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by
Jongmoo Jay Choi
Elyas Elyasiani

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Derivative Exposure and the Interest Rate and Exchange Rate Risks of U.S. Banks [1]

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Abstract: This paper estimates the interest rate and exchange rate risk betas of fifty-nine large U. S. commercial banks for the period of 1975-1992, as well as the bank-specific determinants of these betas. The estimation procedure uses a modified seemingly unrelated simultaneous method that recognizes cross-equation dependencies and adjusts for serial correlation and heteroskedasticity. Overall, the exchange rate risk betas are more significant than the interest rate risk betas. More importantly, we find a link between the scale of a bank's interest rate and currency derivative contracts and the bank's interest rate and exchange rate risks. Particularly noteworthy is the influence of currency derivatives on exchange rate betas.

Keywords: Off-balance sheet, Bank risk Derivatives, Interest rate risk, Exchange risk exposure

JEL classification: G2, Gl, F3

Jongmoo Jay Choi and Elyas Elyasiani are at Temple University, Professor of Finance and International Business, School of Business and Management, Philadelphia, PA 19122.

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1. Introduction

Large trading losses reported from derivative transactions by banks (and their corporate clients) has heightened public interest concerning the role of banking institutions in derivative transactions. The debate centers around two issues. The first issue is whether bank clients are adequately informed (and protected) about the nature of the risk involved with these transactions. The second issue is how derivative transactions affect the level of a bank's overall risk exposure -- with derivatives constituting a potential source of increased solvency exposure.[1]

From the standpoint of a bank's management (and accountants), derivatives are regarded as off-balance sheet items despite their importance as a source of profit and risk.[2] Derivative contracts, however, are different from traditional off-balance sheet activities such as letters of credits and loan commitments. One difference is the payoffs from these contracts are dependent on an underlying primary market asset. That is, a derivative contract is an innovated product whose value is derived from a primary product. Hence, the characteristic of the primary market

[1]Institutions reported to have big losses from derivative transactions recently include Gibson Greetings, Procter and Gamble, Bankers Trust, Kidder Peabody, Baring Securities (U.K.), Daiwa (Japan), Metallgesellschaft AG (Germany) and Orange County (California), For responses from policymakers to better monitor and regulate derivative transactions, see *Wall Street Journal*, "SEC is seeking data on firm's derivative risk," (5/24/94); "New capital proposals will push banks to better reflect risks of derivatives," (9/2/94); and "New guidelines to toughen monitoring of derivatives transactions by banks, " (10/24/94). The *Fortune* magazine also has an article, "Untangling the derivative mess" (3/20/95).

[2]Recognizing this feature of contingent contracts, Diamond (1984) argues that a bank's participation in off-balance sheet activities is a means of diversifying its asset portfolios. Kane and Unal (1990) similarly characterize the off-balance sheet activities as a "hidden capital" of the bank.

product -- outside the bank -- directly affects the value of derivatives held by the bank. Traditional off-balance sheet products in contrast, do not derive from an external primary product in the market, but rather are contingent on the bank's willingness to grant loans or credits. The two products also differ in terms of the interest rate and exchange rate exposures they entail. As evidenced by their popularity as a risk management and trading tool, derivatives directly affect a bank's interest rate and exchange risk profile. Loan commitments and letters of credit, on the other hand, are more directly related to a bank's credit risk exposure rather than interest rate and exchange rate risk exposures as such.

This paper examines how derivative transactions have affected the interest rate and exchange rate risk exposures of banking firms. An emerging literature on off-balance sheet banking has investigated the effect of traditional off-balance activities on bank operations and risk, without focusing on derivatives and their impact on interest rate and exchange rate risks specifically.[3] While a few authors, such as Choi, Elyasiani and Kopecky (1992) and Grammatikos, Saunders and Swary (1986), have examined the sensitivity of bank returns and profits to interest rate and exchange rate risks through traditional on-balance sheet bank operations, we are unaware of any study that examines the ***joint*** effect on a bank's interest rate and exchange rate risk exposures due to off-balance sheet *derivative contracts.*[4] This paper uses monthly data, from

[3] These studies investigate the effect of traditional off-balance sheet activities on bank risk and profits in general, and do *not* focus on the effect of derivatives on systematic exchange rate and interest rate risks of banks. See, for example, James (1987), Boot and Thakor (1991), Brewer and Koppenhaver (1992), Hassan, Karel and Peterson (1994), and Khambata (1989).

[4] Gorton and Rosen (1995) recently examined the interest rate sensitivity of banks regarding their use of interest rate swaps. However, they do not consider other interest rate derivative products such as options or futures and forwards nor currency derivative contracts.

January 1975 to December 1992, for fifty-nine large U. S. banks to estimate the effect of off-balance sheet derivative exposures, as well as on-balance sheet exposures, on interest rate and exchange rate risks -- while recognizing the jointly determined nature of these risks. The results of this study provide the first formal estimates of the joint effect of derivative exposures on the systematic interest rate and exchange rate risks of U. S. banks.

The rest of the paper proceeds as follows. Section 2 outlines the theoretical framework. Section 3 describes estimation methods. Empirical results are discussed in Section 4. Section 5 concludes with a summary.

2. Theoretical Framework

The basic model used in this paper is a three-factor model:

$$R_{it} = \alpha_i + \beta_{im}R_{mt} + \beta_{ir}r_t + \beta_{ie}e_t + \mu_{it} \qquad (1)$$

where R_{it} is an excess rate of return of stock i over the risk-free rate q at time t, R_{mt} is an excess rate of return on market portfolio over the risk-free rate, r_t is the interest rate risk factor measured by the percentage rate of changes in risk-free rate, i.e., $(q_t-q_{t-1})/q_{t-l}$ when q is three-month U.S. Treasury bill rate, and e_t is the exchange rate risk factor measured by the percentage rate of change in currency exchange rate, i.e., $(f_t-f_{t-1})/f_{t-l}$ when f is the value of the U. S. dollar against a basket of foreign currencies. Although we take the multifactor model as given, it is still necessary to provide a concrete meaning to risk betas.[5]

[5] There is a well-grounded support for the inclusion of interest rate and exchange rate risk factors in stock return equations in the literature. For interest rate risk, see, for instance, Stone (1974), Flannery and James (1984), and Sweeney and Warga (1986). For exchange rate risk, see Solnik (1974), Ikeda (1986), Jorion (1991), Choi and

Consider a U.S. bank that has a net basic balance-sheet exposure of B_i and a net derivative off-balance sheet exposure of D_i, with respect to both interest rate and exchange rate risks.[6] The return on stocks, R_i, can be restated as:

$$R_{it} = a_i B_{it} + b_i D_{it} + \varepsilon_{it} \quad (2)$$

where a_i and b_i are arbitrary parameters, and ε_{it} is a component related to other risks as well as measurement errors. Note that equation (2) is in vector form, summarizing the sensitivity of stock returns with respect to both basic balance sheet and derivative off-balance sheet exposures to interest rate and exchange rate risk measures.

In equation (l), the standard definition of market risk beta is

$$\beta_{im} = \text{cov}(R_i, R_m)/\text{var}(R_m). \quad (3)$$

By applying similar definitions for interest rate and exchange rate risk betas and substituting (2) for R_i, we obtain:

$$\beta_{ir} = \text{cov}(R_i, r)/\text{var}(r) = [a_i \text{cov}(B_i, r) + b_i \text{cov}(D_i, r)] /\text{var}(r) \quad (4)$$

and

$$\beta_{ie} = \text{cov}(R_i, e)/\text{var}(e) = [a_i \text{cov}(B_i, e) + b_i \text{cov}(D_i, e)] /\text{var}(e). \quad (5)$$

Prasad (1995), and Dumas and Solnik (1995). For inclusion of both factors, see Grammatikos, Saunders and Swary (1986), Choi, Elyasiani and Kopecky (1992), Bartnov and Bodnar (1994), and Prasad and Rajan (1995).

[6]We leave the discussion of the actual measurement of these exposure to the empirical section. For the moment, it is sufficient to assume that such exposures can be appropriately measured by current off-balance sheet accounting methods.

It is useful to examine the nature of these covariances in more detail. To this end, suppose the bank has a nominal on-balance sheet net asset position of A_i at home and A_i^* abroad at the beginning of the period. The bank's net asset at the end of the period in dollar terms is

$$B_i = A_i(1+q) + A_i^* g(1+q^*), \qquad (6)$$

where q and q* are interest rate levels for domestic and foreign-currency denominated default risk-free assets respectively, g = l/f is the end-of-the period domestic-currency value of a unit of foreign currency. The interest rate levels, q and q*, at time t are certain (known and default risk-free) but their dynamic rates of change over time, r and r*, are stochastic. The exchange rate, g, as well as its rate of change, x, is stochastic.

Note the identity,

$$q^* = q - x + \theta \qquad (7)$$

where θ is a deviation from uncovered interest rate parity and is assumed to have a distribution of $N(0, \sigma)$. Substitute (7) in (6) and take the expected value. For a given number of shares, a change in the market value of a bank's net asset equals expected rate of return on its stocks. Hence, we can express the expected stock return as:

$$E(R_i) = A_i E(r) + A_i^* E(xr) - A_i^* E(x^2) + \theta A_i^* E(x) \qquad (8)$$

making use of $r = (q_t - q_{t-1})/q_{t-1}$ and $x = (g_t - g_{t-1})/g_{t-1}$. Equation (8) indicates that, for given A_i and A_i^*, the expected return on bank stocks is influenced by four factors: (a) the expected domestic interest rate changes, (b) a term indicating the interaction between expected domestic interest rate changes and expected exchange rate changes, (c) the expected exchange rate volatility, and (d) the deviation from uncovered interest rate parity. This indicates that the exposure coefficients in the bank stock return equation reflect the first and second order influences of interest rate and exchange rate state variables jointly.[7]

Derivatives are used by banks (for their own account or for clients) as an instrument of hedging as well as trading (or speculation). When a derivative is used for hedging purpose, its use will likely increase with the amount of the basic on-balance sheet exposure to be hedged. However, no such relation is expected when a derivative is used for trading or speculation. In addition, a bank's use of derivatives depends on learning and adaptation. When a bank has introduced and adapted an innovated product in its risk management practice, the use of that product is likely to increase up to a point as the bank tries to exploit its capability in all risk reducing (hedging) and return-increasing (speculation or trading) banking functions. Thus, for a major commercial bank that uses derivatives for hedging and/or trading, we would expect $cov(B_i,D_i) \geq 0$ in general. Similar to the case of basic balance sheet exposures above, derivative-related covariances can also be stated in terms of underlying state variables. A formal specification of these covariances, however, is difficult because of the complex payoff structure of various contingent claims.

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[7]If necessary, it is possible to derive expressions for interest rate and exchange rate betas using (8) rather than (2). The resulting beta equations would be the same as (4) and (5), except that $cov(B_i,r)$ and $cov(B_i,e)$ in those equations are specified in terms of variance-covariances of underlying state variables:

$$cov(B_i,r) = A_i\, var(r) + A_i^*(r^2/x)\, var(x) + A_i^*(\theta - x)\, cov(x,r)$$

and

$$cov(B_i,e) = A_i\, cov(r,x) + A_i^*(x^2/r)\, var(r) + A_i^*(\theta - x)\, var(x).$$

Without further specifications, there are no changes in derivative-related covariances, $cov(D_i,r)$ and $cov(D_i,e)$.

The purpose of this paper is to investigate the linkage between a bank's systematic risk and its use of off-balance derivative transactions, and equations (4) and (5) provide that linkage. The two equations indicate that the interest rate and exchange rate risk betas are a function of both the firm's basic balance sheet exposure and derivative off-balance sheet exposures, while the subsequent discussion addresses the sources of these exposures. Moreover, they also reveal that the interest rate and exchange rate betas are interdependent, which suggests that some sort of simultaneous framework is appropriate to estimate bank-specific determinants of betas.

3. Estimation Methods and Data

We utilize monthly data from January 1975 to December 1992 for 59 large U.S. bank holding companies. The estimation proceeds in two steps: first, we estimate the beta coefficients for each bank using time series data and equation (l), and second, we estimate the bank-specific determinants of interest rate and exchange rate risk betas based on cross sectional bank-specific exposure data and equations (4)-(5). This two-step estimation method is consistent with the method used by Fama and French (1992).[8] However, to adjust for possible bias due to cross-equation dependencies, the return equations in each group are estimated as a simultaneous equation system, using a modified Seemingly Unrelated Technique (SUR). The modified SUR technique, due to Chamberlain (1982) and Macurdy (1981a, 198lb), is a variation of the standard SUR method and produces asymptotically efficient estimates without imposing either conditional homoskedasticity or serial independence restrictions on disturbance terms.

[8] It should be pointed out that, unlike Fama and MacBeth (1974), we do not estimate risk premia in the second step; instead we estimate bank-specific determinants of beta coefficients.

The first step estimates risk betas for each bank holding company in the sample. Fifty nine bank holding companies with complete return data for the entire sample period of January 1975 to December 1992 on the CRSP Price-Dividends-Earnings tapes are selected out of the ranking of largest U.S. bank holding companies in asset size as of the end of 1992 as reported by *Fortune*, May 31, 1993. These banks represent all U.S. commercial bank holding companies with a total asset size of at least $9.5 billion as of the end of 1992. This selection method is subject to survivorship bias, but ensures the consistency of data throughout the period. The survivorship bias indicates a possibility that the risk coefficients for a group are underestimated because of the elimination of weak (and high risk) banks from the sample. Monthly data for the sample period produces 215 observations for each bank holding company (losing one observation to calculate returns). To retain homogeneity, the sample is sorted by total assets and divided into three groups, each including 20, 20 and 19 banks respectively. To investigate the robustness of the results, estimation is also carried out for a sub-period of January 1981- December 1992 (144 observations) in addition to the entire sample period of January 1975- December 1992. January 1981 is chosen to examine whether the monetary deregulation that became effective in January 1981 has caused a structural shift.

One issue in estimating a multi-factor index model of the type proposed by eq. (1) is whether actual or orthogonalized variables should be employed as independent variables. While risk factors can be easily orthogonalized by running a side regression, Giliberto (1985) has shown that such orthogonalization may also introduce bias. Accordingly, in this study we use actual changes for interest rate risk and exchange rate risk variables. Since we use changes, not levels, the correlations among independent variables are actually quite low (see Table 1 for the description and correlation of these variables). If the market is informationally efficient, *changes* in interest rates and exchange rates are likely to be largely unexpected.[9]

In the second step, the interest rate and exchange rate betas generated in the first stage are regressed against bank-specific on and off-balance sheet exposure variables. Bank-specific data are extracted from the Federal Reserve's *Call Report* tapes published by the National Technical Information System. Banks with missing balance sheet variables are dropped from estimation in the second step. This reduces the sample size in the second step to 50 banks. The cross sectional estimation is based on bank-specific data for 1992. In this step, too, interest rate and exchange rate beta equations are estimated as a system using the modified SUR to improve efficiency of the estimates. While we would ideally need a more disaggregated data than those provided in Table 1 (e.g., the breakdown of a bank's positions and derivatives by currency and by detailed category), such data are not available from the *Call Report* tapes at this time.

Cross-sectional estimation in the second step acknowledges the simultaneity between β_r and β_e discussed in Section 2. Interest rate and exchange rate betas are thus estimated as a simultaneous function of bank-specific basic balance sheet and derivative off-balance sheet exposures. The simultaneous estimation accounts for biases arising from interactions between interest rates and exchange rates, as well as the dependence between bank-specific variables. The estimable equation system can be specified as

[9] We also ran some preliminary estimation of orthogonalized variables, but the results are basically similar.

$$\begin{bmatrix} \beta_{ir} \\ \beta_{ie} \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} + \begin{bmatrix} b_2 \\ b_2 \end{bmatrix} \begin{bmatrix} B_{ir} & B_{ie} \end{bmatrix} + \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} \begin{bmatrix} D_{ir} & D_{ie} \end{bmatrix}. \tag{9}$$

Note that, as in the estimation of betas in the first step, the estimation of (9) is simultaneous because the balance sheet and derivative exposure variables affect both the interest rate and exchange rate betas. The modified SUR procedure enables us to incorporate the interaction of the two exposure equations as a system. [10]

4. Empirical Results

(a) Estimation of Interest Rate and Exchange Rate Risk Exposure Coefficients

Table 2 reports the result of SUR of a multifactor index model for each of the 59 large U.S. bank holding companies for the entire sample period of January 1975 to December 1992. Banks are classified into three groups based on asset size. Estimation was also performed for a sub-period of 1981-92 to see whether the similar patterns hold intertemporally.

Estimation results for the entire sample period of 1975-1992 indicate that the market risk beta is statistically significant (at five percent level on two-tail test) for all 59 individual banks and for all bank groups. The interest rate risk beta, however, is significant for only 23 banks out of 59, although significant for all three bank groups at ten percent level. The exchange risk beta is significant for a majority of banks (49 out of 59) and for all bank groups except for the third

[10] Note that we could further nest the estimating equation by substituting, in (4) and (5), equations in footnote 7 and similar equations concerning derivatives. Such a step would show β_{ir} and β_{ie} as a function of variance-covariances of state variables r and e. We do not pursue this here because we wish to estimate betas as a function of bank-specific exposures rather than underlying state variables.

group. While more banks have significant exchange rate risk betas than interest rate risk betas, the interest rate risk betas that are significant are all negative, while the signs of the significant exchange rate risk betas are divided: for a total of 49 significant exchange rate coefficients, 14 are positive while 35 are negative. The result on exchange rate coefficient reflects different exchange exposures (positive or negative net basic exposed asset and cash flow positions as well as exposed derivative contracts), as well as different sensitivity to a given exposure, of individual banks.[11] The fact that exchange rate coefficients are more significant than interest rate coefficients shows the relative importance of these exposures for individual banks. Such implication, however, may not be transferable to government policymakers who are more interested in the banking system as a whole rather than an individual bank. Unlike the interest rate betas that all have the same sign, the exchange rate betas have different signs for different banks. Therefore the potential for risk reduction at the system level is greater for exchange risk than interest rate risk.

Table 2 also shows a differing pattern of betas for different groups of banks. The market risk beta, for the entire sample period, is highest for the first group of largest 20 banks, followed by the second and the third group after that. This pattern of correspondence between bank size and market risk beta is interesting and at odds with the popular notion that a smaller firm has a higher risk. The magnitude of the interest rate risk betas by group indicates a mild inverted U shape, with the highest absolute values shown in the second group rather than in the highest or

[11] Hodrick (1982) and Choi (1984, 1986) show theoretically how exchange rate changes can influence firm values or stock returns. Bartov and Bodnar (1994) report empirical results concerning the effect of exchange rate changes on corporate earnings. Choi and Prasad (1995) examine the exchange risk exposures of U.S. multinationals using different exchange rate data and by considering firms with positive and negative exchange rate coefficients.

lowest bank group. Since the largest banks are likely to be dealers rather than end users, they may use dealer activities to limit risk. An alternative explanation is that they have better risk management. However, there is no appreciable relation between bank group size and exchange risk, in terms of either the magnitude of coefficients or the number of significant coefficients.

To examine the intertemporal stability of beta coefficients, the same return equation was estimated for shorter time periods. Compared to the results from the entire time period, the level of significance from the sub-period estimation of 1981-92 is about the same for exchange rate risk (and market) betas, but is generally lower for interest rate betas. The sub-period estimation shows 11 banks with significant β_r coefficients. This compares with 23 banks with significant interest rate risk betas reported for the entire sample period of 1975-92. The different result for the sub-period suggests a possibility that the structure of the model may have changed because of changes in market environments and external shocks.

Table 3 uses dummy variables to examine such possibilities in more detail. External shocks for both interest rates and exchange rates are analyzed. For interest rates, we examine the effect of the change in U.S. monetary policy regime from interest rate targeting to bank reserve targeting in October 1979 (0 for pre-October 1979 and 1 thereafter) and the regulatory change due to the enactment of Depository Institutions Deregulation and Monetary Control Act that became effective in January 1981 (0 for pre-January 1981 and 1 thereafter).[12] Dummies are also introduced for exchange rates given the wide secular swing in exchange rates during the sample

[12] See Johnson (1981) for discussion of monetary and regulatory changes during this period.

period. We examine the switch from a strong dollar to a weak dollar period. The foreign currency value of the U. S. dollar has increased very steeply for the period of January 1981 to March 1985 (prior to the signing of the Plaza Accord), followed by a period of equally steep decline and stagnation (April 1985- December 1992). The exchange rate regime dummies used are 1 (strong dollar period), 2 (weak dollar period), and 0 (the rest of the sample period). The three-way dummies imply that the resulting coefficients should be interpreted qualitatively rather than numerically. Dummies are introduced in both the intercept and the slope of interest rate and exchange rate betas.

Estimation results with dummies are summarized in Table 3 in terms of the number of significant variables. One striking result is that the effects of monetary policy shocks are rather modest. Of the total of 59 banks in the sample, only 15 show significant interest rate effect of the October 1979 monetary policy change dummy (2 in intercepts and 13 in the slope coefficients), and only 4 for the January 1981 monetary deregulation dummy. The signs of the significant dummy coefficients, however, indicate that the 1979 monetary policy change has raised stock returns of these banks while the 1981 deregulation has lowered them. These results show that changes in market environments in 1979 and 1981 have affected banks quite selectively rather than uniformly for all banks. It is possible that banks were subject to market transition shocks for a more extended period of time, say, from 1979 to 1982 [Yourougou (1990)]. However, the weaker result of the January 1981 dummy than the October 1979 dummy discounts such a possibility. Using a data-based methodology, Kane and Unal (1990) report that a switch occurred in bank stocks around March 1977. Their result effectively affords the market an ability to anticipate and internalize, as early as March 1977, the upcoming October 1979 monetary policy change. We are hesitant in giving the market such an advanced foresight and therefore employ dummy variables based on clearly identified external policy shocks.

The result from the exchange rate dummy shows that a total of 21 banks are significantly affected by changes in exchange rate regime: 14 banks show significant changes in intercepts or slope dummy coefficients with respect to the strong dollar dummy, and 7 banks with respect to the weak dollar dummy. The differential response to the strong and weak dollar period is likely to be related to a bank's basic and derivative exposure positions. For example, if a bank has a net positive asset exposure, then a strong dollar will lower the value of the bank's stock in dollar terms, while a weak dollar may raise it. This effect of currency translation, however, can be partially mitigated by an economic effect of exchange rate changes on operational cash flows (e.g., a strong dollar or a weak foreign currency may help increase revenue from foreign operations).[13] In addition, the bank's use of derivatives for hedging, speculation and trading purposes will affect its interest rate and exchange rate risk levels.

Banks that show significant interest rate or exchange rate dummies include a number of large banks in the first group as First Interstate, Bankers Trust, Citicorp., J.P. Morgan, Wachovia, and First Union. However, there are more banks in the second and third groups that show

[13] Hodrick (1982) analyzes the effect of exchange rate changes on the value of a firm through the firm's asset and liability positions. Choi (1986) examines the same through changes in operational cash flows. An alternative reason for the differential result for the two sub-periods is downward price rigidity. If prices are sticky downward (at least more so than upward) in the short run, domestic price inflation brought about by a depreciating domestic currency will not be as large, in magnitude, as price deflation due to an appreciating domestic currency by the same percentage. Then the resulting effects on earnings and stock returns will be different.

sensitivity to policy or regime shocks. For example, 8 banks in the third group are shown to have significant October 1979 interest rate dummy effect compared to only 2 banks in the first group. Similarly, 5 and 3 banks in the third group are sensitive to the strong dollar and weak dollar dummies respectively, compared to 4 and 2 banks for respective exchange rate regimes in the first group. Although these results with respect to bank groups are not overwhelming, they support the notion that bigger banks are generally less susceptible to external policy shocks than smaller banks because of their superior hedging efficiency with respect to derivatives. This is also consistent with the finding of Gunther and Siems (1995) who report a positive relationship between derivative activities and the size of bank capitalization.[14]

(b) Bank-Specific Determinants of Interest Rate and Exchange Rate Risk Betas

Table 4 provides a description of firm-specific balance sheet and derivative exposure variables used in the second-step cross-sectional estimation. The cross-sectional estimation is based on equations (4) and (5) that state the interest rate and exchange rate betas as a function of firm-specific exposure variables. Firm-specific variables are basic and derivative exposure variables with respect to interest rate and exchange rate risks. Basic exposure variables are traditional balance-sheet and income statement variables of individual banks. Derivative exposure variables include commitments of interest rate and currency options, futures and forwards, and swap contracts.

[14]The results reported here are conditional on various assumptions. For example, the relation between stock returns and risk factors is assumed to be linear. The beta coefficients also reflect the bank's use of hedging as well as its innate sensitivity to risk factors. In addition, the estimation may be biased by intertemporal variability of risk factors and lagged responses to market developments.

Correlations among independent variables used in the second-step estimation are presented in Table 5. Correlations among basic exposure variables are generally low (less than 0.40), but correlations among derivative exposure variables are generally high (higher than 0.80). Correlations between derivative contracts of similar kinds (e.g., options versus swaps, or interest rate options versus and currency options) are also high. The use of one form of a derivative contract often appears to be accompanied by the use of another. From a statistical point, this implies that the coefficient of an *individual* derivative variable is potentially subject to multicollinearity. Therefore derivative variables were included selectively. In addition, the interest rate and exchange rate beta equations were estimated as a system to capture the joint influences of these derivative variables. Thus, regardless of any question on an individual coefficient given the complementary nature of these products, a meaningful inference can still be made for the effect of derivative contracts *as a group*.

Parenthetically, it is interesting that all basic and derivative variables are positively (but imperfectly) correlated. This is consistent with a notion that banks use derivatives partially for hedging purposes. However, the correlations are higher for a pair of currency variables than interest rate variables. This indicates that derivatives are more commonly used (for hedging) for currency risk than the interest rate risk.

The results of the second-step cross-sectional estimation regarding the determinants of interest rate and exchange rate risk betas are presented in Table 6. This estimation procedure permits simultaneous interactions between interest rate and exchange risk exposure variables. The result for the interest rate risk beta in the first panel indicates a mixed picture with respect to the significance of a bank's basic financial statement variables. As expected, it is shown that a bank's mortgage exposure is a significant determinant of its interest rate risk beta. However, the amount of a bank's fixed rate loan portfolio (as a percentage of total asset) is not. This may be attributable to the fact that large U.S. banks are hedged against interest rate risk. However, we have seen in Table 5 that the correlations between basic interest rate exposure variables and interest rate derivatives are generally small (ranging from 0.21 to 0.42). Overall this may indicate that the interest rate risk hedging by banks is principally done by fundamental balance sheet management (e.g., securitization of fixed rate assets) rather than the usual off-balance sheet interest rate derivatives.

In contrast to the mixed result of basic balance sheet or income statement variables, it is noteworthy that the derivative exposure variables are generally significant overall. The interest rate options bought or sold are significant for all four models. The bank's commitments to interest rate forwards and futures are also significant for two out of the four models estimated. The interest rate swaps do not appear to have an independently significant effect on the bank's interest rate betas. However, the pattern of interactions among the interest rate derivative contracts seen above suggests a strong likelihood that the interest rate derivative contracts as a group has a significant impact on the bank's interest rate beta.

Bank-specific exposure variables have even stronger effect on exchange rate risk betas in Table 6. Traditional basic exchange exposure variables reported in the bank's balance sheet or income statement -- such as foreign asset ratios, foreign interest and non-interest expense ratios -- are shown to be all significant at least at the ten percent level (two-tail test). That is, a rise in a bank's foreign asset or foreign interest expense reduces a bank's domestic currency exposure coefficient or raises its foreign currency exposure coefficient. (Note that the exchange rate variable, e, is the rate of appreciation of the U.S. dollar against the basket of foreign currency so that a reduction in domestic currency exposure coefficient implies an increase in foreign currency exposure coefficient.) Foreign non-interest expense ratios, however, reduce its foreign currency exposure, indicating a possibility that non-interest expenses serve, operationally, as a means of diversification or hedging against foreign exchange risk.

A striking finding in table 6 is the result on currency derivative contracts. Major currency derivative contracts -- such as currency options bought, currency forwards and futures, and currency swaps -- are shown to have a significant effect at the five percent level. Moreover, they all have a negative coefficient, i.e., an increased exposure to these contracts by the bank leads to a decrease in domestic currency (dollar) risk or an increase in foreign currency risk. As expected, currency options sold, however, have a significant positive coefficient. The significant coefficients of currency derivative contracts compare with significant yet somewhat qualified effects of interest rate derivative variables.

In sum, we have established the connection between derivative activities and a bank's interest rate and exchange rate risks in a framework that permits simultaneity across banks and across risk categories. The influence of currency derivatives, however, is generally more pronounced than that of interest rate derivative contracts. Thus the foreign exchange market appears to be more important than the domestic money market for large U.S. banks as a source of potential systematic risk, and reward, originating from derivative products. However, the lack of more disaggregated data on currency positions and derivative holdings confounds our analysis. In addition, we did not address the issue of why derivatives are used.

5. Summary and Conclusions

This paper has estimated the interest rate risk and exchange rate risk betas of 59 large U.S. commercial banks for the period of January 1975 to December 1992 in a multifactor model framework. The estimation procedure uses a modified seemingly unrelated simultaneous method that adjusts for cross-equation dependencies as well as heteroskedasticity and serial correlation. Using this method, the estimation is carried out in two steps. First, the interest rate risk and exchange rate risk betas are estimated for individual banks, and second, the betas are estimated as a function of bank-specific basic and derivative exposure variables. The equations are estimated as a system in both steps, to capture, respectively, the cross-bank dependencies and the joint influences of interest rate and exchange rate exposure variables.

The result of the first step estimation shows that the exchange rate risk betas are generally more significant than the interest rate risk betas. In addition, there are significant variations in interest rate and exchange rate risk betas across banks and across periods. We interpret this as a result of different exposure positions of banks. Changes in market conditions due to external policy shocks similarly have differential influences on bank risk and stock returns. The result of the second step estimation reveals the importance of traditional financial statement variables and derivative contract variables as firm-specific determinants of interest rate and exchange rate risk betas. It is shown that the use of derivative contracts creates a significant additional potential systematic risk beyond the level that reflects a bank's traditional financial statement exposures. The influence of derivatives is particularly important in the case of exchange rate betas.

Thus we have established a link between derivative activities and a bank's interest rate and exchange risk betas. The present paper provides a formal estimate useful to a popular issue regarding the influence of derivative contracts on bank risk. Although the complementary nature of derivative contracts does not permit us to draw a conclusion on an individual derivative contract, we have shown how derivatives as a group, or with respect to interest rate versus currency derivatives separately, affect a bank's interest rate and exchange rate risk profile. Comparison of the effect of interest rate versus currency derivative contracts indicates that currency derivatives generally have a greater influence. A policy implication is that the behavior of currency and interest rate derivatives needs to be carefully monitored by monetary and regulatory authorities as a potential source of systematic interest rate and exchange rate risks for large banks. Insofar as the derivatives are concerned, however, the currency market is more important as a source of systematic uncertainty (and more attention is needed) than the domestic money market. It is true that exchange rate betas often have different signs across banks and thus leave room for risk reduction for the banking system as a whole while the interest rate betas have the same sign. Still, the systematic exchange risk is significant for the system as well as individual banks, and currency derivatives are important sources of such risk. An interesting issue left for future work is whether and how derivative exposures influence a bank's default risk. In addition, the future work must ascertain the differential effects of more disaggregated bank-specific data and address the issue of why derivatives are used.

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Table 1
Description of Variables in Asset Return Equation

(A) Definitions and Descriptive Statistics

	Definition	mean	SD	min	max
R_m	Excess rate of return on Standard and Poor's 500 index including dividends over the three-month U.S. Treasury bill rate (in percentage)	1.9685	53.740	-300.16	142.69
r	Rate of change in three-month U.S. Treasury bill rate (in decimal)	-0.000818	0.0678	-0.3464	0.2123
e	Rate of change in currency exchange rates (in decimal) The exchange rate is the value of U.S. dollars against a basket of 17 national currencies (Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Ireland, Japan, Netherland, Norway, Spain, Sweden, Switerland, U.K., and U.S.)	0.17368	2.3033	-0.9889	33.480

(B) Correlation Matrix

	R_m	r	e
R_m	1.0000		
r	-0.2198	1.0000	
e	-0.0136	0.0038	1.0000

Sources: CRSP Price-Dividends-Earnings tape
I.M.F., International Financial Statistics, various issues

Table 2
Seemingly Unrelated Robust Estimates of Beta Coefficients

$$R_i = \alpha + \beta_m R_m + \beta_r r + \beta_e e$$

where R_i is excess return on stock i, R_m is excess return on market portfolio, r is interest rate risk factor, and e is exchange rate risk factor. Estimates for each bank group are obtained by pooling all bank data at each point in time.

	1975-92 (n=215)			1981-92 (n=144)	
	β_m	β_r	β_e	β_r	β_e
All 59 banks	0.812**	-69.903**	-0.697**	-14.060	-0.544**
	(20.14)	(-2.096)	(-5.78)	(-0.371)	(-5.16)
(A) Largest 20 banks	0.933**	-86.294*	-1.034**	-14.746	-0.984**
	(17.94)	(-1.867)	(-6.116)	(-0.290)	(-6.65)
Citicorp.	1.226**	63.276	-0.410	241.46*	-0.590
	(12.34)	(0.736)	(-1.043)	(1.835)	(-1.343)
Chemical	1.060**	-38.850	0.130	-25.068	0.130
	(8.37)	(-0.443)	(0.365)	(-0.169)	(0.317)
BankAmerica	1.091**	134.14	-5.799**	236.62	-5.807**
	(7.72)	(1.305)	(-14.52)	(1.511)	(-13.16)
Nationsbank	1.228**	-158.82**	-1.207*	-119.29	-1.313**
	(10.51)	(-2.082)	(-1.830)	(-1.068)	(-2.001)
Morgan (J.P.)	1.001**	22.735	-1.689**	99.104	-1.890**
	(10.57)	(0.270)	(5.802)	(0.961)	(6.384)
Chase Manhattan	1.290**	125,523	-1.229**	197.032	-1.211**
	(11.40)	(1.310)	(-2.768)	(1.385)	(-2.538)
Bankers Trust	1.180**	-26.438	-0.169	-42.559	-0.159
	(10.88)	(-0.306)	(-0.571)	(-0.401)	(-0.532)
Wells Fargo	1.199**	-0.872	-1.841**	159.45	-1.915**
	(11.41)	(-0.010)	(-5.564)	(1.294)	(-5.218)
First Chicago	1.328**	44.777	2.840**	84.751	2.707**
	(10.26)	(0.519)	(5.518)	(0.678)	(4.945)
First Interstate	1.093**	-102.33	-4.349**	-134.74	-4.176**
	(10.74)	(-1.088)	(-17.19)	(-0.928)	(-13.83)
Bank One	0.838**	8.046	-1.456**	96.912	-1.558**
	(9.89)	(0.089)	(-7.567)	(1.011)	(-6.732)
First Union	0.887**	-218.80**	1.244**	-176.48	1.218**
	(10.42)	(-2.531)	(3.289)	(-1.556)	(3.008)
Fleet Financial	0.986**	-186.67**	-3.478**	-181.12	-3.481**
	(9.45)	(-2.489)	(-10.58)	(-1.516)	(-9.810)
PNC Financial	0.901**	-127.25**	-1.352**	-106.05	-1.355**
	(10.85)	(-2.132)	(-5.901)	(-1.136)	(-4.951)
Bank of New York	1.028**	-84.796	-0.533	9.363	-0.619
	(9.01)	(-1.090)	(-1.062)	(0.068)	(-1.168)
Norwest	1.073**	-73.458	1.245**	-78.79	1.246**
	(12.63)	(-1.058)	(3.583)	(-0.934)	(3.260)
Suntrust	0.964**	-194.42**	-2.562**	-186.42*	-2.587**
	(9.22)	(-2.773)	(-6.158)	(-1.746)	(-6.018)
Wachovia	0.731*	-138.71*	-1.448**	-99.935	-1.621**
	(8.39)	(-1.933)	(-6.371)	(-1.024)	(6.959)
Barnett Banks	1.247**	-116.675	1.446**	-153.12	1.500**
	(9.77)	(-1.382)	(2.777)	(-1.424)	(2.809)
Bank of Boston	1.134**	-54.891	-2.735**	-30.045	-2.747**
	(9.43)	(-0.564)	(-9.562)	(-0.212)	(-7.742)
(B) The Second Group	0.924**	-112.75**	-1.145**	-76.354	-1.102**
	(18.09)	(-2.85)	(-7.87)	(-1.571)	(-7.06)
Republic NY	0.849**	-126.06	0.898**	-254.31**	1.143**
	(5.98)	(-0.980)	(2.685)	(-2.282)	(3.301)
First Fid Bancorp.	0.866**	-47.212	-2.591**	53.220	-2.742**
	(9.36)	(-0.629)	(-9.375)	(0.464)	(-8.488)
NBD Bancorp.	0.953**	-106.20	-0.189	-138.79*	-0.227
	(11.60)	(-1.413)	(-1.159)	(-1.937)	(-1.300)

(Table 2 continued)

	1975-92 (n=215)			1981-92 (n=144)	
	β_m	β_r	β_e	β_r	β_e
Mellon Bank	0.914**	-59.188	-0.790*	-53.509	-0.711**
	(9.38)	(-1.003)	(-2.351)	(-0.534)	(-1.969)
National City	0.786**	-188.10**	2.601**	-109.19	2.581**
	(7.98)	(-2.798)	(12.90)	(-1.018)	(10.45)
Continental Bank	1.302**	114.07	1.161*	15.307	1.483*
	(6.26)	(0.966)	(1.647)	(0.078)	(1.894)
Keycorp.	0.846**	-128.92*	-1.741**	-109.14	-1.843**
	(9.96)	(-1.871)	(-6.496)	(-0.765)	(-6.125)
Shawmut National	0.808**	-79.060	-0.730**	-91.178	-0.693**
	(5.90)	(-0.857)	(-2.660)	(-0.660)	(-1.993)
Corestates Financial	0.899**	-105.43*	-0.673**	-49.478	-0.750**
	(9.51)	(-1.929)	(-3.053)	(-0.592)	(-3.044)
U.S. Bancorp.	1.045**	45.830	-1.381**	-35.295	-1.319**
	(11.00)	(0.514)	(-4.401)	(-0.360)	(-4.242)
First Bank System	1.132**	-28.205	-1.280**	-51.648	-1.315**
	(12.03)	(-0.399)	(-5.050)	(-0.418)	(-4.971)
Midlantic	0.930**	-133.72	-1.941**	-289.12*	-1.827**
	(7.00)	(-1.350)	(-5.549)	(-1.657)	(-4.405)
MNC Financial	1.115**	-100.77	1.393**	-183.49	1.389**
	(10.12)	(-1.207)	(4.297)	(-1.351)	(3.682)
Society Corp.	0.885**	-214.71**	0.660**	-108.45	0.616**
	(12.11)	(-3.267)	(2.232)	(-1.497)	(2.064)
State Street Boston	1.268**	-4.221	-3.428**	177.236	-3.675**
	(11.85)	(-0.046)	(-13.33)	(1.392)	(-12.46)
Comerica, Inc.	0.940**	-155.62**	-5.122**	-39.719	-5.188**
	(11.05)	(-2.082)	(-25.895)	(-0.416)	(-22.42)
UJB Financial	0.760**	-135.79*	-1.695**	-136.67	-1.746**
	(6.89)	(1.769)	(-5.541)	(-1.072)	(-4.691)
Northern Trust	0.754**	-118.77**	-0.685	-39.212	-0.893
	(8.97)	(-1.977)	(-1.148)	(-0.421)	(-1.437)
Huntington Bancshares	0.662**	-272.01**	-0.251	-252.31**	-0.239
	(6.89)	(-3.843)	(-0.571)	(-2.307)	(-0.516)
Firstar Corp.	0.903**	-177.09**	-0.697	-262.73**	-0.636
	(9.46)	(-2.701)	(-0.804)	(-2.520)	(-0.748)
(C) The Third Group	0.650**	-100.16**	0.127	-72.734	-0.423**
	(12.73)	(-2.440)	(1.130)	(-1.149)	(-2.50)
Crestar Financial	0.908**	-150.47	-5.275**	-34.772	-5.290**
	(7.74)	(-1.575)	(-24.67)	(-0.245)	(19.91)
Bancorp Hawaii	0.765**	-112.81	-2.321**	-209.00**	-2.336**
	(9.04)	(-1.487)	(-8.345)	(-2.016)	(-7.706)
Signet Banking	1.095**	-126.93	-5.729**	-37.100	-5.882**
	(8.38)	(-1.376)	(-17.09)	(-0.224)	(-15.14)
Valley National	1.134**	-110.55	-2.472**	-124.81	-2.386**
	(9.25)	(-1.096)	(-6.764)	(-0.913)	(-5.620)
Michigan National	0.877**	-286.71**	-1.201**	-241.59*	-1.094**
	(7.39)	(-3.148)	(-3.064)	(-1.712)	(-2.518)
Dominion Bankshares	0.942**	-159.59*	-2.984**	-134.62	-2.984**
	(8.95)	(-1.651)	(-9.705)	(-0.755)	(-8.295)
Baybanks	0.817**	-163.58**	-0.582	-225.27	-0.572
	(7.56)	(-2.111)	(-1.569)	(1.601)	(-1.312)
Amsouth Bankcorp.	0.800**	-53.253	3.019**	-13.594	2.838**
	(5.55)	(-0.529)	(5.073)	(-0.087)	(4.648)
First Empire State	0.543**	-52.428	3.896**	-162.89	3.895**
	(5.59)	(-0.725)	(9.158)	(-1.402)	(9.539)
Banponce corp - New	0.773**	-56.964	0.739**	58.067	0.630**
	(9.39)	(-0.904)	(3.645)	(0.562)	(2.601)
Mercantile Bancorp.	0.791**	-131.57*	-0.851**	-82.285	-0.913**
	(6.72)	(-1.769)	(2.433)	(-0.751)	(-2.489)

(Table 2 continued)

	1975-92 (n=215)			1981-92 (n=144)	
	β_m	β_r	β_e	β_r	β_e
First Tennessee	0.674**	-183.93**	1.881**	-132.66	1.849**
	(7.72)	(-2.701)	(10.35)	(-1.309)	(8.970)
Marshall & Ilsley	0.869**	-146.28*	1.120**	-170.36	1.130**
	(8.02)	(-1.786)	(3.806)	(-1.550)	(3.355)
First Security, Utah	0.473**	-61.437	-0.014	-36.844	-0.081
	(4.65)	(-0.956)	(-0.061)	(-0.369)	(-0.310)
Commerce Bancshares	0.610**	-95.101	-1.064*	-140.58	-1.056*
	(7.74)	(-1.284)	(-1.818)	(-1.443)	(-1.781)
First Alabama	0.574**	-190.09**	-3.839**	-191.73*	-3,886**
	(4.39)	(-3.072)	(-9.097)	(-1.855)	(-9.205)
First Hawaiian	0.810**	-57.212	-1.405**	11.885	-1.506**
	(8.06)	(-0.756)	(-6.141)	(-0.108)	(-5.834)
First Virginia	0.852**	-206.42**	-3.168**	-294.39*	-3.227**
	(9.26)	(-2.404)	(-7.910)	(-1.943)	(-6.931)
Riggs National Corp.	0.518**	16.265	-1.837**	126.12	-1.757**
	(3.22)	(0.163)	(-3.265)	(0.708)	(-2.756)

** Significant at 5% level, * Significant at 10% level (two-tail test)

Table 3
The Effect of Dummy Variables

The numbers in the table are the number of banks that are affected significantly (ten percent level, two-tail test) by the interest rate or exchange rate policy shocks. The interest rate shocks include the October 1979 (the change of monetary policy from interest rate targeting to bank reserve targeting) or the January 1981 (enactment of Depository Institutions Deregulation and Monetary Control Act) dummies. The exchange rate dummies are the strong dollar (1/81 - 3/85), weak dollar (4/85 - 12/92) , and trendless (1/75 - 12/80) periods. All October 1979 dummy coefficients are positive (except one indicated by an asterisk) , while all January 1981 dummy coefficients are negative. All exchange rate dummies are positive. No banks are affected through the intercept and slope dummies simultaneously for a given external shock.

	Interest Rate Effect				Exchange Rate Effect			
	October 1979		January 1981		Strong Dollar		Weak Dollar	
	Intercept	β_r	Intercept	β_r	Intercept	β_e	Intercept	β_e
Largest 20 banks	1	1	1	1	3	1	1	1
Second 20 banks	1*	4	2	0	4	1	1	1
Third 20 banks	0	8	0	0	2	3	0	3
Total	2	13	3	1	9	5	2	5

Following is the list of individual banks that are affected significantly by the interest rate or exchange rate dummies in the intercept or slope coefficients (in each category, banks are separated by a scud-colon depending on whether they show significance in the intercept or slope dummies) .

In the first group:
- Interest rate effect: First Interstate; Bankers Trust (October 1979)
  J.P. Morgan; Citicorp. (January 1981)
- Exchange rate effect: Citicorp. , J.P. Morgan, Wachovia; First Union (strong dollar)
  J.P. Morgan; First Union (weak dollar)

In the second group:
- Interest rate effect: State Street Boston; NED Bankcorp., Shawmut National, Midlantic, Comerica (October 1979)
  State Street Boston, Northern Trust (January 1981)
- Exchange rate effect: First Fid Bankcorp. , CoreStates, State Street Boston, UJB Financial; Comerica Inc. (strong dollar)
  Northern Trust; Comerica (weak dollar)

In the third group:
- Interest rate effect: Crestar, Michigan National, Baybanks, First Empire State, Mercantile, First Tennessee, Marshall & Ilsley, First Alabama (October 1979)
- Exchange rate effect: Signet Banking, First Virginia;
  Crestar, First Hawaiian, Riggs (strong dollar) ;
  Crestar, First Hawaiian, Riggs (weak dollar)

Table 4
Description of Firm-Specific Exposure Variables

Definition		mean	SD	min	max
1. Interest Rate Risk Exposure					
(a) Derivative Exposure (as a ratio of total asset)					
IOPTB	Interest rate options bought	0.2430	0.6867	0.0	4.628
IOPTW	Interest rate options written	0.1867	0.4839	0.0	2.763
IFF	Interest rate futures and forwards	0.6293	1.4358	0.0	6.394
ISWAP	Interest rate swaps	0.8325	2.0091	0.0	12.105
(b) Basic Exposure (as a ratio of total asset)					
FIXR	Fixed interest rate loans	0.4766	0.1341	0.083	0.931
MORT	Mortage recourse exposure (FNMA, GNMA, Private and Farmers)	0.0020	0.0050	0.0	0.024
2. Exchange Rate Risk Exposure					
(a) Derivative Exposure (as a ratio of total asset)					
XOPTB	Currency options bought	0.1032	0.2905	0.0	1.454
XOPTW	Currency options written	0.1005	0.2838	0.0	1.356
XFF	Currency futures and forwards	1.1778	2.8148	0.0	12.757
XSWAP	Currency swaps	0.1232	0.4439	0.0	2.758
(b) Basic Exposure					
FOA	Assets in foreign offices over assets in domestic offices	0.1691	0.3426	0.0	1.659
FXDEP	Deposits denominated in foreign currencies over deposits in domestic currency	0.0001	0.0003	0.0	0.002
FOIY	Foreign interest income over total interest income	0.0685	0.1329	0.0	0.598
FOIE	Foreign interest expenses over total interest expenses	0.1387	0.1898	0.0	0.605
FONIE	Foreign non-interest expenses over total non-interest expenses	0.2354	0.4768	0.0	2.434

Source: Federal Reserve Call Report Tape by National Technical Information System. Exposure data are as of the end of or during 1992.

Table 5
Correlations among Firm-Specific Exposure Variables

(A) Interest Rate Risk Exposure Variables

	IOPTB	IOPTW	IFF	ISWAP	FIXR	MORT
IOPTB	1.0000					
IOPTW	0.9291	1.0000				
IFF	0.7390	0.8154	1.0000			
ISWAP	0.9472	0.9449	0.8687	1.0000		
FIXR	0.4210	0.2115	0.2988	0.3697	1.0000	
MORT	0.0651	0.0773	0.1912	0.1038	0.1413	1.0000

(B) Exchange Rate Risk Exposure Variables

	XOPTB	XOPTW	XFF	XSWAP	FOA	FXDEP	FOIY	FOIE	FONIE
XOPTB	1.0000								
XOPTW	0.9983	1.0000							
XFF	0.8151	0.8119	1.0000						
XSWAP	0.8490	0.8266	0.6161	1.0000					
FOA	0.8383	0.7904	0.8671	0.7951	1.0000				
FXDEP	0.1697	0.1645	0.3945	0.0786	0.4401	1.0000			
FOIY	0.5917	0.5783	0.8210	0.4953	0.8232	0.3646	1.0000		
FOIE	0.6767	0.6743	0.7632	0.5678	0.8198	0.2220	0.8556	1.0000	
FONIE	0.8182	0.7958	0.8285	0.8470	0.9320	0.2134	0.8247	0.8359	1.0000

(C) Derivative Exposure Variables

	Correlations between Interest Rate and Exchange Rate Risk Variables
OPTB	0.8239
OPTW	0.8232
FF	0.8410
SWAP	0.8372

Data definition: See table 4.

Table 6
Determinants of Interest Rate and Exchange Rate Risk Betas

Estimation is carried out using the simultaneous heteroskedasticity-adjusted method that permits interactions between interest rate risk and exchange rate risk exposure variables. The data used in this table are firm-specific variables for 50 U.S. banks and the interest rate and exchange rate risk betas estimated in the first step.

Variables	Model 1	Model 2	Model 3	Model 4
IC	-108.279**	-96.561**	-108.029**	-96.838**
	(-2.347)	(-7.059)	(-2.355)	(-6.919)
IOPTB	-120.896**	-112.831*	-131.050**	-122.924**
	(-1.968)	(-1.911)	(3.465)	(-6.545)
IOPTW	217.886**	205.365**	212.755**	200.996**
	(3.112)	(5.122)	(3.276)	(5.240)
IFF	-13.444	-12.517	-16.394*	-15.387*
	(-0.854)	(-0.791)	(-1.700)	(-0.865)
ISWAP	-6.5535	-6.2728	--	--
	(-0.197)	(-0.191)		
FIXR	25.594	--	24.419	--
	(0.285)		(0.275)	
MORT	3887.75**	3942.35**	3911.44**	3962.66**
	(3.584)	(3.268)	(3.438)	(3.142)
XC	-0.0597	-0.0597	-0.0595	-0.0595
	(-0.173)	(-0.173)	(-0.172)	(-0.172)
XOPTB	-41.294**	-41.280**	-41.290**	-41.276**
	(-2.071)	(-2.072)	(-2.068)	(-2.069)
XOPTW	42.600**	42.596**	42.584**	42.581**
	(2.110)	(2.111)	(2.104)	(2.105)
XFF	-0.6252**	-0.6247**	-0.6229**	-0.6225**
	(-2.844)	(-2.836)	(-2.754)	(-2.749)
XSWAP	-3.9192**	-3.9184**	-3.9215**	-3.9206**
	(-2.409)	(-2.410)	(-2.411)	(-2.411)
FOA	6.9320**	6.9097**	6.9206**	6.8996**
	(3.379)	(3.325)	(3.324)	(3.279)
FXDEP	-1089.00	-1087.57	-1094.46	-1092.86
	(-1.620)	(-1.614)	(-1.627)	(1.621)
FOIY	2.2333	2.2360	2.2121	2.2154
	(0.441)	(0.442)	(0.436)	(0.438)
FOIE	-14.281**	-14.268**	-14.285**	-14.272**
	(-3.736)	(-3.723)	(-3.737)	(-3.725)
FONIE	4.9583*	4.9573*	4.9705*	4.9691*
	(1.834)	(1.834)	(1.839)	(1.838)

IC, XC = constant in interest rate and exchange rate equation respectively;
Following variables are defined as a ratio of total asset:
IOPTB, XOPTB = options bought, interest rate (I) and currency (X) respectively;
IOPTW, XOPTW = options written, interest rate and currency respectively;
IFF, XFF = forwards and futures, interest rate and currency respectively;
ISWAP, XSWAP = swaps, interest rate and currency respectively;
FIXR = fixed interest rate loans;
MORT = mortgage recourse exposure.
Following variables are defined as a ratio of domestic or total corresponding variables:
FOA = assets in foreign offices over assets in domestic offices;
FXDEP = deposits denominated in foreign currencies over deposit in domestic currencies;
FOIY = foreign interest income over total interest income;
FOIE = foreign interest expenses over total interest expenses;
FONIE = foreign non-interest expenses over total non-interest expenses.