MANAGING INTEREST RATE EXPOSURE AT A RURAL BANK USING DURATION GAP: A CASE STUDY

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by

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I. Introduction

Community banks have been confronted with greater interest rate exposure in recent years.[2] So far, most of the emphasis in managing interest rate exposure at these banks has been placed in the utilization of risk management techniques such as matching the maturities of interest sensitive assets and liabilities and using either renegotiable or variable rate loans. These management techniques have helped to reduce interest rate exposure.

However, it is becoming increasingly difficult for banks to rely only on these traditional tools to assure an adequate net interest margin. On the one hand, the response time involved when using the traditional tools is often inadequate. By the time a bank has adjusted its exposure position, interest rates might have moved against that position, thus reducing interest rate margins. On the other hand, a community bank localized in a particular market may not be able to change a large proportion of its loan portfolio to variable rates without losing a substantial amount of business. Meeting the needs of a given customer base may pose important practical problems to managing interest rate exposure through traditional methods. These methods are not flexible enough to allow adjustment on the scale and in a time frame that market changes require.

A non-traditional tool--financial futures contracts--offer a potentially more effective method of managing interest rate exposure. But, despite the potential advantages

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[2] See Barret Binder and Thomas Lindquist, Asset/Liability and Funds Management at U.S. Commercial Banks, Bank Administration Institute, Rolling Meadows: Ill. 1982.

that financial futures offer to reduce interest rate exposure, presently they are not widely used by banks.[3]

Reasons cited for minimal use of futures are either a result of bank regulations or the lack of experience in using financial futures markets. These are important factors. However, these reasons completely ignore the first step of interest exposure management: interest rate exposure measurement. A relevant question is how banks actually measure their rate exposure. An answer to this question as it relates to the use of financial futures has been suggested in the banking literature recently.[4] Quoting Toevs:

> Because the gap model does not generate a single number for risk exposure, it cannot be easily used to determine the number of futures contracts that would hedge the overall risk of the bank, a calculation of current interest to many bankers. (p.24)

Gap analysis[5] is the most widely used method of interest rate exposure management. A conceptual specification of how the gap model works is consistent with the following formula:

$$\begin{aligned} E(\Delta NII) &= RSA\$.E(\Delta r) - RSL\$.E(\Delta r) \\ &= Gap\$.E(\Delta r) \qquad (1) \end{aligned}$$

where Δ means change, $E(\Delta NII)$ is the expected change in net interest income, and $E(\Delta r)$ is the expected change in interest rates.

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[3] See Mark Drabenstott and Anne O'Mara McDonley, "The Impact of Financial Futures on Agricultural Banks," Economic Review, FRB of Kansas City, May (1982):19-30.; Donald L.Koch, Dolores W.Steinhauser and Pamela Whigham, "Financial Futures as a Risk Management Tool for Banks & S&Ls," Economic Review, FRB of Atlanta, September(1982):4-14.; and Theodore E.Veit and Wallace W.Reiff, "Commercial Banks and Interest Rate Futures: A Hedging Survey," The Journal of Futures Markets, Vol.3 no3(1983):283-293.

[4] Alden L.Toevs, "Gap Management: Managing Interest Rate Risk in Banks and Thrifts," Economic Review, FRB of San Francisco, Spring (1983):20-35.

[5] For an extensive description of the gap model see James V. Baker, Asset/Liability Management, American Bankers Association 1981.

Gap$ is the difference between interest rate sensitive assets and liabilities.[6] If Gap$ is negative the bank will realize profits(loses) if interest rates decline(rise); and conversely if Gap$ is positive the bank will realize loses(profits) if interest rates decline(rise).If the bank wants to hedge NII against changes in interest rates, then the model recommends setting the Gap$ equal to zero.

Although intuitively appealing, the gap model has several shortcomings that make it difficult to use as an aid in determining futures positions consistent with bank's goals.

The objective of this study is to apply an alternative method of interest rate exposure management -duration gap- to a case study bank in order to measure interest rate exposure and examine the capabilities of a duration gap model as an aid in asset/liability management.

II.Research Method and Data

Duration[7] relates changes in interest rates and percentage changes in bond prices.[8] Recently, Toevs[9], Kaufman[10], and Bierwag and Kaufman[11] using the duration concept, have developed a measure of the bet that a financial

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[6] Rate sensitive assets or liabilities are those that can experience contractual changes in interest rates during a specified time period.

[7] Duration is a weighted average of the times in the future when interest payments of a loan are to be received, where the weights are related to the present values of the payments in each period.

[8] Michael H.Hopewell and George G.Kaufman, "Bond Price Volatility and Term to Maturity: A generalized Respecification," American Economic Review, Vol.63 no4 (1973):749-753.

[9] Toevs, 1983(n.5, above).

[10] George G.Kaufman, "Measuring and Managing Interest Rate Risk: A Primer," Economic Perspectives, FRB of Chicago, Jan/Feb (1984):16-29.

[11] Gerald O.Bierwag and George G.Kaufman, "Duration Gaps for Financial Institutions," Revised Draft for Publication in Financial Analysts Journal, 8-28-84.

institution is actually making on movements in interest rates, namely, its exposure to interest rate movements. They called this measure "duration gap".

The duration gap measure used in this study is that developed by Toevs for net interest income using current bank accounting practices. The assumptions underlying the model are the following:

1. The bank has a one year planning period.

2. The unbiased expectation hypothesis of the term structure of interest rates holds; that is to say, any change in interest rate is unexpected.

3. The term structure of interest rates is flat. This implies that the market forecasts that all one period spot rates for any one financial instrument are equal. Differences between instruments are due to reasons other than time to maturity.

4. The unexpected changes in spot rates of all assets and liabilities are of the same magnitude and direction along the term structure. This assumption implies parallel shifts of the term structure.

5. There are no net deposit withdrawals at any time for accounts that do not have a defined maturity date such as passbook savings, demand deposits, and NOW accounts.

6. There are no loan prepayments or security sales before maturity.

Duration gap for net interest income is defined as:

$$DG_{nii} = MVRSA(1-D_{rsa}) - MVRSL(1-D_{rsl}) \qquad (2)$$

where MVRSA and MVRSL are the market values of rate sensitive[12] assets and liabilities respectively, and D_{rsa} and D_{rsl} are the durations for rate sensitive assets and liabilities respectively.

Two important dimensions of duration gap are sign and absolute value. The sign indicates the type of rate risk to which the financial institution is exposed. The absolute value is a proportional measure of the amount of risk.

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[12] Since the planning horizon is one year, rate sensitive assets or liabilities are those which will either mature or will be repriced within a year.

In this study, duration gap is used in two ways. The first is to calculate how net interest income will change if the term structure of interest rates unexpectedly shifts. The second use is in the calculation of the appropriate adjustment in rate sensitive assets and/or liabilities to remove net interest income risk.

It can be shown that an accurate approximation to the change in net interest income if the term structure changes is given by the following:

$$\Delta NII_o = DG_{niio} \cdot \Delta i \qquad (3)$$

where NII_o is the unexpected realized change in net interest income over the one-year gapping period, DG_{niio} is the duration gap calculated based on the market expectations on interest rates at t_o. Since the term structure is assumed to be flat, ñi represents the amount by which all asset and liability rates unexpectedly change. The first analysis in this study is performed under this assumption.

Equation (3) is used to calculate the potential changes in net interest income given the calculated duration gap of the bank and a forecast for unexpected rate changes.

The assumption of equal unexpected rate changes for all assets and liabilities is clearly unrealistic. Hence, a second analysis builds on the more realistic assumption that rate changes, while perfectly correlated, have different magnitudes across assets and liabilities. Thus, the change in one particular rate can be used as a benchmark against which changes in other asset and liability rates will be related.

Under this assumption the calculation of duration gap changes slightly.[13] The benchmark rate chosen in this study is the 90-day treasury bill rate. Proportionality "constants" were estimated using historical series of monthly bank rates for the different assets and liabilities by multiple linear regression using the ordinary least squares estimator.

The second use of duration gap is in the selection of the appropriate adjustment in rate sensitive assets and/or liabilities to remove net interest rate risk. If $DG_{nii} < 0$, it is clear from (3) that the bank will realize profits(loses) if the benchmark rate unexpectedly decreases(increases).

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[13] See Toevs, 1983 (n.4,above).

Thus, to achieve NII immunization the bank will have to add an amount \$a in market value of net rate sensitive assets with the duration D_a, such that:

$$\$a = \left|DG_{nii}\right| / (1-D_a) \qquad (4)$$

where $\left|DG_{nii}\right|$ is the absolute value of duration gap.

If $DG_{nii}>0$ then, to achieve NII immunization the bank will have to add \$a in market value of net sensitive liabilities.

This use of duration gap is of practical importance to the asset/liability manager because it provides a method for achieving NII immunization while taking into account balance sheet constraints and customer demands.

A summary of the information made available by the case study bank for the realization of this study is presented in Tables 1 and 2.

At this point let's summarize briefly. Three different duration gap analyses are performed in this study. The first assumes that unexpected interest rate changes are equal across assets and liabilities. The second analysis assumes that unexpected changes, while perfectly correlated, have different magnitudes across assets and liabilities. In this case, "historical" interest rate proportionality constants are used. The third analysis is based on the same assumption as the previous one but uses the ex-post May 1985 proportionality constants. Finally, the results of the third analysis are used to calculate the adjustment that the bank should make in order to change its exposure position.

III. Results and Discussion

The information needed to calculate the duration gap measure under the assumption of equal interest rate changes across assets and liabilities is presented in Tables 3 and 4.

The duration gap measure indicates that if rates unexpectedly increase by one percentage point at the beginning of the planning period and they remain at that level for twelve more months, then, annual[14] interest rate margin will be reduced by \$205,771=(0.01x(-20,577,152)). Conversely, if rates unexpectedly decrease by one percentage point, then, interest rate margin will increase by the same amount.

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[14] The annual period considered in this study was May 1, 1985 to April 30, 1986.

Table 1. Information and relative importance of each asset account for the case study bank as of April 30' 1985.

Account	Percentage of Total Assets	Information
A. Securities	36.30	
1. U.S. Treasury Notes & Bonds	10.30	Coupon rate, Par value Acquisition date, Maturity date, Cost.
2. Government Agencies Notes & Bonds	6.00	"
3. State & Municipal Notes & Bonds	20.00	"
B. Commercial Loans	17.20	
1. Fixed Rate Demand Notes		Rate, Principal Maturity Month
2. Variable Rate Demand Notes		"
3. Time Notes Maturing at Month 1,..,12.		Rate, Principal, Maturity Month
C. Mortgages	15.00	
1. Variable Rate		Monthly Payment, Original Principal, Term, Balance, Rate
2. Fixed Rate		Balance, Rate
D. Installment Loans	22.00	
1. New Loans		Balance, Months to Maturity, Rate
2. Old Loans		Payments due in May
E. Federal Funds Sold	4.20	Rate, Principal
F. Cash & Due	5.30	-
Total Assets($)	381,082,578	

Table 2. Information and relative importance of each liability account for the case study bank as of April 30, 1985.

Account	Percentage of Total Liabilities	Information
A. Passbook Savings	16.10	Monthly Balance
B. Certificates of Deposit (CD's)	36.00	CD Type, Days to Maturity, Amount, Rate
C. Individual Retirement Accounts (IRA's)	5.00	Type, Amount, Rate, Days to Maturity
D. Money Markey Deposit Accounts (MMDA's)	24.40	Monthly Balance, Rate
E. Negotiable Orders of Withdrawal (NOW's)	1.50	Monthly Balance, Regulated Rate
F. Negotiable Orders of Withdrawal Held by Municipalities	1.00	Monthly Balance, Regulated Rate
G. Demand Deposit Accounts	16.00	Monthly Balance
Total Liabilities ($)	341,081,105	

Table 3. Market Value and Duration for Liabilities

Liabilities	Market Value of cash flows (1)	Duration (months) (2)	(1)x(2)
MMDAs	78,961,271	0.2333	18,421,664
CDs	90,836,701	4.0755	370,204,977
IRAs	10,297,098	6.4004	65,905,444
TOTAL	180,095,070	2.5238	454,532,185

Table 4. Market Value and Duration for Assets

Assets	Market Value of cash flows (1)	Duration (months) (2)	(1)x(2)
Investments			
1.U.S.Treasuries	21,064,800	5.5325	116,540,261
2.Agencies	12,809,446	4.7885	61,336,495
3.State & Munis	33,324,914	4.8387	161,249,262
Commercial Loans			
1.Loans	53,595,845	1.2628	67,682,248
Mortgage Loans			
1.Variable Rate	3,062,086	6.3764	19,525,084
2.Fixed Rate	9,886,115	6.3945	63,216,764
Installment Loans			
1.Old Loans	16,517,339	6.4608	106,715,224
2.New Loans	10,920,082	6.3815	69,685,993
Fed Funds Sold			
1.Funds Sold	16,000,000	0.0333	533,333
TOTAL	177,180,627	3.7616	666,484,685
Duration Gap = -20,577,152			

Table 5. Interest rate proportionality constints
Benchmark rate: monthly 90-day T-Bill.

Account	Proportionality Constant	Standard Error
U.S.Treasury and Agency notes	0.4202	0.0617
State and Municipal Notes and Bonds	0.0989	0.0234
Commercial Loans	0.2991	0.0379
Mortgage Loans	0.1392	0.0320
Installment Loans	0.1978	0.0456
Federal Funds	1.0656	0.1380
MMDAs	0.1622	0.0416
CDs	0.6638	0.1007
IRAs	0.2058	0.0482

Since this analysis is based on the assumption that unexpected rate changes are of the same magnitude for both assets and liabilities, exposure arises only from two sources: the difference in the market values of assets and liabilities repriced during the year, and the difference in the average time to repricing of each of them. The market value of liabilities that are repriced during the year is only 1.6% larger than the market value of assets. On the other hand, the "average time to repricing" (duration) of liabilities is 33% shorter than for assets. Hence, the results of the analysis show that in this particular case interest rate exposure occurs when a slightly larger amount of liabilities is repriced faster than assets. Quantitatively, ninety percent of interest rate exposure as measured by duration gap is explained by the different times to repricing of assets and liabilities.

However, as mentioned before, the assumption of equal unexpected rate changes across assets and liabilities is unrealistic and therefore, these results do not represent the real world accurately.

Table 5 presents the results of the proportionality constant estimation and Tables 6 and 7 the needed information to calculate duration gap with interest rate for any one asset or liability change as a constant proportion of the benchmark rate.

This measure of duration gap is a more accurate estimate of interest rate exposure than the previous one. The inclusion of the more realistic assumption on how unexpected rate changes occur across assets and liabilities reduces duration gap substantially as compared to the first analysis. In this analysis exposure arises from three sources:the difference in market values repriced during the year, the difference in the average time to repricing, and the difference in magnitude by which interest rates for an account change with respect to the others. The term (1-t)p combines the influence of these last two factors. The term (1-t)[15] represents the time period from repricing to the end of the year. If rates change, an asset will pay to the bank the repricing rate for (1-t) time. Analogously, a liability will have to pay the bank customer the repricing rate for (1-t).

The proportionality factor p measures the magnitude of a particular rate change relative to the benchmark. Therefore, the magnitude of the term (1-t)p is an indication of how fast and by how much an asset or liability is repriced.

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[15] Where t is expressed as a fraction of the year.

Table 6. Market Value and $(1-t_j)p_j$* factors for Assets

Assets	Market Value of cash flows (1)	$(1-t_j)p_j$ (2)	(1)x(2)
Investments			
1.U.S.Treasuries	21,064,800	0.22644	4,770,003
2.Agencies	12,809,446	0.25250	3,234,349
3.State & Munis	33,324,914	0.05900	1,966,161
Commercial Loans			
1.Loans	53,595,845	0.26761	14,343,007
Mortgage Loans			
1.Variable Rate	3,062,086	0.06521	199,683
2.Fixed Rate	9,886,115	0.06500	642,612
Installment Loans			
1.Old Loans	16,517,339	0.09130	1,507,954
2.New Loans	10,920,082	0.09260	1,011,224
Fed Funds Sold			
1.Funds Sold	16,000,000	1.06256	17,000,969
TOTAL	177,180,627	0.25215	44,675,962

* t_j is the period of time as a proportion of the year until the jth asset or asset account is repriced, and p_j is the proportionality constant for the rate of the jth asset or asset account.

Table 7. Market Value and $(1-t_k)p_k$ factors for Liabilities.

Liabilities	Market Value of cash flows (1)	$(1-t_k)p_k$ (2)	(1)x(2)
MMDAs	78,961,271	0.15905	12,558,720
CDs	90,836,701	0.43837	39,819,671
IRAs	10,297,098	0.09604	988,908
TOTAL	180,095,070	0.29633	53,367,299
Duration Gap = 44,675,972 - 52,367,299= -8,691,337			

The relative responsiveness of each account's interest rate to rate movements in national markets is thus a very important factor in generating interest rate exposure at the bank level.

In this study, the estimation of proportionality constants assumes that interest rates at the bank level adjust symmetrically to interest rate movements in national markets. Thus, proportionality constants must be considered only as the "average" historical relationship between bank monthly rates and monthly 90-day T-Bill rates. The actual exposure faced by the bank on April 30 is a function of the actual relationship between T-Bill rate changes and asset and liability rate changes occurring immediately after April 30. It is likely that this relationship will be different from the historical one. Table 8 shows the estimated historical proportionality constants together with the actual proportions calculated based on monthly rate changes during the month of May 1985. The third duration gap analysis uses these last constants. Tables 9 and 10 show the data needed to calculate duration gap.

Surprisingly, duration gap is not only larger in absolute value but it has changed in sign. With a positive duration gap, annual net interest margin will be reduced when interest rates move down. The 90-day T-Bill rate decreased by 47 basis points in May. Thus, this measure of duration gap indicates that annual interest rate margin should have declined by (44,455,210 x -0.0047)=$208,939 in May. On the other hand, duration gap calculated using historical constants indicates that annual interest rate margin would have increased by (-8,691,337 x-0.0047)=$40,849. The annualized interest rate margin for May actually declined by $1,068,000 at the case bank.

In comparing the predicted change in interest rate margins with the actual one, one must keep in mind that duration gap forecasts margin changes that are due only to interest rate changes. Margin changes related to portfolio changes are not considered by duration gap.

In this study there is evidence that the discrepancy between the estimated and the actual margin changes is due to a portfolio change involving fed funds sold. After correction for the effect of the change in portfolio, duration gap calculated using the actual ex-post May constants yields a very accurate estimate of the actual change in interest rate margins in May. Exposure so calculated represents only 4.5% of the realized after-tax net income in 1984.

So far, duration gap has been used in this study as a descriptive measure of exposure. It can, however, also be used in the determination of the adjustment that the bank should make in order to change its exposure position.

Table 8. Historical and May 1985 rate proportionality constants.

Account	Historical	May
U.S.Treasury and Agency notes	0.4202	1.4170
State and Municipal Notes and Bonds	0.0989	0.8511
Commercial Loans	0.2991	1.0638
Mortgage Loans	0.1392	0.0000
Installment Loans	0.1978	1.0638
Federal Funds	1.0656	0.6000
MMDAs	0.1622	0.5319
CDs	0.6638	0.5319
IRAs	0.2058	0.1064

Table 9. Market Value and $(1-t_j)p_j$ factors for Assets when May proportionality constants are used.

Assets	Market Value of cash flows (1)	$(1-t_j)p_j$ (2)	(1)x(2)
Investments			
1.U.S.Treasuries	21,064,800	0.7637	16,087,186
2.Agencies	12,809,446	0.8516	10,908,524
3.State & Munis	33,324,914	0.5079	16,925,724
Commercial Loans			
1.Loans	53,595,845	0.9519	51,017,884
Mortgage Loans			
1.Variable Rate	3,062,086	0.0000	0
2.Fixed Rate	9,886,115	.0.0000	0
Installment Loans			
1.Old Loans	16,517,339	0.4911	8,111,665
2.New Loans	10,920,082	0.4981	5,439,293
Fed Funds Sold			
1.Funds Sold	16,000,000	0.5983	9,572,800
TOTAL	177,180,627	0.6663	118,063,078

Table 10. Market Value and $(1-t_k)p_k$ factors for Liabilities when May proportionality constants are used.

Liabilities	Market Value of cash flows (1)	$(1-t_k)p_k$ (2)	(1)x(2)
MMDAs	78,961,271	0.5216	41,186,199
CDs	90,836,701	0.3513	31,910,933
IRAs	10,297,098	0.0496	510,736
TOTAL	180,095,070	0.4087	73,607,868

Duration Gap = 118,063,078 - 73,607,868 = 44,455,210

Interest rate exposure can be eliminated by reducing duration gap to zero. If duration gap is positive, an \$x amount of net market value of liabilities should be sold such that:

$$\$x = DG_{NII}/(1-D_l)p_l$$

where D_l is the duration of the liabilities as a proportion of the year and p_l is the proportionality constant of the liabilities with respect to the benchmark rate.

The net market value of liabilities needed to reduce duration gap to zero is therefore directly proportional to the duration of the liabilities and inversely proportional to their rate responsiveness as measured by p_l. In other words, the longer the duration of the liabilities the larger will be the market value needed to reduce duration gap to zero provided rate responsiveness remains constant. Conversely, the smaller the rate responsiveness of the liabilities, the larger will be the market value needed to reduce duration gap to zero provided duration remains constant.

Assume for example that the case study bank wants to immunize interest rate margins from changes in interest rates and that it has chosen to sell three month CDs to do so. Assume also that rate responsiveness for CDs as measured by p_l is equal to one. The market value of CDs that the bank will need to sell in order to reduce duration gap to zero will be:

$$\begin{aligned} MVCDs &= \$44,455,210/(1-0.25)^{16} \\ &= \$59,273,613 \end{aligned}$$

This result deserves some comment. We have already seen that the case bank does not face a substantial amount of exposure. However, reducing this small exposure to zero would require that the bank assume a cash position that represents 15% of its total assets. The \$59,273,613 could finance a new asset with cash flows beyond a year. Notice however, that as one tries to hedge net interest margins in the cash market one may push some asset and liability choices outside the current gapping period, potentially exacerbating problems associated with hedging net interest margins in future years. Furthermore, for the case study bank it is certainly not possible to sell extra liabilities that represent 15% of its current total assets. Thus, the conclusion is obvious: reducing even a small rate exposure in the cash market may involve taking positions that the bank is not able to take.

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[16] Duration of the three month CDs is 3 months which as a proportion of the year is 0.25.

The use of financial futures contracts would avoid the problems mentioned above. On the one hand, a net liability(asset) position can be achieved by simply taking a long(short) position in futures. On the other hand, taking a substantial position in futures would be rather inexpensive as compared to taking the same position in the cash markets. This is the reason why financial futures are one of the few alternatives that banks such as the study bank have in order to manage their interest rate exposure.

IV. Summary

Duration gap analysis is applied to a case study bank in order to measure interest rate exposure on April 30, 1985. The analysis is performed under two assumptions on how the whole constellation of interest rates for assets and liabilities unexpectedly changes. Duration gap correctly predicted the direction and magnitude of the change in net interest income for May, 1985. Duration gap analysis also shows that reducing even small amounts of interest rate exposure would require taking large cash positions, thus suggesting the use of financial futures as one of the few alternatives that community banks can use to adequately manage interest rate exposure.

This study shows how interest rate exposure is strongly influenced by the different rates at which financial instruments adjust in local markets in response to interest rate movements in national markets. Results suggest that two identical banks (i.e., bank balance sheets) may face very different exposure if they operate in markets where interest rates adjust differently to rate movements in national markets. That is to say, each local market may be somewhat unique. On the other hand, two different banks in the same market area, because of different balance sheets and mixes of assets and liabilities, likely, face different interest rate exposure as well.

Another implication of the study is that the "proportionality constants" between national rates and local market rates are very unstable over time. Hence, the ex-ante expected exposure may be quite different than the actual exposure that results. Taking a position in financial futures based on wrong proportionality constants (historical or estimated relationship may be inadequate) could increase exposure rather decrease it. An intuitive feel for this risk may well be an important reason why rural banks have made little use of financial futures.