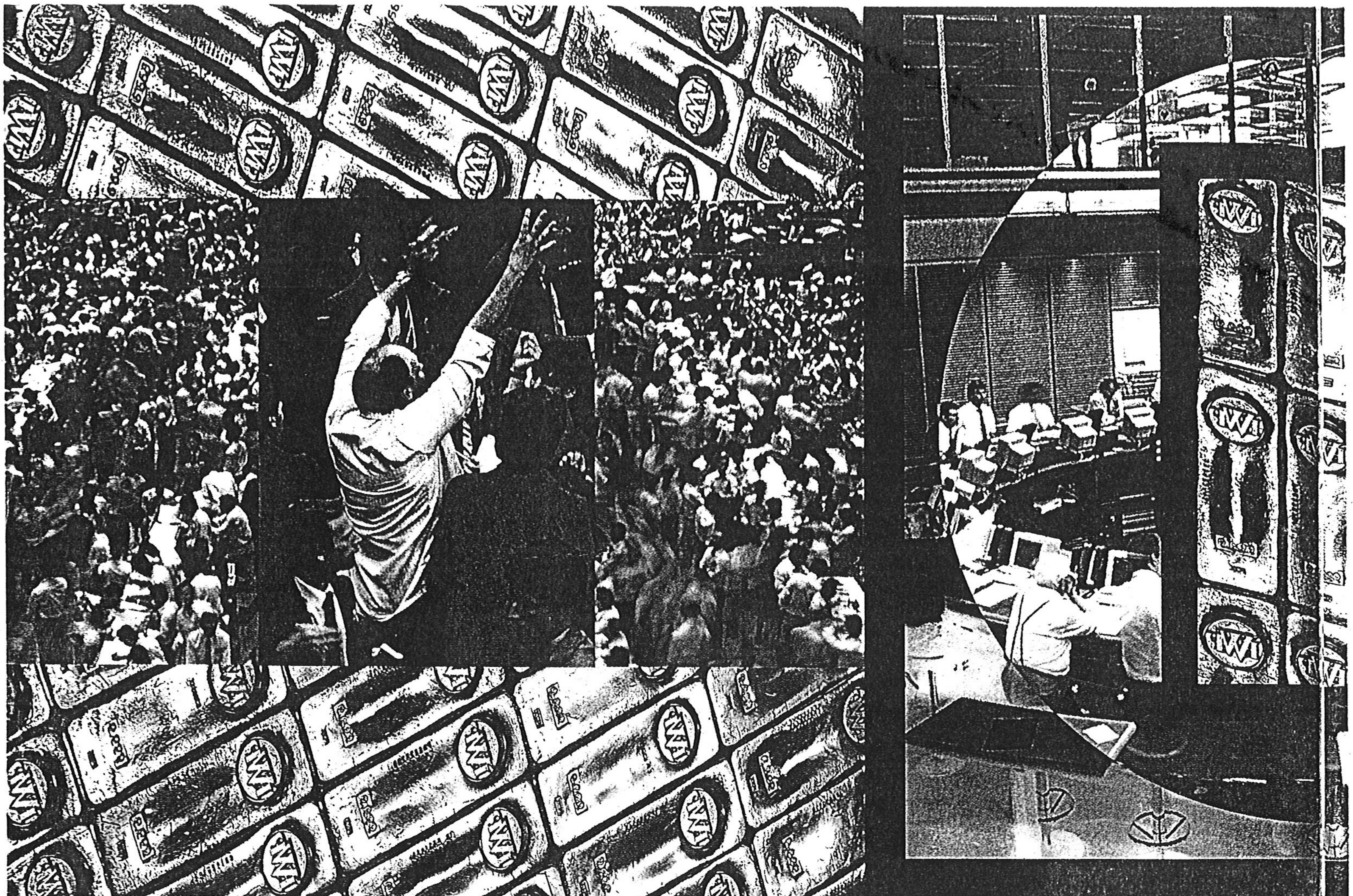


CALCULATED GAMBLING

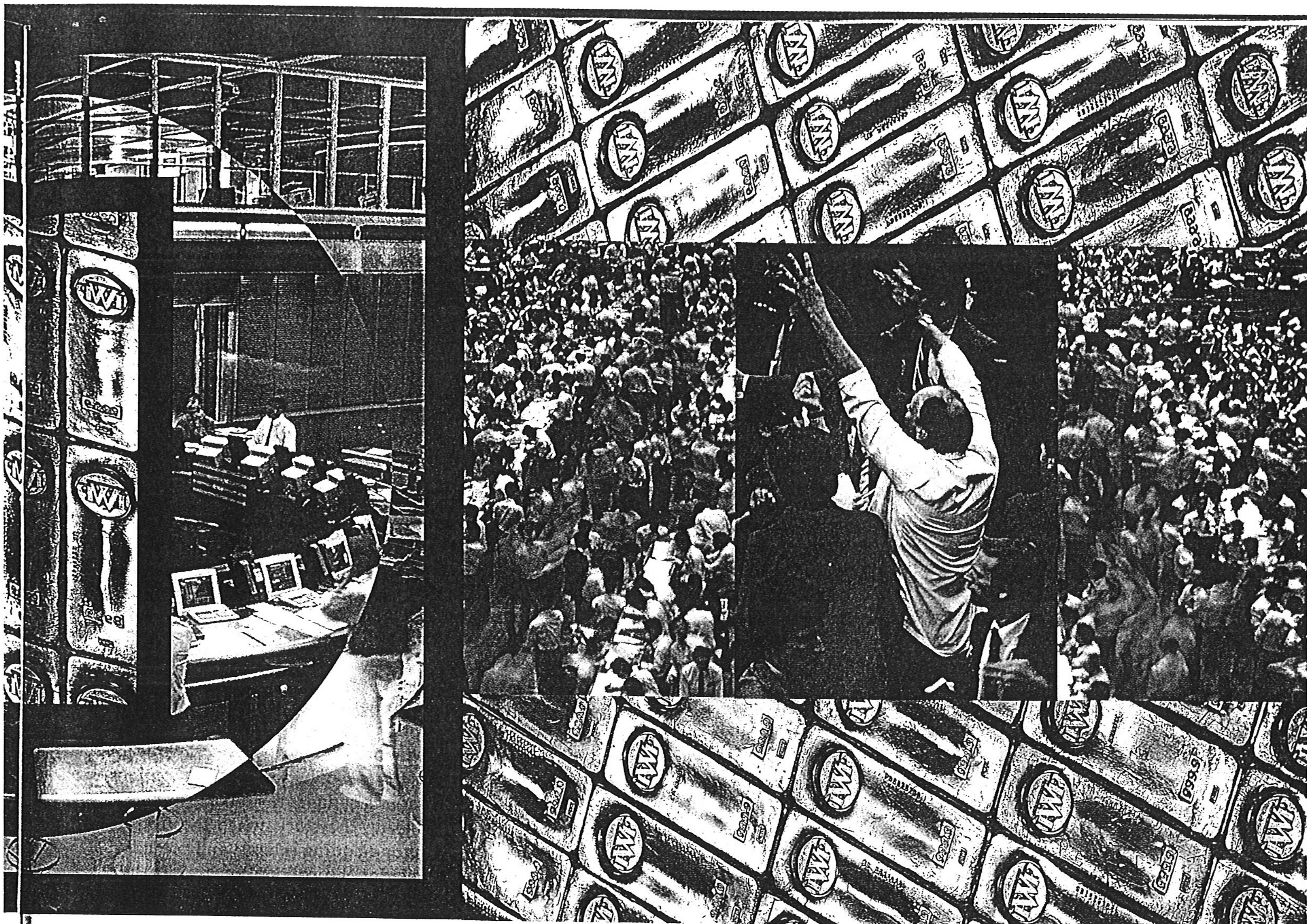
What is a vanilla option? Why would you want to buy an Act of God bond? *Joe Pimbley* explains the peculiar world of derivatives traders and the complex equations that rule everything they do

PETER BARING, former chairman of Barings bank, will never forget the name Nick Leeson. From a desk in Singapore, the sandy-haired derivatives trader single-handedly lost £830 million of the bank's money through ill-considered trading in options and futures between July 1992 and February 1995. Barings collapsed, and in a masterpiece of understatement the Bank of England concluded that "Nick Leeson was not properly supervised".

Now it has happened again, this time at Britain's National Westminster Bank. Last month, six managers of its investment banking branch resigned after the firm lost a cool £77 million in "interest rate swap options" and "options books", two of the bewildering array of complex derivative instruments now bought and sold on the world's financial markets.

Derivatives, it would seem, are terrifically risky. But are they really riskier than traditional stocks and bonds? Or are such disasters just further evidence of the human disposition toward irrationality?

Increasingly, these questions have been



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prompting financial institutions to call in the mathematicians as they search for equations and software that can best hedge their bets on these unusual products. For unlike traditional stocks and bonds, which give the holder part ownership of a company or a steady interest income, derivatives are intangible bundles of mere rights and obligations, which refer only to "virtual" purchases or sales at some time in the future. Wise investment requires an astute reckoning of the values of the things that are bought and sold. And while this is straightforward for stocks and bonds—since supply and demand fixes their prices in the marketplace—assessing the value of a package of rights isn't so easy.

But it turns out that with a little mathematics, derivatives can be assigned values every bit as precise as those for other financial products. Financial theorists use probability theory, partial differential equations and stochastic calculus to tease out the formulas. And as a result, derivatives needn't be especially risky despite their ethereal nature.

But why do such unwieldy products exist in the first place? There are plenty of opportunities to invest in the ordinary stock, bond, commodity and currency markets, where the only rules are buy low, sell high and swear a lot.

But suppose you want to buy stock in, say, the XYZ company, but don't have enough cash on hand. Or perhaps you want to reserve the right to buy some stock in the future, but only if the price is right. What then? This is where derivatives come in. Derivatives give investors opportunities they wouldn't normally have.

Let's imagine you want to buy 1000 shares of XYZ stock, which is today valued at £100 per share, but you have no money to hand. A derivatives trader will agree to sell the 1000 shares, for delivery one year in the future, at a fixed price that you agree on now. This is a "forward contract", and allows you to plan your investment strategy even when you are short of cash. You hope the stock will be higher next year than the price you agreed, but it could be lower.

The derivatives trader takes a risk too. For if the trader waits in the hope that the stock price will fall, only to watch it rise, he or she will suffer a loss when the deal comes due. The trader would have to buy 1000 shares at the higher rate and sell them to you at the lower rate agreed the previous year.

Any sane trader

Why then would any sane trader agree to such a scheme? Well, everything has a price. To determine the "forward price", the trader simply works out the cost of eliminating the risk. In this case, the trader buys the stock today, just after entering the contract with you (see diagram on p 40). After holding it for a year, the trader hands it over to you for the agreed price, and is indifferent to any changes in its value that might have occurred in the meantime. This strategy completely eliminates the trader's risk.

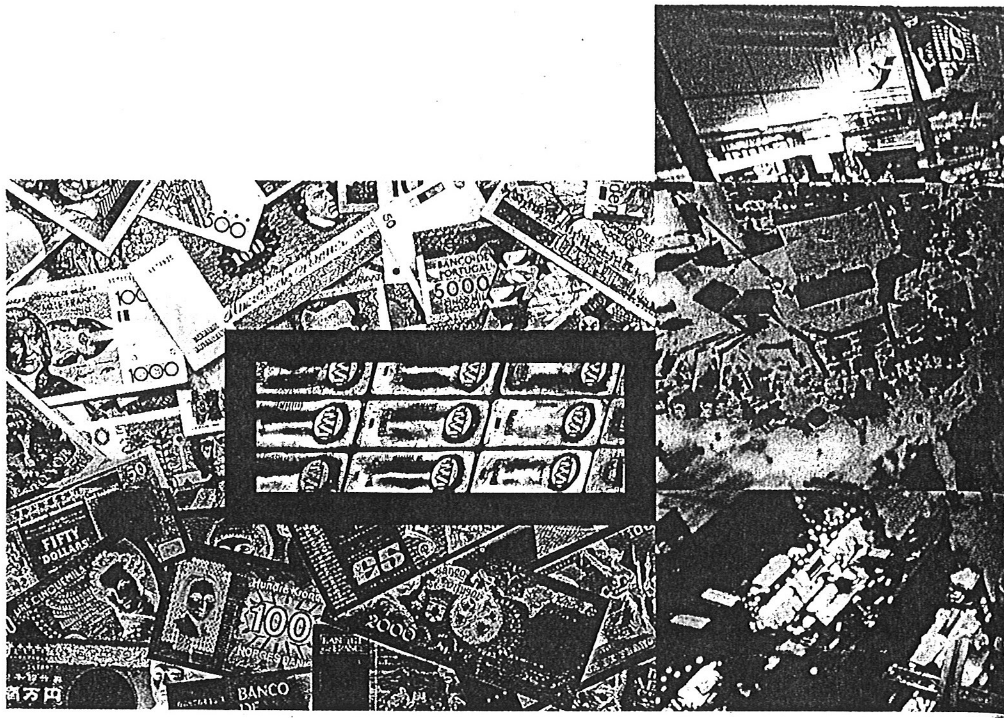
To do this, the trader incurs the cost of borrowing £100 000 for a period of 1 year in order to buy the stock. At, say, 5 per cent interest for the year, he or she has to repay £105 000 when the year is up. The trader will then ask you for £105 000 plus a "reasonable" profit, probably not more than £1000, as the forward price to be paid in a year's time.

Hedge trimmers

So, the forward price has nothing to do with anyone's predictions of what might happen over the next year, but is determined by the cost of the trader's strategy for eliminating risk, otherwise known as a "hedge". Hedging derivatives trades is a trader's primary responsibility, and always involves buying or selling appropriate amounts of the "underlying" asset—that is, the stock or other asset to which the contract refers. Random variations in the values of the forward contract and the stock cancel out, leaving the trader with no net risk.

This seems easy. And it is. But things get more complicated with other derivatives such as "options". In the last example, you had to buy the 1000 shares of stock at £105 per share, regardless of the stock's value after 1 year. If the stock were worth only £95 per share at year end, you would still have to pay £105, and lose £10 per share.

To avoid this risk, you might instead buy a "call option" on XYZ stock which would be valid for a year and have a "strike price" of £105. In this contract, you have the right after a year to purchase 1000 shares at £105 per share. If the stock is only worth £95 per share, you won't exercise your right. But if the value of the shares is £120 then you will, because you can buy it cheaply and immediately make a profit by re-selling it.



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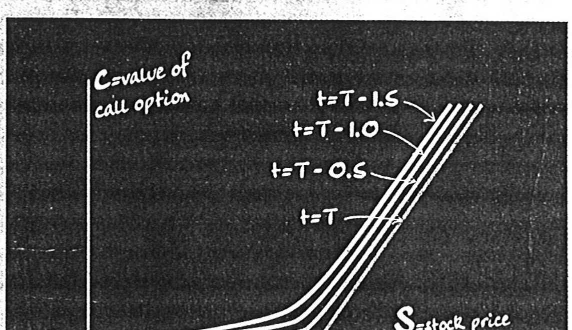
From your perspective, the call option is clearly preferable—you're not locked into anything. Because of this advantage, options must be purchased at the outset. So how much do you have to pay for a call option? Again we face the question: what is the value of a package of rights?

In one form or another, options have existed for more than a century. But until 25 years ago, there was no satisfactory theory for valuing them. Then, in 1973, Fischer Black of the University of Chicago and Myron Scholes of the Massachusetts Institute of Technology published a now famous paper that showed how to do it. As in the problem of valuing a forward purchase, the Black-Scholes method looks at how a derivatives trader should hedge the option that he or she has just sold to an investor. In other words, the cost of the option is the cost of hedging. But for options, the trader's hedge is not quite as simple as purchasing the stock when the contract begins and adding interest and profit.

Consider the call option to buy 1000 shares of stock in XYZ after 1 year at some fixed strike price. The price of the stock varies randomly, and if it goes up, the option is clearly more valuable than if it goes down. The trader has to make good on the deal if the option is exercised, and so runs a risk. Just buying and holding the stock for a year can't eliminate this risk, because the stock price might plummet,

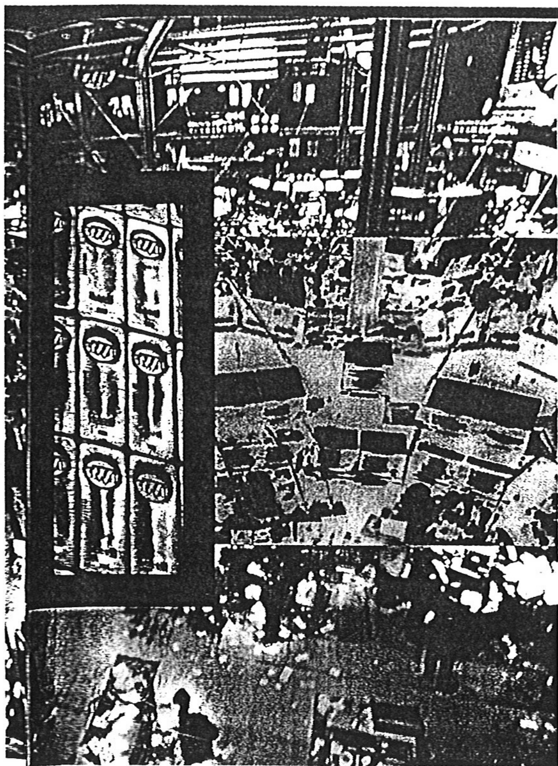
Valuing your options



Consider a call option to purchase stock at strike price E at some time T in the future. At any moment during its lifetime, the option's value depends on several things, such as the current stock price S, the prevailing interest rate, the stock's volatility, and the time remaining before the option matures. By solving the Black-Scholes differential equation, derivatives traders obtain a formula for the option's value as it depends on these things.

The diagram shows the value of a call option, according to the formula, at several moments (measured in months) prior to its maturity date. The option's value is generally higher if the current stock price is high. But the option still has some value even if the stock price S is less than the strike price E, because there is still some chance that the stock price will rise.

Curiously, the Black-Scholes equation is directly analogous to those used by physicists and engineers to describe the diffusion of neutrons in a nuclear reactor, or the flow of heat through a slab of steel. In solving it, the financial world draws heavily on the toolbox of the mathematical physicist.



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in which case the owner of the option won't exercise it, and the trader will lose money on the stock.

At any time, the value of the option depends on the current stock price. The higher this price goes relative to the strike price, the more the option is worth since it promises to pay off in the end. But the option's value also depends on other things, such as the time remaining until the option expires, the prevailing interest rate, and the volatility of the stock. The volatility is a measure of how much the stock's price has fluctuated in the past (see Valuing your options p 38).

The Black-Scholes equation

The Black-Scholes equation takes all this into account, and assesses the cost of hedging away the risk of holding the stock that you may want to buy. After selling the option at the price arrived at by solving the Black-Scholes equation, the trader can then use the same formula each day to work out whether it is advisable to buy or sell the stock as its price moves about. In this way, the trader will eventually get rid of all the stock if the price ends up being low at expiry, or will have bought all the necessary stock if the price is high at expiry. If the option expires at prices very close to the strike price, the trader will not lose too much either way. On the other hand, the holder of the option may want to sell the option to a third party, and will use the same formula to arrive at its value. In any case, the equation counsels the proper strategy.

Investors use solutions like this to decide, depending on current prices and the time until the options expiry, how and when to trade options. The solution to the equation also gives precise instructions to the trader on the exact strategy of hedging that needs to be followed. And by following the strategy, the trader automatically ends up holding just the right amount of stock at maturity.

Solving complex differential equations may seem like a lot to go through just to work out a price. But the solution is relatively easy to set up on a spreadsheet or pocket calculator, and it gives an exact result, which is quite valuable when millions of pounds are at stake. As one company has it: "Trading options without the Black and Scholes formula is like wandering in the desert without a compass."

Effectively, the procedure is the same as that used in the case of the forward contract. The trader pays money—in the form of interest to some lending bank—to buy and hold the stocks necessary to hedge his or her position. And this is the cost of the option.

The important thing to remember is that the entire scheme is based on the concept of hedging. The trader does not want to expose him or herself to risk. Of course, the buyer of an option does have a risk, and will lose the small fee paid whether or not the option is exercised.

Call options are not the end of the story. In financial vernacular, a call option is a "vanilla" option, and much more complex or "exotic" contracts abound. For example, it is possible to purchase an option not to buy a stock, but to buy another option. And in still other options, the strike price isn't a fixed value at all, but depends in some complicated way on the history of the asset's price during the life of the option. There's an element of gambling in these deals, and almost anything is possible in a derivative since it is merely a contract.

And yet, despite the complexity of these financial instruments, they can all be valued rationally and efficiently by using variants of the Black-Scholes equation, which is truly the theoretical workhorse of the finance industry. Investment firms with great resources can work in the market from a position of knowledge regarding the behaviour of the instruments they buy and sell.

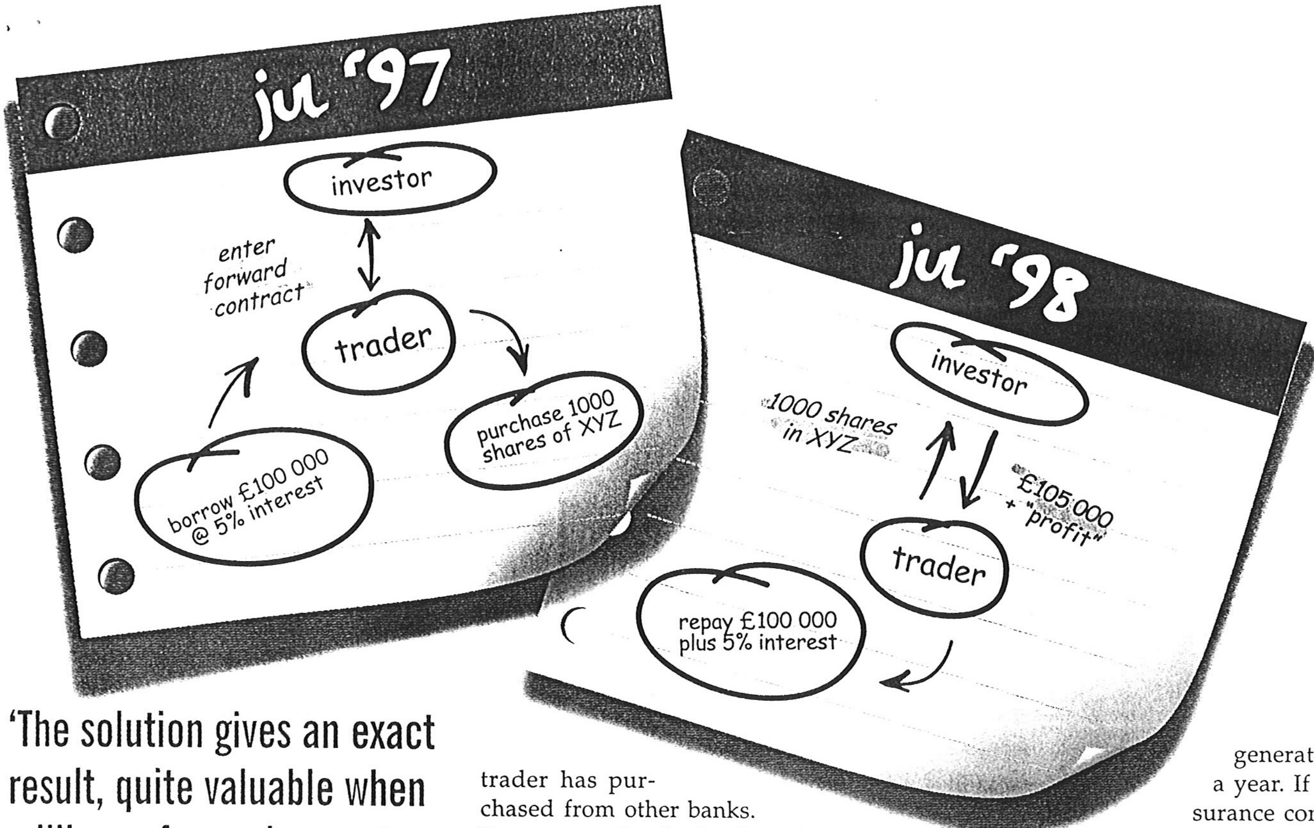
Refinements to the Black-Scholes equation are hawked by specialised software companies hoping to persuade their clients that they can steal a march on their competitors. Individual traders have their own tweaks in assessing volatility—with so much money at stake, new angles are constantly being developed.

Incredible naivety

Given their edge in knowledge, it is perhaps not surprising that derivatives traders frequently dream up and market to customers complicated options that serve little business purpose. Their intent is merely to persuade people to buy them and to earn a commission on the sale. What is more surprising is that some corporate treasurers go along with this and buy them. The lack of sophistication of many nonfinancial firms coupled with their propensity to enter contracts they don't understand is often stunning, and has produced some incredible losses.

But lack of understanding isn't confined to unsophisticated investors. Although traders and most investors have a firm grip on derivatives transactions based on stocks, currencies, commodities and even interest rates, some new derivative products are emerging that even the most savvy trader cannot value rationally. One of these is the "credit" derivative, which permits banks and other companies to improve their credit risk management. Here's a typical story.

Banks suffer from the "credit paradox". In short, banks develop good relationships with a small group of customers, and it is less expensive to do business with these "repeat" customers than to insist that every new loan be made to a new customer. You have already checked their credit, and know their history. If you've done your job well as a bank, the corporate customers who have borrowed



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money from you in the past will return to you time and time again. What could be wrong with that?

The trouble is, it runs completely counter to good credit risk management. Conventional wisdom—which is, in fact, quite wise—dictates that banks should spread their lending among as many companies in as many industries as possible. Diversification is key. But then what should banks do with their most loyal customers? Turn them away? This is the "credit paradox".

Credit derivatives known as "credit swaps" can help. The bank can have it both ways. First, it can lend as often as it likes to its small group of borrowers. Then, through a derivatives trader who acts as an intermediary between banks, it can "swap" some of its credit exposure—the risk of loss it faces should creditors default—with other banks that face similar problems. For instance, a bank might sell its exposure or risk on some loans to a trader, and, at the same time, buy the exposure on loans of equal value that the trader has purchased from other banks. Done correctly, the bank ends up with the same amount of money outstanding in loans, but with its credit risk diversified.

No market

If, for example, bank A has loaned money to Arthur and bank B to Bronwen, Arthur pays interest to bank A and Bronwen to bank B. But after a credit swap, bank A will shuttle the money it gets from Arthur to bank B, while bank B will shift the interest it gets from Bronwen over to A. Bank A is protected if its loan to Arthur defaults, and bank B is protected if Bronwen doesn't pay up. By using credit swaps, banks make loans to a small group of customers, but also get the benefit of highly diversified lending.

But there is an inherent difficulty with these derivatives because they aren't yet traded on an exchange. When traders look to the market to buy or sell the underlying asset—exposure on loans in this case—they can have a hard time finding someone willing to make a deal. The efficient hedging of risk with tools like the Black-Scholes equation depends on the existence of a ready market of buyers and sellers. But in credit derivatives, where the market is sparse—"illiquid" in the jargon—traders find it hard to hedge their positions, making the value of a credit derivative difficult to determine.

Insurance derivatives suffer from the same problems. These are often based on the cost of damage, say, that hurricanes in Florida or earthquakes in California will generate over a year. If an insurance company writes a one-year policy, it agrees to pay for damages that exceed a fixed minimum.

These insurance companies "lay off" or hedge some of this risk through reinsurance. But now they are also trying to hedge away the risk in the capital markets as well, by selling catastrophe bonds or "Act of God" bonds to Wall Street investors. The interest rates of these bonds are tied to disaster indices—rough measures of the monetary value of all disaster damage in a given year. So insurance companies can expect to pay less interest if there are more catastrophes. This offsets their losses, and so hedges away their risk. But with very few investors dealing in such bonds, and few insurance companies selling them, this derivative market is also "illiquid".

So for now, these new markets are difficult to understand, and their derivatives particularly risky. But this doesn't account for Nick Leeson or the NatWest losses, which came from trading well-understood products. Just think what might be happening this very minute in the 24-hour-a-day market for the more complex derivatives. After all, a substantial part of the funds available to the traders is our savings and pensions money. □

Joe Pimbley is a financial analyst in New York. His opinions offered here do not represent those of any past or current employer
Further reading: The mathematics of financial derivatives by Paul Wilmott, Sam Howison and Jeff Dewynne (Cambridge University Press, 1995)