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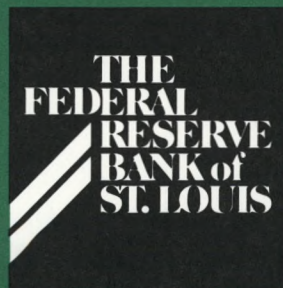
Vol. 72, No.1

January/February 1990

3 Market Discipline of Bank Risk:
Theory and Evidence

19 On the Use of Option Pricing
Models to Analyze Deposit
Insurance

35 What Do We Know About the
Long-Run Real Exchange Rate?



In This Issue . . .

Policymakers in the federal government are considering various changes in deposit insurance in response to the large number of bank and thrift failures in recent years and the associated large losses by the insurance funds. Some proposed reforms would reduce the government's insurance coverage to increase the effectiveness of market forces in limiting the risk that banks assume. Other reforms would base insurance premiums on the risk that banks assume.

In the first article in this *Review*, "Market Discipline of Bank Risk: Theory and Evidence," R. Alton Gilbert investigates the implications of deposit insurance reform proposals based on market discipline. Gilbert uses a simple theoretical exercise to illustrate how market forces could limit the risk assumed by banks under different approaches to reforming deposit insurance. He also summarizes the empirical studies of the effectiveness of market discipline to determine whether market forces actually could be expected to limit such risks.

Under the current arrangements, the cost of resolving bank and thrift failures is borne largely by the taxpayer through the federal deposit insurance agencies. In the policy debate, which considers the flaws and potential alternatives to the present system, a number of economists have utilized a set of theoretical tools — called option pricing models — for analytic purposes. In the second article of this issue, "On the Use of Option Pricing Models to Analyze Deposit Insurance," Mark D. Flood outlines the basic theory of option pricing, which was originally developed to assign dollar values to the option contracts traded on financial exchanges. The author then illustrates how an option model can be usefully employed to analyze the claims of bankers, depositors and insurers on the assets of a bank or thrift by applying the model to several insurance arrangements. Finally, Flood considers some of the limitations of this approach.

* * *

Exchange rates have been at the center of numerous economic policy discussions in the 1980s. In the third article in this *Review*, "What Do We Know About the Long-Run Real Exchange Rate?" Cletus C. Coughlin and Kees Koedijk review what is known about movements in one type of exchange rate, the long-run real exchange rate. Despite much research, there is no consensus on which variables cause changes in the real exchange rate. Coughlin and Koedijk review the literature to provide an elementary understanding of the three primary approaches and the variables thought to influence the long-run real exchange rate. Using a data set covering the current floating-rate period, the authors compare the three approaches empirically and conclude that none provides an adequate explanation of movements in the long-run real exchange rate.

R. Alton Gilbert

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Market Discipline of Bank Risk: Theory and Evidence

BECAUSE of the many failures of banks and thrift institutions in recent years and the high cost of liquidating or reorganizing the bankrupt savings and loan associations, policymakers are now considering major changes in the way they supervise and regulate depository institutions in the United States. The Financial Institutions Reform, Recovery and Enforcement Act of 1989, which provides the funds for closing bankrupt savings and loan associations (S&Ls), calls for several government agencies to study the issues involved.¹ The federal budget document for fiscal 1991 discusses the basis for reform of deposit insurance and the advantages of various reforms.²

To some extent, the unusually high failure rate of depository institutions (hereafter called banks) can be attributed to developments in the economy such as declines in the prices of oil and farmland in the early 1980s. Some studies conclude that fraud and mismanagement account for many of the bank failures.³ The general consensus, however, is that deposit insurance creates an incentive for banks to assume higher risk than they would without it. Such risk may be gauged in terms of the variance of

a bank's return on assets as a percentage of its capital. The logic that underlies this consensus is that without deposit insurance, banks that choose portfolios of assets with higher variance in their rates of return, or lower ratios of capital to total assets, would have to pay higher interest rates on deposits. Deposit insurance blunts this penalty. The relatively high failure rate and losses of the deposit insurance funds reflect, to some extent, the banks' response to the incentives to assume risk created by deposit insurance. Thus, a major issue in the debates over financial reform is the future role of deposit insurance.

Some recent proposals to reform deposit insurance are designed to increase the effectiveness of market forces in reducing the risk assumed by banks. Under these proposals, bank owners and creditors would be exposed to larger losses if their banks fail. The theory is that if bank owners and creditors have greater exposure to losses, they will limit the risk assumed by their banks. In some proposals, this influence would complement the efforts of bank supervisors. In others, market discipline would replace government supervision.

¹Title X of the act directs the Secretary of the Treasury and the Comptroller General, in consultation with various federal government agencies and individuals from the private sector, to prepare reports on issues related to the reform of deposit insurance, including the implications of policies that would enhance the effectiveness of market discipline.

²Budget (1990), pp. 246-53.

³Graham and Horner (1988) and Office of the Comptroller of the Currency (1988).

This paper describes some of these proposals for enhancing the effectiveness of market discipline and illustrates how they would affect the banks' incentive to assume risk. The paper also examines the empirical evidence on the effectiveness of market discipline. Proposals for the reform of deposit insurance that rely on market discipline assume that market participants can differentiate among banks on the basis of risk, and that market yields on bank debt reflect that risk. The paper lists the results of several empirical studies and draws conclusions about the potential effectiveness of these proposals in reforming deposit insurance.

THE OBJECTIVES OF DEPOSIT INSURANCE

Various approaches to enhancing the effectiveness of market discipline of bank risk are presented in table 1. Choosing one approach over another depends in part on which basic objective of deposit insurance is considered to be most important.

The following are the primary objectives of deposit insurance:

1. To protect depositors with small accounts,
2. To prevent widespread runs by depositors on banks, and
3. To protect the insurance fund from losses that would bankrupt it.⁴

There are tradeoffs among these objectives. The policy that provides the greatest protection against runs by depositors is complete coverage of all deposit accounts. That policy, however, eliminates any incentive for depositors to exert their discipline over the risk assumed by their banks, leading perhaps to an increase in the insurance fund's losses.

The dollar limit on the amount in each account that is insured, currently \$100,000, reflects an attempt to balance these objectives. Total coverage of accounts less than \$100,000 protects small depositors. The limit on the insurance coverage per account is designed to induce the depositors with large accounts to monitor their banks and require that riskier banks pay higher interest rates on their deposits. Those with relatively large accounts are assumed to be better able to impose such market discipline. The limit on insurance coverage

Table 1

Proposals to Increase the Effectiveness of Market Discipline of Bank Risk

- (1) Phase out federal deposit insurance to facilitate the development and use of private deposit insurance. Short and O'Driscoll (1983), Ely (1985), England (1985) and Smith (1988).
- (2) Lower the ceiling on federal insurance coverage per account. Council of Economic Advisers (1989), pp. 203-4.
- (3) Co-insurance: limit federal deposit insurance to some fraction of each account. Boyd and Rolnick (1988).
- (4) Place a ceiling on federal deposit insurance per individual at all depository institutions. England (1988).
- (5) All institutions must maintain subordinated debt liabilities that are some fraction of their total assets. Cooper and Fraser (1988), Keehn (1989) and Wall (1989).
- (6) Early closure: close or reorganize depository institutions when their capital ratios, reflecting the market value of assets and liabilities, are low but still positive. This proposal is designed to enhance the effectiveness of market discipline by closing or reorganizing banks whose shareholders have weak incentive to limit risks. Benston and Kaufman (1988).

per account, however, tends to undermine the objective of preventing runs by depositors on the banking system.

Of course, a run by depositors on an *individual* bank does not create a serious problem for the banking system, because these depositors simply remove their cash from one bank and deposit it in another in which they have more confidence. If the bank subject to the run cannot meet its depositors' demand for currency, it will have to close. Its depositors will be paid as the assets of the failed bank are liquidated. A run on a bank can serve a useful purpose—a mechanism for closing a bank in which depositors have lost confidence.

Runs become a problem for the banking system, however, when depositors withdraw currency and, hence, reserves from banks as a group. Banking history in the United States and

⁴Federal Deposit Insurance Corporation (1983), pp. viii-xiii.

the United Kingdom prior to their central banks acting as lenders of last resort indicates that runs on banking systems have occurred, although they tended to be separated by many years.⁵

Some argue that deposit insurance is not necessary to avoid the adverse social effects of banking system runs. They maintain that, as long as the central bank acts as an effective lender of last resort, the liquidity it provides would limit any damage that runs on individual banks could do.⁶ An alternative view emphasizes the dangers of relying on the central bank to operate as the lender of last resort to a banking system without deposit insurance. A central bank might respond inappropriately in a financial crisis, as the Federal Reserve did in the early 1930s, leading to rapid declines in the assets of the banking system and widespread bank failures. Deposit insurance reduces the role of the central bank in maintaining stability in the operation of the banking system. Thus, the choice among the potential reforms of deposit insurance rests on views about the vulnerability of the banking system to runs and the effectiveness of a lender of last resort in dealing with runs.

If the primary objectives of deposit insurance are to protect small depositors and to protect the insurance funds from large losses, a logical change would be to reduce the insurance coverage per account. This was proposed by the President's Council of Economic Advisers in 1989. Those who consider the possibility of banking system runs a serious threat to the stability of the banking system would oppose a large reduction in the insurance coverage on bank deposits.

THE EFFECTS OF REFORM PROPOSALS ON BANKING RISK

The reform proposals are designed to reduce the incentives for banks to assume risk. In evaluating their effectiveness, it is useful to consider three indicators of the banking system's performance that reflect this risk: the expected loss by depositors due to the bank failure, the

expected loss of the Federal Deposit Insurance Corporation (FDIC), and the probability that a bank will fail. The expected loss by depositors and the FDIC are considered separately since proposals that reduce the FDIC's expected loss tend to increase the expected loss by depositors. Focusing on only one of these measures of performance misses some of the reform proposals' implications. The third measure, the probability of bank failures, is of interest because of evidence that bank failures have adverse effects on economic activity in addition to the wealth losses by depositors and owners.⁷ The studies that find adverse effects of bank failures on economic activity attribute those effects to the constraints on the availability of credit created by bank failures.

The proposals' implications for the effectiveness of market discipline can best be derived by using a model of the behavior of banks and their creditors.⁸

Nature of the Model

The implications of the various reform proposals are derived by examining the effects of proposed changes in deposit insurance on the optimal choice of risk by a representative banker. Several assumptions are made to simplify the model.

Rate of Return on Assets — The only random variable in the model is the rate of return on assets of the representative bank, which has the same probability distribution under all assumptions about the nature of deposit insurance. Bank regulators are assumed to determine the probability distribution of the rate of return by restricting the types of assets the bank may hold. The only choice for the representative banker in this model is the *level* of the bank's total assets. The capital of the bank is held constant at \$100 in each case. With a given level of capital and a given probability distribution of the rate of return on assets, the probability of failure (losses exceeding capital) is positively related to the total assets of the bank. Management is assumed to choose the level of

⁵Gilbert and Wood (1986) and Dwyer and Gilbert (1989).

⁶See Kaufman (1988) and Schwartz (1988).

⁷See Bernanke (1983), Calomiris, Hubbard and Stock (1986), Grossman (1989), and Gilbert and Kochin (1989).

⁸To illustrate the need for such a model, consider a basic reform of eliminating deposit insurance. That change would increase the interest expense of a bank with a given

portfolio of assets, thereby tending to increase its probability of failure. The penalty of higher interest expense imposed by depositors on those banks that assume more risk would induce banks to assume less risk in their choice of assets. The net effect of eliminating deposit insurance on the probability of bank failure must be derived from a theoretical model that specifies the risk preferences of depositors and bank managers.

total assets that maximizes the expected profits of the bank.

With a given level of bank capital, the conditions under which the bank fails can be derived only with a specific probability distribution of return on assets. This paper uses the discrete probability distribution presented in table 2.⁹ For each of the seven possible outcomes, the rate of return on assets is net of the operating cost of servicing the assets.

The rate of return associated with each outcome is assumed to be inversely related to the size of the bank's total assets. One reason for this assumption of an inverse relationship is that, as the bank increases its total assets, it must lend to borrowers beyond the local area in which it has some market power. Another reason is diseconomies of scale in the operating cost of servicing assets. For each outcome with a positive return on assets, therefore, the rate of return falls as total assets increase. This feature of the model yields a maximum expected profit for the bank under each assumption about deposit insurance.¹⁰

Bank Costs — For a given level of total assets, the bank's cost depends on the insurance coverage on its liabilities. This paper considers the four cases described below. If, as in case A, all deposits are fully insured, the bank can attract an unlimited supply of deposits by paying the risk-free rate of interest. Under each of the

four assumptions about deposit insurance, the costs of servicing deposit accounts are offset by fees charged to depositors.

For a given level of total assets, the highest expense occurs in case B, with no deposit insurance. In this case, the interest rate that the bank must pay on deposits is positively related to its total assets. Depositors are assumed to be risk-neutral and to know the probability distribution of the bank's return on assets. Hence, the bank must pay the rate to depositors that makes their expected return on deposits equal to the risk-free rate.¹¹

The interest rate that the bank pays depositors is above the risk-free rate if the bank fails in at least one of the seven possible outcomes. If it fails, the depositors receive the liquidation value of the bank's assets. Liquidation value in those outcomes reflects the probability distribution of the bank's return on assets. There is no additional loss to depositors resulting from the elimination of the bank as a going concern.¹² The equation for calculating the rate paid to depositors in case B is presented in table 2.

Cases C and D reflect two methods of enhancing the effectiveness of market discipline of bank risk, while retaining some form of deposit insurance. Co-insurance in case C limits deposit insurance coverage to 90 percent of each deposit account.¹³ In case D, deposits are fully insured, but each bank is required to keep its

⁹The use of a discrete probability distribution, with a limited number of outcomes, makes the presentation simpler than if a continuous probability distribution was used. In using a discrete probability distribution, there is a trade-off between simplicity and continuity of the probability of failure with respect to leverage. The smaller the number of possible outcomes, the larger the jumps in the probability of failure at certain asset levels. Increasing the number of possible outcomes, however, increases the difficulty of illustrating the calculations. Thus, the probability distribution in table 2 is arbitrary.

¹⁰The model abstracts from possible losses by our representative bank on the deposits it holds at other banks. If a reform proposal increases the probability of losses on interbank deposits, the effects of such reform proposals on the probability of failure at our representative bank would be understated.

This point about possible loss on interbank deposits is most relevant in comparing the case with no deposit insurance to the other cases examined below. The model in this paper is not modified to reflect directly the effects of possible losses on interbank deposits.

This model also ignores losses from runs on the bank by its depositors in reaction to the failure of other banks. If deposit insurance coverage is reduced or eliminated, the

failure of some banks may induce depositors to run on other banks to receive currency in exchange for their deposits. Several such episodes occurred in the United States prior to the establishment of deposit insurance in the 1930s. See Dwyer and Gilbert (1989). To incorporate the possible effects of runs, the probability distribution of the return on assets at the representative bank would have to be specified as a function of the number of bank failures.

¹¹The general nature of the comparisons among the four cases would not be changed if depositors were assumed to be risk averse.

¹²The assumption that a bank's assets lose no value when they are liquidated results in an understatement of the expected loss of depositors and bank creditors in the various cases. A study by the Federal Deposit Insurance Corporation, Bovenzi and Murton (1988), reports that when the FDIC liquidates the assets of failed banks, their liquidation value averages about 70 percent of the book value of the assets of failed banks.

¹³Boyd and Rolnick (1988) suggest 90 percent coverage of deposits in their proposal for a form of co-insurance in deposit insurance.

Table 2

A Model of Bank Profits**NET REVENUE**

Revenue of the bank, net of the operating cost of servicing assets, is a random variable with a discrete probability distribution. Let A be the assets of the bank. The probability distribution is as follows.

Outcome number	Net revenue	Probability
1	$0.4(1 - A/10,000)A$	0.01
2	$0.3(1 - A/10,000)A$	0.04
3	$0.2(1 - A/10,000)A$	0.10
4	$0.1(1 - A/10,000)A$	0.70
5	$0.0(1 - A/10,000)A$	0.10
6	$-0.1(1 - A/10,000)A$	0.04
7	$-0.2(1 - A/10,000)A$	0.01

COST

The cost of the bank is not a random variable. It is the same in each of the seven outcomes. Expected profits are calculated for four cases, each involving a different assumption about the interest expense of the bank. In those outcomes in which the bank has a loss, the maximum loss to the shareholders is their investment of \$100.

Case A: All Liabilities Fully Insured
The bank pays the risk-free rate of 8 percent on deposits, which equal $A - \$100$.

Case B: No Deposit Insurance
At each level of total assets of the bank, the interest rate on deposits is set at the level that makes the expected return to holders of uninsured deposits equal to the risk-free rate of 8 percent.

The interest rate on deposits in case B, for a given level of assets, can be derived by solving the following equation for R , the interest rate on deposits. To economize on notation, let $A^* = (1 - A/10,000)A$. Then,

$$\begin{aligned}
 1.08(A - 100) = & \\
 & 0.01(1 + R)(A - 100), \text{ or} \\
 & 0.01(1.4A^*) \text{ if } 0.4A^* - R(A - 100) < -100 \\
 + & 0.04(1 + R)(A - 100), \text{ or} \\
 & 0.04(1.3A^*) \text{ if } 0.3A^* - R(A - 100) < -100 \\
 + & 0.1(1 + R)(A - 100), \text{ or} \\
 & 0.1(1.2A^*) \text{ if } 0.2A^* - R(A - 100) < -100 \\
 + & 0.7(1 + R)(A - 100), \text{ or} \\
 & 0.7(1.1A^*) \text{ if } 0.1A^* - R(A - 100) < -100 \\
 + & 0.1(1 + R)(A - 100), \text{ or} \\
 & 0.1(A^*) \text{ if } -R(A - 100) < -100 \\
 + & 0.04(1 + R)(A - 100), \text{ or} \\
 & 0.04(0.9A^*) \text{ if } -0.1A^* - R(A - 100) < -100 \\
 + & 0.01(1 + R)(A - 100), \text{ or} \\
 & 0.01(0.8A^*) \text{ if } -0.2A^* - R(A - 100) < -100
 \end{aligned}$$

 Table 2 continued

A Model of Bank Profits

Case C: Co-insurance

The calculation of the stated interest rate on deposits as in case B is modified by setting the minimum return to depositors in each outcome at 90 percent of their principal plus stated interest.

The equation for the interest rate on deposits is the same as that presented for case B, except that in each of the seven possible outcomes, the return to the depositors can be no less than: $0.9(1 + R)(A - 100)$.

Case D: Subordinated Debt Requirement

The bank is required to have liabilities that are uninsured and subordinated to deposits, equal to at least 10 percent of its total assets. Deposits are fully insured. The interest rate on deposits is 8 percent. The interest rate on subordinated debt, for a given level of assets, can be derived by solving the following equation for R.

$$1.08(0.1)(A) =$$

$$0.01(1 + R)0.1A, \text{ or}$$

$$\text{if } 0.4A^* - R(0.1A) - 0.08(0.9A - 100) < -100,$$

$$0.01 \text{ (the greater of } 1.4A^* - 1.08(0.9A - 100) \text{ or zero)}$$

$$+ 0.04(1 + R)0.1A, \text{ or}$$

$$\text{if } 0.3A^* - R(0.1A) - 0.08(0.9A - 100) < -100,$$

$$0.04 \text{ (the greater of } 1.3A^* - 1.08(0.9A - 100) \text{ or zero)}$$

$$+ 0.1(1 + R)0.1A, \text{ or}$$

$$\text{if } 0.2A^* - R(0.1A) - 0.08(0.9A - 100) < -100,$$

$$0.1 \text{ (the greater of } 1.2A^* - 1.08(0.9A - 100) \text{ or zero)}$$

$$+ 0.7(1 + R)0.1A, \text{ or}$$

$$\text{if } 0.1A^* - R(0.1A) - 0.08(0.9A - 100) < -100,$$

$$0.7 \text{ (the greater of } 1.1A^* - 1.08(0.9A - 100) \text{ or zero)}$$

$$+ 0.1(1 + R)0.1A, \text{ or}$$

$$\text{if } -R(0.1A) - 0.08(0.9A - 100) < -100,$$

$$0.1 \text{ (the greater of } A^* - 1.08(0.9A - 100) \text{ or zero)}$$

$$+ 0.04(1 + R)0.1A, \text{ or}$$

$$\text{if } -0.1A^* - R(0.1A) - 0.08(0.9A - 100) < -100,$$

$$0.04 \text{ (the greater of } 0.9A^* - 1.08(0.9A - 100) \text{ or zero)}$$

$$+ 0.01(1 + R)0.1A, \text{ or}$$

$$\text{if } -0.2A^* - R(0.1A) - 0.08(0.9A - 100) < -100,$$

$$0.01 \text{ (the greater of } 0.8A^* - 1.08(0.9A - 100) \text{ or zero)}$$

subordinated debt liabilities equal to 10 percent or more of its total assets.¹⁴

In cases C and D, the interest rates on bank liabilities also are set at levels that make expected returns to bank creditors equal to the risk-free rate. Equations for calculating the interest rates on bank liabilities are specified in table 2.

Other reform proposals are of interest but are more difficult to incorporate into this simple model. For instance, more detail would be necessary to model the effects of changing the deposit insurance limit per account or limiting FDIC coverage for each depositor to a given amount at all insured institutions.

Case A: All Liabilities Fully Insured

The bank maximizes expected profits in this case with total assets around \$1800 (see figure 1). At this level, the bank fails (losses exceed the \$100 of capital) in outcomes 5, 6 and 7. Thus, the probability that the bank will fail is 15 percent, based on the probability distribution for the return on assets in table 2. The FDIC's expected loss, \$14.26, is about 0.84 percent of insured deposits. The expected loss of depositors, of course, is zero.

Case B: No Deposit Insurance

Several reform proposals call for phasing out deposit insurance (see table 1). With no deposit insurance, depositors lose part of their principal plus interest if the bank fails (if losses exceed the \$100 of capital). The interest rate on deposits charged by risk-neutral depositors is positively related to the bank's total assets (see figure 2).

The bank maximizes its expected profits with total assets equal to \$1,000. It fails only in outcomes 6 and 7. Thus, the probability that the bank will fail is only 5 percent, compared with a 15 percent probability of failure associated with maximum profits in case A. Case B illustrates how a bank that maximizes expected profits can be induced to limit its probability of failure through market discipline imposed by its creditors.

The FDIC's expected loss in this case is zero. The expected loss of depositors with total assets equal to \$1000 is \$4.21, which is about one-half of one percent of deposits.

Case C: Co-insurance

Under the co-insurance option, federal deposit insurance coverage would be limited to a fraction of each deposit, with some low level of each account fully covered to protect small depositors. Those who advocate co-insurance argue that the depositors subject to fractional coverage at the margin would monitor the risk assumed by their banks and demand relatively high interest rates on deposits at the banks that assume relatively high risk.

To simplify the illustration, all deposit accounts are subject to the same percentage of insurance coverage. In those outcomes in which the bank fails, payments to depositors under the co-insurance option would be the larger of:

- (1) the liquidation value of the bank's assets, or
- (2) 90 percent of the principal plus interest on their deposits. The FDIC incurs a loss only if the bank fails and the liquidation value of the bank is less than 90 percent of the principal plus interest on deposits.

As in case B, the market interest rate on deposits is set at the level that makes the expected return on deposits equal to 8 percent. The difference in this case is that depositors have the option of receiving 90 percent of their principal plus interest from the FDIC if their banks fail. Figure 2 indicates that for a given level of total assets, the market interest rate on deposits is lower in case C than in case B, because in case C the losses of depositors are limited by deposit insurance.

Under the assumptions of case C, the bank maximizes expected profits with total assets of \$1100. The bank must pay 8.44 percent to attract the \$1000 in deposits. With assets of \$1100, the probability of the bank failing is 5 percent. The FDIC's expected loss is only 0.072 percent of insured deposits, about 9 percent of

¹⁴Case D involves a higher percentage of subordinated debt to total assets than some of the proposals that call for subordinated debt requirements. For instance, the recent proposal of the Federal Reserve Bank of Chicago recommends that banks be required to maintain a 4 percent

ratio of subordinated debt to total assets. See Keehn (1989). The 10 percent requirement in case D is chosen to indicate that the degree of market discipline that can be imposed through a co-insurance proposal can be matched with a subordinated debt proposal.

Figure 1
Expected Profits

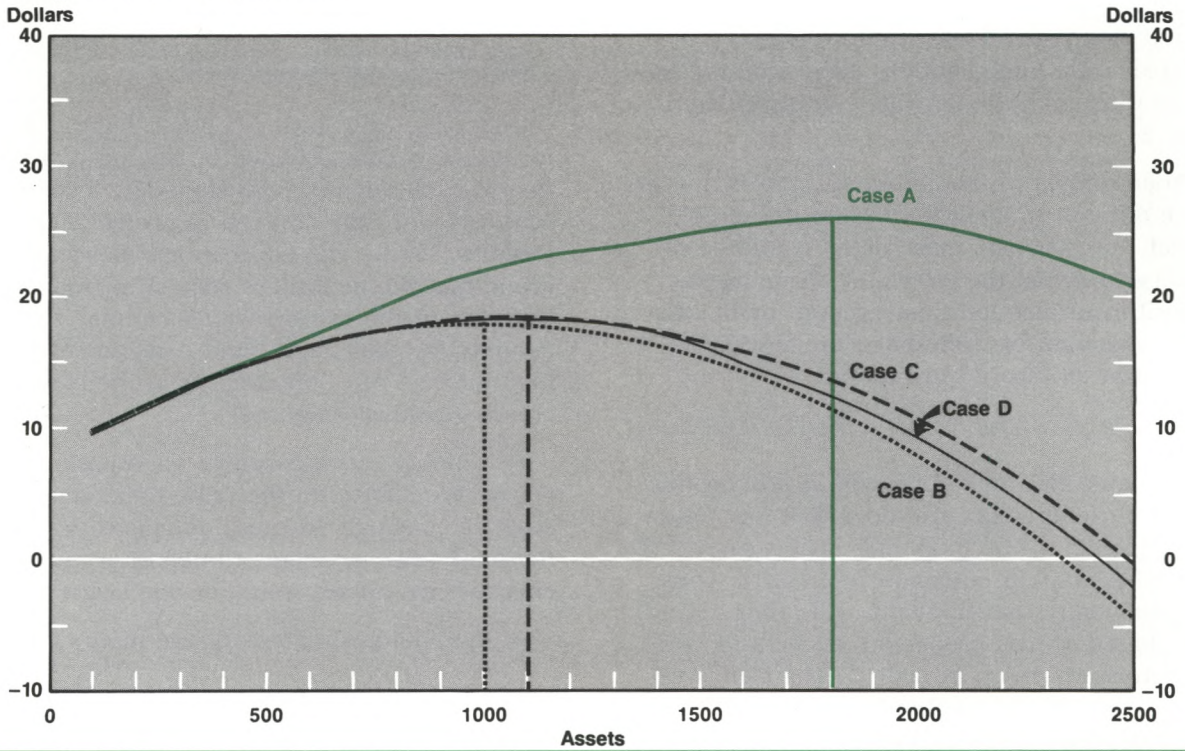
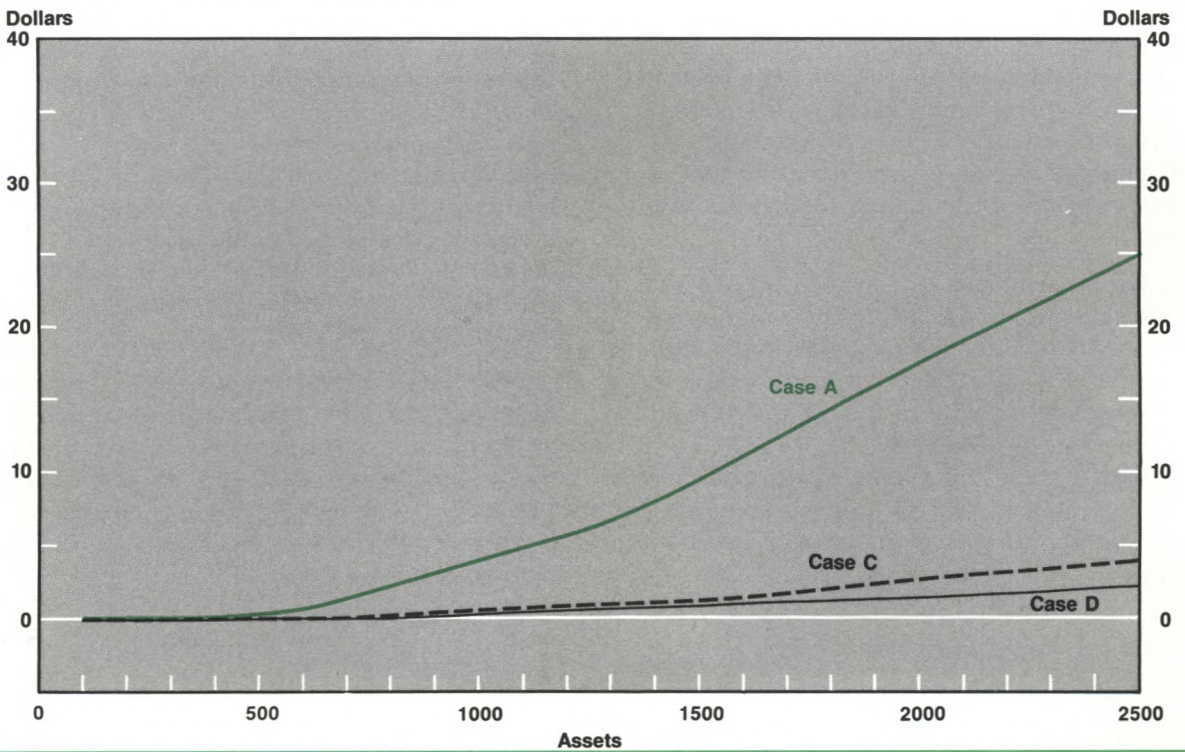


Figure 2
Expected Loss to FDIC



the loss rate for case A, with total assets at \$1800. The expected loss to depositors is \$5.09, which is about one-half of one percent of total deposits.

From the FDIC's perspective, there are two advantages of co-insurance (case C) over full deposit insurance (case A). First, the bank chooses a level of assets associated with a lower probability of failure. Second, for a given level of total assets of the bank, the FDIC's expected loss is lower under case C.¹⁵

Case D: Subordinated Debt Requirement

Some proposals for deposit insurance reform would require banks to issue subordinated debt liabilities that are not federally insured. The term "subordinated" refers to the status of creditors of a firm in bankruptcy. If a failed bank is liquidated, those who hold subordinated debt would receive payments only if all depositors are paid in full.

In case D, all deposits are fully insured by the FDIC. The bank, however, must have uninsured liabilities, which are subordinated to deposits, that equal at least 10 percent of its total assets. The bank would choose to keep subordinated debt liabilities at the 10 percent minimum since, except at relatively low levels of total assets, the interest rate on subordinated debt exceeds the risk-free rate paid on insured deposits.

As in cases B and C, those who invest in subordinated debt are assumed to be risk-neutral and know the probability distribution of the net return on assets. Figure 3 presents the interest rate on subordinated debt as a function of the total assets of the bank.¹⁶ For most levels

of total assets, the interest rates on subordinated debt is higher than the rates on deposits in the cases analyzed earlier because the expected loss is higher for those holding subordinated debt. If the bank's losses exceed the \$100 investment of the shareholders, holders of the subordinated debt receive some payment only if the liquidation value of the bank exceeds total deposits.

The bank maximizes expected profits with total assets equal to \$1100. At that level, the bank must pay 12.12 percent on its subordinated debt liabilities. The FDIC incurs losses only if the loss of the bank exceeds the \$100 capital of the shareholders plus the subordinated debt. The bank has a 5 percent probability of failure, and the expected loss of the FDIC with total assets equal to \$1100 is 0.06 percent of insured deposits. Depositor losses are zero.

Comparison of Cases B, C and D

A comparison of risk in the operation of the banking system under various assumptions depends on one's assumption about the probability of runs on the banking system. If this probability is assumed to be zero, the elimination of deposit insurance (case B) induces banks to assume minimum risk. The FDIC's expected loss is zero in this case, and the bank is induced by market forces to choose the lowest level of total assets. One advantage of the subordinated debt requirement over the other options is that, while the bank is induced to choose a level of total assets below that in case A, the subordinated debt is not subject to runs. Thus, the comparison of risk between cases A and D does not depend on assumptions about runs on the banking system.

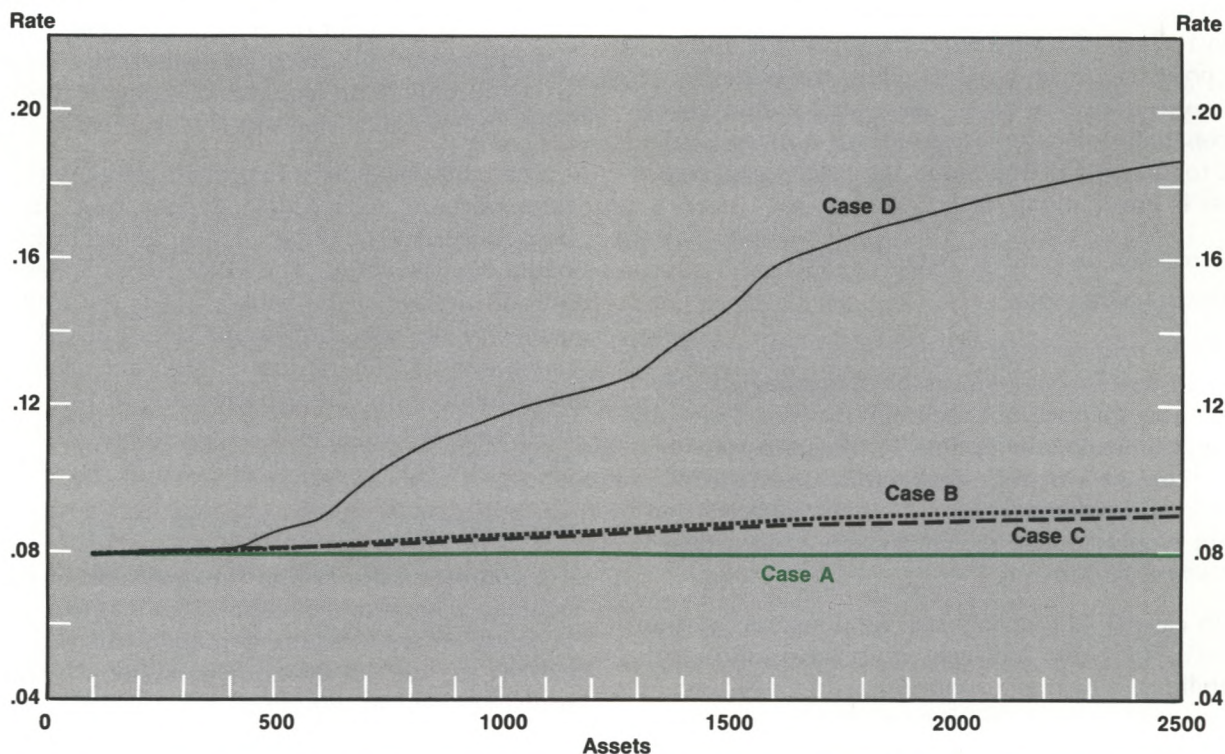
¹⁵Co-insurance, however, has one disadvantage. A change from full coverage of insured deposits to co-insurance creates an incentive for depositors to run on banks in response to information (or rumors) about problems at banks. Even with the FDIC insuring 90 percent of the principal and interest of deposit accounts, depositors have an incentive to avoid the 10 percent loss by withdrawing their deposits from a failing bank. Thus, in comparing cases A and C, co-insurance reduces the significance of deposit insurance in preventing runs on the banking system, placing greater responsibility on the role of the Federal Reserve in stabilizing the banking system in a financial crisis, as it functions as the lender of last resort. If there is some doubt that the Federal Reserve will execute its role as lender of last resort, co-insurance may be less advantageous than full insurance of deposits.

¹⁶The humped pattern of the interest rate on subordinated debt for case D in figure 3 reflects the particular discrete probability distribution of returns on the assets used in this

paper. With a continuous probability distribution, or a discrete distribution with more possible outcomes, the plot of the interest rate as a function of total assets would have a less humped pattern.

The fact that the interest rate on subordinated debt is higher at higher levels of total assets of the bank might indicate a way in which the management of the bank could take advantage of those who invest in subordinated debt. The bank could issue some subordinated debt at a low level of total assets, at a relatively low interest rate, and then increase total assets and issue more subordinated debt at a higher rate. Investors in subordinated debt can protect themselves from such actions by insisting on covenants in the subordinated debt agreements that limit additional debt. If management of the bank violates such a covenant, the holders of the subordinated debt could go to court to make their debt instruments payable on demand. Restrictions on the issuance of additional debt are common in bond covenants. See Smith and Warner (1979).

Figure 3
Market Interest Rate on Bank Liabilities



The co-insurance option is not superior under any combination of assumptions. If the possibility of runs on the banking system can be ruled out, there is a subordinated debt requirement that induces the same degree of market discipline of banking risk as co-insurance.

EMPIRICAL STUDIES OF MARKET DISCIPLINE OF THE RISK ASSUMED BY BANKS

Market forces will be effective in constraining the risk assumed by banks only if investors can assess the relative degrees of risk assumed by individual banks, and then set differential prices on the stock and debt instruments issued by

banks that reflect their information about risk. The results of the studies described in table 3 are relevant in evaluating the effectiveness of market discipline. These studies estimate the influence of measures of risk assumed by banks on the stock prices of banks and on the market interest rates on uninsured deposits and the subordinated debt of banks.¹⁷ These studies do not test the hypothesis that banks adjust their risk in response to signals from the markets for bank stocks and debt.¹⁸

The Market for Bank Equity

All but one of these studies report evidence that is consistent with the hypothesis that stock prices are inversely related to the risk assumed

¹⁷The studies described in this section include only those based on data for individual banking organizations. Some studies cited in the literature estimate indices of returns on share prices or interest rates on bank liabilities for groups of banks as functions of aggregate data on banking risk. Such results are not relevant in determining whether participants in the equity and debt markets can distinguish among the banking organizations, which would be necessary if market discipline of bank risk were to be effective.

¹⁸Gendreau and Humphrey (1980) claim to have developed a model in which there is feedback from adverse signals in the bank equity market to bank leverage. It is difficult to see a feedback relationship between the stock price and leverage in this study, since the relationships among stock prices, leverage and other variables are estimated using contemporaneous observations. Estimating a feedback relationship from market signals to variables under the control of bank management would require dynamic relationships.

Table 3

Implications of Empirical Studies for the Effectiveness of Market Discipline of Bank Risk

Authors	Relationships estimated	Results	Results consistent with the effectiveness of market discipline
MARKET FOR BANK EQUITY			
Beighley, Boyd and Jacobs (1975)	Share prices of bank stocks estimated as a function of (1) capital ratios, (2) earnings and growth of earnings, (3) asset size, and (4) loss rates.	Holding constant the influence of earnings banks with higher capital ratios and lower loss rates tend to have higher share prices.	Yes
Pettway (1976)	Betas for individual banks (a measure of risk derived from stock prices) estimated as a function of the capital ratios of individual banks.	The coefficient on the capital ratio is negative for one year but insignificant for other years. The negative coefficient on the capital ratio indicates that investors consider banks with higher capital ratios to be less risky.	Yes
Pettway (1980)	For several large banks that failed, returns to shareholders are simulated for several years prior to their failure. Simulations are based on returns from holding stocks of large banks that did not fail.	On average, returns on the stocks of banks that failed declined relative to simulated returns two years before failure.	Yes
Brewer and Lee (1986)	Betas for individual banks are estimated as functions of ratios from balance sheets and income statements used by bank supervisors to reflect risk.	Some of the measures chosen to reflect risk have positive, significant regression coefficients.	Yes
Cornell and Shapiro (1986)	Returns to shareholders of 43 large banks are estimated as functions of the composition of their assets and liabilities in the years 1982-83.	The percentage that Latin American loans was of total assets had a significant, negative impact on returns in 1982. Energy loans had a negative impact in 1982-83. Loans purchased from Penn Square Bank had a negative impact on returns in the month in which that bank failed.	Yes
Shome, Smith and Heggstad (1986)	Prices of bank stocks are estimated as a function of its earnings and capital ratios.	The coefficient on the capital ratio is positive and significant for some years, insignificant for other years.	Yes
Smirlock and Kaufold (1987)	Changes in stock prices of large banks at the time of the announcement by Mexico in 1982 of its moratorium on debt payments as a function of the ratio of Mexican debt to equity capital at individual banks.	Coefficient on the ratio of Mexican debt to equity capital is negative and significant. Banks were not required to disclose their Mexican debt at the time of the 1982 moratorium.	Yes

Table 3 continued

Implications of Empirical Studies for the Effectiveness of Market Discipline of Bank Risk

Authors	Relationships estimated	Results	Results consistent with the effectiveness of market discipline
MARKET FOR BANK EQUITY continued			
James (1989) and Cargill (1989)	Returns on holding the stock of BHCs estimated as a function of the change in the market value of the BHCs' loans to less-developed countries and dummy variables for individual banks and individual time periods.	The change in the market value of loans to less-developed countries has a positive, significant coefficient which is not significantly different from unity.	Yes
Randall (1989)	This is a case study of 40 BHCs that reported relatively large losses in the 1980s. For each BHC, a time period is designated when it began assuming relatively high risk and a time period when problems became public knowledge. Stock prices are compared to market averages before and after the problems became public knowledge.	Stocks prices of the BHCs that reported relatively large losses declined relative to market average stock prices only after the problems became public knowledge, not during the periods which the banks began assuming relatively high risk.	No
MARKET FOR UNINSURED DEPOSITS			
The interest rate on large denomination certificates of deposit is the dependent variable in each study.			
Crane (1976)	Identifies the determinants of the CD rate using factor analysis.	The factor that reflects profit rates and capital ratios is not a significant variable in explaining the CD rate.	No
Herzig-Marx and Weaver (1979)	Estimates CD rates as a function of variables used by bank supervisors to reflect risk.	Of bank risk variables, only the liquidity measure has a significant coefficient. Capital and loss ratios have insignificant coefficients.	No
Baer and Brewer (1986)	CD rate estimated as a function of variables used by bank supervisors to reflect risk, and separately, as functions of level and variability of the prices of bank stocks.	Coefficients on risk measures used by bank supervisors are not significant. Measures of the level and variability of stock prices help explain CD rates.	No
James (1987)	The average interest rates paid by 58 large banks on their large denomination deposits are estimated as functions of leverage, loan loss provision divided by total loans and the variance of stock returns.	Each of these measures of risk have positive, significant coefficients.	Yes
Hannan and Hanweck (1988)	CD rate is estimated as a function of (1) the variability of the ratio of income to assets, (2) the capital ratio and (3) bank assets.	These three variables have significant coefficients. CD rates tend to be higher at banks with more variable income and lower capital ratios, holding constant the influence of total assets.	Yes

Table 3 continued

Implications of Empirical Studies for the Effectiveness of Market Discipline of Bank Risk

Authors	Relationships estimated	Results	Results consistent with the effectiveness of market discipline
MARKET FOR UNINSURED DEPOSITS continued			
James (1989)	Interest cost on large CDs estimated as a function of risk measures: domestic loans/capital, foreign loans/capital and the loan loss provision/total loans.	Interest cost positively related to the ratio of domestic loans to capital and the loan loss provision. The negative relation between interest cost and the ratio of foreign loans to capital is interpreted as evidence of an implicit government guarantee of foreign loans.	Yes
MARKET FOR SUBORDINATED DEBT:			
In each study the measure of the interest rate on the subordinated debt of banks is the rate on the subordinated debt minus the rate on long-term U.S. Treasury securities, called the rate premium.			
Pettway (1976)	The rate premium is estimated as a function of the capital ratio of banks and other independent variables.	The coefficient on the capital ratio is not significant.	No
Beighley (1977)	The rate premium is estimated as a function of several measures of risk, including a loss ratio and a leverage ratio.	The coefficients on the loss and leverage ratios are positive and significant.	Yes
Fraser and McCormack (1978)	The rate premium is estimated as a function of the capital ratio and the variability of profits divided by total assets.	Neither independent variable has a significant coefficient.	No
Herzig-Marx (1979)	The rate premium is estimated as a function of several measures of risk assumed by banks.	None of the risk measures have significant coefficients.	No
Avery, Belton and Goldberg (1988)	The rate premium is estimated as a function of risk measures derived from balance sheets and income statements and of the asset size of banks.	Coefficients on the risk measures derived from balance sheets and income statements are not significant.	No
Gorton and Santomero (1988)	Use data in Avery, Belton and Goldberg (1988) to derive a measure of the variance of assets of banks implied by a contingent claims valuation model. The measure of the variance of assets is estimated as a function of the risk measures derived from balance sheets and income statements.	Some of the risk measures derived from the balance sheets and income statements have significant coefficients.	Yes

by banks, holding constant other determinants of stock prices. The one study that concludes that stock prices do not reflect the risk assumed by banks, by Randall (1989), examines movements in the stock prices of bank holding companies that reported relatively large losses in the 1980s. Randall concludes that these stock prices fell relative to the stock prices at other banks after their problems became common knowledge; however, they did not decline during the periods when the banks were assuming the relatively high risk that led to losses. Randall concludes that the stock market does not discipline the risk assumed by banks, since the relative declines in bank stock prices did not precede public information on the consequences of risk assumed by these banks.

Randall's study, however, has several weaknesses. It is a case study, not a statistical study of the determinants of stock prices. The dating of points at which problems became common knowledge is arbitrary; the choice of such dates, however, determines the results. About half of the cases involve banks in the Southwest. We would not expect relative declines in the stock prices of these banks before the large decline in oil prices. We cannot expect the participants in the market for bank stocks to have greater foresight in predicting the decline in the price of oil than the participants in the market for oil.

Two studies are particularly interesting in terms of investors' ability to differentiate among banks on the basis of risk. Pettway (1980) compares stock prices of large banks that failed with simulated stock prices that were based on data from banks of comparable size that did not fail. Returns to stockholders of the failed banks declined relative to their simulated returns about two years before the banks failed. Relative returns of the failed banks also declined before the bank supervisors put them on the problem bank list. Smirlock and Kaufold (1987) find that, when Mexico announced the moratorium on its debt payments in 1982, the declines in the stock prices were proportional to the Mexican debt held by banks relative to the book

value of their equity capital. At the time of the moratorium, banks were not required to disclose their loans to other nations. Nevertheless, investors appeared to have sufficient information, without such requirements, to make the appropriate adjustments to the prices of bank stocks.

The Markets for Uninsured Deposits and Subordinated Debt

The findings about the relationship between risk and interest rates on uninsured deposits and on subordinated debt are more mixed. Three of the six studies of bank CD rates report no evidence that higher CD rates are paid by banks that assume more risk. Four of the six studies of the determinants of rates on the subordinated debt of banks find no significant effects of risk measures on interest rates.

Implications for the Effectiveness of Market Discipline

In evaluating these results, it is important to note that, under the procedures followed by federal bank regulators in recent years, risk has a more certain implication for bank profits than for the returns to the holders of uninsured deposits or subordinated debt. Losses on bank assets reduce profits, and if losses force a bank to fail, the bank shareholders are likely to receive nothing after the liquidation or sale of the bank.

Uninsured depositors and holders of subordinated debt, in contrast, receive less than the principal plus contracted interest *only* if a bank fails. In most cases, the failed bank is merged with another bank, and the surviving banks assume all liabilities of the failed banks, including those in the form of uninsured deposits and subordinated debt. Most of the cases in which uninsured depositors and holders of subordinated debt absorb some losses involve banks smaller than those included in the studies described in this paper.¹⁹ These observations are consistent with the conclusion that interest rates on bank liabilities would be more sensitive

¹⁹This contrast can be illustrated using some recent studies and bank failure cases. Avery, Belton and Goldberg (1988) use observations for the 100 largest BHCs, which had total assets above \$3 billion in 1985 and 1986. The total assets of the banks in the sample used by Hannan and Hanweck (1988) average \$4 billion. In 1985 and 1986, 69 failed banks did not have their liabilities assumed by surviving

banks. Of these 69 failed banks, 66 had total assets less than \$100 million, while the remaining three had total assets less than \$200 million. The failure of some large banking organizations in the Southwest, in which the BHC's bondholders absorbed losses, occurred after the periods covered by these studies.

to the risk assumed by banks if bank creditors lost at least part of their principal plus interest in each bank failure.

The empirical results cannot be used to indicate the degree of risk that banks would assume if bank supervisors eliminated various forms of supervision and regulation, relying instead on market forces to limit bank risk. To illustrate such a change in policies, suppose bank supervisors eliminate capital requirements and restrictions on the types of assets that banks may acquire, substituting a requirement that banks issue subordinated debt. The empirical results do not tell us whether the probability of bank failures would increase or decrease under such a change in policies. The only useful information from the empirical studies is that investors in bank stocks, who have the strongest incentives to be sensitive to the risk assumed by banks, are able to differentiate among banks on the basis of risk.

CONCLUSIONS

This theoretical exercise illustrates how market forces could limit the incentives for banks to assume risk. The incentives for banks to assume relatively high risk are reduced if the insurance coverage of bank creditors drops from full to partial coverage. One of the important differences among the various approaches to promoting market discipline of banking risk involves the vulnerability of banks to runs. Banks are more vulnerable to runs if depositors are at risk than if the risks are borne by those holding long-term bank debt that is subordinated to deposits.

Empirical studies of the effectiveness of market discipline report mixed results. The most consistent result is that the stock prices of individual banks reflect the risk assumed by banks. Market discipline of such risk would tend to be more effective if bank creditors were forced to absorb losses in a more consistent fashion in bank failure cases.

The empirical studies do not indicate the degree of risk that banks would assume if deposit insurance were reformed to enhance the effectiveness of market discipline. Thus, the empirical studies do not permit us to determine whether the probability of bank failures would rise or fall if the current forms of bank regulation were eliminated in favor of market discipline by bank shareholders and creditors.

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On the Use of Option Pricing Models to Analyze Deposit Insurance

THE FAILURE rate of banks and thrifts has exploded over the past decade, making reform of the deposit insurance system a topic of considerable interest to regulators, bankers, and economists. As illustrated by figure 1, which shows the total number of failed commercial banks (excluding thrifts) for each year since the chartering of the Federal Deposit Insurance Corporation (FDIC), the annual number of commercial bank failures in each of the last several years has exceeded its previous peak, attained during the Great Depression. The status of the thrift industry is even more grim, with losses to the Federal Savings and Loan Insurance Corporation (FSLIC) estimated at \$160 billion or more. The primary consequence of these failures for public policy is the enormous losses, especially to the FSLIC, as depositors in these failed institutions are reimbursed.

This article considers a particular set of economic tools used to evaluate deposit insurance.¹ Option pricing models are among the techniques available for analyzing the deposit insurance system. These models can be used to assign

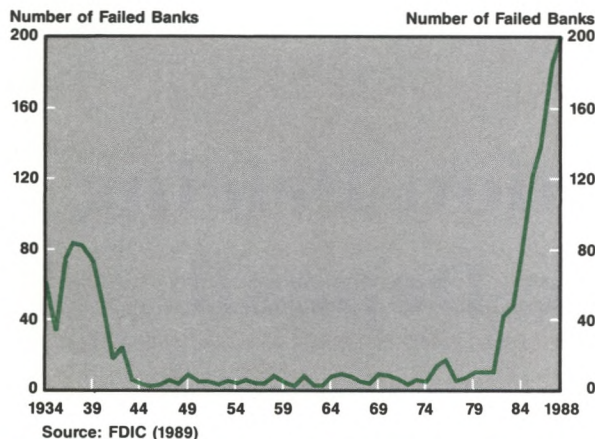
specific values to the claims of each of the interested parties involved in the deposit insurance system — the insurer, financial institutions, and depositors. Such valuations can then be used, for example, to estimate the net value of the government's insurance fund or to determine a fair price that a bank should pay for its insurance. More generally, by comparing insurance valuations with different model parameters, one can investigate the system of incentives under a given regulatory scheme, such as the risk incentives for bank shareholders and depositors under the present system. Finally, comparisons of insurance values and incentives can be made across various proposed regulatory schemes. These applications are illustrated below with some examples.

The usefulness of option pricing models for evaluating deposit insurance is of special interest for two reasons. First, the consensus among the interested parties is that the present deposit insurance system has contributed to the current crisis. Second, in the context of this debate, a number of economists have used the

¹This article does not address the issue of why we should have deposit insurance. The rationale for the current system of bank regulation and for deposit insurance in particular is based on two related principles: protection of the depositor and the mitigation of contagious bank runs. See FDIC (1984) and U. S. Treasury (1985). Benston and

Kaufman (1988) identify three reasons for bank regulation in addition to the two traditional rationales, namely disruption to communities from localized bank failures, moral hazard induced by deposit insurance and restrictions on competition.

Figure 1
Bank Failures (Insured and Uninsured)



modern theory of option pricing to explain the incentives and measure the costs both of the current system of deposit insurance and of some suggested alternatives. This paper presents the basic theory of option pricing, explains how it can be applied to deposit insurance, and analyzes some of the issues involved in its use.

A PRIMER ON OPTION PRICING

This paper presumes no knowledge of options or of the various economic models that have been used in the academic literature to assign values to options. Thus, it begins with a brief description of options and some of the major contributions to the theory of pricing options that have been made in the past two decades.

Contingent Claims, or Options

A *call option* is a legal contract that gives its owner the right to buy a specified asset at a fixed price on a specified date.² Similarly, a *put option* gives its owner the right to sell a specified asset at a fixed price on a specified date. Option contracts are usually sold by one party to another.³ The person who owns an option contract is called the *holder* of the option. The per-

son who sells an option contract — that is, the person who will be compelled to perform if the option holder invokes her right as specified in the contract — is called the *writer* of the option. The act of invoking the contract is called *exercising* the option. The fixed price identified by the option contract is called the *striking price*. The date at which the option can be exercised is called the *expiration date* of the option.

These legal contracts are probably best known by the stock options that are bought and sold by brokers in the trading pits of organized options exchanges in Chicago, New York and elsewhere. In addition to options on common stock, there are active markets for options on agricultural commodity futures, foreign currencies, stock index portfolios, and government securities, to name only a few. The definition of an option, however, does not limit the term to those contracts actively traded on the floors of organized financial exchanges. By definition, an option is any appropriately constructed legal contract between the writer and the holder, regardless of whether it is ever traded.

Expiration-date Values of Options

Consider now the value to the holder of an expiring put option, as illustrated in figure 2. The value of the underlying asset specified by the contract is given on the horizontal axis, while the value of the option itself is given on the vertical axis. The point K on the horizontal axis is the specified striking price for the asset. If the value of the underlying asset is above the striking price on the expiration date, then the put option will not be exercised; anyone who truly wanted to sell the asset would do so outright at the going price, rather than using the option and receiving the striking price. In this case, the option expires worthless, and the option holder experiences no gain or loss on the expiration date.

On the other hand, if the value of the asset is below the striking price, then the holder will exercise her option and receive the striking

²This definition is a paraphrase of the definition given by Cox and Rubinstein (1985), p. 1. It describes a "European" option, which is distinguished from an "American" option. An American option gives its owner the right to buy at any time on or before the specified date.

³They are sold, because options have a non-negative value; because they are a right to buy (or sell) the asset, they do

not compel the owner of the contract to do anything. Although they are valuable, nothing in the definition of an option requires that they be offered for sale; that is, their value does not depend on how they were obtained.

Figure 2
Value of Put Option to Holder

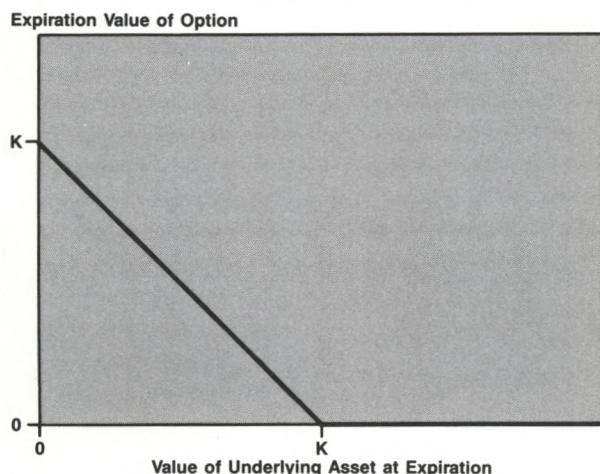
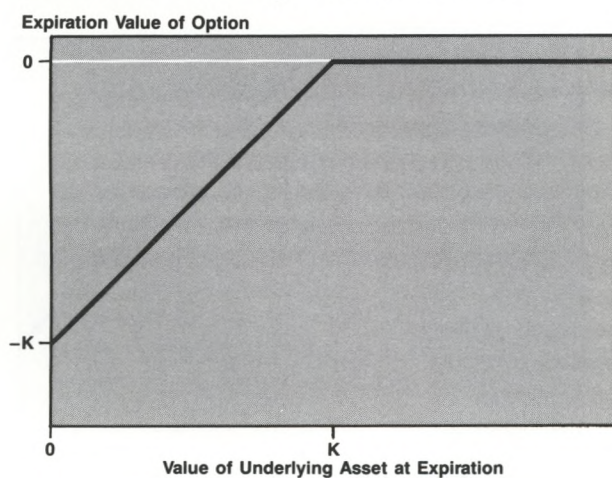


Figure 3
Value of Put Option to Writer



price for the asset. In this case, her net gain on the expiration date will be $(K - A_T)$, the difference between the striking price and the current price, since she can turn around and replace the asset immediately, if she wants to. Thus, the expiration value of the option and the decision about whether to exercise are contingent upon the value of the underlying asset at that time:

(1) State	Action	Option value
$A_T < K$	Exercise	$P = K - A_T$
$A_T \geq K$	No exercise	$P = 0$.

For this reason, options are also referred to as “contingent claims” on the underlying assets.

The corresponding net payoffs to the writer of the put option are given in figure 3. Notice that his payoffs are exactly the inverse of those for the option holder. Also note that the payoff at expiration to the writer of an option is never positive; at best it is zero. It is for this reason that options are sold to the holder, rather than being given away free of charge. The price initially paid for the option — the option price or option premium — could be incorporated into the figures by simply shifting the holder's payoffs down and the writer's payoffs up by the appropriate amount.

The payoffs at expiration to the holder and writer of a call option are given in figures 4 and 5, respectively. The corresponding analysis for call options is precisely analogous to the analysis just given for put options.

The Black-Scholes Option Valuation Model

Having described the value of an option at expiration leaves the question of its value prior to expiration unanswered. Instead of being a simple function of A_T and K , the value of an option before maturity depends on several additional factors. Although a number of bounds had been placed on the value of an unexpired option by using relatively simple arbitrage arguments, an important advance in the valuation of unexpired options was made by Black and Scholes (1973).⁴ They obtained an exact equation for the value of a put option under an unrestrictive set of assumptions.⁵ Their result has since been elaborated and generalized by others.⁶

In their model, the value of an unexpired option depends on five things:

⁴For an exposition of the arbitrage bounds on option prices, see Merton (1973), or Cox and Rubinstein, ch. 4.

⁵Almost all derivations of option pricing models, including that of Black and Scholes, are stated in terms of call rather than put options. As it happens, this distinction is largely irrelevant, because call option valuations are readily converted to put option valuations, and vice-versa, via an arbitrage relationship known as “put-call parity”. Put-

call parity is an exact relationship for European options and an approximate one for American options (see Cox and Rubinstein, pp. 150-52); throughout this paper it is treated as exact. Put-call parity is first presented by Stoll (1969).

⁶One such generalization is found in the shaded insert. For a partial survey of option pricing models, see Cox and Rubinstein, ch. 7.

K = the striking price
 A = the current asset price
 T = the time remaining to expiration
 σ = the volatility of the asset price
 R = the risk-free interest rate.

Almost as notable is what the option's value does not depend on: any characteristic of the holder or the writer.⁷ Under their assumptions, Black and Scholes are able to include an option in a riskless portfolio. Such a portfolio must earn the risk-free interest rate, and they are able to use this result, along with an assumption about the probability distribution of the asset price, to identify an exact value, P , for a put option:

$$P = (K \cdot e^{-RT}) \cdot N(X + \sigma\sqrt{T}) - A \cdot N(X),$$

where:

$$X = \frac{1}{\sigma\sqrt{T}} \left[\ln(K \cdot e^{-RT}) - \ln(A) \right] - \frac{1}{2}\sigma\sqrt{T}$$

$N(\bullet)$ = the $\sqrt{\bullet}$ standard normal cumulative probability function

$\ln(\bullet)$ = the natural logarithm function

e = the base of the natural logarithm

Although this formula may at first appear complicated, a rough intuition can be provided relatively painlessly.⁸ First, e^{-RT} is just the present value discount factor for T periods at interest rate R with continuous compounding, so that $K \cdot e^{-RT}$ is the present value of the striking price. Keeping in mind that $N(X + \sigma\sqrt{T})$ is a probability, the first term is the expected present value of the striking price at expiration, given that $A_T < K$. Similarly, the second term, $A \cdot N(X)$, is the expected present value of the expiration-day asset price, again given that $A_T < K$.⁹ Thus, the value of the option is the expected present value of its value at expiration, given by condition 1 above.

Unfortunately, no easy, correct interpretation can be attached to the specific probabilities, $N(X + \sigma\sqrt{T})$ and $N(X)$, in the two terms. These

Figure 4
Value of Call Option to Holder

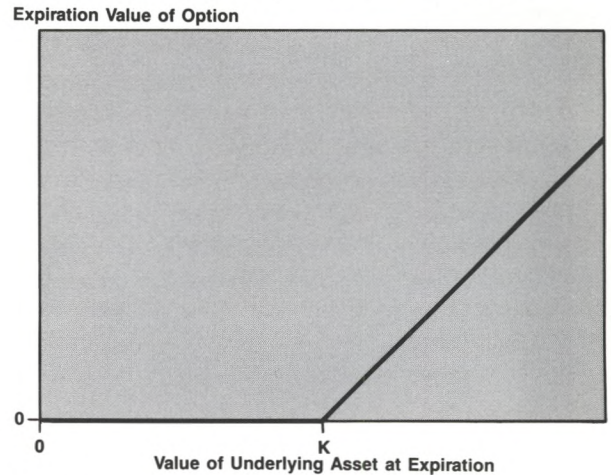
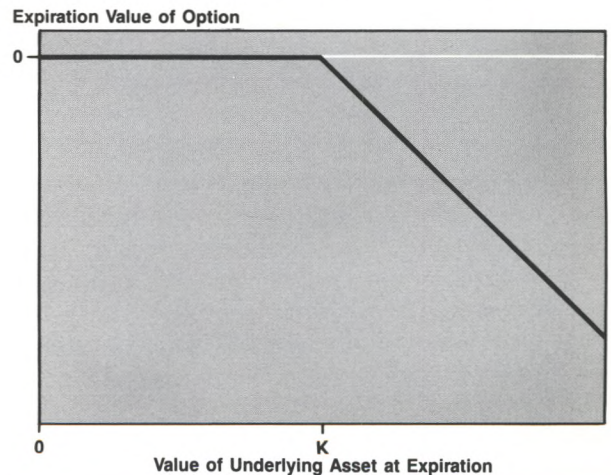


Figure 5
Value of Call Option to Writer



probabilities are closely related to the probability that $A_T < K$, but they are not quite the same, because the present value of the striking price is known with certainty, whereas the present value of the asset's price on the expiration day, $A_T \cdot e^{-RT}$, is not; the current asset price, A , appears instead.

⁷For example, one might suspect that the holder's attitudes toward risk or her beliefs about the asset price at expiration should influence the option's value to her. This is not the case, however. Also note that four of the five factors, at least theoretically, are well-defined and directly observable at the time of valuation. The exception is asset volatility, which must be estimated from observable factors; see Cox and Rubinstein, pp. 280-87, for an example of an estimation technique.

⁸A full derivation of the formula is fairly involved and will not be presented here. Interested readers are referred to

Malliaris (1983) for a mathematically advanced approach or to Cox and Rubinstein, ch. 5, for a longer but less technical derivation.

⁹The corresponding expected present values for the case when A_T is greater than K are both zero, because then the expiring option is worthless and will not be exercised; hence, this possibility adds nothing to the current value of the option.

In spite of its complexity, the option pricing equation is still a useful tool. In one sense, the formula can be treated as a black box in which the five parameters (K , A , T , σ and R) enter at one end, and the value of the put option, P , comes out at the other; a computer spreadsheet or calculator can be programmed to perform the intervening calculations defined by the formula. For example, if the current asset value is $A = \$985$, the standard deviation of asset returns is $\sigma = 0.3$ percent, the striking price of the option is $K = \$1000$, the time to expiration is one year, and the riskless interest rate is 8 percent per year, then the Black-Scholes equation tells us that the put option is worth \$85.45. Figure 6 graphs the Black-Scholes value of a put option for a range of current asset values from zero to \$1500, where the values of the other four parameters are the ones just given.

The Brownian Motion Assumption

Not surprisingly, the distribution of asset prices is a crucial factor in determining the exact form of the option pricing equation. In their derivation, Black and Scholes assumed that the price of the underlying asset progressed randomly through time according to geometric Brownian motion. This is the assumption that leads to the specific normal probability functions in their pricing equation.

Brownian motion was first used to describe the random progress of a single molecule through a gas from a given starting point.¹⁰ It is a mathematical model of motion that identifies the way the particle can move. Three restrictions are implied by Brownian motion:

- 1)The path followed must be continuous;¹¹
- 2)All future movements are independent of all past movements;¹²
- 3)The change in position between time s and time t is normally distributed with mean equal to zero and a standard deviation equal to $\sigma\sqrt{t-s}$.

Note that standard deviation is directly proportional to the amount of time that has passed.

Figure 6
Value of Put Option to Holder

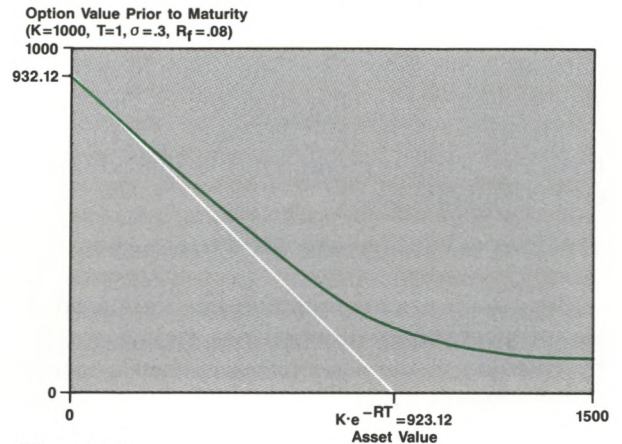
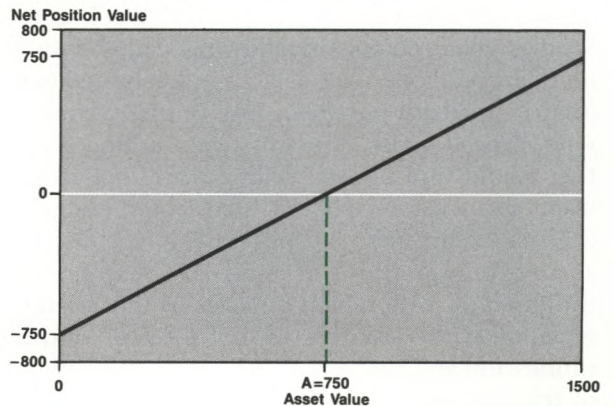


Figure 7
Value of Net Asset Position



Thus, the longer one waits, the less certain one is about the location of the molecule, or, in our case, the price of the asset.

Simple Brownian motion is not completely satisfactory for describing asset prices, however. While a normally distributed random variable can take on negative values, an asset price cannot. Therefore, geometric Brownian motion, a variant, is assumed for the Black-Scholes model.¹³ Under geometric Brownian motion, the third restriction is modified, so that the logarithm of the change in position, rather than the

trend. It does not mean that the future location is independent of the past location.

¹³By way of terminology, simple Brownian motion (also known as arithmetic Brownian motion) and geometric Brownian motion are examples of the Wiener process (also known as the Gauss-Wiener process), which, in turn, is a special case of the Itô process.

¹⁰We are here concerned with only a single dimension of motion, for example, the East-West coordinate of the molecule or the price of an asset.

¹¹Although this may be true of molecules, it need not be the case for asset prices, as is considered in the shaded insert on Merton's jump-diffusion model.

¹²This implies, for example, that the molecule cannot build up momentum or that prices do not have a predictable

change in position itself, is normally distributed with mean zero and standard deviation $\sigma\sqrt{(t-s)}$. This distributional assumption gives us the specific functional form which appears in the Black-Scholes equation. Thus, this assumption is important: a different distribution would generally yield a different pricing equation, as illustrated by Merton's (1976) jump-diffusion option pricing model, which is presented in the shaded insert on the opposite page.

Risk and Hedging in Options

The option pricing equation has the paradoxical property that, although risk (as measured by volatility in the asset price) is itself a factor in the option's value, the attitudes toward risk of the holder and the writer (and anyone else) are not. The option's value is a function of five variables, none of which depends on the characteristics of the individuals involved. Black and Scholes achieved this by showing that the option can be made part of a completely hedged (that is, riskless) portfolio. Any option writer who offered a risk discount when selling an option would find himself selling many option contracts to investors who, in turn, could hedge the risk completely and pocket the risk discount as an arbitrage profit. It is for this reason that the discount rate which appears in the pricing equation is the risk-free rate of interest, and attitudes toward risk are irrelevant to the value of the option.

To see how the hedged portfolio works, consider the value of a put option to the holder before expiration, depicted in figure 6, and the value of the underlying asset purchased for the amount A , depicted in figure 7. The value of the net asset investment increases one for one as the price of the asset increases, and the value of the option decreases, although not in a constant proportion.

The key to the hedged portfolio is to buy put options and underlying assets in the appropriate ratio, so that, when the asset price increases, the increase in value of the net asset investment will be precisely offset by the decrease in value of the option position, and vice-versa. This implies a riskless total portfolio. Of course, the appropriate ratio (called the "hedge ratio" or "option delta") also changes as the asset price changes, because the value of a put option does

not decrease as a constant proportion of the asset value (the put option's value is represented by a curved line). This implies that the holder of a completely hedged portfolio must continuously adjust the relative proportions of options to assets if the hedged portfolio is to remain riskless. Black and Scholes presume that at least some investors are large and sophisticated enough to do this.

Because the risk of an option can be completely diversified, the risk-free rate is the appropriate interest rate to use for discounting the option's uncertain payoff at expiration. Nevertheless, the risk (defined as price volatility) of the underlying asset is a factor in the option's value, because asset risk affects the expected value of the option's payoff. This is due to the limited liability nature of the option. Although increasing the volatility of the asset price increases both the chance of getting a very high expiration-day asset price and the chance of getting a very low expiration-day asset price, the bad (high price) outcomes all have a weight of zero in the put option valuation, while the good (low price) outcomes have a weight of $(K - A_T)$. The volatility of the option's value also increases with that of the asset price, but the volatility of the option's value is irrelevant, because it can be completely hedged.

DEPOSIT INSURANCE AND OPTIONS

The analysis of deposit insurance is a natural, albeit not obvious, extension of option pricing models. The connection between the two comes through the limited liability property common to both options and common stock.¹⁴ This property implies an "expiration-day" payoff for deposit insurance that can be modeled as an ordinary put option. Similarly, other claims on a financial intermediary's assets can be modeled as options or combinations of options. The benefit is that, given such a model, option pricing theory allows us to assign values to each of the claims. These values are the key to option pricing's usefulness in this context, because they allow two sorts of comparisons to be made.

First, variations in the parameters of the option pricing equation can be considered.¹⁵ Such variations are of special interest, because, in the

¹⁴This connection was first made by Black and Scholes and first applied to deposit insurance by Merton (1977).

¹⁵For example, in Black and Scholes' model, the five parameters: K , A , T , σ and R would be varied.

Merton's Jump-Diffusion Model

The Black and Scholes (1973) derivation of an option's value was based, in part, on a particular assumption about the random behavior of the price of the underlying asset. Their assumption of geometric Brownian motion as a description of the movements of asset prices is by no means the only possibility. In general, different assumptions about the statistical properties of asset price behavior produce different valuation equations for an option on that asset. Merton's jump-diffusion model is one of several alternative formulations that have been developed.¹

Just as arithmetic Brownian motion was not an apt model of asset price movements, empirical research suggests that geometric Brownian motion, at least for some assets, is similarly inappropriate. An alternative, proposed by Merton (1976), is a combination of geometric Brownian motion with random, discontinuous jumps in the asset price, such as might occur at the announcement of some news event.² This arrangement violates the first condition for Brownian motion and modifies the third condition again.³ When a jump occurs, the asset price is abruptly shifted by a random amount; the logarithm of this shift is normally distributed, analogously to geometric Brownian motion.

This new process has two important implications for the option pricing model. First, the option pricing equation is different from the Black and Scholes formula, since it must account for the new jumps. If we relabel the Black-Scholes value as $P_{bs} = P_{bs}(K, A, T, \sigma, R)$,

then we can write the Merton formula as a function of the Black-Scholes value:

$$P_m = \sum_{i=0}^{\infty} \left[\beta_i \cdot P_{bs}(K, A, T, \Theta_i, R) + (1 - \beta_i) \cdot (K \cdot e^{-RT} - A) \right],$$

where:

$$\beta_i = \frac{e^{-gT} \cdot (gT)^i}{i!}$$

$$\Theta_i = \sqrt{(\sigma^2 + h^2 i)/t}$$

g = the Poisson frequency of jumps

h^2 = the variance of the shift distribution.

Not surprisingly, the Merton equation is more complicated than the Black and Scholes equation. Nevertheless, it is still a function of variables that are at least hypothetically observable.⁴

Second, the presence of the jumps complicates the diversification problem. The simple hedging portfolio used for the Black-Scholes model will not do, because even continuous rebalancing cannot insure the portfolio's value at the jump points. If, however, the jumps are idiosyncratic (that is, firm-specific), then their risk can still be eliminated by holding a well-diversified portfolio that includes the assets of many firms in many industries. If the jump disturbances are idiosyncratic, then the risk-free interest rate is still the appropriate discount rate for the expected option payoff, and individual attitudes toward risk are not a factor in the option's value before expiration.

¹Some others are McCulloch's (1981, 1985) Paretian-stable process, and Cox and Ross's (1976) alternative jump processes and constant elasticity of variance (CEV) Itô process.

²Merton's derivation is only one of several alternatives to the Black and Scholes model. It was chosen to illustrate some of the issues involved in selecting an appropriate pricing model, not because it outperforms the others in some sense. See Rubinstein (1985) for a performance comparison of several models.

³The discontinuous jumps arrive according to a Poisson process, which conforms to the second condition.

⁴In practice, the statistical parameters: σ , h and g would have to be estimated, either from previous observations or via some other technique. The equation given here is a special case of a more general formulation given by Merton (1976). His derivation is of a call option price, which has been re-arranged here using put-call parity.

context of deposit insurance, some of the parameters can be controlled or influenced by the parties to the option contract. Thus, each party has a clear interest in influencing the parameters to his own benefit and therefore to the

detriment of the other. The risk-incentive problem presented below exemplifies this sort of application. Comparisons based on option pricing models indicate not only the direction, but also the magnitude, of such incentives.

Second, various deposit insurance structures can be compared. The structure of deposit insurance is defined here by the number and type of options pertaining to each of the interested parties. Changes in deposit insurance structure are different from the parameter changes within an insurance structure, considered in the preceding paragraph. Thus, for example, the FDIC could use option models to estimate the net increase or decrease in the present value of the insurance fund caused by a switch from one structure to another; or it could examine the change in risk incentives occasioned by the same switch. Three different structures, illustrating some of the issues involved, are presented in the following examples.¹⁶

100 Percent Deposit Insurance Coverage

To see how deposit insurance and options are related, consider the following simplified banking scenario. A single banker both owns and runs a bank, a single large depositor provides the entire liability portfolio of the bank, and a single insurer, the FDIC, insures deposits and will liquidate the bank in the event of insolvency.¹⁷ The liability portfolio consists of a single deposit due at year-end. Also at year-end, the FDIC examines the bank to determine the value of assets, which will, in turn, determine whether liquidation occurs. If the bank is economically insolvent, it is closed by the FDIC, which liquidates the assets at market values and pays off the depositor in full.¹⁸ If the bank is economically solvent, control remains with the banker, who can either renegotiate the deposit or liquidate the bank.

Now consider the payoffs to the three interested parties — banker, FDIC and depositor — when the year-end audit is performed. These payoffs are illustrated in figures 8-10. Each party's year-end payoff is plotted as a function of the year-end value of the bank's assets. Note that the sum of the payoffs to all of the parties (obtained by adding the graphs vertically) equals the value of the bank's assets. These functions show how the bank's assets will be distributed after the audit is performed. Also note the shape of the payoff functions for the banker and the FDIC; in effect, the banker's portfolio consists of the bank's assets, whose value is uncertain before the audit but known afterward, the bank's deposits, whose value is known to be L , and a put option with striking price L written by the FDIC.¹⁹ The FDIC, on the other hand, has effectively written the put option on the assets of the bank and sold that option to the banker for the price of the deposit insurance premium.²⁰ The depositor has issued the bank a risk-free loan, which pays off the amount L , including accrued interest.

With this in mind, the usefulness of an option pricing model to evaluate deposit insurance becomes more apparent. An option pricing model provides an estimate of the actuarial dollar value of deposit insurance, as well as a tool with which to analyze the economic incentives that deposit insurance creates. The depositor, for example, has a portfolio, D , that is worth, at the beginning of the year, simply the present value of the deposit liability discounted at the riskless rate, $L \cdot e^{-RT}$; if his year-end payoff, L , is \$1000, and the riskless rate, R , is 8 percent, then the value of this portfolio at the beginning

¹⁶Full coverage is considered first, because it is the simplest insurance structure possible, and because it approximates the current system of extensive coverage combined with the FDIC's tendency to arrange purchase and assumption transactions, rather than deposit payouts, for failed banks.

¹⁷The assumptions of a single owner-manager for the bank and a lone depositor are clearly broad abstractions from reality. The owner-manager assumption allows us to ignore principal-agent incentives; see Barnea, Haugen and Senbet (1985). Similarly, the assumption of a single depositor effectively precludes the ability of depositors to withdraw their funds individually without forcing an immediate closure of the bank. Although these are both important issues, the purpose of the present analysis is to illustrate the general principles involved in the application of option models to deposit insurance, rather than to model a bank in its full complexity.

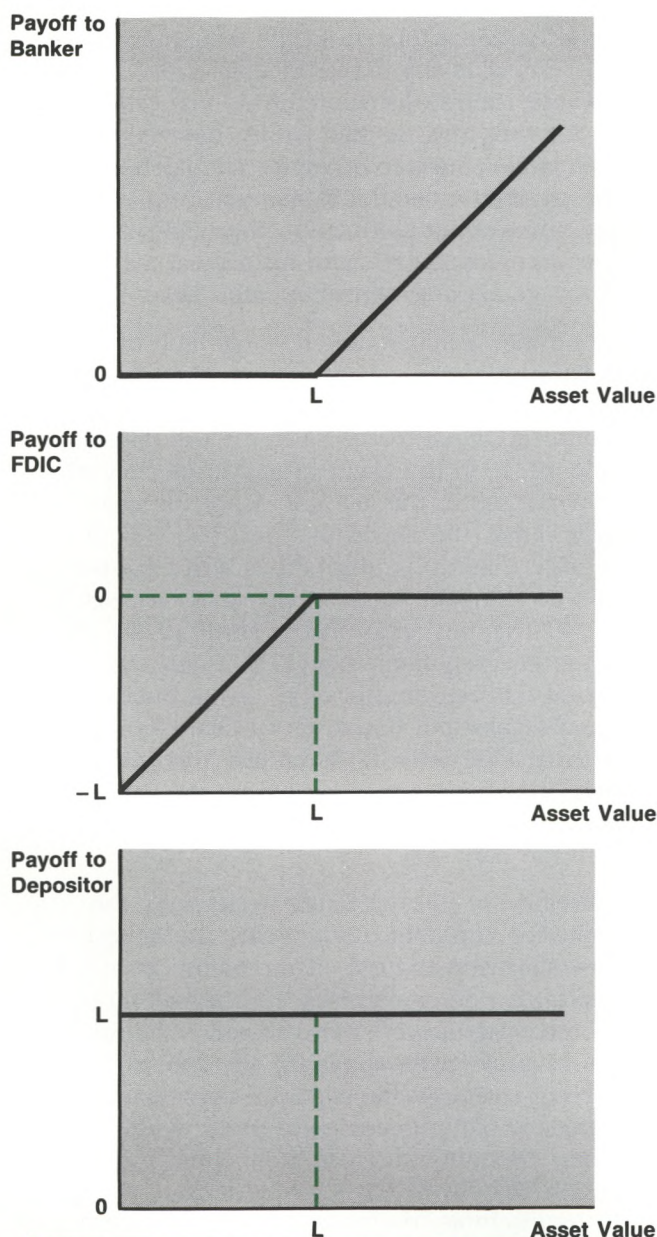
¹⁸The bank is defined as economically insolvent when the market value of its assets is less than the present value of its liability to the depositor. This terminology is meant to

contrast with an illiquidity, or legal insolvency, which is brought on by an inability to meet maturing short-term liabilities with liquid assets. The legal profession has a separate terminology for these two concepts: the "balance sheet test" is used to determine economic insolvency, and the "equity test" is used to determine legal insolvency. See Symons and White (1984), pp. 603-16, for an exposition. Since there are no short-term liabilities in the simplified world here, legal insolvency is not germane.

¹⁹The bank's deposits represent a "short" position, or borrowing, for the banker. The net payoff shown in figure 8 can be gotten by drawing the individual payoff graphs for the components of the portfolio and adding these together vertically as before. This portfolio is also equivalent, via put-call parity, to a simple call option on the assets of the bank.

²⁰Compare figure 9 with figure 3. The insurance premium is considered a sunk cost at the time of the audit and hence is not included in the graphs.

Figures 8-10



of the year is $\$1000 \cdot e^{-.08} = \923.12 . The FDIC, on the other hand, has written a put option with striking price $L = \$1000$; if, for example, the standard deviation of the bank's asset returns is $\sigma = 0.3$ percent, and the current value of the bank's assets is $\$985$, then the value of the FDIC's portfolio is given by the Black-Scholes equation as $-P = -\$85.45$.

Of particular interest are the incentives created by deposit insurance. Under 100 percent insurance, the depositor does not care about the value of the bank's assets, since he receives his deposit back with interest, regardless of the bank's condition. The banker, however, receives the positive equity capital, if the bank is solvent; if the bank is insolvent, the loss is charged to the FDIC. This "heads I win, tails you lose" arrangement is certainly not peculiar to banks; it applies to any corporate entity with limited stockholder liability. In the absence of other incentives, the banker will make the corporation as risky as possible.²¹

What is peculiar to banks under 100 percent flat-rate deposit insurance is the absence of such other incentives for the depositor and the banker to limit risk. Normally, creditors impose a risk premium on corporations, based on the riskiness of the firm's assets.²² By definition, flat-rate insurance implies that the FDIC charges no risk premium. Similarly, the depositors charge no risk premium, because they are fully insured. The result, in our simplified model, is that the banker has an unmitigated incentive to increase the riskiness of the bank's assets, while the FDIC has the inverse incentive to reduce the bank's risk-taking.²³ The risk incentive implied by extensive, flat-rate deposit insurance is the impetus for most of the current proposals for deposit insurance reform.²⁴ In analyzing both the current system and proposed reforms, many authors have used option pricing models.²⁵

²¹Recall that the value of an option to the holder increases with the volatility of the underlying asset. For the Black and Scholes model, risk is defined as the standard deviation of the logarithm of the asset's value.

²²This is the function of bond rating services, such as Moody's and Standard and Poor's. See Barnea, Haugen, and Senbet, especially pp. 33-35, for an exposition of the risk-incentive problem.

²³For this reason, risk-taking is restricted by extensive regulation of commercial bank activities. In practice, the banker's incentive may also be mitigated by the potential loss of a valuable bank charter or by nonpecuniary factors, for example, the potential loss of a bank manager's professional reputation in the event of a failure. These factors are beyond the scope of the option model.

²⁴Reform proposals include: risk-based insurance premia, risk-based capital requirements, larger capital requirements, reduced insurance coverage, depositor co-insurance, subordinated debt requirements, increased supervision and more stringent asset regulation. See White (1989) for a survey of current proposals.

²⁵See, for example, Merton (1977, 1978), McCulloch (1981, 1985), Sinkey and Miles (1982), Pyle (1983, 1984, 1986), Brumbaugh and Hemel (1984), Marcus (1984), Marcus and Shaked (1984), Ronn and Verma (1986, 1987), Thomson (1987), Furlong and Keeley (1987), Pennacchi (1987a, 1987b), Osterberg and Thomson (1988), Flannery (1989a, 1989b), and Allen and Saunders (1990).

APPLICATIONS TO OTHER DEPOSIT INSURANCE ARRANGEMENTS

We can now extend the options model to other arrangements for deposit insurance, to evaluate their relative impacts. Two illustrative cases will be presented: a coverage ceiling clause and a deductible clause. A significant characteristic of both these cases is that they impose a portion of the bank's asset risk on the depositor. The FDIC benefits directly from such provisions, because they shift some potential losses directly to the depositors. In addition, imposition of a possible loss on the depositor mitigates the risk-incentive problem that exists under 100 percent, flat-rate deposit insurance. In general, the depositor will monitor the bank more closely and will require a higher interest rate to compensate for the possibility of default.

Maximum Insurance Coverage Limit

Although 100 percent coverage is often treated as the *status quo de facto* of federal deposit insurance, coverage extends legally only to the first \$100,000 per depositor per institution.²⁶ A maximum coverage limit is a form of co-insurance, a technique used by insurers to reduce the moral hazard problem (the tendency of insurance to alter the behavior of the insured). Other basic forms of co-insurance are the deductible and fixed proportional sharing of losses.²⁷

The applicability of the maximum coverage limit considered here is complicated by the FDIC's current closure protocol. Bank closures by the FDIC can take one of two forms: purchase and assumption or deposit payout. Under a purchase and assumption closure, healthy assets and *all* deposits are transferred to another healthy bank, with the FDIC absorbing the problem assets and any net loss.²⁸ This sort of transaction is best modelled by the 100 percent coverage considered above.

Under a deposit payout closure, the FDIC itself takes all of the bank's assets and liabilities into receivership. It then sells the assets and pays the depositors up to the maximum coverage limit plus any excess of asset sales over insurance claims, distributed on a pro rata basis. As a result, this method is best modelled by the deductible considered below. The upshot is that the payoffs under the FDIC's maximum coverage limit do not conform to the familiar (from, say, automobile or health insurance) maximum coverage arrangement illustrated here.

Consider a maximum coverage limit of M dollars for the depositor (where $M < L$), illustrated in figures 11–13. Under this arrangement, the depositor receives the full deposit amount, L , in the event of any insolvency or shortfall, up to the amount, M , of the coverage limit. Thus, the depositor's portfolio contains the deposit amount, L , and he has written a put option on the bank's assets with striking price ($L - M$). This put option is the result of the maximum coverage limit. The FDIC holds the put option with striking price ($L - M$), but has written a second put option on the bank's assets with striking price L . As before, this put option (with striking price L) is held by the banker, who also owns the assets and owes the amount L to the depositor.

Because of the put option written by the depositor and held by the FDIC, the depositor now shares in the risk of the bank's assets. His deposit is now worth less, and he will discount the promised payoff more steeply. Extending the example given above for the case of 100 percent coverage, the depositor's portfolio, which contained only the riskless deposit, worth \$932.12 when discounted, is now augmented by the put option written with a striking price of ($L - M$). If, for example, the coverage limit is set at $M = \$100$, so that the striking price is \$900, then with $\sigma = 0.3$ percent, $R = 8$ percent and $A = \$985$ as before, the Black-Scholes value of this put option to the depositor is $-P = -\$47.96$, and the total value of his portfolio is $D =$

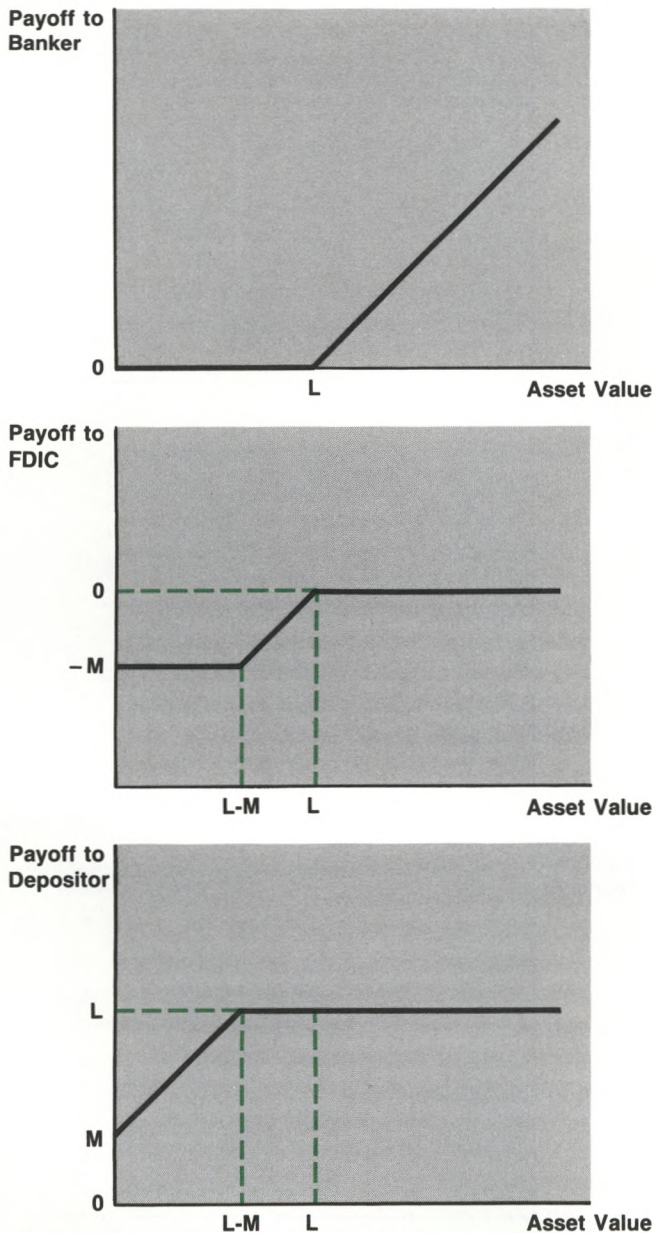
²⁶The original limit was \$2500 under the Banking Act of 1933; see FDIC (1984), pp. 44, 69. The impact of the coverage ceiling is limited by the availability of brokered deposits and by the tendency of the insurer to arrange purchase and assumption solutions to bank failures.

²⁷There are other possibilities. For example, deposit insurance in the United Kingdom involves fixed proportional sharing combined with a coverage ceiling [see Llewellyn (1986), p. 20], and a temporary deposit insurance program

in the United States was to have sharing in staggered proportions [see FDIC (1984), p. 44]. Analyses of co-insurance tend to focus on proportional sharing arrangements. See Boyd and Rolnick (1989), and Benston and Kaufman (1988), ch. 3.

²⁸Defining a "healthy" asset is a difficult chore. The task is generally accomplished by individual evaluation of assets, rather than the application of a generic rule.

Figures 11-13



$\$932.12 - \$47.96 = \$884.16$. In other words, given deposit insurance with a \$100 coverage limit, \$884.16 is the amount deposited at the beginning of the year in exchange for a *promised* year-end payoff of \$1000.

In general, we can use an option pricing model to solve algebraically for a measure of

the risk premium that the depositor would charge under this risk-sharing arrangement. On the one hand, we can think of the deposit as a riskless deposit combined with a put option. On the other hand, we can think of it as a single risky promise of repayment from the banker, to be discounted at some risk-adjusted interest rate, r , so that the value of the deposit is:

$D = L \cdot e^{-rT}$. We can equate these two interpretations thus:

$$\begin{aligned} D &= L \cdot e^{-RT} - P(L - M, A, T, \sigma, R) \\ &= L \cdot e^{-rT}, \end{aligned}$$

where $P(\bullet)$ is the value of the put option before expiration, as defined, for example, by the Black-Scholes model, and r is the risk-adjusted discount rate implied by the presence of the coverage limit. Given the other variables, we can rearrange this to find the risk premium:

$$(2) \quad (r - R) = -\frac{1}{T} \ln \left[e^{-RT} - \frac{1}{L} P(\bullet) \right] - R.$$

Applying this to the numerical example, the stated risk-adjusted interest yield on the deposit is:

$$\begin{aligned} r &= -\ln \left[e^{-.08(1)} - \frac{\$47.96}{\$1000.00} \right] \\ &= -\ln(0.87515) = 13.3\%, \end{aligned}$$

implying a risk premium, $r - R$, of 5.3 percent.

In practical terms, such an estimate of the magnitude of the risk premium implied by a given coverage ceiling might be useful in calibrating the degree of market discipline in a reform of the insurance system. If bank risk-taking is to be curbed by limiting deposit insurance, forcing riskier banks to pay higher risk premia as some have suggested, then the insurance limitations must be such that the risk premium implied by equation 2 is large enough to make bankers alter their behavior.²⁹

The magnitude of the risk premium might also serve as a readily observable vital sign, registering the financial health of the bank's assets, and aiding the regulator in scheduling audits. This presumes that depositors have some advantage over regulators in assessing the bank's risk between audits.³⁰ Such applications, how-

²⁹For some examples of market discipline proposals, see Boyd and Rolnick (1989), Gilbert (1990), Gorton and Santomero (1988, 1989), or Thomson (1987).

³⁰Note that uninsured or co-insured depositors might find it more practical to engage in capital rationing, i. e., limiting

the amount lent to a bank based on that bank's risk, in addition to pricing that risk.

ever, are subject to some limitations which are illustrated by the next example.

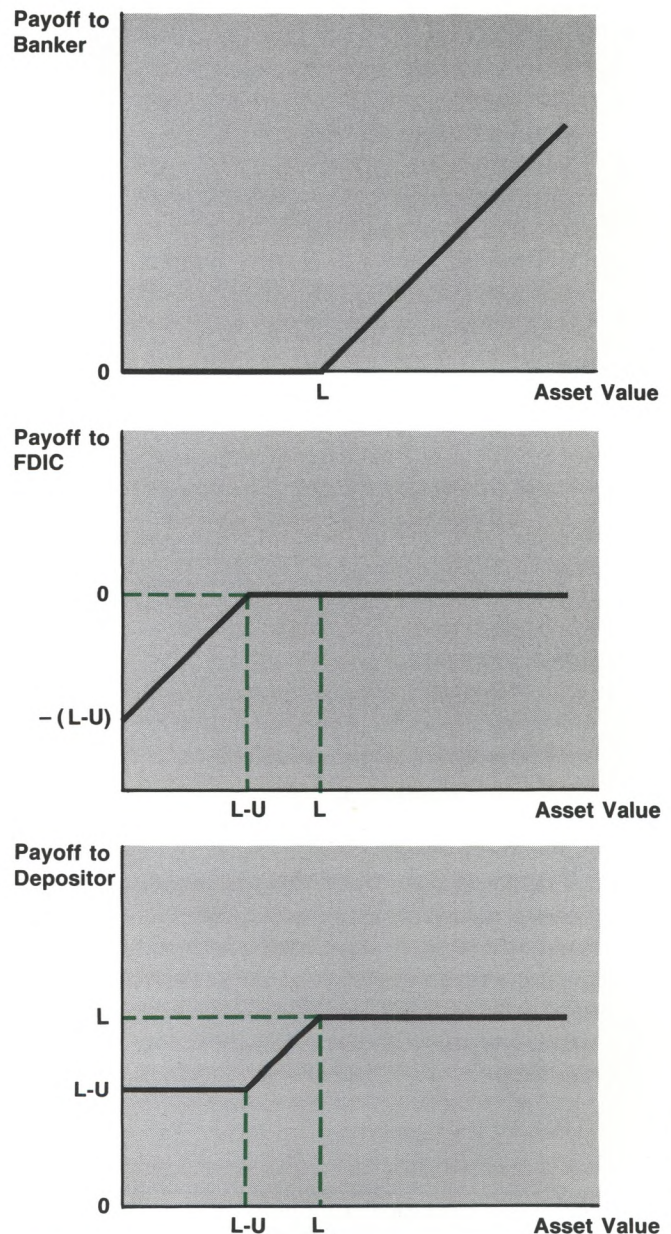
Deductible

Another form of co-insurance is a deductible. The case of a deductible on insurance coverage introduces a twist to the problem. Now the depositor's portfolio effectively consists of two put options, one written and one held, in addition to the promised repayment of the deposit with interest. This case is of special interest, because it applies to a deposit payout closure as considered above and because it can also be applied to subordinated debt, which is the object of a recent debate on sources of market discipline of bank risk-taking. In both cases, the payoffs to one of the bank's creditors can be modeled as a pair of put options with different striking prices.³¹

In this example, the depositor is promised the return of his deposit amount, with accrued interest, for a total of L dollars. Because of the deductible provision, however, this promised repayment is not certain; in the event of the bank's insolvency, the depositor will be the first to share in the shortfall. For year-end asset levels below L , the shortfall is deducted from the depositor's payoff until the deductible amount, U , is exhausted. Any shortfall beyond that is absorbed by the FDIC. Thus, the depositor effectively holds the deposit amount L and has written a put option with striking price L , that is held by the banker; in addition, he holds a put option with striking price $(L - U)$, which is written by the FDIC. These payoffs are illustrated in figures 14-16.

The deductible provides a cushion for the FDIC, which, in the preceding examples, had written a put option with striking price L rather than $(L - U)$. The year-end payoffs for the banker are the same as before. The real difference applies to the depositor's incentives and the resulting impact on the price he charges the banker for the deposit. Although he always prefers a higher asset value, as before, his attitude toward the riskiness of the bank's assets is now ambiguous, because he is long one put option and short another, with two different striking prices. Volatility in the bank's asset

Figures 14-16



returns increases the value of the long position and decreases the value of the short position.

As Black and Cox (1976) point out, the net impact of these countervailing forces will depend on the current asset value relative to the striking prices. Specifically, there is an inflection

³¹The relevant creditors in each case are the depositor and the subordinated debt-holder, respectively. For an analysis of option models in the case of subordinated debt, see Black and Cox (1976) and Gorton and Santomero (1988, 1989). For an analysis of subordinated debt and bank

regulation, see Gilbert (1990). The approach here is at odds with that of Ronn and Verma (1986), who calculate the value for a single put on total debt and then scale that value down by the proportion of insured to total liabilities.

point equal to the discounted geometric mean of the two striking prices.³² For an asset value above the inflection point, which includes all cases in which the bank is solvent (i. e., $A > L \cdot e^{-RT}$), the effect of the short position outweighs that of the long position, and the depositor will prefer less risk. Conversely, when the current market value of assets falls below the inflection point, the long position outweighs the short, and the depositor would prefer a riskier asset portfolio, given the low asset value. Thus, a decrease in the "risk premium" charged by the depositor no longer necessarily implies that the bank's assets are less risky; for example, such a decrease could instead be the result of an increase in the current asset value and an increase in the volatility of those assets.

Under such circumstances, it is a reasonable taxonomic question whether the interest rate markup over the riskless rate should be called a risk premium at all. The current value of the depositor's claim and the implicit risk premium can be calculated as before:

$$D = L \cdot e^{-RT} - P(L, A, T, \sigma, R) + P(L - U, A, T, \sigma, R) \\ = L \cdot e^{-rT} \quad \rightarrow$$

$$(r - R) = -\frac{1}{T} \ln \left\{ e^{-RT} - \frac{1}{L} [P(L, \bullet) - P(L - U, \bullet)] \right\} - R,$$

but the risk premium so defined is a measure of the expected difference between cash promised, L , and cash ultimately received. It is a poor measure of the volatility of the returns on the bank's assets, because the expected difference between cash promised and cash received depends on several factors and is no longer a simple direct relation of the volatility of assets.

Figure 17 graphs the value of the depositor's claim for a range of asset levels and volatilities.³³ In interpreting this graph, note the connection between it and figure 16. In particular, as the volatility, σ , goes to zero in figure 17, the

value of the deposit resembles more and more the staggered year-end payoff function of figure 16. In fact, if the year-end payoff of figure 16 is scaled down by the risk-free present value discount factor, e^{-RT} , it becomes identical to the extreme case of figure 17 where $\sigma = 0$. Figure 17 also illustrates graphically the Black and Cox argument that for some (higher) asset levels, depositors will charge a risk premium, while for other (lower) levels, they will offer a risk discount.

It is also clear from the picture, however, that the asset level has a much more significant effect on the value of the claim than does the volatility.³⁴ All of this suggests that bankers, depositors and policymakers should give considerable care to an appropriate definition of risk in this context, and that similar care should be given to designing a practical measure of that risk. Risk defined as volatility in bank asset returns and measured by the risk premium charged on equity, subordinated debt or uninsured deposits may not be apt for the tasks to which it has been applied.

SOME CAVEATS

The preceding analysis has illustrated some uses of option pricing models in evaluating deposit insurance. There are some limitations, however, on the use of options models in this context. Most of these limitations derive from the assumptions that form the basis for the option pricing equation, and the extent to which these assumptions are valid for the case at hand.

Perhaps the most basic problem is the question, who truly holds the option.³⁵ Until now, it has been presumed, based on the end-of-period payoffs, that deposit insurance represents a put option written by the FDIC and held by the banker. In fact, however, the FDIC decides whether a bank is insolvent, and, more importantly, whether to close a bank that is already insolvent (or one that is not quite insolvent).³⁶ In the face of a large-scale bank failure or run,

³²The discount rate used to calculate this inflection point includes a risk premium. Since all other discounting in this context is at the riskless rate, this means that the inflection point can fall below the present value of the lower discount rate, $(L - U) \cdot e^{-RT}$, if the risk premium, $\sigma^2/2$, is large enough. For the same reason, the inflection point is always smaller than the solvency point, $L \cdot e^{-RT}$.

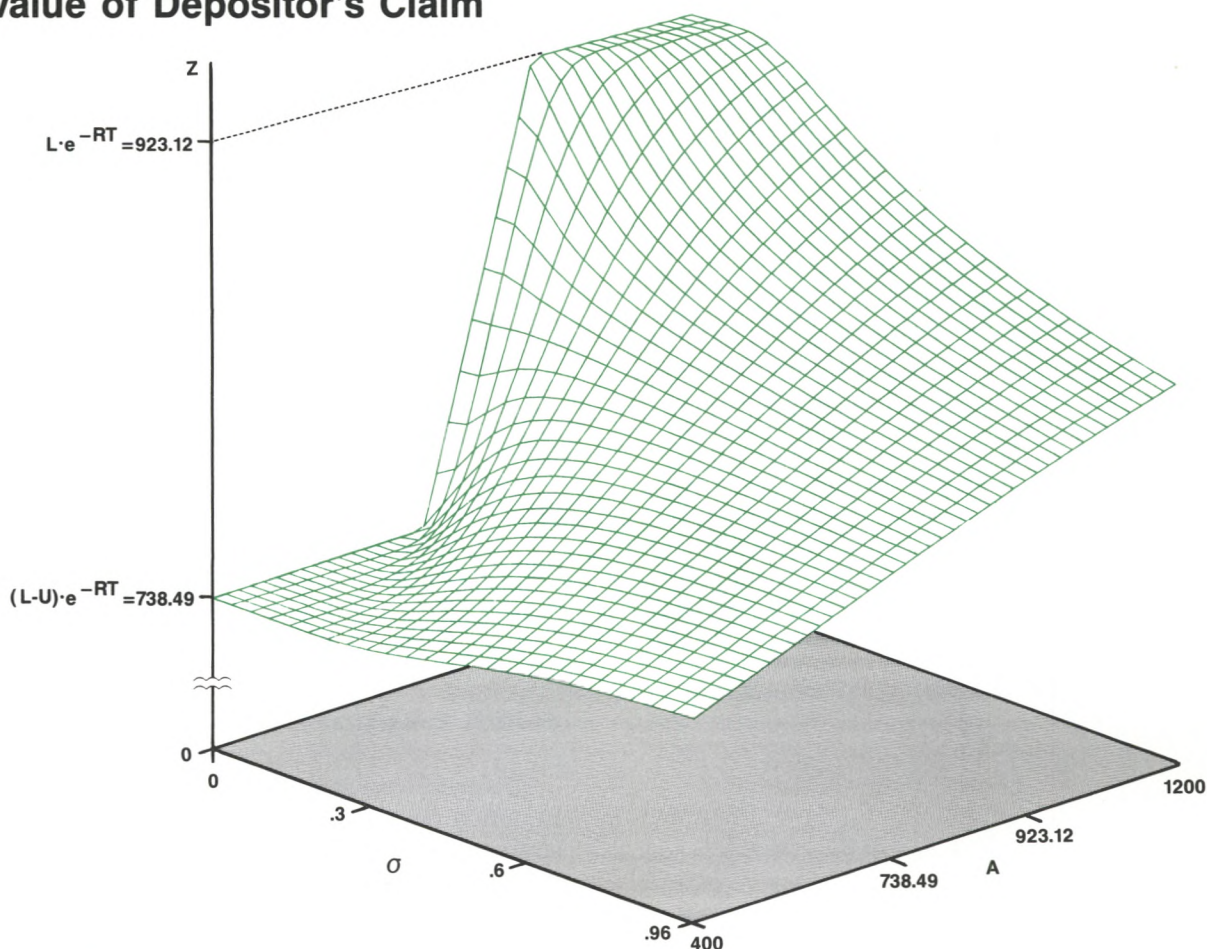
³³The riskless rate was set at 8 percent, time to maturity was one year, promised repayment was \$1000, and the deductible amount was \$200. Similar graphs with other maturities and deductible amounts reveal no surprises.

³⁴This fact is noted by Pyle (1983), p. 13.

³⁵This issue is addressed by Brumbaugh and Hemel (1984) and Allen and Saunders (1990).

³⁶Recall that the definition of insolvency used in this paper ignores the possibility that the bank might be deemed insolvent on the basis of its current ratio — i. e., its inability to meet maturing liabilities with liquid assets. This problem relates to the maturity structure of the bank's portfolio, which will be considered briefly below.

Figure 17
Value of Depositor's Claim



short-term political considerations may overwhelm any prior prescriptions on closure policy. The FSLIC's actions in the thrift crisis indicate that this is not idle speculation; numerous thrifts were left open long after their insolvency had been discovered. Conversely, as Benston and Kaufman (1988) suggest, the FDIC could close solvent banks, if they have come close enough to insolvency. If the insurer were to follow scrupulously a well-defined rule one way or the other, there would be little at issue, since the striking price and year-end payoffs could then be easily adjusted within the context of the current model. As matters stand, however, bankers and depositors effectively face a random striking price, because the insurer decides if the option will be exercised. As a practical

matter, it is difficult to envision how such a well-defined closure rule might be implemented.³⁷

A related issue is the measurement of bank asset values. The option pricing model presented above presumes that the current asset price can be readily observed. For stock options, this is an uncontentious assumption, because stock prices can be observed on the floor of the exchange or in the over-the-counter market. For an option on the assets of the bank, however, the relevant price is not readily observable. Indeed, one of the primary functions of bank credit analysis is to assign values to assets for which there is no active market. Similarly,

³⁷A rule is well-defined if it leaves no doubt about the circumstances which imply closure, with no room for FDIC discretion. Note that defining a closure rule, in general, is

not sufficient for our purposes; the closure rule must be defined so that the values of the resultant claims conform to the values given by the option pricing equation.

the insurer must invest significant effort, in the form of an audit, to determine the year-end asset value.

The inherent inaccessibility of bank asset values has two implications for option models. First, it is no longer possible for an option holder to construct the appropriately hedged portfolio described in the Black and Scholes derivation, because the hedge ratio depends on the value of the underlying asset. This casts doubt upon the appropriateness of the riskless rate in discounting the expected end-of-period payoffs.³⁸ Second, the current asset value is important, because it partly determines the probabilities for the various end-of-period payoffs. Ignorance of the current asset value adds another layer of uncertainty, and this additional uncertainty significantly affects the value of the option.³⁹

A closely related issue is the measurement of asset risk. The option pricing models presented here use the variance of the asset's returns as a measure of risk.⁴⁰ Producing an accurate assessment of the variance is problematic, even for stock options, because the volatility that matters is the variance of the process over the *future* life of the option. For bank assets, the measurement problem is compounded, because even past values are generally unavailable. Pyle (1983) and Flannery (1989b) consider some of the implications of this problem in using the option models to price deposit insurance.

Just as asset values and the volatility of returns are not observable directly, there is the more general moot question of which stochastic returns-generating process should be incorporated in the option pricing model. As we've seen above, the difference in the assumed returns process between Black and Scholes's model and Merton's model resulted in a substantially different pricing equation. Although the choice of an appropriate returns process for modeling a bank's assets is beyond the scope of this paper, it is sufficient to note

that this choice is a salient factor in the option's value, because it determines the probability of each of the possible year-end payoffs.

The empirical evidence to date testifies to the sensitivity of the results to the specification employed. Marcus and Shaked (1984) use the basic Black-Scholes model, adjusted for dividends, and find that federal deposit insurance is currently substantially overpriced relative to the "actuarially fair" estimates provided by their option model.⁴¹ They note, however, that "McCulloch's (1981, 1983) estimates of insurance values derived from the Paretian-stable distribution greatly exceed" their own.⁴² Pennacchi (1987b) uses a more complicated model which includes the degree of regulatory control wielded by the insurer. He finds that deposit insurance may be either overpriced or underpriced, depending on the level of regulation assumed. McCulloch's (1985) study assumes non-normal, Paretian-stable asset returns and non-stationary random interest rates. He finds that insurance values are highly sensitive to the level and volatility of interest rates. Ronn and Verma (1986), however, using a variant of Merton's (1977) model, conclude that neither random interest rates nor non-stationary equity returns significantly affect the insurance valuations. In brief, the empirical evidence suggests that a wide range of insurance valuations can be reached by varying the returns process employed in the model.

Finally, it has been assumed in the preceding examples that there is a single deposit that does not mature until the end of the year. In fact, of course, banks maintain many deposit accounts with a wide range of maturities, starting with the instant maturity of demand deposits. This is significant, because it gives many depositors another type of insurance. A depositor who can withdraw his funds from a failing bank sooner than the FDIC can close it has 100 percent insurance, regardless of the balance in the account or the insurance scheme in effect.⁴³ The

³⁸One might resort to the argument that the riskless rate is appropriate if the asset has no idiosyncratic (that is, firm-specific) risk, as noted in the context of Merton's (1976) pricing model (see the shaded insert), but such an assumption is not particularly credible for bank asset portfolios, *prima facie*.

³⁹See Pyle (1983) for an analysis of asset value uncertainty. Figlewski (1989) and Babbal (1989) consider the impossibility of hedging, along with many other difficulties in the application of stock option pricing models.

⁴⁰Merton's (1976) approach uses that variance together with the parameters of the jump distributions.

⁴¹For an exposition of the dividend adjustment to the Black-Scholes model, see Merton (1973).

⁴²Marcus and Shaked (1984), p. 449. Their reference to McCulloch (1983) was a working paper, later published as McCulloch (1985).

⁴³It need only be the case that the bank funds the deposit outflow somehow, for example, through a fire sale of its assets. Such a run on Continental Illinois by institutional depositors prompted the FDIC to extend 100 percent insurance to uninsured depositors.

result is that the simple application of an option pricing model does not provide an accurate evaluation of such deposits, because it ignores certain relevant strategies.

CONCLUSIONS

The usefulness of option models in the study of deposit insurance results from two important characteristics. First, these models distill the host of economic factors involved down to a handful of relevant parameters whose interaction is well-defined by the option-pricing equation. Second, they are able to evaluate deposit insurance claims under a wide variety of insurance structures. Although only three such structures were elaborated here, they can be generalized to other applications. Thus, option models provide a unified context for analyzing incentives within an insurance structure, as well as for comparing alternative insurance schemes.

Unfortunately, option pricing models, like most economic models, are an imperfect tool when directly applied to the complexities of the real world. Beyond certain fundamental qualitative results, there are theoretical and empirical reasons to believe that the insurance valuations given by any particular option pricing model will be incorrect, highly sensitive to changes in their specification, or both. As a result, the absolute dollar magnitudes provided by options models of the value of deposit insurance are suspect. The contradictory empirical evidence on fair pricing is indicative of this problem.

In defense of these models, however, there is no reason to believe that option models are any worse in this regard than any alternative economic model. Indeed, there is some reason to believe that, although the absolute magnitude of the valuations provided by option models may be unstable, the rankings they provide for a sample of banks are not.⁴⁴ Similarly, inaccuracies in determining the scale of insurance values do not deny the ability of option models to identify the direction of incentives or the impact of marginal changes in the structure of deposit insurance. Therefore, used judiciously, option pricing models can be an effective analytical tool in the study of deposit insurance.

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p. 511] indicate that the stability of the rankings is significant but imperfect. Further research along these lines would be welcome.

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What Do We Know About the Long-Run Real Exchange Rate?

A REAL EXCHANGE rate is defined as the foreign currency price of a unit of domestic currency (that is, the nominal exchange rate) multiplied by the ratio of the domestic to the foreign price level. The real exchange rate has been at the center of economic policy discussions in the 1980s for at least two reasons. First, this relative price has been more variable in the floating-rate period than in the preceding era of fixed (nominal) exchange rates.¹ Second, this price is related to international trade patterns because the competitive position of an individual exporting (import-competing) firm in a

country is affected adversely by an appreciating (depreciating) real exchange rate.²

Despite much research, however, there is no consensus on which variables cause changes in the real exchange rate. Like any asset price, real exchange rates are related to the determinants of the relevant supply and demand curves now and in the future.³ With real exchange rates, the relevant determinants are those affecting the relative supplies and demands for the currencies of two countries. Claims have been made, however, that the real exchange rates

¹See Frankel and Møese (1987) and Dornbusch (1989) for surveys of this literature. As noted by Dornbusch, the increased variability and lack of knowledge have contributed to divergent policy recommendations, which include a return to some form of a managed exchange-rate system, taxes on foreign exchange transactions as well as doing nothing.

²The U.S. dollar has been at the center of the controversy, with the dollar allegedly being undervalued in the late 1970s/early 1980s and overvalued in the mid-1980s. During the period of undervaluation, U.S. tradeable goods industries were stimulated and induced to overexpand. The costs of this alleged overexpansion were exacerbated by the subsequent overvaluation, which resulted in layoffs, plant closings and bankruptcies in these same industries.

³This elementary principle is ignored when the exchange rate in macroeconomic settings is treated as an ex-

ogenous rather than endogenous variable. For example, a standard assertion is that a depreciating dollar boosts U.S. manufacturing output. A declining dollar is expected to raise the dollar prices of U.S. imports and lower the foreign currency prices of U.S. exports. Consequently, consumption and production of U.S. exports and import-competing goods would rise. This analysis is faulty because changes in the value of the dollar are not independent of U.S. industrial developments and, in fact, can be the direct result of industrial developments. For example, an economic policy that boosts productive capacity can generate a positive relationship between the value of the dollar and U.S. manufacturing output. Details on this argument can be found in Tatom (1988).

often differ substantially from levels consistent with the underlying economic fundamentals and that these differences persist for long periods.

A primary goal of our research is to provide an elementary understanding of the major theoretical approaches to the determination of long-run real exchange rates. These approaches identify numerous variables that have been tested for their relationships to the changing values of the real exchange rate. Empirically, we examine the six bilateral real exchange rates among the United States, West Germany, Japan and the United Kingdom.⁴ Using a data set covering approximately the same time period, we make a straightforward comparison of the three primary approaches and present a clear picture of what can be said about the determinants of real exchange rates.

Research to explain movements in the long-run real exchange rate is unnecessary if purchasing power parity (PPP) holds in the long run. Thus, we begin by reviewing the literature on PPP in the long run. This provides a natural starting point from which to examine the different theoretical approaches to real exchange rate determination and the major empirical findings. Next, we undertake unit root and cointegration tests to examine whether long-run relationships exist between the real exchange rate and some of its potential determinants.

IS THE REAL EXCHANGE RATE A RANDOM WALK?

As a point of departure, it is useful to define the real exchange as it is used throughout this paper. A standard representation expresses all variables in logarithms, so that a real exchange

rate, q , is defined as follows:

$$(1) q = e + p - p^*$$

where e is the foreign currency price of a unit of domestic currency, p is the domestic price level as measured by the consumer price index and p^* is the similarly measured foreign price level.⁵

Since the advent of flexible exchange rates in 1973, real exchange rates have been more variable than they were previously. This point is illustrated in figure 1 over 1957 to 1988 for the pound/dollar, mark/dollar and yen/dollar real exchange rates. The increased variability has induced many researchers to focus on the fundamental relationships that determine real exchange rates.

The concept of purchasing power parity has been one of the most important building blocks for nominal, as well as real, exchange rate modeling during the 1970s and 1980s. In its absolute version, PPP states that the equilibrium value of the nominal exchange rate between the currencies of two countries will equal the ratio of the countries' price levels.⁶ Thus, a deviation of the nominal exchange rate from PPP has been viewed as a measure of a currency's over/undervaluation. In its relative version, PPP states that the equilibrium value of the nominal exchange rate will change according to the relative change of the countries' price levels. A noteworthy implication of both versions of PPP is that the real exchange rate will remain constant over time.

Economists have debated whether PPP applies in the short run, long run or neither. By the end of the 1970s, PPP, at least in the short run, was rejected convincingly by the data.⁷ Whether PPP in the long run can be rejected is less clear. A standard theoretical argument in support of

⁴Our selection of countries is based on research by Koedijk and Schotman (1989), which indicates that the movements of real exchange rates for 15 industrial countries can be partitioned into four groups led by the United States, West Germany, Japan and the United Kingdom.

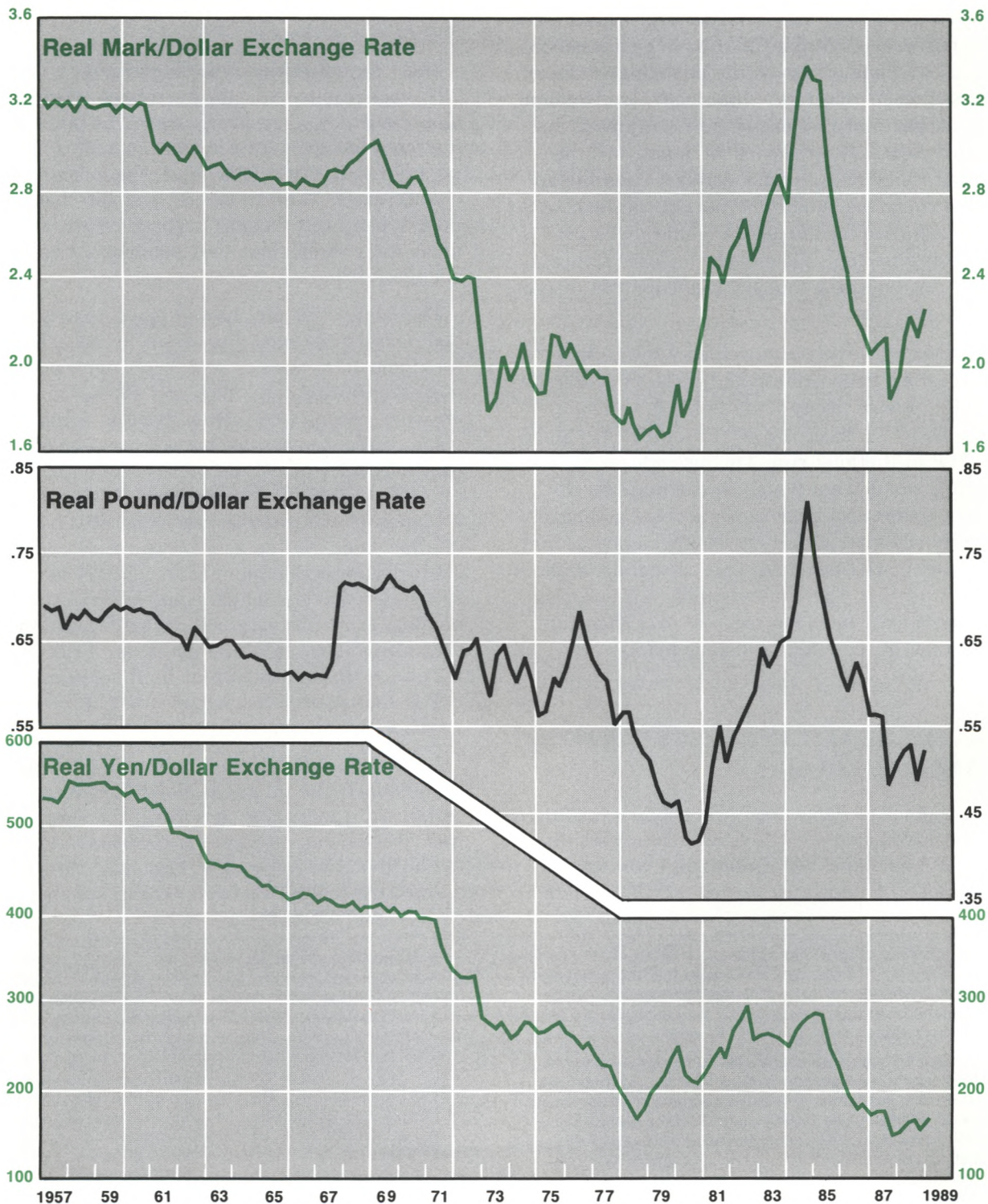
⁵Wholesale price indexes are also frequently used in the calculation of real exchange rates. The use of wholesale rather than consumer prices can generate different results. For an example, see McNown and Wallace (1989). For a brief discussion of why a broad-based measure of prices such as consumer prices is more appropriate than one of wholesale prices in calculating real exchange rates, see Cox (1987).

⁶More generally, PPP has been stated in Edison and Klovland (1987) as $E = K(P/P^*)$, where E is the exchange

rate (domestic currency value per unit of foreign currency), P is an index of domestic prices, P^* is an index of foreign prices and K is a scalar. In this view, the PPP hypothesis is a homogeneity postulate of monetary theory rather than an arbitrage condition. Thus, a monetary disturbance causes an equiproportionate change in money, commodity prices and the price of foreign exchange, while relative prices are unchanged. The influence of real factors on the relationship between exchange rates and national price levels is captured by K , which is a function of structural factors that can alter the relative prices of goods.

⁷See Adler and Lehmann (1983) for the references underlying this consensus.

Figure 1
Real Bilateral Exchange Rates in the Fixed and Floating Rate Periods



PPP is that deviations from parity, assuming zero transportation costs and no trade barriers, indicate profitable opportunities for commodity arbitrage. Deviations from PPP imply that the same good, after adjusting for the exchange rate, will sell at different prices in two locations. Simultaneously buying the good in the low-price country and selling the good in the high-price country will force the nominal exchange rate to PPP and the real exchange rate to some constant value.

The chief issue is whether the real exchange rate returns over time to a fixed value, the long-run equilibrium real exchange rate. On the other hand, it is possible that the equilibrium value of the real exchange rate is not constant over time, but instead changes in response to changes in some fundamental economic variables. For example, an increase in a country's real interest rate, *ceteris paribus*, could cause an appreciation of the country's real exchange rate.

One conclusion, however, is clear: if the real exchange rate follows a random walk, long-run PPP does not hold. A variable is said to follow a random walk if its value in the next period equals its value in the current period plus a random error that cannot be forecast using available information. If the real exchange rate follows a random walk, then it will not return to some average value associated with PPP over time. In fact, its deviation from the PPP value becomes unbounded in the long run.

The unit root test is a common procedure to use in determining whether a variable follows a random walk.⁸ If the existence of a unit root

cannot be rejected, then the variable is said to follow a random walk. Using data from various developed countries, recent studies by Darby (1983), Adler and Lehmann (1983), Huizinga (1987), Baillie and Selover (1987) and Taylor (1988) could not reject the unit root hypothesis for the real exchange rate in the current floating rate period and, hence, rejected the notion of long-run PPP.

The issue, nevertheless, remains controversial. One reason is that some researchers have found evidence to reject the random-walk hypothesis in some cases.⁹ In addition, doubts about the power of standard tests to discriminate between true random walks and near random walks have been raised. For example, Hakkio (1986) demonstrated that, when the real exchange rate differs modestly from a random walk, the results of standard tests are biased in favor of the random-walk hypothesis. In other words, there is a high probability of failing to reject the random-walk hypothesis even if it is false.¹⁰

Another possibility is that the current floating-rate period is too brief to assess accurately the validity of PPP. Lothian (1989), using unit root tests and annual data for over 100 years for Japan, the United States, the United Kingdom and France, found that real exchange rates tended to return to their long-run equilibrium values, but that the period of adjustment was quite long. For example, adjustment periods ranging from three to five years were found. Consequently, the current floating-rate period might not be long enough to identify the long-run tendency of the real exchange rate to return to an equilibrium.

⁸The issue is whether the real exchange rate is stationary. If the real exchange rate is stationary, then random disturbances have no permanent effects on this rate. If the real exchange rate is nonstationary, then there is no tendency for this rate to return to an "average" value over time. To determine whether the real exchange rate is stationary, a standard procedure is to use the Dickey-Fuller test for unit roots. This procedure is described later in the text.

⁹Examples include Cumby and Obstfeld (1984) and Frankel (1986). Using monthly data between September 1975 and May 1981, Cumby and Obstfeld rejected the random-walk hypothesis for the real exchange rate between the United States and Canada. On the other hand, they were unable to reject the random-walk hypothesis for the real exchange rate when the United States was paired with each of the following countries—United Kingdom, West Germany, Switzerland and Japan. Frankel (1986) rejected the random-walk hypothesis for the real U.S. dollar/British pound exchange rate using annual data between 1869 and 1984, but was not able to reject the hypothesis using data for 1945-1984.

¹⁰The preceding problem motivated Sims (1988) to develop a new test for discriminating between true and near random walks. Applying this new test, Whitt (1989) was able to reject the hypothesis that the real exchange rate was a random walk. A forthcoming issue of the *Journal of Econometrics*, however, concludes that the appropriateness of Bayesian approaches in detecting unit roots remains in doubt because many questions, some requiring highly technical responses, have not been answered. Consequently, we did not use this technique in our analysis.

APPROACHES TO REAL EXCHANGE RATE DETERMINATION IN THE LONG RUN

Our goal is not to resolve the preceding controversy about PPP in the long run. Rather, it is to examine, as well as extend empirically, the research efforts of those who have provided models that allow for the long-run real exchange rate to vary over time. In other words, our goal is to examine the attempts by researchers skeptical about PPP in the long run to explain movements in the long-run real exchange rate. Two real approaches and a monetary approach to exchange-rate determination have been used to explain movements in the equilibrium real exchange rate. The first real approach is concerned with movements in the real exchange rate that arise from incorporating the difference between tradeable and non-tradeable goods prices. The other real approach deals with the implications of incorporating a balance of payments constraint. The monetary approach, in contrast, focuses on the relationship between real exchange rates and real interest rates.

Tradeables and Non-Tradeables

Absolute PPP implies that the equilibrium value of the nominal exchange rate between the currencies of two countries would equal the ratio of the countries' price levels, which is commonly measured by the respective consumer price indexes. Ignoring transportation costs, free international trade eliminates the price difference between the same good in two countries; however, price differences across countries for non-traded goods may persist and may change substantially over time. Frequently, this possibility is referred to as PPP holding only for internationally traded goods; however, one could view this possibility as a substantial modification of PPP. To prevent confusion, we do not call this PPP, but rather characterize it as the law of one price for traded goods.

A simple model illustrating this approach is presented below. Let p be the logarithm (log) of

the overall price level, and p_T and p_{NT} be the logs of the price levels of traded and non-traded goods; an asterisk denotes the foreign country. The overall price level is related to the prices of tradeable and non-tradeable goods by

$$(2) p = (1 - \alpha)p_T + \alpha p_{NT}$$

and

$$(3) p^* = (1 - \beta)p_T^* + \beta p_{NT}^*$$

where α and β denote the shares of the non-tradeable goods sectors in the economies.¹¹ Assuming the law of one price for tradeable goods,

$$(4) e + p_T - p_T^* = 0,$$

where e is the log of the nominal exchange rate, measured as the foreign currency price of a unit of domestic currency.¹²

By substituting equations 2, 3 and 4 into equation 1, the real exchange rate, q , can be written as

$$(5) q = -\alpha(p_T - p_{NT}) + \beta(p_T^* - p_{NT}^*).$$

Thus, the real exchange rate depends on relative prices between tradeable and non-tradeable goods as well as the sizes of the non-tradeable goods sectors in the two countries. Our focus is restricted to the possibility that persistent differences between the price changes of tradeable and non-tradeable goods across the two economies can cause real exchange rate movements.

Two main proxies, one using relative prices, the other using output measures, have been used to measure the tradeables/non-tradeables distinction. As Wolff (1987) has noted, a standard empirical proxy in analyzing relative prices in a world with internationally traded and non-traded goods is the ratio of wholesale prices to consumer prices. The reasoning is straightforward. Wholesale price indexes generally pertain to baskets of goods that contain larger shares of traded goods than consumer price indexes do. Consumer price indexes tend to contain relatively larger shares of non-traded consumer services. To date, however, empirical evidence on

¹¹These indexes suggest that the price level is constructed as follows: $P = P^{(1-\alpha)} P_{NT}^{\alpha}$, where the upper-case Ps represent levels. Price indexes are not really constructed this way; however, following Hsieh (1982), this construction was chosen to simplify the derivation. Hsieh has argued that his empirical results were not distorted by this assumed construction because he used highly aggregated data.

¹²As a check, using wholesale prices for the prices of traded goods, we found that $e + p_T - p_T^*$ was not stationary. Thus, one of the building blocks for this approach does not hold for our data. In addition, even if one were to define the real exchange rate using wholesale rather than consumer prices, PPP would not appear to hold in the long run.

the importance of relative prices in explaining real exchange rate movements is lacking.

The other proxy for the tradeables/non-tradeables distinction was highlighted by Balassa (1964). Balassa assumed that the law of one price held for traded goods, that wages in the tradeable goods sector are linked to productivity and that wages across industries are equal. These assumptions cause the price of non-tradeable goods relative to tradeable goods to increase more over time in a country with high productivity growth in the tradeable goods sector than in a country with low productivity growth. Such a productivity differential, in conjunction with a general price index that covers both traded and non-traded goods, will result in a real exchange rate appreciation for fast-growing countries even with the prices of traded goods equalized across countries.

For the empirical application of the productivity approach, Balassa suggested that there should be a positive link between the real exchange rate and real per capita gross national product, which assumes that inter-country productivity differences are reflected in per capita income levels. The effect of shifts in sectoral productivity have been investigated by Hsieh (1982) and Edison and Klovland (1987). Hsieh found that real exchange-rate changes for West Germany and Japan could be explained by differences in the relative growth rates of labor productivity between traded and non-traded sectors for these countries and their major trading partners.

Similarly, Edison and Klovland, using annual data, found a long-run equilibrium relation between the pound/Norwegian krone real exchange rate and the real output differential and between the real exchange rate and the commodity/service productivity ratio differential. The results of Edison and Klovland raise a number of interesting questions because the data cover a period that is both long, 1874-1971, and does not encompass the current floating-rate period. Consequently, one is left wondering whether 15 years of data, which require the use of data more frequent than annual observations, is sufficient to reach strong conclusions about the current period and whether Edison and Klovland's results would be altered by data from the current period.

The Real Approach Using the Balance-of-Payments Equilibrium

An alternative real approach to analyze movements in the real exchange rate is to include a balance-of-payments constraint.¹³ This approach focuses on the theoretical relationship between changes in the equilibrium real exchange rate and changes in the current account. The long-run equilibrium real exchange rate is the rate that equilibrates the current account in the long run. Recall that balance-of-payments accounting ensures that the current account is identical to the negative of the capital account, which is simply the rate of change of net foreign holdings. Thus, the current account equilibrium in the long run is determined by the rate at which foreign and domestic residents wish to change their net foreign asset positions in the long run.

Any fundamental economic factor that influences the current account affects the real exchange rate. Consequently, the long-run equilibrium real exchange rate depends on real factors—whose changes can either be anticipated or unanticipated—that cause shifts in the demand for and supply of domestic and foreign goods. The most notable example is the relative output differential. Relatively faster output growth domestically will induce an appreciation of the long-run equilibrium real exchange rate.

A key aspect of this approach focuses on the possibility that unanticipated changes in the current account affect the long-run real exchange rate. Unexpected changes in the current account are assumed to reflect changes in underlying determinants that, in turn, require offsetting changes in the real exchange rate to ensure current account equilibrium in the long run. A long-run balance-of-payments constraint suggests that any revisions in expectations about the long-run values of variables that affect the balance of payments affect the expected value of the long-run real exchange rate. As Isard (1983) notes, the substantial changes in the relative price of oil during the 1970s are excellent examples of how unexpected changes in a determinant of the current account caused revised expectations about the long-run real exchange rate.

An illustration highlighting the importance of unanticipated current account changes is pre-

¹³Examples may be found in Isard (1983) and Frenkel and Mussa (1985).

sented by Dornbusch and Fischer (1980). In their model, a current account surplus causes a rise in wealth through the net inflow of foreign assets. Assuming the rise in wealth is unanticipated, excess demand in the domestic goods market occurs. In turn, an increase in the real exchange rate is required for the new goods market equilibrium. This increase induces the necessary shift from domestic to foreign goods by domestic and foreign consumers to eliminate the excess demand.

Hooper and Morton (1982) use this framework to relate changes in the real exchange rate to economic fundamentals. They use the cumulated current account as a determinant of the long-run equilibrium real exchange rate. In their model, unanticipated changes in the current account are assumed to provide information about shifts in the underlying determinants that necessitate offsetting shifts in the real exchange rate to maintain current account equilibrium in the long run. Consistent with this balance-of-payments approach, their results indicate that, between 1973 and 1978, movements in the current account have been a significant determinant of movements in the real exchange rate for the U.S. dollar, predominantly through changes in expectations.

The Monetary Approach

As mentioned previously, the monetary approach focuses on the relationship between real exchange rates and real interest rates. A straightforward exposition of this approach, which can be found in Meese and Rogoff (1988), is based on models developed by Dornbusch (1976), Frankel (1979) and Hooper and Morton (1982). These models are "sticky-price" versions of the monetary model of exchange rates; they assume that prices of all goods adjust slowly in response to disturbances. Thus, temporary deviations in the real exchange rate from its long-run equilibrium value (that is, purchasing power parity) are possible.

These temporary deviations necessitate an exchange-rate adjustment mechanism to restore the long-run equilibrium value. A standard as-

sumption is that the deviations are eliminated at a constant rate. The adjustment process can be represented as follows:

$$(6) E_t(q_{t+k} - \bar{q}_{t+k}) = \theta^k(q_t - \bar{q}_t), \quad 0 < \theta < 1,$$

where E is an expectations operator, the subscripts designate the time period, q is the logarithm of the real exchange rate, the bars indicate values that would prevail if all prices were fully flexible instantaneously and θ is the speed-of-adjustment parameter. Consequently, there is a monotonic adjustment of the real exchange rate to the long-run equilibrium, \bar{q}_t , over time with lower values of θ indicating a quicker adjustment process.¹⁴

The long-run equilibrium value changes with random real shocks; however, assuming all real shocks follow random-walk processes, these shocks do not affect the expected long-run equilibrium exchange rate. Consequently,

$$(7) E_t \bar{q}_{t+k} = \bar{q}_t.$$

Substituting equation 7 into equation 6 yields

$$(8) q_t = \delta(E_t q_{t+k} - q_t) + \bar{q}_t,$$

where $\delta = 1/(\theta^k - 1) < -1$. The observed real exchange rate is its temporary deviation from its long-run equilibrium value plus its long-run equilibrium value.

To complete the model, uncovered interest parity is assumed.¹⁵ This assumption is expressed as follows:

$$(9) E_t e_{t+k} - e_t = {}_k r_t^* - {}_k r_t,$$

where e is the logarithm of the nominal exchange rate (foreign currency per domestic currency unit), ${}_k r_t$ is the k -period nominal interest rate at time t and the asterisk denotes a foreign value. In other words, changes in the nominal exchange rate are directly related to nominal interest rate differentials. As domestic nominal interest rates rise relative to foreign rates, the nominal exchange rate of the domestic country is expected to depreciate.

Equation 9 implies that the expected change in the real exchange rate reflects the expected real interest rate differential. In symbols,

¹⁴For example, a comparison of $\theta = .6$ with $\theta = .4$ after two periods reveals that, in the former case, the expected difference between the actual and long-run equilibrium is .36 of the difference in the current period, while in the latter case the expected difference is .16 of the difference in the current period.

¹⁵The appropriateness of this assumption can be questioned. The uncovered interest parity assumption requires that the forward rate be an unbiased and efficient predictor of the future spot rate; however, the empirical results summarized by Baillie and McMahon (1989) suggest otherwise.

$$(10) E_t(q_{t+k} - q_t) = {}_kR_t^* - {}_kR_t,$$

where the k -period interest rate, ${}_kR_t$, is the difference between the nominal interest rate less the expected rate of change in prices. Substituting equation 10 into equation 8 yields

$$(11) q_t = \delta({}_kR_t^* - {}_kR_t) + \bar{q}_t.$$

Therefore, the essence of the monetary approach is that changes in the real exchange rate are directly related to changes in the real interest differential. As expected real domestic interest rates rise relative to foreign rates; the real exchange rate of the domestic country rises as well.

Equation 11 provided the foundation for various statistical tests by Meese and Rogoff (1988). As noted in the appendix, the measurement of expected real interest rates is problematic. While the sign of the relationship between the long-term real interest rate differential and the real exchange rate was consistent with theory, the relationship was not statistically significant.

Potential Determinants

In summary, the existing literature points to five potential determinants of long-run real exchange rates that we use. The real approach identifies three possibilities, two based on the tradeables/non-tradeables distinction and one based on the balance-of-payments equilibrium. The proxies to measure the tradeables/non-tradeables distinction have used the ratio of wholesale to consumer prices and real per capita gross national product differences, while the cumulated current account difference is used for the balance of payments. The other major approach, the monetary approach, highlights the role of interest rate differentials. Both short-term and long-term interest rate differentials across countries have been used.

AN EMPIRICAL ANALYSIS OF REAL EXCHANGE RATES AND POTENTIAL DETERMINANTS

Our empirical analysis proceeds in two steps. First, using unit root tests, we test for the stationarity of the six real exchange rates that result from pairwise combinations of the foreign exchange rates of the United States, Japan, West Germany and the United Kingdom. The stationarity of five potential determinants for these exchange rates is examined as well. Details on the construction of these variables are presented in the appendix. Unless noted otherwise, we used monthly data from June 1973 to June 1988 for all variables. Thus, in the first step, we provide additional evidence on the existence of PPP in the long run. Second, we test for cointegration between the real exchange rates and each of the potential determinants. The goal is to identify which variables, if any, from the models that we have reviewed explain variations in the real exchange rate over time.

Testing for Unit Roots

We used the test developed by Dickey and Fuller (1979) for testing for unit roots.¹⁶ In the present case, the test consists of regressing the first difference of the variable under consideration on its own lagged level, a constant and, to control for autocorrelation, an appropriate number of lagged first differences.¹⁷ The coefficient estimate on the lagged level is crucial, because the null hypothesis of a unit root implies that it is zero. The test-statistic is simply the estimate of the coefficient divided by its standard error. This test-statistic, which does not have the usual t -distribution, is then compared with critical values tabulated in Fuller (1976).

The results listed in table 1 show that we cannot reject the null hypothesis of a unit root for any of the bilateral real exchange rates.¹⁸ The

¹⁶See Trehan (1988) for a basic introduction to the intuition underlying unit roots and cointegration, as well as a practical illustration.

¹⁷If lagged first differences are needed, then the test is an "augmented" Dickey-Fuller test; otherwise, the test is simply a Dickey-Fuller test. The chosen lag length is the smallest lag length for which there is no autocorrelation.

¹⁸An important caveat concerning the interpretation of unit root tests is the extremely low power of these tests. Given a sample size of approximately 100 observations, the probability of accepting a coefficient of 1.0 on the lagged dependent variable when it is actually 0.95 is roughly 80

percent. Given the nature of the cointegration tests, this caveat applies to these results as well.

Table 1

Unit Root Tests For Real Exchange Rates and Potential Determinants

Countries	q	PW/PC-PW*/PC*	GNP-GNP*	TB-TB*	RS-RS*	RL-RL*
UK/US	1.63	0.31	2.20	1.86	2.96 ¹	2.77
WG/US	1.27	0.13	1.51	2.72	3.15 ¹	1.52
JP/US	0.88	1.44	-0.47	0.10	3.66 ¹	1.48
UK/WG	1.56	1.15	2.48	2.08	2.04	2.03
JP/WG	0.84	0.43	0.70	2.56	2.92 ¹	2.68
UK/JP	1.27	0.68	0.32	1.91	4.40 ¹	2.73

¹ Statistically significant at the 0.05 level.

NOTE: The test-statistic reported is minus the regression t-statistic on α in a regression of the following general form:

$$\Delta x_t = c - \alpha x_{t-1} + \sum_{i=1}^n \beta_i \Delta x_{t-i} + \varepsilon_t$$

The lag length n is chosen as the smallest value for which no autocorrelation exists. For a sample of 100 observations, the critical value for a significance level of 5 percent is 2.89.

real exchange rate measures are nonstationary since there is no tendency for the real exchange rates to return to an average value over time. Thus, consistent with studies cited previously, we reject long-run PPP.

Table 1 also contains the results of unit root tests for the potential determinants of real exchange rates. Both proxies used to measure the tradeables/non-tradeables distinction, the difference between countries of their ratios of wholesale to consumer prices (PW/PC-PW*/PC*) and real per capita gross national products (GNP-GNP*), are nonstationary. An identical conclusion is reached for the cumulated current account difference (TB-TB*), the proxy based on the balance-of-payments approach. In every case, we cannot reject the null hypothesis of a unit root.

The results for the two proxies based on the monetary approach are mixed. The difference between the short-term interest rates (RS-RS*) appears to be stationary in most cases. In only one case, United Kingdom/West Germany, the null hypothesis of a unit root is accepted. On the other hand, the difference between the long-term interest rates (RL-RL*) appears to be nonstationary because the null hypothesis of a unit root is accepted in each case.

Testing for Cointegration

Even though the real exchange rate has a unit root, it is possible that there is a long-run relationship between it and other variables that also contain unit roots. For an equilibrium relationship to exist between these variables, the disturbances that cause nonstationary behavior in one variable must also cause nonstationary behavior in the other variable.

To test whether there is a long-run relationship between variables that contain unit roots, the residuals from an ordinary-least-squares regression between the variables can be examined for stationarity. In other words, a Dickey-Fuller test is performed on the residuals resulting from regressing one variable—the real exchange rate in our case—on a potential determinant. The first difference of the residual series is regressed on its lagged level, a constant and an appropriate number of lagged first differences. A hypothesis test is performed using the coefficient estimate on the lagged level. If the null hypothesis of a coefficient of zero can be rejected, then the residuals are stationary. If the residuals are stationary, then the variables will not drift away from each other. Such variables are said to be cointegrated. Since cointegration

Table 2
Cointegration Tests of Real Exchange Rates and Potential Determinants

Countries	PW/PC-PW*/PC*	GNP-GNP*	TB-TB*	RS-RS*	RL-RL*
UK/US	1.62	1.64	1.57	1.83	1.71
WG/US	1.49	1.53	1.64	2.45	3.12 ¹
JP/US	1.90	1.07	1.07	1.21	1.23
UK/WG	2.76	2.11	2.29	2.11	2.37
JP/WG	2.63	3.50 ¹	2.06	1.39	1.33
UK/JP	2.41	1.49	1.32	1.51	1.80

¹ Statistically significant at the 0.05 level.

tests are oriented toward rejecting any long-run relationship, finding cointegration suggests the existence of a significant statistical link between the variables.

Table 2 shows the results of such cointegration tests. Overall, there is little evidence to indicate that the examined variables explain variations in the real exchange rate over time. Real exchange rates and the differences between ratios of wholesale to consumer prices across countries do not appear to be cointegrated. Despite augmented Dickey-Fuller statistics that approach the critical value in two cases, United Kingdom/West Germany and West Germany/Japan, the residuals are nonstationary in each case. The real exchange rate and the difference between the real per capita gross national products are cointegrated only for West Germany and Japan. The cointegration tests also reveal that the residuals are nonstationary for both the cumulated trade balance and short-term interest rate differences.

One interesting result is the significant relationship between the real exchange rate and the long-term real interest differential for the United States and West Germany. This result

contrasts with Campbell and Clarida (1987) and Meese and Rogoff (1988) who fail to find cointegration between these variables. Since our proxy for the long-term real interest differential is exactly the same as that used by Meese and Rogoff, the additional 18 more recent months of data seem to account for the different result.¹⁹

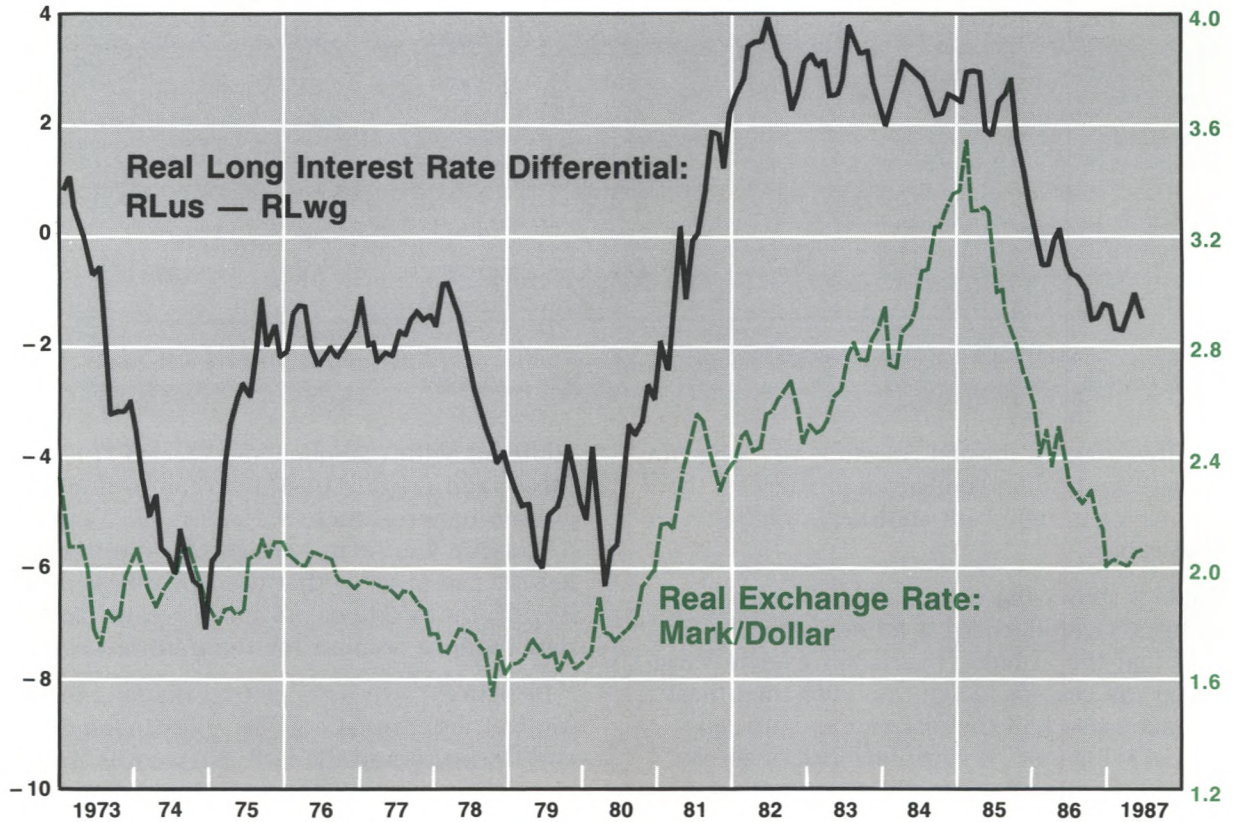
In figure 2, we have plotted the long-term real interest differential between the United States and Germany and the real mark/dollar exchange rate. As is apparent from the figure, there is a strong link between these variables: a higher long-term real interest rate in the United States relative to Germany means a stronger dollar.

SUMMARY

Unfortunately, as our review of a host of studies reveals, little is known about the determinants of real exchange rates in the long run. Our systematic survey of five potential explanatory variables suggests that no approach to this issue is satisfactory. For example, for certain exchange rates, the real approach based on the tradeables/non-tradeables distinction yields evidence of an equilibrium relationship between

¹⁹The sample used by Meese and Rogoff (1988), as stated in their table V, terminated in December 1985, while our sample using long-term interest differentials between West Germany and the United States terminated in June 1987. When we delete these 18 months of observations, the regression t-statistic is 2.77 rather than the 3.12 reported in our table 2. Like Meese and Rogoff, we would fail to find cointegration.

Figure 2
Colintegration of Real Mark/Dollar Exchange Rate
and Real Long Interest Rate Differential



the real exchange rate and differences in real per capita gross national product across countries. On the other hand, the monetary approach seems to have some value in the West German/United States case. An equilibrium relationship appears to exist between the real exchange rate and the difference in long-term interest rates. In view of the low power of unit root tests, this finding is especially noteworthy.

The fact remains that our knowledge of the determination of real exchange rates is meager, at best. The logical question is to ask where research might be directed to expand our knowledge in this area. Numerous explanations, in addition to measurement problems, can be offered for the fact that fundamental variables have not yielded good explanations of real exchange rate movements. One possibility is that the recent period of floating exchange rates is

too brief, especially in view of our statistical tools, to draw conclusions about the long-run behavior of real exchange rates. Assuming no change in exchange-rate regime, the passage of time will ultimately rectify this problem. Until sufficient time passes, however, it would be premature to discard the theoretical approaches that have been proposed.

A second possibility is that the existing models are deficient. Our review identified instances in which the assumptions underlying the models did not hold. In addition, since real exchange rates are asset prices, the role of expectations is an aspect of the modeling process that deserves additional scrutiny. The failure of existing models might result from the fact that expectations are formed differently than our models suggest. Consequently, the development of alternative expectations formation mechanisms might prove productive.

A final possibility is that random shocks of various origins, such as oil price shocks, have moved the real exchange rate. While identification of the real factors that might have affected exchange rates is difficult, Meese and Rogoff (1988) suggest that further attention should be focused on the role of real shocks. Thus, models utilizing modern real business-cycle research might generate some insights. All of these "mights" serve as a final reminder of how little we know.

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Appendix

Data Sources and the Construction of Variables

For all variables except interest rates, we use monthly data from *International Financial Statistics* for June 1973 to June 1988. Recall that q is the log of the real exchange rate with the consumer price index of the respective countries as the deflator. GNP is the log of real gross national product, where nominal gross national product is deflated with the gross national product price deflator. Since gross national product data are not available monthly, we interpolated from quarterly to monthly observations using industrial production. Note that all the potential determinants are defined as differences, with an asterisk indicating the respective value in the other country. PW/PC is the log of the wholesale price index divided by the consumer price index. TB is the cumulated trade balance (that is, the sum from January 1972 to time period t of the difference between exports and imports) divided by gross national product.

For the interest rates not involving Japan, the time period is June 1973 to June 1987, while for those involving Japan, the time period is July 1977 to June 1987. The nominal short-term interest rates and their sources are as follows: Japan—one-month Gensaki rate from the Bank of Japan; United Kingdom—one-month interbank deposit rate from the *Financial Times*; West Germany—one-month interbank rate from the *Frankfurter Allgemeine Zeitung*; and United States—the yield on one-month Treasury bills until April 1984 and, afterward, the interest

rate on three-month Treasury bills from the Federal Reserve Board.

The nominal long-term interest rates and their sources are as follows: Japan—average yield to maturity on government bonds with constant remaining maturity of nine years from the Bank of Japan; United Kingdom—average yield to maturity on government bonds with remaining maturity between eight and 12 years from the *Financial Times*; West Germany—average yield to maturity on government bonds with remaining maturity over eight years from the *Frankfurter Allgemeine Zeitung*; and United States—yield to maturity of government bonds with remaining maturity of 10 years from the Federal Reserve Board. We calculated the real short-term and long-term interest rates, RS and RL , in the same manner as Meese and Rogoff (1988). Thus, actual inflation rates based on the preceding 12 months as measured by the consumer price index are subtracted from the nominal interest rates to generate the real rates. As a result, the inflation measure does not correspond to the term of the interest rates. A problem with this construction, as well as many others, is that negative real interest rates are computed. For example, the long-term (short-term) real interest rate is negative for 25 (42) percent of the U.S. observations, 38 (30) percent of the British observations, 0 (9) percent of the West German observations and 6 (7) percent of the Japanese observations.



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