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Journal of Banking & Finance 28 (2004) 633–646

Journal of BANKING & FINANCE

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A model of the monetary sector with and without binding capital requirements

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Received 9 August 2001; accepted 4 November 2002

Abstract

Bank equity is exogenous in the standard deposit-and-loan-expansion multiplier model, so that model is inappropriate for analyzing the interaction between monetary and bank regulatory policies. This paper examines the effect of a binding capital requirement on the loan expansion process. We evaluate how the conflict between the monetary and regulatory authorities evolves when bank equity adjusts to a binding capital requirement. We find that capital requirements are not innocuous for monetary policy. Nevertheless, the monetary authority can assert control over the loan expansion process in the long run, although multiplier values will differ considerably from those in the standard multiplier model.

JEL classification: G21; G28; E51
Keywords: Bank capital requirements; Monetary policy

1. Introduction

In this paper we use a model of bank behavior to investigate the interaction between monetary policy and bank capital regulation (for a comprehensive survey of the literature on capital requirements, see Berger et al., 1995). This interaction is not satisfactorily analyzed in the textbook deposit multiplier model because bank

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0378-4266/$ - see front matter
doi:10.1016/S0378-4266(03)00038-4

equity is assumed to be exogenous in that model. Essentially, the textbook model implies that an aggressive bank regulatory authority, imposing a high capital requirement, can thwart a loan expansion desired by the monetary authority because the banks would lack 'required' capital. The multiplier model, however, is silent on the resolution of the conflict and on the implications for the longer run nature of the loan/reserve multiplier.

Our contribution is to endogenize the bank equity decision while retaining a deposit multiplier perspective. Within this framework, we derive the effect of a binding regulatory capital requirement (B-CR) on bank loan expansion and contrast this effect with the case in which the regulatory capital requirement is non-binding (NB-CR). We examine the following questions: Is the conflict between the monetary and regulatory authorities only evident when equity is assumed to be predetermined, as in the textbook model? How is the conflict altered when equity is allowed to change? What is the implication of this resolution for the loan expansion process?

We use a non-stochastic competitive framework, in which banks maximize profits in the presence of costs arising from managing various assets, liabilities and equity. We derive the banks' notional supply of loans for the alternative NB-CR and B-CR cases and examine the loan supply effects of changes in bank reserves and the capital requirement. Our analysis shows that a monetary policy framework that fails to address the issue of binding capital requirements can produce inaccurate predictions. We demonstrate that binding capital requirements alter the banks' desired acquisition of equity and thereby affect the responsiveness of bank loans to changes in reserves, the latter of which is either exogenous or endogenous depending on the monetary authority's operating target. The predicted monetary policy effects depend on the model's parameters, so we also provide a quantitative assessment by calibrating/simulating an important derivative of the general model. We find that, while a binding capital requirement is not innocuous for monetary policy, it also not detrimental in the long run.

Our analysis complements other research on the general topic of monetary policy and capital requirements. Thakor (1996) uses a stochastic loan-screening model to highlight the effects of a risk-based capital requirement, but equity is predetermined in his model. [2] Kishan and Opiela (2000) present a theoretical and empirical analysis

[2] Thakor's framework is consistent with recent approaches emphasizing the derivation of economic conditions that lead to the existence of banks (Fama, 1980) and the types of assets and liabilities on the banks' balance sheets (Diamond and Dybvig, 1983; Diamond and Rajan, 2000). Calem and Rafael (1999) provide an overview of various aspects of this literature. Conditional on an assumed monetary policy system, which typically remains unspecified, these approaches emphasize microeconomic factors that motivate depositors and borrowers to use the specific assets and liabilities of an intermediary. In a general-equilibrium framework, Thakor's approach should turn out to be consistent with the deposit multiplier approach: the deposits created by the banks, acting as agents of the monetary authority, are the deposits demanded by the public, and the public views the same demand deposits as savings (loanable funds) that it has provided to the banks, acting as intermediaries. Our model shows that one can identify the essential elements of the interaction between monetary policy and bank capital regulation without justifying the existence of banks or their assets and liabilities.

that emphasizes cross-sectional differences of the banks' response to monetary policy arising from different capital classifications of banks, but equity is also predetermined in their model. Chami and Cosimano (2001) emphasize the role of bank interest rate adjustments based on anticipations of whether capital requirements will bind in future periods, but in contrast to our competitive assumption, banks operate in an imperfectly competitive market in their model. Our results also do not depend on the assumption of imperfections in the market for bank equity, as in Van den Heuvel (2002), nor do they depend on general-equilibrium interactions, as in Seater (2001), although our framework could in principle be extended into a dynamic, general-equilibrium setting.

The outline of the paper is as follows: Section 2 presents the model's structure and its solutions for the banks' loan supply under both the NB-CR and B-CR cases. A brief conclusion is provided in Section 3. Appendix A presents a more general solution of the model and reports the simulation results of that model.

2. The supply of bank loans under binding and non-binding capital requirements

2.1. Model structure

The banking model's structure is given by the following equations:

$$\text{Balance sheet}: \quad R + G + L = D + T + E, \tag{1.1}$$

$$\text{Reserve requirements}: \quad R \geqslant \rho D, \tag{1.2}$$

$$\text{Capital requirements}: \quad E \geqslant \theta L, \tag{1.3}$$

$$\text{Excess reserve demand}: \quad X^D = 0, \tag{1.4}$$

$$\text{Securities cost}: \quad C_G = (g/2)G^2, \tag{1.5}$$

$$\text{Transactions deposit cost}: \quad C_D = (a/2)D^2, \tag{1.6}$$

$$\text{Equity cost}: \quad C_E = (b/2)E^2, \tag{1.7}$$

$$\text{Non-transactions deposit cost}: \quad C_T = (c/2)T^2, \tag{1.8}$$

$$\text{Loan cost}: \quad C_L = (f/2)L^2, \tag{1.9}$$

where R = bank reserves, G = government securities, L = bank loans, D = transactions deposits, T = non-transactions deposits, E = bank equity, X = excess reserves, C_i = bank resource costs for $i = D, T, E, L, G$, ρ = required reserve ratio against transactions deposits, and θ = loan-based capital requirement ($\theta \leqslant 1$).

Eq. (1.1) is the balance-sheet constraint, and (1.2) defines reserve requirements on transactions deposits. [3] Capital requirements in (1.3) require banks to hold an amount of equity equal to a fraction, θ, of bank loans. We assume a zero demand for excess reserves in (1.4), which is reasonable since the model is non-stochastic. Alternatively, we could make excess reserve demand proportional to transactions deposits, i.e., $X^D = \beta D$, with no change in the interpretation of our results. [4] Note that our model derives the demand for securities endogenously. We could also make this demand proportional to transactions deposits under the assumption that banks use G to meet the liquidity needs of depositors. [5] But again this assumption would have no effect on the interpretation of our results.

Eqs. (1.5)–(1.9) assume quadratic costs for managing the components on the banks' balance sheet, so that marginal costs are increasing in the respective quantities, D, T, E, L and G. The costs of managing and altering the quantities of transactions and non-transactions deposits are readily apparent. The payments mechanism requires resources to function effectively. Moreover, as banks attempt to penetrate local markets more deeply for transactions deposits and national markets for non-transactions deposits, marketing and other costs rise rapidly in the presence of household and corporate resistance. Increasing the size of the loan portfolio requires larger expenditures for the origination, processing and maintenance of loans, especially if banks go out of their local lending areas. Securities, while traded in national markets, are also costly to manage, although most likely to a lesser extent than loans. Regarding equity, its cost is likely to contain fixed as well as variable components. Fixed costs would be represented by the bank's need to comply with SEC regulations irrespective of the size of an equity issue. Variable costs arise because issuing equity involves significant 'middlemen' costs such as those associated with the due diligence of the investment banking sector. This type of cost can be approximated by the gross spread, which equals the difference between the price at which equity is sold to the public and the price paid to the issuing bank. Damodaran (1997, p. 406) shows that the gross spread declines and then levels off as a function of the size of an equity issue. Marginal equity costs, therefore, decline at first and then become flat. However, as the size of the equity issuance increases, this type of cost must begin to rise at an increasing rate, reflecting the increasing difficulty of placing equity within the private sector as the size of a bank and/or the banking system expands relative to the aggregate economy.

Thus, there are non-trivial costs relating to the size of the various components in the banking system's portfolio, which play a key role in influencing bank adjustments

[3] For reserve requirement purposes, the distinction between transactions and non-transactions deposits is important in the US because reserve requirements against non-transactions deposits are presently set at zero. The distinction is less important in Europe where reserve requirements are generally positive against all types of bank deposits. For simplicity, we assume the required reserve ratio against non-transactions deposits is zero.

[4] The β term would be joined additively with ρ as $(\beta + \rho)$ in the solutions below.

[5] In this case the proportionality factor, say γ, would be joined additively with ρ as $(\gamma + \rho)$ in the solutions below.

to capital requirements. [6] Besanko and Kanatas (1996) recognize a similar point, although in a different context. In their model of individual bank behavior, adjustment cost in the form of management effort interacts with capital requirements to generate endogenous changes in the risk of failure at individual banks. In our analysis, the focus is on the impact of adjustment costs and capital requirements on endogenous loan expansion in the banking system as a whole.

2.2. The benchmark model without binding capital requirements

We first present solutions for the NB-CR case. Essentially, banks expect that the optimal ratio of equity to loans will be determined at a higher value than θ (or $\theta = 0$) and thus that θ will not be binding on the optimal decisions regarding the composition of the portfolio of the banking system.

Substituting the reserve requirement constraint (1.2) into (1.1), we obtain a semi-reduced-form expression for loan supply:

$$L = \hat{\rho}R + E + T - G, \tag{2}$$

where $\hat{\rho} = (1-\rho)/\rho$. This equation shows the net influence of the four underlying sources of loan capacity within the banking system: reserves, non-transactions deposits, equity and securities. In an elementary deposit multiplier model, T and G are both set equal to zero in (2), and E is an exogenous variable. Thus, changes in loan supply are induced only by changes in reserves, as long as $E/L > \theta$. To provide a more complete solution for L, we endogenize E, T and G in (2) while retaining the essence of the deposit multiplier's non-stochastic approach to the supply of bank loans. [7]

Given the cost functions in (1.5)–(1.9), we assume that banks maximize profits:

$$\Pi = r_L L + r_G G - r_E E - r_T T - r_D D - \frac{a}{2}D^2 - \frac{b}{2}E^2 - \frac{c}{2}T^2 - \frac{f}{2}L^2 - \frac{g}{2}G^2, \tag{3}$$

where r_L = the loan rate, r_G = the securities rate, r_T = the non-transactions deposit rate, r_D = the transactions deposit rate, and r_E = the required return on equity. Assuming $f = 0$, [8] which allows for a direct comparison to the standard deposit multiplier model and using the symbol $*$ to denote an optimal quantity in the benchmark

[6] Using internal capital is an alternative method for augmenting equity. This process is costly because of the inherent time delay encountered prior to crediting capital to the banks' equity account. Our paper, however, does not explicitly analyze the internal acquisition of equity.

[7] R is determined by the monetary authority. The loan supply functions in (4.4) and (5.4) below can be readily adapted to examine alternative operating targets. In the polar case of a pure reserves target, R becomes exogenous and the mathematical structure of the notional loan supply functions remains unchanged. For the other extreme case of a pure interest rate target, if we assume that the demand for transactions deposits depends positively on the transactions deposit rate and negatively on the policy-determined level of the short-term interest rate, r, bank reserves will also depend explicitly on r. This solution for the endogenous level of reserves in terms of r can then be substituted wherever R appears in the loan supply solutions.

[8] The solutions with $f > 0$ are given in Appendix A.

NB-CR case, it is straightforward to derive the following notional bank functions for the case where $(E/L)^* > \theta \geqslant 0$:

$$T^* = (r_L - r_T)/c, \tag{4.1}$$

$$E^* = (r_L - r_E)/b, \tag{4.2}$$

$$G^* = (r_G - r_L)/g, \tag{4.3}$$

$$L^* = \hat{\rho}R + \frac{[g(c+b) + bc]r_L - g(br_T + cr_E) - cbr_G}{cbg}. \tag{4.4}$$

Eqs. (4.1) and (4.2) have similar properties. When $f = 0$, the supplies of equity and non-transactions deposits depend negatively on their respective own rates and positively on the loan rate, but not on the level of bank reserves. Moreover, as (4.3) shows, securities and loans are substitute assets in the banks' portfolio. In this special case, which represents a generalization of the standard multiplier model to an optimizing framework, [9] the influence of bank reserves is transmitted solely through the loan supply function, as in (2). Of course, the complete adjustment of banks to a change in reserves depends on induced variations in interest rates, which will create further changes in the optimal quantities in (4.1)–(4.4). Our main focus, however, is not on equilibrium interest rates but rather on the structure of the supply functions of the banking system and how this structure is influenced by a binding capital requirement.

2.3. The benchmark model with unexpectedly binding capital requirements

Capital requirements can become binding either because an unanticipated evolution of bank reserves leads to a rise in L^* (as described by (4.4)) that triggers a capital adequacy problem or because the regulatory authority unexpectedly introduces or increases the capital requirement beyond a triggering level. In either case, $(E/L)^* < \theta$.

We first describe the reaction of the banking system when equity is predetermined in a short-run period. The banks would re-optimize (3) assuming $E = \bar{E}$ and taking the capital constraint (1.2) explicitly into account. Letting T^{SR} and G^{SR} represent optimal short-run quantities, we have, for $(E/L)^* < \theta$:

$$T^{\mathrm{SR}} = [r_G - r_T - g(\hat{\rho}R + \hat{\theta}\bar{E})]/(c+g), \tag{4.5}$$

$$G^{\mathrm{SR}} = [r_G - r_T + c\hat{\rho}R - \hat{\theta}(c+2g)\bar{E})]/(c+g), \tag{4.6}$$

[9] When $f > 0$, the influence of bank reserves is spread throughout the balance sheet, as is shown in Appendix A, equations (A.1)–(A.4). In the presence of a positive loan cost, an increase in bank reserves induces banks to economize on the desired quantities of both non-transactions deposits and equity to attenuate the rise in costs associated with the induced expansion in desired loan supply.

where $\hat{\theta} = (1 - \theta)/\theta$. It is natural to expect that the loan rate would rise when loan supply is unexpectedly constrained at $\bar{L} = \bar{E}/\theta$, as would occur for the loan demand function, $L^D = a_0 - a_1 r_L$. But the movement in the loan rate would have no impact on bank behavior in the short run because (in contrast to (4.1) and (4.3)) the binding capital constraint disconnects time deposit supply and securities demand from the loan rate. Nonetheless, an unexpectedly binding θ would have a direct expansionary effect on both T^{SR} and G^{SR}, since the θ partial derivatives are positive in (4.5) and (4.6). Thus, the model predicts that in the short run the banking system would reduce loans, expand their holding of securities and issue more deposits (to pay for the cost of increasing G). Essentially, the banks would resemble money-market-mutual funds when capital requirements unexpectedly bind bank loans. This conclusion is similar to that predicted by Thakor (1996). In his framework, however, the portfolio adjustment to capital requirements arises from bank loan-screening decisions, whereas in our framework it is driven by balance-sheet adjustments required to maintain banking system equilibrium.

What are the implications for the conduct of monetary policy within this environment? Given a capital-constrained short-run quantity of loans, a desired expansion in bank loans associated with $\Delta R > 0$ would be completely frustrated. [10,11] Instead, the increase in reserves would be channeled into larger holdings of securities, a result consistent with the money-market-mutual-fund status of equity-constrained banks. The banking system, nonetheless, would produce larger quantities of transactions deposits, but these would be used not only to fuel the purchase of additional securities but also to reduce the banks' reliance on time deposits as (4.5) shows.

The conflict between the monetary and regulatory authorities can be seen more clearly in Fig. 1, in which $(E/L)^*$ is graphed against reserves, R, and the capital requirement is denoted by θ_0. In the model of (4.1)–(4.4) (and the corresponding equations in Appendix A), the desired capital/loan ratio is negatively related to R. The crucial reserve level that divides the non-binding and binding regulatory regimes is indicated by $\hat{R}$. When reserves are at a level beyond $\hat{R}$, banks cannot move along the $(E/L)^*$ curve because this movement leads to a violation of the capital requirement. In the standard multiplier model undesired excess reserves would arise, but that model provides no guidance about either the resolution of this conflict between the regulatory and monetary authorities or how undesired excess reserves are purged from the banking system. Our short-run analysis also does not offer any resolution of the conflict. The resolution comes from a longer run adjustment, as banks realize that E^* $(\equiv \bar{E})$ is no longer optimal and resolve (3) for a value of equity that takes the capital requirement explicitly into account.

[10] In reality, banks are likely to have 'excess' equity. However, such excess equity cannot protect banks against unpredictably large permanent changes in reserves. There always exists a value of R such that a change in R would have no effect on L in the NB-CR case.

[11] Most researchers have concluded that the imposition of risk-based capital requirements led to at least a partial loan contraction, particularly in New England (see Furlong, 1992; Brinkmann and Horvitz, 1995; Peek and Rosengren, 1995, 1996).

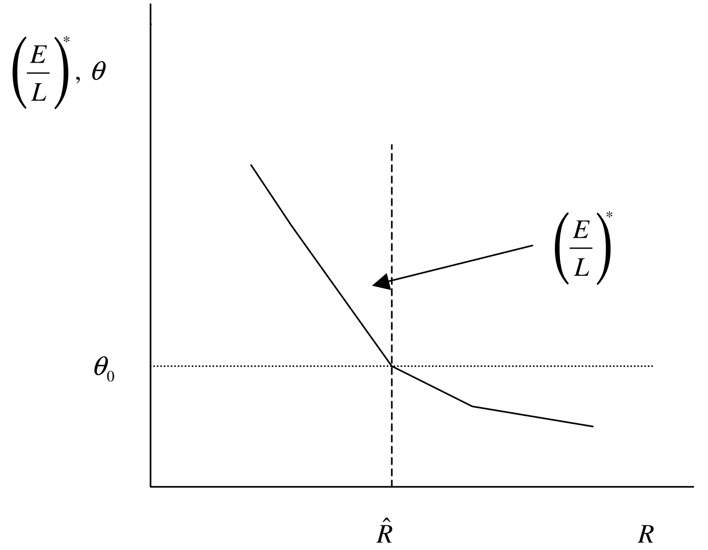

Fig. 1. The equity/loan ratio and reserves.

2.4. The model with binding capital requirements

When banks re-optimize in the face of binding capital requirements, the notional supplies for L, T and E and notional demand for G become consistent with the regulatory value of θ. Using $**$ to denote optimal values under B-CR and assuming that $f = 0$, [12] we derive the following notional bank functions for $\theta > (E/L)^*$:

$$T^{**} = \frac{-[b\theta^2 + (1-\theta)^2 g]r_T + b\theta^2 r_G + g(1-\theta)(r_L - \theta r_E) - gb\theta^2\hat{\rho}R}{b\theta^2(c+g) + cg(1-\theta)^2}, \tag{5.1}$$

$$E^{**} = \theta L^{**}, \tag{5.2}$$

$$G^{**} = \frac{-b\theta^2 r_T + [b\theta^2 + (1-\theta)^2 c]r_G - c(1-\theta)(r_L - \theta r_E) + bc\theta^2\hat{\rho}R}{b\theta^2(c+g) + cg(1-\theta)^2}, \tag{5.3}$$

$$L^{**} = \frac{-g(1-\theta)r_T - c(1-\theta)r_G + (g+c)(r_L - \theta r_E) + (1-\theta)cg\hat{\rho}R}{b\theta^2(c+g) + cg(1-\theta)^2}. \tag{5.4}$$

A comparison of the B-CR and NB-CR cases reveals a different adjustment pattern in the notional portfolio of the banking system in response to a change in bank reserves. Both L^{**} and E^{**} are positively related to a change in R, but T^{**} responds *negatively*. (Recall that in the benchmark case with $f = 0$ and a non-binding capital

[12] Appendix A reports the solutions for $f > 0$.

requirement, T^* is not influenced by a change in R.) It is not surprising that the supply of bank equity expands as R increases, because capital requirements create an essential one-to-one connection between bank loans and bank equity, which is not present in the benchmark $f = 0$ case. Given an increase in R and the resulting increase in transactions deposits, the banks' desire to increase the quantity of loans automatically calls for additional equity. Thus, in comparison to the benchmark NB-CR case, binding capital requirements induce a different desired quantity of bank equity.

The surprising result is the negative relation between bank reserves and the supply of non-transactions deposits. Essentially, the expansion in D induced by an increase in R enables banks, if desired, to reduce their reliance on the use of other liabilities to fund loans and government securities. In the benchmark case the notional quantities of equity and non-transactions deposits do not change, because (by assumption) the induced change in loans (due to ΔR) imposes no additional equity or other loan costs on the banks. But the binding capital requirement, by forcing banks to tie together loans and equity, creates an *artificial* loan adjustment cost that is not present in the benchmark case. Loans are costly not per se (since $f = 0$) but because of the requirement to accumulate costly equity. In this cost-based environment the expansion in D (due to R) enables banks to choose between a loan expansion (requiring costly equity) and/or a reduction in non-transactions deposits T (which economizes on the cost of managing the portfolio of liabilities and equity). The choice depends importantly on the value of c, which determines the magnitude of the marginal cost of T. As (5.1) and (5.4) show, if this parameter is sufficiently small, banks will desire to use almost the entire increase in D to reduce T. Such a desired recomposition in liabilities, while inhibiting loan expansion, enables banks to escape additional equity costs and thereby reduce their overall costs.

When bank reserves increase, the model predicts that desired loans and equity respond such that an expansion in loans is consistent with the θ_0 line to the right of $\hat{R}$ in Fig. 1. The banks would move, therefore, from the short-run equilibrium described above (with E predetermined) to a longer run equilibrium with E determined endogenously according to (5.2). In the long run, the conflict between the monetary and regulatory authorities to the right of $\hat{R}$ is eliminated as banks resolve for their optimal portfolios. The loan/reserve derivative does differ, however, under B-CR relative to NB-CR. In the B-CR case, the response of loans to a change in reserves depends importantly on bank cost parameters, whereas under NB-CR only the required reserve ratio affects the derivative. Thus in the B-CR case the loan/reserve derivative is a mixture of bank behavior and regulatory ratios. Regarding a decrease in bank reserves under B-CR and assuming that bank equity is initially predetermined, binding capital requirements would not impede a reduction in loan supply since the $(E/L)^{**}$ ratio is not constrained in the upward direction. Banks would, however, have 'excess' equity, which they would reduce by buying back outstanding equity as they sought to re-attain an optimal portfolio with $(E/L)^{**} = \theta_0$.

In the binding region, the degree of responsiveness of L^{**} to R is also influenced by θ. That is, changes in the regulatory value of θ will alter the desired adjustment of bank loans in response to a change in bank reserves under B-CR. Specifically, with $\theta > (E/L)^{*}$,

$$\frac{\partial L^{**2}}{\partial R\,\partial\theta} = \frac{cg\hat{\rho}[cg(1-\theta)^2 - (c+g)b\theta(2-\theta)]}{b\theta^2(c+g) + cg(1-\theta)^2}. \tag{6}$$

In (6) a larger value of θ makes L^{**} less responsive to R, the smaller is c and the larger is b. The first influence enhances the reduction in desired non-transactions deposits (due to ΔR), while the second increases the marginal adjustment cost of equity and thus of loans. Both of these influences act to retard the desired loan expansion. We calibrate and simulate a generalized version of (6) in Appendix A.

In the B-CR case, (5.2) applies, and an increase in reserves induces an increase in desired equity. One should view the additional equity as an artifact of the regulatory authority. In the absence of a binding capital requirement, the banking system would be able to achieve the larger desired quantity of bank loans through the additional funding provided by the transactions deposit expansion induced by ΔR, with no change in the optimal amount of equity (as in (4.2) in the NB-CR benchmark case). That is, as Fig. 1 shows, the NB-CR benchmark $(E/L)^{*}$ curve continues to the right of $\hat{R}$ and lies below θ_0. The regulatory authority, therefore, has inadvertently imposed an additional impediment on the conduct of monetary policy. While the safety and soundness of the banking system is a socially desirable objective, the larger induced supply of bank equity imposes costs on society, because equity funds are transferred from other sectors of the economy (as measured by r_E) and additional costs are borne by the banking system (as measured by b). As a result, when capital requirements are binding, the conduct of monetary policy can also affect resource allocation in the real economy.

3. Conclusion

This paper has focused on the impact on the banking system of the interaction between the monetary and regulatory authorities. The monetary authority influences reserves and the regulatory authority is concerned with bank equity. Models designed to analyze monetary policy (such as the standard deposit multiplier model), however, assume that bank equity is exogenous, while the models commonly used for regulatory analysis are not tied into a specific monetary sector framework. In this paper we have provided a generalization of the standard multiplier model in which bank equity and loans are endogenously determined by underlying cost parameters. We solved the model for two cases, with and without binding capital requirements.

Our results can be used to provide a chronology of events in the banking system when capital requirements unexpectedly bind. First, the outstanding amount of bank equity, which initially represents an optimal solution under a non-binding capital requirement regime, induces a loan contraction and an increase in the loan rate in the short run. In the longer run, banks re-optimize and adjust their portfolios, including bank equity, in light of the binding capital requirement. Thus, our analysis suggests that there is an initial conflict between the monetary and regulatory authorities that is resolved gradually via induced adjustments on the part of the banking system. Ultimately, it is the induced increase in equity that alters the loan transmission mechanism relative to the benchmark deposit multiplier model and resolves the potential conflict between the regulatory authority and an expansionary monetary authority. Our results, therefore, indicate that, while a binding capital requirement is not innocuous for monetary policy, it is also not detrimental in the longer run. The θ effect, which regulators employ to connect bank loans and equity, also creates an unintended, unavoidable, but ultimately reconciling connection between bank reserves and bank equity. Monetary policy ultimately works on loans, but not in the fashion portrayed in the standard deposit multiplier model.

Acknowledgements

We thank Sherrill Shaffer, Charles Swanson and three anonymous referees for their comments on an earlier version of this paper.

Appendix A

A.1. Generalized model solutions

Assuming $f > 0$, the supplies of non-transactions deposits, equity and loans and the demand for securities in the NB-CR benchmark case, in which $(E/L)^* > \theta \geqslant 0$, are given by:

$$T^* = \frac{-[g(b+f)+fb]r_T + fbr_G + gbr_L + gfr_E - fgb\hat{\rho}R}{cg(b+f)+fb(c+g)}, \tag{A.1}$$

$$E^* = \frac{gfr_T + cfr_G + cgr_L - [cg+f(c+g)]r_E - cfg\hat{\rho}R}{cg(b+f)+fb(c+g)}, \tag{A.2}$$

$$G^* = \frac{-bfr_T + [c(b+f)+bf]r_G - bcr_L - cfr_E + bcf\hat{\rho}R}{cg(b+f)+fb(c+g)}, \tag{A.3}$$

$$L^* = \frac{-bgr_T - bcr_G + [cg+b(c+g)]r_L - cgr_E + bcg\hat{\rho}R}{cg(b+f)+fb(c+g)}. \tag{A.4}$$

For the B-CR case, $\theta > (E/L)^*$, we have

$$T^{**} = \frac{-[b\theta^2+f+g(1-\theta)^2]r_T + (b\theta^2+f)(r_G - g\hat{\rho}R) + g(1-\theta)(r_L - \theta r_E)}{(c+g)(b\theta^2+f)+cg(1-\theta)^2}, \tag{A.5}$$

$$E^{**} = \theta L^{**}, \tag{A.6}$$

$$G^{**} = \frac{[b\theta^2 + f + c(1-\theta)^2]r_G + (b\theta^2 + f)(c\hat{\rho}R - r_T) - c(1-\theta)(r_L - \theta r_E)}{(c+g)(b\theta^2 + f) + cg(1-\theta)^2}, \tag{A.7}$$

$$L^{**} = \frac{-(1-\theta)(gr_T + cr_G) + (1-\theta)cg\hat{\rho}R + (g+c)(r_L - \theta r_E)}{(c+g)(b\theta^2 + f) + cg(1-\theta)^2}. \tag{A.8}$$

The analog to (6) is

$$\frac{\partial L^{**2}}{\partial R\,\partial\theta} = \frac{cg\hat{\rho}[cg(1-\theta)^2 - (c+g)(b\theta[2-\theta] + f)]}{[(c+g)(b\theta^2 + f) + cg(1-\theta)^2]^2}. \tag{A.9}$$

A.2. Calibration and simulation of the model

To gain some quantitative insight into the model's prediction concerning the effect of θ on the loan/reserve multiplier, we evaluate (A.9) by calibrating and simulating the model. We set the required reserve ratio ρ to 0.10 and the capital ratio θ to 0.04, which are the current minimum required reserve and leverage capital ratios. Although direct estimates of the quadratic cost parameters for non-transactions deposits, equity, loans and securities, b, c, f and g are not available, we can use the estimates of bank deposit supply in Elyasiani et al. (1995) to infer a range of values for a, the quadratic cost parameter for transactions deposits [13] in (3) and then adopt this range for the cost parameter, c. In Elyasiani et al. the potential range for the transactions-deposit cost parameter is $0 \leqslant a \leqslant 0.10$. The estimate of a implied by the "best" fit of their general model (Group II banks of intermediate size) is 0.04, and the average value of a across all groups is approximately 0.02. Thus in the simulations we adopt the range $0.001 < c < 0.10$ for the parameter c and set $0.001 < b < 8$ for b. The latter represents a wide range for the equity cost parameter. We also set g, the securities cost parameter at 0.001, which is the lower bound for the loan parameter, f.

Table 1 reports simulations of (A.9). In principle, the effect of an increase in θ on the sensitivity of loan supply to changes in reserves depends on configurations of the underlying parameters. The table, however, indicates that in the most reasonable case in which f is equal to or larger than g, so that the marginal cost of extending and monitoring loans is at least as large as the marginal cost of managing the bank's securities portfolio, the sensitivity is reduced (negative) over the empirically relevant ranges of values of b and c. Thus, these simulation results suggest that higher capital

[13] We are grateful to a referee for suggesting this approach to assessing the quantitative implications of the model.

Table 1
Simulations of Eq. (A.9)

	$c = 0.001$	$c = 0.02$	$c = 0.04$	$c = 0.08$	$c = 0.10$
$f = 0.001$					
$b = 0.001$	−1.234	−0.451	−0.403	−0.378	−0.373
$b = 0.01$	−2.594	−2.008	−1.962	−1.938	−1.933
$b = 0.02$	−4.044	−3.685	−3.641	−3.618	−3.614
$b = 0.04$	−6.768	−6.879	−6.843	−6.822	−6.818
$b = 0.08$	−11.576	−12.682	−12.664	−12.653	−12.650
$b = 0.10$	−13.697	−15.317	−15.310	−15.304	−15.303
$b = 0.40$	−31.368	−40.201	−40.426	−40.537	−40.559
$b = 0.80$	−36.855	−51.602	−52.092	−52.339	−52.338
$f = 0.04$					
$b = 0.001$	−0.109	−0.200	−0.205	−0.207	−0.208
$b = 0.01$	−0.111	−0.204	−0.208	−0.211	−0.211
$b = 0.02$	−0.113	−0.208	−0.212	−0.215	−0.215
$b = 0.04$	−0.117	−0.215	−0.220	−0.223	−0.223
$b = 0.08$	−0.125	−0.231	−0.236	−0.239	−0.239
$b = 0.10$	−0.129	−0.238	−0.244	−0.246	−0.247
$b = 0.40$	−0.149	−0.276	−0.282	−0.285	−0.286
$b = 0.80$	−0.264	−0.349	−0.357	−0.361	−0.362

In the simulations, $\rho_D = 0.10$, $\theta = 0.04$, $g = 0.001$, and b and c determine the marginal cost of equity and non-transactions deposits, respectively. The simulations are conducted for alternative values of f, the determinant of the marginal cost of loans.

requirements tend to reduce the sensitivity of loan supply to any given change in monetary policy operating through bank reserves.

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