Monetary Policy with a Touch of Basel

Abstract

The unfolding subprime crisis and the challenges facing central banks in using monetary policy to resolve the possible credit crunch, highlight the importance of understanding the relationship between monetary policy and risk-based capital requirements. We explore the implications of risk-based capital requirements, à la Basel, for the conduct of monetary policy. A "bank balance-sheet channel" of monetary policy is identified, which operates through bank capital and influences the bank's loan decision. Using a dynamic banking model, we endogenize the capital decision and show that banks are likely to hold capital above the regulatory minimum to avoid being constrained. We derive the option value of holding capital, and show how this value is affected by monetary policy, level of economic activity, structure of the banking industry, and by changes in the level of regulatory capital.

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1. INTRODUCTION

The ongoing subprime crisis illustrates the interconnection between regulatory constraints and the effectiveness of monetary policy.[1] Recently, the top 25 banks in the United States (Europe), which had 8.3% (8.1%) Tier 1 capital and 11.4% (11.6%) in the form of total capital in the third quarter of 2007 (right before the substantial losses due to subprime lending), had to raise more than $270 Billion of new capital to increase their ability to issue new loans.[2] Thus the ability of the Federal Reserve and the ECB to stimulate the economies of countries affected by the subprime crisis was limited by the availability of required capital.

A growing body of research has now documented the implications of the new risk-based capital requirements for the banks' behavior, in particular for asset portfolio allocation and lending behavior.[3]Over the last twenty years, the Basel Accord, originally developed for the G-10 countries, was gradually adopted by a large percentage of countries in the world.[4] A growing body of research has documented the implications of the new risk-based capital requirements for the banks' behavior, in particular for asset portfolio allocation and lending behavior.[5] While some of the implications were clearly intended by the designers of the Basel Accord, there is now consensus on the unintended effects of the capital requirements on the banks' behavior. Recently, a number of papers have pointed out that Basel type risk-based capital requirements may have contributed to the credit crunch of the early 90s in the US and in other emerging economies, and induced banks to engage in what is now referred to as "regulatory capital arbitrage."[6] This has given rise to a debate on the optimal design of

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[1] See VanHoose (2008), Giles and Tett (2008), and BIS (2008).

[2] See Thomson Financial (2007). More specifically, CitiGroup announced in their Fourth Quarter 2007 Earnings Review that they raised $12.5 Billion of capital January 15, 2008. This action raised their Tier 1 (Total capital ratio) capital ratio to 6.6% (8.2%), since their Tier 1 capital ratio fell from 6.7% (8.3%) in the first quarter of 2007 to 5.7% (7.1%) in the fourth quarter of 2007. The Tier 1 capital ratio must be above 6% for a bank to be classified as "well capitalized" in the United States.

[3] In fact, most banks focus on capital as the binding constraint in deciding whether to issue a loan. A bank identifies the risk-adjusted rate of return on a particular loan. This rate of return must exceed the return on capital for the loan to be funded.

[4] See Barajas, Chami and Cosmano (2004) for adoption dates for 125 countries.

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[6] See Bernanke and Lown (1991), Chiuri, Ferri and Majnoni (2002), and Jones (2000), among others. See also Kupiec (2001) for a critique.

bank regulations and supervision measures that rely on capital as a sufficient statistic, but which recognize the incentive effects of risk-based capital requirements on bank behavior. With the push towards global harmonization of bank regulations and the increased reliance on capital adequacy ratios to control bank behavior, the question now becomes, what are the implications for the conduct of monetary policy?

In this paper, we show that, under Basel-type capital requirements, monetary policy will influence a bank's capital and, as a result, its lending behavior. We develop a dynamic model in which risk neutral banks are assumed to maximize the present value of all future profits, subject to a total capital constraint in an imperfectly competitive banking industry. To mimic the Basel Accord the loans are restricted based on the amount of total capital determined in the previous quarter. This industry structure implies that the optimal net interest margin on loans is usually above the marginal resource cost of deposits and loans such that there usually are economic profits. We show that in anticipation of the possibility that the total capital constraint binds, and its negative impact on bank profits, the bank will choose an optimal level of total capital this quarter to minimize the possibility of the total capital constraint binding next quarter subject to a marginal cost of total capital. Thus, banks in this world find it optimal to hold capital above the regulatory level.[7]

Monetary policy, in this model, influences the bank's decision to extend credit, by affecting the option value of holding bank capital, and the bank's equity decision. For example, a tight monetary policy, which raises the federal funds rate, will induce the bank to raise its current and future deposit rate. In the presence of an imperfectly competitive loan market, the bank will also reduce the net interest rate margin between loan and deposit rates. Moreover, the persistent increase in the deposit rate will raise the marginal cost of funding, which all else being equal, reduces the supply of future loans and the probability that the capital constraint will bind during the next quarter. This reduces the option value of holding more capital. As a result, the bank will hold less equity this quarter, which further reduces the supply of loans issued next quarter. Thus, contractionary monetary policy, through the decline in the bank's total capital, leads to a decline in loans in the next quarter. By affecting the bank capital, monetary policy affects the capacity of banks to lend. This gives rise to a "bank capital financial accelerator" in our model, which is distinct from the well known financial accelerator discussed in the literature; the latter arises due to the impact of the monetary policy on the balance sheet of borrowers, and, consequently, on the demand for loans. Nevertheless, the two effects, one arising from the supply side of loans and the other from the demand side for loans, together amplify the impact of monetary policy on the economy.

[7] Barajas, Chami, and Cosimano (2004) provide evidence that the total capital and Tier 1 ratios are significantly above the Basel regulation for 125 countries.

Capital regulations are shown to introduce asymmetries in the impact of monetary policy on the supply and cost of loans.[8] For example, when the capital constraint binds and there is an easing of monetary policy, the resulting drop in the marginal cost of loans will not generate the desired increase in the quantity of loans or a drop in the loan rates. In fact, in this case, the lower marginal cost of lending only results in lower deposit rates and higher profits for the capital-constrained banks. On the other hand, a rise in the marginal cost of lending, due to a tightening of monetary policy, will generate the desired quantity and price effects.

This asymmetry is also present in the impact of demand for loan shocks on the initial supply of loans. When the capital constraint is binding, a sudden rise in the demand for loans (perhaps generated by a booming economy) would only translate into higher loan rates, as banks are prevented from extending more loans due to the presence of the capital constraint. On the other hand, a sudden drop in the demand for loans will result in lower rates and a lower supply of loans.

Finally, an important implication of our work suggests that Basel type capital requirements may actually induce greater price collusion among banks in a given market. Rotemberg and Saloner (1986) showed earlier that implicit collusion on price can breakdown resulting in a price war, when there is a significant increase in the demand for a firm's output. We show that in the case of an oligopolistic banking industry, the possibility of a price war is in fact reduced by the presence of regulatory capital requirements. These regulatory constraints limit a bank's ability to expand the supply of loans to benefit from an increase in the demand for loans. Thus, by reducing the expected profits from undercutting other banks, the new capital requirements may inadvertently favor collusive behavior at the expense of price competition.

The rest of the paper is organized as follows: the next section provides a survey of the relevant literature. Section 3 establishes the relationship between the total capital constraint under the Basel Accord and the bank's balance sheet. Section 4 introduces the model of bank behavior under an oligopolistic industry structure. Section 5 analyzes the impact of monetary policy under the Basel Accord. Section 6 concludes.

2. RELATED LITERATURE

Several papers have analyzed the impact of monetary policy on banks with capital constraints, but with differing conclusions.[9] Whether monetary policy affects bank lending

[8] Kishan and Opiela (2006) provide evidence for the asymmetric effect of monetary policy after the introduction of the Basel Accord in the United States.

[9] There is also work dealing with the optimal capital holding form banks and the regulation of these decisions. See Koehn and Santomero (1980), Rochet (1992), Dewatripont and Tirole (1993), Froot and Stein (1998), Santos (1999), Jayaratne and Morgan (2000), and Kashyap, Rajan and Stein (2002). See Berger, Herring and Szego (1995) and Santos (2001) for surveys of this work.

or not depends on the assumption that bank loans are financed by reservable deposits, or on the imperfect elasticity of the supply of nonreservable deposits.[10] For example, Labadie (1994), using an overlapping generations framework, shows that the addition of capital constraints on banks has no real effect. This result hinges on the assumption that banks can costlessly raise equity or external funds. On the other hand, Kopecky and VanHoose (2004a, 20004b), in deterministic models, assume an increasing marginal cost of equity in a competitive banking industry with capital constraints binding in the short term. Monetary policy in their framework has real effects. Thakor (1996), using an asymmetric information model of bank lending, but maintaining the assumption of costly external funds, shows that monetary policy impacts bank lending. Bolton and Freixas (2000) provide an asymmetric information explanation for the high cost of external funds for banks. In a general equilibrium model, they demonstrate how an open market sale of securities decreases the net interest margin for the bank, which shifts lending away from firms with poor projects. Firms with positive net present value projects as well as banks, on the other hand, shift away from bonds, since they are crowded out by government bonds. However, with the total capital constraint always binding, the total amount of lending does not change. Van den Heuvel (2001), using a dynamic model of banking, analyzes the role of "bank capital channel" in the transmission of monetary policy. Banks in his model fail to fully hedge interest rate risk. He shows through simulations that the resulting interest rate mismatch implies that monetary policy affects the supply of loans through its impact on the value of bank capital.

In our framework, the presence of imperfect competition in the banking industry is important for the transmission of monetary policy through the "bank balance-sheet channel." There is ample evidence to justify this assumption since there is a high degree of concentration within the banking industry in various countries around the world.[11] In addition, De Bandt and Davis (2000) use a test of contestability to find anti-competitive behavior in Europe and the United States. Claessens and Laeven (2004) also use this test to find noncompetitive pricing in 50 countries over the time period 1994-2001. There are also several papers that provide indirect evidence of anti-competitive pricing in the U. S. banking industry.[12] Thus, we choose to model the banking industry as oligopolistic.

While the role of asymmetric information is not explicitly modeled in this paper, however some of the assumptions made accord with the presence of information problems. For example, the presence of market power in the banking industry and the bank-dependence of some borrowers can be attributed to the private information that banks possess with regard to

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[10] Kashyap and Stein (1995) and Stein (1998) make this point.

[11] See Cetorelli and Gambera (2001).

[12] See Berger, Bonime, Covitz, and Hancock (2000), and Cosimano and McDonald (1998).

the quality of the loans.[15] Moreover costly equity and the fact that banks, in this paper, maintain an endogenously determined, positive level of equity can also be linked to the role of internal equity as a signaling device, when information asymmetries exist. However, it is feasible within the present framework to accommodate imperfect information assumptions, be it on the borrower's or lender's side.

Before proceeding further with the analysis of bank behavior under the Basel capital requirements, we will first highlight the main features of the Basel capital requirements as they pertain to a bank's balance sheet, and the market value of its capital.

3. THE BASEL ACCORD AND FINANCING TOTAL CAPITAL

The Basel Accord defines both capital and risk adjusted assets. Capital has two components: Tier 1, in principal, is the book value of bank capital defined as the difference between the accounting value of assets and liabilities;[16] Tier 2 basically consists of preferred stock and subordinated debt. Total capital is the sum of Tier 1 and Tier 2 capital. While there are several capital constraints associated with the Basel Accord it is easy to show that the binding constraint is the total capital constraint. The total capital constraint requires that the sum of Tier 1 and Tier 2 capital be no less than 8% of risk adjusted assets. We assume for simplicity that there is only one type of capital, b_t, which pays the return r_t^b. In addition, this total capital is reissued at market prices every period so that b_{t+1} is the market value of capital and b_t is the book value of capital.[17] In order to maintain the book value feature of regulatory capital and its sensitivity to market valuation, we assume that last quarter's market value of capital determines the capital constraint facing the bank this quarter.[18]

Risk adjusted assets are defined by placing each balance sheet and off-balance sheet item into a risk category. The more risky assets are assigned a larger weight. Category 1 is mainly cash and treasury securities and has zero weight. Category 2 is more risky marketable securities and has a weight of 20%. Category 3 is essentially loans connected with home mortgages and

[15] See Holmstrom and Tirole (19997), Bolton and Freixas (2000), and Kashyap and Stein (2000).

[16] See Koch and MacDonald (2000 chapter 13) for complete specification.

[17] Kane and Unal (1990) estimate the correlation between the book value and the market value of bank capital to be around 95%. Moreover, the push in the accounting profession toward the market valuation of bank assets and liabilities further erodes the perceived difference between the accounting and the economic value of bank capital.

[18] See Dewatripont and Tirole (1993, chapter 9) for a discussion of how historical cost accounting introduces a measurement error into the monitoring of banks.

has a weight of 50%. Category 4 is given a weight of 100% and consists of loans to private agents.[19] As a result, risk adjusted assets are a weighted average of the various assets of the banks. It is assumed that there are two assets in the banking model: loans, L_t, and treasury securities, T_t. Consequently, the risk adjusted assets in the model constitute the amount of loans issued by the bank.

Let θ be the ratio of total capital to loans so that the total capital constraint is

$$\theta L_t \leq b_t \ . \tag{1}$$

To establish the relation between bank profitability and the Basel Accord, a model of bank financing is introduced following Altuğ and Labadie (1994, pp. 165-168). For now let profits of the bank, π_t, be given. The profits are used to meet the bank's obligations. These obligations include the payment of the promised return on capital, $r_t^b b_t$. The bank also pays a marginal deadweight cost of total capital τ_t which is imposed on new capital b_{t+1}. The retained earnings, after these payments are made, are given by the following condition

$$re_t = \pi_t - r_t^b b_t - \tau_t b_{t+1} \ .$$

Following Holmstrom and Tirole (1997), Stein (1998), Froot and Stein (1998), Bolton and Freixas (2000), and Repullo and Suarez (2000), we assume that there is a constant marginal cost of total capital, τ. This assumption is meant to capture the various arguments for a higher cost of external capital, such as asymmetric information and monitoring costs. We could make this external cost of total capital a non-linear function of the level of total capital, but this would not materially influence this argument.

To understand the impact of retained earnings on the capital of the bank we start with the bank balance sheet at time t+1

$$L_{t+1} = D_{t+1} + b_{t+1} + S_{t+1} \ .$$

Here L refers to loans, D is deposits, and S is the undistributed profits of the bank. The subscript refers to the time period. For simplicity we ignore investment in plant and equipment. Next look at the change in the balance sheet of the bank

$$\Delta L_{t+1} = \Delta D_{t+1} + \Delta b_{t+1} + \Delta S_{t+1} \ .$$

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[19] The off balance sheet items are placed in similar types of categories. See Koch and MacDonald (2000, chapter 13).

It is assumed that the bank funds its loans with deposits $\Delta L_{t+1} = \Delta D_{t+1}$, since the marginal cost of deposits is less than the marginal cost of equity. In addition, the change in undistributed profits is given by retained earnings in the previous period, $\Delta S_{t+1} = re_t$. Consequently, the financial constraint of the bank is given by

$$re_t = [b_t - b_{t+1}].$$

So that retained earnings are used to buy back total capital. If the expression for retained earnings is substituted into this condition, the profits of the banks are given by

$$\pi_t = (1 + r_t^b)b_t - (1 - \tau_t)b_{t+1}.$$

Solving for the new total capital we have

$$b_{t+1} = \frac{1}{1 - \tau_t}\left[(1 + r_t^b)b_t - \pi_t\right] .$$

Consequently, the new total capital is based on the financial payments of the bank minus its profits. As a result, the bank's decisions today influence the future value of total capital for the bank. This equation of motion for the total capital is a constraint that is imposed on the bank's optimization problem in the next section. Note that, using accounting rules for the bank's book value of total capital (see Koch and McDonald (2003) chapter 3) would result in the same equation of motion for total capital. An argument for using the book value of capital rather than the market value of capital is that the market value of capital is forward looking whereas the book value of capital is backward looking. To capture this book value effect, we use the market value of capital in the previous period in condition (1) to represent the Basel Accord constraint. We will show, however, that despite the introduction of this backward-looking aspect of bank capital, the bank is still forward looking since the bank will attempt to anticipate when the future total capital constraint is binding.

In the next section we develop the bank's optimal behavior for a bank with market power, and derive results that highlight the implications of the capital adequacy requirements for bank behavior.

4. Bank's Behavior in an Oligopolistic Industry

To establish the impact of monetary policy under the Basel Accord, we consider the behavior of a bank operating in an oligopolistic industry, where banks enjoy market power.[21] We

[21] Market power in the banking industry can also be introduced using alternative frameworks. For example, VanHoose (1985) discusses monetary policy within a banking model with Cournot competition. Keeley (1990) looks at the impact of monopoly power on the Tobin Q for a bank. Pecchenino (1998) assumes risk adverse bank managers choose loans subject to (continued)

assume that an individual bank precommits to a quantity of loans through its dividend policy this quarter, which is followed by loan rate competition in the next quarter. Thus, the banking industry here is characterized as a super game of oligopolistic behavior, following Abreu, Pearce, and Stacchetti (1990) and Rotemberg and Saloner (1986). The basic idea is to have each bank follow a coordinated policy for setting the loan rate as long as the other banks follow the same policy. If any bank undercuts this loan rate, then it is punished with Bertrand competition, in which the net interest margin between loans and deposits is set equal to its marginal resource cost.

We first characterize the cooperative behavior of the banks. In the cooperative solution the industry follows the monopoly solution in which each bank receives an equal share of the market. The bank, which represents the industry, is assumed to maximize its total market value, which includes the payments to total capital holders. While the loan market is assumed to be imperfectly competitive, the deposit market is assumed to be perfectly competitive, so the bank takes the deposit rate as given. The bank enters the current quarter with a predetermined level of total capital and chooses the loan rate and total capital for the next period. Note that the total capital decision is intertemporal because current profits determine the amount of total capital available next quarter, which, in turn, restricts the supply of loans next period.

4.1 Optimal Bank Behavior

The bank attracts deposits, D_t, at a fixed marginal cost, c_D. This marginal resource cost represents the cost of check clearing and bookkeeping for these deposits. Deposits serve as money in the economy excluding currency, *i.e.*, they are components of *M*2. It is assumed that the supply of deposits by individuals is still positive, even when the deposit rate, r_t^D, is below the treasury rate by the marginal cost of deposits.[22]

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the optimal behavior of the other risk adverse bank managers within a static context. Stein (1998) assumes that risk neutral banks choose the loan rates subject to an increasing marginal cost of loans in a two period framework. Bagliano, Dalmazzo, and Giancarlo (2000) also follow Rotemberg and Saloner (1986), but they do not consider capital constraints.

[22] This can be rationalized by either the transaction services provided by bank deposits or the existence of deposit insurance. Mulligan (1997) provides estimates for the supply of deposits by firms. Mulligan and Sala-i-Martin (2000) do the same for individuals. They find that the key issue is individuals' decision to use banking services. Once they do, the key variable is the product of the spread between treasury rates and deposit rates times the amount of financial assets. Labadie (1994) demonstrates the impact of deposit insurance on the optimal behavior of banks within a general equilibrium model.

These funds are lent out by the bank as one period loans, L_t, at the loan rate, r_t^L.[23] These loans have a constant marginal cost, c_L, which represents the cost of monitoring and screening loans. The bank faces a demand for loans given by

$$L_t = l_0 - l_1 r_t^L + l_2 M_t + \varepsilon_{L,t}.$$

Here, M_t is a generic variable that represents the level of economic activity in the bank's loan market, and $\varepsilon_{L,t}$ is a random shock to the demand for loans that has support $[\underline{L}, \overline{L}]$ and is independent of the exogenous state vector x_t. This exogenous state vector includes the deposit rate r_t^D, and economic activity M_t. $F(\cdot)$ is the cumulative distribution of the shock to loans. The elasticity of demand is $\frac{l_1 r_t^L}{L_t}$, which would tend to ∞ in a perfectly competitive environment.

The bank's problem is to maximize its total market value of the bankby choosing the loan rate, deposits, and total capital at time t+1, given the current state of total capital.

$$V(b_t, x_t) = Max\left\{\pi_t + \lambda_t\left[b_t - \theta L_t\right] - r_t^b b_t - \tau_t b_{t+1} + E_t\left[m_{t,1} V\left(b_{t+1}, x_{t+1}\right)\right]\right\} \tag{2}$$

subject to

$$\begin{aligned} \pi_t &= r_t^L L_t - r_t^D D_t - c_L L_t - c_D D_t, \\ L_t &= l_0 - l_1 r_t^L + l_2 M_t + \varepsilon_{L,t}, \\ b_{t+1} &= \frac{1}{1-\tau_t}\left[(1 + r_t^b)\, b_t - \pi_t\right], \end{aligned} \tag{3}$$

and

$$L_t = D_t + b_t\ .$$

Here, λ_t is the Lagrange multiplier for the total capital constraint, $E_t[z]$ is the expectation of z conditional on the bank's information at time t and $m_{t,1}$ is the investor's stochastic discount factor for valuing payments in one quarter. The bank's information set includes all

[23] The bank-dependence of borrowers has been the subject of previous research by Kashyap and Stein (1995, 1997) and Cooley and Quadrini (2001). Peterson and Rajan (1994) look at evidence on the demand for loans by small businesses.

current random shocks denoted by subscript t, as well as how long these shocks persist into the future. However, the bank does not know all future shocks denoted by $t+j$ for $j=1,\ldots\infty$.

The optimal conditions for the bank's choice of loan rate, deposits, and total capital are[24]

$$\frac{\partial \pi_t}{\partial r_t^L}\left[1+\frac{\tau_t}{1-\tau_t}-\frac{1}{1-\tau_t}E_t\left\{\int_{\underline{L}}^{\bar{L}} m_{t,1}\frac{\partial V}{\partial b_{t+1}}\,dF(\varepsilon_{L,t+1})\right\}\right]+\lambda_t\theta\, l_1=0,$$
$$\theta_2 L_t \le b_t, \tag{4}$$

and

$$-\tau+E_t\left\{\int_{\underline{L}}^{\bar{L}} m_{t,1}\frac{\partial V}{\partial b_{t+1}}\,dF(\varepsilon_{L,t+1})\right\}=0. \tag{5}$$

Here the marginal value of the bank is

$$\frac{\partial V}{\partial b_t}=\lambda_t+r_t^D+c_D-r_t^b\ . \tag{6}$$

Substituting the optimal decision for bank's total capital (5) into the optimal decisions for the loan rate (4) reveals that this decision can be solved independent of time. Remarkably, this result would follow no matter how complicated we make the external cost of total capital, because the envelope theorem would still hold. Interestingly, the separation of the optimal total capital decision of the bank from the other bank's decisions implies that the behavior of the bank can be generalized to account for dynamic elements in the bank's decision without technical difficulty.[25]

The structural model of the bank (2) and (3) may be viewed as a basic skeleton which may be enhanced to incorporate more realistic aspects of bank's decisions in the face of capital constraints. First, the *ad hoc* demand for loans can be replaced with the reduced form for an optimal loan contract along the lines of Bernanke, Gertler, and Gilchrist (1999). Second, loan defaults can be included such that they increase during recessions as in Zicchino (2004).

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[24] The conditional expectation refers to the future random shocks to the state vector as well as the shock to the demand for loans. We explicitly write the conditional expectation with respect to the shock to the demand for loans since this shock determines the option value of the bank's capital.

[25] See Cosimano (1988), and Cosimano and Van Huyck (1989).

Third, Ayuso, Perez and Saurina (2004), Kashyap and Stein (2004), and Estrella (2004) demonstrate that the Basel II makes the total capital ratio inversely related to the default probabilities of loans. Zicchino (2004) also incorporates this effect into our model. Fourth, the distinction between book and market value of capital can be more distinct. In particular, a random change in the loan loss reserve may be added to the market value of total capital. This would lead to an increase in the uncertainty that the capital constraint will bind next period so that the bank would tend to hold a larger amount of total capital to guard against the imposition of the constraint in the future. Fifth, the bank could have a demand for total capital independent of regulation based on the possibility that the bank may go into costly bankruptcy as in Rochet (1992), Decamps, Rochet, and Roger (2004), Barrios and Blanco (2003), Froot and Stein (1998), Labadie (1994), and Koehn and Santomero (1980). However, the main message of this paper would still hold in that total capital regulation generates an option value which leads the banks to hold more total capital than required by the regulation.

4.2 Optimal Bank Capital

The separation of the dividend policy from the bank's loan rate and deposit decision makes the determination of the optimal quantity of loans and loan rate straightforward. When the total capital constraint is not binding, the optimal level of loans occurs, where the marginal revenue from loans is equal to the marginal cost of loans, $c_L + r_t^D + c_D$. In this case an increase in the exogenous demand for loans, $l_0 + l_2 M_t + \varepsilon_{L,t}$, leads to an increase in the quantity of loans and in the loan rate. Moreover, a decrease in the marginal cost of loans causes an increase in the quantity of loans and a decrease in the loan rate. In both cases the profits of the bank increase.

The presence of the capital constraint, however, introduces an asymmetry in the impact of changes in the demand for loans or in the marginal cost of loans, on the price and quantity of bank loans. When the total capital constraint binds, an increase in the demand for loans or a reduction in the marginal cost of loans will not lead to an increase in the supply of loans. At the critical level of loans, $L_t^* = \frac{b_t}{\theta}$, any additional demand or decrease in the marginal cost of loans no longer impact the amount of loans. At this level, the loan rate is determined by the demand for loans. As a result, further increases in the demand for loans will increase the loan rate, but not the quantity of loans. This increase in the loan rate does lead to more profits. However, these profits would be higher if the total capital constraint were not binding, since the capital-constrained bank is prevented from increasing loans even though marginal revenue is above the marginal cost of loans.

Given the expected demand for loans and marginal cost of loans, it is possible to solve for a critical shock to the demand for loans, $\varepsilon_{L,t}^*$, so that the total capital constraint will just bind, *i.e.*, $L_t = L_t^*$. It turns out that the marginal value of total capital, $\lambda_t^* = \frac{\varepsilon_{L,t} - \varepsilon_{L,t}^*}{l_1 \theta} = 2\frac{L_t - L_t^*}{l_1 \theta}$. As a

result total capital is only useful to the bank when a shock to loan demand is above this critical value.

The bank views the marginal value of total capital as a call option with strike price, $\varepsilon^*_{L,t}$ as in Figure 1. The marginal payoff, when the option is in the money, is $\frac{1}{l_1\theta}$ for each additional increase in loan demand. Thus, this marginal payoff is smaller when either the degree of monopoly power falls or the total capital ratio increases. In both cases, relaxing the total capital constraint implies that a marginally higher total capital yields a smaller possible change in the optimal loan rate and profits.

In setting the optimal dividends this quarter, the bank realizes that there is a chance that the total capital constraint is binding next quarter. The cost of this constraint binding is λ^*_{t+1}, which is positive only for $\varepsilon_{L,t+1} > \varepsilon^*_{L,t+1}$. The value of this call option is dependent on the degree of uncertainty in loan demand. Let σ measure a mean preserving spread of the distribution of the shock to the demand for loans. As the next result shows, $\varepsilon^*_{L,t+1}$ is positively related to the current quarter's total capital, since more capital makes it less likely the bank would face a limitation on its loans next quarter. This argument leads to the following:

Proposition 1 *The bank's optimal total capital decision is based on a comparison of the net marginal cost of total capital with the value of a call option. This call option has a strike price* $\varepsilon^*_{L,t+1} = 2\frac{b_{t+1}}{\theta_2} - \left[l_0 + l_2 M_{t+1}\right] + l_1\left[c_L + r^D_{t+1} + c_D\right]$. *In addition, the marginal payoff is*

$$\begin{cases} \frac{1}{l_1\theta} \text{ if } \varepsilon_{L,t+1} > \varepsilon^*_{L,t+1} \\ 0 \text{ if } \varepsilon_{L,t+1} \le \varepsilon^*_{L,t+1} \end{cases}.$$

In choosing total capital, the bank compares the marginal cost of total capital with the expected marginal benefit of total capital. The expected marginal benefit of additional total capital has two components. The first component arises because additional equity or bonds reduces the marginal cost of raising deposits in the next quarter. To the extent that the bank has more total capital, the bank does not have to attract as many deposits next quarter. The difference between these two terms is called the net marginal cost of total capital. The second marginal benefit of total capital is the expected marginal benefit from the total capital constraint being reduced in the next quarter, λ^*_{t+1} which is only in the money when the shock to loan demand exceeds the strike price for the call option.

4.3 Banking Industry Equilibrium

We can now discuss the equilibrium in the banking industry. The Bertrand equilibrium would result in the competitive loan rate equal to the marginal cost of loans $c_L + r_t^D + c_D$. An alternative trigger strategy equilibrium can be described as follows: each bank charges the monopoly loan rate and issues $\frac{1}{N}$ of the loans that maximize the banking industry's profits, as long as no bank has deviated from this strategy. The individual firm raises total capital $\frac{b_{t+1}}{N}$, and earns $\frac{1}{N}$ of the profits. If a bank follows this strategy, then the value of the bank is

$$\begin{aligned}\tfrac{1}{N} v(b_t, x_t) = \tfrac{1}{N} \{ & \pi_t - \tau_t b_{t+1} - r_t^b b_t \\ & + \sum_{i=1}^{\infty} E_t \left[m_{t,i} \left(\int_{\underline{L}}^{\varepsilon^*_{L,t+i}} \pi_{t+i} dF(\varepsilon_{L,t+i}) + \int_{\varepsilon^*_{L,t+i}}^{\overline{L}} \pi^*_{t+i} dF(\varepsilon_{L,t+i}) - \tau_{t+i} b_{t+1+i} - r^b_{t+i} \right) \right] \}. \end{aligned} \tag{7}$$

Now an individual bank can renege on the deal by setting the loan rate slightly below the rate charged by every other bank. Interestingly, here the bank's benefit from reneging is restricted by the constraint on loans, $\frac{b_t}{N\theta}$. There is no benefit to undercutting the other banks when the shock to loans is above its critical value, given in Proposition 1, since the bank is not allowed to issue additional loans at the lower rate. The bank would only undercut the other banks when the shock is significantly below this critical value. Even in this case the benefit of undercutting the loan rate is limited by the additional sales being only $\frac{1}{N}\left[\frac{b_t}{\theta} - L_t\right]$ where the loans are unconstrained. The total gain from undercutting the loan rate is

$$\pi_t^U = \frac{1}{N}\left[\frac{b_t}{\theta} - L_t\right]\left[r_t^L - \left(c_L + r_t^D + c_D\right)\right],$$

This result is opposite of that reached by Rotemberg and Saloner (1986). In their model, an oligopolistic firm is more willing to undercut the cooperative price when the demand for the product is high, since it is then that the benefit from undercutting the other firms is highest. But, depository institutions face an additional constraint, for under the Basel Accord a bank cannot undercut the cooperative price, because the bank comes up against the total capital constraint. If the bank could secretly raise total capital, then it would be more likely to undercut the loan rate since this would lessen the constraint on total capital. Presumably, the bank would do this in the case of high loan demand as in Rotemberg and Saloner (1986). The problem with this is that secret attempts to raise additional capital could become public through SEC filings in the United States.

In the event that a bank undercuts the cooperative loan rate the other banks are assumed to follow a punishment strategy. For example the banks could respond by setting the loan rate

equal to the Bertrand level indefinitely. In this case the bank would earn zero economic profit. The bank suffers a net penalty of $E_t\left[m_{t,1}V_{t+1}^C\right]=\frac{1}{N}E_t\left[m_{t,1}V\left(q_t s_{t+1}+b_{t+1},x_{t+1}\right)\right]$. Thus, the bank undercuts the loan rate only in the case of $\pi_t^U > \pi_t + E_t\left[m_{t,1}V_{t+1}^C\right]$. This discussion leads to the following result

Proposition 2 *If a bank does not undercut the cooperative loan rate when the quantity of loans is given by* $\frac{1}{4}L_t^*$, *then a bank will never find it optimal to undercut the cooperative loan rate. In the case where it does, there is a finite neighborhood of this quantity of loans such that the bank reneges on the cooperative solution. In addition, the upper bound on this neighborhood is significantly below,* $L_t = L_t^*$.

The above Proposition has a very important implication for collusive behavior among banks, for it implies that the probability of cooperative behavior among the banks is higher under the Basel Accord. The bank would never undercut the loan rate at the constrained level of loans, since the bank cannot expand its loans beyond the regulatory constraint. Thus, the bank does not undercut the loan rate when there is a high demand for loans. In addition, the gain in profits from undercutting is maximized at the quantity of loans, $\frac{1}{4}L_t^*$. If profits from undercutting the loan rate at this shock are not greater than the penalty imposed on the bank, then the bank would always find it optimal to cooperate with the other banks.

4.4 Comparative Static Analysis

Here, we show that higher capital requirements, à la Basel, are likely to increase the option value of holding equity and with it, loan supply. However, they may also increase the incentives for risky behavior on the part of the bank, since the value of the call option rises. Moreover, greater uncertainty regarding the demand for loans raises the possibility that the capital constraint will bind in the future, which increases the option value of holding more capital for the bank, so as to avoid being constrained.

In making these evaluations, the bank needs to know the stochastic behavior for economic activity and the deposit rate, which are part of the exogenous state vector, x_t. Assume that they follow first order autoregressive stochastic processes

$$M_{t+1} = \rho_M M_t + \varepsilon_{M,t+1},$$
and (8)
$$r_{t+1}^D = \rho_{r^D} r_t^D + \varepsilon_{r^D,t+1},$$

where $\varepsilon_{M,t+1}$ and $\varepsilon_{r^D,t+1}$ are mean zero stochastic shocks to economic activity and the deposit rate, respectively.

The optimal behavior of the bank's total capital is described by

Proposition 3 *If the marginal deadweight cost of total capital is zero, then the bank would raise sufficient capital to completely circumvent the total capital constraint. Otherwise, the total capital of the bank satisfies*

$$b_{t+1} = h\Big(\tau - \big\{E_t\big[m_{t,1}\big]\big(\rho_{r^D} r_t^D + c_D - r_{t+1}^b\big) + E_t\big[m_{t,1}\varepsilon_{r^D,t+1}\big]\big\},$$

$$l_0 + l_2\rho_M M_t, c_L + \rho_{r^D} r_t^D + c_D, \sigma, l_1, \theta\ \Big),$$

such that $h_1 < 0, h_2 > 0, h_3 < 0, h_4 > 0,$ and $h_5 < 0.$[26] *In addition,* $h_6 > 0,$ as long as $L < 2L^*$.

The optimal total capital function in Proposition 3 is found by substituting the marginal value of the bank (6) into the optimal decision for total capital (5), where the Lagrange multiplier is given by $\lambda_t^* = \frac{\varepsilon_{L,t} - \varepsilon_{L,t}^*}{l_1\theta} = 2\frac{L_t - L_t^*}{l_1\theta}$. Here, $\varepsilon_{L,t}^*$ is the strike price of the call option identified in Proposition 1. The properties of the optimal total capital function are then determined by applying the Implicit Function Theorem.

Propositions 1 and 3 highlight some interesting characteristics of the option value of the bank's total capital. First, banks would tend to hold more total capital than actually required. Holding a buffer of total capital allows the banks to take advantage of a sudden increase in the desire to issue loans. This is more likely to happen during periods of unanticipated increase in the demand for loans, or when there is a decrease in the marginal cost of loans. This result corresponds with the evidence reported by Barajas, Chami and Cosimano (2004) who find a total capital ratio of 15.37% across 125 countries after the introduction of Basel through 2000. The more recent data reported in the introduction is also consistent with this result throughout the Subprime lending crisis.

Second, a bank holds less total capital if the expected net marginal cost of external funds goes up, $h_1 < 0.$ This result suggests that smaller banks on average hold less total capital. Fama and French (1996) show that small firms in general incur a higher cost of external funds vis-à-vis large firms so that the small banks would have a higher cost of raising external funds. This result helps to explain the increased concentration in banking, since banks with ready access to the financial markets have a cost advantage in raising total capital.

Third, an increase in the expected demand for loans leads a bank to hold more total capital, $h_2 > 0.$ The demand for loans increases, so that the total capital constraint is more likely to be binding. As a result, the strike price of the call option falls in Figure 1. The bank responds to this possibility by raising its total capital, since the value of the option is higher. This result implies that during an expansion in the economy, the banks hold more total capital.

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[26] The partial derivative of the function h with respect to the fifth variable l_1 is denoted by the subscript 5 in $h_5 < 0.$

Fourth, a bank with a higher expected marginal cost of loans holds less total capital, $h_3 < 0$. The marginal cost increases, such that the total capital constraint is less likely to be binding. As a result, the strike price of the call option increases in Figure 1 and the option value of total capital decreases. The bank responds to this situation by holding less total capital. On the other hand, a technological innovation, which reduces the cost of operations, would induce the bank to hold more total capital.

Fifth, higher demand volatility increases the option value of holding capital. Thus, a bank would choose to hold more total capital when there is a mean preserving spread in the distribution of the stochastic shock to loan demand, $h_4 > 0$. The bank realizes that there is a greater chance that the total capital constraint will be binding next period. So, the call option of total capital is "in-the-money." Thus, by holding additional total capital, the bank is able to maintain the option of increasing lending, in the face of a possible increase in loan demand.

Sixth, a decrease in monopoly power increases the strike price of the call option and decreases the marginal payoff for each possible shock to loan demand. A decrease in monopoly power increases the elasticity of demand for loans, which occurs when l_1 increases. As a result, the value of the call option for total capital decreases. Thus, the bank decides to hold less total capital when there is a decrease in monopoly power.

Finally, an increase in the required total capital ratio, θ, has an ambiguous impact on the amount of total capital the bank holds. Figure 1 demonstrates the two changes in the payoffs of the call option for total capital, which arise due to an increase in the required capital. First, note that an increase in the total capital ratio causes the strike price to fall. As a result, the value of the call option increases. On the other hand, the marginal payoff of the option decreases (note that the slope is $\frac{1}{\theta l_1}$), which leads to a decline in the value of the option. It turns out that the first effect dominates when the unconstrained amount of loans is less than twice the constrained level of loans. As long as the first effect is stronger, the bank will choose to hold more total capital when the required total capital ratio increases.

Under the cooperative solution in Proposition 2 and 3 the impact of monetary policy on the banking industry is discussed in the next section. However, the magnitude of this impact will decline as the monopoly power in the industry falls. In the extreme case in which the cooperative solution breaks down the banks follow Bertrand competition so that there are no economic profits and the net interest margin is equal to the marginal cost of operations. In this case changes in interest rates no longer have a significant impact on the profits of the bank so that bank-balance sheet channel is no longer operative.

5. MONETARY POLICY UNDER THE BASEL ACCORD

The impact of monetary policy under the Basel Accord on the value of the bank (7) can be examined using Propositions 1, 2 and 3. The deposit rate increases when the central bank

raises the treasury rate. By Proposition 3 it follows that the bank holds less total capital for next period, since there is a smaller chance that the capital constraint binds next period. In this case, the bank chooses to hold less total capital, so that the loans of the bank are more likely to be constrained next quarter. Thus, a tightening of the monetary policy today reduces the option value of holding capital and results in a reduction in the bank's capacity to make loans in the future. This gives rise to a "bank capital accelerator effect" that is distinct from the financial accelerator, which arises from the borrower's side.[27] Because the persistence of monetary policy assumed in (8) is fully anticipated by the banks, this decrease in total capital persists into the future. In addition, the larger the persistence of monetary policy, the greater would be the effect of the increase in interest rates on the total capital of the bank in the future. The direct effect on the value of the bank (7) of this decrease in total capital is to reduce the deadweight cost of capital, $\tau_t \; b_{t+1}$, both now and in the future so that the value of the bank increases. Yet, the main effect on bank's value is to decrease the bank's profits in each period whether or not the capital constraint is binding.[28] This decrease in bank's profits is larger when the bank is capital constrained. Thus, the value of the bank (7) is reduced when the central bank increases interest rates.

In a fully specified general equilibrium model, the decrease in bank leading, resulting from the contractionary monetary policy, would lead to a reduction in the level of economic activity through the traditional channels such as in Bernanke, Gertler, and Gilchrest (1999). This reduction in economic activity, following the results in Propositions 1, 2 and 3, leads to a further decrease in future lending by the bank, since the bank finds an additional reason to cut back on total capital both now and in the future. Again this results from a decrease in the probability that the capital constraint would bind in the future. This change in total capital then promulgates to further declines in the profits and the value of the bank. Thus, the two traditional effects of monetary policy, an increase in interest rates and a decrease in economy activity would both be amplified by the bank capital effect.[29]

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[27] This result may help explain the finding by Berger (1995) in which there is two-way causality between bank capital and earnings. First, higher profits lead to more capital follows directly from our model. In addition, the bank chooses to hold more capital when they anticipate higher earnings in the future, so that an increase in total capital precedes the increase in earnings.

[28] Our IMF working paper provides all the calculations and conditions for this argument.

[29] This effect would be mitigated to the extent that there is a mean preserving spread in the distribution of future loan demand during declines in the economy, since Propositions 2 and 3 show that this would increase the option value of capital.

6. CONCLUSION

With the recent trend toward relying on risk-based capital as an instrument to control bank behavior, the question arises as to what, if any, are the implications for the conduct of monetary policy. This paper shows that monetary policy, in the presence of risk-based capital requirements, à la Basel, will affect the capacity of banks to supply loans when there is non-competitive behavior in the banking industry. The monetary policy works through the "bank balance-sheet channel" by impacting the value of a bank's capital, its profitability and the value of its stock. Thus, capital requirements can have a significant impact on the banking industry and on the economy as a whole.

We show that holding capital endows the bank with a call option whose value is affected by the monetary policy, the level of economic activity, the structure of the banking industry, technological shocks to banking services, and by changes in the level of regulatory capital. Thus, we use a contingent-claim contract approach to highlight the impact of the aforementioned factors on the supply and pricing of loans, on the bank's profitability, and on the value of its capital. Capital requirements are shown to introduce asymmetries into the effects of these variables on the banking industry. Basel capital requirements also have an interesting and important impact on the banking industry. In economies where there is bank concentration and market power is present, capital requirements are shown to maintain, and perhaps enhance, collusive behavior among the banks. Capital requirements, when present, reduce the expected profits to cheating banks, and as a result, reduce the incentive for individual banks to renege on cooperative agreements.

Market power in the banking industry has significant implications for the transmission of monetary policy. Thus, monetary policy impacts the value of holding capital through its effect on the bank's net interest margin. A reduction in the net interest margin, say, due to a tightening of monetary policy, will reduce the bank's profitability and the value of its capital. As a result, a bank is less likely to hold capital, which, in turn, will constrain the supply of loans in the future. Thus, we identify a "bank capital financial accelerator" which is distinct from the demand-driven financial accelerator. The latter arises due to the impact of monetary policy on the balance sheet and creditworthiness of borrowers. Interestingly, the presence of asymmetries in the impact of the monetary policy and the other factors, mentioned earlier, imply pro-cyclical impact on the banking industry and on the economy. How the two financial accelerator effects interact and their implications for the economy, as a whole, remains a topic for our future research.

Finally, the three pillars approach of the new Basel Accord will not fundamentally change our results concerning the transmission of monetary policy.[30] The new accord, which maintains the same definition of regulatory capital and the minimum eight percent capital adequacy as in Basel I, will continue to have explicit restrictions on the amount of lending

[30] Zicchino (2004) shows how to adjust our model to reflect these issues.

albeit with a more complex market measure of risk adjusted assets. In addition, Kashyap and Stein (2004), Ayuso, Perez and Saurina (2004), and Barajas Chami and Cosimano (2004) point out that Basel II will make the capital requirement more burdensome during recessions since the probability of default on loans increases during these times. To the extent that the subprime crisis underscores the interconnection between monetary policy and regulatory policy, we argue that understanding how the bank capital channel of monetary operates, would go a long way to ensuring a better coordination between both policies.

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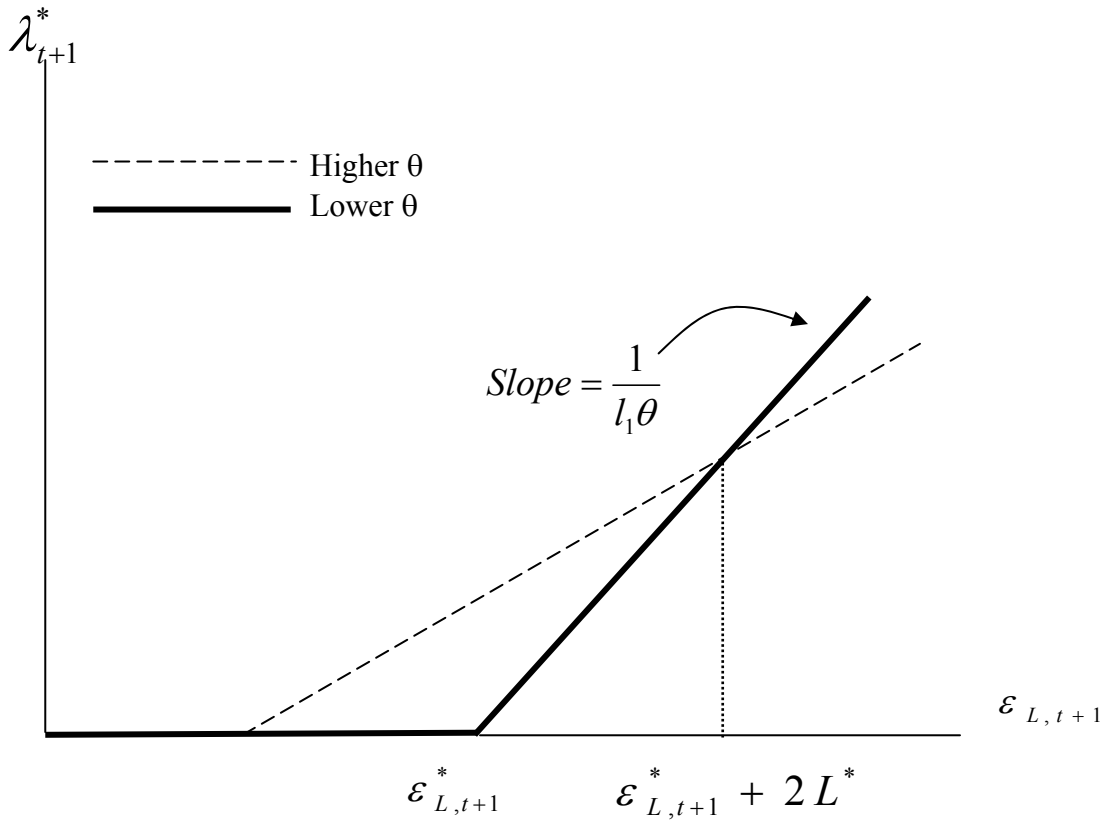
Figure 1. Option Value of Bank Capital



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