Netting Agreements and the Credit Exposures of OTC Derivatives Portfolios

by Darryll Hendricks

Recent years have witnessed substantial growth in over-the-counter (OTC) derivative transactions, much of it concentrated in interest rate and cross-currency swap agreements. The rapid expansion of this market has necessarily given rise to credit risk concerns, particularly among the large, internationally active commercial banks that are dealers in OTC derivatives. Although rates of contract default have been quite low to date, both market participants and their supervisory authorities are eager to identify strategies for managing the credit exposures associated with OTC derivatives.

One strategy developed by dealer institutions is the use of bilateral closeout netting agreements. A bilateral closeout netting agreement is a legally binding agreement between two parties (customarily referred to as counterparties) stipulating that if one counterparty defaults, legal obligations arising from derivative transactions covered by the netting agreement must be based solely on the net value of such transactions. With a valid bilateral closeout netting agreement in place, a counterparty cannot simultaneously default on negatively valued derivative contracts while also continuing to demand payments on positively valued derivative contracts.

This article examines the effectiveness of bilateral closeout netting agreements in reducing the credit exposures associated with OTC derivatives. Particular attention is given to the difficult issue of whether netting agreements reduce potential credit exposures, a credit risk concept largely unique to OTC derivative transactions.

The article finds that potential credit exposures can be reduced on average by the adoption of netting agreements. The agreements dampen fluctuations in the volatility of credit exposures, thereby reducing the volatility of these exposures on average, although not at every point in time. The decreased volatility of credit exposure on average in turn leads to a reduction in potential credit exposure on average.

The article's first section explains the concept of potential credit exposure and its treatment by international bank supervisors under the Basle Accord. This background leads to a discussion of the magnitude of U.S. commercial banks' credit exposures to OTC derivatives.

Credit exposures for OTC derivatives

Credit risk is perhaps the predominant risk faced by all banking institutions. Indeed, with many traditional banking activities such as lending, credit risk engendered by the possibility of borrower default is the primary risk facing the bank. Derivative transactions can also lead to credit risk since one of the two counterparties will very likely have to make payments to the other under the terms of the contract.

Interest rate swaps

Interest rate swaps, the largest single class of OTC derivative contracts, provide a useful example of the risks of derivative transactions.[1] The swaps are typically structured and priced so that no exchange of funds accompanies the initiation of the contract. Over the life of the contract (which can range from a few months to many years), however, one side or the other will often be required to make payments under the terms of the contract. For example, a so-called plain vanilla interest rate swap obliges the counterparties periodically to swap the difference between a contractually

[1] Although this article focuses on interest rate swaps, the arguments presented here also apply to many other derivative instruments.

determined fixed interest rate and a floating rate of interest (commonly six-month LIBOR) multiplied by a notional amount of principal. Thus one of the counterparties assumes the role of fixed rate payer and floating rate receiver, while the other counterparty acts as the floating rate payer and fixed rate receiver.

Many interest rate swaps specify that payments be made semiannually. If floating rates have risen above the contractually specified fixed rate, then the floating rate payer will make a payment to the floating rate receiver based on this differential. In this instance, a default by the floating rate payer will lead to a credit loss by the floating rate receiver. If no recovery is possible, the total credit loss will not consist simply of the amount of the next payment due under the terms of the swap contract but will equal the present value of the net interest payments over the remaining life of the contract.[2] This amount is termed the *replacement cost* of the derivative contract.

Current credit exposure

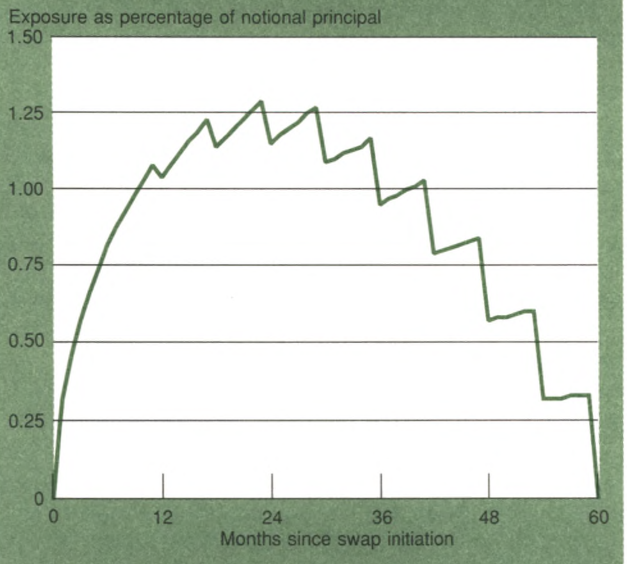
The replacement cost of a derivative contract is the appropriate measure of the credit loss resulting from the default of one's counterparty. If the derivative contract has a positive market value to the nondefaulting counterparty, then the replacement cost of the contract will equal this market value, since this is the amount that counterparty would have to pay in the market to obtain a derivative contract with the same terms. Note, however, that if default occurs on derivative contracts with negative market values to the nondefaulting counterparty, then that counterparty is typically *not* free to walk away from these transactions and reap a windfall gain.[3] This condition implies that the replacement cost of a derivative contract is equal to the greater of zero and the current market value of the contract.

In the absence of closeout netting agreements, the *current credit exposure* of a portfolio of derivative contracts therefore equals the sum of the replacement costs of those contracts. Current credit exposure, however, only provides a snapshot of credit exposure at a single point in time. The nature of derivative contracts is such that their market values can fluctuate substantially, even over relatively short periods of time. Chart 1 shows the average replacement cost of a five-year interest rate swap over its lifetime.[4] On average, replacement costs are pushed upward over time by the divergence of interest rates from the levels prevailing at the initiation of the swap. This effect is eventually overtaken, however, by the semiannual transfers of payments required by the swap, because the fewer the remaining payments, the lower the remaining credit exposure. The combination of these two effects produces the characteristic shape of an interest rate swap pictured in Chart 1.

Two important points emerge from Chart 1. First, the average credit exposure of an interest rate swap is typically a small percentage of the notional amount of the swap; at its maximum, the average exposure is only slightly above 1.25 percent of the notional amount. Second, swap credit exposures can fluctuate considerably over time, particularly when these changes are measured on a percentage basis. For example, a given swap's exposure can easily rise by 25 percent or more over a six-month period.[5] In fact,

Chart 1

Average Replacement Cost Profile for Five-Year Interest Rate Swap



Notes: The chart is generated from 5000 simulations of a matched pair of interest rate swaps. The interest rate model used in the simulation is taken from Francis A. Longstaff and Eduardo S. Schwartz, "Interest Rate Volatility and the Term Structure: A Two-Factor General Equilibrium Model," *Journal of Finance*, September 1992, pp. 1259-82. Although the volatility of the short rate in this model is variable, it averages approximately 175 basis points per year in absolute terms.

[2] In certain yield curve environments (for example, when the yield curve is steeply declining), the pay-floating side of the swap could have a positive market value even if the floating rate currently exceeds the fixed rate. In this case, the floating rate payer has credit exposure to the floating rate receiver.

[3] Contract provisions that do allow such gains are known as limited two-way payments provisions or walkaway clauses. The latest Basle Supervisors' Committee proposal (April 1993) would prohibit contracts with this feature from being eligible for the reduced capital treatment associated with netting.

[4] Chart 1 is generated from 5,000 simulations of a matched pair of five-year interest rate swaps. Although the volatility of the short rate in this model is variable, it averages approximately 175 basis points per year in absolute terms.

[5] Observe that the average exposure rises from approximately 0.75 percent of the notional amount six months from inception to over 1.00 percent of this amount twelve months from inception, a percentage increase of 33 percent.

this type of rapid change in credit exposure is even more common than Chart 1 suggests, since the chart only shows what happens on average. Moreover, the capacity for rapid changes in credit exposures is a feature of derivatives generally, not simply of the interest rate swap that is used here as an example.[6]

Potential credit exposure

Because the credit exposure of derivatives can fluctuate dramatically, measuring current exposure at a single point in time is not the most prudent approach to assessing the credit exposure of an OTC derivatives portfolio. Accordingly, both market participants and supervisors have chosen to use the concept of *potential credit exposure* to measure the possibility of increases in current credit exposure over a fixed time horizon. That is, the potential exposure of a portfolio measures how much the current credit exposure of that portfolio could increase over some period of time in the future. A commonly used time horizon for this purpose is the six-month period extending from the point in time when current credit exposure is measured.

Clearly one cannot predict precisely how the credit exposure of a portfolio will evolve over time, since exposures are tied to unpredictable movements in underlying market factors. It is possible, however, to use economic simulation models to estimate reasonable upper bounds for increases in current credit exposures. These upper bounds are frequently expressed in terms of a statistical degree of confidence—that is, a confidence level of 95 or 99 percent. In using these terms, a market participant is estimating that a larger credit exposure will occur only 5 percent or 1 percent of the time, respectively, given the built-in assumptions about the probability distribution of the market interest rates or other factors.

In a 1993 study of derivatives, the Group of Thirty recommended that "dealers and end-users...measure credit exposure on derivatives in two ways: (1) current exposure... and (2) potential exposure, which is an estimate of the future replacement cost of derivative transactions."[7] The inclusion of this recommendation in a study prepared with substantial help from market participants confirms that market participants recognize the importance of potential exposure.

International banking supervisors have also recognized the need to measure potential credit exposures for OTC derivatives and to hold capital against the credit equivalent amounts of OTC derivatives, including the potential exposure portion. The 1988 Basle Accord includes an approach to measuring the total credit exposure of OTC derivatives based on the sum of current credit exposure and potential credit exposure.[8] The Accord specifies a procedure for calculating an amount (commonly known as the "add-on") to cover potential credit exposure. This procedure involves multiplying the notional amount of the derivative contract by a factor that depends on the remaining maturity of the contract and the type of underlying security (Table 1).

Derivatives and credit exposure: empirical estimates

Using the Basle framework, it is possible to provide some indication of the magnitude of the current and potential credit exposures associated with OTC derivatives. Chart 2 plots the growth in OTC derivative activity by U.S. commercial banks as measured by total notional amounts on a quarterly basis. Chart 3 plots the current credit exposures and add-ons (to cover potential credit exposure) for the same sample of institutions over the same time period. Note that the trends in notional amounts are not always identical to the trends in credit exposures.

The aggregate current credit exposure of U.S. commercial banks to OTC derivatives was approximately $143 billion as of December 31, 1993. Approximately $60 billion was also assessed under the Basle Accord on this date as the aggregate add-on charge for the coverage of potential credit exposure.[9]

Evidence in Chart 3 suggests that the add-on charges performed well during the period from the end of the first

[6] Other contract types can have very different exposure profiles than that shown in Chart 1. The cross-currency swap, for example, has an average replacement cost profile that rises throughout its life.

[7] Group of Thirty, *Derivatives: Practices and Principles, Recommendations* (Washington D.C., 1993), p. 13.

[8] Basle Supervisors' Committee, *International Convergence of Capital Measurement and Capital Standards* (Basle, Switzerland, July 1988). The Basle Committee on Banking Regulations and Supervisory Practices comprises representatives of the central banks and supervisory authorities of the Group of Ten countries (Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Sweden, the United Kingdom, and the United States), Switzerland, and Luxembourg. The Committee meets at the Bank for International Settlements, Basle, Switzerland.

[9] Note that these amounts are exposure figures, not the capital amounts required to be held against these exposures. Under the Basle framework, required capital for these transactions is equal to 8 percent of the total exposure multiplied by a risk weight that depends on the type of counterparty.

Table 1

How the Basle Accord Measures Potential Credit Exposure

Remaining Maturity of Contract	Interest Rate Contracts (Percent of Notional)	Foreign Exchange Contracts (Percent of Notional)
<1 year	0.0	1.0
≥1 year	0.5	5.0

Notes: The total credit exposure on a derivative contract is equal to the current credit exposure plus the potential credit exposure. The Basle Accord measures potential credit exposure by multiplying the notional amount of the contract by the factors shown in the table. The specific factor used depends on the type of contract and its remaining maturity.

quarter of 1992 until the end of the third quarter of 1992. That is, current credit exposure increased significantly over each quarter during this period, but not by an amount larger than that already covered by the add-ons at the end of the previous quarter.[10]

Note too that $135 billion of the $143 billion in current credit exposures could, according to Call Report data, be found in ten large institutions as of December 31, 1993. In other words, 94 percent of all current credit exposures to off-balance-sheet derivatives among U.S. commercial banks were concentrated in ten large dealer banks.[11] Although supervisors will obviously monitor all institutions regardless of size, this figure does imply that measures mitigating the credit exposures of dealer institutions will have a very significant impact on aggregate credit exposures.

Closeout netting agreements: Introduction

Closeout netting agreements provide for the exchange of a single net closeout amount for all covered transactions when one counterparty defaults on its derivatives contracts. Closeout netting is now a standard provision in many of the contracts and master agreements that serve as legal documentation for OTC derivative transactions, including the widely used 1992 International Swaps and Derivatives Association Master Agreement.

In April 1993, the Basle Supervisors' Committee released for consultation a proposal that would allow institutions to take bilateral closeout netting agreements into account when calculating current credit exposures.[12] If adopted, this proposal should substantially reduce the magnitude of current credit exposures reported by institutions that participate actively in the OTC derivative market.

Gross exposure vs. net exposure

To see how closeout netting agreements can reduce current credit exposures, consider the following example. A very simple portfolio consists of three contracts, all with the same counterparty (Table 2). Two of the contracts currently have positive market value, while one contract has a negative market value. In the absence of a closeout netting agreement with this counterparty, the applicable measure

[10] Some of the increase in exposures can be attributed to newly initiated instruments, but new instruments often have minimal exposures near the beginning of their lives. Thus, much of the increase in exposure can reasonably be traced to changes in market risk factors (for example, interest rates and exchange rates).

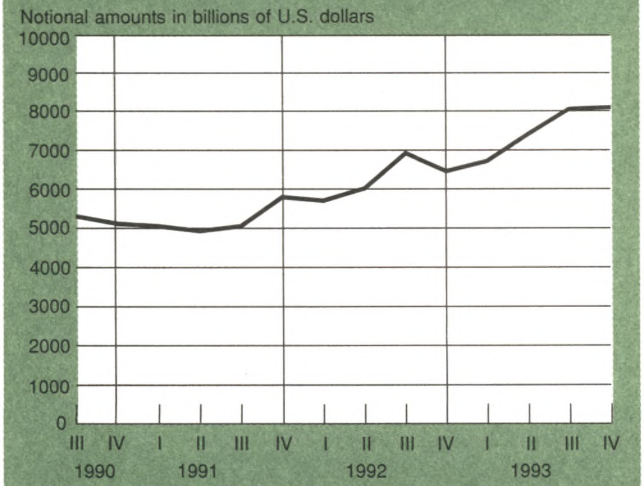
[11] For purposes of comparison, note that the on-balance-sheet loan exposure of these ten institutions was a combined $431 billion as of December 31, 1993.

[12] Basle Supervisors' Committee, *The Supervisory Recognition of Netting for Capital Adequacy Purposes* (Basle, Switzerland, April 1993).

Chart 2

Total Notional Amounts of Off-Balance-Sheet Derivatives for U.S. Commercial Banks

End-of-Quarter Data

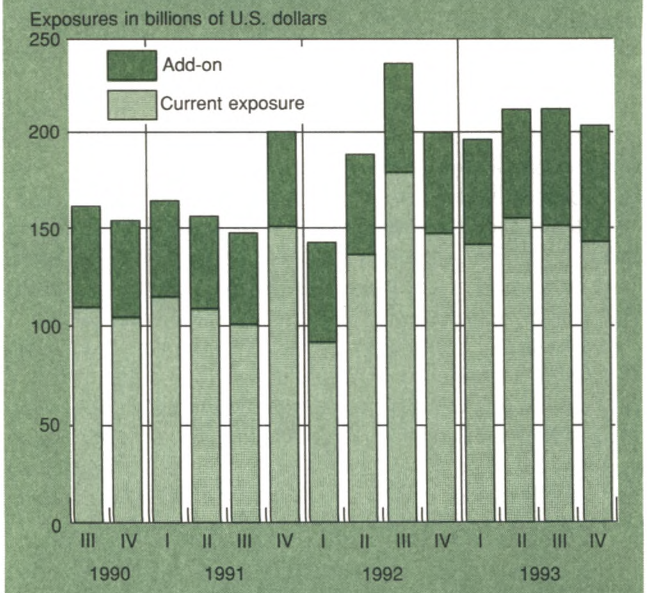


Source: Federal Financial Institutions Examination Council, Reports of Condition and Income, Schedule RC-R.

Chart 3

Credit Exposures of Off-Balance-Sheet Derivatives for U.S. Commercial Banks

End-of-Quarter Data



Source: Federal Financial Institutions Examination Council, Reports of Condition and Income, Schedule RC-R.

of current credit exposure is the *gross exposure,* which is simply the sum of the replacement costs of the three contracts. The replacement cost of the interest rate swap in this example is zero, since this contract currently has a negative market value. The gross exposure of the portfolio is therefore $30 million.

If a valid closeout netting agreement with this counterparty is in place, however, then *net exposure* is the relevant measure. The net exposure of a portfolio is equal to the sum of the market values of all contracts covered by the netting agreement or zero, whichever is greater. In this example, the sum of the market values (or net portfolio value) is $15 million (10 + 20 - 15). Since this is a positive number, the net exposure of the portfolio is also $15 million. If the sum of the market values had been negative, then the net exposure would have been zero.

Net exposure must, by definition, be no greater than gross exposure. The gross exposure can be thought of as the sum of some number of positive values, while the net exposure will equal the sum of these same positive values as well as some number of negative values. In fact, evidence in the International Swaps and Derivatives Association's public comment on the April 1993 Consultative Proposal indicates that adoption of the proposed revision to the Basle Accord could reduce the magnitude of the reported current credit exposures for dealer institutions by as much as 50 percent.[13] If the add-ons for potential exposure remain unchanged (as would be the case under the April 1993 proposal), then large reductions in the current exposure portion will necessarily imply an increase in the fraction of total exposure that is intended to capture potential exposure.

Do netting agreements reduce potential credit exposures?
Market participants have argued that closeout netting also reduces potential exposure and, consequently, that the add-ons should be reduced to reflect the full benefits of closeout netting. To understand the basis for this claim, recall from the previous section that the need to cover potential exposure arises from the volatility of current credit exposures. That is, larger add-ons are necessary when the volatility of current credit exposures is higher. It may appear that reducing the level of current credit exposures by calculating current exposure on a net basis rather than a gross basis will decrease volatility as well. In fact, however, the reduction in the level of current credit exposure does not guarantee that the volatility is also reduced.

Chart 4 illustrates two possible cases: in one, the intuition about the reduction in volatility is valid, but in the other it is not. The topmost line plots the gross current credit exposure of a hypothetical portfolio over time. The other two lines provide examples of the possible behaviors of the net current exposure of the portfolio. In case A, represented by the solid line, net exposures are lower on average than gross exposures but are approximately equally volatile. That is, the fluctuations in net exposure are nearly as large as the fluctuations in gross exposure. In case B, represented by the dashed line, net exposures are not only lower on average than gross exposures, but are also much less volatile in that the fluctuations of net exposure are significantly smaller than the fluctuations of gross exposure.

Intuition might lead one to believe that case B is closer to the truth than is case A. In fact, however, this issue is substantially more complex than intuition would suggest. The remainder of this article focuses on the factors influencing the volatilities of both net and gross exposures. This analysis can clarify the conditions under which one should expect to observe case A rather than case B and vice versa. This is important because the potential exposure of a portfolio will fall when netting agreements are adopted if and only if the volatility of gross exposures is higher than the volatility of net exposures.

The volatility of net exposure

The net credit exposure of a portfolio of derivative contracts with a single counterparty is equal to either the current market value of the portfolio or zero, whichever is greater. (Unless otherwise indicated, the term portfolio is used in the remainder of the article to refer to a portfolio of contracts with a single counterparty, *not* to the overall portfolio of contracts with all counterparties.) Clearly, then, the

[13] International Swaps and Derivatives Association, *Comment Letter on "The Supervisory Recognition of Netting for Capital Adequacy Purposes"* (New York, December 1993).

Table 2
How Netting Agreements Reduce Current Credit Exposure: An Illustration

Contracts in Portfolio	Value (Dollars)	Replacement Cost (Dollars)
FX forward	10 million	10 million
Interest rate swap	–15 million	0 million
Currency swap	20 million	20 million
Total	Net exposure=15 million	Gross exposure=30 million

volatility of the net credit exposure will be determined primarily by the volatility of the portfolio's market value. If the portfolio's value fluctuates widely over time, then the net exposure of the portfolio can also be expected to fluctuate widely. Thus, a good starting point for the analysis of the volatility of net credit exposures is to identify the factors that influence the volatility of portfolio value.

First, however, let us clarify what is meant by volatility. Although volatility is often measured by calculating variances or standard deviations, the term simply refers to the tendency of a quantity to vary or fluctuate over time. A highly volatile portfolio has a tendency toward large fluctuations in value over short periods of time. In addition, the volatility itself can vary over time. For example, as some derivative contracts mature and others are added, the tendency of the portfolio to fluctuate in value can change.

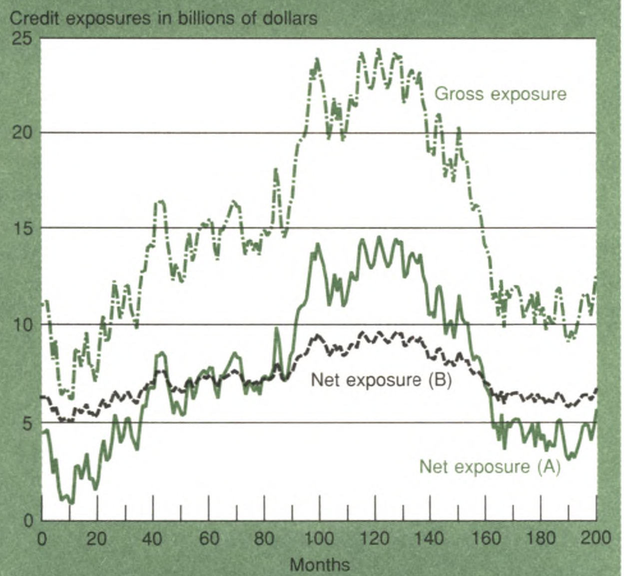
What influences the volatility of portfolio value?

Three factors influence the volatility of a derivatives portfolio: (1) the number and size of the contracts in the portfolio, (2) the volatility of each individual contract, and (3) the extent to which contracts move together in response to changing market conditions. The first of these factors is an obvious one, a simple issue of scale. A portfolio with a large dollar volume of contracts is more likely to experience wide fluctuations in dollar value, all else equal, than a portfolio with a smaller dollar volume of contracts. The importance of the second factor should also be intuitively clear. Portfolios that consist of more volatile contracts (for example, foreign exchange contracts) are more likely to exhibit wide fluctuations in value, all else equal, than portfolios that consist of less volatile contracts (for example, many interest rate contracts).

The last of the three listed factors influencing portfolio volatility may not be so obvious, and yet it may be the most important factor of all. This factor refers to the degree to which different contracts in the portfolio respond similarly to changing market conditions. At one extreme, all contracts in the portfolio are identical and respond identically to all possible changes in market conditions. In this case, the portfolio would be described as highly undiversified. A portfolio of this kind will be susceptible to large fluctuations in value since all portfolio components will respond in tandem to changing market conditions.

Chart 4

Possible Effects of Netting on the Volatility of Exposure



Source: Author's calculations.

Notes: Data are illustrative only. The net exposure A series shows a reduction in mean exposure without a corresponding decrease in the volatility of exposure. The net exposure B series shows a reduction in both the mean and the volatility of exposure.

Diversification and the volatility of portfolio value

A highly diversified portfolio consists of contracts that do not all move identically in response to changing market conditions. Instead, when some contracts increase in value, others will decrease in value, while still others may be completely unaffected. This diversity of responses to changing market conditions dampens the tendency for the value of the portfolio as a whole to fluctuate widely over time. Thus, the greater the diversity of the portfolio, all else equal, the lower the volatility of the portfolio's value. The logic of this point is, of course, familiar to all who are acquainted with modern portfolio theory.

A portfolio consisting entirely of identical derivative contracts can be thought of as *perfectly positively correlated.* Because all of the contracts respond in exactly the same way to changing market conditions, this portfolio is likely to be quite susceptible to large fluctuations in value. An example of such a high-volatility portfolio would be a portfolio consisting entirely of 100 identical pay-fixed interest rate swaps. This portfolio would gain in value substantially if interest rates moved higher, but would fall in value substantially if interest rates declined.

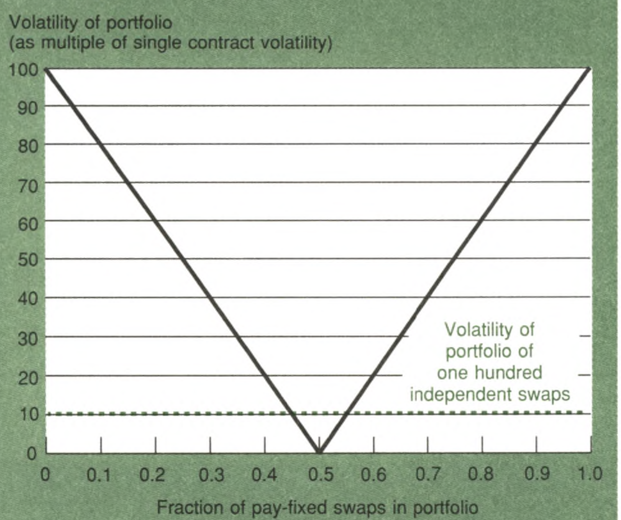
In a *perfectly hedged* portfolio, each contract is matched by another contract that moves in exactly the opposite fashion when market conditions change. For example, imagine a portfolio consisting of fifty identical pay-fixed interest rate swaps and fifty identical pay-floating interest rate swaps. Apart from whether the swaps are pay-fixed or pay-floating, all features of the two sets of swaps are identical. In this case, an increase in interest rates would increase the value of each pay-fixed swap but would decrease the value of each pay-floating swap by an exactly offsetting amount. A decrease in interest rates would have precisely the opposite effect: the pay-floating swaps would gain in value, but the pay-fixed swaps would decline by an exactly offsetting amount. The volatility of this portfolio would be zero because changes in market conditions could not lead to any net change in portfolio value.

In contrast to a perfectly hedged portfolio, an *uncorrelated* portfolio consists of contracts that move independently of one another. That is, given the response of one contract to changing market conditions, the response of the other contracts is equally likely to be the same or to be different. In principle, derivative contracts on completely unrelated market factors would be uncorrelated. In reality, however, all market factors (including interest rates, exchange rates, and commodity and equity prices) are likely to be related to some extent, making it difficult to provide a realistic example of a portfolio that consists of completely uncorrelated contracts.

Nevertheless, an uncorrelated portfolio can be considered quite well diversified because the contracts in this portfolio will have no special tendency to respond similarly to changing market conditions. Therefore, the volatility of an uncorrelated portfolio would be intermediate between that of a perfectly hedged portfolio and that of a perfectly positively correlated portfolio. An uncorrelated portfolio can thus serve as a useful benchmark for the degree of diversity in a derivative portfolio. In other words, it will be helpful to consider whether a given derivatives portfolio is more or less volatile than an uncorrelated portfolio of the same size.[14]

Chart 5

Volatility of Portfolio Value Relative to the Fraction of Pay-Fixed Swaps



Source: Author's calculations.

Diversification and portfolio balance

Chart 5 plots the volatility of the value of a portfolio consisting of 100 interest rate swaps as the proportion of pay-fixed swaps in the portfolio moves from zero to 100 percent. At the left edge of the horizontal axis, the portfolio consists of 100 pay-floating swaps, so that the portfolio in this case is perfectly positively correlated. Note that the volatility of the portfolio achieves its maximum value at this point. This maximum is also achieved, of course, when the portfolio consists of 100 pay-fixed swaps (the rightmost edge of the horizontal axis).

At the exact center of the horizontal axis, the portfolio consists of fifty pay-fixed swaps and fifty pay-floating swaps. At this point, the portfolio is perfectly hedged: changes in the values of the pay-fixed swaps are exactly offset by changes in the pay-floating swaps. The volatility of the portfolio in this case is therefore equal to zero.

Note that as the portfolio becomes more unbalanced (that is, as one moves away from the center), the volatility of the portfolio rises. This observation is consistent with the idea that as the diversity of the portfolio decreases, the volatility increases. The dashed line in Chart 5 plots the volatility of an uncorrelated portfolio of 100 contracts as a benchmark. In fact, it is apparent that the portfolio of swaps must be well balanced to match or exceed the diversity of the uncorrelated portfolio. Specifically, the proportion of pay-fixed swaps in the portfolio must lie between 45 percent and 55 percent for the swap portfolio to have a lower volatility than the uncorrelated portfolio.

Derivatives portfolios of dealer institutions will obviously be more complex than these examples. In fact, dealer portfolios are likely to include a variety of contract types and to be sensitive to a wide array of market factors beyond interest rates. The basic principles of these simple examples carry over, however, to actual trading portfolios. Particularly relevant is the principle that the greater the diversity of the response to changing market conditions, the lower the portfolio's volatility.[15]

The diversity of dealers' portfolios

Evaluating the volatility of a dealer's derivatives portfolio with a given counterparty therefore requires some knowledge of the degree of diversity among the contracts in the portfolio. Consider first a customer counterparty—for example, a nonfinancial corporation attempting to hedge its exposure to higher interest rates. This corporation might

[14] Additional insights into the mathematical properties of portfolio volatility and its relation to the correlations between contracts in the portfolio are provided in the appendix following the text.

[15] See the appendix for arguments that apply to a variety of contract types.

wish to be a fixed rate payer and floating rate receiver. Thus, the dealer will enter into interest rate swaps with the corporation so that the dealer is a fixed rate receiver. If this is the only type of derivative contract that the dealer enters into with this counterparty, then the portfolio will lack diversity and the volatility of the portfolio's value will be high (relative to other portfolios of equal size).

Now consider a portfolio with a dealer counterparty. Many dealer institutions attempt to minimize the market risks of their overall portfolios by entering into transactions that offset the market risks of customer-driven transactions. Thus, a dealer who enters into a pay-floating swap to satisfy customer demand will often enter into a pay-fixed swap with another dealer in order to keep the overall swap book well matched from a market risk perspective. If the demand (across all customers) is more or less evenly split between pay-fixed and pay-floating contracts, then the portfolio of contracts with another dealer will also combine pay-fixed and pay-floating contracts.[16]

If this is the case, then the fraction of pay-fixed contracts in the portfolio with another dealer will average approximately 50 percent. Of course, this fraction will not always be precisely 50 percent; sometimes it may be as high as 65 percent and sometimes as low as 35 percent, for example. Recall that Chart 5 shows substantial differences in portfolio volatility as this fraction changes. Thus, if the fraction is exactly 50 percent, the volatility is likely to be very low, while if the fraction is 35 percent or 65 percent, the volatility is likely to be higher.

If portfolios with dealer counterparties tend to have equal mixtures of both types of swaps over time, then it is reasonable to assume that the volatility of the portfolio value varies within a range matching that of the fraction of pay-fixed swaps in the portfolio. For example, if this fraction ranges between 35 percent and 65 percent, then Chart 5 implies a volatility that can range from a low of zero to a high of approximately thirty times the volatility of a single contract.

The likelihood of observing different proportions of pay-fixed swaps in a portfolio that is balanced on average can be assessed through an experiment.[17] The experiment consists of repeatedly choosing 100 swaps at random, with each type of swap (pay-fixed or pay-floating) equally likely to be chosen. The resulting (binomial) frequency distribution of portfolio compositions is depicted in Chart 6. It is plain that only in a very small percentage of cases will such a portfolio be unbalanced to the point where the proportion of pay-fixed swaps falls below 35 percent or rises above 65 percent. In addition, one can prove that the volatilities of the portfolios produced through this experiment will average ten times the volatility of a single contract. Note that this level of volatility is also precisely the volatility of the uncorrelated benchmark portfolio shown in Chart 5.

To summarize, portfolios with dealer counterparties are likely to have relatively even proportions of both types of swaps (pay-fixed and pay-floating). The maintenance of even proportions in turn reduces the volatility of the portfolio's value. If the proportions are perfectly balanced in the long run but are allowed to fluctuate randomly in the short run, then the amount of portfolio volatility will, on average, equal the volatility of a portfolio of uncorrelated contracts. Of course, dealers may wish to reduce portfolio volatility further by actively managing the portfolios to keep them closely balanced even in the short run.[18]

The volatility of gross exposure

The previous section dealt with the volatility of net exposures by focusing on the factors influencing the volatility of net portfolio value. This section is concerned with the volatility of gross exposures. Recall that gross exposure is the applicable measure of current credit exposure in the absence of netting agreements, so that if the volatility of gross exposures exceeds that of net exposures, the potential exposure of a portfolio will fall when netting is implemented.

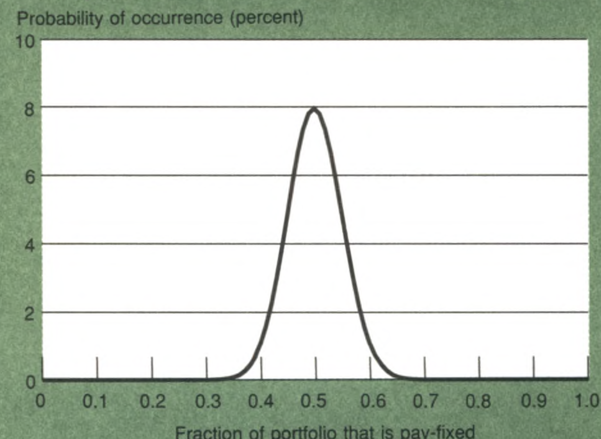
[16] One need not assume that each customer deal is microhedged with an exactly offsetting transaction. The same logic also applies when interdealer transactions are used to hedge the residual exposures resulting from multiple customer transactions.

[17] A portfolio that is balanced on average will not persistently favor one type of swap (pay-fixed or pay-floating) over another. This does not imply perfect balance at every point in time, however.

[18] Chart 5 points up the possible benefits of this strategy. The tighter the fluctuations in the fraction of pay-fixed swaps around 50 percent, the lower the volatility of the portfolio on average.

Chart 6

Probability Distribution of Fraction of Pay-Fixed Swaps in a Portfolio That Is Balanced on Average



Source: Author's calculations of binomial probability distribution.

Gross exposure and in-the-money contracts

While the volatility of net exposure is closely related to the volatility of the portfolio's overall, or net, value, the volatility of gross exposure behaves somewhat differently. To understand this, recall that the calculation of gross exposure essentially ignores all contracts that currently have negative value. Because these contracts, known as out-of-the-money (OTM) contracts, have zero replacement costs, they do not add to or subtract from the gross exposure of the portfolio. Rather, it is only the in-the-money (ITM) contracts that have positive replacement costs and therefore add to gross exposure.

The distinction between ITM and OTM contracts is of crucial importance in assessing the volatility of gross exposure. The reason is that movements in gross exposure will largely be the result of changes in the values of contracts that are currently ITM.[19] The ITM subset of contracts will often differ substantially in composition from the set of all contracts with a given counterparty. In other words, the volatility of gross exposure can differ from the volatility of net exposure because the volatility of gross exposure is influenced by the properties of a special subset of contracts, whereas the volatility of net exposure is influenced by the properties of all contracts with a counterparty taken together.

Although the volatility of gross exposure is affected primarily by the properties of the ITM subset rather than the whole portfolio, it has the same three determinants as the volatility of net exposure: (1) the number and size of the contracts in the ITM subset,[20] (2) the volatility of each individual contract, and (3) the extent to which contracts move together in response to changing market conditions.

The first two of these factors will have much the same influence on gross exposures as on net exposures, but the third factor must be examined more carefully. The extent of diversity among contracts overall may not be a reliable guide to the extent of diversity among the contracts in the ITM subset, as the following example suggests.

The diversity of in-the-money contracts

Table 3 decomposes the contracts in an interest rate derivatives portfolio along two dimensions. The two rows in the table decompose contracts into those that are pay-fixed and those that are pay-floating. The two columns of the table decompose contracts into those that are currently ITM and those that are currently OTM. Every interest rate contract with a given counterparty falls into one of the four cells of the table, labeled A–D. The contracts in cells A and D have contractual fixed rates below prevailing interest rates, so that pay-fixed contracts (cell A) are ITM and pay-floating contracts (cell D) are OTM. The contracts in cells B and C are in the reverse situation because the contractual fixed rates for these contracts are above prevailing interest rates.

Consider a counterparty portfolio that has equal numbers of pay-fixed and pay-floating contracts. The arguments of the preceding section suggest that the volatility of the portfolio's value, and thus the volatility of its net exposure, would be very low, possibly even zero. This same conclusion does not apply to the volatility of the gross exposure, however. Because the volatility of gross exposure is a function only of the contracts in the ITM subset (those in the left column of Table 3), it depends exclusively on the balance of contracts between cells A and C, not on the overall balance of the portfolio.

If cell A has many more contracts than cell C, then the ITM subset has many more pay-fixed contracts than pay-floating contracts. In this case, a large increase in interest rates will lead to a substantial increase in the value of the pay-fixed contracts and a substantial decrease in the value of the pay-floating contracts. Under the assumption that cell A has many more contracts, however, the gross exposure of the portfolio will also rise substantially as the increases overwhelm the decreases. Exactly the opposite will occur if cell C has many more contracts than cell A. But if cell A happens to have approximately as many contracts as cell C, the gross exposure of the portfolio will not tend to move substantially in reaction to changes in interest rates, since increases in some contracts will be offset by decreases in others.

Thus far, the arguments in this section have suggested two important conclusions. First, the volatility of gross exposure will be primarily determined by the diversity of contracts in the ITM subset. Second, the diversity of the counterparty portfolio overall is not a reliable guide to the diversity of contracts within the ITM subset. The next step is to identify the factors that influence the diversity of contracts in the ITM subset.

Historical interest rates and the composition of the in-the-money subset

Consider once again a portfolio that is perfectly balanced between pay-fixed and pay-floating swaps. Imagine that the portfolio is constantly adding new swaps at different contractual rates, but that whenever a pay-fixed swap is added, a pay-floating swap with the same terms is added as well. This portfolio will be perfectly hedged as a whole. The ITM subset will not in general be perfectly hedged, however.

If interest rates have been rising steadily for some time, then prevailing interest rates will likely be above the contractual rates of all of the contracts in the portfolio. This sce-

[19] Obviously, some ITM contracts become OTM and vice versa over any given time horizon. However, simulation evidence not presented here suggests that these effects are sufficiently small that they do not affect the arguments made in the text.

[20] It might seem that the dollar volatility of gross exposure must be lower than that of net exposure since the ITM subset is likely to include fewer contracts than the portfolio overall. This factor is offset, however, by the fact that the net exposure will be zero some fraction of the time, lowering the dollar volatility of net exposure by approximately the same extent.

nario implies that most of the contracts in the portfolio will be located in cells A and D of Table 3. In other words, the swaps in cell A will far outnumber those in cell C. If, on the other hand, interest rates have been falling steadily, then most contracts will be in either cell B or cell C, leaving cell A with far fewer swaps than cell C. Finally, if prevailing interest rates are near the middle of the different contractual rates in the portfolio, then a balanced division of swaps between cells A and C is likely.

It should be apparent, then, that the path of interest rates over time will influence the relative numbers of swaps in cells A and C, and hence the volatility of gross exposure. The greater the imbalance in the number of contracts in these two cells, the greater the volatility of gross exposure. This effect is the same as that depicted in Chart 5 — namely, that a large imbalance between the two types of swaps can result in a portfolio (in this case, a subset) with high volatility.[21]

Some insight into the probable balance between cells A and C can be gained by using historical interest rate data to simulate the behavior of a hypothetical interest rate swap portfolio over time. The results of this experiment are presented in Chart 7. The experiment consists of using U.S. interest rate data to track the value of a hypothetical swap portfolio over the period from 1959 to 1992.[22] The swap portfolio adds new matched pairs (that is, both pay-floating and pay-fixed contracts) of one-year, two-year, three-year, four-year, and five-year swaps each month. After five years, the portfolio composition reaches a steady state: sixty pairs of swaps that were originally five-year swaps, forty-eight pairs that were originally four-year swaps, thirty-six pairs that were originally three-year swaps, twenty-four pairs that were originally two-years swaps, and twelve pairs that were originally one-year swaps. The distribution of swaps by *remaining* maturity will be staggered; for example, at any given time there will be five pairs with one month remaining and only one pair with fifty-four months remaining. The greater concentration of swaps with shorter remaining maturities is consistent with the composition of typical interdealer portfolios.

Since the portfolio consists of matched pairs of swaps, precisely 180 swaps will always be ITM.[23] The proportion of these that are pay-fixed will change over time, of course, as interest rates change. Chart 7 depicts the resultant frequency distribution of the fraction of the ITM swaps in the portfolio that are pay-fixed. In other words, it plots the frequency distribution of the fraction of the ITM swaps that fall into cell A. Chart 7 makes it clear that this fraction will quite often be far from 50 percent. In fact, the frequency distribu-

[21] Note that this phenomenon can lead, under certain circumstances, to gross exposure that is less volatile than net exposure. This outcome could occur, for example, in a portfolio that consists primarily of pay-fixed swaps with a small number of pay-floating swaps. Although the portfolio is not very diverse overall (implying high volatility of net exposure), a steep drop in interest rates could render most, but not all, of the pay-fixed swaps OTM. Thus, the ITM subset would consist of roughly equal numbers of pay-fixed and pay-floating swaps and would therefore be relatively well diversified.

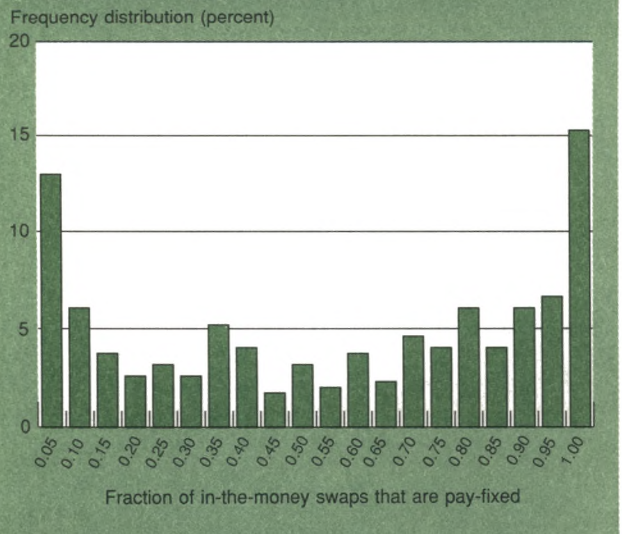
[22] Yields for months 1-6 are drawn from the six-month Treasury bill yield file and yields for months 12, 24, 36, 48, and 60 are from the Fama-Bliss discount bond file, both from the Center for Research in Security Prices bond file. Linear interpolation is used to determine other zero-coupon yields. These data are used to construct the pure discount-bond term structure needed to price and value interest rate swaps.

[23] In other simulations, not reported here, the portfolio contained a random mixture of pay-fixed and pay-floating swaps. The behavior of the ITM contracts in these simulations was virtually identical to the behavior of the ITM contracts in the perfectly matched portfolio.

Table 3
Decomposition of Interest Rate Swap Portfolio

	In-the-Money (Positively Valued)	Out-of-the-Money (Negatively Valued)
Pay-fixed	A Contractual rates below current rates	B Contractual rates above current rates
Pay-floating	C Contractual rates above current rates	D Contractual rates below current rates

Chart 7
Frequency Distribution of Fraction of In-the-Money Swaps That Are Pay-Fixed



Source: Author's calculations.

Notes: Values are calculated using historical U.S. term structures for a hypothetical swap portfolio over the period 1959-92. Reported frequencies cover a range of 0.05 ending with the labeled value.

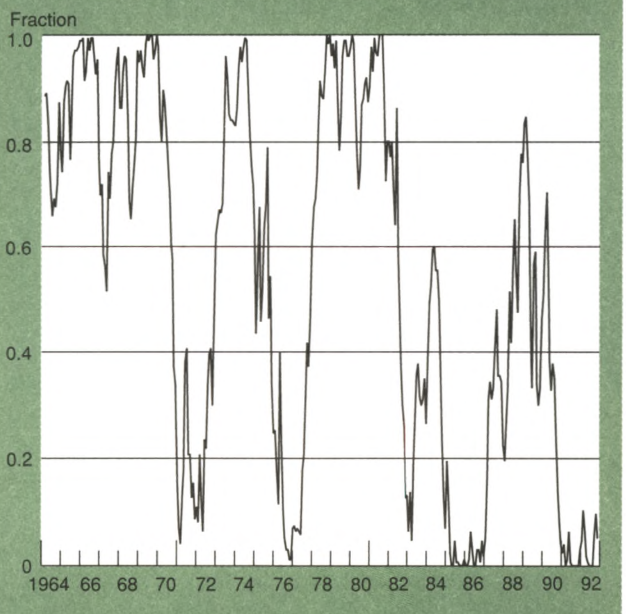
tion spikes at both endpoints, indicating a substantial likelihood that the ITM subset will be significantly unbalanced. In such instances, the volatility of gross credit exposure will therefore tend to be particularly high.

Moreover, the proportion of the ITM subset that is pay-fixed can also change rapidly over short periods of time, implying rapid fluctuations in the volatility of gross exposure. Chart 8 depicts the time series of this proportion for the above experiment. The speed of changes in this proportion is clearly evident in Chart 8: witness the hypothetical increase from near zero percent to almost 100 percent from mid-1977 to mid-1978 that would have been caused by increases in prevailing interest rates.

When the ITM subset is significantly unbalanced, the volatility of gross exposure will be significantly higher than when the ITM subset is balanced. This experiment makes it plain that periods of high volatility of gross exposure are likely to be common, even for a portfolio that is perfectly matched overall. This finding confirms that the volatilities of net and gross exposures are subject to separate influences, and that the extent of diversity in the portfolio as a whole does not provide a reliable indicator of the extent of diversity in the ITM subset.

Chart 8

Fraction of In-the-Money Swaps That Are Pay-Fixed



Source: Author's calculations.

Notes: Values are calculated using historical U.S. term structures for a hypothetical swap portfolio over the period 1959-92.

Conclusions

This article analyzes the factors influencing the volatilities of both net and gross credit exposure, primarily to determine whether the volatility of net exposure is lower than the volatility of gross exposure. This question, however, is complicated by the fact that the volatilities of both gross and net credit exposures are likely to vary considerably over time, depending on the extent to which contracts move together in response to changing market conditions.

If current credit exposure is measured on a *net* basis (that is, a netting agreement is in place), then the volatility of current credit exposure will depend on the degree to which *all* contracts with a counterparty move together. This will largely be a function of the extent to which the portfolio of contracts is balanced between one side and the other (for example, pay-fixed as opposed to pay-floating swaps). If interdealer portfolios do not systematically favor one side over the other, then it is unlikely that they will become extremely unbalanced simply by chance.

If current credit exposure is measured on a *gross* basis (that is, no netting agreement is in place), then the volatility of current credit exposure will primarily depend on the degree to which the ITM contracts with a counterparty move together. Even if the overall portfolio of contracts with a counterparty is well balanced, the subset of ITM contracts will often be extremely unbalanced because of the effects of changing market conditions.

The volatility of gross credit exposure is therefore likely to vary over a wider range than will the volatility of net credit exposure. This conclusion implies that while the volatility of gross credit exposure will sometimes be similar to the volatility of net exposure, it can also be expected to exceed the volatility of net exposure at some points. Thus, on average, the volatility of gross exposure is higher than that of net exposure.

In summary, this analysis points to significant benefits from legally valid closeout netting agreements. First, netting agreements unequivocally lead to reductions in current credit exposures, which make up the bulk of total credit exposures. Second, under certain circumstances, netting agreements reduce fluctuations in the volatility of the credit exposures of dealer institutions, thereby lowering the volatility of the institutions' credit exposures on average. Netting agreements can therefore lead to reductions, on average, in potential credit exposures, the second major component of total credit exposures to OTC derivatives.

Appendix: Assessing the Volatility of a Derivatives Portfolio

This appendix develops a simple mathematical formula that can be used to assess the volatility of a portfolio of derivative contracts. The assumptions underlying the formula are as follows:

(1) There are N contracts in the portfolio.
(2) The distribution of the change in the value of each individual contract is normal, with a mean of zero and a standard deviation given by σ (the same for all contracts).
(3) The correlation between the changes in the values of any two contracts in the portfolio is given by ρ_{ij}.

Under these assumptions, the volatility (standard deviation) of the change in portfolio value will be given by the following equation:

$$(1) \qquad \sigma_{Portfolio} = \sigma \sqrt{N + 2\sum_{i=1}^{N}\sum_{j=i+1}^{N}\rho_{ij}} \quad .$$

The portfolio volatility therefore rises proportionately with the volatility of the individual contracts, σ. Inside the square root, the first term (N) represents the contribution of the variances of the individual contracts, while the double summation represents the contribution of the covariances across contracts. Note that there will be a total of $(N^2-N)/2$ terms in the summation.

It is clear from equation 1 that values of the individual ρ_{ij}'s affect the portfolio volatility only through their sum. It is thus convenient to work with a quantity that can be termed the "average correlation":

$$(2) \qquad \overline{\rho} = \frac{\sum_{i=1}^{N}\sum_{j=i+1}^{N}\rho_{ij}}{(N^2-N)/2} \quad .$$

Intuitively, the average correlation represents the average degree to which any pair of distinct contracts will be correlated. The average correlation thus constitutes a proxy for the degree of diversification across the entire portfolio. The higher the average correlation, the lower the diversity of the portfolio. With this notation, equation 1 can be rewritten as follows:

$$(3) \qquad \sigma_{Portfolio} = \sigma \sqrt{N + (N^2-N)\,\overline{\rho}} \quad .$$

From equation 3, it follows that there are three major influences on portfolio volatility—N, σ, and $\overline{\rho}$. These three variables correspond to the three factors discussed in the text of the article.

With respect to the volatility of net credit exposure, N would equal the total number of contracts in the portfolio and $\overline{\rho}$ would refer to the average correlation across all of these contracts. In this context, note that the volatility of net credit exposure will be less than the volatility of the change in net portfolio value because the net portfolio value will often be negative, leading to zero net credit exposures.†

With respect to the volatility of gross credit exposures, N would equal the number of ITM contracts in the portfolio, and $\overline{\rho}$ would refer to the average correlation across this subset of contracts only. Clearly, this calculation abstracts from the possibility that contract values would change sign over the time horizon of interest. Simulation results that do not ignore this possibility indicate that the approximation error is not great, however.‡

The value taken on by $\overline{\rho}$ in equation 3 is in many respects the crucial determinant of portfolio volatility. If $\overline{\rho}$ equals one, then the portfolio is perfectly positively correlated and has a volatility of σN. If $\overline{\rho}$ equals zero, then the portfolio is uncorrelated and has a volatility equal to $\sigma\sqrt{N}$. A perfectly hedged portfolio has a volatility of zero. In this last case, $\overline{\rho}$ will achieve its minimum possible value of $-1/(N-1)$. Although two variables can have a correlation as low as −1, it is not possible for all N variables to have a correlation of −1 with each of the other variables.

† The variance of net exposure will be approximately one-half of the variance of net portfolio value under the assumptions listed above, leading to a reduction of approximately 30 percent in the standard deviation.

‡ Darryll Hendricks, "Netting Agreements and Potential Credit Exposure," January 1994. Copies are available from the author upon request.