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Bank Capital Standards for Foreign Exchange and Other Market Risks

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The Basle Committee on Banking Supervision has proposed methods for incorporating consideration of market risks—exchange rate, interest rate, and equity price risks—into risk-based capital standards for banks. This paper shows that the separate and seemingly different proposed approaches to the three sources of risk are consistent with one another, reflecting a single unifying theme. That theme is the measurement of risk through a weighting of two different measures of portfolio size, the gross position and the net position. A simple theoretical model demonstrates that such an approach can be viewed as a simple (specifically, an affine) approximation to a portfolio variance calculation based on the full variance-covariance matrix of market returns, and thus provides a reasonable basis for a practical approach to capital standards. An empirical test of one part of the framework, the proposal for exchange rate risk, shows that the approximation may be very accurate: the proposed Basle approach captures over 95 percent of the variation in foreign exchange risk across a sample of banks from the Twelfth Federal Reserve District.

I. Introduction

This paper investigates the extension of risk-based capital standards to cover market-related risks. In 1988, the Basle Committee on Banking Supervision (the Basle Committee) published standards for capital adequacy, establishing a system in which minimum capital requirements for banking firms are sensitive to differences in risk.[1] The risk-based capital standards specified in the Basle Accord came into full force at the end of 1992, and have been adopted by many countries. When the standards were issued, the Basle Committee acknowledged that the resulting assignments of minimum capital primarily reflected an assessment of credit risk, or the risk of losses due to counterparty default. Consideration of other types of risk was left to national regulatory authorities or to future deliberations of the Basle Committee and its subgroups.

In April 1993, the Basle Committee sought comments on a consultative paper describing proposals for incorporating additional types of risk into the original framework (Basle Committee, 1993). "Market risks" are those due to unexpected changes in financial market prices that are unrelated to the creditworthiness of particular borrowers or counterparties; the Basle proposals cover stock prices, the prices of foreign currencies as reflected in exchange rates, and debt prices as reflected in interest rates. Since market risk is considered distinct from credit risk, the emphasis is on price fluctuations that reflect general market movements, rather than those related to changes in the condition of specific issuers.

This paper develops a conceptual model in which the new market risk proposals can be understood and analyzed. The underlying, unifying theme of the standards is emphasized. Building on the conceptual model, the suitability of the proposals is evaluated. For purposes of illustration, much of the analysis is based on consideration of foreign exchange rate risk, which in some ways is the simplest of the three; the paper discusses the parallel implications for other types of market risk in less detail.

1. The Basle Committee consists of representatives from Belgium, Canada, France, Germany, Italy, Japan, Luxembourg, the Netherlands, Sweden, Switzerland, the United Kingdom, and the United States. It usually meets at the Bank for International Settlements in Basle, Switzerland.

II. CONVENTIONAL AND RISK-BASED CAPITAL STANDARDS

Before turning to market risk, it is helpful to review the general role of capital standards in bank supervision. Risk is an unavoidable element of the business of banking, and banks must take risks to be economically useful in the financial system. Managers of well-run banks are aware of the risks they face, and take steps to manage those risks to maximize the net value of their banks. However, certain features of the banking system—most notably the imperfectly priced government support of banks through deposit insurance and other elements of the federal "safety net," and the externalities associated with bank failures—lead to a tendency toward excessive risk. Levels of risk are "excessive" to the extent that the probability of bank failure resulting from the private, unregulated decisions of bank managers exceeds the level of failure that maximizes social welfare. To deal with this tendency toward excessive risk, central authorities in most countries impose some type of oversight on the banking system in special licensing, regulation, and ongoing supervision.

Standards for capital adequacy are an aspect of bank regulation common to most countries. These capital standards establish minimums for bank capital. The term "capital" is used in many ways in economics and finance, but in the context of bank capital adequacy it is the portion of a bank's financing that can absorb losses that would otherwise cause the bank to fail and impose an external cost on the economy. Generally this means equity, although regulators consider certain types of debt to be capital in some circumstances.

Minimum capital requirements help ensure the solvency of regulated institutions, but the only capital standard that can *guarantee* solvency is a requirement of complete equity financing. Such a standard is impossible with depository institutions by definition, so regulators instead set capital standards to reduce the probability of insolvency to some acceptable level. The acceptable level depends on regulators' tolerance for risk, which in turn may reflect judgments regarding the potential welfare costs of insolvency balanced against the costs imposed by the regulations.

The probability that a bank will become insolvent depends on the level of its capital and the variance or standard deviation of changes in that capital. The conventional approach to capital adequacy sets minimum capital relative to the assets of the bank, with a floor placed under allowable capital-asset ratios. Under certain assumptions, such an asset-based standard is equivalent to requiring capital to exceed a multiple of the standard deviation of changes in capital. Specifically, if all bank assets have the same variance, and provided liabilities contribute trivially if at all to total risk, then the standard deviation of changes in capital can be expressed as $\sigma_A A$, where σ_A is the standard deviation of a bank's return on assets. In that case, a minimum capital ratio of $\gamma\sigma_A$ can set the probability of insolvency at the acceptable level, with the coverage ratio γ determined by regulators. If σ_A is about 2 percent (a typical empirical finding) and regulators aim to cover two standard deviations (that is, $\gamma=2$), then the minimum capital ratio should be 4 percent.[2]

In contrast to conventional asset-based leverage constraints, the risk-based capital standards established under the 1988 Basle Accord set minimum capital relative to a weighted sum of the bank's assets.[3] Levonian and Kendall (1993) show within a simplified model of the Basle Accord that the credit risk standards can be viewed as an extension of simple leverage standards; the Accord relaxes the assumption that all asset types have a common variance, making σ_A a weighted average of the volatilities of the different asset types. However, the Basle Accord retains the assumption that liabilities are irrelevant, and the risk weights largely reflect only credit risk.

III. MARKET RISKS IN THEORY

Neither the conventional nor the credit-risk-based approaches to capital standards can be stretched to cover market risks. Credit risks generally run in one direction: The bank gains if the credit standing of a counterparty improves, and loses if credit quality deteriorates. On the

2. An asset-based standard ignores differences in bank profitability, implicitly assuming that the expected change in capital is zero. In practice, regulators aim to err on the side of conservatism, and are reluctant to presume that banks will achieve a positive rate of return. Bank supervision may incorporate profitability more subtly, perhaps in the enforcement of capital standards; for example, supervisors might exert less pressure on a profitable bank with low capital than on an unprofitable bank in the same position.

3. The Basle framework applies to assets and off-balance-sheet items. The notional value of a bank's off-balance-sheet exposures are converted into "credit equivalent" amounts through a set of conversion factors intended to reflect the amounts actually at risk for the bank; on-balance-sheet assets are combined with the converted off-balance-sheet amounts and classified into one of several categories according to the credit risk associated with the underlying counterparties. Amounts in each risk category are then multiplied by a risk weighting factor (higher for riskier categories) and the weighted amounts are summed. The resulting total risk-weighted assets forms the basis for the capital adequacy calculation; minimum ratios of various types of capital to risk-weighted assets are established in the Basle Accord. For further description of the standards established under the Basle Accord, see Bhala (1989).

other hand, increases in market prices can cause either gains or losses for a bank, because exposure to these prices can be either long or short.[4] Liabilities create short positions; for example, a deposit denominated in a foreign currency creates short foreign exchange exposure for the issuing bank. Since such positions may contribute substantially (either positively or negatively) to total portfolio risk, liabilities cannot be ignored, and a simple asset-based calculation cannot correctly capture the potential for losses due to market risk.

With risky positions both long and short, the variance of changes in capital requires a matrix presentation. Suppose there are N market variables—stock prices, interest rates, or exchange rates—that might affect the solvency of banks. Let Σ represent the variance-covariance matrix of percentage changes in the prices of these instruments; thus Σ is $N \times N$, with the variance of each instrument on the diagonal, and the covariance between each pair off the diagonal. Let D represent a vector of the bank's net dollar positions in the instruments, with N components. Then the bank's portfolio variance—that is, the variance of the change in total portfolio value—is given by $\sigma_p^2 = D'\Sigma D$.

It is tempting to regard this matrix-based portfolio calculation as the solution to the market risk problem. Regulators could set minimum capital at some multiple γ of the portfolio standard deviation σ_p, at a level deemed adequate for protection against bank failures. Such standards would accurately reflect differences in risk across banks and over time.

However, practical considerations may require standards for market risk to meet additional criteria. Foremost among these is simplicity; the more complicated the regulation, the greater the expense, for several reasons. Complex standards are more difficult to draft, and once written are more difficult to explain to regulated banks, to supervisory staff, and to others. Complicated standards often are information intensive, increasing the reporting burden imposed on banks and raising the costs of data collection and analysis for regulators. Banks and regulators also may find it more difficult to monitor compliance. Moreover, to the extent that more complicated methods rely on sophisticated computational techniques, or on unobservable values that must be estimated or subjectively determined, enforcement costs are likely to climb.

4. Positions are defined as "long" if a rise in price increases the value of the portfolio; this might occur if the bank actually holds the currency, bond, or stock, or has contracts to receive delivery of those items at some future date at a prespecified price. Conversely, "short" positions lose value when price rises; shorts generally result from commitments to make future delivery.

One aspect of simplicity is that elementary functional forms are desirable. Linear forms are among the simplest, and therefore are preferred. Regulators also may want any new capital standards to have the general form of the old standards, under which minimum capital is set as a ratio to some measure of value such as total assets or risk-weighted assets. Requiring that a market risk standard be expressed similarly places even greater constraints on the functional form than does the requirement that it be linear. The history of the Basle Committee's work suggests that these considerations were important. Of course, simplicity cannot be the only goal in establishing a capital standard; the standard also must be accurate, with risk measured fairly precisely. An optimal policy balances these concerns, trading off simplicity for precision. A degree of imprecision may be acceptable when the cost of implementing more precise but more complex regulatory regimes is considered.

Viewed within the context of this tradeoff, the matrix-based portfolio variance calculation is precise but is unlikely to be simple enough. The policy challenge is to develop a precise measure of market-related risks—with precision measured relative to portfolio variance—that is sufficiently simple, preferably one that results in a dollar figure against which a typical minimum capital ratio can be applied. To meet this challenge, the Basle Committee began by examining existing approaches in use by bank supervisors around the world. Of the various market risks, foreign exchange is the one for which regulators have developed the best quantitative measures of exposure. The next section discusses the range of existing practice examined by the Basle Committee.

IV. Foreign Exchange Market Risk in Practice

In many countries, banks are required to calculate their overall currency positions at given points in time; regulators use the resulting "aggregate open position" for each bank as a measure of exchange rate risk. Implicitly, regulators assume that foreign exchange risk depends positively on the size of this open position, analogous to the assumption in conventional capital standards that portfolio risk is proportional to total assets. Such calculations are based on the vector of positions D, and do not explicitly use the matrix Σ. Since portfolio variance depends on both D and Σ, it is reasonable to think that these open position calculations might be related to risk, but with a loose and imperfect linkage.

Each of the various aggregation approaches in common use begins by constructing a hypothetical portfolio of foreign currency positions for each bank, or a foreign exchange "book," with risk identical to the bank as a whole. For some banks this mirrors the way exposure actually is managed: Each business unit within the bank hedges away any currency risk it generates through internal transactions with the bank's foreign exchange trading desk. However, the same principle applies whether or not this is actually done. With all of the relevant risk collapsed into a single actual or hypothetical book, the problem becomes one of computing the total exposure arising from this foreign exchange portfolio. Long and short positions generally are netted within any single currency, but national practices differ in important ways with regard to the degree of netting of long and short positions *across* currencies. Three alternative approaches for netting across currencies to obtain a measure of aggregate open position are in common use by bank supervisors in major countries.

To illustrate the three alternatives, simple schematic diagrams of two foreign exchange books are presented in Figure 1. The relative dimensions of the rectangles reflect the relative values of the long (L) and short (S) positions, and the net portfolio position (T), all in terms of the domestic currency. In Portfolio I the aggregate value of long positions exceeds the aggregate value of short positions, and the foreign exchange book is a net asset for the bank; in Portfolio II the short positions are worth more than the longs, and the book is a net liability. What is a valid measure of exposure to exchange rate changes for these portfolios?

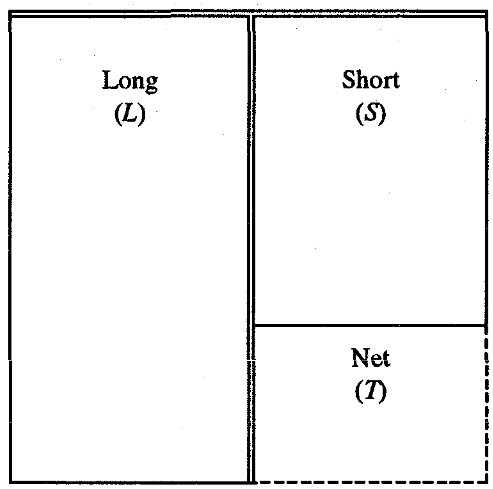
One intuitively appealing measure of potential loss is the net position, which is simply equal to T in Figure 1. This reflects the net investment of the bank in the foreign exchange book at a point in time, or the cost of acquiring or divesting the portfolio on the current market. The net position has been used by some regulators as the measure of foreign exchange exposure, most notably in Japan; it will be referred to here as Net Aggregate Position (NAP). NAP also can be computed as the absolute value of the sum of all foreign currency positions, counting shorts as negative values.

However, suppose the long exposure is in Canadian dollars and the short exposure is in German marks. If the dollar exchange rates for these two currencies move in opposite directions, the bank's total loss could far exceed T; for example, the net position might change from positive to negative. Consequently, some regulators have chosen to assess exposure by taking the total of the two areas L and S; this measure has been used in Germany and other countries. This will be referred to as Gross Aggregate Position (GAP). GAP is calculated as the sum of the values of all long positions, plus the absolute value of all short positions; that is, it is the sum of all foreign currencies counting shorts as positive positions. Thus, the gross measure is $\text{GAP} = L + S$, whereas the net measure is $\text{NAP} = T = |L - S|$. From the definitions, it is evident that GAP$\geq$NAP, and GAP$=$NAP only if $L = 0$ or $S = 0$.

FIGURE 1

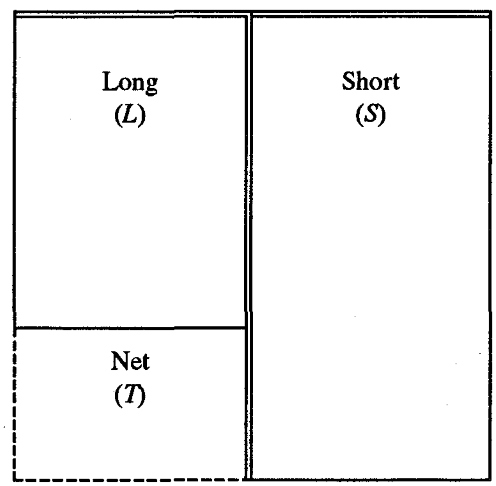
TWO TYPICAL FOREIGN EXCHANGE BOOKS

PORTFOLIO I: NET LONG



$$\text{NAP} = |L - S| = T$$
$$\text{GAP} = L + S$$
$$\text{BAP} = L$$

PORTFOLIO II: NET SHORT



$$\text{NAP} = |S - L| = T$$
$$\text{GAP} = S + L$$
$$\text{BAP} = S$$

A third practical gauge of foreign exchange exposure, generally attributed to bank regulators in the U.K. but adopted by other countries as well, is the larger of the absolute values of shorts and longs. This "Bank of England" Aggregate Position, or BAP, is therefore max$[L,S]$. As the larger of L and S, BAP is always the "length" of the T-account balance sheet, the total value of one side; in Portfolio I, this would be L, whereas in Portfolio II it would be S. An alternative definition of BAP that is sometimes used is "the sum of short positions in all currencies, including the home currency." The equivalence of the two definitions is clear from Figure 1. The rectangular area T gives the net position in the domestic currency, which in Portfolio I can be viewed as additional short exposure: If the domestic currency rises in value against other currencies, the value of the book declines. Hence in Portfolio I the short position *including* the home currency is the total area of rectangles S and T together, which is of course equal to L, the larger of L and S. Similarly, in Portfolio II the domestic currency position effectively is a long position, so the aggregate short position is simply S; this again is equivalent to taking the larger of L and S.

Each measure—NAP, GAP, and BAP—was considered and tested by the Basle Committee; in the end, the Committee favored BAP. The Basle Committee perceived BAP to be a compromise between the "conservative" GAP and the "liberal" NAP. In fact, it is a compromise in a very significant sense: BAP is the simple average of GAP and NAP. To see this, first note that:

$$(1)\qquad \begin{aligned} \text{GAP} &= L + S = \max[L,S] + \min[L,S] \\ \text{NAP} &= |L - S| = \max[L,S] - \min[L,S] \end{aligned}$$

Then BAP can be written as:

$$(2)\qquad \begin{aligned} \text{BAP} &= \max[L,S] \\ &= \tfrac{1}{2}\,(\max[L,S] + \max[L,S]) \\ &= \tfrac{1}{2}\,(\max[L,S] + \min[L,S] \\ &\quad + \max[L,S] - \min[L,S]) \\ &= \tfrac{1}{2}\,(\text{GAP} + \text{NAP}) \end{aligned}$$

An equivalent restatement is that BAP always yields a result halfway between the gross and net exposures. Thus BAP is indeed a "compromise" measure.[5]

NAP, GAP, and BAP can be viewed as variants of a more general measure of portfolio position. Define "weighted aggregate position" (WAP) as the weighted sum of gross and net aggregate positions:

$$(3)\qquad \text{WAP} = w_g\text{GAP} + w_n\text{NAP}$$

The other measures are easily seen to be special cases:

$$(4)\qquad \text{WAP} = \begin{cases} \text{GAP if } w_g = 1 \text{ and } w_n = 0 \\ \text{NAP if } w_g = 0 \text{ and } w_n = 1 \\ \text{BAP if } w_g = \tfrac{1}{2} \text{ and } w_n = \tfrac{1}{2} \end{cases}$$

Turning from risk measurement to the construction of capital standards, a capital requirement for foreign exchange risk could be based on WAP. A minimum ratio c of capital to aggregate foreign exchange position could be established, with position measured by BAP or any other variant of WAP. This is precisely the Basle Committee's proposal: banks would be required to have enough capital (above that required to cover other types of risk) to cover 8 percent of BAP.[6] As indicated in Section II, to be adequate this minimum capital should correspond to $\gamma\sigma_p$, where σ_p is the standard deviation of changes in capital (in this case flowing entirely from the foreign exchange portfolio) and γ is regulators' desired coverage ratio.

V. Equity and Interest Rate Risk Proposals

The recent Basle release also covers equity price risk and interest rate risk. The equity proposal applies to banks' holdings of common equity shares, as well as options, futures, warrants, and other instruments whose value depends on share prices or the level of stock market indexes. The interest rate proposal applies to traded debt securities and derivatives; as a result, it only incorporates a portion of total interest rate risk, ignoring major components such as loans and deposits.[7] This section provides an overview of both proposals. As with foreign exchange, these two proposals turn out to be versions of WAP.

One notable difference between these two proposals and the foreign exchange proposal is that they substitute completely for the old treatment; that is, traded debt and equity instruments would no longer be covered by the original

5. The relation BAP = ½(GAP + NAP) is also evident from Figure 1. Since GAP + NAP is equal to the sum of L, S, and T, it is twice the value of either side of the balance sheet separately; BAP is always equal to the total value of *one* side of the balance sheet, and hence is always exactly half of the sum of the other two measures.

6. The Basle Committee also has suggested a possible alternative, under which banks would simulate the response of their portfolios to typical exchange rate fluctuations.

7. A separate proposal from the Basle Committee describes a framework for collecting information on interest rate exposure for all of the assets and liabilities of the bank, both on- and off-balance-sheet. That framework is for information only; there is no explicit risk calculation or capital charge, although the Committee expects that the information may be used as the foundation for future capital standards covering the bank as a whole.

risk-based capital framework. Capital required under the foreign exchange market risk proposal would be in *addition* to any capital required to meet the existing credit risk standards.

Equity Price Risk

The equity proposal covers risk due to changes in stock prices. Some banks have direct holdings of equity shares or equity-linked instruments. In some countries this could be quite important, depending on the extent of bank powers. Also, the new standards apply on a consolidated basis; in countries (such as the United States) where banks are affiliated with brokerage or investment banking units, the equity risk standards may be important.

As in the foreign exchange proposal, banks convert options and futures into spot equivalents, and then consolidate all exposures into a single hypothetical portfolio. The result in the foreign exchange case was a set of long and short positions in individual currencies; for the equity case, the positions are in the shares of different issuers or in stock market indexes. Positions may be long or short in each equity, with short exposure arising from short sales or from short positions in derivative instruments.

The proposal uses the long and short positions to compute gross and net aggregate positions, GAP and NAP. Gross and net positions are then weighted and summed to set minimum capital. This obviously is a weighted aggregate position calculation of the form discussed above. The weights proposed by the Basle Committee are 1.0 and 1.0, unless the portfolio is well diversified, in which case the weights are 1.0 on NAP and 0.5 on GAP. The resulting aggregate position is multiplied by a minimum capital ratio of 8 percent. The Basle draft combines the capital ratio with the weights; for example, the weights for the diversified portfolio case are expressed as 8 percent of net and 4 percent of gross. The Basle document refers to the composite weight on GAP as "x" and the weight on NAP as "y," and calls this "the x plus y approach." It clearly is equivalent to WAP.

Interest Rate Risk

The traded debt securities proposal is much more complicated, and has some features that do not fit neatly within the WAP framework. As with the other market risks, a hypothetical portfolio is constructed: Whereas in the foreign exchange case the positions were in individual currencies, and in equities the positions corresponded to different issuers or indexes, in the debt proposal banks report net positions in different maturities or repricing periods. Derivative instruments are converted to spot equivalents, and duration weights are used to convert each time band to a corresponding interest rate sensitivity. In addition, each position is multiplied by a risk weight that combines an interest rate volatility (standard deviation) and a factor for the number of standard deviations of capital coverage desired by regulators; in terms of the discussion in Section II above, the risk weights correspond to $\gamma\sigma$.

Banks report long or short positions in each of the 13 bands, which are grouped into three "zones" corresponding to short-term, medium-term, and long-term. Table 1 illustrates the structure of the basic maturity ladder. Exposures are netted in stages, first within maturity bands, then across bands within each of the three maturity zones, and then finally across the zones. At each stage, a certain amount of the netting is "disallowed," using various "disallowance factors." An aggregate position results. Since individual positions have been premultiplied by risk weights corresponding to $\gamma\sigma$, the result after the netting process is *not* multiplied by a capital ratio (such as 8 percent); it already corresponds to a dollar amount of capital.

The way the disallowances are computed turns the netting process into a WAP calculation. Consider one stage of the netting, say, between time bands within a single zone. In each band the bank may have either a long or a short position. (For example, there would be a maximum of

TABLE 1

Maturity Ladder for Interest Rate Risk

Time Band	Maturity Range	Zone
1	0–1 month	Zone 1 (Short Term)
2	1–3 months	
3	3–6 months	
4	6–12 months	
5	1–2 years	Zone 2 (Medium Term)
6	2–3 years	
7	3–4 years	
8	4–5 years	Zone 3 (Long Term)
9	5–7 years	
10	7–10 years	
11	10–15 years	
12	15–20 years	
13	over 20 years	

six long or short positions in Zone 3.) These band exposures are netted, generating a NAP for that zone. The disallowance factor is a number δ (between 0.10 and 1.50, differing by zone and band) to be multiplied by the smaller of the total long and total short positions; the resulting dollar-value disallowance is added to NAP from the zone to compute a position for that zone. Formally, the calculation is $\text{NAP} + \delta\min[L,S]$.

It may not be obvious that this is a WAP calculation. Note from the pair of equations in (1) that $\text{GAP} - \text{NAP} = 2\min[L,S]$. Then the computed position is:

$$(5)\quad \text{NAP} + \delta\min[L,S] = \text{NAP} + \frac{\delta}{2}(\text{GAP} - \text{NAP}) = \frac{\delta}{2}\text{GAP} + \left(1 - \frac{\delta}{2}\right)\text{NAP}$$

Equation (5) shows that the netting process with disallowances does yield WAP. The amount of the disallowance is related to the weighting: a larger disallowance factor gives relatively more weight to gross versus net. Note that $\delta = 0$ corresponds to NAP, $\delta = 1$ corresponds to BAP, and $\delta = 2$ corresponds to GAP.

Thus, the equity and interest rate risk proposals reflect the same underlying theme as the foreign exchange proposal: The use of WAP to weight gross and net aggregate positions, yielding a dollar exposure against which a minimum capital ratio can be applied. Since all three use versions of WAP, WAP is the key to understanding and analyzing the market risk proposals. The next section returns to the example of exchange rate risk to examine whether WAP is likely to be a good measure of market risk.

VI. WAP IN A SIMPLIFIED PORTFOLIO

WAP is a simple, practical measure of portfolio position, linearly combining elements of the position vector D. WAP has the distinct advantages of readiness of comprehension and ease of application, as do its variants, such as the Basle Committee's foreign exchange selection BAP. Moreover, WAP could serve as the foundation for a proportional standard, with minimum capital set at some ratio c relative to WAP. But since WAP bears little obvious resemblance to the portfolio variance $\sigma_p^2 = D'\Sigma D$ discussed in Section III, its precision—that is, its ability to accurately reflect interbank differences in risk—may seem questionable. This section presents a simplified model of a portfolio showing that GAP and NAP, the components of WAP, are clearly related to the portfolio variance calculated from the variance-covariance matrix; this result has implications for the likely precision of WAP in general. Foreign exchange risk is again used as a convenient example, although the currency positions could just as easily be interpreted as debt or equity positions.

Consider a U.S. bank managing a portfolio of N foreign currencies. Assume that the portfolio consists of n short currency positions, and therefore $N - n$ long currencies. The value of each currency is measured in units of the domestic currency (the U.S. dollar) as numeraire; thus, there are $N + 1$ total currencies in the model. The dollar value of currency i in the portfolio is d_i.

Prices of the foreign currencies fluctuate randomly from period to period due to changes in supply and demand, perhaps with some anticipated trend. Assume that the unanticipated rate of change in each of the N exchange rates is distributed with variance σ^2, and that all cross-currency correlations are equal to ρ. If D is the $N \times 1$ vector of positions and Σ is the $N \times N$ variance-covariance matrix of the rates of change in exchange rates—with diagonal elements equal to σ^2 and off-diagonal elements equal to $\rho\sigma^2$—then the variance of changes in the value of the foreign exchange portfolio is given by:

$$(6)\quad \sigma_p^2 = D'\Sigma D = \sum_{i=1}^{N} \sigma^2 d_i^2 + 2\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} \sigma^2\rho d_i d_j .$$

To simplify the problem further, assume that each position is of equal absolute dollar value.[8] Long positions have positive value $d_i = d > 0$ and total dollar value $(N - n)d$, whereas short positions are effectively liabilities and hence have $d_i = -d < 0$ and negative total value $-nd$. Then the variance can be written:[9]

$$(7)\quad \sigma_p^2 = \sigma^2 d^2 N(1-\rho) + \sigma^2 d^2 (N-2n)^2 \rho .$$

Defining a "portfolio composition factor" P as:

$$(8)\quad P = \sqrt{d^2 N(1-\rho) + d^2(N-2n)^2\rho},$$

the portfolio variance can be written simply as:

$$(9)\quad \sigma_p^2 = \sigma^2 P^2 .$$

An attractive interpretation of this expression for σ_p^2 is that foreign exchange risk in a bank's portfolio can be viewed as the product of two components. One component is exchange rate volatility arising from the external environment of the foreign exchange markets, in this model represented by σ^2. This variance is multiplied by the second component, the square of the portfolio composition factor P, which reflects the size and composition of the individual bank's foreign exchange book. Since the exchange rate environment does not vary across banks within

8. Alternatively, σ_i could be permitted to vary across currencies and d_i assumed proportional to $1/\sigma_i$ (that is, smaller positions in more volatile currencies).

9. Details of this step are given in the Appendix.

a given financial system, the value of σ^2 affects the level of risk in the system but not how risk varies across banks; differences in risk across banks must stem from differences in portfolio composition.

P is related algebraically to the simpler aggregate position measures used by bank supervisors around the world. In the N foreign currency model, GAP $= Nd$. With n short positions and N–n long, NAP $= |N-2n|d$. Substituting into equation (8) above yields:

$$(10) \qquad P^2 = \text{GAP}^2 \frac{(1-\rho)}{N} + \text{NAP}^2\rho \, .$$

Thus P^2 is a weighted sum of squares of GAP and NAP, with the weights depending on cross-currency correlations of exchange rates for any given number of currencies.

In view of this relationship, consider the WAP measures—GAP, NAP and BAP—that have been used in the past to measure risk. A precise standard would set minimum capital at $\gamma\sigma_p$, which is equal to $\gamma\sigma P$ from equation (9). If WAP happened to be proportional to P, then minimum capital could be set as a ratio to WAP, with γ and σ incorporated into the capital ratio. Such a standard would be precise, in the sense that it would measure risk correctly for any combination of NAP and GAP, and at the same time would be simple. Is any variant of WAP proportional to P?

Several special cases are interesting. Equation (10) implies that $P =$ NAP if $\rho = 1$, an intuitive result: If changes in exchange rates are perfectly correlated, then the foreign currencies are effectively interchangeable, and can be treated as a single currency. Long and short positions within a single currency of course should be netted. As a result, NAP, which nets longs and shorts across the entire book, treats the exposures correctly. With $\rho = 1$, a minimum capital ratio $c = \gamma\sigma$ applied to NAP is simple, proportional, and precise. (This result is independent of the particular form of the model.)

If exchange rate changes are uncorrelated ($\rho = 0$), then equation (10) implies $P = \text{GAP}/\sqrt{N}$. In that case, a capital standard for foreign exchange risk could be based on GAP as the measure of exposure, with the minimum capital ratio $c = \gamma\sigma/\sqrt{N}$. The special case of NAP $= 0$ also is interesting; NAP is zero if a bank runs a "balanced book," with no net position in the domestic currency. GAP again is precisely proportional to portfolio risk: equation (10) shows that $P = \text{GAP}\sqrt{(1-\rho)/N}$. The appropriate minimum capital ratio would be $c = \gamma\sigma\sqrt{(1-\rho)/N}$.

Nevertheless, it is clear from (10) that in general a WAP standard cannot be perfectly precise, because WAP depends linearly on GAP and NAP while P depends on the square root of their weighted sum of squares. If a standard based on a weighted root sum of squares of gross and net exposure were regarded as sufficiently simple, P itself could yield a very precise capital standard. However, such a standard may be regarded as unacceptably complex. Given that the simpler WAP is imprecise, it still may be "close enough" to P to be acceptable.

Equation (10) describes P as a function of net and gross exposure; in three dimensions, P is a portion of an asymmetric cone. In contrast, WAP is affine;[10] it is a plane in three dimensions. The task of devising a capital standard based on WAP can be viewed as one of choosing the weights to make the WAP plane approximate the P cone fairly closely for all n and d, given the number of currencies N and the correlation coefficient ρ. As discussed above, WAP can fit P perfectly only under polar conditions, with $\rho = 0$ or $\rho = 1$. In the general case, WAP can only be made "close" to P; the fit of the capital standard is tailored by adjusting the relative weights on net and gross exposures, w_n and w_g. The best weighting will depend in part on N and ρ.

VII. Optimizing the WAP Weights

The preceding section suggested that WAP might be a good risk measure, balancing simplicity and precision: simple because it builds on current practice and is a linear combination of exposures, and precise because a correct choice of the relative weights on gross and net could make WAP approximate the theoretically correct portfolio composition factor. The Basle Committee's foreign exchange proposal incorporates a specific weighting, BAP, in which the weights on NAP and GAP are both ½. Are these the best choices? More generally, how should the weights be chosen?

Returning to the simple portfolio model with a fixed number N of foreign currencies and a variance-covariance matrix Σ, assume that bank portfolios differ only in scale. That is, assume that all banks have the same currency mix (reflected in uniform values of n, or equivalently in uniform ratios of NAP to GAP), but may have positions of different sizes (d differs). Let Δ be the common NAP/GAP ratio; Δ reflects the degree of portfolio imbalance, with $\Delta = 0$ for a balanced portfolio, and $\Delta = 1$ if exposure is all long or all short.[11] All bank currency portfolios thus lie along a single ray with slope Δ in the NAP-GAP plane,

10. An affine function is the multidimensional equivalent of a linear function; a function f is affine if $f(x) = Ax + b$, where x is a vector of variables, b is a vector of constants, and A is a fixed matrix of constants. In three dimensions, an affine function is a plane.

11. This assumption might not be too unrealistic; banks would have the same, or nearly the same, net currency positions if they all used similar portfolio optimization algorithms to manage exposure.

although as exchange rates change randomly over time Δ is likely to vary.

If w_n and w_g are chosen to make WAP tangent to P along the ray defined by NAP/GAP$=\Delta$, then WAP will be locally precise, in the sense that WAP will equal P for any portfolio scale d selected by individual banks. Moreover, WAP will track changes in risk precisely for local variation in Δ, since tangency equates the partial derivatives of WAP and P with respect to Δ; first order changes in measured risk would be the same as first order changes in actual portfolio risk.

Formally, since $\Delta = |N-2n|/N$ it is possible to rewrite WAP and P (from equations (3) and (8)) as functions of Δ and d, given N and ρ:

$$\text{WAP} = Nd(w_g + w_n\Delta) \tag{11}$$

and

$$P = Nd\left(\frac{(1-\rho)}{N} + \rho\Delta^2\right)^{1/2}. \tag{12}$$

Since WAP and P both pass through the origin (that is, both are zero when d is zero), the weights that make WAP tangent to P at a given Δ can be derived by simultaneously equating the partial derivatives of WAP and P:

$$\frac{\partial P}{\partial d} = \frac{\partial \text{WAP}}{\partial d} \quad \text{and} \quad \frac{\partial P}{\partial \Delta} = \frac{\partial \text{WAP}}{\partial \Delta}. \tag{13}$$

The relevant partial derivatives are:

$$\frac{\partial P}{\partial d} = N\left(\frac{(1-\rho)}{N} + \rho\Delta^2\right)^{1/2}, \tag{14a}$$

$$\frac{\partial P}{\partial \Delta} = Nd\rho\Delta\left(\frac{(1-\rho)}{N} + \rho\Delta^2\right)^{-1/2}, \tag{14b}$$

$$\frac{\partial \text{WAP}}{\partial d} = N(w_g + w_n\Delta), \tag{14c}$$

$$\frac{\partial \text{WAP}}{\partial \Delta} = Ndw_n \tag{14d}$$

Equating (14a) to (14c) and (14b) to (14d) as in (13) allows solution for the optimal weights w_n^* and w_g^*:

$$w_n^* = \rho\Delta\left(\frac{(1-\rho)}{N} + \rho\Delta^2\right)^{-1/2} \tag{15}$$

and

$$w_g^* = \frac{(1-\rho)}{N}\left(\frac{(1-\rho)}{N} + \rho\Delta^2\right)^{-1/2}.$$

Values of the optimal weights can be computed from equations (15) for realistic values of N, ρ, and the ratio Δ. What are reasonable choices of parameters? If N is interpreted as the number of *major* currencies, then ρ might be interpreted as the average correlation coefficient. The vast bulk of currency exposure for U.S. banks is concentrated in six major foreign currencies—German mark, Japanese yen, British pound, Swiss franc, Canadian dollar, and Australian dollar—suggesting $N=6$. The average correlation between biweekly changes in dollar exchange rates of these six currencies (measured over non-overlapping two-year intervals from 1981 through 1992 as described in Section VIII below) ranges from .38 to .56, with a mean of .47. Table 2A presents illustrative calculations of w_n^* and w_g^* based on these parameter values. Besides the six major foreign currencies, U.S. banks tend to have moderate exposures in other currencies such as the Italian lira, French franc and Dutch guilder; to consider the implications of differences in the number of currency positions, Table 2B presents optimal weights for $N=9$.

Even for a given combination of the parameters N and ρ, the accuracy of the WAP approximation varies depending on the NAP/GAP ratio Δ. Thus, in practice the choice of weights for WAP should depend on the range of net and gross positions that regulators aim to fit most closely. For example, other elements of bank supervision may lead most banks to run foreign exchange books that are balanced or nearly balanced, so that the typical NAP (and Δ) is small. In that case, the choice of weights likely would be made from the left-most column of Table 2A or of Table 2B.

There are two ways these weights could be used for capital regulation. Consider the case of $N=6$, $\rho=.47$, and NAP/GAP$=.33$. Under one approach, banks would compute their open foreign exchange positions as 42 percent of their net exposure plus 24 percent of their gross exposure, and might be required to have capital equal to at least 4.4 percent of this sum.[12] This is how the Basle foreign exchange proposal uses WAP in its BAP incarnation. A second approach would combine the capital ratio with the weights w_n^* and w_g^*; a composite capital charge would be made against the net position, and an additional charge would be made against the gross position. In this example, banks would be required to have at least enough capital to cover 1.8 percent of net exposure (4.4 percent of 0.42) *and* 1.0 percent of gross exposure. This composite approach

12. The standard deviation of two-week rates of change over the entire 1981-1992 period for the six major foreign currencies was 1.46 percent. Three standard deviations of coverage ($\gamma=3$) would imply a capital ratio of about 4.4 percent to be applied against the aggregate open position.

TABLE 2A

OPTIMAL WAP WEIGHTS WITH $N=6$

	NAP/GAP=1		NAP/GAP=.67		NAP/GAP=.33		NAP/GAP=0	
ρ	w_g	w_n	w_g	w_n	w_g	w_n	w_g	w_n
.38	.15	.55	.20	.49	.27	.33	.32	0
.47	.12	.63	.16	.57	.24	.42	.30	0
.56	.09	.70	.13	.66	.20	.51	.27	0

TABLE 2B

OPTIMAL WAP WEIGHTS WITH $N=9$

	NAP/GAP=.78		NAP/GAP=.56		NAP/GAP=.33		NAP/GAP=.11	
ρ	w_g	w_n	w_g	w_n	w_g	w_n	w_g	w_n
.38	.13	.54	.16	.49	.21	.38	.25	.16
.47	.10	.62	.13	.58	.18	.47	.23	.21
.56	.08	.70	.10	.66	.15	.56	.21	.26

would correspond to the treatment in the Basle Committee's equity price risk proposal, the "x plus y" approach.

From (15), the ratio of the WAP weights from the optimal approximation is:

$$\frac{w_n^*}{w_g^*} = \frac{\rho N \Delta}{1-\rho} \quad (16)$$

This ratio depends positively on ρ, N, and Δ. If exchange rates are highly correlated, then changes in the value of long positions tend to be offset by changes in the value of short positions; net exposure becomes most relevant, and the optimal w_n^* is high relative to w_g^*. With a larger number of foreign currencies, N, diversification eliminates more portfolio risk for any given gross size of the portfolio, and w_g^* is reduced relative to w_n^*. Finally, as Δ goes to zero and portfolios become more balanced (NAP goes to zero), then risk comes to depend mainly on GAP, and the optimal w_g^* becomes large relative to w_n^*.

The Basle Committee's foreign exchange proposal places equal weights on gross and net.[13] Figure 2 shows combinations of Δ and ρ for which the ratio in equation (16) is equal to one (and the Basle weighting is optimal) for various N. The graph implies that with ρ in the range of .35 to .55, the Basle proposal may be optimal provided bank portfolios are reasonably balanced (with NAP no greater than about 30 percent of GAP). The Basle proposal would be optimal for lower values of ρ if long and short currency positions within portfolios tend to be unbalanced.[14]

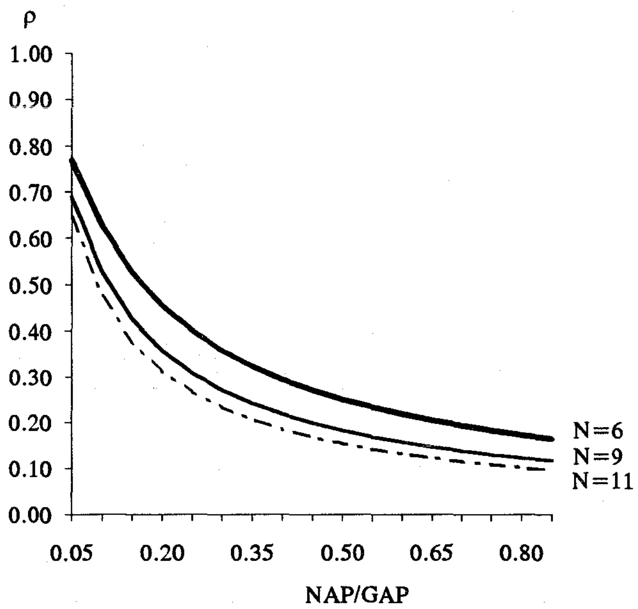
Capital standards based on WAP are fairly clever. They appear to depend only on the dollar size of positions, and are simple in form; they also appear to ignore correlations between different exchange rates. However, information from the variance-covariance matrix *is* incorporated in the choice of weights for gross and net exposures: the covariance determines the relative weights, and the variance scales the weights proportionally.

13. The Basle weights are 0.5 and 0.5, but to evaluate WAP's ability to track risk across banks and over time only the relative weights matter, not their absolute levels. Since WAP is multiplied by a minimum capital ratio to set a standard for capital adequacy, the weights can be scaled up or down proportionally, with the capital ratio scaled in the opposite direction for the appropriate degree of coverage. For example, weights of $w_n=.8$ and $w_g=.4$ with a minimum capital ratio of 4 percent have exactly the precision and coverage of $w_n=.4$, $w_g=.2$, and an 8 percent standard.

14. These results suggest that the Basle proposal may weight gross exposure too heavily. However, other risks related to settlement and delivery may be relatively high in transactions involving currency exchange. Those risks plausibly depend on gross exposure; if so, additional capital related to GAP may be warranted.

FIGURE 2

PARAMETER COMBINATIONS THAT MAKE EQUALLY WEIGHTED WAP OPTIMAL



VIII. A TEST OF THE BASLE FOREIGN EXCHANGE MEASURE

The analysis in the preceding section suggests that BAP might be expected to work reasonably well in some cases. However, the model used in that analysis makes highly stylized assumptions regarding exchange rate processes and foreign exchange portfolio structures. In practice, banks do not all have the same ratio of NAP to GAP, and may not even be tightly distributed around any particular ratio. Thus, rather than a WAP plane that is tangent along a single ray, the optimal policy might be a plane that leads to small differences between WAP and P for combinations of NAP and GAP over some *range* of Δ ratios, perhaps one minimizing the integral of the squared difference. In addition, relaxation of other simplifying assumptions (such as the special structure of the Σ matrix) may mean that in practice the surface mapping NAP-GAP combinations into σ_p is less regular in form than the P cone described above. Thus, actual bank portfolios probably are scattered around on an irregular surface above the NAP-GAP plane, and the practical question is whether a WAP approximation can be constructed to fit these points acceptably well. Requiring that the result be expressed as a conventional-looking capital ratio applied to WAP adds an additional constraint, that the plane should go through the origin, so that risk is measured at zero (and no capital is required) if both NAP and GAP are zero.

Considering these real-world wrinkles, the relevant question is an empirical one: Can WAP be made approximately proportional to the actual σ_p?[15] More specifically, the Basle Committee has proposed BAP, the equally weighted variant of WAP, to gauge exchange rate risk. This section uses a regression approach to evaluate BAP empirically as an affine approximation (see footnote 10) to actual foreign exchange portfolio risk, using data on exchange rates and on banks' foreign exchange positions.

The data on banks' foreign currency positions come from the FFIEC 035 report, a confidential survey of currency exposure conducted by federal banking regulators. The format of the collected data corresponds closely to the theoretical specification of the position vector D above. For the FFIEC 035 report, all of a bank's exposures in any single currency—including those arising from loans, deposits, securities and other sources denominated in foreign currency, both spot and forward—are collapsed into a single hypothetical position, either long or short. The only divergence from the theoretical model is that the positions are denominated in units of foreign currency; for this analysis, they were converted to U.S. dollars using the exchange rate prevailing as of the reporting date.

Currency positions were taken from the December reports for 1990, 1991, and 1992, for all banks in the Twelfth Federal Reserve District. Virtually all of the exposure was in the six major foreign currencies, so only these are considered in the analysis. One notable feature of the FFIEC 035 data is that relatively few banks file the report, reflecting the fact that many banks have immaterial foreign exchange exposure; in the Twelfth District, only 15 banks reported foreign exchange exposures for 12/90, 9 banks for 12/91, and 8 banks for 12/92. Thus, foreign exchange risk may not be a widespread concern, although it may be large for some individual banks. The six individual major currency positions were calculated for each bank, and BAP was computed from these positions.

Portfolio variances for each bank also were calculated from the vector of positions, based on variance-covariance matrices of percentage changes in exchange rates. The FFIEC 035 positions were considered to be typical portfolios that banks could hold at any time, and applied to Σ matrices estimated for specific dates to compute the portfolio variances as they would have been if the portfolios had

15. The theoretical analysis in Section VI investigated the relationship between WAP and P. Under the assumptions of that model, WAP $= P$ implied σWAP $= \sigma_p$, so an analysis of the first condition encompassed the second as well.

been held at those dates.[16] For the matrix estimations, the 1981–1992 period was divided into six two-year subperiods. Two-year subperiods were deemed to be a reasonable compromise: Σ is more likely to be stable over shorter periods, but an estimation period that is too short produces estimates with unacceptably wide confidence intervals. A series of non-overlapping two-week percentage changes in exchange rates was constructed from actual dollar exchange rates within each subperiod for each of the six major foreign currencies. (The two-week convention, initiated by the Basle Committee in testing the proposal, is based on considerations of how rapidly bank portfolio losses due to exchange rate changes can be recognized and acted upon by banks or regulators.) Six variance-covariance matrices (one for each subperiod) were estimated from the percentage changes in exchange rates. Portfolio standard deviations were estimated as $\sigma_p = [D'\Sigma D]^{1/2}$, where each of the observed currency portfolios is characterized by a dollar position vector D. Combining 32 bank portfolios with matrices from six subperiods yielded a data set with 192 observed pairs of $(\sigma_p)_{it}$ and BAP_{it}, one for each bank i in period t.

A rough nonparametric test of the strength of the relationship between BAP and σ_p can be constructed from the rank correlation of the two variables. At a minimum, BAP or any other proposed measure of portfolio risk should yield higher values for higher risk portfolios and lower values for lower risk portfolios. Calculation of the Spearman rank correlation coefficient indicates that BAP and σ_p are highly rank correlated: The coefficient for the entire sample is 0.991, significantly greater than zero at virtually any confidence level.

The high rank correlation is encouraging, but BAP should pass more rigorous tests if it is to be the foundation for a simple yet precise capital standard. In particular, BAP should be roughly proportional to the theoretical portfolio composition factor P, that is $P \approx \beta\mathrm{BAP}$. The portfolio standard deviation σ_p then would be approximately equal to $\sigma\beta\mathrm{BAP}$, from equation (9). Thus, in a regression of the form:

$$(17) \qquad (\sigma_p)_{it} = \alpha + \sigma\beta BAP_{it} + \varepsilon_{it}\,,$$

goodness-of-fit should be high and the coefficient β should be measured with little error; for BAP to be proportional to σ_p, the coefficient α should equal zero. In addition, it may be desirable for β to be stable across subperiods. If those conditions are satisfied, then BAP is a simple, proportional, and relatively precise measure of foreign exchange portfolio risk. For estimation, the exchange rate standard deviation σ is replaced with the average standard deviation, averaged across the major foreign currencies for each subperiod. Denoting the variance-covariance matrix for subperiod t as Σ_t, the average volatility is computed as the square root of the average variance for each subperiod, or $\bar{\sigma}_t = \sqrt{\mathrm{trace}(\Sigma_t)/6}$. Setting a capital standard then requires an estimate of $\bar{\sigma}$, but this average volatility is constant across banks, and in practice developing a representative estimate should not be hard. A coverage ratio of γ would be achieved by setting a minimum capital ratio of $c = \gamma\bar{\sigma}\beta$.

Two types of heteroskedasticity are likely in estimating (17). One is related to the scale of bank portfolios: the error variance is likely to be higher for larger portfolios. A simple correction for scale-related heteroskedasticity is to divide through by BAP before estimating, creating a transformed equation with errors that are no longer proportional to BAP. The second type relates to the subperiods used to estimate the matrices of exchange rate variances and covariances: In theory, the ability of BAP to match P depends on ρ for a given number of currencies, and exchange rate correlation coefficients vary across the two-year subperiods. This second source of heteroskedasticity is handled through weighted least squares estimation, allowing the variance of the regression residuals to vary across subperiods.

With the correction for scale-related heteroskedasticity, the equation to be estimated is:

$$(18) \qquad \frac{(\sigma_p)_{it}}{\mathrm{BAP}_{it}} = \alpha\frac{1}{\mathrm{BAP}_{it}} + \bar{\sigma}_t\beta + u_{it}\,,$$

where i is an index for the portfolio, t indexes the sample subperiod, and $u_{it} = \varepsilon_{it}/\mathrm{BAP}_{it}$. Estimation results are shown in the first column of Table 3, with standard errors reported in parentheses below each coefficient. $\bar{R}^2$ is the usual goodness-of-fit statistic corrected for degrees of freedom, and the sum of squared residuals is reported as SSR.[17]

The results show that most of the conditions for use of BAP as the basis for a capital standard are satisfied (intertemporal stability is addressed separately below). The estimate of α is insignificantly different from zero and

16. The obvious drawback to this approach is that banks' decisions regarding foreign exchange exposures may depend in part on the variance-covariance matrix of exchange rates. The empirical importance of this problem is left as an issue for future testing.

17. The same regression was run without division by BAP, yielding coefficient estimates that were qualitatively similar to those reported in the table. Inspection of the residuals from both regressions indicated that scale-related heteroskedasticity was in fact an issue in the untransformed regression, and that dividing each observation by BAP largely eliminated the problem.

TABLE 3

ESTIMATION OF EQUATION (18)

	(1)	(2)
α	0.01	—
	(0.01)	—
β	0.88	0.89
	(0.01)	(0.01)
$\bar{R}^2$	0.970	0.971
SSR	14.70	14.94

the standard error of β is relatively small, so σ_p can be assumed proportional to BAP with relative impunity (given $\bar{\sigma}$). The fit of the regression as measured by the adjusted R^2 is high, perhaps remarkably so considering the simplicity of the BAP approach for measuring market risk. The second column presents the results with the intercept restricted to zero to illustrate the relatively minor effect on β of forcing σ_p to be proportional to BAP.

In equation (18) and Table 3, the slope and the intercept of the relationship between BAP and the portfolio variance are restricted to be the same in each of the sample subperiods. These restrictions on the coefficients must be relaxed if the stability of β is to be evaluated. An alternative regression is:

$$\text{(19)} \quad \frac{(\sigma_p)_{it}}{\text{BAP}_{it}} = \sum_{t=1}^{6} \alpha_t \frac{1}{\text{BAP}_{it}} + \sum_{t=1}^{6} \bar{\sigma}_t \beta_t + u_{it}$$

In this form, restrictions on the coefficients α_t and β_t can be tested with standard F tests.

Table 4 shows the estimation results for equation (19). In the first column, both intercept and slope are allowed to differ for each subperiod. (In effect these are six separate regressions, one for each period, since the error variances also differ across subperiods.) None of the intercepts is significantly different from zero at the 5 percent level. The slope coefficients range from 0.82 for the 1985–1986 period to 0.94 for the 1981–1982 period. In the second column of the table, β is restricted to be the same for all subperiods. The restricted coefficient estimate is 0.88; in this form, α is significantly different from zero for the 1981–1982 and 1989–1990 subperiods. An F test of the β restrictions yields a test statistic of 2.91, with 5 and 180 degrees of freedom; this value lies between the 95th percentile of the F distribution (2.26) and the 99th percentile (3.12). Thus, although β is not truly stable, it is not terribly unstable. Additional testing reveals that the 1983–1984 and 1985–1986 periods are statistically different from the other subperiods; an F test fails to reject the hypothesis that β takes one value (0.82) for 1983–1986, and a second value (0.93) for the remainder of the sample. The fact that even the statistically different coefficients for the 1983–1986 period are in the rough vicinity of the other estimates suggests that the Basle approach may be workable.

TABLE 4

ESTIMATION OF EQUATION (19)

	NO RESTRICTIONS	β RESTRICTED	α RESTRICTED
α_{81-82}	0.03	0.04	0.01
	(0.02)	(0.02)	(0.01)
α_{83-84}	0.00	−0.01	0.01
	(0.01)	(0.01)	(0.01)
α_{85-86}	0.00	−0.01	0.01
	(0.02)	(0.02)	(0.01)
α_{87-88}	0.02	0.03	0.01
	(0.01)	(0.01)	(0.01)
α_{89-90}	0.03	0.04	0.01
	(0.02)	(0.01)	(0.01)
α_{91-92}	−0.02	−0.01	0.01
	(0.02)	(0.02)	(0.01)
β_{81-82}	0.94	0.88	0.96
	(0.04)	(0.01)	(0.04)
β_{83-84}	0.83	0.88	0.82
	(0.03)	(0.01)	(0.03)
β_{85-86}	0.82	0.88	0.81
	(0.03)	(0.01)	(0.02)
β_{87-88}	0.92	0.88	0.93
	(0.03)	(0.01)	(0.03)
β_{89-90}	0.94	0.88	0.95
	(0.04)	(0.01)	(0.03)
β_{91-92}	0.91	0.88	0.89
	(0.04)	(0.01)	(0.04)
$\bar{R}^2$	0.961	0.970	0.959
SSR	12.66	13.69	13.22

The third column of Table 4 shows the effects of restricting the intercept across subperiods. As would be expected from the first column of the table, an F test does not reject this restriction. The restricted intercept is not significantly different from zero, making a BAP-based proportional capital standard feasible. The primary conclusion from the regressions is that BAP is approximately proportional to P. The F tests imply that the factor of proportionality β is fairly stable over time, and that the value of P is typically about 80 to 95 percent of BAP.

One concern in moving from equation (19) to the construction of practical capital standards is that β is the factor of proportionality between P and BAP, whereas the ratio of σ_p to BAP at time t is actually $\overline{\sigma}_t\beta_t$. Thus, evidence that β_t is fairly stable might be of limited relevance, since the combination $\overline{\sigma}_t\beta_t$ may not be. Additional regressions were run with $\overline{\sigma}_t$ set equal to 1.0 in both (18) and (19), a restriction which effectively forces the coefficient β to incorporate the effects of exchange rate volatility σ, and therefore permits direct tests of the stability of $\overline{\sigma}_t\beta_t$. The results were not materially different from Tables 3 and 4, and so are not reported; goodness-of-fit was comparable, the intercepts were still insignificant, and the stability results for the slope coefficient were the same. As would be expected, the values of the β coefficients were higher, reflecting the fact that they include a $\overline{\sigma}$ factor that averages 1.46 over the entire sample period.

Using the restricted estimate of $\beta = 0.88$, the portfolio standard deviation is $\sigma_p \approx 0.88\overline{\sigma}$BAP. Based on the average $\overline{\sigma}$, capital equal to 1.28 percent (88 percent of 1.46) of the typical bank's BAP is sufficient to cover one standard deviation of changes in the value of the bank's aggregate foreign currency portfolio. If three standard deviations of coverage is considered desirable (a level which would cover all but 0.13 percent of the probable losses under a normal distribution), then the minimum capital ratio should be 3.85 percent of BAP. The Basle Committee has proposed applying an 8 percent ratio to BAP. Even taking the highest estimate of β from Table 4 (0.96 from the 1981–1982 subperiod with α restricted) and the highest $\overline{\sigma}_t$(1.86 percent for 1985–1986), three standard deviations of coverage would correspond to a 5.36 percent capital ratio. Under these extreme assumptions, 8 percent capital provides about 4.5 standard deviations of coverage. Thus, while BAP appears to be a reasonably precise measure of risk, the proposed level of capital coverage appears to be very conservative. Such an apparently excessive degree of coverage might be justified as compensating for errors in the BAP approximation. Alternatively, regulators may want to allow for non-normality in the statistical distribution of exchange rate changes; stochastic processes may incorporate discrete random jumps, or distributions may be leptokurtic (fat-tailed).

IX. SOME COMMENTS ON THE OTHER MARKET RISKS

A similarly detailed analysis of the equity and traded debt (or interest rate) components of the Basle Committee's market risk proposals is beyond the scope of this paper, and is deferred for future research. However, a few observations can be made about particular aspects of these other drafts.

As noted in Section V, the Basle proposal for equity price risk gives gross exposure less weight in diversified portfolios than in undiversified portfolios. The analysis in Section VII indicates that this difference in weighting may be appropriate: For WAP to approximate P, NAP should get more weight relative to GAP when the number of positions is large. (Recall from (16) that w_n^*/w_g^* increases with N.) The equity proposal also gives GAP less relative weight than it is given in the foreign exchange proposal. Such a difference in weights is appropriate if the number of different issues in a diversified portfolio of equities is larger than the number of currencies in a typical bank currency portfolio, a reasonable assumption. Finally, calculations of return variances for the 30 stocks in the Dow Jones Industrial Average indicate that stock returns tend to be more volatile than exchange rate changes. Thus the higher coverage levels implicit in the equity proposal may be desirable (the composite capital weights on GAP and NAP are 4 percent and 8 percent respectively for diversified portfolios, and 8 and 8 for undiversified portfolios, compared to 4 percent and 4 percent for foreign exchange).

The traded-debt-instruments proposal also seems at least superficially in accord with the conceptual model. As discussed in Section V, the netting/disallowance process in the proposal effectively applies WAP in stages. WAP is a simple measure of portfolio risk for any portfolio, including sub-portfolios of, for example, Zone 2 (medium-term) securities. Thus, this proposal can be construed as an attempt to compute simple but accurate measures of position for various sub-portfolios, then combine these in a building-block approach to obtain a measure of total interest rate risk for the debt portfolio. In practice, the traded-debt framework may provide a better measure of risk than either the foreign exchange or the equity market risk components; both of those proposals use a single pair of weights on gross and net exposures for all portfolios, whereas the debt proposal in effect permits some flexibility in the NAP/GAP weighting. Allowing the weights to vary somewhat according to the composition of a bank's debt portfolio could provide superior results. Another desirable feature of the proposal is that differing volatilities of maturity bands are recognized directly, through the premultiplication by risk weights; in contrast, the foreign exchange proposal does not account for the fact that some exchange rates tend to vary more than others.

As equation (5) shows, the weights on gross and net in the interest rate risk proposal are determined by the disallowance factors; higher disallowance factors give relatively more weight to GAP versus NAP. Section VII indicates that an emphasis on GAP is desirable if the correlations between instruments in a portfolio (or subportfolio) are low. The Basle Committee's proposed disallowance factors are lowest within maturity bands, somewhat higher across bands within a single zone, and higher still across zones, with the highest disallowance factor (1.5) applying to netting between the short-term and long-term zones. These differences appear to correspond to the empirically observed pattern of correlations between interest rate changes across the term structure. Thus, the general pattern of disallowances seems roughly appropriate, although a more confident conclusion would require careful analysis of the entire proposal.[18]

Future research should consider applying regression analysis to both the equity and interest rate proposals, as was done in this paper for empirical analysis of the foreign exchange proposal. One difficulty is that data on bank positions with respect to these other market risks are inferior to the FFIEC 035 currency data. Central banks in various countries have done some confidential analyses of this type.

X. Conclusion

The recent proposals from the Basle Committee for incorporating market risks into risk-based capital standards are coherent and sensible, embodying a unified underlying theme: The minimum adequate level of bank capital is computed as a ratio of capital to risk exposure, with exposure measured as a weighted sum of gross and net positions from a hypothetical composite portfolio for each bank. The conceptual model developed in this paper suggests that this approach can produce capital standards that are reasonably accurate, and at the same time are simple enough to be practical. A weighting of gross and net exposures (the WAP approach) can be viewed as an affine approximation (the equivalent of linear in several dimensions) to the true portfolio variance, and hence can link capital standards fairly tightly to portfolio risk in order to prevent failure probabilities from reaching excessive levels. A system based on a weighted root sum of squares of gross and net would be more precise, but also more complex.

Empirical testing of the foreign exchange proposal was based on exchange rate data for the six major non-U.S. currencies from 1981–1992 and a recent sampling of actual U.S. bank currency positions. The results indicate that the measurement framework proposed by the Basle Committee tracks foreign exchange rate risk remarkably well, capturing over 95 percent of the total variation in foreign exchange risk across the sample of banks. However, the level of coverage implicit in the 8 percent capital ratio may be somewhat high.

Conclusions regarding the equity price risk and interest rate risk proposals are tentative, since a detailed empirical analysis was not conducted in this paper. However, an initial reading of the other two market risk proposals against the background of the conceptual model suggests that they incorporate a number of appealing features.

Unfortunately, neither the common thread running through the market risk proposals nor the desirable properties of the WAP approach have been articulated clearly in the consultative documents released for public comment. The equity risk proposal is the only one of the three that explicitly describes the capital charge as a weighting of gross and net exposures, and that presentation is muddied by a discussion of "general risk" and "specific risk" that has little to do with the analytical merits of WAP. The interest rate risk proposal, as described above, uses a system of netting with "disallowances" to accomplish the weighting, which obscures the fact that the proposal is fundamentally a WAP calculation. The foreign exchange draft does point out that the proposal reflects the assumption of "some, but not perfect, correlation between the movements of different exchange rates" (Basle Committee, 1993, p.39). However, the aggregate foreign exchange position calculation is described as "the sum of the short positions or the sum of the long positions, whichever is the greater" (*ibid*, p.38); as shown in Section IV, this is equivalent to equally weighted WAP, but the equivalence may not be obvious.

The Basle Committee is international, and the proposed standards are to apply internationally. This paper evaluates

18. Federal banking regulators in the United States have proposed a somewhat different approach to measuring interest rate risk for capital adequacy. The U.S. proposal is similar to the Basle proposal in the construction of a hypothetical portfolio broken into time bands, and the use of risk weights based on potential changes in the value of debt instruments when rates change. However, the U.S. proposal makes no use of "disallowance factors," implicitly setting δ to zero. As demonstrated above, $\delta = 0$ makes WAP equivalent to NAP, with no weight on gross exposure; this is in effect the approach taken by U.S. regulators, with long exposures in any time band netted against short exposures in any other band. As also shown above, NAP is the correct measure if $\rho = 1$, that is, if rates in all time bands are perfectly correlated. The Basle approach using disallowances can be viewed as a simple way to incorporate the fact that correlations across the yield curve are not perfect.

the proposals solely from a U.S. perspective; results for other countries might differ. Parallel analyses have been, and continue to be, pursued at other central banks around the world. Obviously, the final form of the market risk standards will be the result of international negotiation and agreement, and agreement will depend on how well the proposals meet the needs of the many countries involved. The Basle Committee also has suggested that the standards could be applied to other types of financial firms, such as securities houses and insurance companies, if regulators in those industries agree. Introducing an interindustry dimension adds to the challenge of reaching a consensus, and complicates any complete analysis of the market risk proposals.

As a final note, throughout the Basle documents (and this paper) each of the many types of risk—including credit risk, exchange rate risk, equity price risk, and interest rate risk—is considered and treated separately from the others. Such a presumption of separability may not be realistic in view of the likely interactions among these various sources of risk. Ideally, capital regulations should consider all types of risk simultaneously in a unified framework. However, breaking the capital adequacy problem into more manageable pieces may be the only practical approach, and separability may be a workable approximation. The possible damage done by this assumption should be the subject of future research.

APPENDIX

This appendix describes one of a number of ways to demonstrate the transition from equation (6) to equation (7) in the text. The variance of a portfolio of N currencies with equal variance and correlation, slightly modified from (6), is:

$$\text{(A1)} \quad \sigma_p^2 = \sigma^2 \sum_{i=1}^{N} d_i^2 + 2\sigma^2\rho \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} d_i d_j \, .$$

The crux is evaluation of the summation terms. Note that by assumption each of the d_i is either d (for long positions) or $-d$ (for shorts). Clearly $d_i^2 = d^2$ for either type of position, so the first summation is simply d^2N.

The second term involves the double summation of products of positions in all pairs of foreign currencies. The total number of pairings in a set of N objects is $N(N-1)/2$, so this is the total number of $d_i d_j$ terms. These terms fall into three groups:

Both currencies long: $d_i d_j = d^2$
Both currencies short: $d_i d_j = d^2$
One long, one short: $d_i d_j = -d^2$

If the positions were either all long or all short, then the terms in the double summation would sum to $d^2N(N-1)/2$. However, by assumption there are n short positions and $N-n$ long positions. The number of pairings of x objects with y objects is xy; hence the number of short-long pairs is $n(N-n)$. It follows that the number of $d_i d_j = d^2$ pairs is not the maximum number $N(N-1)/2$, but rather $N(N-1)/2 - n(N-n)$. In addition, of course, each of the $n(N-n)$ positions with opposing signs contributes $d_i d_j = -d^2$ to the sum. Hence:

$$\text{(A2)} \quad \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} d_i d_j = d^2 \left(\frac{N(N-1)}{2} - n(N-n) \right) - d^2 n(N-n) \, .$$

Substituting this into the expression for the portfolio variance in (A1) gives:

$$\begin{aligned} \text{(A3)} \quad \sigma_p^2 &= \sigma^2 d^2 N + \sigma^2 d^2 (N(N-1) - 4n(N-n))\rho \\ &= \sigma^2 d^2 N + \sigma^2 d^2 ((N-2n)^2 - N)\rho \\ &= \sigma^2 d^2 N \, (1-\rho) + \sigma^2 d^2 (N-2n)^2 \, \rho \end{aligned}$$

as asserted in the text.

REFERENCES

Basle Committee. 1993. *The Supervisory Treatment of Market Risks: Consultative Proposal by the Basle Committee on Banking Supervision* (April). Basle, Switzerland, April.

Bhala, Raj. 1989. *Perspectives on Risk-Based Capital: A Guide to the New Risk-Based Capital Adequacy Rules.* Bank Administration Institute.

Levonian, Mark, and Sarah Kendall. 1993. "A Contingent Claim Analysis of Risk-Based Capital Standards for Banks." Research Discussion Paper #9302. Reserve Bank of Australia.