls short of (exceeds) its target level by 1 percent.[15]

The results in Table 3 suggest a more important role for demand shocks and exogenous changes

[14] Because an auxiliary equation is used to estimate the capital surplus variable, our estimation of equation (2) is subject to a generated regressor bias. We use a bootstrap procedure to address this problem.

[15] We also considered differences in the impact of capital deviations on lending between BHCs operating with capital surpluses and BHCs operating with capital shortfalls. We did in two ways. The first way was to split our sample depending on the sign of the capital deviation and then re-estimate equation (2) for each group. The second way was to include a dummy variable that depends on whether a shortfall or surplus is present. This dummy variable then interacts with $Z_{i,t}$ in equation (2) and thus allows for different values of κ depending on whether $Z_{i,t}$ represents a surplus or shortfall. In both cases the results (not shown) indicated that the sensitivity of loan growth is smaller for BHCs facing capital shortfalls, although this difference is not statistically significant.

in net charge-offs in determining both total and C&I loan growth. Specifically, the response of BHC loan growth measured by GDP growth implies that a 1 percentage point reduction in GDP growth lowers the growth rate of total lending by 0.8 percentage point and lowers the growth rate of C&I lending by 1.8 percentage points. Furthermore, the potential effects of continued write-downs through further increases in net charge-offs imply a large and significant impact in both specifications. For example, a 1 percentage point increase in the net charge-off ratio depresses the growth rate of both total and C&I BHC lending by about 3/4 percentage point. These findings are consistent with the recent sharp contraction in bank lending depicted in figure 2. Although the coefficient on securities-to-assets ratio is significant, the effect of increased holdings of securities on the BHC lending growth is small. A 1 percentage point increase in the securities-to-assets ratio leads to about 0.1 percentage point increase in both total and C&I lending growth. Finally, lending standards in both the total and C&I lending equations enter negatively (as expected), but appear statistically insignificant. This latter observation may be explained by the fact that the capital surplus measure and the increase in the charge-off ratio already capture potential effects associated with banks' dimished willingness to lend.

2.2 Bank capital ratios and bank lending

An alternative approach to investigate the link between bank capital and lending is to use our regression framework to gauge the effects of shocks to capital ratios on bank lending growth. For this purpose, we replace in equation (2), our measure of the capital surplus by the lagged value of different capital ratios as the main variable of interest; specifically, the equity-to-assets ratio (book leverage ratio), the risk-based total capital ratio, the risk-based tier 1 capital ratio, and the tangible common equity (TCE) ratio. We consider each capital ratio separately. The equity-to-assets ratio attempts to measure the impact on loan growth of capitalization decisions, while both risk-based capital ratios would more broadly reflect the effect of capitalization and portfolio decisions because it also includes off-balance sheet assets. The (TCE) ratio is a more conservative measure of bank capital, intended to represent the first loss position in case of bank failure. We include this alternative measure of bank capital because it has been the recent focus of market participants as to evaluate the financial strength of banking institutions.

The estimation results for the impact of shocks to capital ratios on BHC lending growth are reported in table 4. As seen from the table, all variables enter with the expected sign and most are statistically significant. For example, there are positive and significant coefficients on the BHC capital ratios, which is consistent with the growth rate of bank loans being larger for banks with higher capital ratios. However, regardless of the capital ratio we use as our main explanatory variable, the effects of shocks to capital on the BHC lending growth is small. Depending on the capital ratio employed, our results in table 4 suggest that a 1 percentage point increase in capital ratios leads to an increase in the annualized BHC lending growth only between 0.7 and 1.2 percentage points.

As in the case of our estimates for the effects of capital shortfalls, the model estimation suggests that demand shocks and exogenous changes in net charge-offs play the most important role in determining total loan growth. The response of BHC loan growth to demand shocks, measured by GDP growth, implies that a 1 percentage point reduction in GDP growth leads to about 7 percentage points decline in annualized lending growth. Furthermore, the potential effects of continued write-downs through further increases in net charge-offs imply a large and significant impact in all specifications. Although the coefficient on the securities-to-assets ratio is significant, the effect of increased holdings of securities on BHC lending growth is small. A 1 percentage point increase in the securities-to-assets ratio leads to a 0.3 percentage point increase in BHC lending growth. Finally, the coefficient on lending standards has the expected negative sign but has also small effect on BHC lending. As in our previous estimation using capital shortfall, this latter observation may be explained by the fact that the capital shock and the increase in the charge-off ratio already capture potential effects associated with banks' diminished willingness to lend.

As can be seen in the last column of table 4, the TCE ratio has a larger coefficient than the equity-to-assets ratio. However, their impact on BHC total loan growth is still small: A 0.3 percentage point decrease in this ratio implies 0.4 percentage point decline in BHC annualized lending growth. The reduction in this capital ratio observed in recent months occurred mainly as the result of adverse perceptions of bank risk.

2.3 The effect of recent capital injections on BHC lending growth

The previous regression results can also be employed to provide estimates of the effect of the original TARP disbursement ($182 billion) on BHC lending. More specifically, the CPP capital infusions during 2008:Q4 raised the equity-to-assets ratio about 1.4 percentage points (on average) and the risk-based capital ratio about 1.7 percentage points (on average). As seen in columns 1 and 2 of table 4, the estimated impact varies a little depending on the capital ratio definition, but is on the magnitude of at most 0.3 percentage point increase in quarterly lending growth. As mentioned above, our results suggest that a 1 percentage point of capital injections would boost annualized BHC lending growth between 0.7 and 1.2 percentage points. In nominal terms, this result implies that the $182 billion increase in capital that large BHCs received would result in an increase in their lending between $60 billion and $97 billion over the following year, significantly less than the boost in lending capacity based on the U.S. Treasury assumptions.[16]

Overall, the results derived from the empirical model suggest a modest impact of both capital shortfalls and shocks to capital ratios (for example, recent capital injections) on BHC total loan growth, relative to the impact of other factors such as demand shocks or increased bank risk perception. This provides one interpretation for the notable slowing of BHC lending growth observed over the last two quarters: The impact of sizable increases in the availability of loanable funds from various government provisions was offset (1) by weak economic conditions that reduced loan demand, and (2) by increased risks, as borrowers might still appear less creditworthy.

2.4 Robustness analysis

Because our estimates of the effect of capital shortfalls on lending appear small we conduct a number of robustness checks (which we ultimately find do not alter our key findings).

First, we considered an alternative, atheoretic, approach to calculating the capital shortfall. Specifically, instead of employing an estimated model to calculate the banks' capital targets, we use a one-sided Hodrick-Prescott filter applied to each BHC's time-series of capital. The capital surpluses and shortfalls implied by the filter's estimates are smaller and smoother than their model-based counterparts, but are also less consistent with the conventional wisdom regarding when the banking system was operating with capital surpluses or shortfalls. Indeed, it is principally for this reason that we chose the model-based target measure as our primary specification. Nonetheless, we still considered how the alternative measure of the target capital level altered our estimates of the effects of capital shortfalls on lending and found that the estimates, which were significant, were larger—on the order of a 0.2 percentage point reduction in lending growth when capital is 1 percent below its target level—but still small relative to estimates from the early 1990s credit crunch.

We also perform rolling-window panel regressions over the sample period, since we were concerned with decreasing effects of shocks to bank capital on lending. In particular, we were concerned that estimating the equations over a fourteen-year period, during which capital surpluses predominated, could dilute the effect of capital shortfalls or shocks to capital ratios on lending growth. We use fixed-size rolling windows of six, seven and eight years with quarterly data starting in 1994:Q1, for the regressions that use both capital surplus and different capital ratios as the

[16] The CPP program considered that a dollar invested in capital would generate between eight to twelve dollars of lending capacity. Taking into account the $250 billion of capital injections over the fourth quarter of 2008, the Treasury assumptions would imply about $2 to $3 trillion increase in bank lending capacity. See Treasury Department Press Release (TG-95) "Treasury Secretary Timothy Geithner, Opening Remarks, as Prepared for Delivery to the Congressional Oversight Panel," April 21, 2009 for the quoted lending capacity estimates. Although not stated in the testimony, the likely basis for these estimates is the view that banks maintain constant leverage ratios (see Adrian and Shin, 2007).

main explanatory variables. In all cases, we find that the coefficients on our variables of interest were relatively stable, implying, therefore, a small impact on lending. For example, the coefficients fluctuate between 0.05 and 0.09 for the capital surplus measure, and between 0.10 and 0.55 for the equity-to-assets ratio. The largest coefficients correspond to the regressions that start between 1994 and 1995, which we interpret as being consistent with the largest rates of loan growth observed over the second half of the 1990s and the early 2000s, precisely the time when large BHCs hold significant capital surpluses.

Finally, we tried performing variants of the regressions described in equations (1) and (2) over a shorter sample period—specifically the most recent four years. [17] In this case we obtained a slightly larger coefficient on the capital surplus term in equation (2), although one that still rounded to imply a 0.1 percentage point reduction in lending growth when the capital shortfall is 1 percent.

2.5 Why are the effects of capital shortfalls and shocks to capital ratios on lending growth so small?

Figure 5 provides some explanation of why—even with the same methodology—our estimates for the effects of capital shortfalls on lending growth are small relative to estimates obtained in the early 1990s. Figure 5 shows the distributions of actual capital ratios and target capital ratios distributions for 2008:Q3 and for 1990. Differences between the early 1990s episode and now are quite apparent from the figure. As can be seen from the top panel, the differences between actual and target bank capital in the current episode (as calculated in section 2.1) are very slight relative to the sharp differences, shown in the bottom panel, that underlie the estimates of Hancock and Wilcox (1993). This in turn reflects the fact that U.S. banks appear to be better capitalized in 2008 than they were in 1990. Simply put, in recent years, banks seem better prepared to handle pressures on their own balance sheets and have not had to shrink their balance sheets to achieve their target capital ratios. Our finding of a relatively small difference between actual and target bank capital in the current episode corroborates responses from the Senior Loan Officer Opinion Survey, which over the past year has found that a deterioration in current or expected capital positions is the least important reason mentioned by respondents for their tightening of lending standards.

Our results of small effects of shocks to bank capital ratios, such as the recent capital injections

[17] In performing the regressions described in equations (1) and (2) we omit the lagged dependent variables from the regressions since, given the short sample period, the presence of fixed effects would, as discussed earlier, otherwise lead to biased OLS estimates. Prior to using them, we verified that for the entire sample period, the regressions without the lagged dependent variable, although with slightly lower goodness of fit, were still appropriate (for example, explanatory variables had slightly different coefficients but entered the regression with the expected sign and significance).

under the CPP, are consistent with more recent developments in credit markets. Despite the large amount of capital funds injected in the banking sector, lending conditions worsened during the last three quarters. For example, over the last quarter of 2008 and the first quarter of 2009, large BHCs reduced their total loans about $288 billion. Furthermore, over the second half of 2008 large BHCs were hoarding liquidity and using their capital injections to boost their capital positions-likely in an effort to build up a cushion against further expected capital losses and write-downs-rather than lending these funds. Moreover, our results are also consistent with those contained in Frame, Hancock and Passmore (2009), who used a panel-VAR methodology to find no statistically significant lending response to an equity injection for the largest banks in their sample. In contrast, they argue that capital injections in small-and medium-sized banks are likely to result in both increased bank lending and more rapid GDP growth.

Finally, regarding out-of-sample predictions, the model performs well in explaining the large drop in BHC lending observed after 2008:Q4. Given the observed drop in GDP growth, the increase in the charge-off ratio, and the reduction in the federal funds rate as of 2009:Q1, the model predicts a 11.2 percent reduction in the annualized growth rate of BHC loans, which is fairly close to the observed 9.6 percent reduction (on average) during 2008:Q4 and 2009:Q1. However, this lending contraction even after large amount of capital injections may also reflect other factors beyond the model, such as a broad-based de-leveraging, precautionary liquidity hoarding or more important contemporaneous effects of GDP growth on bank lending.

3 Bank Capital and Bank Lending at the Aggregate Level

In this section we use aggregate data and a vector autoregression model to study the effects of commercial-bank capital ratios on bank lending. We use several approaches to do this, which in all cases rely on the identification of structural innovations in bank capital ratios. Our principal approach is to compare the importance of these structural innovations for fluctuations in bank capital ratios themselves with their importance for fluctuations in bank lending. We do this both for the VAR model's entire sample period as well as for the specific episode of the reduction of bank capital and bank lending over the last year. In addition, we undertake an exercise very much like that performed in section 2.3 looking at the effect of an exogenous structural innovation in bank capital ratios on bank lending, although in this case allowing for the possibility of general equilibrium effects of such a shock.

3.1 Estimation and identification of the VAR model

The vector autoregression model that we use is a slightly modified version of the extended VAR with bank capital considered by Lown and Morgan (2006). Our VAR consists of six variables: real GDP growth and GDP price inflation (excluding food and energy), the Federal funds rate, the growth rate in commercial bank and thrift lending, the aggregate capital to assets ratio of the commercial bank sector, and the net fraction of loan officers at commercial banks reporting a tightening of credit standards for C&I loans. The VAR is estimated using quarterly data over the period 1990:Q2 to 2009:Q1 and includes two lags of each variable (a longer lag structure is precluded by our short sample period, which is in turn dictated by the availability of data on bank lending standards).

The first three variables in the VAR are standard components of a monetary-policy VAR, while the last three variables—commercial bank and thrift lending, the capital-asset ratio, and lending standards—are added to the model to allow us to study the interaction between banks and the macroeconomy. The residuals obtained from each of the estimated OLS regressions are combinations of structural innovations to the model. Importantly, the structural innovations have economic interpretations, such as, exogenous shocks to monetary policy, technology, and the mark-up of prices over costs in the monetary-policy part of the model and exogenous shocks to bank lending standards (reflecting changes in cautioness), bank capital ratios, and bank lending volumes (due to conditions in other credit markets) in the banking part of the model.

However, although structural innovations underlie the residuals implied by the estimated regression they cannot, in the absence of any addtional assumptions, be either observed or inferred. A wide variety of assumptions can be used to identify structural innovations from estimated equation residuals; for our VAR we make recursive assumptions (based on the ordering of variables described above) regarding the contemporaneous effects that different variables in the model can have on each other in order to identify the key structural shocks. We are primarily interested in identifying shocks to bank capital ratios as well as standard shocks. Our identification method assumes that structural innovations to any of the model's banking variables do not affect contemporaneously the model's macro variables but that innovations to the model's macroeconomic variables do affect contemporaneously the model's banking variables. One interpretation for this assumption as it relates to economic activity and inflation is that households and firms can arrange their spending, production, and price-determination plans for the *current* period in such a way that surprise developments in the credit sector will not prevent these plans from taking place. That said, such plans can be modified in response to surprise developments (captured by macroeconomic shocks) of direct relevance for spending, production, and price-determination, which moreover will affect variables in the banking sector. Likewise monetary policymakers do not alter their interest-rate setting decisions in response to within-quarter developments in the bank lending sector; although monetary policy surprises can have immediate effects on conditions in the banking sector.

Within the banking part of the VAR model our identification method assumes that structural innovations to bank lending can affect bank capital ratios and lending standards immediately but that innovations to these variables do not have contemporaneous effects on lending. The first of these assumptions suggests that structural innovations to bank lending originate from outside of the banking sector as well as the real economy. Thus, a reasonable interpretation of these innovations is that they reflect credit developments outside of banking, such as in CP markets or among finance companies. The assumption that capital ratios and lending standards do not affect lending contemporaneously reflects the time that it takes to arrange a loan. This assumption appears at first to be at odds with our assumption that changes in the real economy can affect lending contemporaneously, however, in the case of real-economy developments we have in mind households and firms drawing down or repaying lines of credit on pre-arranged loans. Clearly, credit limits on loans that take the form of credit lines (such as HELOCs, credit cards, or C&I commitment loans) can be modified by banks in response to capital-ratio or standards innovations, but these changes are difficult to implement quickly. Of course, our identification assumption that changes in lending standards have no impact on lending volumes contemporaneously raises the question of what it is then that tighter or looser lending standards actually impact on given that the question in the survey asks how the standards applied to approving applications for loans made in the standards variable's reference period for the differs from those applied in the preceding period. There are many ways, however, via which banks can tighten standards other than altering loan volumes contemporaneously. For example, banks can change the maturity of loans, the cost of credit lines, the spreads on loan rates, the covenants on the loan, and the loans' collateralization requirements and our identifying assumption assumes banks make these changes at least in the period in which standards are tightened.

Our identification method also means that standards innovations do not affect bank capital ratios contemporaneously, although bank capital ratios do affect standards. The first assumption accords quite closely with the previous discussion that documented reasons why standards innovations did not affect lending volumes. The second assumption reflects the fact that lending standards are in the current period the most easily altered variable in the VAR, albeit on the non-volume front.

Finally, note that we only separately identify bank lending volume, bank capital, and bank lending standards stuctural innovations, we do not identify the model's macroeconomic shocks separately from each other. Thus in any results we show, we report the *combined* effects of the model's macroeconomics shocks.

3.2 Impulse response functions

Figures 6, 7, and 9 show the responses of key model variables—specifically, output growth, lending growth, the capital-assets ratio, and standards—to one standard deviation own-variable shocks for standards, the capital-to-assets ratio, and lending, respectively.

As can be seen from Figure 6 a one standard deviation shock to standards implies an immediate 9 point increases in the net tightening series. This increase is persistent; that is, standards continue to increase for about a year following the shock. Tighter standards reduce lending growth for about two years following the shock with the peak response of about 1 p.p. occurring about one year after the shock hits. Tighter standards and reduced lending also slow GDP growth for about two years following the shock, although the peak response of 0.6 p.p. occurs only about two quarters after the shock. The response of the capital-assets ratio is essentially insignificant although the response in the first quarter is just significant, albeit negative. Although this reduction in the capital ratio may seem at first counterintuitive, given that lending is contracting, it could be consistent with a reduced volume of leading resulting in lower bank profits and thereby lower capital ratios.

As shown in Figure 7 a one standard deviation shock to bank capital ratios implies an immediate 16 basis point increase in the variable, which then declines only very gradually back to steady state. Lending standards immediately loosen about 3 p.p. in response to the increase in capital ratios and lending growth is boosted for about two years with a maximum response of about 0.5 percent two quarters after the impact of the shock. The response of GDP growth is quite rapid and short-lived (about one year), peaking at 0.4 percent in the period following the shock. One possible reason for the smaller and shorter-lived response of output growth relative to lending growth is that some of the growth in lending may just represents the substitution across institutions as to where debt is being held. Indeed additional analysis, which involves estimating an impulse-response function for mortgage and consumer credit held by ABS issuers (as measured by the flow of funds), suggests this to be the case.

Figure 8 shows in the top two panels impulse response functions to a capital-assets ratio shock for bank and thrift lending growth and growth in mortgage and consumer credit held by ABS issuers. Two estimated impulse response functions, which are derived from different methods but are conceptually equivalent, are shown for bank and thrift lending growth. The black line is the impulse response function generated by the VAR model described in subsection 3.1 and reported for lending growth in Figure 7, albeit here only for six steps out. The blue line is an impulse response function for lending growth that can be generated by fitting simple a OLS regression that relates the growth rate of bank and thrift lending to lags of the estimated capital-asset ratio innovations obtained from the VAR of the previous sub-section, for which the coefficient that we estimate on the s-th lag of the structural innovation is the s-step-ahead response to the innovation.[18] We show this for lending mainly for the purposes of comparing the two methods. For mortgage and consumer credit held by ABS issuers we show only the impulse responses generated by this latter method because given our relatively short VAR sample period we prefer not to estimate additional impulse-response functions via the usual approach of simply including the additional measure of credit to the VAR. The two panels below show the implied deviation of the levels of bank and thrift lending and of mortgage and consumer credit held by ABS issuers as a percent—for both series—of steady-state bank and thrift lending. As can be seen from a comparison of these panels, some of the increase in bank lending in response to a positive capital-to-assets ratio shock does seem to represent a substitution across institutions as to where debt is being held.

Figure 9 shows the response to a one standard deviation shock to the growth rate of bank and thrift lending. An immediate and long sequence of net tightenings in credit standards results suggesting that the increase in lending is involuntary perhaps as a result of firms' drawing on existing lines of credit when other sources of financing became more costly or less available or, as was the case in late 2007, large banks and banks affiliated with securities firms being forced, due to market turmoil, to retain on their books loans that had been intended for syndication. Reflecting the fact that a positive lending shock appears to be associated with some adverse shock elsewhere in the credit sector, GDP growth contracts, albeit modestly, in response to this shock. Capital-asset ratios move up, perhaps, as was the case in Figure 6 due to increased leading resulting in higher bank earnings and profits and thereby higher capital ratios.

3.3 The effects of capital-assets ratio shocks

We now use the identified VAR model described above to consider the role of commercial-bank capital ratios on bank lending. Our approach is to compare the importance of the structural innovations in capital ratios for fluctuations in bank capital ratios relative to their importance for fluctuations in bank lending, where we do this both over the model's full sample period as well as over the recent period during which bank capital ratios and bank lending both contracted notably.

We focus on bank capital ratio innovations to be sure that any positive co-movement in capital ratios and lending is not caused by some third factor affecting both variables. Adverse macroeconomic conditions can, for example, reduce simaltaneously capital ratios—because a large number of loan defaults result in bank losses—and lending—because aggregate and thereby loan demand is subdued. The same is potentially true for developments in credit markets. For example, tighter standards or more easily available credit in other markets can reduce bank lending volumes,

[18]Note that the coefficients are then rescaled (since as estimated they represent the response to a one-unit rather than to a one-standard-deviation structural innovation).

bank profits, bank capital, and, on net, capital ratios.

In the first exercise we consider we generate variance decompositions for all of the variables in the model. Here we find that structural innovations in capital ratios explain 95 to 75 percent of the fluctuations in bank capital ratios over the one- to four-quarter horizon and 75 to 50 percent of fluctuations over the one- to eight-year horizon. In contrast these innovations explain only 2 to 5 percent of fluctuations in bank lending over the one- to four-quarter horizon and 5 to 7 percent of fluctuations over the one- to eight-year horizon. Thus structural innovations in capital ratios, while accounting for the lion's share of capital ratio fluctuations, explain very little of any fluctuations in bank lending, thereby suggesting a fairly modest role for changes in capital ratios in influencing bank lending.

In the second exercise we consider we generate unconditional forecasts as well as forecasts conditioned on a specific sequence of shocks for the model's variables over the most recent recession. This allows us to determine the relative importance of structural innovations to capital ratios to developments in model variables. Here we find that structural innovations in capital ratios explain essentially all of the decline in bank capital ratios over the second half of 2008 and about half of their subsequent rebound—see Figure 10. In contrast, and as shown in Figure 11, structural innovations in capital ratios explain at most one-fifth of the below-par pace of lending growth since mid-2008, while stardards shocks and nonfinancial shocks account for roughly equal portions of the remaining shortfall. Thus again structural innovations in capital ratios, while accounting for most of the decline in the capital ratio over the past year, explains only a modest portion of the reduction in bank lending, therely suggesting again a fairly minor role for changes in capital ratios in explaining movements in bank landing.

3.4 The effects of recent capital injections on commercial bank lending growth

In this section we undertake an exercise similar to that performed in section 3 using panel data, which is to estimate using the VAR model's impulse response functions the magnitude of the impact of recent capital injections, via the CPP, on bank lending. As noted in subsection 2.4 CPP capital injections raised the equity-to-assets ratio 1.4 percentage points. Given the impulse response functions for a one standard deviation capital-to-assets ratio shock reported in Figure 7 this would suggest that the CPP capital injections would boost lending by 3.7 percentage points in over the first year following the impetus. This is about four times larger than the effect estimated using the panel regression approach, which is perhaps not surprising given that the VAR approach allows for the endogenous response of several variables most notably standards and real GDP growth, which themselves have additional effects on lending growth. We therefore shut down these effect so as to see how the magnitude of the effects using the aggregate commerical bank data compare to those using institution level BHC data.

Figure 12 reports the responses to a one standard deviation capital-to-assets ratio shock with various endogenous responses of different variables eliminated. In particular, the red line in Figure 12 shuts down the response of standards to the capital-to-assets ratio shock, the blue line shuts down the response of real GDP growth to the capital-to-assets ratio shocks, while the green line shuts down both the standards and real GDP growth responses. These results suggest that in the absense of endogenous responses from other variables, bank lending growth should increase approximately 1.2 percentage points in response to a one percentage point capital-assets ratio shock. This increase is about twice as large as the increase in lending growth implied by the panel regressions but is nonetheless considerably smaller than the estimates implied by the Adrian and Shin analysis.

3.5 Taking this model to the credit-crunch question

Given that the models used in section two were all originally developed to study whether a credit crunch occurred in the early 1990s, we might ask the extent to which the model developed in this section to gauge the effects of capital ratios on lending can also be used to investigate the occurrance of a credit crunch. Clearly, the model's identification of the shocks underlying the fluctuations in all of the series of the VAR model means that it is possible to decompose these series into shocks stemming from either the model's nonfinancial sector or from its credit sector; indeed, this is exactly what we did in Figure 10 and 11—albeit broken down more finely between specific shocks. In the left panel of Figure 13 we show the path of the *level* of lending from 2005:Q4 to the present (the solid black line), along with the paths of three forecasts that jump off from the period preceding the start of the recession; specifically (i) the model's unconditional forecast (the dotted black line), (ii) the model's forecast conditional on credit-sector shocks alone (the red line), and (iii) the model's forecast conditional on nonfinancial-sector shocks alone (the blue line). The vertical line markets the start of the recession. As can be seen from the red line, nonfinancial-sector shocks account for most of the shortfall in actual lending from what the VAR model would project based on data preceding the start of the recession. The top part of Table 6 reports the percentage share of the deviation between the actual and unconditionally forecasted paths of lending accounted for by the two sets of shocks. Ignoring the first two periods (for which the numbers look odd because the shocks generated offsetting errors and the overall forecast errors were small) it can be seen for the current recession nonfinancial shocks account for most of the shortfall in lending. This share has been declining, however, as the recession has progressed and indeed in the last period of data credit shocks account for just over half of the shortfall in lending.

In the right panel of Figure 13 we show the path of the *level* of lending from 1988:Q3 to 1993:Q1 (the solid black line). The vertical lines in the figure show the start and end dates of the recession. We extend the data's time period to beyond the end of the recession since the early 1990s credit-crunch was associated more with the recovery, for which it acted as a headwind. The 1993:Q1 date chosen to end the chart represents the end of the Fed's easing cycle in the early 1990s recession. We also plot the the paths of three same forecasts as plotted in the left panel that again jump off from the period preceding the start of the recession. Also, as before, the lower part of Table 6 reports the percentage share of the deviation between the actual and unconditionally forecasted paths of lending accounted for by the two sets of shocks. Both the figure and table show that until the middle of 1991 credit shocks accounted for little of the downturn in lending, but after that they began accounting for a greater share of the forecast error. By mid 1992 credit shocks accounted for as much of the weakness in lending as nonfinancial shocks and by late 1992 credit shocks were dominant. Thus, we would find evidence for credit conditions affecting lending, albeit a couple of quarters later than what proponents of the credit crunch would argue the effect was taking place.

It is worth noting that apart from the results shown in right-side panels of Table 6 and Figure 13 all of the results that we have shown in this part of the paper are quite robust to different survey measures of bank's readiness to extend credit. For example, while we have shown in this section results using bank C&I lending standards, our impulse response functions and variance decompositions are not greatly changed if we instead use bank willingness to extend consumer credit. In addition, our findings with regard to the sources of shocks for the current business-cycle downturn are little altered by the use of this alternative measure.

4 Summing up

Motivated by the recent importance of the issue of how bank capital-to-asset ratios influence the extension of bank credit, this paper applies a number of different methods to address this issue. First we apply to more current data on bank lending models that were developed in the early-to-mid 1990s by Bernanke and Lown (1991) and Hancock and Wilcox (1993,1994) to address precisely this question. This analysis finds relatively small effects of BHC capital-to-asset ratios on BHC bank lending. This result stands in marked contrast with current perceptions of the effect of bank capital-to-asset ratios on bank lending, which appear to be largely informed by a scatter plot of asset growth against leverage growth for commercial banks that was contained in a paper—not actually about this topic—by Adrian and Shin (2007). Specifically, the scatter plot reported by Adrian and Shin gives the strong impression that banks very actively maintain constant leverage—and thereby bank capital-to-assets ratios—thus suggesting that changes in bank capital-to-assets ratios have very large effects on bank lending as banks attempt to adjust their assets so as to reverse capital-ratio changes.

Since our panel regression results conflict so sharply with those of Adrian and Shin (2007) we perform additional analysis so as to investigate our results further. Here we consider the effects of capital ratios on lending using macroeconomic time series and aggregate commercial bank balance-sheet data in a modified variant of one of the extended versions of Lown and Morgan's (2006) vector autoregression (VAR) model, which includes as one of its variables the bank capital-to-assets ratio. Again, we find relatively modest effects of bank capital ratio changes on lending, albeit slightly larger effects than in the panel regressions.

Clearly, understanding the differences between our results and the apparent take-away message from Adrian and Shin's (2007) scatter point is the next critical step in resolving this issue. It is possible that there is no conflict between the chart and our empirical results but rather that the message being inferred from chart is not the right one. We leave this to the next draft of the paper.

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Table 1: **Summary Statistics for BHC-Level Panel Data**

This table presents summary statistics for the sample of 141 BHC from 1994 to 2008 used in the panel estimation. The data are taken from the Consolidated Financial Statements for BHCs (FR Y-9C). The sample excludes institutions with missing observations in total assets, loans and capital, and also BHCs that remain in the sample for less than 30 quarters. To minimize the influence of outliers, observations with more than 50 percent growth in total assets over a single quarter were also removed. The remaining variables were winsorized at the 1 percent and 99 percent levels.

Variable	N	Median	Mean	Std.Dev.
Total Assets ($ million)	10860	3460.22	25080.84	132958.20
Total Loan Quarterly growth	10860	2.25%	3.14%	5.00%
C&I Loan Quarterly growth	10690	2.25%	3.09%	8.76%
Equity/Assets	10860	8.12%	8.33%	2.13%
Tier 1 Capital ratio	7070	10.65%	11.29%	3.21%
Total Capital ratio	7070	12.46%	13.15%	2.86%
TCE ratio	9270	6.82%	7.00%	2.20%
Return on Assets	10860	0.1409	0.1347	0.7281
Securities/Assets	7994	0.2218	0.2403	0.1153
Net Chargeoffs/Assets	10852	0.1628	0.2668	0.3590

Table 2: **Determinants of BHC Capital Asset Targets**

This table presents the fixed-effect regression estimates of equation (4) for the determinants of BHC's target capital ratios. Bank-specific variables include *Size*, measured as the log of total assets, the return on assets *ROA*, the ratio of net charge-offs to total assets, the shares of C&I loans, Real Estate loans, Consumer loans, and Investment Securities in total assets. The regression also includes an institutional variable, called regulatory pressure, defined as a dummy variable that equals one if the BHC's equity capital ratio is less than 1.5 percentage points above the minimum of 5 percent. Aggregate variables include the stock-market volatility index provided by the Chicago Board Options Exchange (CBOE S&P 100 volatility index), and the ratio of net charge-offs to total loans for the commercial banking sector. Regressions include quarterly dummies to control for seasonal factors. Robust t-statistics are given in parenthesis. . *, **, and *** denotes significance at the 10%, 5%, and 1% respectively.

	Model 1		Model 2	
	Estimate	t-stat	Estimate	t-stat
Lagged capital ratio	0.9040***	(78.96)	0.9185***	(88.33)
Size	0.0953***	(4.23)	0.0780***	(5.13)
ROA	0.0411	(1.49)	0.0475**	(2.23)
Aggregate Volatility	-0.0063***	(-3.99)	-0.0035***	(-4.14)
C&I loan share	-0.0126***	(-2.80)		
Real Estate loan share	-0.0080***	(-3.53)		
Consumer Loan share	-0.0002	(-0.04)		
Securities share	-0.0072***	(-2.99)		
Regulatory Pressure	0.1608	(1.47)	0.0791	(2.63)
Sector Chargeoff/Loan	0.1552	(1.44)	0.0791***	(2.63)
Chargeoffs/Asset	0.0173	(0.35)	0.0151	(0.50)
intercept	-0.0257	(-0.06)	-0.5476	(-2.65)
R^2	0.838		0.869	
N	7657		10640	

Table 3: **Effect of Capital Surplus on BHC Lending growth**

This table reports the fixed-effect regression estimates from a regression of bank lending growth on a measure of BHC's capital surplus and control variables. The dependent variable is the quarterly growth rate of total loans and C&I loans. Explanatory variables are as follows: four lags of loan growth, the measure of capital surplus, calculated as percent deviations of actual capital level relative to estimated capital targets, the ratio of investment securities to total assets, the ratio of net charge-offs to total assets, three lags of lending standards (fraction of banks reporting tightening lending in the Senior Loan officer Opinion Survey), four lags of quarterly GDP growth, four lags of the quarterly change in the Fed Funds rate, and four lags of the inflation rate (cumulative percent change of the Consumer Price Index during the previous three months). Regressions include quarterly dummies to control for seasonal factors. Because an auxiliary equation is used to estimate the capital surplus variable, standard errors are adjusted to correct for the generated regressor bias through bootstrap methods. *Chi2*-statistics are given in parenthesis. *, **, and *** denotes significance at the 10%, 5%, and 1% respectively. Dependent variable: BHC Total loan growth

	Total Loans		C&I Loans	
	Estimate	*Chi2*-stat	Estimate	*Chi2*-stat
Loan Growth Lags (sum)	0.1540***	(9.32)	0.0860	(1.01)
Surplus capital	0.0526***	(58.19)	0.0628***	(16.97)
Securities/Asset	0.0739***	(13.03)	0.0559	(2.11)
Net Chargeoffs/Asset	-1.7937***	(13.27)	-1.9305***	(7.71)
Lending Standards (sum)	-0.0130	(2.44)	-0.0170	(1.27)
GDP Growth Lags (sum)	0.9636***	(5.19)	2.4903***	(6.48)
Fed Funds Lags (sum)	-0.4252	(0.98)	-0.1420	(0.03)
Inflation Lags (sum)	0.3311	(0.36)	-1.0160	(0.87)
intercept	-0.4128	(0.18)	0.7074	(0.76)
R^2	0.220		0.102	
N	6985		6953	

Table 4: **Effect of Capital shocks on BHC lending growth**

This table reports the fixed-effect regression estimates from a regression of bank lending growth on capital ratios and control variables for a sample of large 141 BHCs from 1994 to 2008. Columns 1-4 report estimation results for each of the different capital ratios. The dependent variable is the quarterly growth rate of total loans. Explanatory variables are as follows: four lags of total loan growth, the capital ratio as indicated in each column, the ratio of investment securities to total assets, the ratio of net charge-offs to total assets, three lags of lending standards (fraction of banks reporting tightening lending in the Senior Loan officer Opinion Survey), four lags of quarterly GDP growth, four lags of the quarterly change in the Fed Funds rate, and four lags of the inflation rate (cumulative percent change of the Consumer Price Index during the previous three months). Regressions include quarterly dummies to control for seasonal factors. Robust t and F-statistics are given in parenthesis. *, **, and *** denotes significance at the 10%, 5%, and 1% respectively.

	Equity-to-Asset Ratio (1)		Risk-based Capital Ratio (2)		Risk-based Tier 1 Ratio (3)		TCE Ratio (4)	
	Estimate	t/F-stat	Estimate	t/F-stat	Estimate	t/F-stat	Estimate	t/F-stat
Loan Growth Lags (sum)	0.1494***	(24.23)	0.1633***	(24.88)	0.1619***	(24.56)	0.1592***	(27.78)
Capital ratio	0.1423***	(2.98)	0.1969***	(4.09)	0.2127***	(4.42)	0.2629***	(5.13)
Securities/Asset	0.0609***	(5.07)	0.0439***	(2.62)	0.0424**	(2.49)	0.0545***	(4.34)
Net Chargeoffs/Asset	-1.9224***	(-6.68)	-2.0157***	(6.82)	-1.9960***	(6.77)	-1.9182***	(6.47)
Lending Standards (sum)	-0.4889	(1.09)	-0.5518	(1.27)	-0.6149	(1.56)	-0.6949	(2.16)
GDP Growth Lags (sum)	1.4449***	(40.36)	1.2215***	(24.34)	1.1417***	(20.81)	1.2623***	(29.31)
Fed Funds Lags (sum)	-0.1930	(0.74)	-0.3604	(2.38)	-0.3710	(2.51)	-0.2743	(1.52)
Inflation Lags (sum)	-0.2199	(0.48)	-0.1096	(0.11)	-0.0608	(0.04)	0.0565	(0.03)
intercept	-1.0295	(-1.63)	-2.1681**	(-3.19)	-1.9227***	(-3.11)	-1.5933**	(-2.72)
R^2	0.1861		0.197		0.198		0.191	
N	7492		6585		6585		7492	

Table 5: **Selective Variance Decompositions in the VAR Model**

	Variance Decomposition of K/A Ratio			
	Macro	Lending	K/A	Standards
1	4.4	0.9	94.8	0.0
2	13.5	4.4	80.9	1.2
4	18.4	7.4	73.3	0.8
8	25.2	8.4	65.6	0.8
16	33.8	8.2	52.6	5.4
32	33.8	9.0	51.4	5.8
	Variance Decomposition of Lending Growth			
	Macro	Lending	K/A	Standards
1	16.0	84.0	0.0	0.0
2	32.0	65.8	1.8	0.4
4	34.4	49.4	4.8	11.4
8	34.1	39.9	5.5	20.5
16	38.7	28.9	4.1	28.4
32	36.6	26.3	6.6	30.5
	Variance Decomposition of GDP Growth			
	Macro	Lending	K/A	Standards
1	100.0	0.0	0.0	0.0
2	94.9	0.1	3.2	1.9
4	83.4	0.5	2.9	13.2
8	76.2	2.4	3.1	18.2
16	71.5	2.7	5.0	20.9
32	70.3	2.7	5.0	22.1

Table 6: **Contribution of Credit and Real Shocks to Lending Developments**

	Current Recession			1990-91 Recession	
	Credit Shocks (percent)	Real Shocks (percent)		Credit Shocks (percent)	Real Shocks (percent)
07:4	226.7	-126.7	90:3	-187.2	287.0
08:1	-82.1	182.1	90:4	-144.3	243.4
08:2	17.2	82.8	91:1	-33.0	132.5
08:3	29.2	70.8	91:2	-24.3	123.8
08:4	41.0	60.0	91:3	17.2	83.2
09:1	45.9	55.1	91:4	32.7	68.1
09:2	55.9	46.1	92:1	36.1	64.8
			92:2	49.8	51.3
			92:3	55.0	46.2
			92:4	56.7	44.7
			93:1	56.0	45.6

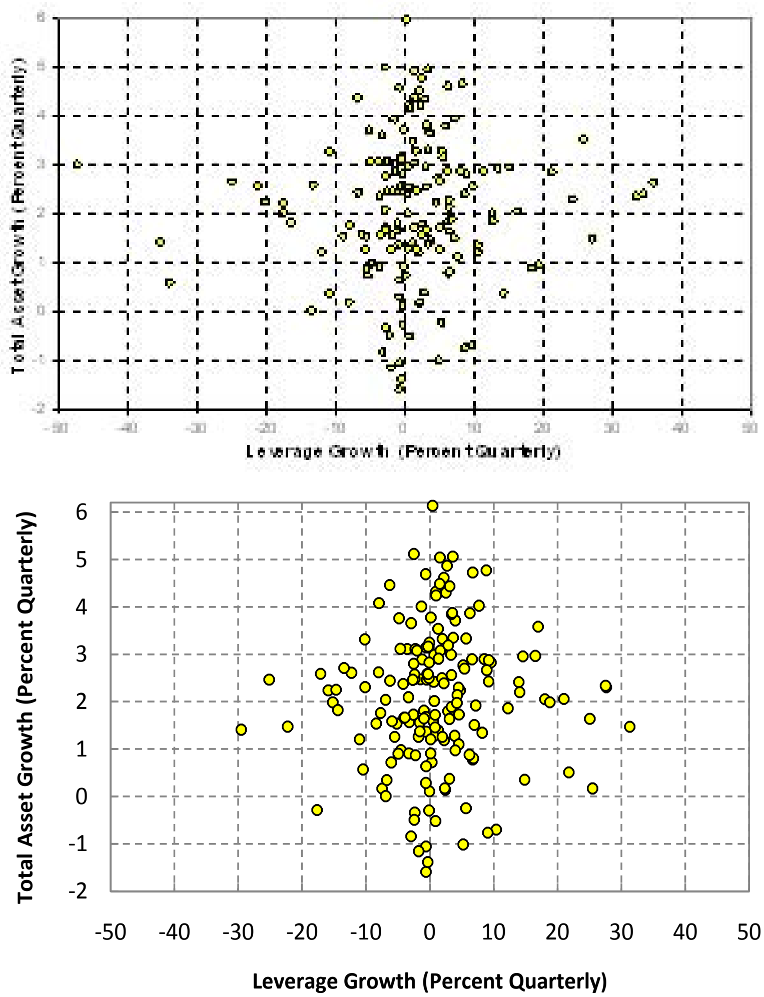


Figure 1: Assets and Leverage of Commercial Banks (from Adrian & Shin and attempt to replicate)

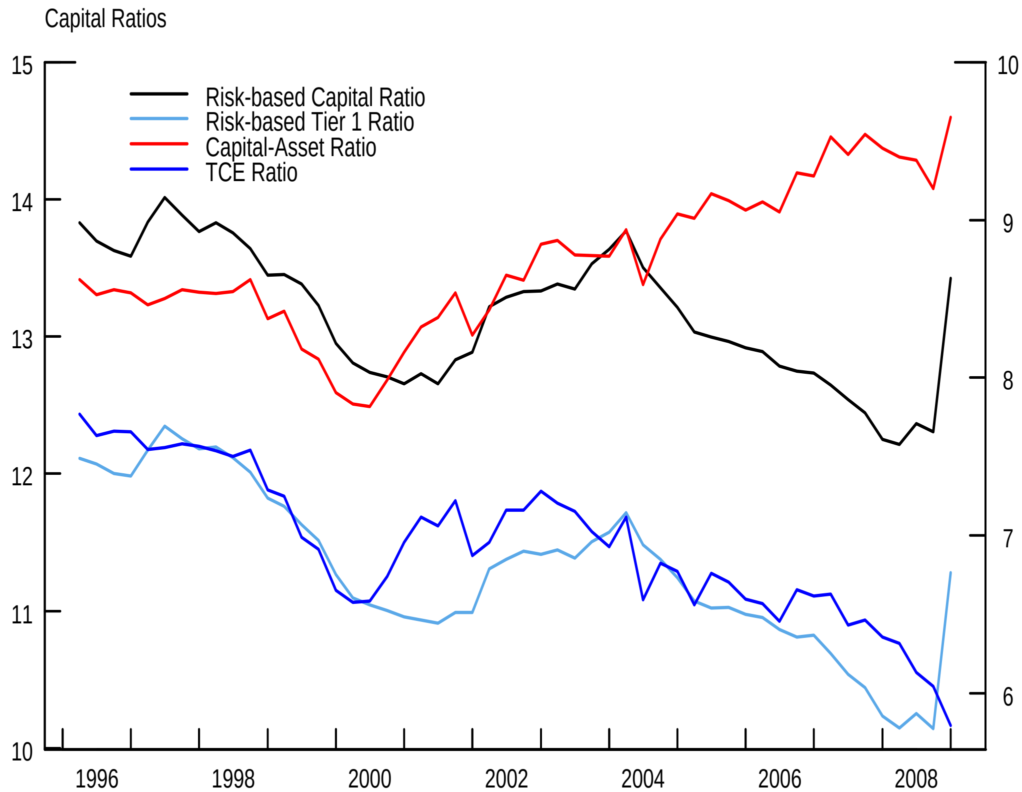


Figure 2: BHC Capital Ratios

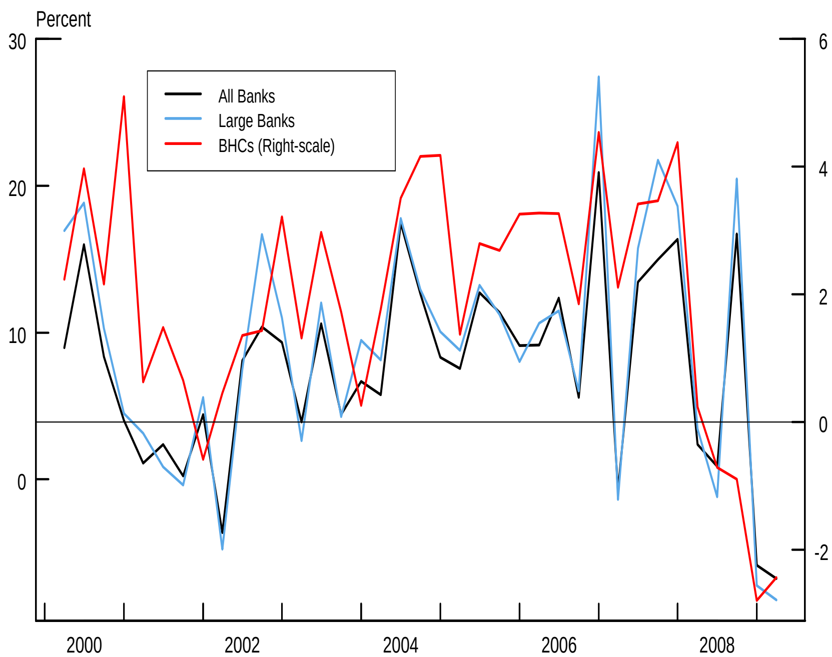


Figure 3: Commercial Banks and BHC Lending Growth

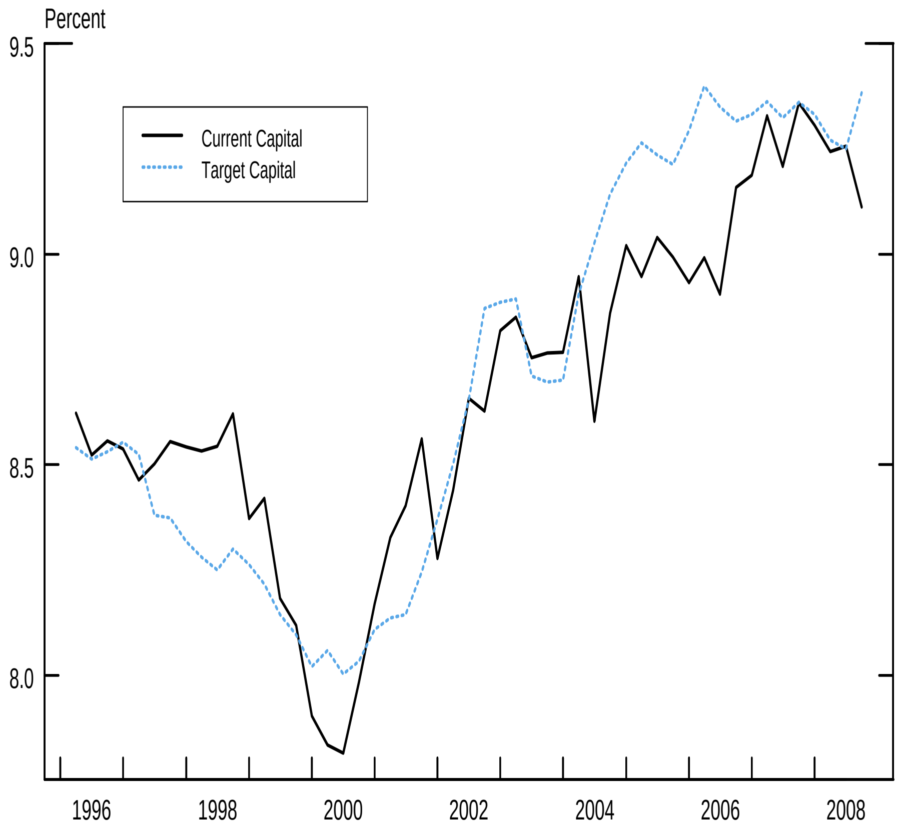


Figure 4: Average Actual and Target BHC Capital-to-asset Ratios

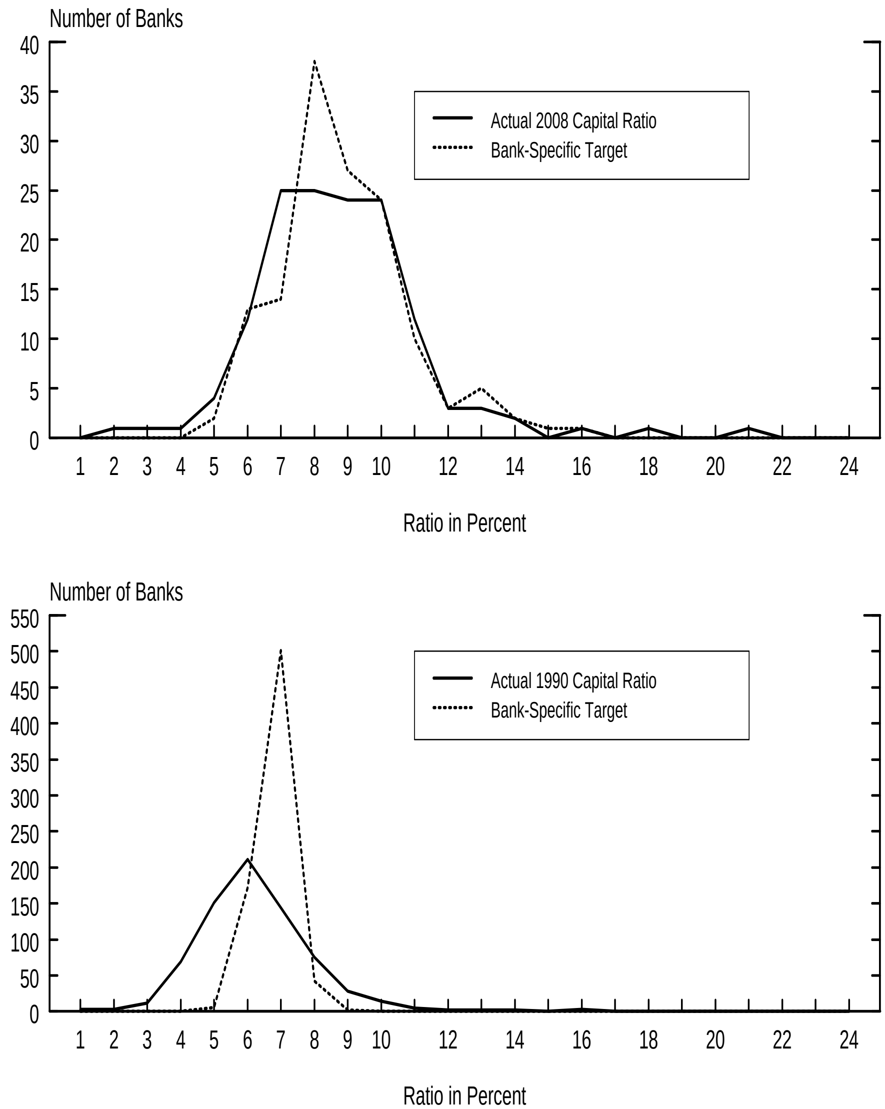


Figure 5: Distribution of Actual and Target Capital-to-asset Ratios

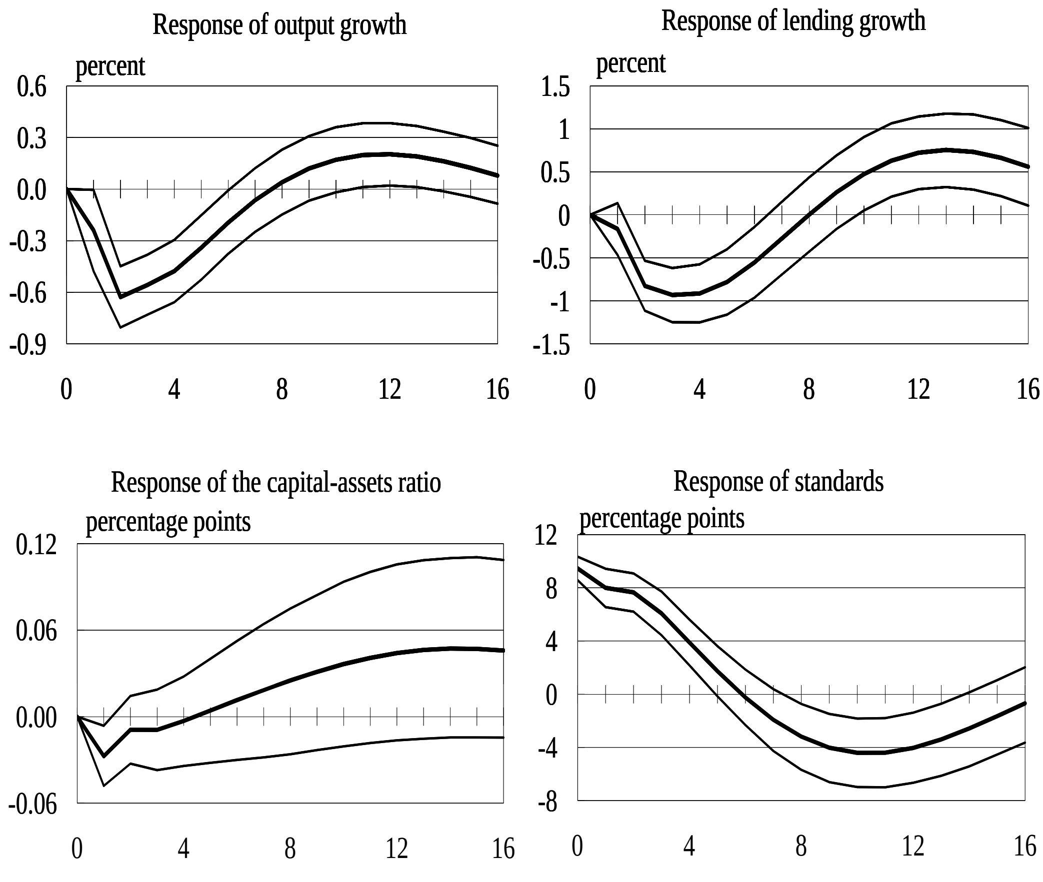


Figure 6: Response to a Lending Standards Shock

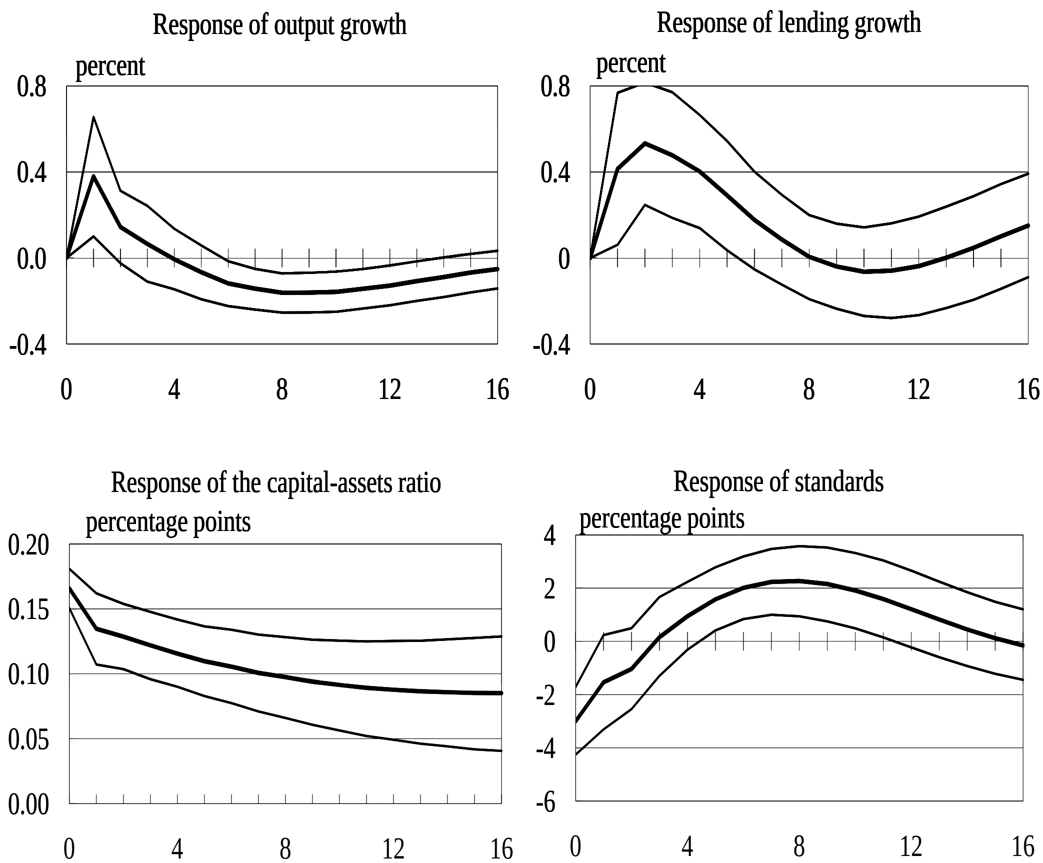


Figure 7: Response to a Capital-to-asset Ratio Shock

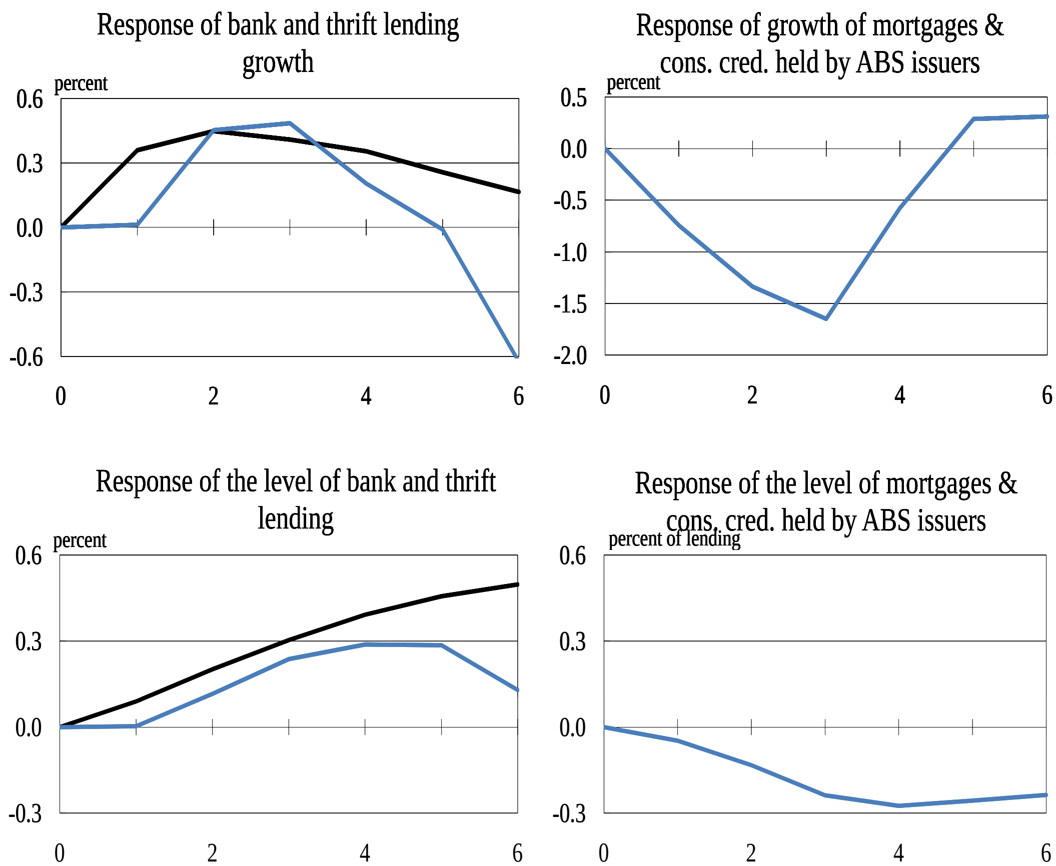


Figure 8: Other Responses to a Capital-to-asset Ratio Shock

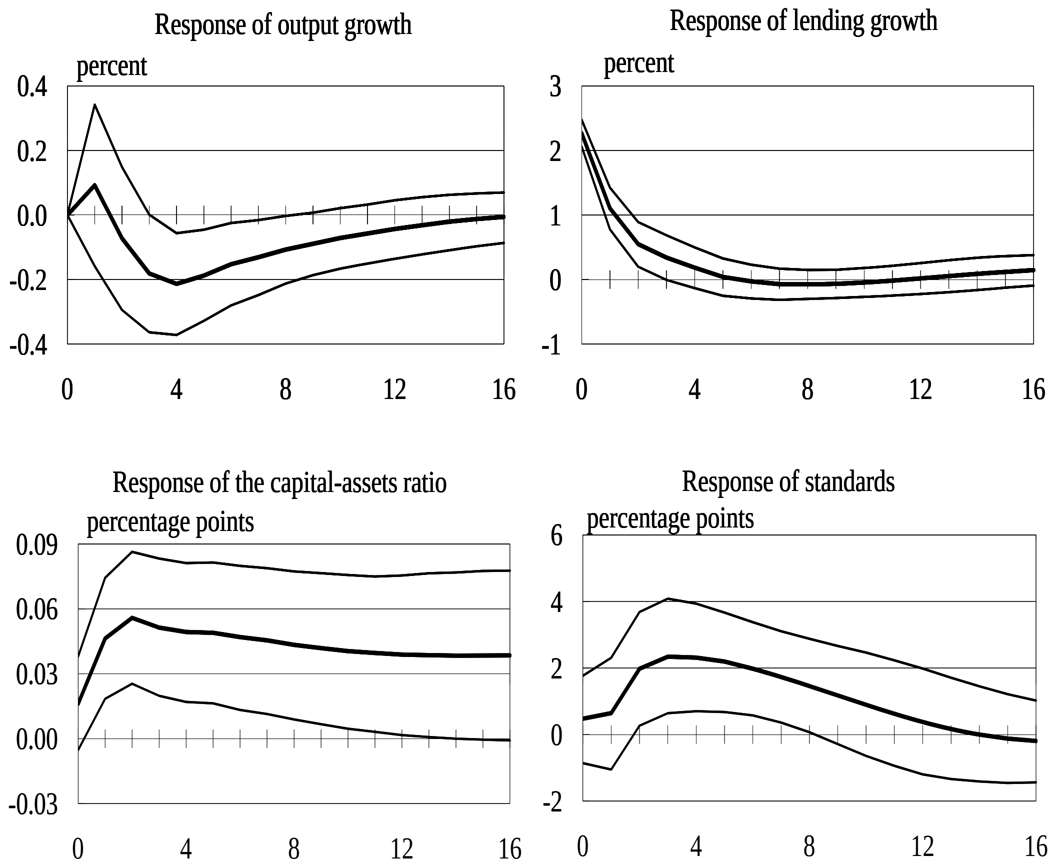


Figure 9: Response to a Lending Shock

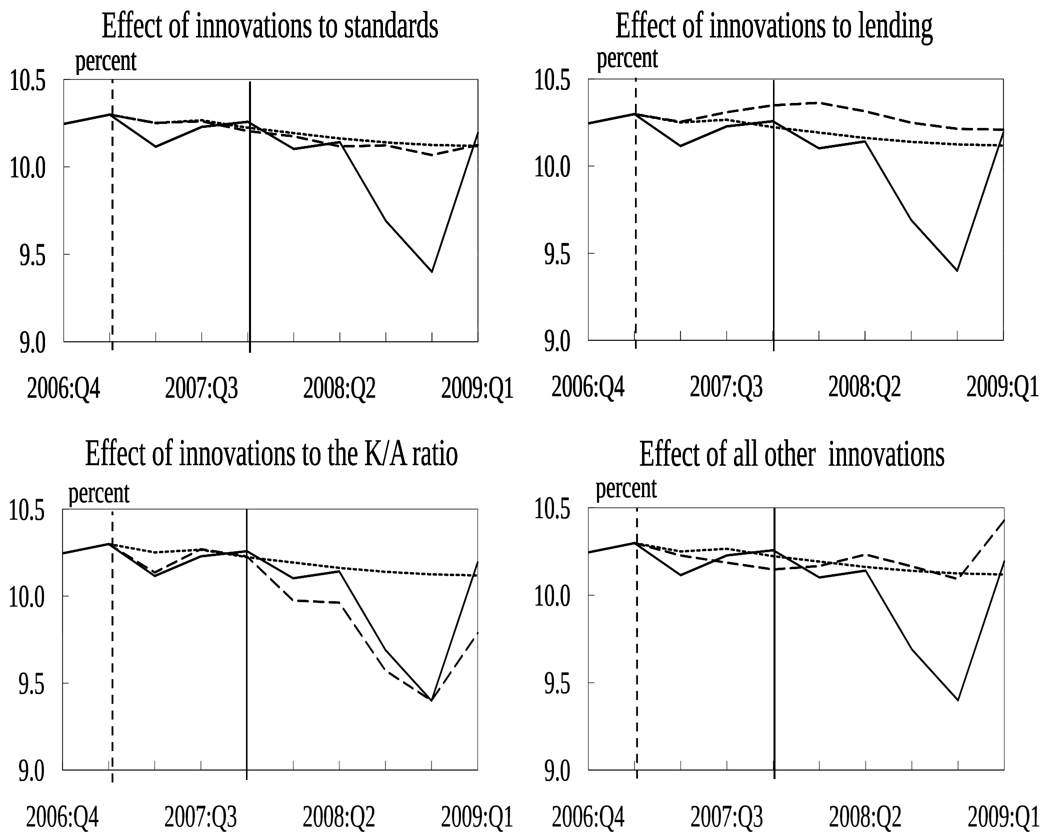


Figure 10: Decomposition of Recent Capital-to-asset Ratio Movements

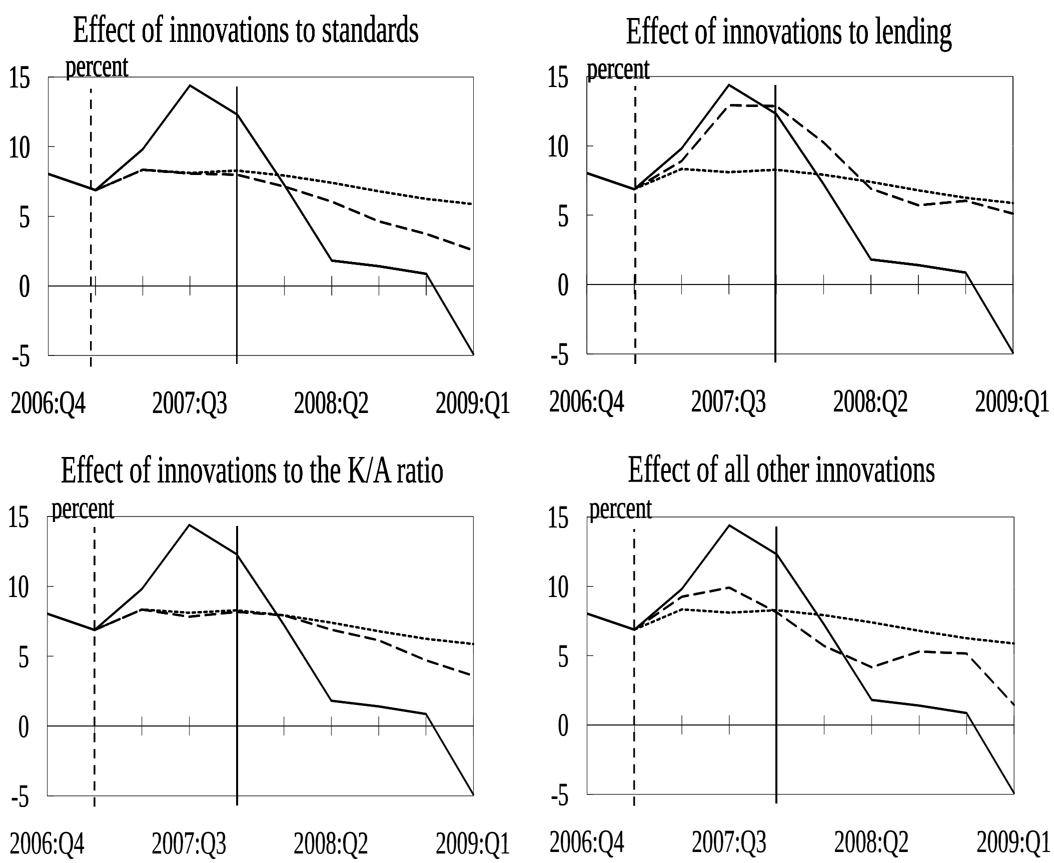
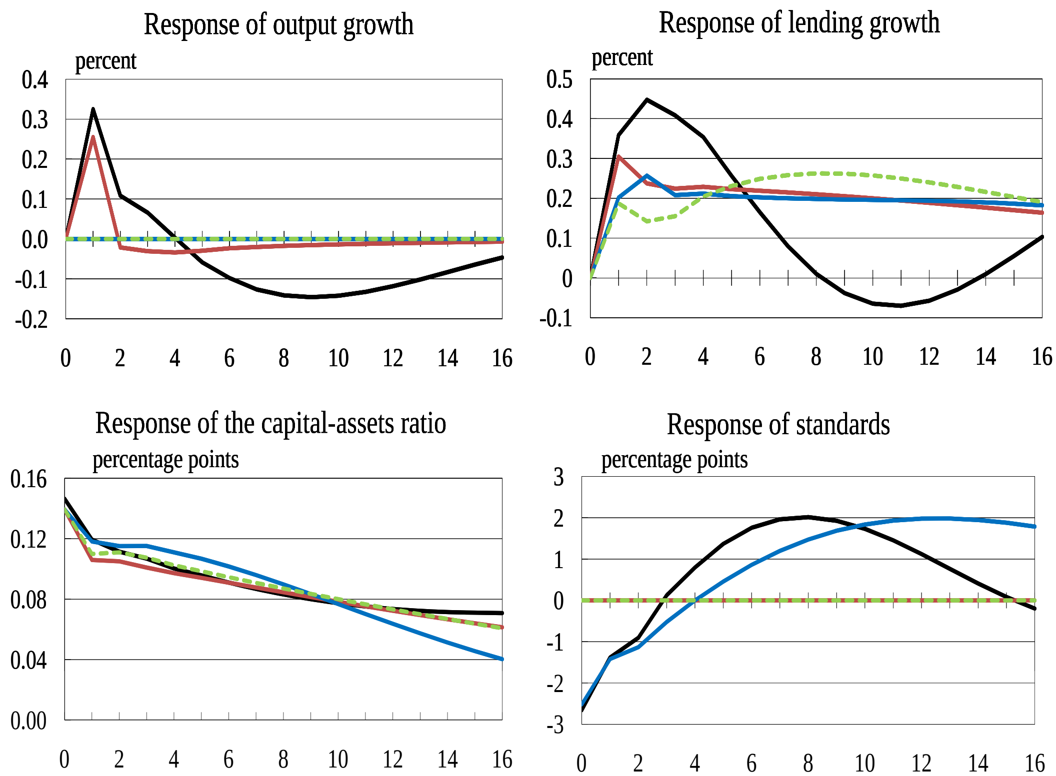
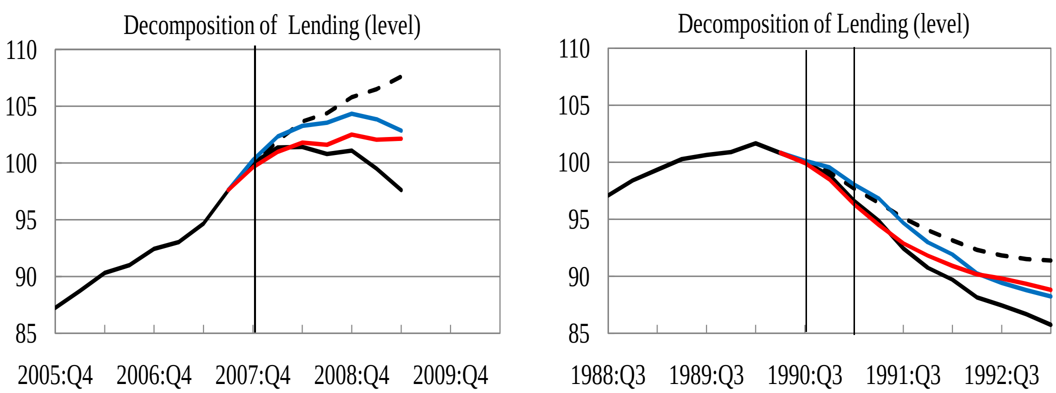


Figure 11: Decomposition of Recent Lending Growth Movements



Black - Full response; Red - Standards response only shut down;
Blue - GDP response only shut down; Green (dotted) - Standards and GDP response both shut down.

Figure 12: Response to a Lending Shock



Black (solid) - Actual path; Black (dotted) - Unconditional forecast

Blue - Forecast conditional on credit-sector shocks; Red - Forecast conditional on real-sector shocks

Figure 13: Decomposition of Lending