Working Paper 8913

PORTFOLIO RISKS AND BANK ASSET CHOICE

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The author gratefully acknowledges helpful
comments from Mark Gertler, Donald Morgan,
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October 1989

ABSTRACT

This paper investigates the effects of both credit risk and interest-rate risk on bank portfolio choices. It presents a model of banking that explains portfolio risks with informational asymmetries; depositors cannot observe the returns on bank loans and banks cannot observe depositors' liquidity needs. Bank capital must cover possible losses due to loan default and high future deposit costs given the maturity imbalance of bank portfolios. We show how bank capital inadequacy may prevent a bank from investing in the optimal portfolio and how the efficiency of the bank's intermediation technology affects its choice of second-best portfolio.

I. INTRODUCTION

Depository institutions are unique in the degree of asset transformation associated with their **intermediation** activities. These institutions (hereafter referred to as banks) invest in a portfolio of claims, many of which cannot be traded individually in direct credit markets, and are often issued by borrowers who would find it prohibitively costly to obtain external finance. Banks fund these investments largely by issuing highly liquid claims that serve as substitutes for legal tender in depositors' portfolios. These activities allow banks to profit while creating a primary market for certain borrowers and liquidity for bank depositors. The purpose of this paper is to examine how the risks associated with asset transformation affect bank portfolio choices.

Recent literature formalizing the allocative role of banks has considered the implications of their maturity transformation, diversification, and information production. Diamond and Dybvig **(1983)**, **Bhattacharya** and Gale **(1987)**, and Bernanke and Gertler (1987) motivate the maturity transformation services associated with demand-deposit contracts by assuming that depositors face unobservable stochastic consumption preferences. Banks must manage the liquidity risk of their deposit liabilities.

Another branch of the financial intermediation literature focuses on the monitoring and diversification services that banks provide on the asset side of their balance sheets (Diamond [1984], Williamson [1986], Boyd and Prescott [1985], and Bernanke and Gertler [1987]). In these papers, banks minimize the real resources used to monitor risky investments in a world where information about investment returns is costly.[1] Also, by diversifying

across many borrowers, banks can promise a more certain return to depositors.[2] Many of the results in this area hinge on the ability of intermediaries to diversify perfectly. **Bernanke** and Gertler relax this assumption by restricting the ability of banks to diversify away default risk. The resulting variability of privately observed bank portfolio returns implies that the quantity of bank capital will affect bank performance.

Previous researchers have usually examined risk on only one side of the balance sheet, treating asset and liability management as separate decisions.[3] However, risks on each side of the balance sheet are jointly considered in portfolio management.

This essay describes a model of a banking sector in which intermediation exposes banks to portfolio risks on both sides of their balance sheets. We consider banks that are "special" because they initiate risky investments that would not be funded in direct credit markets due to information costs **(Fama [1985])**. These banks transform both the maturity and the default risk of the indirect securities they issue relative to the assets in their portfolios. We then examine the effects of credit risk and short-term **interest-rate** variability on bank portfolio management

portfolio risks arise because of **informational** asymmetries; depositors cannot observe the returns on bank loans and banks cannot observe depositors' liquidity needs. The deposit contract depends on banks' information about depositors as well as depositors' information about banks. As a result, deposit liabilities have a **shorter** maturity than bank assets and **pay** a return that is not contingent on unobservable bank portfolio risks.

The structure of deposit contracts introduces interest-rate risk into bank portfolios. This risk translates into uncertainty about deposit costs. Interest-rate swings can create fluctuations in the relative values of bank assets and liabilities and in bank earnings; consequently, they impact the capital accounts of banks. We abstract from the moral hazard problem of monitoring the risk of bank investments to focus on the implications of interest-rate risk for investment activity.

When banks cannot diversify away privately observed risks perfectly, bank capital must cover possible portfolio losses due to either loan default or high deposit costs. The greater the degree of possible interest-rate volatility, the more banks must rely on their capital accounts to buffer corresponding fluctuations in earnings.

When a banker's capital is insufficient to absorb possible losses on the profit-maximizing level of bank projects, the bank is **"capital-constrained."** This constraint requires that a second-best portfolio be chosen to ensure bank solvency. An alternative "reserve" asset will be substituted for risky bank projects in order to eliminate some of the portfolio risk. However, as the expected return on an alternative asset is less than that of the risky project, expected profits are lower for constrained banks. We formalize how interest-rate risk increases the likelihood that a bank will become capital-constrained.

We then consider how bank monitoring costs and the relative portfolio risks affect the optimal choice of a reserve asset. A bank can use its technology to fund long-term bank projects with less credit risk or to fund short-term storage projects costlessly. The return on the former is

higher for banks with an efficient monitoring technology. However, as long-term(albeit safer) bank projects do not eliminate interest-rate risk from the bank portfolio, their effectiveness per project in reducing portfolio risk is smaller. A capital-constrained bank faces a retum and risk-reduction **trade-off** in choosing among alternative reserve assets. This further illuminates the dual role of banks in transforming both the credit risk and maturity of their specialized loan portfolio.

An important conclusion of this analysis is that the efficiency of a bank's specialized intermediation technology will affect its choice of second-best portfolio. For relatively efficient but capital-constrained banks, the retum from using their technology may be sufficient to cover losses from maturity imbalances. We describe when long-term bank projects are the preferred reserve assets because of the real return to utilizing bank technology. We also show how the degree of relative risk on either side of the bank's balance sheet affects the choice of the optimal reserve asset.

Section II outlines the model of the banking sector. Sections **III** and IV describe the alternative equilibria for banks with differing degrees of efficiency in funding investments. Section V is the conclusion.

II. THE BASIC MODEL OF DEPOSITORS AND BANKS

This section presents the framework used to **examine** the effects of both default risk and short-term interest-rate risk on the banking equilibrium.

Production Possibilities

Three production technologies are available in the economy. Each

technology requires an initial investment of the economy's endowment in a project that yields consumption goods in a future period. The investment opportunities of the economy are described by the following three projects:

1) Default-free long-term projects, I^*, yield a certain gross rate of return, R^*, two periods after the projects are undertaken.

2) Risky long-term projects, 1, have an expected gross rate of return, R, in the second period after the projects are undertaken. The returns on these projects are random and can be observed only by the originator of the investments. The gross rate of return on this technology has a lower bound of R^m. The distribution of returns on risky projects is costlessly **observed** by all individuals in the economy.

3) Default-risk free, short-term storage projects, s, yield a certain gross rate of return, r, one period later. The gross yield from this technology can be consumed or reinvested at a future short-term rate. However, the future short-term storage rate, effective upon reinvestment, is random when the projects are undertaken. In the initial investment period, the one-period future storage rate has an expected gross rate of return, r_1, and an upper bound, r^h, which is observed by all individuals in the economy.

   Both long-term investments are funded through banks that possess the technology to locate these projects and to monitor them, when necessary. Monitoring and locating requires a fraction of the total resources invested in the project, $\delta(\Theta)$. This monitoring cost differs across bankers; $\delta(\Theta_i)$ is the marginal monitoring cost of a type Θ_i banker. The distribution of bankers will be ordered by the efficiency of their technology, where

(2.1) $\delta(\Theta_i) < \delta(\Theta_j)$,

as $\theta_i < \theta_j$ and where θ_i is the fraction of all individuals with monitoring costs of $\delta(\theta_i)$ or less. The following relationships are assumed to hold:

$$(2.2) \quad \frac{R^m}{(1+\delta(\theta))} < \frac{R^*}{(1+\delta(\theta))} < \frac{R}{(1+\delta(\theta))} < rr^h.$$

All individuals in the economy can invest in short-term storage projects.

Depositors and Bankers

The economy consists of a continuum of individuals measured along the interval $(0,1)$. These individuals live for three periods, indexed by $(0,1,2)$. In period 0 they receive an endowment w, which they invest to maximize expected utility. An exogenous fraction, α, will be called depositors. The remaining fraction, $(1-a)$, will be called bankers.

As in Diamond and Dybvig (1983), depositors face privately observed liquidity risks modeled as preference shocks. A fraction, t, will desire to consume their wealth in period one. The remaining fraction will desire to consume it in the following period. A depositor's ex-post preferences are not observable. Depositors do not know their preference type in period zero; thus, they desire to hold a portfolio that can be liquidated completely in either period.

One investment option for depositors is short-term storage. Alternatively, banks issue deposits to fund bank-specific projects. Banks offer a deposit contract, described below, which can be liquidated or reinvested in period one.

Formally, a representative depositor maximizes his expected utility given his endowment, αw:

(2.3)   Max $E(U(c_1,c_2)) = t \ln(Ec^d_1) + (1-t) \ln(Ec^d_2)$

    (d,s^d) s.t.

(2.4) $E(c^d_1) = r^d d + r s^d,$

(2.5) $E(c^d_2) = r^d_2 d + rr_1 s^d,$

(2.6) $aw = d + s^d,$

where d are deposits, s^d is direct investment in storage assets, and c^d_1 and c^d_2 are first-period and second-period consumption, respectively. The expected one-period and two-period deposit rates are r^d and r^d_2. The first-order necessary conditions for d and s^d imply that depositors will hold bank liabilities only if they yield at least the expected return on the storage technology.

Bankers' fraction of the population is (1-a). They live for three periods and maximize their expected consumption in period two. Bankers possess the technology for locating and monitoring long-term investment projects. In period zero, a given banker decides whether or not to operate a bank. If he operates a bank, he invests his :endowment as bank capital and issues deposit liabilities to fund bank-specific projects. The efficiency of his intermediation technology determines whether he can operate profitably; the expected return on bank-specific projects must be greater than that of the storage technology. In choosing among bank-specific projects, a banker maximizes investment in projects with the highest expected return. From (2.1) and (2.2), a banker of type θ_j will operate a bank if

(2.7) $rr_1 \leq \dfrac{R}{(1+\delta(\theta_j))},$

where $rr_1 = R/(1+\delta(\hat{\theta}))$ defines $\hat{\theta}$ as the type of the marginal operating bank and the fraction of individuals who operate as bankers. A banker with a more efficient technology has a **higher** expected net return from locating and monitoring long-term projects.

To ensure that some fraction of bankers will operate ($\hat{\theta} > 0$), it is assumed that the gross expected rate of return on the storage technology is below that of the long-term risky project. To ensure an interior solution for the number of operating banks in the economy, it is assumed that the **least-efficient** banker does not find it profitable to operate:

(2.8) $\dfrac{R}{(1+\delta(1-\alpha))} < rr_1,$

where $\delta(1-\alpha)$ is the monitoring cost of the least-efficient banker (type $\theta_j=(1-\alpha)$) in the population.

Nonoperating bankers lend to operating banks. Because they are risk-neutral and maximize expected period-two consumption, they will be willing to hold two-period "time deposits."

Operating bankers are located in a **"market."** The remaining bankers **and** short-term depositors are distributed evenly across markets, and **cannot costlessly** move across markets. Thus, a bank knows the quantity of depositors it will receive and the minimum rate of return it must pay to attract depositors.[4]

The following quantities will be used in characterizing the economy. The total monitoring costs in the economy are

(2.9) $(\hat{\theta}) = \displaystyle\int_0^{\hat{\theta}} \delta(\theta)d\theta,$

where $0 \leq \hat{\theta} \leq (1-\alpha)$. Normalizing the number of operating bankers at unity, the average quantities of demand deposits, time deposits, and bank capital are $w^d = \alpha w$, $w^t = (1-\alpha-\hat{\theta})w$, and $w^b = \hat{\theta}w$, respectively.

The Portfolio Choice of an Operating Bank

In this section, the optimization problem of an operating banker is described. The nature of the profit-maximizing deposit contract must satisfy the banker's maximization problem and the utility maximization problem of depositors. (The indexes identifying the technological type of banker have been omitted for notational clarity.)

In period zero, an operating bank chooses an investment portfolio funded by bank capital and deposit liabilities that satisfies the following portfolio balance constraint:

(2.10) $\qquad (1+\delta)(1 + 1^*) + s = w^b + d + d^t$,

where d and d^t are the quantities of demand deposits and time deposits issued by the bank. In period zero, expected period-two bank profits are

(2.11) $\qquad E(\pi) = R1 + R^* 1^* + r_1 s_1 - r^d_2 (1-t)d - r^t d^t$,

where s_1 is the share of bank assets invested in the storage technology in period one, r^d_2 is the gross expected yield on demand deposits held for two periods, and r^t is the gross time-deposit rate.

Technological and informational assumptions affect the contracts issued by banks to attract deposits. One important friction is that a project's return is observed only by the originating bank. A second important assumption is that a bank funds a finite number of risky projects and thus cannot perfectly diversify idiosyncratic risk on its most profitable

investments. Finally, we assume that depositors 1) can observe bank balance sheets in their locality, 2) know the distribution of depositors in their locality, 3) **know** the distribution of future short-term rates, and 4) know the lower bound on bank-specific projects.

A bank must issue demand-deposit contracts that 1) promise a default-free rate of return, 2) promise an expected yield that is competitive with that of the storage technology, and 3) can be withdrawn after one or two periods. A bank can fulfill these conditions by satisfying

$$(2.12) \quad rs \geq r^d_j td \quad (j=1,h),$$

$$(2.13) \quad R^m 1 + R^{*} 1^{*} + r^j s_1 \geq r^d_{2j}(1-t)d + r^t d^t, \quad (j=1,h),$$

$$(2.14) \quad r^d_2 \geq rr_1,$$

$$(2.15) \quad r^d \geq r.$$

Equations (2.12) and (2.13) state that the return on a bank's portfolio will be able **to** compensate depositors as promised in any state of nature (where the subscripts 1 and h refer to the states where the lower bound and upper bound on the future storage rate are realized, respectively). Equations (2.14) and (2.15) require that the expected return on deposit contracts be at least equal to the expected return on the short-term storage technology.

The Maximization Problem of the Marginal Operating Banker

The constrained-optimization problem of the marginal operating banker determines the **profit-maximizing** deposit contract. An operating banker desires to maximize the share of his portfolio invested in long-term, risky projects. A demand-deposit contract, where storage is held solely to pay off early consumers, minimizes a bank's holdings of short-term projects (and maximizes

expected bank profits).[5] This contract promises to pay a deposit rate equal to the current short-term rate.[6] Thus, a bank pqols the liquidity risks of depositors (by issuing them demand deposits) while investing in long-term assets.

The constrained-optimization problem of the marginal operating banker also determines when this optimal portfolio is feasible. Other operating **bankers'** portfolios will be related to the marginal banker's portfolio via the distribution of the monitoring technology. The marginal operating banker will make zero expected economic profits as his net expected return on long-term risky **investments** equals the two-period expected rate of return on short-term investments. The marginal banker in the economy solves

(2.16)   Max $E(\pi(\hat{\theta}))$,

          $(1^*, 1, s)$,

subject to (2.12)-(2.15)   and

(2.17) $rs - r^d td = s_1$,

where $\pi(\hat{\theta})$ is defined by (2.11). Substituting the constraint (2.17) for s_1 and using the portfolio balance constraint (2.10) to eliminate d from the problem, the first-order necessary conditions for 1, 1^*, and s are

(2.18) $\dfrac{(R+\beta_1 R^m)}{(1+\delta)} \geq r^d t(r_1+\beta_1 r^h+\beta) + (1-t)(r^d_2+\beta_1 r^d_{2h})$,

(2.19) $\dfrac{R^*(1+\beta_1)}{(1+\delta)} \geq r^d t(r_1+\beta_1 r^h+\beta) + (1-t)(r^d_2+\beta_1 r^d_{2h})$,

(2.20) $r(r_1+\beta_1 r^h+\beta) \geq r^d t(r_1+\beta_1 r^h+\beta) + (1-t)(r^d_2+\beta_1 r^d_{2h})$,

respectively, where β is the multiplier for constraint (2.12) and β_1 is the multiplier for the solvency constraint (2.13). All banks pay depositors the opportunity cost of their funds. The profit-maximizing deposit costs are 1) $r^t = rr_1$, 2) $r^d = r$, and 3) $r^d_{2j} = rr^j$, where the future short-term

rate is bounded by (r^l, r^h). The marginal operating bank has a monitoring cost of

(2.21) $\frac{R}{rr_1} - 1 = \delta(\hat{\theta})$,

and makes zero expected profits.[7]

III. THE UNCONSTRAINED BANKING ALLOCATIONS

This section describes the alternative equilibrium portfolios of an operating bank and of the aggregate economy. The results presented are for banks that can intermediate funds only in their particular location.[8]

We assume that the marginal operating bank uses its technology; thus, (2.9) and (2.21) determine the number of operating banks as a fraction of the population, $\hat{\theta} < (1-a)$.

For all banks with monitoring costs below $\delta(\hat{\theta})$,

(3.1) $\frac{R}{(1+\delta(\theta))} > rr_1$ for $\theta < \hat{\theta}$.

These banks maximize profits by maximizing their investments in the long-term, risky technology and holding storage projects only to meet expected period-one withdrawals; this describes the "optimal portfolio." A type θ bank has the following portfolio balance constraint for the optimal portfolio:

(3.2) $l(\theta)(1+\delta(\theta)) + s = w^b + w^t + w^d$.

The left-hand side of equation (3.2) shows that a 'bank's investments vary inversely with its monitoring costs, since each bank has the same resources to invest. Actual bank profits will vary randomly with 1) the actual return on risky projects and 2) the actual future interest costs on demand deposits. The

bounds of possible default losses and future &posit   costs are defined by

(2.2). The worst possible profit scenario occurs when a bank realizes the

maximum default losses and the highest deposit costs.

The Unconstrained Banking Allocation

The unconstrained allocation for a type θ bank is feasible if

$$(3.3) \quad \frac{R^m w^b}{(1+\delta(\theta))} \geq (1-t)w^d(rr^h - \frac{R^m}{(1+\delta(\theta))}) + w^t(rr_1 - \frac{R^m}{(1+\delta(\theta))}).$$

The optimal portfolio for an unconstrained bank is thus

$$(3.4) \quad (1+\delta(\theta))l^*_u = 0,$$

$$(3.5) \quad (1+\delta(\theta))l_u = w^b + w^t + (1-t)w^d,$$

$$(3.6) \quad s_u = tw^d,$$

where the subscript u denotes that a bank is unconstrained.

If the marginal operating **bank's** portfolio satisfies **(3.3)**, all banks

of types $\theta_i < \hat{\theta}$ are also unconstrained. Summing over all operating

banks, expected bank profits for the economy are

$$(3.7) \quad E(\pi) = \int_0^{\hat{\theta}} R(w^b + w^t + w^d(1-t))\frac{1}{(1+\delta(\theta))}d\theta - rr_1(w^t + (1-t)w^d),$$

since **s=tw^d**. We will compare alternative constrained allocations to the

unconstrained allocation.

IV. ALTERNATIVE CAPITAL-CONSTRAINED BANKING ALLOCATIONS

To invest in the optimal bank portfolio, a bank's capital

must be sufficient to cover possible losses on the share of risky bank assets,

funded by deposit liabilities. When this condition is not satisfied, a bank

is capital-constrained. This occurs when

$$(4.1) \quad A = (1-t)w^d(rr^h - \frac{R^m}{(1+\delta(\theta))}) + w^t(rr_1 - \frac{R^m}{(1+\delta(\theta))}) - \frac{R^m w^b}{(1+\delta(\theta))} > 0.$$

The first term in (4.1) is the maximum possible portfolio losses on savings deposits, due to both high future short-term rates and asset default. The second term is the maximum losses on time deposits due to default losses on investments made with these funds. The expression **(4.1),** to be called A, is strictly positive when the solvency constraint is binding. We shall describe the alternative equilibria that satisfy the bank solvency constraint in terms of the optimal portfolio and the term A.

Since A is increasing in $\delta(\theta)$, the distribution of monitoring costs will determine the marginal unconstrained bank. Letting $\delta(\theta^u)$ solve A = 0, then θ^u is the share of operating banks that attain the first-best equilibrium.

A capital-constrained bank must choose an alternative investment, a **"reserve"** asset to reduce the risk of the bank portfolio. It has two possible asset-management options:

1) invest in more short-term storage projects, reinvesting the yield in period one, as a substitute for a share of risky investments; and

2) invest in a larger share of default-free, long-term investments as a substitute for risky investments.

These choices shall be referred to as options 1 and 2, respectively. Because both of these assets have a lower expected return, capital-constrained banks will have lower expected profits than if they could invest in the **unconstrained** portfolio. Thus, when $\theta^u < \hat{\theta}$, the aggregate quantity of long-term risky investments and aggregate expected profits will be less than the unconstrained levels.

A second-best portfolio minimizes the decrease in expected profits relative to the optimal portfolio while meeting the capital constraint. The second-best portfolio is not identical for all banks; the optimal reserve asset depends on the efficiency of a banker's technology. Bank technology determines the relative rate of return on using option 1 versus option 2 to meet the capital constraint; more efficient banks find that option 2 has a higher (per-unit) rate of return. However, option 2 reduces only default risk in a bank's portfolio; it provides a smaller per-unit degree of risk reduction. The degree of default risk relative to interest-rate risk in asset markets determines how much of the respective reserve assets must be held to meet the capital constraint.

A bank will unambiguously use the storage asset as a reserve asset when that return dominates the return on default-free bank projects. This will be the case for operating banks of types $\theta_i > \theta^*$, where $\delta(\theta^*)$ solves

$$(4.2) \qquad \frac{R^*}{(1+\delta(\theta^*))} = rr_1 \ .$$

If $\theta^* > \theta^u$, capital-constrained banks of types $\theta_i < \theta^*$ may find it optimal to use long-term projects as a reserve asset. For a bank with sufficiently low monitoring costs, the higher rate of return on long-term projects outweighs the opportunity cost of investing a larger share of the portfolio in the reserve asset.

The alternative allocations are derived in the appendix. In the following sections, options 1 and 2 will be described and compared to the first-best allocation.

Alternative Constrained Allocations

Option 1 can be expressed in terms of A as

(4.3) $s_{c1} = A(rr^h - \frac{R^m}{(1+\delta)})^{-1} + tw^d = \frac{A}{c_1} + tw^d,$

(4.4) $l_{c1} = 1^u \cdot \frac{A}{c_1(1+\delta)},$ where $c_1 = (rr^h - \frac{R^m}{(1+\delta)}).$

Option 2 can be expressed in terms of A as

(4.5) $l^*_{c2} = \frac{A}{(R^* - R^m)} = \frac{A}{c_2},$

(4.6) $l_{c2} = 1^u - \frac{A}{c_2},$ where $c_2 = (R^* - R^m).$

Note that as c_1 (described as the risk reduction per unit of storage) is greater than c_2, l_{c1} is greater than l_{c2}.

Comparing Alternative Portfolio Strategies

In the unconstrained equilibrium, expected profits are

(4.7) $E(\pi^u) = Rl^u - rr_1((1-t)w^d + w^t).$

Expected profits in the two alternative constrained equilibria are

(4.8) $E(\pi_{c1}) = R(1^u - \frac{A}{c_1(1+\delta)}) + rr_1(\frac{A}{c_1}) - rr_1((1-t)w^d + w^t),$

(4.9) $E(\pi_{c2}) = R(1^u - \frac{A}{c}) + R^*(\frac{A}{c}) - rr_1((1-t)w^d + w^t).$

Expected profits are higher for banks when investing in default-free, long-term projects to reduce portfolio risk when

(4.10) $\frac{(R^* - R)}{c_2} > \frac{(rr_1 - \frac{R}{(1+\delta(\theta))})}{c_1}$

The expected profitability of option 2 is inversely related to monitoring costs (and to A). Letting $\delta(\theta_{c2})$ solve (4.10) with equality, we find that the marginal monitoring cost below which option 2 represents the second-best equilibrium is

(4.11) $\delta(\theta_{c2}) = \frac{(R^* - R^m)(R - rr_1) - (R - R^*)(rr^h - R^m)}{(R^* - R^m)rr_1 + (R - R^*)rr^h}$

The value of $6(\theta_{c2})$ represents a corner solution for banks.[9]

Also, the number of banks choosing option 2 is positively related to the degree of default risk relative to interest-rate risk. Determining the **parameter** values such that no bank will find **option c2** to be more profitable than option **c1** involves solving (4.11) for $\delta(\theta_{c2}) = 0$. Rearranging the resulting expression illustrates that $\delta(\theta_{c2})$ is positive and increasing in the following expression:

$$(4.12) \quad \frac{(R - rr_1)}{(rr^h - R^m)} - \frac{(R - R^*)}{(R^* - R^m)} > 0.$$

This expression has a useful interpretation. The terms in the numerators of the ratios reflect the expected opportunity cost (per unit) of options 1 and 2, respectively, independent of bank monitoring costs. The terms in the denominators measure the degree of portfolio risk-reduction (per unit) of options 1 and 2, respectively. Thus, the ratio measures the marginal cost relative to the marginal benefit of the alternatives for all banks. As the **cost/benefit** ratio of option 1 rises relative to that of option 2, $\delta(\theta_{c2})$ increases, and banks with less-efficient technologies find it profitable to shift to using bank projects as a reserve asset.

When default losses have a large weight in the risk of bank portfolios, default-free bank projects are a more efficient substitute for risky assets than the storage technology. A mean-preserving spread on R unambiguously increases the marginal monitoring cost below which option 2 is optimal. It should be noted that the share of banks that are constrained increases as well. Thus, the total holdings of these reserve assets increase.

When interest-rate variability plays a larger role in constraining bank portfolio choices, the storage technology is a more efficient reserve asset. A mean-preserving spread of the distribution of future short-term rates

increases the fraction of banks that use option 1 (**Θ_{c2}** falls); this, in turn, increases the share of banks that are constrained as well as the aggregate quantity of storage projects.[10]

V. CONCLUDING REMARKS

This paper has focused on analyzing the implications of bank asset transformation for bank portfolio choice. Our model shows how a short-term substitute for bank liabilities and informational **asymmetries** force banks to consider interest-rate variability as well as default risk.

A frequent result in the asymmetric information literature is that information costs create a nonlinearity in the optimization problem of risk-neutral agents, which makes them behave as if they are risk-averse. The **dispersion** of imperfectly observed variables affects the expected information costs associated with making a transaction.

In our framework, there are sufficiently high costs for 1) risk-neutral depositors to observe bank project returns and 2) risk-neutral banks to observe depositors' preference shocks. Hence, banks "self-insure" that they can pay off deposit liabilities under all possible portfolio outcomes. When a bank is capital-constrained, meeting the worst possible outcome involves choosing a second-best portfolio, and a risk-neutral banker is forced to sacrifice (expected) return for portfolio risk-reduction. Although both depositors and bankers are risk-neutral, asymmetric information forces a constrained bank to consider risk factors as well as (expected) return.

Given that a bank is capital-constrained, the relative portfolio risks affect a bank's choice of a reserve asset to reduce portfolio risk. The expected relative return from using bank technology and the relative portfolio risks affect the choice of the most efficient **reserve** asset. A bank will weigh the expected **return/risk-reduction** trade-off of alternative bank investment opportunities. In a sense, a bank has an efficient frontier of projects, and the parameters of the binding capital-constraint determine its portfolio choices.

Capital-constrained banks behave as if they are risk-averse to avoid the extreme costs of indifference toward risk, which is the inability to conduct intermediation and profit from their technology.

FOOTNOTES

1. See Gertler (1988) for an expose on this literature.

2. These models do not model deposit insurance in their analyses.

3. Bemanke and Gertler (1987) do have both risky assets and demand deposits, but the latter are relatively inconsequential to their analysis.

4. This market structure results in a banker accruing all of the profits when the (expected) marginal **return** on his portfolios is above the opportunity cost of funds.

5. This is the case because a mutual-fund-type "share" contract requires banks to hold a reserve of storage assets to meet higher period-one deposit costs when future storage rates are low.

6. Because the expected return on risky projects is greater than the expected two-period storage rate for all but the marginal operating banker, bankers minimize their storage holdings and satisfy (3.12) and (3.15) by linking one-period **deposit** returns to market rates.

7. The multiplier $\beta = 0$, even when constraint (3.9) is holding with equality.

8. This separation of banking markets is necessary because bankers have different monitoring costs, which are assumed to exhibit constant returns to scale. Another way to avoid having a monopolistic banker would be to place an upper bound on the quantity of projects a banker can evaluate.

9. $\delta(\theta^{c2})$ is decreasing in r, $r_{,}$, r^h, and R, and increasing in R^* and $\mathbf{R^m}$.

10. The effect on the quantity of long-term, default-free investments is uncertain.

APPENDIX: ALTERNATIVE CAPITAL-CONSTRAINED ALLOCATIONS

Option 1 can be described by

(A.1) $l^*_{c1} = 0$,

(A.2) $(1+\delta)l_{c1} + s_{c1} - tw^d = (1+\delta)l^u$,

(A.3) $(s_{c1} - tw^d) > 0$,

where s_{c1} solves

(A.4) $\dfrac{R^m}{(1+\delta)}(l^u(1+\delta)-(s_{c1}- tw^d)) + rr^h(s_{c1}tw^d) = rr^h(1-t)w^d + rr_1w^t$.

Using (A.1), (A.2), (A.3), and the appropriate substitutions, s_{c1} and l_{c1} can be expressed in terms of A (in section IV) as:

(4.3) $s_{c1} - tw^d = A(rr^h- \dfrac{R^m}{(1+\delta)})^{-1} = \dfrac{A}{c_1}$,

(4.4) $l_{c1} = l^u - \dfrac{A}{c_1(1+\delta)}$, where $c_1 = rr^h - \dfrac{R^m}{(1+\delta)}$.

Option 2 involves substituting default-free long-term projects for risky, long-term investments to satisfy the solvency constraint; thus,

(A. 5) $(1+\delta)l^*_{c2} = w^b + (1-t)w^d + w^t - l_{c2}(1+\delta)$,

(A. 6) $l_{c2} < l^u$,

(A.7) $s_{c2} = s^u = tw^d$.

The value for l^*_{c2} will solve

(A.8) $\dfrac{R^m}{(1+\delta)}(w^b + (1-t)w^d + w^t- l^*_{c2}(1+\delta)) + R^*l^*_{c2} = rr^h(1-t)w^d + rr_1w^t$.

From (A.5) to (A.8), expressions for l^*_{c2} and l_{c2} in terms of A are

(4.5) $l^*_{c2} = \dfrac{A}{(R^*-R^m)} = \dfrac{A}{c_2}$,

(4.6) $l_{c2} = l^u - \dfrac{A}{}$,   where $c_2 = (R^* - R^m)$.

Because c_1 (which is the risk-reduction per unit of storage) is greater than c_2, $l_{c1} > l_{c2}$.

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