DEFAULT RISK AND DERIVATIVES: AN EMPIRICAL ANALYSIS OF BILATERAL NETTING

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ABSTRACT

This paper discusses the determination of a capital charge to cover default risk on a netted derivatives portfolio. Different methods of setting a capital charge are investigated. Their ability to track a more sophisticated measure of credit risk is tested for Australian banks' portfolios. The effect on the level of credit risk of moving from an environment without bilateral netting, to one where netting has firm legal basis, is examined. We find that, while there are theoretical grounds for arguing that more sophisticated measures would track exposures more closely than the approach currently used in capital adequacy requirements, as an empirical matter, no single formulation clearly outranked any other.

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1. INTRODUCTION

Bilateral netting is an arrangement that allows amounts owing between two counterparties to be combined into a single net figure payable from one to the other. Of greatest interest to supervisors is the potential offered by bilateral netting to reduce credit risk arising from banks' derivative transactions.

In the absence of a netting arrangement, a bank would examine each single contract with a counterparty and measure its credit exposure as the sum of the figures owing to it. That amount would represent the maximum loss that would be incurred should the counterparty fail. The alternative is where a bank nets the results of its individual transactions with a counterparty, setting off its obligations to its counterparty against sums owing to it. In theory, once an appropriate netting agreement is in place, the total amount owed by the bank, and owed to it in relation to a single counterparty, could be represented as a single figure which, in the event of failure by either party, becomes the amount due and payable.

The current capital adequacy standards applying to banks set out a method of calculating the minimum amount of capital that must be held to cover the risk of counterparty default on both on and off balance sheet activities of banks (including their derivative transactions). In determining that minimum capital level, a fairly restrictive form of netting is recognised - netting by novation.[1] Under that arrangement, only contracts between counterparties that are settled in the same currency and on the same date can be netted. The effect is to reduce exposure to credit loss and thus reduce required capital.

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[1] Netting by novation commonly refers to a master contract between two counterparties under which any obligation between the parties to deliver a given currency on a given date is automatically amalgamated with all other obligations under the agreement for the same currency and value date. The result is to legally substitute a single net amount for the previous gross obligations.

In line with the rapid growth in banks' derivative and market-related transactions over the late 1980s, interest of both market practitioners and of supervisors has turned to ways in which expanded and more effective netting agreements can be devised to reduce banks' credit exposure to counterparties by amounts greater than can be achieved through existing methods. The particular focus has been "close-out" netting. Such an arrangement typically involves the use of a master agreement in which all contracts with a single counterparty, covering all maturity dates, are included. The market value of the portfolio can be calculated by evaluating the present value of positive and negative cash flows associated with all contracts and the net result becomes the amount which, in the event of counterparty default, would be owed by one to the other. Because of the range of potential contracts captured under such an arrangement, the reduction in capital arising from close-out netting could be considerable compared with current practice.

The inclusion of extended netting arrangements into capital adequacy calculations hinges on two factors, one legal, one technical:

- the legal issue is the extent to which such close-out netting contracts are enforceable at law. In some countries Corporations or Bankruptcy laws effectively prevent such arrangements by including provisions which give liquidators of failed companies the right to "walk-away" from particular contracts (typically those which involve payments to counterparties). Where such laws exist, close-out netting would have little meaning since, for the failed company, only favourable contracts would be recognised. A great deal of effort has been devoted, in a number of countries, to clarifying the law relating to netting;[2] and

- the second, and more technical question, comes after the legal issues have been resolved. It has to do with the method used to calculate the capital charge on a netted derivative portfolio.

This paper focuses on the second of those issues.

The starting point is a proposal issued by the Basle Committee on Banking Supervision in April 1993 which envisages an extension of current netting

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[2] In the US, for example, special legislation has been enacted to give broad legal effect to netting arrangements.

arrangements to capture close-out netting. It sets out a particular method for calculating a capital charge on a netted derivative portfolio. The charge is based on a measure of total credit exposure of a portfolio calculated as the sum of the net mark-to-market value of the portfolio and an "add-on", or additional capital charge, to account for potential or future credit exposure. In its present form, the add-on component is measured as a proportion of the total notional value of each transaction. Some market participants have argued that the approach, particularly in regard to the calculation of the add-on, is excessively conservative and leads to a capital charge that is too high relative to the true risks faced by banks.

The difficulty is that the appropriate methodology for setting a capital charge cannot be determined solely on intuitive grounds. Current credit exposure should fall as a result of netting, so long as a counterparty's contracts are not all on one side of the market (the magnitude of any reduction being dependent upon the extent to which negatively valued contracts are out-of-the-money).[3] However, the effect of moving from a non-netting to a netting environment on potential exposure is less clear. To the extent that the market values of contracts within a portfolio are negatively correlated, movements in those values will tend to be offsetting, thus reducing the potential for the portfolio to increase in value and thus reducing future exposure. On that basis, it would seem appropriate to adopt an add-on formulation which reflects that fact.

It is possible, however, that in moving from a non-netting to a netting environment, total credit exposure (current plus potential) may fall by less than the reduction in current exposure. There is nothing which strictly links the current value of a portfolio and the variability of that portfolio. The gap between current exposure and total exposure, which must be covered by the potential exposure add-on may, therefore, increase.

In seeking to cover the exposure associated with any portfolio, it would be possible to base a capital charge on any variable, provided the multiplier is high enough. Determining an appropriate base for a capital charge, however, is about more than absolute coverage. It is a matter of specifying a charge which covers exposure

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3 A bank holding a contract with a positive mark-to-market value is "in-the-money", that is, it would have the right to receive payment from the counterparty if the contract were terminated. A bank holding a contract with negative mark-to-market value is "out-of-the-money" on that contract, that is, the bank is under an obligation to pay the counterparty.

under all likely circumstances and does so with an efficient allocation of capital. The search, then, is for a base that is reasonably strongly correlated with a portfolio's exposure.

In this paper, the efficiency and coverage of alternative capital charges are tested by regressing them against a more sophisticated measure of credit risk. The tests are performed using portfolios of interest rate swaps and forward rate agreements obtained from Australian banks.

The next section describes interest rate swaps - the financial product on which our empirical results are based. Section 3 sets out a method for determining credit exposure employing interest rate simulations. It is this measure of credit exposure which is used as a benchmark against which the performance of the various capital charges is compared. Section 4 discusses, from an intuitive perspective, the impact of moving from a non-netting to a netting environment on the credit risk of a bank's swap portfolio. Section 5 provides a description of the current capital adequacy arrangements and a number of approaches that have been put forward as possible alternatives. The results of testing the performance of the current calculation method and the alternative methods are presented in Section 6. Section 7 presents evidence on the rescaling of capital charge add-ons required to reflect the change in potential exposure resulting from a move to a netting environment. Concluding comments are in Section 8.

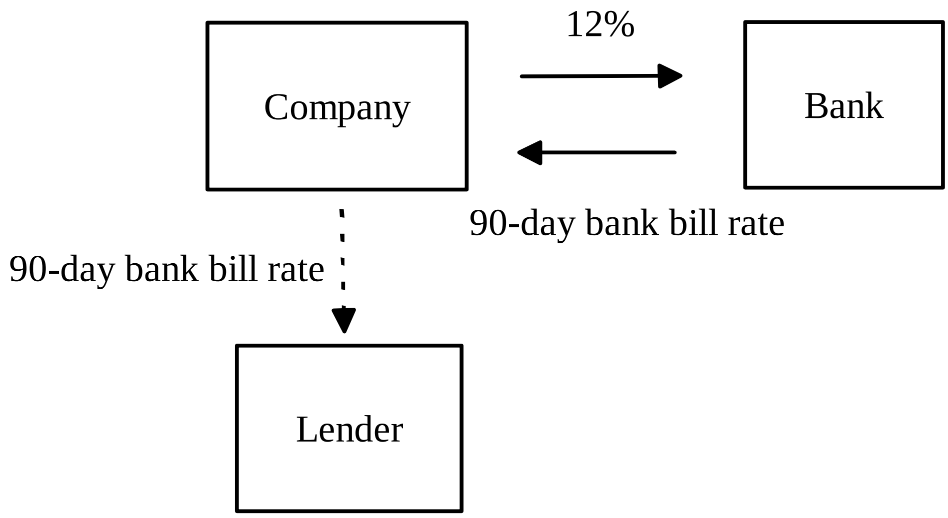
2. INTEREST RATE SWAPS

An interest rate swap is an agreement to exchange (swap) interest payment streams of differing characteristics denominated in the same currency. The interest payments are calculated by reference to an agreed amount of notional principal, although at no time is this amount exchanged between the counterparties.

By way of example, consider a company which has an existing borrowing of $10 million where the interest rate payable is set at the bank bill rate at the beginning of each quarter. The company would prefer a fixed rate loan. By entering into a fixed-for-floating swap with a bank, the company can effectively set a fixed rate on its loan. Under the swap agreement the company will pay a fixed 12 per cent and receive the bank bill rate each calculated on a nominal principal of

$10 million. The fixed rate is termed the "swap rate". The combination of the loan and the swap results in the company paying 12 per cent and receiving the bank bill rate on the swap, and paying the bank bill rate on the loan, thereby giving a 12 per cent fixed rate. Figure 1 illustrates the company's interest payments, the broken line representing the original loan and the solid lines the swap cash flows.

Figure 1: A Fixed-for-Floating Swap



The portfolios on which our results are based include both interest rate swaps and forward rate agreements (FRA). FRAs are cash-settled forward contracts on interest rates. On the settlement date of an FRA the difference between two interest payments is exchanged between the FRA counterparties. The first interest payment is determined by a fixed interest rate agreed between the two parties at the inception of the FRA. The second payment is set with reference to a floating rate observed in the market on the FRA's settlement date. An FRA can be treated as a one period swap. Hence the discussion of the credit risk on swap contracts in subsequent sections applies equally to FRAs.

3. CREDIT EXPOSURE

The credit risk of swaps relates only to the cash flows exchanged by the counterparties and does not involve the underlying notional principal. Credit risk on these instruments arises only when a counterparty defaults and interest rates have changed such that the bank can arrange a new swap only at inferior terms. Default alone, therefore, does not expose the bank to loss. In the absence of a change in interest rates the bank could negotiate a new swap on the same terms as the old swap. If interest rates do change, however, it may not be possible to replace the swap on comparable terms. In such cases, the bank may experience a loss relative to its position had the counterparty not defaulted. The size of this loss will depend on the interest rate environment at the time of default and cannot be perfectly foreseen.

3.1 Credit Exposure at a Point in Time

The basic concept used in this study to measure credit exposure, for a single swap, is replacement cost. This method estimates the economic impact on the bank from default of a counterparty as a function of the original contract fixed rate and the market rate that would be used when finding a substitute counterparty. Replacement cost is calculated as the difference between the fixed rate of interest of the swap and the market rate, discounted back from each settlement date to the revaluation date. This approach assumes that the bank closes out its exposure arising from a defaulting swap by writing a replacement swap (the approach, which focuses on the fixed rate side of swap transactions, assumes that the loss in replacing the floating rate side of a swap will be minimal).

To value a swap a standard zero coupon methodology is used. Zero coupon rates are pure discount interest rates for securities with no intermediate coupons (that is they repay interest and principal in one payment at maturity). This method overcomes the weakness of traditional internal rate of return calculations in which cash flows of varying maturities are revalued using a single interest rate. Par yield structures implicitly assume that all coupons or intermediate cash flows are invested at the same yield to maturity.[4] In contrast zero coupon rates do not involve reinvestment risk. Zero coupon methodology allows the identification of a discount rate appropriate to the timing of each cash flow.[5]

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4 Most traded securities are not zero coupon securities but rather involve both a final principal payment and regular coupon payments. The par yield is that yield for such securities commonly observed in the market.

5 For a full exposition of the zero coupon methodology see Das (1994).

By way of example, consider a 4-year swap which was entered into on 30 September 1990 with a fixed rate of 14 per cent per annum payable semi-annually. The bank receives the fixed rate from its counterparty in exchange for paying some floating rate. The transaction is for a notional principal of $20 million. Assuming that on 30 September 1992 the market swap rate (that is, the fixed rate the bank would receive if it entered into a swap on 30 September 1992) has moved to 10 per cent and that the zero yield curve is as shown in Table 1, the bank's exposure to its counterparty on that date may be calculated as follows:

Table 1: Exposure to a Swap Counterparty

Date	Payment due to bank	Payment bank receives under replacement swap	Difference	Zero rate	Present value
30 Sep 92	1,400,000	1,000,000	400,000	--	400,000
30 Mar 93	1,400,000	1,000,000	400,000	5.00	390,438
30 Sep 93	1,400,000	1,000,000	400,000	5.50	379,147
30 Mar 94	1,400,000	1,000,000	400,000	5.85	367,388
30 Sep 94	1,400,000	1,000,000	400,000	6.25	354,325
				Total:	1,891,299

The first column in Table 1 sets out the remaining coupon payment dates on the original swap. The payment due to the bank each six months on that swap is 0.14 x $20 million / 2 = $1,400,000. Similarly the payment receivable under the replacement swap is 0.10 x $20 million / 2 = $1 million. Hence, in the event that the counterparty defaults, the bank would, at each coupon payment date, receive $400,000 less than if the counterparty continued to meet its obligations. Assuming a zero yield curve as shown in Table 1 the present value of this lost income stream is $1,891,299.

Note that credit risk is not symmetric. If the counterparty defaulted when interest rates had risen to, say 16 per cent, then the bank would be able to replace the contract at a profit. In such a case the credit exposure on the contract is nil.

3.2 Credit Exposure Over Time

Calculating the current credit exposure on an interest rate swap or an FRA is relatively straightforward. Complexity arises in the calculation of future or potential exposure, however, because the value at risk changes over time as interest rates change. Frye (1992) and Simons (1993) set out a methodology for the estimation of future exposure. This begins with an interest rate model which is used to predict future interest rate paths. From the interest rate model, a confidence interval (say 95 per cent) is taken to yield the "worst case" upward and downward movements in interest rates. Figure **Error! Bookmark not defined.** provides an illustration of the projections from a simple model. The interest rate model used for the simulations presented in this paper is set out in Appendix 1.

Figure 2: Simple Model

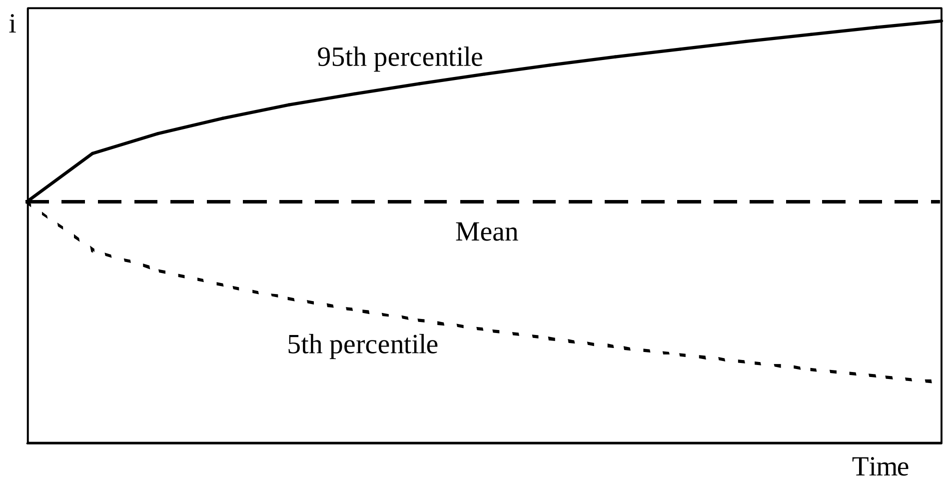
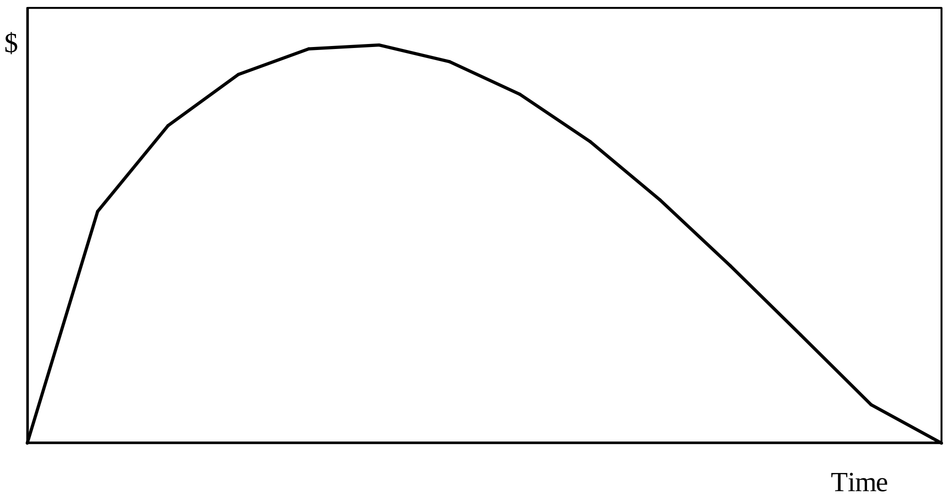


Figure 3: Potential Exposure



The swap is then revalued from the current date forward, through to its maturity using the projected worst case interest rates. This gives the potential exposure for any future date. Figure **Error! Bookmark not defined.** shows the theoretical time path of potential exposure for a standard swap. Two factors affect the potential exposure. Firstly, the potential in-the-money amount which moves directly with interest rates. And secondly, the total coupon amount outstanding which declines each time a coupon payment is made.

3.3 Counterparty Exposure

Once the credit exposure for individual contracts has been calculated, the next step is to calculate the exposure to a counterparty that has several swaps and FRAs in force. This is a three-step process:

1. Calculate the potential exposure time path for each contract.

2. Combine the potential exposures of all contracts, at each point in time, to arrive at the total exposure to the counterparty over time. The way in which the contracts are combined depends upon whether the contracts can be netted. In the case that netting is applicable, the contract values, at each date, can simply be summed. In the absence of netting, exposure to a counterparty is assessed as the sum of the replacement cost of all contracts that are in the money (that is, all contracts wherein the counterparty owes the bank money, or those contracts that would be replaced in the market at a cost to the bank). The exposure on out-of-the-money contracts is zero.

3. Credit exposure at each point in time is taken to be equal to the maximum exposure obtained under each of the various interest rate scenarios to obtain a time path for worst case losses.[6] To collapse these time paths into a single credit exposure number the maximum exposure is taken. Choosing the maximum

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[6] This eliminates one set of mutually exclusive events; reflecting the fact that interest rates cannot be at both the upper and lower bounds of their confidence interval at the same time. An alternative approach would be to constrain the speed of shifts in the yield curve, for example, setting a rule that the 3-year rate cannot move by more than a set amount in two years, and divide events accordingly. This can have the effect of reducing estimated counterparty exposure, on a bank's total portfolio by as much as 40 per cent.

exposure assumes that the counterparty will default at the worst possible time. Alternatively, average exposure over time may be calculated. Use of the average measure assumes that the counterparty is equally likely to default at any time between now and the maturity of the contract.[7]

In determining the exposure to a counterparty, assumptions must be made about the composition of the portfolio through time. The simplest approach (and the one used in the calculations set out below) is to assume that the portfolio remains static. The difficulty with this is that as the portfolio ages, contracts mature and drop out of the portfolio. An alternative approach is to assume some pattern whereby the portfolio is replenished over time. Not allowing for new contracts to be entered into over the life of the portfolio, means that exposure to many counterparties is underestimated. However, imposing arbitrary assumptions about the evolution of the portfolio is also problematical and can lead to errors in estimating exposure.

4. THE EFFECTS OF NETTING ON CREDIT EXPOSURE

This section aims to provide some intuitive understanding of the impact on the credit risk of a swaps portfolio in moving from a non-netting to a netting environment.

It is clear that current credit exposure is reduced by netting, so long as the portfolio is not comprised of contracts that are all on one side of the market; the magnitude of the reduction in credit exposure depending upon the value of the out-of-the-money contracts.

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[7] In theory it is possible to specify the expected probability that a counterparty will fail at any given time (for example, it may be unlikely that the counterparty will default in the next year, but more likely that it will fail in two year's time) and so calculate a probability weighted expected exposure.

Consider the following portfolio of four swaps:

Table 2: Sample Portfolio

Swap	Counterparty	Market value ($)
1	A	+10
2	A	-10
3	B	+10
4	B	-10

In the absence of netting, the current credit exposure of the portfolio is equal to $20 (the sum of swaps with a positive replacement cost, there is no credit risk in swaps with a negative value). If netting is applied, then the credit exposure of the portfolio is reduced to zero (the positive and negative exposures to each counterparty offset each other).

The effect of netting on potential exposure is less clear, as it depends on the composition of the portfolio. There are two simple ways to look at the behaviour of potential exposure: firstly, through the use of projections of the value of a portfolio over some worst case interest rate scenario, as discussed in Section 3.3 above; and secondly by looking at the statistical behaviour of changes in the value of a portfolio.

4.1 Worst Case Scenarios

The following two figures present the worst case time paths of credit exposure for two FRAs (the solid lines) and the worst case time path for the net exposure on the two contracts (the broken line). Maximum potential credit exposure is equal to the maximum exposure obtained over the life of the contracts.

Figure 4: No Reduction in Maximum Exposure

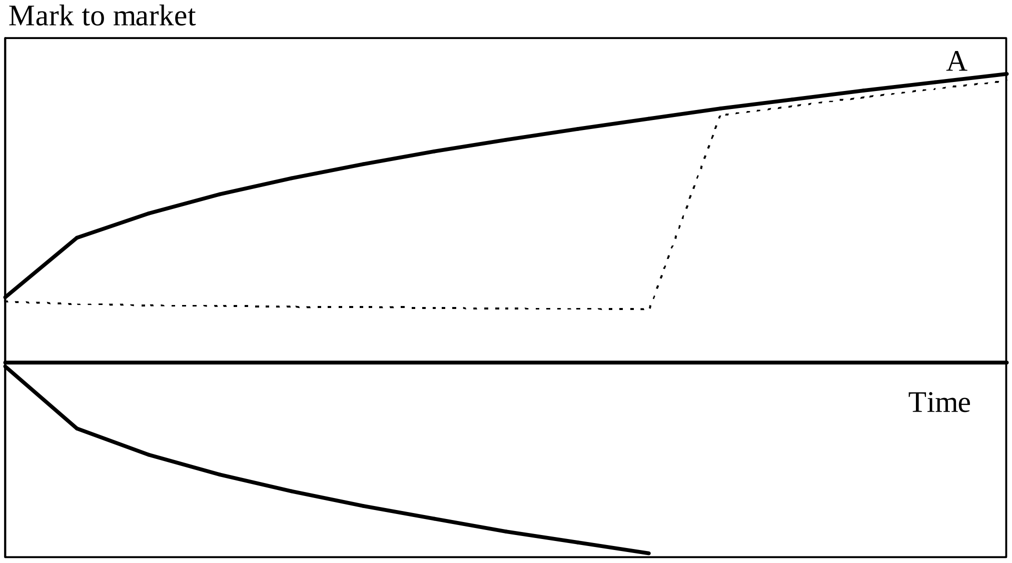
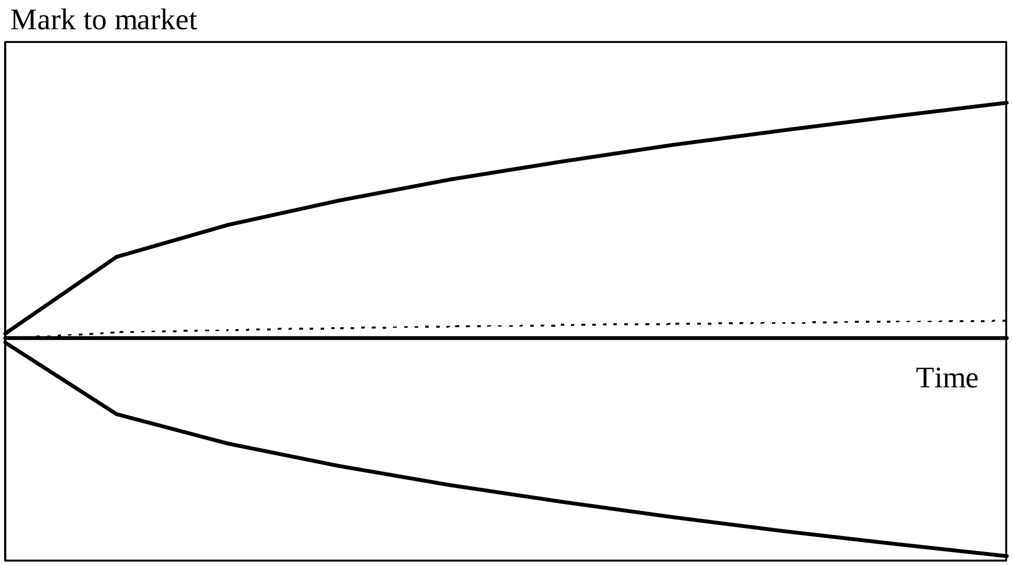


Figure 5: Closely Matched FRA's



It is possible to envisage situations where a portfolio is comprised of contracts on opposite sides of the market, but maximum exposure is not reduced because that occurs after the maturity of the contracts that are out-of-the-money. Figure **Error! Bookmark not defined.** illustrates this. In the absence of netting, total credit exposure is equal to the exposure on the positively valued contract (the upper solid line). Once the two contracts are netted, credit exposure (the broken line) on the portfolio is reduced over the life of the negatively valued contract. But, the portfolio exposure reaches the same maximum (point A) irrespective of whether or not the portfolio is netted. Average exposure, however, is reduced.

If deals between a bank and its counterparty are perfectly offsetting, netting eliminates current and potential exposure. Figure **Error! Bookmark not defined.** shows the credit exposure on closely matched FRAs with the same maturity date. In this case, both the maximum and average potential exposure are greatly reduced when the contracts are netted. The more strongly correlated the two contracts, the greater the reduction in credit exposure. Table 3 contains the correlation coefficients between monthly changes in Australian interest rate swap rates and government bonds of varying maturities between February 1990 and September 1993. It can be seen that, over this period at least, swap rates across different maturities are, in fact, quite highly correlated.

Table 3: Interest Rate Correlations

		Swaps								**Bonds**		
		6M	**1Y**	**2Y**	**3Y**	**4Y**	**5Y**	**7Y**	**10Y**	**1Y**	**5Y**	**10Y**
Swaps	**6M**	1										
	1Y	0.874	1									
	2Y	0.821	0.981	1								
	3Y	0.811	0.968	0.995	1							
	4Y	0.817	0.956	0.985	0.994	1						
	5Y	0.808	0.945	0.975	0.986	0.996	1					
	7Y	0.756	0.895	0.931	0.942	0.964	0.970	1				
	10Y	0.682	0.812	0.856	0.871	0.905	0.920	0.976	1			
Bonds	**1Y**	0.949	0.957	0.922	0.909	0.903	0.892	0.849	0.775	1		
	5Y	0.806	0.943	0.971	0.979	0.988	0.986	0.967	0.925	0.902	1	
	10Y	0.618	0.750	0.794	0.806	0.839	0.853	0.931	0.967	0.726	0.877	1

4.2 Changes in the Value of a Portfolio

The second way of looking at potential exposure follows from the observation that potential exposure can be closely linked to the market risk facing the portfolio. Consider a bank that has contracted, as the result of an interest rate swap, to receive fixed rate payments in exchange for floating rate cash flows. If the swap rate falls the bank profits - it could enter into an offsetting swap at the lower rate and lock in a profit equal to the difference between the initial swap rate and the current market rate. The bank has gained from the movement in market rates. However, if the counterparty defaults the bank loses those profits. This is credit risk. When the swap rate rises the bank incurs a loss - if it were to enter into an offsetting swap it could only do so at a loss. This is market risk. This paper is concerned only with credit risk. However, the analytical tools developed for evaluating market risk are useful in investigating the behaviour of potential credit exposure.

Hence, another way of looking at potential exposure is to consider changes in net replacement cost.[8] The more volatile the change in net replacement cost the greater the potential credit risk. While netting may, therefore, reduce the *level* of the current credit risk of a swap portfolio, that fact says little about potential exposure since it is determined by *changes* in net replacement cost. This volatility is determined by the volatility of the contract rates and the correlation between those rates.

Under a netting agreement the changes in the values of swaps, both in and out-of-the-money, are summed. In the absence of netting, current net replacement cost is calculated by summing all positive swap values and ignoring all negative swap values (that is, those that are out-of-the-money). Without netting, the change in net replacement cost is approximately the sum of changes in the values of in-the-money swaps. There is no reason to believe that the volatility of positive valued swaps is any larger, on average, than the volatility of all swaps (which determines potential exposure in the presence of netting). This suggests that the adoption of netting will not necessarily lower potential exposure.

Consider again the portfolio of swaps presented above in Table 2. Suppose that each of the swaps has the same variance so that its value can be expected to move up or down in value by $4 in the next year. Assuming that the movements in the value of each swap are independent, then there are sixteen possible outcomes at the end of the year. These are shown in Table 4. In the absence of a netting agreement, there are four cases when the credit exposure of the portfolio rises by $8 and four

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8 This section draws heavily from Hendricks (1992).

when it falls. With netting there are four cases where credit exposure rises by $8 and one case where credit exposure rises by $16. In no single case does it fall.

Using this simple example, we see that the *change* in credit risk on a netted portfolio is at least as large as the non-netted case in all but one of the sixteen cases. This is in spite of the fact that the *level* of exposure with netting is less than the level without netting in every instance.

More generally, Estrella and Hendricks (1993) demonstrate that, in the case where the swaps making up a portfolio are uncorrelated, then the variance of the portfolio's value does not change when moving from a non-netting to a netting environment.

Table 4: Netting When Movements in the Value of Each Swap are Independent

	Counterparty A		Counterparty B		Without netting		With netting	
	Swap 1	**Swap 2**	**Swap 3**	**Swap 4**	**Portfolio credit exposure**	**Change**	**Portfolio credit exposure**	**Change**
Initial swap value	10	-10	10	-10	20	-	0	-
Case	Possible swap values							
1	6	-14	6	-14	12	-8	0	0
2	14	-14	6	-14	20	0	0	0
3	6	-6	6	-14	12	-8	0	0
4	14	-6	6	-14	20	0	0	0
5	6	-14	14	-14	20	0	0	0
6	14	-14	14	-14	28	8	0	0
7	6	-6	14	-14	20	0	0	0
8	14	-6	14	-14	28	8	8	8
9	6	-14	6	-6	12	-8	0	0
10	14	-14	6	-6	20	0	0	0
11	6	-6	6	-6	12	-8	0	0
12	14	-6	6	-6	20	0	8	8
13	6	-14	14	-6	20	0	0	0
14	14	-14	14	-6	28	8	8	8
15	6	-6	14	-6	20	0	8	8
16	14	-6	14	-6	28	8	16	16

An important caveat is that, rather than being independent, changes in swap values tend to be positively correlated. The greater the correlation between swap prices the greater the reduction in the variability (and hence potential exposure) of the swaps portfolio under netting. As shown in Table 3 above, swap rates do tend to be quite highly correlated.

5. CAPITAL STANDARDS

5.1 The Current Capital Requirements

For the purposes of capital adequacy the credit risk of financial derivative transactions is divided into two parts.[9] Firstly current exposure, which captures the loss that would result if a counterparty were to default today. This is measured as the mark-to-market valuation of all contracts with a positive replacement cost. Secondly, since the value at risk from counterparty default changes over time, an allowance for changes in the value at risk, in the event of default, is calculated for all contracts.

The add-on for potential exposure is calculated as a percentage of the nominal principal amount of each contract. The factors to be applied are set out in Table 5.

Table 5: Add-On Factors

Remaining term to maturity	Interest rate contracts %	Exchange rate contracts %
Less than one year	nil	1.0
One year or longer	0.5	5.0

Counterparty weights (10 per cent for State and Commonwealth Governments, 20 per cent for Australian and OECD public sector entities and banks, and 50 per cent otherwise) and the 8 per cent capital charge are then applied to the value at risk to determine the level of capital to be held against derivative transactions. For further details see Reserve Bank of Australia (1990).

9 The following discussion summarises the current exposure method of determining credit risk. A simpler approach, the original exposure method, is available to banks which simply sets total credit exposure equal to a proportion of notional face value according to whether the contract is an interest rate of foreign exchange derivative and the total term to maturity of the contract. As at December 1993, all Australian banks, except two, employed the current exposure method. Both banks using the original exposure method were moving towards adopting the current exposure method.

5.2 The Basle Committee's Proposal on Netting

The proposal on netting sets out the minimum legal requirements for netting to be recognised for the purpose of capital adequacy and the calculation of credit risk for those jurisdictions where netting is legally enforceable. Current exposure will be calculated on a net basis to produce a single credit or debit position for each counterparty. With regard to the add-ons for potential exposure, however, the proposal recommends the maintenance of the existing calculation method.

5.3 Formulating a Capital Charge

While it is important to maintain a suitably conservative and easy-to-understand capital standard, it is possible there may be more efficient methods of capturing credit exposure than the proposed method. Determining an appropriate approach requires choosing a method which covers exposure under all likely circumstances and one that does so with an efficient allocation of capital. That is, the capital charge should be based on a variable that is reasonably strongly correlated with a portfolio's exposure.

Three issues arise in formulating a more efficient capital charge:

- whether only current exposure needs to be covered, or add-ons should also be applied to allow for potential exposure;
- how to better express total credit exposure as a function of the gross and/or net market values; and
- how to calculate the add-on itself.

5.3.1 Why Have Add-Ons?

The need for add-ons flows directly from the fact that the value of derivative portfolios is volatile. The mark-to-market value of a portfolio only captures current exposure. The net market value of contracts can change significantly over a relatively short time. A capital charge must provide a margin of safety to ensure that sufficient capital is held not only to cover current exposure but also to cover potential exposure.

In general, the probabilities of credit exposure either increasing or decreasing are about equal. Thus the average change in credit exposure will be small. However, this does not imply that there is no need for add-ons. Without an add-on the capital charge will cover actual exposure only in those cases where net replacement cost does not increase. A capital charge that provides adequate coverage only half of the time is not providing a very good margin of safety. To provide better coverage an add-on is required.

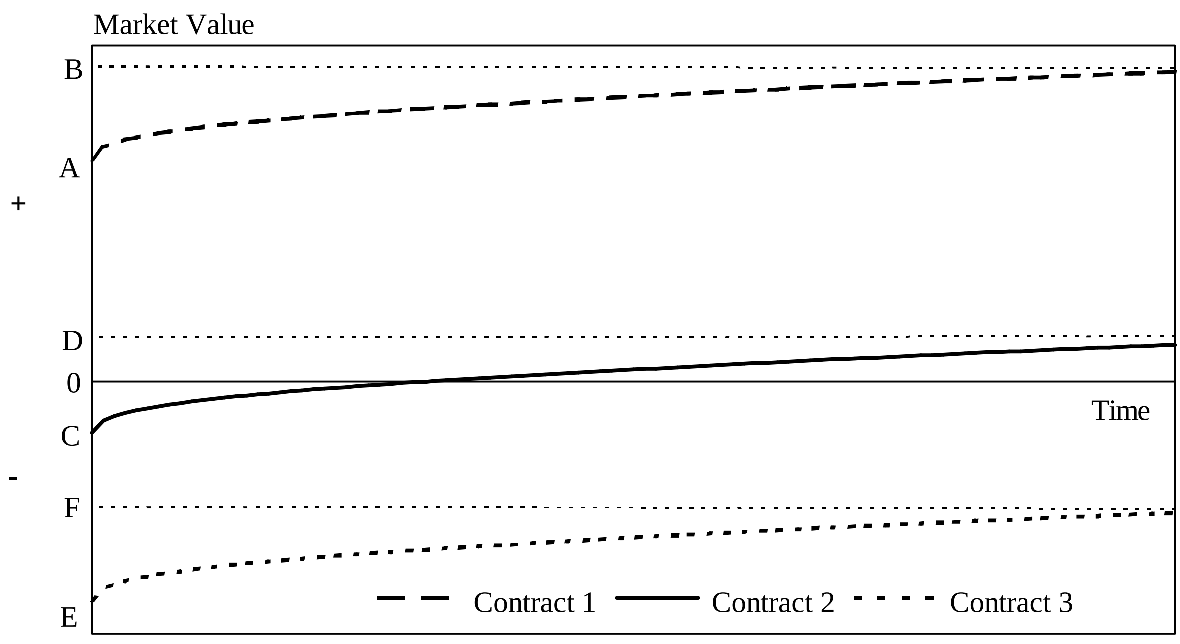
5.3.2 Total Credit Exposure

The Basle Committee's proposed method calculates credit exposure as being equal to the sum of net mark-to-market, if positive, plus the add-on. That is:

$$\text{Credit exposure} = \max(\text{net mark-to-market}, 0) + \text{add-on} \qquad (1)$$

There is a difficulty, however, with this construct. Regardless of how negative the net mark-to-market value of the portfolio, a bank is still required to hold capital against the full amount of the add-on. Thus, for two otherwise identical portfolios, one which has a positive current net replacement value must have a higher potential future replacement value than one with a negative current value.

Figure 2: Combining Current and Potential Exposure



By way of example, consider the three hypothetical contracts depicted in Figure 2. The figure shows the current value of the three contacts and the values these contracts would take over time under worst case interest rate movements.

For contract 1, which currently has positive value (and hence, positive credit risk) the maximum loss is equal to B. Assuming the add-on covered the increase in value over the life of the contract (B - A) then the current netting proposal calculates credit exposure as A + (B - A) = B, which is the correct amount. In the case of contract 2, however, the maximum loss in the event of counterparty default is equal to D. The Basle proposal would calculate credit exposure as being equal to the distance between C and D, since current exposure is set equal to zero. This overstates total credit exposure by the amount C. In the most extreme case, contract 3, the contract is so far out-of-the-money that it is not expected ever to take on a positive value. In this case there is no credit risk, but the bank would still be required to hold capital against the amount (F - E).

One option, presented in Gumerlock (1993) which would correct this distortion would be to recast the measure of credit exposure along the following lines:

$$\text{Credit exposure} = \max[(\text{net mark-to-market} + \text{add-on}), 0] \qquad (2)$$

That is, credit exposure for each counterparty is calculated as the sum of the net mark-to-market and the add-on, if this sum is positive, and zero otherwise. Using this formula would ensure that capital is not required to be held against contracts that would not be subject to credit risk even under the worst-case movement in underlying interest rates.

A quite different approach to estimating total exposure, which also makes an allowance for the volatility in the value of swap contracts as market rates change, is to adopt a form of scenario analysis. Under such an approach, total credit exposure, for each counterparty, could be calculated as the maximum, if positive, value of all contracts under various interest rate scenarios. For example:

- current rates;
- interest rates rise by a given amount; and
- interest rates fall by a given amount.

For the purposes of this exercise, upward and downward shifts in the yield curve of one per cent have been applied and tested.

5.3.3 Add-Ons

There have been a range of suggestions as to how, in a netting environment, an add-on for potential exposure could be formulated.

Market participants argued, initially, for an add-on calculated as a proportion of the net replacement cost of the portfolio where net replacement cost is defined as the market value of the portfolio if positive and zero otherwise. There is, however, one fundamental shortcoming in using the net mark-to-market value as a base for an add-on. Where the net mark-to-market value was zero, there would, by definition, be no add-on and thus no coverage for potential exposure. There is no reason to expect that portfolios with a zero net mark-to-market do not have the potential to increase in value, though, across a total portfolio containing a reasonably large number of counterparties this effect may not be empirically important.

Hendricks (1992) and Estrella (1992) investigate the performance of net replacement cost as a base for a capital charge, in comparison with notional principal. As stated previously, the potential credit exposure of a derivative instrument is a function of the variance of the net replacement cost of that instrument. Hence, some insight may be gained into the appropriate base by investigating the relationship between the variance of the market value of swap contracts and the notional principal and between the variance and the net replacement cost.

Estrella (1992) sets out the mathematical functional form for the potential exposure of an interest rate swap by defining potential exposure as being directly proportional to the standard deviation of the market value of a swap. Estrella substitutes a general model of interest rates into an equation specifying the value of a swap (a simplified version of equation (A5) discussed in Appendix 1). This enables changes in the value of the swap to be decomposed into a deterministic and a random component, from which, an expression for the standard deviation, and therefore, the potential exposure of the swap value is obtained.

The functional form of the expression for potential exposure obtained by Estrella demonstrates that potential exposure is a rising function of notional principal. However, the relation between potential exposure and net replacement cost may be positive or negative, and therefore, of itself the relation is not informative.

Further simulation work conducted by Hendricks (1992) tested how well add-ons based on notional principal and net replacement value covered potential exposure as the proportion of the portfolio being netted increases. An add-on calculated as 35 per cent of net replacement cost provided adequate cover both in the absence of netting and when a small proportion of the portfolio is netted. As the proportion of the portfolio being netted increased the coverage afforded by the add-on based on net replacement cost fell significantly. If the weight applied to net mark-to-market was set so as to provide adequate coverage in all cases it would be quite high (for Hendricks' portfolio the figure of 35 per cent increased to around 900 per cent of the net mark-to-market value). The add-on based on gross notional principal provided a level of cover which varied much less as the proportion of the portfolio being netted changes. It provided adequate cover independent of the extent of netting.

An alternative to an add-on set as a simple proportion of net mark-to-market is to express potential exposure as a more complex function of gross and net values. For instance, the International Swap Dealers' Association (ISDA) has suggested scaling the existing add-ons by the ratio of net to gross market values. Here, net is defined as the higher of the difference between the positive market values minus the negative market values and zero. Gross is set equal to the sum of the market values of all positive valued contracts. The net to gross ratio is one measure of the extent of offsetting contracts within a portfolio. So long as the values of the contracts in a portfolio exhibit some degree of correlation, netting can be expected to reduce potential exposure. The greater the number of offsetting contracts the greater the reduction in potential exposure. Thus an add-on can be cast in the form:

$$\text{Add-on} = \text{Basle gross add-on} \times \text{NGR} \qquad (3)$$

where the Basle gross add-on is calculated as a proportion of the nominal principal amount (as set out in Section 5.1) and NGR is the ratio of the net mark-to-market to gross mark-to-market. The difficulty with this construction, as in the more simple add-on based solely on the net mark-to-market value, is that when the net mark-to-market is zero, no capital is held. Unless the contracts are perfectly correlated and perfectly offsetting, this will not be an adequate measure of potential exposure.

To retain the same general approach, but ensure a minimum level of capital is held when the net mark-to-market is zero, the add-on can be expressed alternatively as:

$$\text{Add-on} = \text{Basle gross add-on x } [\text{NGR} + \beta(1 - \text{NGR})] \qquad (4)$$

where β is a constant between 0 and 1. The level of minimum coverage, when the net mark-to-market is zero, would be set by appropriate choice of β.

However, there are some difficulties with the conventional definition of the net-to-gross ratio as it appears in both equations (3) and (4).[10] Consider the two portfolio s presented in Table 6 (below). The first portfolio is out-of-the-money. The net to gross ratio, therefore, is zero. For an add-on of the form (3) it is implicitly assumed that portfolios that are out-of-the-money will not increase in value in the future. This is inappropriate. The object of calculating an add-on is to provide for potential increases in the value at risk and this should be done for all counterparties, not just those with a net positive market value. The ISDA ratio is also inappropriate when using (4), as this would assume that all out-of-the-money portfolios could be expected to increase in value by the same amount. Taking the absolute value of the net mark-to-market when calculating the net to gross ratio is one method of overcoming this problem.

Table 6: NGR Versus the Absolute Ratio

Portfolio	**1**	**2**
	-15	-3
	-20	-5
Contract market values	-2	-5
	10	-7
	18	-8
Net mark-to-market	0	0
Gross value	28	0
NGR	0	?
Absolute ratio	9/65 = 0.1385	1

[10] Net here is defined as zero when the difference between the positive and negative market values is zero.

For the second portfolio which contains only contracts that are out-of-the-money, the gross mark-to-market is equal to zero. Hence, the net-to-gross ratio is undefined. Since all the contracts are on one side of the market, intuitively, the net-to-gross ratio should be set equal to one. Replacing the ISDA ratio with the ratio of the absolute value of the net mark-to-market to the sum of the absolute market value of each contract, which we term the absolute ratio, achieves this.[11]

Another approach is one that relaxes the assumption, implicit in the Basle Committee's proposed method of calculating add-ons, that at the time a counterparty defaults there has been a worst case movement in the underlying rates of all contracts. This approach begins with the observation that the contracts that make up a portfolio can be divided into short and long contracts. Short contracts are those that increase in value as interest rates rise, while long contracts are those that increase in value as interest rates fall.

Consider a matched pair of offsetting contracts. At any point in time only one of these contracts, either the short or the long contract, will be in-the-money and hence carrying credit risk. The Basle method requires that an add-on be charged against both contracts. For both contracts to be in-the-money would require the one underlying market rate to be at two different levels at the same time.

More generally, within any portfolio (whether perfectly matched or not) for any given shift in swap interest rates the credit risk on either the short or the long contracts will increase. Thus potential exposure is limited to the maximum of potential exposure on the short contracts and the potential exposure on the long contracts. This could be reflected by setting a capital charge which takes the maximum of the add-ons on all short contracts and the add-ons on all long contracts.[12]

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11 Moving from the conventional definition of the net-to-gross ratio to the absolute ratio leads to a slight increase in the amount of capital required. However, this can be offset by an adjustment of the weights set out in Table 5.

12 For more complex portfolios splitting the portfolio up into shorts and longs is not necessarily straightforward. For example, a portfolio of foreign exchange swaps is exposed to movements in, at least, three underlying markets, namely, interest rates in each currency and the exchange rate. Hence it is possible to describe short and long positions in each of those underlying markets. The simplest solution is to treat the contract as though it is only exposed to the most variable factor (in this example, the exchange rate). It is then possible to take the maximum of short and longs in each product category (interest rate, foreign exchange, equity derivatives

The assumption implicit in the Basle add-ons of simultaneous worst case movements in the underlying rates of all contracts is equivalent to assuming that there is no correlation between the prices of any contracts. Levonian (1994) demonstrates that taking the maximum of short and long add-ons represents a halfway case which is appropriate when there is some correlation, but not perfect correlation between contracts.[13] From Levonian (1994) it follows that the absolute value of the difference between the short and long add-ons (termed the net of short and long add-ons) is appropriate in the case that there is perfect correlation between contract values. Levonian (1994) suggests a generalisation of the short/long approach, namely taking a weighted average of the gross and net measures. The higher the correlation between contracts the greater the relative weight on the net amount.[14] All three measures discussed here were tested.

An approximation of the short/long approach which requires slightly less information is to split the portfolio between positively and negatively valued contracts. If the interest rate cycle is relatively smooth and the average maturity of the bank's portfolio is short then the positive/negative approach will provide a reasonably close approximation of the short/long add-ons. As in the short/long case we tested three means of combining the add-ons on positively and negatively valued contracts - the maximum, the absolute value of the difference between the add-ons on positively and negatively valued contracts (that is the net add-on) and a weighted average of the gross (that is, the current Basle add-ons) and the net add-ons.

Yet another approach to the determination of a capital charge derives from the fact that two perfectly correlated contracts, on opposite sides of the market, will have a zero potential exposure in a netting environment; as movements in the price of the positively valued contract will always be offset by the negatively valued contract.

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etc.) and sum the results across all product categories. However, this ignores any correlation between interest rates, exchange rates, equity prices and other asset prices.

[13] Levonian (1994) analyses the market risk embodied in a foreign exchange portfolio. This analysis can be applied here by noting that the short and long foreign exchange positions in Levonian's discussion are analogous to the add-ons on all short contracts and the add-ons on all long contracts in our credit risk analysis.

[14] As a practical matter one difficulty with the weighted approach is that the optimal weights tend to vary over time. Hence the weights and banks' systems for monitoring capital adequacy would need to be updated frequently.

Thus, for contracts that are highly correlated, there may be a case for allowing add-ons to be netted.

One means of doing this would be to apply a broader range of factors to calculate add-ons than the four factors currently specified in the capital adequacy guidelines.[15] For example, time bands could be established for both interest rate and exchange rate contracts of differing maturities. This would allow long and short contracts of like maturity, and similar pricing behaviour, to be grouped and netted against each other.

To test that approach, interest rate contracts were divided up into the time bands shown in Table 7. The bands were set to roughly correspond with the general risk weights specified in Basle's proposal covering market risk on traded debt instruments.[16]

Table 7: Time Bands

Remaining term to maturity (years)	Per cent
term < 1	0
1 ≤ term < 2	0.2
2 ≤ term < 3	0.3
3 ≤ term < 4	0.4
4 ≤ term < 5	0.5
5 ≤ term < 7	0.6
7 ≤ term < 10	0.7
10 ≤ term < 15	0.8
15 ≤ term < 20	0.9
term ≥ 20	1

A final approach is one that extends the time bands approach. Rather than increasing the weight on notional principal in discrete steps, the potential exposure add-on is specified as a smooth, linear function of the term to maturity.

That is the add-on can be expressed as:

$$\text{Add-on} = 0.045 \times t \times FV \tag{5}$$

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15 See Section 5.1.

16 Basle Committee on Banking Supervision (1993), Annex 2.

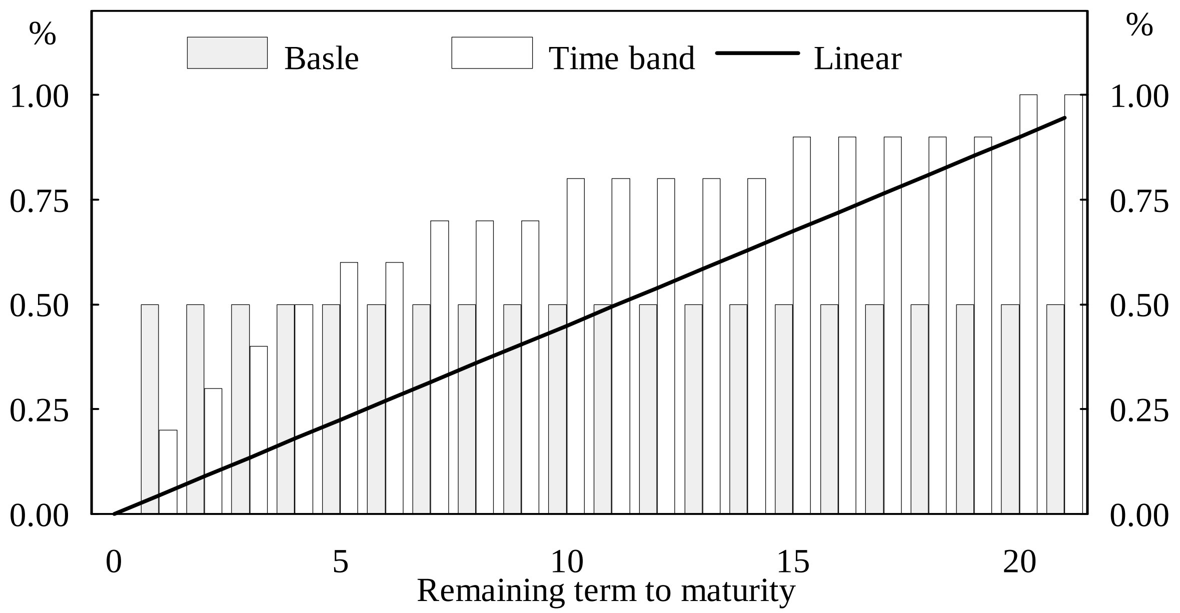
where:

t denotes the remaining term to maturity; and

FV denotes the notional principal amount of the contract.

The scaling factor of 4.5 per cent was chosen to approximate the time band weights set out in Table 7. The weights applied to the notional face value of interest rate contracts under this, linear approach, the current Basle method and the time bands method are shown in Figure 3.

Figure 3: Add-On Weights



The rationale behind the linear approach is that the volatility of the value of interest rate contracts increases smoothly and continually as the term to maturity lengthens rather than in discrete jumps. Therefore, a linear function may provide a better approximation of the true pattern of price volatility than a step function.

As is the case with the time band approach, the add-ons can be calculated either on a net or gross basis. For the linear method, we net across all contracts with a counterparty regardless of maturity. Given that the correlation even between the yields on six month and ten year swaps is quite high (refer Table 3) there is some justification for netting across all contracts. This overcomes a weakness of the time band approach - the capital required to cover potential exposure can increase sharply when closely, but not perfectly, matched contracts fall into separate time bands.

In addition to looking at the gross and net add-ons under the linear approach we combine the linear approach with the short/long approach. That is the maximum and a weighted average of the add-ons (calculated using equation (5)) on short and long contracts are also tested in the following sections.

6. RESULTS

6.1 Data

The data used to test the various methods for setting a capital charge consists of interest rate swap and forward rate agreement portfolios obtained from a number of Australian banks. In some cases the portfolios are complete - covering all counterparties. In other cases, those counterparties conducting the most business with the bank were selected. For the bulk of the portfolios, maximum credit exposure was calculated using the interest rate model and methods detailed in Section 3 and Appendix 1. However, in the case of five portfolios, credit exposure was calculated by the banks themselves using their own interest rate models and aggregation methods. The number of contracts and counterparties in each portfolio are presented in Table 8.

Table 8: Bank Portfolios

Bank	Counterparties	Contracts
1	214	1302
2	270	1635
3	32	283
4	43	773
5	45	316
6	22	93
7	255	1687
Total - RBA model	881	
8	141	1490
9	262	1625
10	54	164
11	248	1587
12	120	--
Total - banks' own models	825	
Total	1706	

6.2 Add-Ons

To test the alternative forms of add-ons, each was regressed against maximum potential exposure. Maximum potential exposure was calculated as the difference between maximum credit risk and the current net mark-to-market if positive and zero otherwise. Here, we are testing the ability of the add-on to cover the worst case increase in a portfolio's value.

For each bank's portfolio, the set of contracts with each counterparty are treated as separate sub-portfolios. This paper focuses on the structure of the portfolios made up of the contracts between a bank and one counterparty, rather than the portfolio of contracts across all counterparties. Traditionally credit risk analysis has looked at a total portfolio and argued that since swap portfolios are generally built up so as to avoid any market risk, a swap portfolio can be approximated as a collection of matched pairs of the swaps.[17] The difficulty with this when addressing the effect of netting is that, in most cases the set of contracts with each counterparty are not fully offsetting and the extent to which they are offsetting determines the impact of netting on both current and potential credit exposure. Hence, the capital charge is calculated for each counterparty.

[17] For example, Board of Governors of the Federal Reserve System and Bank of England (1987).

For each bank we regress (across counterparties) the capital charge against maximum potential exposure. That is, for each bank and each method of calculating an add-on, we estimate the equation:

$$PE_i = \beta \text{ Add-on}_i + \varepsilon_i \tag{6}$$

where:

PE denotes the estimate of potential exposure obtained using the methods set out in Section 3 and Appendix 1;

Add-on is the capital charge for potential exposure; and

i indexes the bank's counterparties.

The R^2 from these regressions are reported in Table 9. Note that the regressions are estimated without the inclusion of a constant, hence it is possible to obtain negative R^2 values. A common problem in cross sectional regression analysis is heteroscedasticity where the variance of the regression errors is not constant. In most cases it was found that the error variance increased with the size of the counterparty portfolio. Hence, the heteroscedasticity was corrected for by performing weighted least squares estimation using the sum of notional principal for each counterparty as a scaling factor.

In total, twenty separate methods were tested as a capital charge for potential exposure. They fall into seven broad groups.

1. The standard Basle add-on together with two different ways of calculating net mark-to-market. The first alternative calculates the net mark-to-market (Net RC) as the sum of the market value of all contracts in the portfolio if this sum is positive, and zero otherwise. This is the conventional way of calculating net credit exposure. It can be seen that except for one bank the net replacement cost performs poorly compared to the Basle approach. The second 'net' calculation (ABS Net) is to take the absolute value of the sum of the market value of the portfolio's contracts. This provides a much better measure of potential exposure, outperforming the conventional net measure in every case. It is more highly correlated with potential exposure than the Basle measure in a number of cases, but overall fails to out-perform the Basle add-ons.

2. The second group of capital charges are those suggested by ISDA and are denoted in Table 9 as ISDAC1, ISDAC2 and ISDAC3. They are calculated from equations (3) and (4), using the conventional definition of net (the sum of the contracts' market values if positive and zero otherwise) and gross (the sum of the positive market values in a portfolio). ISDAC1 is calculated from equation (3). ISDAC2 is calculated using equation (4) with β set equal to 0.25 (the value suggested by ISDA as being appropriate). A grid search was used to find an optimal value of β at 0.35. ISDAC3 is calculated using that value of β. For all banks, ISDAC2 and ISDAC3 are more highly correlated with potential exposure than ISDAC1.

3. The third group of measures, comprising ISDA1 and ISDA2, are also calculated from equations (3) and (4), but are based on the absolute net-to-gross ratio (that is, the absolute value of the sum of all contracts' net market value divided by the sum of the absolute market value of each contract). In this case, a grid search confirmed 0.25 as the appropriate value for β. These measures strongly out-rank those using the conventional net ratio in all cases except one. Because very few counterparties have a net market value of zero there is little difference in the explanatory power of the two formulations (ISDA2 outranking ISDA1 in five of the nine banks).

Table 9: Correlation Between Maximum Potential Exposure and the Proposed Add-Ons (R^2)

	Bank 1[a]	Bank 2	Bank 3[a]	Bank 4[a]	Bank 5[a]	Bank 6	Bank 7[a]	All - Fed model[a]	Bank 8	Bank 9[a]	Bank 10[a]	Bank 11
Basle	0.0731	0.0540	0.3392	0.0087	0.1295	0.2142	0.3862	0.2165	0.1340	0.3087	0.1066	0.2830
Net RC	-0.3302	-0.2705	0.0590	0.1321	-1.1168	-0.2409	-0.2198	-0.4928	-0.2097	0.1535	-0.6911	0.0578
ABS Net	-0.1847	0.3556	0.4425	0.6087	-0.0226	0.0118	0.3086	-0.2524	0.2646	0.4033	-0.0658	0.4187
ISDAC1	-0.3615	-0.0770	0.0428	0.0805	-0.2305	0.0001	0.1999	-0.0835	-0.0148	--	-0.4616	-0.7735
ISDAC2	-0.1735	-0.0156	0.2602	0.1489	0.0030	0.0714	0.3127	0.0636	0.1257	--	-0.1934	0.3587
ISDAC3	-0.1132	0.0022	0.3050	0.1414	0.0546	0.0965	0.3406	0.1054	0.1455	--	-0.1152	0.3587
ISDA1	0.2871	0.1647	0.7340	0.3526	0.2276	0.2345	0.4829	0.3589	-0.0090	--	0.1321	--
ISDA2	0.2754	0.1505	0.6862	0.3141	0.3002	0.2387	0.4949	0.3573	0.1299	--	0.2034	--
Short/Long:												
Maximum	0.1923	0.1320	0.5651	0.0599	0.2497	0.2382	0.5092	0.3309	0.0773	0.3246	0.1789	0.4169
Net	0.2488	0.2015	0.5825	-0.0841	0.1617	0.1906	0.5328	0.3601	0.0062	0.2730	0.0460	0.5972
Weighted	0.2502	0.1953	0.6223	-0.0213	0.2126	0.2066	0.5455	0.3701	0.0196	0.2894	0.0977	0.5760
+/- MTM:												
Maximum	0.1989	0.1318	0.5631	0.0559	0.2109	0.2382	0.4840	0.3202	0.1082	--	0.1789	0.4371
Net	0.2765	0.2027	0.5825	-0.0793	0.0780	0.1906	0.4733	0.3385	-0.0078	--	0.0460	0.5593
Weighted	0.2632	0.1850	0.6385	0.0185	0.1754	0.2193	0.5031	0.3537	0.0445	--	0.1360	0.5603
Time band:												
Gross	0.2503	0.1825	0.5416	0.2831	0.3994	0.2139	0.3836	0.3535	0.1220	0.3138	0.1909	0.2639
Net	0.4313	0.3331	-0.1443	0.5652	0.1912	0.3154	0.4315	0.4173	0.0700	0.2796	0.0620	--
Linear:												
Gross	0.2865	0.1802	0.5193	0.3089	0.4126	0.1580	0.3665	0.3562	0.1539	0.2842	0.1707	--
Maximum	0.4185	0.3116	0.7743	0.4954	0.4827	0.2545	0.4701	0.4807	0.0874	0.2759	0.2748	--
Net	0.4824	0.4590	0.8978	0.5210	0.3882	0.2227	0.4917	0.5241	0.0156	0.2170	0.0291	--
Weighted	0.4802	0.4326	0.9114	0.5677	0.4334	0.2501	0.3020	0.5299	0.0322	0.2361	0.1402	--

Note: [a] Estimation by weighted least squares.

Table 10: Correlation Between Total Credit Exposure and the Proposed Capital Charges (R^2)

	Bank 1[a]	Bank 2[a]	Bank 3[a]	Bank 4[a]	Bank 5[a]	Bank 6	Bank 7[a]	All - Fed model[a]	Bank 8	Bank 9[a]	Bank 10	Bank 11	Bank 12
Basle	0.9954	0.7498	0.7186	0.2201	0.6264	0.9882	0.8016	0.9779	0.6706	0.6109	0.8644	0.9903	0.9998
Basle alternative	0.9951	0.7248	0.6290	0.0884	0.5833	0.9862	0.7682	0.9757	0.6368	0.5964	0.8511	0.9887	--
Scenario	0.9956	0.7425	0.6329	0.1910	0.6196	0.9889	0.7827	0.9791	--	--	0.8884	--	--
ABS Net	0.9959	0.8479	0.8504	0.3069	0.6501	0.9873	0.8403	0.9810	0.5456	0.5989	0.8111	0.9736	0.9991
ISDA1	0.9953	0.7471	0.6987	0.1253	0.5941	0.9881	0.7873	0.9768	0.5637	--	0.8378	--	0.9998
ISDA2	0.9953	0.7479	0.7044	0.1518	0.6027	0.9881	0.7911	0.9771	0.6193	--	0.8449	--	0.9998
Short/Long:													
Maximum	0.9954	0.7492	0.7062	0.1812	0.6138	0.9881	0.7960	0.9775	0.6554	0.6079	0.8583	0.9896	0.9260
Net	0.9953	0.7483	0.6912	0.1347	0.6000	0.9879	0.7898	0.9770	0.6329	0.6045	0.8507	0.9881	0.3690
Weighted	0.9960	0.7818	0.7786	0.2728	0.6560	0.9898	0.8283	0.9806	0.4884	0.6192	0.8819	0.9874	--
Time band:													
Gross	0.9953	0.7492	0.6925	0.1891	0.6181	0.9872	0.7690	0.9772	0.6742	0.6074	0.8598	0.9896	0.9998
Net	0.9952	0.7492	0.6522	0.1656	0.5964	0.9873	0.7843	0.9766	0.6557	0.6055	0.8597	--	0.9998
Linear:													
Gross	0.9880	0.8481	0.3880	0.4401	0.8042	0.9593	0.8162	0.8974	0.1091	0.4402	0.5300	--	--
Maximum	0.9935	0.9116	0.5884	0.6702	0.9215	0.9893	0.8904	0.9391	0.0643	0.5053	0.6463	--	--
Net	0.9961	0.9251	0.7484	0.7019	0.9389	0.9892	0.8892	0.9606	0.0145	0.5362	0.6115	--	--
Weighted	0.9485	0.8279	0.3700	0.5676	0.8891	0.9778	0.7581	0.7392	0.0019	0.4140	0.4346	--	--

Note: [a] Estimation by weighted least squares.

4. The fourth set of add-ons measure the capital charge as a function of short and long positions. First, the maximum of the sum of the Basle add-ons on all short and long contracts was taken. Second, the absolute difference between the total add-ons on short and long contracts was considered (this is denoted short/long net in the table). Finally, a weighted sum of the Basle add-ons (that is, the short/long gross add-on) and the short/long net position is calculated. The respective weights were determined by regressing the two components of the weighted sum against maximum potential exposure. The optimal weights estimated were 23 per cent of the net add-ons and 2 per cent of gross add-ons. This reflects a strong correlation between the swap rates in the portfolios. Moving from the net short/long to the weighted short/long adds little to the explanatory power of the capital charge. The net add-ons tend to perform better than the maximum of the short and long add-ons.

5. The fifth group of add-ons approximate the short/long approach by splitting the portfolio between positively and negatively valued contracts. On the whole, these measures performed much like the short/long add-ons. The short/long approach appears to be slightly better at tracking potential exposure. The positive/negative approach can be expected to be a reasonably good proxy for the short/long add-ons given that swap rates have steadily declined for the four years prior to the date these portfolios were selected and that the average remaining term to maturity of the contracts is quite short (three-quarters of the contracts have a remaining term to maturity of less than three years). Further details of the maturity profile of the portfolios is presented in Table 11. Once the interest cycle moves beyond a turning point the performance of this set of add-ons can be expected to deteriorate. Moreover, while the interest rate cycle is fairly smooth, other asset prices such as foreign exchange rates tend not to follow such smooth cycles and so this approach may not be appropriate for foreign exchange and derivatives written against other commodities.

6. The sixth group are those based on the time band approach, the first being based on the gross time band, the second, on net time bands. In all cases, except one, the gross time band out-performs the Basle add-ons. Overall, the net time bands outperform the gross time band add-ons. However, the net add-ons perform poorly for several banks.

Table 11: Maturity Breakdown
(percentage of portfolio in each maturity band)

Years:	<1	1-2	2-3	3-4	4-5	5-7	7-10	10-15	15-20
Bank									
1	42.78	30.26	15.90	6.53	2.76	1.38	0.38	0.00	0.00
2	45.44	23.73	11.80	7.40	4.04	4.95	2.51	0.06	0.06
3	30.39	26.50	21.91	12.72	4.24	2.83	1.41	0.00	0.00
4	39.97	24.45	17.46	7.24	2.85	4.27	3.75	0.00	0.00
5	22.78	24.05	14.87	11.08	7.59	10.44	8.86	0.32	0.00
6	29.03	45.16	15.05	5.38	4.30	0.00	1.08	0.00	0.00
7	29.16	26.08	18.44	7.71	5.99	8.42	4.03	0.18	0.00
8	35.17	24.70	16.11	7.79	5.70	6.31	3.76	0.47	0.00
9	45.17	23.88	11.88	7.38	4.06	4.98	2.52	0.06	0.06
10	12.20	17.07	29.27	12.80	9.15	10.98	8.54	0.00	0.00
11	--	--	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--

7. The final group of add-ons are based on the linear function, equation (5). The gross measure (simply summing the add-ons for each contract) outperforms Basle and is on par with the detailed time bands gross result. The net measure, which nets the add-ons across all contracts for each counterparty does particularly well - overall outperforming the net time bands method. A weighted sum of the gross linear add-ons and the net linear add-ons, with weights of 3 per cent and 22 per cent respectively, improved slightly on the net add-on.

The results presented in Table 9 suggest that the Basle method outperforms the other measures in group 1 and those in group 2, but is itself outperformed, overall, by the measures shown under groups 3, 4, 5, 6 and 7. The one approach which appears to correlate most closely with potential exposure is the weighted linear add-on. The net linear add-on also performs particularly well.

These overall results hold, broadly speaking, for individual bank portfolios. There were, however, exceptions. The weighted linear add-on, the best overall measure, performed very poorly in the case of one bank (bank 10). In contrast, despite the inability of the ABS Net measure to track potential exposure across all banks, it generated relatively good results in the case of some individual banks (banks 4, 8 and 9).

6.3 Total Capital Charge

To test whether a total capital charge should be based on equation (1) (Basle preferred method) or equation (2), both measures were calculated using the Basle add-ons and were regressed against the modelled total credit exposure. For each bank and each method of setting a total capital charge, we estimate the equation

$$TE_i = \beta \, Charge_i + \varepsilon_i \qquad (7)$$

where:

TE denotes the estimate of total credit exposure obtained using the methods set out in Section 3 and Appendix 1;

Add-on is the total capital charge; and

i indexes the bank's counterparties.

The R^2 from these regressions are reported in Table 10. From Table 10 it can be seen that while the two approaches have practically the same explanatory power, the current Basle approach consistently outperformed the alternative. This comparison was performed using different methods of calculating the add-on, with the same result. This seems to be due to the fact that the add-ons tend to underestimate the increase in exposure and the standard, more conservative, approach to the calculation of the capital charge compensates for this.

The scenario approach, looking at the worst case credit exposure from current rates, and from up and down shifts in the yield curve, provides similar explanatory power as the Basle approach.

In the light of the results of the add-on tests, the following add-ons were included in a test of the total capital charge:[18]

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[18] The current exposure and the add-on were combined using the method proposed by Basle, that is using equation (4).

- the absolute value of net mark-to-market;
- the absolute net-to-gross ratios;
- the time band approach;
- the short/long approach; and
- the linear approach.

The results show that the variation in total exposure across counterparty portfolios is so dominated by current exposure that there is little to distinguish between the different add-on approaches. Overall, none of the formulations dominate the current Basle proposal by any significant margin.

These results are based on a comparison of the capital measures with the maximum potential exposure and maximum total exposure. In other words, capital is held to cover the possibility of counterparty failure at the worst possible time. A less stringent assumption is that a counterparty fails on any given day during the life of its contracts. In this case, it is more appropriate to consider the capital coverage in terms of average potential exposure and average total exposure. The results using these assumptions are presented in Appendix 2. The conclusions reached from this are broadly consistent with the results obtained from the analysis of maximum exposure. However, the relative performance of the net linear method improves somewhat.

6.4 Offsetting Contracts

The above results were obtained using static portfolios. One possibility is that the recognition of netting within the capital standards may provide an incentive for banks to enter into a greater number of offsetting contracts.

To test the effect of banks taking on a higher proportion of offsetting business, only those counterparties with two-way deals with banks 1 to 7 were selected and the capital charges were tested on this sub-sample. The results of this are presented in Table 12. Again, when considering the add-ons alone, the ISDA, the time band, the short/long and the linear approaches outperform the current Basle add-ons. The net and weighted linear methods are most strongly correlated with potential exposure. In the test of the total capital charge, however, there is no great difference in explanatory power between any of the proposed methods (the Basle method included).

Table 12: Counterparties with Two-Way Contracts: R^2 from Regressing the Capital Charge Against Modelled Exposure[a]

Add-ons		**Total capital charge**	
Basle	0.1977	**Basle**	0.9900
Net RC	-0.5415	**Basle alternative**	0.9887
ABS Net	-0.2998		
		Scenario	0.9906
ISDAC1	0.2705		
ISDAC2	0.2977	**ABS Net**	0.9906
ISDAC3	0.2927		
		ISDA1	0.9889
ISDA1	0.2705	**ISDA2**	0.9892
ISDA2	0.2977		
		Short/Long:	
Short/Long:		**Maximum**	0.9895
Maximum	0.2873	**Net**	0.9890
Net	0.2709	**Weighted**	0.9909
Weighted	0.2964		
		+/- MTM:	
+/- MTM:		**Maximum**	0.9895
Maximum	0.2650	**Net**	0.9889
Net	0.2208	**Weighted**	0.9909
Weighted	0.2686		
		Time band:	
Time band:		**Gross**	0.9894
Gross	0.2846	**Net**	0.9889
Net	0.2896		
		Linear:	
Linear:		**Gross**	0.9020
Gross	0.2824	**Maximum**	0.9485
Maximum	0.3792	**Net**	0.9734
Net	0.3826	**Weighted**	0.8009
Weighted	0.4042		

Notes: [a] Estimation by weighted least squares.

6.5 A Different Yield Curve

All the preceding results obtained took the beginning of 1994 as the starting point for the interest rate simulations. This was, in all likelihood, close to the trough in the Australian interest rate cycle. To test the sensitivity of the results to the level of interest rates the credit risk calculations were performed a second time using rates at the beginning of 1992 (initial short rate 7.4 per cent and long rate 9.75 per cent) for one actual portfolio and one randomly generated portfolio.[19] The results, for both the 1994 and 1992 credit risk calculations are shown in Tables 13 and 14.

Table 13: Shifts in the Yield Curve: Correlation Between Maximum Potential Exposure and the Proposed Add-Ons (R^2)

	Actual 1994	Actual 1992	Random 1994	Random 1992
Basle	0.2760	0.2519	0.0072	0.0171
Net RC	-0.3526	-0.5376	-0.0854	-0.9098
ABS Net	0.1562	-0.0356	0.2891	0.0199
ISDAC1	-0.1547	-0.7556	-0.7298	-1.2703
ISDAC6[a]	0.2057	-0.1583	-0.2208	-0.4000
Short/Long:				
Maximum	0.3272	0.3686	0.0885	0.1258
Net	0.2011	0.3391	--	--
Weighted	0.2496	0.3706	--	--
Net time band	0.1606	0.4006	0.0833	0.1469
Linear:				
Gross	0.2955	0.4178	--	--
Maximum	0.3780	0.5226	--	--
Net	0.1959	0.3285	--	--
Weighted	0.2865	0.4293	--	--

Note: [a] ISDAC6 is the conventional ISDA formulation calculated with b set equal to 0.6.

[19] The size of the randomly generated portfolio was doubled by creating an exactly offsetting deal for each initial deal. Hence the net market value of the total portfolio is zero.

Table 14: Shifts in the Yield Curve: Correlation between Total Credit Exposure and the Proposed Total Capital Charge (R^2)

	Actual 1994	Actual 1992	Random 1994	Random 1992
Basle	0.8644	0.3202	0.9693	0.5185
Basle alternative	0.8511	0.2371	0.9564	0.4106
Scenario	0.8884	0.6000	0.9623	0.6099
ABS Net	0.8111	0.2373	0.9341	0.4925
ISDAC1	0.8377	0.1772	0.9532	0.3727
ISDAC6[a]	0.8534	0.2636	0.9638	0.4619
Short/Long:				
Maximum	0.8583	0.3086	0.9653	0.4844
Net	0.8507	0.2923	--	--
Weighted	0.8819	0.4286	--	--
Net time band	0.8597	0.2590	0.9605	0.436
Linear:				
Gross	0.5300	0.4982	--	--
Maximum	0.6463	0.6337	--	--
Net	0.6115	0.5565	--	--
Weighted	0.4346	0.5043	--	--

Note: [a] ISDAC6 is the conventional ISDA formulation calculated with β set equal to 0.6.

Turning first to the comparison of the add-ons with potential exposure, when the 1992 interest rate scenario is adopted, the performance of the net time band, the short/long and the linear add-ons improves. In the case of the total capital charge, however, the explanatory power of all formulations falls significantly, except the linear approach. The linear and scenario approaches appear to be most robust to the shift in the yield curve, however the scenario approach clearly outranks the linear approach under the 1994 interest rate scenarios.

This result introduces a note of caution in interpreting the results and in imposing a capital charge; the level of interest rates can have an effect on outcomes.

7. COVERAGE

This section presents some evidence on the extent to which credit exposure falls when moving from a non-netting to a netting environment.

The reduction in replacement cost (current exposure) depends upon the composition of each bank's portfolio; in particular the value of out-of-the-money contracts. For banks 1 to 7, we estimate that moving from calculating current exposure on a gross basis to a net basis, will reduce replacement cost by an average of 33 per cent (see Table 15). This assumes that netting agreements are concluded with all counterparties who conduct two-way business.

It is quite possible that, in a netting environment, the reduction in current exposure may be larger (both in proportional and absolute terms) than the reduction in maximum future exposure, which implies that potential exposure may in fact increase. Consider the case of a portfolio of contracts with negative market value overall, but which contains some positively valued contracts. The gross current credit exposure will have some positive value, while the net current exposure will be zero. Hence, adoption of netting will result in a 100 per cent reduction in current credit exposure. However, it is quite possible that in *both* the gross and net environments, future potential exposure will take on some positive value. While the gross potential exposure may be considerably higher than the net potential exposure, so long as net potential exposure is positive, the proportionate reduction in potential exposure when moving from gross to net will be less than 100 per cent.

Table 15 shows that the average increase in the gap between maximum exposure and the capital held for current exposure is small, at just one per cent. However, for individual banks the gap can increase by as much as 30 per cent. Reflecting this, Table 16 shows that the coverage of potential exposure by the Basle add-on is little different, overall, between the netted and non-netted scenarios. Table 16 also demonstrates that while the Basle measure of credit exposure covers only a proportion of maximum credit exposure (a reflection, in part of the comparatively severe assumptions behind this measure of exposure) it more than adequately covers average credit exposure.

Table 15: Percentage Change from Non-Netted to Netted Exposure

				The gap between total exposure and current exposure:	
	Maximum exposure	Average exposure	Capital for current exposure	Maximum exposure	Average exposure
Bank 1	-16.89	-39.42	-20.88	-6.53	2.15
Bank 2	-18.66	-21.44	-25.13	-7.08	-31.89
Bank 3	-36.11	-32.46	-14.61	-41.46	-49.10
Bank 4	-35.12	-39.72	-70.04	31.17	-123.89
Bank 5	-13.77	-19.49	-43.92	27.75	-200.28
Bank 6	-8.34	-9.13	-7.78	-10.21	-6.45
Bank 7	-21.55	-23.69	-37.59	8.77	-70.99
Total	-20.98	-27.53	-33.13	1.02	-44.59

Table 16: Coverage

	Percentage of potential exposure covered by the Basle add-ons				Percentage of total exposure covered by the Basle credit equivalent			
	Non-netted		Netted		Non-netted		Netted	
	Max exposure	Avg exposure	Max exposure	Avg exposure	Max exposure	Avg exposure	Max exposure	Avg exposure
Bank 1	10.99	100.00	11.76	100.00	76.27	190.63	72.45	248.41
Bank 2	10.98	100.00	11.82	100.00	65.39	157.44	63.92	159.33
Bank 3	7.78	29.18	13.28	57.34	33.36	80.89	36.35	83.36
Bank 4	18.17	100.00	13.85	111.18	68.73	163.99	39.91	102.49
Bank 5	10.83	100.00	8.48	58.04	59.54	118.84	42.96	91.83
Bank 6	20.78	100.00	23.14	100.00	145.02	380.73	82.69	219.00
Bank 7	12.60	100.00	11.59	100.00	65.40	141.59	57.59	128.18
Total	11.98	100.00	11.86	100.00	64.43	148.81	59.93	150.90

8. CONCLUSION

There are strong theoretical arguments in favour of a more sophisticated approach to setting a credit risk capital charge when obligations are netted. However, empirical support for these arguments does not appear to be as strong. The work with Australian banks' portfolios provides some evidence to suggest that a number of approaches to the calculation of the add-on provides a more efficient coverage of potential exposure than the current Basle formula, namely:

- the current Basle add-on scaled by the absolute ratio of net to gross market value;
- the short/long approach;
- a method which allows the add-ons for contracts within given time bands to be netted; and
- a smooth, rather than stepped, function of term to maturity.

The approach to the calculation of a total capital charge which appears most robust to interest rate movements over the cycle is the scenario approach. While several approaches are some improvement over the proposed method, no single formulation clearly outranks all others.

The better performance of these alternative approaches to capturing potential exposure is not sufficient to outweigh the dominance of current exposure in the determination of the total capital charge. So long as the coverage of potential exposure afforded by the add-ons remains low relative to that provided for current exposure, and that is one conclusion of this work, then the capital charge will continue to be dominated by current exposure. That suggests that the case for a more complex formulation of the capital charge is not warranted.

The conclusions of the analysis are, nonetheless, tentative since the work covers only portfolios comprising simple interest rate swaps and forward rate agreements. Exchange rate and other, more complex, derivatives have not been considered. The add-on factors for exchange rate contracts are considerably higher than those for interest rate contracts. Hence, the add-ons for a portfolio made up of both interest rate and other contracts could represent a higher proportion of the total capital charge than for a portfolio of interest rate contracts alone. This remains an empirical question since current exposure on these contracts could also be higher. Whether the add-ons represent a higher or lower proportion of the total capital charge for more complex portfolios, will depend upon the composition of the portfolio and on market conditions.

APPENDIX 1

A1.1 Interest Rate Model

The model used to generate the time paths for interest rates is that used by the Federal Reserve Bank of New York (FRBNY) in some of its work on netting. This model incorporates a simple curved and varying term structure.[20] The two end points of the yield curve are allowed to vary stochastically over time and all points between these two are determined by an exponentially weighted average of those two yields.

Movements in the short yield are assumed to be driven by two factors. Firstly, the short yield is taken to drift towards the current long yield at a fixed speed determined by the parameter k. Secondly, a random shock, ε , is added to this process. The standard deviation of this shock is taken to be proportional to the short yield. The discrete approximation to this process is:

$$S_{t+1} = S_t + k\,(L_t - S_t)\,\Delta t + \varepsilon\, S_t \sqrt{\Delta t} \qquad \text{(A1)}$$

where:

t denotes time;

S_t is a short yield;

L_t is a long yield;

ε is a standard normal deviate; and

k is the rate of reversion of the short rate towards the long rate.

The long yield is modelled as geometric Brownian motion with no drift.

$$dL = \sigma\, L\, dz \qquad \text{(A2)}$$

where:

dz is a Wiener process.

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[20] The FRBNY has conducted work using this model and the more sophisticated model developed by Longstaff and Schwartz (1992). While the simpler model we use lacks the theoretical rigour of the latter model the FRBNY found that, for their work, the two models yielded similar results.

Hence the logarithm of the long rate can be taken to be distributed normally:

$$M_t \sim N(M_0 - \sigma^2 t/2, \sigma^2 t) \qquad \text{(A3)}$$

where:

M_t = $\ln(L_t)$; and

M_0 is the current value of M.

While the long rate is characterised as geometric Brownian motion with no drift, there is drift in the process determining the log of the long rate, M_t. This drift term, $-\sigma^2 t$, is reflected in the simulation process to prevent the simulated interest rate paths from drifting upwards. The stochastic processes ε and dz are assumed to be independent.

Given a short and long yield, yields for any maturity are derived using the following equation:

$$y(\tau) = L + (S - L)\frac{(1 - e^{-k\tau})}{k\tau} \qquad \text{(A4)}$$

where:

$y(\tau)$ denotes the yield for maturity to τ.[21]

Parameters for this model were obtained using weekly observations of the 90-day bank bill rate and the ten-year government bond rate over the period January 1984 to August 1993. σ was estimated to be equal to 0.1, and k was estimated at 0.46.

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[21] Note that the model's long rate is in fact the rate on a security with infinite term to maturity, that is, $y(t) = L_t$ only when $t \rightarrow \infty$. Equation (3) can be modified so that $y(10) = L_t$ by replacing L_t with L_t^* where $L_t^* = \frac{L_t - fS_t}{1 - f}$ and $f = (1 - e^{-10k})/10k$. That is equation (3) is rewritten as $y(\tau) = L^* + (S - L^*)\frac{(1 - e^{-k\tau})}{k\tau}$. For our simulations we do not employ this adjustment, but simply use equation (3) above.

Initial values for the short and long rates were set at 4.75 per cent and 6.82 per cent respectively.[22]

The confidence interval on the short rate is derived from simulations of equation (A1). The confidence interval on the long rate can be obtained directly from equation (A3). For the purposes of the analysis, two worst case interest rate scenarios are considered: firstly, both short and long rates track the upper band of their 95 per cent confidence intervals; and secondly, both short and long rates fall to the lower extreme of their confidence intervals. For each contract we calculate replacement cost at weekly intervals over the life of the contracts for the two interest rate scenarios.

A1.2 Setting the Swap Rate

The interest rate model above determines the yield curve for zero coupon interest rates. To revalue an interest rate swap it is necessary to derive a swap rate from the zero coupon rates.

A fixed-to-floating swap can be characterised as a combination of a standard fixed interest bond and a floating rate note. The fixed rate side can be valued using traditional security valuation techniques based on present value concepts. Valuation of the floating rate side is complicated by the fact that the expected cash flows are not certain as they are contingent on the level of future interest rates. We assume that the floating rate component has been reset to par (notional face value) since the floating rate side is frequently repriced.

Hence, the current market price of the swap, P_0 can be written as:

$$P_0 = \left(-1 + \sum_{j=1}^{n} \left(\frac{iC_j}{(1 + z_j)^j} \right) + \frac{1}{(1 + z_n)} \right) \text{x FV} \qquad \text{(A5)}$$

where:

z_j denotes the zero coupon rate applicable to a cash flow occurring at time j;

n denotes the total number of coupons payable under the swap;

---

[22] These values compare with estimates obtained using US data for σ and k of 0.1 and 0.3 respectively.

C_j	is equal to the jth coupon period;
FV	is the notional principal amount; and
i	is the swap rate.[23]

To determine the swap rate, i, we assume that at the date the swap is written the swap rate is set such that the current market price of the swap is zero. That is, equation (A5) is solved for i setting P_0 equal to zero. In theory competitive forces within the swap market should ensure that this condition holds.

For example, consider a 3-year swap, written on 20 September 1992 with fixed rate payments payable semi-annually, and the following zero coupon rates substituting these values into equation (A5) and setting P_0 equal to zero yields a swap rate of 5.57 per cent.

Table A1: Zero Coupon Rates

Coupon dates	**Zero coupon yield curve z_j**	**Coupon period (years) C_j**
20 Mar 92	4.96	0.4986
20 Sep 92	5.15	0.5041
20 Mar 93	5.30	0.4959
20 Sep 93	5.44	0.5041
20 Mar 94	5.56	0.4959
20 Sep 94	5.67	0.5041

To summarise the process for an individual contract: at each point in time, a worst case zero coupon yield curve is observed. From that yield curve, a swap revaluation rate is calculated which is the market rate to replace the remaining cash flows of the swap. The present value of the difference between the swap's cash flows and the payments made under the replacement swap is calculated to give the value at risk if the counterparty were to default. These steps are repeated at weekly intervals over the life of the swap to generate a time path for the credit exposure of the contract.

23 This is an extension of the formula given in Das (1994) p. 192.

APPENDIX 2

Table A2: Correlation Between Average Potential Exposure and the Proposed Add-Ons (R^2)

	Bank 1[a]	Bank 2	Bank 3[a]	Bank 4	Bank 5[a]	Bank 6	Bank 7[a]	All - Fed model[a]
Basle	-0.0314	-0.0788	0.3254	0.0709	0.0140	-0.2392	0.2410	0.1879
Net RC	-0.3519	0.0836	0.3375	0.5025	-0.2380	-0.2736	0.2065	-0.0110
ABS Net	-0.3517	0.0938	0.3401	0.6314	-0.0872	-0.2722	0.2202	-0.0071
ISDAC1	-0.3393	-0.1362	0.0512	0.2778	-0.3089	-0.2749	0.1325	0.2112
ISDAC2	-0.2513	-0.1207	0.2392	0.2367	-0.1675	-0.2687	0.1950	0.2240
ISDAC3	-0.2112	-0.1140	0.2798	0.2072	-0.1248	-0.2656	0.2109	0.2219
ISDA1	0.1308	-0.0418	0.6933	0.3615	-0.0151	-0.2420	0.3457	0.3293
ISDA2	0.1059	-0.0500	0.6400	0.2836	0.0389	-0.2410	0.3352	0.2960
Short/Long:								
Maximum	0.0619	-0.0564	0.5263	0.1286	0.0332	-0.2358	0.3262	0.2822
Net	0.1390	-0.0283	0.5634	0.1013	-0.0514	-0.2339	0.3680	0.3930
Weighted	0.1308	-0.0333	0.5924	0.1346	-0.0215	-0.2341	0.3694	0.3823
+/- MTM:								
Maximum	0.0700	-0.0562	0.5263	0.1382	0.0129	-0.2358	0.3166	0.1825
Net	0.1670	-0.0273	0.5634	0.1440	-0.0947	-0.2339	0.3460	0.2158
Weighted	0.1381	-0.0371	0.6014	0.1717	-0.035	0.2343	0.3487	0.2152
Time band:								
Gross	0.1228	-0.0203	0.5157	0.1884	0.1335	-0.235	0.2263	0.1937
Net	0.2638	0.0527	-0.0974	0.4199	0.0017	-0.2111	0.2711	0.2370
Linear:								
Gross	0.1604	-0.0133	0.481	0.1991	0.1358	-0.2385	0.2147	0.2054
Maximum	0.2805	0.0454	0.7157	0.3199	0.1509	-0.2408	0.2855	0.2941
Net	0.3744	0.1332	0.8587	0.3923	0.0918	-0.2484	0.3219	0.3458
Weighted	0.3599	0.1127	0.8598	0.4216	0.1154	-0.2461	0.3211	0.3425

Notes: [a] Estimation by weighted least squares.

Table A3: Correlation Between Average Total Credit Exposure and the Proposed Total Capital Charge (R^2)

	Bank 1[a]	Bank 2[a]	Bank 3[a]	Bank 4[a]	Bank 5[a]	Bank 6[a]	Bank 7[a]	All - Fed model[a]
Basle	0.9665	0.6054	0.8844	0.5155	0.5649	0.4979	0.7658	0.7304
Basle alternative	0.9659	0.5874	0.8524	0.4785	0.5337	0.4799	0.7437	0.7244
Scenario	0.9681	0.6250	0.8415	0.5338	0.5681	0.5341	0.7673	0.7568
ABS Net	0.9671	0.6599	0.8982	0.4094	0.5687	0.4837	0.7785	0.7195
ISDA1	0.9662	0.6063	0.8813	0.4896	0.5413	0.4972	0.7564	0.7188
ISDA2	0.9663	0.6062	0.8827	0.4979	0.5476	0.4974	0.7589	0.7218
Short/Long:								
Maximum	0.9663	0.6072	0.8833	0.5121	0.5561	0.4974	0.7629	0.7239
Net	0.9662	0.6087	0.8798	0.5040	0.5463	0.4967	0.7594	0.7171
Weighted	0.9678	0.6312	0.9091	0.5484	0.5909	0.5202	0.7895	0.7343
+/- MTM:								
Maximum	0.9663	0.6073	0.8833	0.5118	0.5544	0.4974	0.7618	0.7848
Net	0.9662	0.6088	0.8798	0.5038	0.5429	0.4967	0.7572	0.7836
Weighted	0.9677	0.6294	0.9085	0.5466	0.5858	0.5193	0.7853	0.7934
Time band:								
Gross	0.9662	0.6096	0.8771	0.5183	0.5613	0.4909	0.7580	0.7246
Net	0.9661	0.6114	0.8615	0.5133	0.546	0.4923	0.7546	0.7169
Linear:								
Gross	0.9844	0.6529	0.2110	0.2087	0.6694	0.6128	0.6981	0.8910
Maximum	0.9886	0.7340	0.3401	0.3617	0.7969	0.6848	0.7936	0.9184
Net	0.9899	0.7815	0.4683	0.4665	0.8442	0.7025	0.8282	0.9224
Weighted	0.9743	0.6957	0.1362	0.2927	0.7877	0.7258	0.6838	0.8499

Notes: [a] Estimation by weighted least squares.

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