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Qiyue Xiong

The role of the bank lending
channel and impacts of stricter
capital requirements on
the Chinese banking industry



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Qiyue Xiong: The role of the bank lending channel and impacts of stricter capital requirements on the Chinese banking industry

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Qiyue Xiong

The role of the bank lending channel and impacts of stricter capital requirements on the Chinese banking industry

Abstract

This paper focuses on the role the bank lending channel in transmission of monetary policy in China. Using unbalanced quarterly panel data from 2Q2000 to 4Q2011, a one-step GMM estimator is applied to establish the existence the bank lending channel. The findings suggest central bank monetary policy asymmetrically affects bank lending behavior. Small banks are found more sensitive to contractionary monetary policy in the Chinese context. Well capitalized banks appear to be more likely to adjust their lending behaviors in response to expansionary monetary policy, and conversely, undercapitalized banks tend to adjust with the advent of contractionary monetary policy. The importance of the bank lending channel declines after China introduced stricter capital regulations in early 2004, but the effect is still apparent in times of expansionary policy.

Keywords: bank characteristics, capital regulation, bank lending channel, asymmetric effects

JEL Codes: E52

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1 Introduction

It has been a quarter of a century since the theoretical framework for the bank lending channel was laid down by Bernanke & Blinder (1988). Researchers have gone on to assess a large body of empirical evidence of the bank lending channel in various countries and regions, so the dearth of work in China's case is somewhat surprising. Even more striking, perhaps, is the inconclusiveness of the existing studies on the lending channel dealing in the world's second largest economy. This paper, hopefully, is a small first step towards rectifying the situation by providing a rough description of the role of the bank lending channel in China.

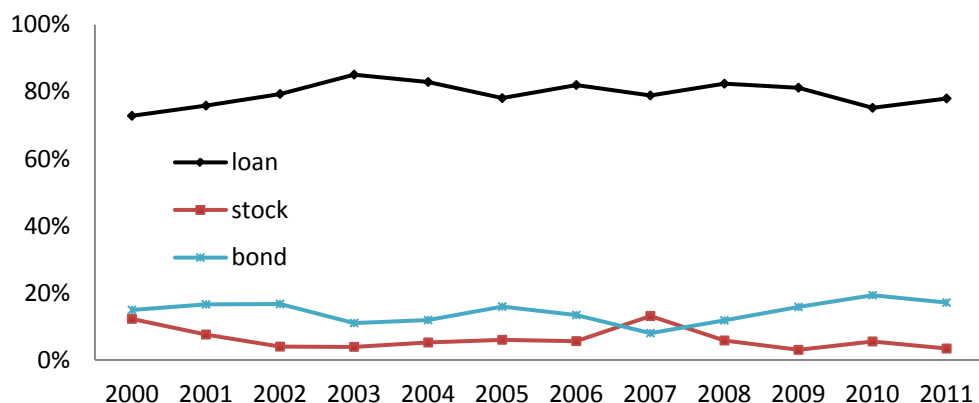
Bank lending channel (BLC) theory suggests the effects of monetary policy extend beyond loan supply to banks. Traditionally, central banks rely on the BLC when (1) banks have limited access to non-deposit financing, that is, they lack other sources of external funding than deposits after the central bank tightens its monetary stance; and (2) enterprises are heavily dependent on bank lending, and specifically, they lack alternative sources of financing when the central bank tightens its monetary stance. In the case of China, both conditions appear to be met.

China's financial markets are still relatively underdeveloped and ill-equipped to efficiently supply financing to enterprises. Small and medium-sized enterprises (SMEs), in particular, are heavily dependent on bank lending for financing. Indeed, bank lending accounted for close to 80% of total social financing from 2000 to 2011 (see Figure 1).

As deposits are the main source of funds for commercial banks, China's central bank often resorts to quantitative monetary tools. From 2006Q4 to 2011Q4, the People's Bank of China (PBoC) adjusted the required reserve ratio 35 times. This constant fussing with rates appears aimed at influencing the availability of funds for lending. Looking closer at the liability structure of commercial banks, we see that bank loans based on deposits constituted 78% of social lending at the end of 2011. China's underdeveloped non-deposit market further implies that banks are sensitive to adjustments in the required reserve ratio.

China's high degree of state-ownership also makes it easy for the central bank to use the bank lending channel. Compared to privately held commercial banks, state-owned banks can be used by the state to pursue macroeconomic goals such as stable growth rather than simple profit maximization or acquiring market share (Micco & Ugo, 2006; Fungacova et al., 2011; Bertay et al., 2012). China's 4-trillion-yuan stimulus in 2009 and 2010 channeled through banks with high state-ownership.

Figure 1 Distribution of total social financing by non-financial enterprises



Source: Monetary Policy Quarterly Report of People's Bank of China. Loan is the percentage of loans to the total social financing; Stock is the percentage of stocks to the total social financing; Bonds is the percentage of bonds to the total social financing.

China has one of the biggest banking sectors in the world, with total assets equaling 245% of GDP as of end-2011. The banking industry reforms of the past decade were led by the March 2004 implementation of an 8% capital requirement for commercial banks by the China Banking Regulatory Commission (CBRC). By the end of 2011, all of China's 390 commercial banks supervised by the CBRC met or exceeded the minimum 8% capital requirement, and the capital ratio of all CBRC-supervised banks averaged 12.8%. In accordance with Basel III guidelines, the CBRC in January 2013 raised the minimum capital requirement to 10.5% for regular banks and 11.5% for systemically important banks.

Banks assets have soared. As of end-2011, China's banking industry had total assets of 111.52 trillion yuan. China's five big state-dominated commercial banks held the lion's share of assets at 52.02 trillion yuan or 46.6% of total banking sector assets. The five big banks and joint-equity banks together (or only about a tenth of all banks) had assets of 70.34 trillion yuan, or 63% of total assets.¹

² Related data are from the 2011 Yearbook of the China Banking Regulatory Commission.

This paper considers three questions related to China's banking industry:

- Does the bank lending channel exist in China?
- What effects do capital requirements exert on the bank lending channel?
- What asymmetric effects arise from the bank lending channel?

We apply a one-step GMM estimator to a dynamic panel model based on individual bank data published by the PBoC. Our four main findings are as follows: (1) Chinese bank lending behaviors change as the PBoC adjusts monetary policy, (2) the big state banks and poorly capitalized banks are less likely to modify their lending behaviors in the face of a monetary shock, (3) the enactment of capital controls weakens bank lending channel effects, and (4) there is a significant asymmetric effect in transmission via the bank lending channel.

The remainder of the paper is organized as follows. In section 2, we present a brief overview of the related theoretical and empirical literature on bank lending channel. We develop a simple motivating model in section 3 to describe the effects of bank-specific variables on the sensitivities of bank lending to monetary policies. Section 4 presents our empirical results and section 5 concludes.

2 Literature review

2.1 Theoretical discussion of the bank lending channel

The theory of bank lending channel was first enunciated by Bernanke and Blinder (1988). Their CC-LM model assumes bank loans cannot be substituted perfectly for bonds, emphasizing that a change in monetary policy not only shifts the liquidity and money (LM) curve through affecting the money demand but also the commodity and credit (CC) curve by influencing credit supply. Peek & Rosengren (1995) develop a model of a bank's optimal loan supply, showing that capital-constrained and capital-unconstrained banks react differently to shifts in monetary policy. Capital constrained banks tend to increase their loan supply with an increase in the benchmark interest rate, while unconstrained banks decrease their optimal loan supply. Stein (1998) incorporates an adverse selection problem into the bank funding market, finding that the information asymmetry between banks and outside investors weakens bank lending channel effects. Bernanke et al. (1998) extend their discussion of the traditional bank

lending channel, providing a DSGE model to show “financial accelerator” effects. Here, tighter monetary policy affects the value of enterprise collateral, which increases the external financing premium and causes a decline in loan demand. Following this insight, Chami & Cosimano (2010) develop a dynamic “capital accelerator” model. Here, the tighter monetary stance increases deposit interest rate, causing bank profits and capital to shrink. This, in turn, causes a cutback in the bank loan supply in the next period.

Tanaka (2002) develops a model of a bank’s optimal loan supply. She finds that the optimal loan supply of a bank is positively and negatively related to the change of loan and bond interest rate. Increases in the capital requirement or poor capitalization of banks weaken the effect of the monetary transmission mechanism.

Milne & Wood (2009) reconsider the bank lending channel, arguing that the effect of bank lending channel is ambiguous. The amplification effect only seems to occur when monetary tightening leads to an outflow of bank funds and a reduction in bank lending. Using multinational aggregated data, they further show that (with the exception of Italy) there is no evidence that bank deposits decrease more than lending in the face of tighter monetary policy.

In addition to the traditional bank lending channel, researchers have begun to turn their attention to the effect of endogenous bank capital in the transmission of policy via the bank lending channel. Markovic (2006) develops a DSGE model to show that after the implementation of contractionary monetary policy, bank profits shrink and three effects become manifest. The first is a “capital loss effect,” whereby the bank needs to raise capital, so it launches a stock offering. This is interpreted as a bad signal to investors fearing dividend dilution (Myers & Majluf, 1984). In seeking reassurances, investors demand higher returns. The second is an “adjustment cost effect,” whereby potential investors are concerned that the bank has underestimated the adjustment, or transition, costs associated with bank financing and demand higher returns. Finally, there is a “default risk effect,” whereby investors are spooked by a decrease in the capital adequacy ratio. As they see the soundness of the bank is threatened, they demand higher returns. These effects all lead to higher interest rates on loans granted by the bank, which, in turn, is likely to reduce the volume of bank lending.

Drumond (2007) brings in the element of liquidity premium in the context of a monetary contraction. Here, banks are faced with shrinking profits and capital, so they need to raise liquidity. Households and investors seek higher interest on deposits or higher returns on bank stock in the face of the increasing risk of default. At the same time, the bank needs to be able to continue to attract deposits by keeping risk low and liquidity high, as well as stay at-

tractive to investors by offering a decent return on equity. These conditions motivate the bank to increase its lending volume.

Disyatat (2010) offers an alternative theoretical framework for the bank lending channel to that of Bernanke and Blinder (1988). Focusing on the bank's balance sheet, he considers bank capital to be endogenous. Thus, a tightening of monetary policy reduces the bank's level of capitalization through decreases in its net interest margin, cash flow and asset valuations. Ultimately, these changes decrease the bank's credit supply.

2.2 Empirical studies of the bank lending channel

Empirical tests for the existence of the bank lending channel have been performed on many economies on a varying scale. Generally speaking, the empirical literature divides into two categories.

The first category is based on the time-series data using VAR-type models. Bernanke & Blinder (1992), using aggregated US data, find that six to nine months after an increase on Federal Reserve fund rate, bank deposits and lending both decrease significantly. Kashyap et al. (1993) also work with the US aggregated data. They find a monetary contraction tends to be followed by a decline in aggregate bank lending. Kakes & Sturm (2002) consider the evidence for a bank lending channel in Germany using a VAR method. Alfaro et al. (2003) find significant evidence of bank lending channel in Chile using aggregated data. Ramlogan (2004) does not identify significant bank lending evidence for Caribbean countries. Al-Mashat & Billmeier (2007) find significant bank lending channel evidence in Egypt. Buigut (2010) determines significant effects of the bank lending channel in Kenya using a VECM approach. Carrera (2010) concludes that Peru's the bank lending channel exists, but is not important for identifying the transmission process from monetary policy to macroeconomic activity.

In recent years, researchers begin to study the bank lending channel on a larger set of aggregated data using a Factor Augmented Vector Auto Regression (FAVAR) method, which avoids the problem of sparse information sets typically generated by VAR models as noted by Bernanke et al. (2005). Dave et al. (2009) use a FAVAR method to identify the bank lending channel in the US, determining that the BLC is stronger than previously thought and that there may be other bank characteristics that could help improve identification of the BLC.

Meanwhile, a consensus has emerged that use of aggregated data cannot disentangle credit demand from supply, preventing proper identification of the bank lending channel. To address this, authors began to study the bank lending channel based on the bank individual data – the second category of empirical studies.

Based on a large panel of US banks, Kashyap & Stein (2000) use a two-step method to test the bank lending channel. They find that illiquid banks are more likely to adjust their lending behavior when there is a shift in monetary policy. Kishan & Opeila (2000) study quarterly data from US bank sector and Altunbas et al. (2002) use annual individual bank data from eleven countries in the euro zone. Both find micro-level evidence of bank lending channel and that less capitalized banks are more responsive to monetary shocks. Gambacorta & Mistrulli (2004) consider bank-level data from Italy, finding evidence of both a bank lending channel and a bank capital channel in Italy. They conclude that highly capitalized banks are more responsive to monetary shock than poorly capitalized banks.

Several other studies also point to the existence of the bank lending channel. Bichsel & Perrez (2004) examine individual bank data from Switzerland. The studies of Gonzalez et al. (2006) (Argentina and Colombia), Bhaduri (2012) (India), Juurikkala et al. (2011) (Russia), Luke (2011) (Australia), all find that bank lending behavior changes in response to shifts in monetary policy. Furthermore, many researchers find that big banks, well-capitalized and well-liquid banks are less likely to be affected by the monetary policy, as pointed by Kashyap & Stein (2000), Kishan & Opeila (2000), Altunbas et al. (2002), Bichsel & Perez (2003), Juurikkala et al. (2011).

The results are surprisingly inconsistent across studies of regions and countries. Gambacorta & Mistrulli (2004) find that highly capitalized banks are more responsive to monetary shocks than poorly capitalized banks. Chang & Jansen (2005) using US data, and Hernando & Pages (2007) using Spanish data, find that big banks are more prone to react to a shift in monetary policy than smaller banks. Carrera (2007) using data from Peru, asserts that big banks are more immune to monetary shocks than smaller banks, and that liquidity and capitalization do not significantly affect the transmission of monetary policy.

Several researchers also suggest that there may be asymmetric effects in the transmission of bank lending channel. Kishan & Opeila (2006) using US data, find that contractionary policy has a stronger effect than expansionary policy for poorly capitalized banks, which are less likely to increase their lending during periods of expansionary policy.

2.3 Studies of China's bank lending channel

There are few studies that use individual bank data to study the bank lending channel in China. Liu & Xie (2006) analyze the bank lending channel and the financial sector of China, but do not apply any econometric models. Most research is based on time-series data using a VAR or Structural VAR method (Xie, 2004; Zhao et al., 2007; Liu et al., 2009; Wang, 2010). These papers conclude that bank lending behaviors are responsive to changes in monetary policy, but fail to identify the effects of credit demand or distinguish differences in the loan supply for banks of various size, capitalization, etc.

Even fewer studies use individual bank data. Gunji & Yuan (2010) find that big banks and banks with low liquidity levels are less likely to be affected by the change of a series of interest rates. As caveats, their research is just based on data on an annual basis which may not capture the short-term effects of monetary policy and their selection of monetary variables is limited. Shu & Ng (2009) and Xiong (2012) point out that the People's Bank of China employs a range of monetary instruments. This makes description of the monetary stance more difficult than in countries that rely largely on a singly policy instrument. Koivu (2012), using quarterly bank group data to test the bank lending channel in China, establishes that the bank lending channel exists and that banks with higher capitalization are less likely to be affected by a shift in monetary policy. She further observes that interest rate policy does not work well in affecting the loan supply of banks. While her research is not on a bank individual data, there are just six bank groups in her sample that can affect the results. Thus, this paper should rightfully be noted as the first study of the bank lending channel in China based on quarterly data for individual banks.

Considering the difficulties in measuring the stance of China's monetary policy, we follow the method of Xiong (2012), a "narrative indicator" compiled from quarterly reports of the People's Bank of China, to describe the stance of monetary policy. We also test the asymmetric effects of the bank lending channel following Kishan & Opeila (2006), and find that there exists a significant asymmetric effect of bank lending channel in China. Finally, when we include dummies of capital regulation, we find that since the impositions of higher capital requirements in 2004, the transmission effects of the bank lending channel have weakened.

3 A motivating theoretical model

Following Peek & Rosengren (1995), Kashyap & Stein (1995), and Tanaka (2002), my goal here is to identify the effects of bank size, capitalization, and the strength of capital regulation on a bank's optimal loan supply under prevailing monetary policy conditions. We develop a model of a representative bank with three assets: Loan (L), Bond (B) and required reserves (R), as well as two categories of liabilities: Deposits (D) and Capital (K). Equation (1) is the balance sheet constraint:

$$L + B + R = D + K \quad (1)$$

On the asset side, the loan market is imperfectly competitive and banks have market power through increasing their loan stock by offering a lower interest rate r_L . \bar{r}_L is the average interest rate on loan market; it is function of the benchmark interest rate r_b . The relationship between L and r_L yields Equation (2):

$$L = l_0 - l_1(r_L - \bar{r}_L) \quad (2)$$

When l_1 , the sensitivity of L to interest premium is $r_L - \bar{r}_L$. This value will be larger if banks have a greater market power. Big banks always have strong bargaining power and more branches to serve potential customers. Confronted with an increase in premium $r_L - \bar{r}_L$, they are likely to secure more credit than a smaller bank. Therefore, l_1 is positively related to bank size A:

$$l_1'(A) > 0 \quad (3)$$

B, the government bond held by the bank, has an interest rate of r_b , which is simply a function of the benchmark interest rate r_b . A bank can hold the bond for either of the two reasons: (a) it does not to be compensated by capital under the framework of capital requirement, or (b) it can liquidize the bond easily, so its serves as a liquidity buffer. Here, we assume the bond B is a percentage of deposits D:

$$B = c_0 + c_1 D - R \quad (4)$$

The coefficient c_1 is negatively related bank size A and capital K. This can be explained by the availability of alternative external financing. Big banks and well capitalized banks find it

easier to secure alternative external financing funds when confronted by a liquidity shock. They are also likely hold a smaller percentage of bonds relative to deposits:

$$c_1'(A) < 0 \tag{5}$$

$$c_1'(K) < 0 \tag{6}$$

R stands for the required reserves held by the bank.² Assuming banks do not hold excessive reserves, bank reserves at the central bank are characterized by Equation (7):

$$R = \rho * D \tag{7}$$

On the liability side, recall D represents bank deposits. Assuming the deposit market is imperfectly competitive, banks can control their deposits D by changing the deposit interest premium over the market rate $r_D - \bar{r}_D$:

$$D = e_0 + e_1(r_D - \bar{r}_D) \tag{8}$$

If e_1 is the sensitivity of deposit D to the interest premium $r_D - \bar{r}_D$, this value will be larger when the bank has stronger market influence. Big banks have greater bargaining power than small banks and more branches to serve a larger base of potential customers. Big banks are also protected (at least tacitly) by deposit insurance from the government. Thus, big banks are able to charge a larger premium $r_D - \bar{r}_D$ over the prevailing market rate. Therefore, e_1 is positively related to bank size A :

$$e_1'(A) > 0 \tag{9}$$

e_1 is also positively related to the level of capitalization K . This can be explained by the information asymmetry between the bank and depositors. The level of capitalization is a good reflection of a bank's willingness to invest in risky projects. Moreover, well capitalized banks will pay more when they sustain losses from risky assets, so depositors may consider weak capitalization as a deal-breaker in screening prospective banks. Banks with higher capital are expected to secure more deposits than poorly capitalized banks, giving inequality (10):

³ Unlike in Western countries, China's required reserve ratio includes both time deposits and demand deposits. Thus, we do not separate demand deposits and time deposits like Peek & Rosengren (1995).

$$e'_1(K) > 0 \quad (10)$$

Over the short run, capital level K is exogenous. The cost of holding capital K is r_K , so we incorporate a penalty function $P(\frac{\theta L}{K})V$ of capital regulation, where $P(\frac{\theta L}{K})$ is the probability that a bank is in violation of the capital regulation. θ is the capital requirement ratio and bond B is riskless, so the bank does not need to allocate additional capital to cover risk. $\frac{\theta L}{K}$ is the inverse of the bank's capital ratio, so an increase in $\frac{\theta L}{K}$ implies that the probability that the bank will violate the capital regulation $P(\frac{\theta L}{K})$ increases. Thus, $P(\frac{\theta L}{K})$ satisfies the following three conditions: (1) $P'(\frac{\theta L}{K}) > 0$; (2) $P''(\frac{\theta L}{K}) > 0$, and (3) $P'''(\frac{\theta L}{K}) = 0$. V is the cost that a bank should pay if it fails to meet the capital requirement, which is usually very costly. Thus, $P(\frac{\theta L}{K})V$ is the expected cost of violating the capital requirement. The bank's objective is to maximize its profit as shown in Equation (11):

$$\max \pi = L^*(r_L - w) + r_B^* B - r_D^* D - r_K^* K - P(\frac{\theta L}{K})V \quad (11)$$

w means the losses incurred by the non-performing loans, using Equations (1), (2), (4), (7), (8), to eliminate r_L, r_B, r_D, D, B Equation (12) is obtained:

$$\max \pi = L^* \left(\frac{l_0}{l_1} - \frac{L}{l_1} + \bar{r}_L - w \right) + \bar{r}_B^* \left[c_0 + \frac{(c_1 - \rho)(L + c_0 - K)}{1 - c_1} \right] - \left[\frac{L + c_0 - K}{(1 - c_1)e_1} - \frac{e_0}{e_1} + \bar{r}_D \right]^* \left(\frac{L + c_0 - K}{1 - c_1} \right) - r_K^* K - P(\frac{\theta L}{K})V \quad (12)$$

Take the first-order condition with respect to L :

$$\frac{d\pi}{dL} = \frac{l_0}{l_1} - \frac{2L}{l_1} + \bar{r}_L - w + \frac{\bar{r}_B^*(c_1 - \rho)}{1 - c_1} - \left[\frac{1}{(1 - c_1)e_1} \right]^* \left(\frac{L + c_0 - K}{1 - c_1} \right) - \left[\frac{L + c_0 - K}{(1 - c_1)e_1} - \frac{e_0}{e_1} + \bar{r}_D \right]^* \left(\frac{1}{1 - c_1} \right) - \frac{\theta}{K} P'(\frac{\theta L}{K})V \quad (13)$$

Use the second-order sufficient condition:

$$\frac{d^2\pi}{dL^2} = -\frac{2}{l_1} - \frac{2}{e_1^*(1 - \rho)^2(1 - c_1)^2} - \frac{\theta^2}{K^2} P''(\frac{\theta L}{K})V < 0 \quad (14)$$

Equation (14) satisfies the maximum condition, i.e. there exists an optimal loan supply L^* that will maximize the bank's profit.

We now consider some comparative statics of L^* ,³ paying special attention to sensitivity of optimal supply to the change of benchmark interest rate r_b and required reserve ratio ρ :

$$\frac{dL^*}{dr_b} = \frac{1}{\frac{2}{l_1} + \frac{2}{(1-c_1)^2 e_1} + \frac{\theta^2}{K^2} P''(\frac{\theta L}{K}) V} * (\frac{-\rho}{1-c_1} * \varphi) < 0 \quad (16)$$

$$\frac{dL^*}{d\rho} = \frac{1}{\frac{2}{l_1} + \frac{2}{(1-c_1)^2 e_1} + \frac{\theta^2}{K^2} P''(\frac{\theta L}{K}) V} * (-\frac{\bar{r}_B}{1-c_1}) < 0 \quad (17)$$

If we drop the condition suggested in Peek & Rosengren (1995), the optimal loan supply decreases in response to an increase in r_b only when the following inequality holds:

$$\frac{d\bar{r}_D}{dr_b} > (1-c_1) \frac{d\bar{r}_L}{dr_b} + (c_1-\rho) \frac{d\bar{r}_B}{dr_b} \quad (18)$$

This inequality means the instrument of benchmark interest rate only works when the interest rate sensitivity of the deposit market to the benchmark interest rate is greater than the linear combination of the sensitivities to both the loan and bond markets.

We further examine the effects of size, capitalization and compliance with capital requirements based on (15) and (16), and find that:

$$\frac{d^2 L^*}{dr_b dA} < 0 \text{ or } > 0 \quad (19)$$

$$\frac{d^2 L^*}{dr_b dK} < 0 \text{ or } > 0 \quad (20)$$

⁴ Following Peek & Rosengren (1995), the benchmark interest rate r_b will have equal effects on the interest rates of loan market \bar{r}_L , bond market and deposit market \bar{r}_D :

$$\frac{d\bar{r}_L}{dr_b} = \frac{d\bar{r}_B}{dr_b} = \frac{d\bar{r}_D}{dr_b} = \phi \quad (15)$$

$$\frac{d^2L^*}{dr_b d\theta} > 0 \quad (21)$$

$$\frac{d^2L^*}{d\rho dA} < or > 0 \quad (22)$$

$$\frac{d^2L^*}{d\rho dK} < or > 0 \quad (23)$$

$$\frac{d^2L^*}{d\rho d\theta} < or > 0 \quad (24)$$

From (19) to (24),⁴ the following conclusions can be drawn:

The marginal effects of bank asset on $\frac{dL^*}{dr_b}$ and $\frac{dL^*}{d\rho}$ are ambiguous, they depend on the tradeoff among the following effects: (1) the monopolistic effects of big banks on both the credit and deposit market $l_1'(A) > 0$ and $e_1'(A) > 0$ which will enhance the effects of monetary tools; while the ability to raise funds from alternative funds $c_1'(A) < 0$ will weaken the effects of monetary policy. The marginal effects of bank capitalization on $\frac{dL^*}{dr_b}$ and $\frac{dL^*}{d\rho}$ are ambiguous. They depend on the tradeoff among the following effects: (1) the monopolistic effects of well capitalized banks on the deposit market $e_1'(A) > 0$ and the lower probability of violate capital regulations $P''(\frac{\theta L}{K}) > 0$ tend to enhance the effect of monetary policy. Well capitalized banks, on the other hand, are free from the capital requirement and have an advantage in securing alternative external funding $c_1'(K) < 0$, which tends to weaken the effect of monetary policy.

The marginal effects of capital requirement on $\frac{dL^*}{dr_b}$ and $\frac{dL^*}{d\rho}$ are unambiguous. A higher capital requirement weakens the impact of monetary policy.

⁵ Detailed derivations are given in Appendix B.

4 Empirical studies

4.1 Econometric model

The empirical specification (based on Ehrmann et al., 2001; Kishan & Opiela, 2000; Kashyap & Stein, 1995; Gambacorta & Mistrulli, 2004; and Juurikkala et al., 2011), has been designed to test whether banks with different characteristics and under different regulatory conditions will react differently to monetary policy. The empirical model is given as Equation (25):

$$DLoan_{it} = \sum_{n=1}^3 \alpha_n DLoan_{it-n} + \sum_{j=0}^3 \beta_j GDP_{t-j} + \sum_{j=0}^3 \varphi_j MP_{it+j} + \eta_n X_{it-1} + \sum_{j=0}^3 \theta_n GDP_{t-j} * X_{it-1} + \sum_{j=0}^3 \delta_n MP_{t-j} * X_{it-1} + SD + t + \psi_i + \varepsilon_{it} \quad (25)$$

With $i = 1 \dots N$ (N = number of banks) and $t = 1 \dots T$ (t = quarters) and where:

$DLoan_{it}$	Growth rate of loans of bank i in quarter t ,
GDP_t	GDP growth rate in quarter t ,
MP_t	Indicator of monetary policy in quarter t ,
X_{it}	Bank-specific variables in quarter t , including asset, capitalization (capital ratio and equity to asset ratio), and liquidity of bank i in quarter t ;
$GDP_t * X_{it}$	Interactions of GDP and bank-specific variables,
$MP_t * X_{it}$	Interactions of monetary policy indicators and bank-specific variables,
SD	Seasonal dummies;
t	Time trend variables.

Lags of $\Delta Loan$ are included to describe the adjustment process of bank loan. As the bank lending channel focuses on the supply side of loan (Bernanke & Blinder, 1988), GDP growth and CPI are included to capture the effects of credit demand.

It is difficult to quantify the monetary policy stance in China. The People's Bank of China (PBoC) has not traditionally used inflation targeting, implementing policy with a range of tools instead. Shu & Ng (2010) provide a detailed summary of the instruments used by the PBoC, as indicated in Table 1. There are market-based, non-market based, quantity-based, and price-based instruments in the monetary toolkit. Thus, it would be unreasonable to characterize the monetary stance only from one indicator. We have selected four indicators to test the bank lending channel, including:

- A quantity- and market-based indicator; required reserve ratio (RRR) for big financial institutions, which is adjusted frequently by the PBoC. This indicator is calculated on a daily weighted basis.⁵
- A price- and market-based indicator, i.e. the benchmark one-year lending interest rate (BLR). It has been adjusted frequently by PBoC in recent years and is calculated on a daily weighted basis.
- A priced-based intermediate target indicator, i.e. the quarterly weighted overnight interbank repo rate. This is the rate most sensitive to changes in market liquidity.
- The narrative monetary stance indicator (MPV) compiled by Xiong (2012).⁶ This indicator is prepared by using -1, 0 and 1 to describe the stance of monetary policy, A value of 1 indicates tightening, 0 is neutral, and -1 means an expansionary or loosening stance.

These characterizations are based on the PBoC's quarterly report of monetary policy from 2001Q1 to 2011Q4. M2 is often mentioned as the important indicator of monetary stance, but we avoid its use for several reasons. First, changes in M2 are not only affected by monetary policy (money supply) but also demand shocks to the financial sector and real economy, financial innovation, changes in non-deposit liabilities of banks, as well as various payment tools that can greatly enhance the endogeneity of M2. Further, M2 reflects foreign capital inflows and export revenues. Since such flows are typically sterilized by the PBoC, the relationship between the growth of M2 after sterilization and the PBoC policy actions remains complicated, and there is the added issue of whether the central bank's sterilization operations succeed or not. Finally, M2 targets announced by the PBoC may be unsuitable as a policy stance indicators as such targets are announced annually and not continuously adjusted to reflect the state of the economy (He & Pauwels, 2008).

⁶ On April 25, 2004, the PBoC implemented a new required reserve policy. The required reserve ratio dependent on the the type of financial institutions. Most of the sample banks are classified as large financial institutions, so we use the daily weighted-average required reserve ratio for the big commercial banks.

⁷ See Appendix A.

Table 1 PBoC instruments of monetary policy

	Market	Non-market
Quantity-based	Issuance size of central bank Bill size of repurchase and reverse repurchase arrangements Reserve requirements	Targeted central bank bills Special deposits from selected banks Foreign currency swaps Credit controls
Price-based	Issuance rate of central bank bills Rate of repurchase and reverse repurchase arrangements Benchmark lending and deposit interest rates	Regulatory changes aimed at changing market behavior, e.g. varying the floating band of interest rates

Source: Shu & Ng (2010)

X_{it} represents our three bank-specific variables: (1) capital ratio car_{it} ⁷, (2) asset size ta_{it} , and (3) liquidity liq_{it} . The variables car_{it} and liq_{it} are normalized as follows:

$$\bar{X}_{it} = X_{it} - \frac{1}{T} \sum_t \left(\frac{1}{N_t} \sum_i X_{it} \right) \quad (26)$$

asset size ta_{it} is normalized so as to remove its increasing trend:

$$\bar{X}_{it} = X_{it} - \frac{1}{N_t} \sum_i X_{it} \quad (27)$$

A dummy cap is also incorporated. It stands for the first quarter of 2004 when China's banking industry implemented stricter capital requirements. Thus, cap equals 0 for observations before 2004Q1, and 1 thereafter. The effect of monetary policy is always short-term, so the time lag for the monetary indicators is 3. SD stands for seasonal dummies might capture the seasonal features of lending behavior. t is the variable for the time trend.

4.2 Data

A quarterly unbalanced panel from 27 commercial banks from 2000Q2 to 2011Q4 has been used to estimate the coefficients. The data of bank specific variables are collected from various sources. We complement the data available from B.V.D. Bankscope database by bank-level data collected by the Center of Bank Management, Wuhan University. The statistical description is in Table 2. Table 2 suggests that the capital ratio and equity-to-asset ratio are

⁸ The equity-to-asset ratio, ea , is used as an alternative indicator of a bank's capitalization level.

growing significantly, and the growth in the lending rate and the percentage of loans to total assets are on the decrease. This provides evidence of the effect of capital requirement and a trend towards financial disintermediation. The macroeconomic variables are taken from China Statistics Yearbook. Our sample banks account for over 65% of banking sector assets and 70 % of loans granted as of end-2011Q4.

To avoid spurious regressions, variables are tested for unit roots by Imm-Pesaran-Shinn (2003) test.⁸ The results are in Table 3, which show that all variables in the econometric model are stationary.

Table 2 Descriptive statistics of the sample

Pre CR(2000Q2-2003Q4)	Banks	Obs.	Mean	Std.	Min.	Max.
Capitalization	16	314	0.0778	0.0476	-0.0482	0.2401
Liquid assets/Liquid Liability	16	314	0.4708	0.2000	0.1363	1.5308
Equity/total assets	16	314	0.0431	0.0167	0.0129	0.0987
Loan/total assets	16	314	0.5547	0.0730	0.6921	0.3792
Loan growth	16	314	0.0755	0.0798	-0.1705	0.4651
Total assets	16	314	10432	13902	93.28	52123
Post CR(2004Q1-2011Q4)	Banks	Obs.	Mean	Std.	Min.	Max.
Capitalization	27	800	0.0957	0.0638	-0.2165	0.3900
Liquid assets/Liquid Liability	27	800	0.4657	0.1600	0.1185	1.5308
Equity/total assets	27	800	0.0507	0.0207	0.0006	0.2144
Loan/total assets	27	800	0.5427	0.0776	0.7167	0.2590
Loan growth	27	800	0.0540	0.0600	-0.1986	0.4420
Total assets	27	800	18533	29880	67.96	154768.7

Note: the unit for total assets is trillion Yuan.

Table 3 Stationarity tests of explanatory variables

Variables	Null Hypothesis	Statistics	P-Value
Car	All the individuals have unit root	-3.8813***(Z-t-tilde-bar)	0.0001
Liq	All the individuals have unit root	-7.0490***(Z-t-tilde-bar)	0.0000
Ta	All the individuals have unit root	-7.1223***(Z-t-tilde-bar)	0.0000
Ea	All the individuals have unit root	3.6299***(Z-t-tilde-bar)	0.0001
DLoan	All the individuals have unit root	-16.3785***(Z-t-tilde-bar)	0.0000
DRRR	DRRR has a unit root	-3.1846***(ADF)	0.0274
DBLR	DBLR has a unit root	-4.0556***(ADF)	0.0027
DREPO	DSHIBOR has a unit root	-5.1550***(ADF)	0.0001
MPV	MPV has a unit root	-3.3982***(ADF)	0.0161
GDP	GDP has a unit root	-5.8943***(ADF)	0.0000

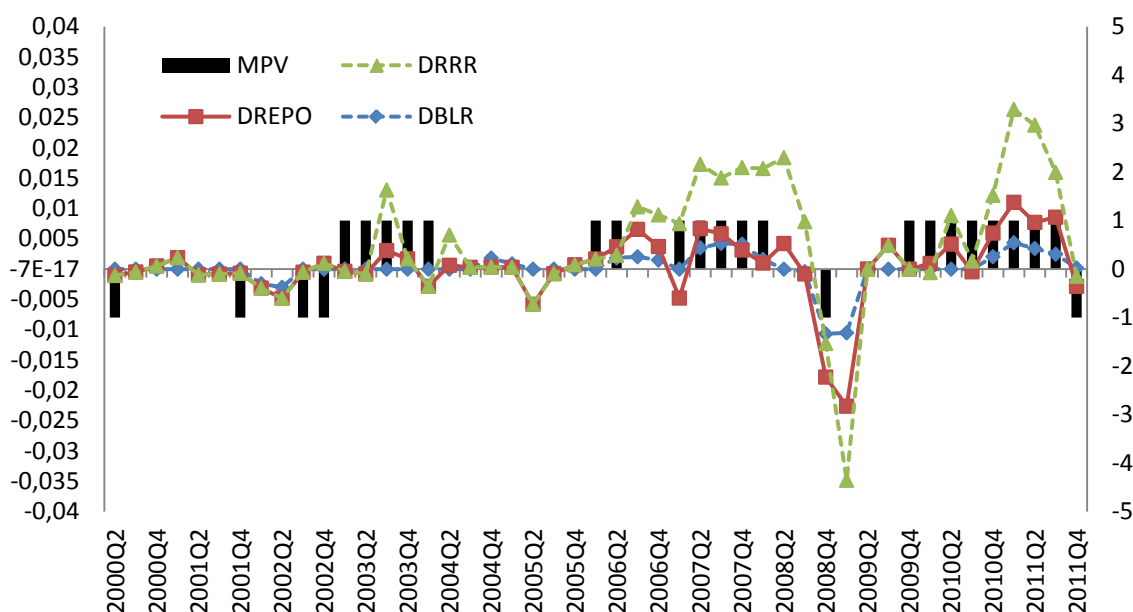
Notes: RRR-required reserve ratio, BLR- one-year lending rate, REPO-overnight interbank repo rate, MPV-monetary policy stance indicator, "D" stand for the first differences.

⁹ The Im-Pesaran-Shin (2003) test is a unit-root test designed for unbalanced panel data.

¹⁰ "D" stands the first order difference of the variables.

Figure 2 shows the chronology of monetary policy indicators in the sample period. Generally speaking, the four indicators have trended together, especially since 2006, when the PBoC implemented a series of monetary operations to fight increasing inflationary pressures and the impact from the financial crisis. The PBoC also shifted at this time to more market-based instruments such as the required reserve ratio and the benchmark interest rate. Prior to 2006, the narrative indicator works much better in describing the monetary policy. During this period, the PBoC's monetary policies relied heavily on non-market instruments such as window guidance which cannot be easily captured by the required reserve ratio or the one-year benchmark lending interest rate.

Figure 2 Monetary policy variables from 2000Q2–2011Q4



Sources: China Statistic Yearbook; Quarterly Report of Monetary Policy.

From Figure 2, we can divide the chronology of the monetary stance into the following phases:

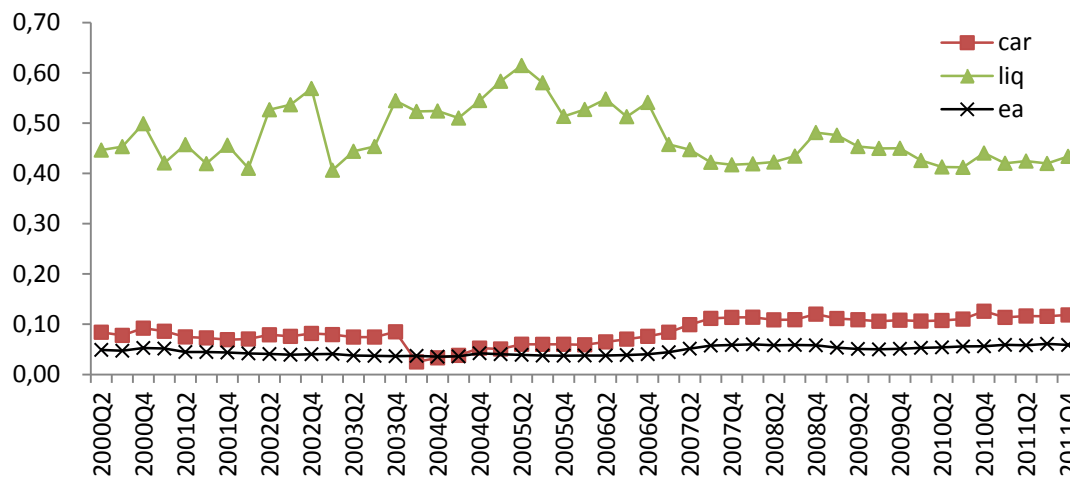
- 2000Q2–2002Q4: China's economy was recovering from the Asian financial crisis, so it pursued a broadly supportive monetary policy.
- 2003Q1–2004Q2: The PBoC tightened policy in order to stave off economic overheating.
- 2004Q3–2005Q4: Economy growth was good and inflation was modest, so the PBoC followed a neutral monetary policy.
- 2006 Q1–2008Q2: A period of intense tightening in the face of booming stock and real estate markets, and a potential asset bubble. The PBoC also implemented

tightening to deal with high inflationary pressures and rapid investment growth. At this time, the PBoC began to adjust the RRR and BLR much more frequently.

- 2008Q3–2009Q2: Substantial monetary easing against the background of the global financial crisis.
- 2009Q3 to 2011Q3: A monetary pullback after rapid growth in investment, and rising inflationary pressures.
- 2011Q4: In our final observation quarter, due to the European sovereign debt crisis and the consecutive tightening monetary operations, the PBoC launches a new round of monetary easing.

Figure 3 shows the trend of bank-specific variables. There is a sharp decrease in the average capital ratio in the year 2004, when the banking industry initiated the “Management Approach of Commercial Banks’ Capital Ratio” and standardized the calculation of the capital ratio. From 2004 to 2007, banks adjust their balance sheets and raise funds in the capital market to meet the 8% capital requirement. As a result, their capital ratios increase significantly before 2007 deadline for meeting the 8% standard. After 2007, the average capital ratio fluctuates around 10%, and the equity-to-asset ratio follows nearly has the identical trend of the capital ratio. Liquidity is generally higher before 2007, averaging around 50%. After 2007, depositors take their money out of the bank, which shrinks banks’ deposits, especially long-term time deposits. In the meantime, in response to the financial crisis in 2008, commercial banks inject huge funding for large projects in the real economy. Liquidity levels overall fall significantly.

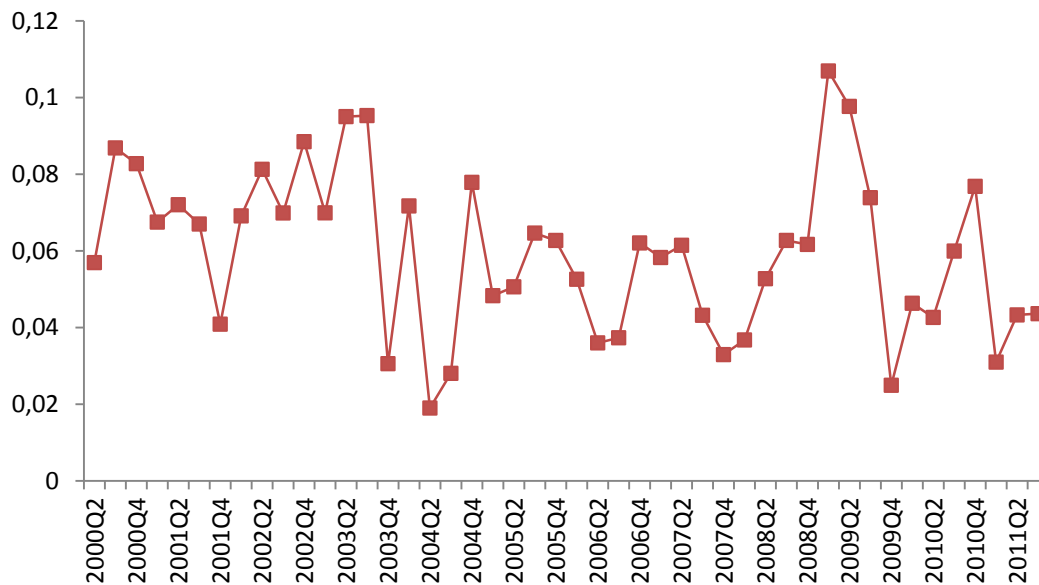
Figure 3 Bank-specific variables 2000Q2–2011Q4



Sources: B.V.D. Bankscope database and Center of Bank Management, Wuhan University. Car: is the average capital ratio of the sample period; Liq: is the average liquid asset/liquid liability ratio in the sample period; Ea: is the average equity to asset ratio in the sample period

Figure 4 presents the growth of the loan stock in the sample period. It appears that loan growth is negatively related the monetary stance. After 2004, the loan stock expands much more slowly than before 2004. There is a dramatic decline in loan growth in the first half of 2004, which may reflect the imposition of stricter capital requirements.

Figure 4 Growth of the loan stock 2000Q2–2011Q4 (seasonally adjusted)



Sources: B.V.D. Bankscope database and Center of Bank Management, Wuhan University

4.3 Methods of estimation

We use a one-step system GMM to estimate the coefficients in Equation (25), considering the lagged dependent variables in the dynamic panel, we hope to avoid the problem of endogeneity by adding lagged instruments. We use a one-step GMM estimator rather than a two-step estimator as it would cause downward-biased standard errors (Bond, 2002).⁹ All estimations are based on the STATA11.

¹⁰ In the sample, we have a number of banks ($N = 27$) and time span ($T = 48$ quarters). Following Kivet (1999) and Bruno (2005), Equation (19) should preferably be estimated with the LSDV method to correct for bias in the process of estimation when all explanatory variables are strictly exogenous. Since this is impossible here, we stick with our one-step GMM estimation.

4.4 Results

We calculate the long-term coefficients of each variable in accordance with Gambacorta & Mistrulli (2004) and Juurikkala et al. (2011). The long-term coefficients are secured from the following equation:

$$\beta_{LC} = \frac{\sum_{i=0}^3 \beta_{t-n}}{1 - \sum_{n=1}^3 \alpha_{t-n}} \quad (28)$$

Where β_{t-n} are the coefficient of explanatory variables (e.g. MP or the interactions of MP and bank-specific variables X), and α_{t-n} are the coefficients of the lagged dependable variables. The long-term coefficients can be explained as the accumulated effects on the rate of loan growth. We use F-statistics to test the following hypothesis:

$$\sum_{i=0}^3 \beta_{t-n} = 0 \quad (29)$$

We report the results for four alternative monetary policy indicators (DRRR, DBLR, DREPO, and MPV).

The response of loan growth to monetary policy

We omitted bank-specific variables in Equation (25), leaving only the variables of monetary indicators and GDP. The results are shown in Table 4. The monetary indicators all take on significant negative relationships with growth in the loan stock. This is seen from the long-

term coefficients and F-statistics of $\sum_{n=0}^3 MP_{it-n}$. The long-term coefficients of $\sum_{n=1}^3 DLoan_{it-n}$

are positive and significant, which describe the dynamic adjustment of bank lending behavior.

The long-term coefficient of $\sum_{n=0}^3 GDP_{it-n}$ is significant, suggesting the pro-cyclicality of loan

demand. The p-values of the Sargan, Hansen and AR (2) test are all solid, indicating the model is robust.¹⁰

¹⁰ Regarding the Sargan and Hansen tests, the null hypothesis in the model does not suffer from an over-identification problem. As for the AR(2) test, the null hypothesis the second-order residuals are not correlated. Therefore, the results are solid.

Table 4 Loan growth: Long-run coefficients of GMM estimations on alternative monetary policy indicators

	(1) DRRR	(2) DINT	(3) DREPO	(4) MPV
$\sum_{n=1}^3 DLoan_{it-n} = 0$	0.177*(3.62)	0.384***(19.30)	0.427***(28.61)	0.359***(19.30)
$\sum_{n=0}^3 MP_{it-n}$	-3.582***(11.20)	-7.519***(21.20)	-5.838***(18.33)	-1.029***(12.98)
$\sum_{n=0}^3 GDP_{it-n}$	0.227*(2.99)	0.222**(4.42)	0.134**(4.66)	0.315***(8.61)
Obs	1114	1114	1114	1114
Sargan-p	0.63	0.67	0.74	0.61
Hansen-p	1.00	1.00	1.00	1.00
AR(2)-p	0.49	0.62	0.62	0.46

Note: Numbers in the parenthesis are F statistics; ***, **, * mean significance at 1%, 5%, 10% confidence levels, respectively.

Seasonal (quarterly) dummies and time trend are included, but not reported. In the initial model specification, we incorporated the CPI. It caused an over-identification problem and the signs were not significant, so the CPI was dropped. Sargan-p, Hansen-p and AR (2) are the p- values of the Sargan and Hansen over-identification and Arrelano & Bond second-order serial tests.

The effects of bank-specific variables

We next examine the effects of bank-specific variables. The results for required reserve ratio (DRRR) and one-year benchmark interest rate (DBLR) are reported in Table 5. The long-term coefficients of DRRR are significantly negative, i.e. a rise in the required reserve ratio leads to a significant decrease in growth rate of the loan stock. The long-term coefficient of GDP is significantly positive, suggesting the pro-cyclicality of bank credit behavior. The long-term coefficients of DRRR*ta are significant, and the positive sign means larger banks adjust their lending practices less than an average bank due to a change in the required reserve ratio. The interactions of required reserve ratio and dummy of capital requirement DRRR*cap are also positively significant. Thus, since the introduction of stricter capital requirements, the effect of required reserve ratio on the banks' credit supply has weakened. GDP*cap is significant. A negative sign here means that since stricter capital regulation, the pro-cyclicality of lending behavior has abated somewhat. This is not in line with the intuition that tighter capital regula-

tion should increase the pro-cyclicality of bank credit behavior (Heid, 2007). As for the interactions of $DRRR*car$, the sign is negative. This means that with an increase in the capital ratio, banks become more sensitive to changes in the required reserve ratio. The long-term coefficient, however, is not significant. As for interactions with the equity-to-asset ratio, $DDRR*ea$ is negative and significant.

The long-term coefficient of $DBLR$ is significantly negative, showing that an increase in the benchmark interest rate leads to a decline in bank credit growth. As for the interactions with the dummy of capital requirement, $DBLR*cap$ is significantly positive. This suggests that after the enactment of the Basel I accord, banks have become less likely to respond to the changes of benchmark lending rate. All the other interactions of $DBLR$ are not significant, which is in line with Koivu (2012). The results show that the effects of benchmark interest rate on loan growth are not affected by bank-specific variables. As for the interactions of GDP , $GDP*liq$ is significantly positive. Thus, highly liquid banks can inject more credit when the economy is in an upturn and less in a downturn. The long-term coefficients of $GDP*ea$ are significantly negative, which means that banks with higher equity-to-asset ratios will inject less credit when the economy is in an upturn and less in a downturn. This has implications for counter-cyclical capital buffer behaviors.

The sum of lagged credit growth coefficients in Table 5 are significant and have a positive and significant impact on the current period loan supply. This seems to validate the choice of a dynamic estimation framework. All the models in Table 5 are valid in Sargan and Hansen over-identification tests with their p values greater than 0.1. The results of AR (2) tests with p-values greater than 0.1 also show that the model estimations are solid.

Table 5 Loan growth: Long-run coefficients of GMM estimations with required reserves ratio and one-year lending rate as monetary policy indicators, full model

	(1)DRRR	(2)DRRR	(3) DBLR	(4) DBLR
$\sum_{n=1}^3 DLoan_{it-n} = 0$	0.182*(3.52)	0.217**(5.44)	0.16*(3.66)	0.187*(3.33)
MP	-4.957*** (14.31)	-4.116*** (8.80)	-24.655* (3.87)	-22.958* (3.31)
MP*liq	-6.910(0.93)	-7.151(1.04)	3.364(0.00)	-4.317(0.30)
MP*ta	0.489** (4.43)	0.716** (7.00)	0.454(0.31)	0.384(0.25)
MP*car	-5.012(0.08)		-45.287(1.60)	
MP*cap	2.099* (3.38)	1.167* (3.11)	22.095* (3.05)	17.16** (4.44)
MP*ea		-4.396* (4.01)		16.600(0.05)
GDP	0.528*** (16.40)	0.494*** (13.62)	0.549*** (17.79)	0.549*** (15.51)
GDP*liq	2.669* (3.04)	2.378* (3.39)	1.787* (2.92)	2.055** (4.40)
GDP*ta	0.048(0.27)	0.033(0.13)	0.057(0.42)	0.059(0.49)
GDP*car	-3.055(0.51)		-2.463(0.61)	
GDP*cap	-0.362** (5.02)	-0.158* (3.96)	-0.586*** (7.88)	-0.208* (4.27)
GDP*ea		-8.331(0.73)		-16.300* (2.93)
Obs	1114	1114	1114	1114
Sargan-p	0.36	0.25	0.24	0.23
Hansen-p	1.00	1.00	1.00	1.00
AR(2)-p	0.46	0.45	0.47	0.56

Note: the bank specific variables, quarterly dummies and time trend are included in the GMM estimation, but the results are not reported here.

The results of DREPO and MPV are presented in Table 6. The long-term coefficient of DREPO is significantly negative, i.e. an increase in the interbank repo rate lead to a decrease in bank lending. The long-run coefficients of DREPO*liq and DREPO*car are significantly negative, so highly liquid and well capitalized banks are more affected by the change of overnight interbank repo rate. The sign of DREPO*ea also suggests this, but it is not statistically significant.

There is also evidence that, with stricter capital requirements, the effect of the interbank repo rate on bank credit growth has been weakened. The long-term coefficient of GDP*liq is positive and significant, i.e. highly liquid banks behave more pro-cyclically with regards to credit. GDP*car is negative and significant, i.e. well capitalized banks behave less pro-cyclically with regard to credit. GDP*cap is significantly negative, i.e. the introduction of tighter capital regulations eliminated a certain amount of pro-cyclical lending behavior.

The long-run coefficient of MPV is significant and negative, so a tighter monetary stance leads to a decrease in credit growth. The long-term coefficient of MPV*ta is positive and significant, i.e. big banks seems to be less affected by the change of monetary stance. The signs of MPV*car and MPV*ea are also negative and significant, suggesting that better capitalized banks change their loan supply more than an average bank to accommodate monetary policy. The signs for the other variables are generally in line with the above-mentioned results.

The significance of $\sum_{n=1}^3 DLoan_{it-n}$ shows that the lagged terms of loan growth are positively related to the current term of growth in the loan stock, and bolsters the case for our selection of a dynamic estimation framework. Models (5)-(8) in Table 6 are valid through Sargan and Hansen over-identification tests with p-values greater than 0.1. The results of AR (2) tests show that the model estimations are valid (p-values greater than 0.1).

Table 6 Loan growth: Long-run coefficients of GMM estimations with interbank rate and Xiong (2012) MPV indicator as monetary policy indicators, full model

	(5)DREPO	(6)DREPO	(7)MPV	(8)MPV
$\sum_{n=1}^3 DLoan_{it-n} = 0$	0.161*(3.50)	0.239**(6.40)	0.105*(2.95)	0.171*(2.99)
MP	-14.737(1.35)	-13.333(0.97)	-0.011*(3.78)	-0.007*(3.66)
MP*liq	-9.720(2.30)	-15.685*** (12.70)	-0.019(0.21)	-0.034(0.82)
MP*ta	0.186(0.19)	0.335(0.55)	0.004**(4.80)	0.008*** (11.48)
MP*car	-43.331*(2.95)		-0.250** (7.27)	
MP*cap	12.098*(3.07)	9.403*(3.49)	0.016*(3.59)	0.033*** (5.38)
MP*ea		-35.898(0.30)		-0.443*(3.35)
GDP	0.567*** (15.05)	0.524*** (10.88)	0.525*** (19.74)	0.455*** (14.64)
GDP*liq	2.650** (4.96)	2.666** (4.67)	2.606* (3.21)	2.439* (4.20)
GDP*ta	0.069(1.72)	0.067(1.23)	0.007(0.01)	0.066(0.67)
GDP*car	-4.900*(3.19)		-2.034(0.50)	
GDP*cap	-0.738*** (24.55)	-0.221*(4.19)	-0.600*** (21.79)	-0.051** (4.28)
GDP*ea		-19.744*(3.36)		-3.873(0.33)
Obs	1114	1114	1114	1114
Sargan-p	0.25	0.24	0.18	0.22
Hansen-p	1.00	1.00	1.00	1.00
AR(2)-p	0.45	0.47	0.44	0.38

Note: the bank specific variables, quarterly dummies and time trend are included in the GMM estimation, but the results are not reported here.

4.5 Effects of contractionary and expansionary monetary policy on the bank lending channel

We now test whether bank lending reacts asymmetrically to contractionary or expansionary monetary policy as suggested by Kishan & Opeila (2006). The empirical specification is as follows:

$$DLoan_{it} = \sum_{n=1}^3 \alpha_n DLoan_{it-n} + \sum_{j=0}^3 \beta_j GDP_{t-j} + \sum_{j=0}^3 \varphi_j TIG_{it+j} + \sum_{j=0}^3 \kappa_j EXP_{it+j} + \sum_{j=0}^3 \zeta_j TIG_{it+j} * X_{it-1} + \sum_{j=0}^3 \delta_j EXP_{it+j} * X_{it-1} + \eta_n X_{it-1} + \sum_{j=0}^3 \theta_j GDP_{t-j} * X_{it-1} + SD + t + \psi_i + \varepsilon_{it} \quad (30)$$

All the other variables are the same as in Equation (25) except for the dummies TIG and EXP. TIG equals 1 for a tightening monetary policy stance (MPV=1) and 0 otherwise.

EXP equals -1 for an expansionary monetary policy stance (MPV=-1), and 0 otherwise.

As a matter of fact, there are 3 states for the stance of monetary policy, expansionary (MPV=-1), neutral (MPV=0) and contractionary (MPV=1), so the two dummies are not the same. The characterization of monetary stance is based on the MPV assessments of Xiong (2012).¹¹ We calculate the long-term coefficients of TIG, EXP, TIG-EXP, and their corresponding interactions with bank-specific variables and use an F-test to check the significance of the following hypotheses:

$$H_a : \sum_{j=0}^3 \varphi_j = 0, \text{ the sum of the contractionary policy TIG equals to 0.}$$

$$H_b : \sum_{j=0}^3 \kappa_j = 0, \text{ the sum of the expansionary policy EXP equals to 0.}$$

$$H_c : \sum_{j=0}^3 \varphi_j - \sum_{j=0}^3 \kappa_j = 0, \text{ the sum of contractionary policy TIG equals to that of expansionary policy EXP.}$$

$$H_d : \sum_{j=0}^3 \xi_j = 0, \text{ the sum of the contractionary policy TIG with bank specific variables equals to 0.}$$

$$H_e : \sum_{j=0}^3 \delta_j = 0, \text{ the sum of the expansionary policy TIG with bank specific variables equals to 0.}$$

$$H_f : \sum_{j=0}^3 \xi_j - \sum_{j=0}^3 \delta_j = 0, \text{ the sum of contractionary policy TIG with bank specific variables equals to that of expansionary policy EXP with bank specific variables.}$$

¹²Detailed MPV characterizations are presented in Appendix A.

¹³The other variables in Eq. 30 are included, but we do not report the results here.

Table 7 Loan growth: Long-run coefficients of GMM estimations on contractionary and expansionary monetary policy

Hypotheses	(1)	(2)	(3)	(4)
$\sum_{n=1}^3 Dloan_{it-n} = 0$	0.161*(2.98)	0.105*(2.95)	0.122*(3.34)	0.168*(2.89)
$TIG : \sum_{j=0}^3 \varphi_j = 0$	-0.019*** (7.97)	-0.039** (6.78)	-0.034* (3.58)	-0.018** (5.19)
$EXP : \sum_{j=0}^3 \kappa_j = 0$	-0.068*** (21.87)	-0.043** (7.35)	-0.038*** (9.35)	-0.074*** (20.15)
$TIG - EXP : \sum_{j=0}^3 \varphi_j - \sum_{j=0}^3 \kappa_j = 0$	0.049** (5.77)	0.004* (3.16)	0.004** (5.45)	0.056** (5.61)
$TIG * liq : \sum_{j=0}^3 \xi_j = 0$	-0.059 (0.97)	-0.074 (1.78)	-0.091 (2.21)	-0.074 (1.59)
$EXP * liq : \sum_{j=0}^3 \delta_j = 0$	0.101 (0.62)	0.039 (0.89)	0.047 (1.11)	0.112 (0.73)
$(TIG - EXP) * liq : \sum_{j=0}^3 \xi_j - \sum_{j=0}^3 \delta_j = 0$	-0.169 (2.47)	-0.103 (1.77)	-0.044 (2.25)	-0.186 (2.24)
$TIG * ta : \sum_{j=0}^3 \zeta_j = 0$	0.006* (2.94)	0.005* (3.43)	0.007** (5.12)	0.009* (3.22)
$EXP * ta : \sum_{j=0}^3 \delta_j = 0$	-0.014 (0.44)	-0.009 (0.35)	-0.007 (0.65)	-0.009 (0.20)
$TIG - EXP * ta : \sum_{j=0}^3 \zeta_j - \sum_{j=0}^3 \delta_j = 0$	0.020* (3.30)	0.014* (3.21)	0.014* (3.14)	0.018* (3.11)
$TIG * car : \sum_{j=0}^3 \xi_j = 0$	-0.169 (1.99)	-0.201 (1.45)		
$EXP * car : \sum_{j=0}^3 \delta_j = 0$	-0.227* (3.28)	-0.251** (4.41)		
$(TIG - EXP) * car : \sum_{j=0}^3 \xi_j - \sum_{j=0}^3 \delta_j = 0$	0.058* (3.21)	0.050* (2.81)		
$TIG * cap : \sum_{j=0}^3 \xi_j = 0$		-0.023** (4.98)	-0.031** (5.21)	
$EXP * cap : \sum_{j=0}^3 \delta_j = 0$		0.035* (4.05)	0.033** (4.49)	
$(TIG - EXP) * cap : \sum_{j=0}^3 \xi_j - \sum_{j=0}^3 \delta_j = 0$		-0.058*** (9.21)	0.064*** (10.11)	
$EXP * ea : \sum_{j=0}^3 \delta_j = 0$			-0.298** (5.01)	
$EXP * ea : \sum_{j=0}^3 \delta_j = 0$			-0.483* (3.01)	-0.822 (2.08)
$(TIG - EXP) * ea : \sum_{j=0}^3 \xi_j - \sum_{j=0}^3 \delta_j = 0$			0.185* (3.33)	0.605* (3.61)
Obs	1114	1114	1114	1114
Sargan-p	0.24	0.21	0.22	0.16
Hansen-p	1.00	1.00	1.00	1.00
AR(2)-p	0.36	0.39	0.38	0.31

Note: Seasonal dummies, GDP, and its interactions are included, but not reported. F-statistics are in parenthesis. *, **, *** denotes significance at 10%, 5%, 1% level. (Numbers in the blank are the sums of the corresponding long term coefficients).

The results for Equation 30 are presented in Table 7. Note that both expansionary and contractionary monetary policies have significant effects on growth in lending. This is specifically seen from the significant F-tests of $\sum_{j=0}^3 \varphi_j = 0$ and $\sum_{j=0}^3 \kappa_j = 0$. While there are significant asymmetric effects in the transmission of the bank lending channel, the hypothesis: $\sum_{j=0}^3 \varphi_j - \sum_{j=0}^3 \kappa_j = 0$ is rejected with its coefficient positively significant, i.e. banks react more to expansionary monetary policy than contractionary policy. $(\text{TIG-EXP})^* \text{ta} \sum_{j=0}^3 \xi_j - \sum_{j=0}^3 \delta_j = 0$ is also significant different from 0. The positive sign means small banks are more sensitive to tighter monetary policy. Since the sign of $(\text{TIG-EXP})^* \text{car} \sum_{j=0}^3 \xi_j - \sum_{j=0}^3 \delta_j = 0$ is positive, banks with high level of capitalization are more sensitive to expansionary policy. $(\text{TIG-EXP})^* \text{ea} \sum_{j=0}^3 \xi_j - \sum_{j=0}^3 \delta_j = 0$ is also significant with a positive sign, again showing the asymmetry effects of capitalization. $(\text{TIG-EXP})^* \text{cap} \sum_{j=0}^3 \xi_j - \sum_{j=0}^3 \delta_j = 0$ is significantly negative, indicating the weakening of capital requirements mainly works during expansionary episodes. The signs of $\text{TIG}^* \text{cap} \sum_{j=0}^3 \xi_j = 0$, $\text{EXP}^* \text{cap} \sum_{j=0}^3 \delta_j = 0$ show that the introduction of stricter capital requirements weakened the transmission effect of expansionary monetary policy, but strengthens the transmission of contractionary monetary policy.

5 Conclusions

This paper investigated the bank lending channel in China. China uses a complicated monetary toolkit in implementing China's monetary policy, so we selected four indicators that are helpful in determining the monetary stance. Our evidence shows changes of monetary policy directly impact bank lending. Large banks and poorly capitalized banks are less likely to adjust their lending behaviors when confronted with a shift in monetary policy; big banks because they can afford to ignore the change and weak banks because the change is likely to hurt their business. Since the enactment of more stringent capital requirements in early 2004, transmission of policy via the bank lending channel has weakened. The bank lending channel is also shown to have asymmetric effects, particularly during expansionary periods. Small banks are more sensitive to a tightening of monetary policy, while well capitalized banks are more likely to adjust their lending practices during an easing of monetary policy. Conversely, banks with low capitalization are more responsive to tightening monetary policy. Capital regulation appears to dampen effects of expansionary policy and strengthen the effects of contractionary monetary policy.

Our results have several important implications for policymakers. First, it is clear that monetary policy operations have less impact on big banks, which already control the lion's share of the credit market. The effectiveness of transmitting policy via the bank lending channel could further be curtailed by certain structural effects. For example, big banks mainly focus on the big private companies and state-owned enterprises. Small banks mainly serve the privately owned small and medium-sized enterprises. This market segmentation leads to a situation where small and medium-sized privately-owned enterprises are prone to be more affected by monetary policy, especially in times of monetary tightening. Second, given the unevenness of impacts, the PBoC needs to consider the level of capitalization of banks when executing monetary policy. Third, the stringency of capital regulation should be taken into consideration. In 2013, for example, China's banking sector will implement Basel III. We fully expect the stronger capital regulation to weaken the bank lending channel as a mechanism for transmitting monetary policy.

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Appendix A

Official characterizations of monetary policy stance by quarter

Quarter	MPV	Characterization of policy offered in the PBoC's quarterly report	Page
2000Q2	-1	There are no quarterly reports in this period, so we use the policy change index in Shu & Ng (2009) and Xiong (2012).	N.A.
2000Q3	0		
2000Q4	0		
2001Q1	0	Aggregate money supply was generally been appropriate; basic capital demands of enterprises were met.	5
2001Q2	0	Money supply growth was moderate and corresponded to the needs of economic development.	1
2001Q3	0	Growth in the money supply was reduced, but basically suited economic development.	1
2001Q4	-1	Money supply growth returned to its normal trajectory through the application of various monetary policy instruments.	2
2002Q1	0	The money supply grew smoothly.	1
2002Q2	0	The money supply and credit grew smoothly.	1
2002Q3	-1	Money supply growth was boosted to support economic growth.	1
2002Q4	-1	The broad monetary aggregate measure, M2, as well as the narrower M1, showed higher growth in response to endogenous demand from economic recovery. Money and credit supplies were fundamentally consistent with the pace and desired trend of economic growth.	1
2003Q1	1	Money supply growth accelerated markedly and growth in lending of financial institutions increased sharply. Deposits with financial institutions were up significantly with a notable rise in household savings deposits.	1
2003Q2	1	The growth of the broad money M2 exceeded the sum of the growth of GDP and CPI by 12%. M2 growth was highest since 1998.	1
2003Q3	1	The money supply continued to grow rapidly. Lending growth by financial institutions remained excessive.	1
2003Q4	1	The overall growth of money and credit, which had expanded too fast in the first half of the year, was under control by the fourth quarter. The exchange rate was stable and the financial industry functioned smoothly.	1
2004Q1	1	Inflows of foreign exchange continued to increase. This led to excessive growth in the money and credit supplies, making it difficult to apply correctly proportioned fiscal and monetary measures.	1
2004Q2	0	Monetary and fiscal measures began to curb growth of money and credit supplies. The exchange rate remained stable and the financial industry ran smoothly.	1
2004Q3	0	Growth in the money and credit supplies moderated, while the structure of credit improved. Growth in money and credit supplies continued to fall and converged with PBoC targets.	1
2004Q4	0	From August to December, M2 growth was in the range of 13–15 %, which was quite appropriate and consistent with economic growth.	1
2005Q1	0	With the enhancement and improvement of the macro control, M2 growth has in the range of 13–15% for eight consecutive months. This is a level consistent with China's economic growth.	1
2005Q2	0	As of end-June, M2 growth had been unchanged for three months.	1
2005Q3	0	M2 growth accelerated, but growth of the loans granted by financial institutions was stable and structure of credit improved. Overall, macroprudential targets were met.	1
2005Q4	0	The growth of the money and credit was moderate, and the credit structure improved. Macroprudential targets were largely achieved.	1
2006Q1	1	The financial industry generally ran well. Growth of the money and credit supplies exceeded PBoC targets.	1
2006Q2	1	Excessive money supply growth fueled a large expansion of credit. The financial industry ran smoothly as a whole.	1

2006Q3	0	The high rate of money and credit supply increase began to abate. This slowing in growth was consistent with the goals of macroprudential regulation. This financial industry ran smoothly as a whole, but there was a slowdown of growth the credit supply due to lower M2 growth.	1
2006Q4	0	The period of very high growth in the money and credit supplies came to an end, which was in line with the macroprudential targets.	1
2007Q1	1	By implementing various macroeconomic measures, there were marked decreases in money and credit growth. Nevertheless, growth overall was still excessive in policy terms.	1
2007Q2	1	Adhering closely to guidance from the central government and the State Council, the PBoC implemented a series of measures to achieve macroprudential control and balance the economy. Money supply growth was still too high, but the high growth seemed to be abating.	1
2007Q3	1	The financial industry ran smoothly as a whole, but there was still considerable pressure from the expansion of money and credit supplies. The loan stock grew quite fast and money supply growth was unacceptably high.	1
2007Q4	1	By implementing various macroprudential measures, high growth in the money and credit supplies was moderated to some extent. Nevertheless, pressure for high credit and money growth remained. At year's end, M1 growth was 4.3% higher than M2 growth, indicating increased liquidity within the banking system.	1
2008Q1	1	Fixed capital investment remained excessively high and there was a spike in excess liquidity. The conditions for lower growth in money and credit supplies have yet to consolidate.	48
2008Q2	0	The rate of money supply growth slowed a bit and M2 growth stabilized.	1
2008Q3	0	Money supply growth was steady and liquidity in the financial system was adequate.	1; 5
2008Q4	-1	The PBoC implemented a moderately loose monetary stance according to arrangements laid out by the central government and the State Council.	8;9;10
2009Q1	0	Banking system liquidity was adequate, with rapid growth in the money and credit supplies. The financial system overall ran steadily.	1
2009Q2	0	The moderately expansionary monetary policy was effectively transmitted. The growth of money supply and credit should support the rebuilding of market confidence and return to China's traditionally high levels of economic growth.	1
2009Q3	0	The rapid growth of money supply and credit were designed to support economic recovery, and largely seem to have been effective.	1
2009Q4	1	Central bank measures implemented during the period caused a slowdown in the rapid expansion of credit. This should help in averting threats to long-term economic growth.	1
2010Q1	1	The growth of money supply and credit are on a path to return to normal levels.	1
2010Q2	1	The commitment to ending last year's high money supply growth and credit and returning to normal levels was reaffirmed.	1
2010Q3	1	Current conditions demand a gradual reduction in the growth of money supply to normal levels.	2
2010Q4	1	Efforts to gradually restrain money supply growth until normal levels are achieved were announced.	1
2011Q1	1	The primary goal of macroeconomic policy was to maintain the price stability. Efforts continued to slow growth of the money supply and gradually return to trend.	1
2011Q2	1	The primary goal of macroeconomic policy was to maintain the price stability. There was enhanced liquidity management and an effort to gradually return credit growth to normal levels.	1
2011Q3	1	Keeping price stability was the primary goal. Policy emphasized stable monetary conditions with enhanced management of bank liquidity.	1
2011Q4	-1	Moderate adjustments in monetary policy were made with a view to boosting economic growth.	1

Sources: The policy assessments for periods 2000Q2 to 2010Q4 are based on Xiong (2012). The final quarters are summarized from the official policy assessments in PBoC quarterly reports.

Appendix B

Important derivations

Starting with the bank's objective function,

$$\max \pi = L^* \left(\frac{l_0}{l_1} - \frac{L}{l_1} + \bar{r}_L - w \right) + \bar{r}_B^* \left[c_0 + \frac{(c_1 - \rho)(L + c_0 - K)}{1 - c_1} \right] - \left[\frac{L + c_0 - K}{(1 - c_1)e_1} - \frac{e_0}{e_1} + \bar{r}_D \right]^* \left(\frac{L + c_0 - K}{1 - c_1} \right) - r_K^* K - P \left(\frac{\theta L}{K} \right) V \quad (1)$$

the first-order condition to L,

$$\frac{d\pi}{dL} = \frac{l_0}{l_1} - \frac{2L}{l_1} + \bar{r}_L - w + \frac{\bar{r}_B^*(c_1 - \rho)}{1 - c_1} - \left[\frac{1}{(1 - c_1)e_1} \right]^* \left(\frac{L + c_0 - K}{1 - c_1} \right) - \left[\frac{L + c_0 - K}{(1 - c_1)e_1} - \frac{e_0}{e_1} + \bar{r}_D \right]^* \left(\frac{1}{1 - c_1} \right) - \frac{\theta}{K} P' \left(\frac{\theta L}{K} \right) V \quad (2)$$

and the second-order condition to L,

$$\frac{d^2\pi}{dL^2} = -\frac{2}{l_1} - \frac{2}{(1 - c_1)^2 e_1} - \frac{\theta^2}{K^2} P'' \left(\frac{\theta L}{K} \right) V < 0 \quad (3)$$

we take the total differentials with respect to r_b and ρ in (2):

$$\frac{d^2\pi}{dL^2} * \frac{dL^*}{dr_b} + \frac{d^2\pi}{dLdr_b} = 0 \quad (4)$$

$$\frac{d^2\pi}{dL^2} * \frac{dL^*}{d\rho} + \frac{d^2\pi}{dLd\rho} = 0 \quad (5)$$

such that we derive,

$$\frac{d^2\pi}{dLdr_b} = \frac{\bar{d}r_L}{dr_b} + \frac{c_1 - \rho}{1 - c_1} \frac{\bar{d}r_B}{dr_b} - \frac{1}{1 - c_1} * \frac{\bar{d}r_D}{dr_b} = \frac{-\rho}{1 - c_1} * \varphi < 0 \quad (6)$$

$$\frac{d^2\pi}{dLd\rho} = -\frac{\bar{r}_B}{1 - c_1} < 0 \quad (7)$$

and obtain the comparative statics of optimal loan supply L^* with (8) and (9)

$$\frac{dL^*}{dr_b} = \frac{\frac{d^2\pi}{dLdr_b}}{-\frac{d^2\pi}{dL^2}} = \frac{1}{\frac{2}{l_1} + \frac{2}{(1-c_1)^2 e_1} + \frac{\theta^2}{K^2} P''(\frac{\theta L}{K})V} * (\frac{-\rho}{1-c_1} * \varphi) < 0 \quad (8)$$

$$\frac{dL^*}{d\rho} = \frac{\frac{d^2\pi}{dLd\rho}}{-\frac{d^2\pi}{dL^2}} = \frac{1}{\frac{2}{l_1} + \frac{2}{(1-c_1)^2 e_1} + \frac{\theta^2}{K^2} P''(\frac{\theta L}{K})V} * (\frac{-\bar{r}_B}{1-c_1}) < 0 . \quad (9)$$

We next take the total differentials with respect to A, K and θ in (4),

$$\frac{d^3\pi}{dL^3} * \frac{dL^*}{dA} * \frac{dL^*}{dr_b} + \frac{d^3\pi}{dL^2 dA} * \frac{dL^*}{dr_b} + \frac{d^2\pi}{dL^2} * \frac{d^2L^*}{dr_b dA} + \frac{d^3\pi}{dL^2 dr_b} * \frac{dL^*}{dA} + \frac{d^3\pi}{dLdr_b dA} = 0 \quad (10)$$

$$\frac{d^3\pi}{dL^3} * \frac{dL^*}{dK} * \frac{dL^*}{dr_b} + \frac{d^3\pi}{dL^2 dK} * \frac{dL^*}{dr_b} + \frac{d^2\pi}{dL^2} * \frac{d^2L^*}{dr_b dK} + \frac{d^3\pi}{dL^2 dr_b} * \frac{dL^*}{dK} + \frac{d^3\pi}{dLdr_b dK} = 0 \quad (11)$$

$$\frac{d^3\pi}{dL^3} * \frac{dL^*}{d\theta} * \frac{dL^*}{dr_b} + \frac{d^3\pi}{dL^2 d\theta} * \frac{dL^*}{dr_b} + \frac{d^2\pi}{dL^2} * \frac{d^2L^*}{dr_b d\theta} + \frac{d^3\pi}{dL^2 dr_b} * \frac{dL^*}{d\theta} + \frac{d^3\pi}{dLdr_b d\theta} = 0 \quad (12)$$

as well as the total differentials with respect to A, K and θ in (5),

$$\frac{d^3\pi}{dL^3} * \frac{dL^*}{dA} * \frac{dL^*}{d\rho} + \frac{d^3\pi}{dL^2 dA} * \frac{dL^*}{d\rho} + \frac{d^2\pi}{dL^2} * \frac{d^2L^*}{d\rho dA} + \frac{d^3\pi}{dL^2 d\rho} * \frac{dL^*}{dA} + \frac{d^3\pi}{dLd\rho dA} = 0 \quad (13)$$

$$\frac{d^3\pi}{dL^3} * \frac{dL^*}{dK} * \frac{dL^*}{d\rho} + \frac{d^3\pi}{dL^2 dK} * \frac{dL^*}{d\rho} + \frac{d^2\pi}{dL^2} * \frac{d^2L^*}{d\rho dK} + \frac{d^3\pi}{dL^2 d\rho} * \frac{dL^*}{dK} + \frac{d^3\pi}{dLd\rho dK} = 0 \quad (14)$$

$$\frac{d^3\pi}{dL^3} * \frac{dL^*}{d\theta} * \frac{dL^*}{d\rho} + \frac{d^3\pi}{dL^2 d\theta} * \frac{dL^*}{d\rho} + \frac{d^2\pi}{dL^2} * \frac{d^2L^*}{d\rho d\theta} + \frac{d^3\pi}{dL^2 d\rho} * \frac{dL^*}{d\theta} + \frac{d^3\pi}{dLd\rho d\theta} = 0 \quad (15)$$

to derive the marginal effects of A, K and θ to (8) and (9).

With respect to A, we obtain

$$\frac{d^2 L^*}{dr_b dA} = \frac{\frac{d^3 \pi}{dL^3} * \frac{dL^*}{dA} * \frac{dL^*}{dr_b} + \frac{d^3 \pi}{dL^2 dA} * \frac{dL^*}{dr_b} + \frac{d^3 \pi}{dL^2 dr_b} * \frac{dL^*}{dA} + \frac{d^3 \pi}{dL dr_b dA}}{-\frac{d^2 \pi}{dL^2}} \quad (16)$$

$$\frac{d^2 L^*}{d\rho dA} = \frac{\frac{d^3 \pi}{dL^3} * \frac{dL^*}{dA} * \frac{dL^*}{d\rho} + \frac{d^3 \pi}{dL^2 dA} * \frac{dL^*}{d\rho} + \frac{d^3 \pi}{dL^2 d\rho} * \frac{dL^*}{dA} + \frac{d^3 \pi}{dL d\rho dA}}{-\frac{d^2 \pi}{dL^2}} \quad (17)$$

$$\frac{d^3 \pi}{dL^3} = \frac{d^3 \pi}{dL^2 dr_b} = 0 \quad (18)$$

$$\frac{d^3 \pi}{dL^2 dA} = \frac{2}{l_1^2} * \frac{dl_1}{dA} + \frac{2}{(1-c_1)^3 e_1} * \frac{dc_1}{dA} + \frac{1}{(1-c_1)^2 e_1^2} * \frac{de_1}{dA} > or < 0 \quad (19)$$

$$\frac{d^3 \pi}{dL dr_b dA} = \frac{-\rho}{(1-c_1)^2} * \varphi * \frac{dc_1}{dA} > 0 \quad (20)$$

$$\frac{d^3 \pi}{dL d\rho dA} = -\frac{\bar{r}_B}{(1-c_1)^2} * \frac{dc_1}{dA} > 0 \quad (21)$$

$$\frac{d^2 L^*}{dr_b dA} = \frac{\frac{d^3 \pi}{dL^2 dA} (sign = ?) * \frac{dL^*}{dr_b} (sign = -) + \frac{d^3 \pi}{dL dr_b dA} (sign = +)}{-\frac{d^2 \pi}{dL^2} (sign = -)} > or < 0 \quad (22)$$

$$\frac{d^2 L^*}{d\rho dA} = \frac{\frac{d^3 \pi}{dL^2 dA} (?) * \frac{dL^*}{d\rho} (sign = -) + \frac{d^3 \pi}{dL d\rho dA} (sign = +)}{-\frac{d^2 \pi}{dL^2} (sign = -)} > or < 0 \quad (23)$$

with respect to K,

$$\frac{d^2 L^*}{dr_b dK} = \frac{\frac{d^3 \pi}{dL^3} * \frac{dL^*}{dK} * \frac{dL^*}{dr_b} + \frac{d^3 \pi}{dL^2 dK} * \frac{dL^*}{dr_b} + \frac{d^3 \pi}{dL^2 dr_b} * \frac{dL^*}{dK} + \frac{d^3 \pi}{dL dr_b dK}}{-\frac{d^2 \pi}{dL^2}} \quad (24)$$

$$\frac{d^2 L^*}{d\rho dK} = \frac{\frac{d^3 \pi}{dL^3} * \frac{dL^*}{dK} * \frac{dL^*}{d\rho} + \frac{d^3 \pi}{dL^2 dK} * \frac{dL^*}{d\rho} + \frac{d^3 \pi}{dL^2 d\rho} * \frac{dL^*}{dK} + \frac{d^3 \pi}{dL d\rho dK}}{-\frac{d^2 \pi}{dL^2}} \quad (25)$$

$$\frac{d^3 \pi}{dL^3} = \frac{d^3 \pi}{dL^2 dr_b} = 0 \quad (26)$$

$$\frac{d^3 \pi}{dL^2 dK} = \frac{2}{(1-c_1)^3 e_1} * \frac{dc_1}{dK} + \frac{1}{(1-c_1)^2 e_1^2} * \frac{de_1}{dK} + \frac{2\theta^2}{K^3} P'' \left(\frac{\theta L}{K} \right) V > or < 0 \quad (27)$$

$$\frac{d^3 \pi}{dL dr_b dK} = \frac{-\rho}{(1-c_1)^2} * \varphi * \frac{dc_1}{dK} > 0 \quad (28)$$

$$\frac{d^3 \pi}{dL d\rho dK} = -\frac{\bar{r}_B}{(1-c_1)^2} * \frac{dc_1}{dK} > 0 \quad (29)$$

$$\frac{d^2 L^*}{dr_b dK} = \frac{\frac{d^3 \pi}{dL^2 dK} (\text{sign} = ?) * \frac{dL^*}{dr_b} (\text{sign} = -) + \frac{d^3 \pi}{dL dr_b dK} (\text{sign} = +)}{-\frac{d^2 \pi}{dL^2} (\text{sign} = -)} > or < 0 \quad (30)$$

$$\frac{d^2 L^*}{d\rho dK} = \frac{\frac{d^3 \pi}{dL^2 dK} (?) * \frac{dL^*}{dK} (\text{sign} = -) + \frac{d^3 \pi}{dL d\rho dK} (\text{sign} = +)}{-\frac{d^2 \pi}{dL^2} (\text{sign} = -)} > or < 0 \quad (31)$$

and with respect to θ ,

$$\frac{d^2 L^*}{dr_b dK} = \frac{\frac{d^3 \pi}{dL^3} * \frac{dL^*}{d\theta} * \frac{dL^*}{dr_b} + \frac{d^3 \pi}{dL^2 d\theta} * \frac{dL^*}{dr_b} + \frac{d^3 \pi}{dL^2 dr_b} * \frac{dL^*}{d\theta} + \frac{d^3 \pi}{dL dr_b d\theta}}{-\frac{d^2 \pi}{dL^2}} \quad (32)$$

$$\frac{d^3 \pi}{dL d\rho d\theta} = \frac{d^3 \pi}{dL dr_b d\theta} = \frac{d^3 \pi}{dL^3} = \frac{d^3 \pi}{dL^2 dr_b} = 0 \quad (33)$$

$$\frac{d^3 \pi}{dL^2 d\theta} = -\frac{2\theta}{K^2} P'' \left(\frac{\theta L}{K} \right) V < 0 \quad (34)$$

$$\frac{d^2 L^*}{dr_b d\theta} = \frac{\frac{d^3 \pi}{dL^2 d\theta} (\text{sign} = -) * \frac{dL^*}{dr_b} (\text{sign} = -)}{-\frac{d^2 \pi}{dL^2} (\text{sign} = -)} > 0 \quad (35)$$

$$\frac{d^2 L^*}{d\rho d\theta} = \frac{\frac{d^3 \pi}{dL^2 d\theta} (\text{sign} = -) * \frac{dL^*}{d\rho} (\text{sign} = -)}{-\frac{d^2 \pi}{dL^2} (\text{sign} = -)} > 0 . \quad (36)$$

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