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SHOULD WE FEAR DERIVATIVES?

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Working Paper 10574

<http://www.nber.org/papers/w10574>

NATIONAL BUREAU OF ECONOMIC RESEARCH

1050 Massachusetts Avenue

Cambridge, MA 02138

June 2004

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NBER Working Paper No. 10574
June 2004
JEL No. G1, G13, G15, F30

ABSTRACT

This paper discusses the extent to which derivatives pose threats to firms and to the economy. After reviewing the derivatives markets and putting in perspective the various measures of the size of these markets, the paper shows who uses derivatives and why. The difficulties firms face in valuing derivatives portfolios are evaluated. Although academics pay much attention to no-arbitrage pricing results, the paper points out that there can be considerable subjectivity in the pricing of derivatives that do not have highly liquid markets. It is shown that the known risks of derivatives portfolios can generally be measured and managed well at the firm level. However, derivatives can create systemic risks when a market participant becomes excessively large relative to particular derivatives markets. Overall, the benefits of derivatives outweigh the potential threats.

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In chemistry, a derivative is defined by the Merriam-Webster dictionary as a “substance related structurally to another substance and theoretically derivable from it” or “a substance that can be made from another substance.” Derivatives in finance work on the same principle. They are financial instruments whose promised payoffs are derived from the value of something else, generally called the underlying. The underlying is often a financial asset or rate, but it does not have to be. For instance, derivatives exist with payments based on the level of the S&P 500, the temperature at Kennedy Airport, or the number of bankruptcies among a group of selected companies.

The last thirty years have seen an astounding growth in the market for derivatives. Some estimates of the current size of the market for derivatives exceed \$200 trillion, which is more than 100 times what it was thirty years ago, when most of the derivatives that comprise this market were not even available.

When derivatives cause losses, they can make headlines. In recent years, derivatives have been associated with the collapse of the Queen’s banker (Barings); with a hedge fund that counted among its partners academics rewarded with a Nobel Prize for their work on pricing derivatives (Long-Term Capital Management); with the collapse of the Thai baht; and with the fall of Enron. Warren Buffett (2003) recently drew attention with a blistering attack on derivatives, writing in the 2002 annual report of Berkshire Hathaway that “derivatives are financial weapons of mass destruction, carrying dangers that, while now latent, are potentially lethal.”

Do derivatives mostly threaten firms and the economy, or do they increase welfare? I first quickly explain the main types of derivatives and describe how they are

priced. I then show how the markets for derivatives grew to their current size and what this size means. Next, I discuss the benefits from derivatives usage and examine the evidence on who uses derivative and why. I finally address the issue of the impact of derivatives on systemic risks. I conclude that even though some serious dangers are associated with derivatives, they have made us better off and will keep doing so.

What Are Derivatives?

Derivatives come in different flavors: plain vanilla and exotic. Plain vanilla includes contracts to buy or sell for future delivery, called forward and futures contracts; contracts that involve an option to buy or sell at a fixed price sometime in the future, called options; and combinations of forward, futures, and option contracts. Exotic derivatives are everything else in the derivatives world.

Forward contracts

A forward contract obligates one party to buy the underlying at a fixed price at a certain time in the future, called “maturity”, from a counterparty who is obligated to sell the underlying at that fixed price. Consider a U.S. exporter who expects to receive €100 million in six months. Suppose that the price of the euro is \$1.20 now. If the price of the euro falls by 10 percent over the next six months, the exporter loses \$12 million. By selling euros forward, the exporter locks in the current forward rate (if the forward rate is \$1.18, the exporter receives \$118 million at maturity). Financial hedging involves taking a financial position to reduce one’s exposure or sensitivity to a risk; hedging is perfect

when all exposure to the risk is eliminated through the financial position. In our example, the financial position is a forward contract, the risk is the euro, the exposure is €100 million in six months, and the exposure to the euro is perfectly hedged with the forward contract. Since no money changes hands when the exporter buys euros forward, the market value of the forward contract must be zero when initiated since otherwise the exporter would get something for nothing.

Options

Although options can be written on any underlying, let's use options on common stock as an example. A *call (put) option* on a stock gives its holder the right to buy (sell) a fixed number of shares at a given price at some future date.¹ The specified price is called the *exercise price*. Whoever sells an option at inception of the contract is called the option writer. When the holder of an option takes advantage of her right, she is said to "exercise it." An option holder who cannot gain from exercising an option before expiration does not exercise it. The purchase price of an option is called the *option premium*.

Options enable their holders to lever their resources while at the same time limiting their risk. Suppose an investor, Smith, believes that the current price of \$50 for Upside Inc. common stock is too low. Let's assume that the premium on a call option that gives the right to buy 100 shares at \$50 per share is \$10 per share. By investing \$1,000, Smith can buy call options to purchase 100 shares. If she does so, she will gain from stock price increases as if she had invested in 100 shares, even though she invests only an

¹ A "European" option gives the right to buy the stock only at maturity only, whereas an "American" option gives that right at or before maturity.

amount equal to the value of 20 shares. With only \$1,000 to invest, Smith could borrow \$4,000 to buy 100 shares. At maturity, she would then have to repay the loan. The gain made upon exercising the option is therefore similar to the gain from a levered position in the stock – a position consisting of purchasing shares with one's own money and some borrowed money. However, if Smith borrows, she could lose up to \$5,000 plus interest due on the loan if the stock price falls to zero. With the call option, she can lose at most \$1,000, which she does if the stock price does not rise above \$50.

Swaps

Suppose that you have an adjustable-rate mortgage with principal of \$200,000 and current payments of \$10,000 per year. If interest rates double, your payments would increase dramatically. You could eliminate this risk by refinancing your mortgage and getting a fixed-rate mortgage, but the transactions costs could be high. A swap contract would be an alternative solution that would not entail renegotiating the mortgage contract. You would agree to make payments to a counterparty, say a bank, equal to a fixed interest rate applied to \$200,000. In exchange, the bank would pay you a floating rate applied to \$200,000. With this interest rate swap, you would use the floating-rate payments received from the bank to make your mortgage payments. The only payments you would make out of your own pocket would be the fixed interest payments to the bank, as if you had a fixed-rate mortgage. Therefore, a doubling of interest rates would no longer affect your mortgage payments.

A swap is a contract to exchange cash flows over the life of the contract. In the example, you exchange cash flows of floating-rate debt for cash flows of fixed-rate debt. The principal used to compute the cash flows, called the notional amount, is not

exchanged. The notional amount for swaps is generally much higher than \$200,000. There are swaps involving exchange rates, different types of floating interest rates, equities, electricity, and so on.

A swap is really just a portfolio of forward contracts. For example, imagine a forward contract that pays the amount you would pay on your mortgage payments in ten years in exchange for the forward price. This forward contract would hedge one interest rate payment. If you entered such forward contracts for each future interest payment date, you would have the equivalent of a swap. Consequently, like forward contracts, the market's assessment of the present value of the cash flows of a swap is zero at initiation of the contract.

Exotics

An exotic derivative is a derivative that cannot be created by putting together option and forward contracts. Instead, the payoff of exotics is a complicated function of one or many underlyings. When Procter and Gamble lost \$160 million on derivatives in 1994, the main culprit was an exotic swap. The amounts P&G had to pay on the swap depended on the five-year Treasury note yield and the price of the 30-year Treasury bond. Another example of an exotic derivative is a binary option, which pays a fixed amount if some condition is met. For instance, a binary option might pay \$10 million if before a given future date one of the three largest banks has defaulted on its debt.

The Pricing of Derivatives

Derivatives are typically priced assuming that there are no frictions in financial markets. With that assumption (and, often, some other more technical assumptions), one can find a portfolio strategy that does not use the derivative and only requires an initial investment such that the portfolio pays the same as the derivative at maturity. The portfolio is called a replicating portfolio. The derivative must be worth the same as the replicating portfolio if financial markets are frictionless, since otherwise there is an opportunity to make a risk-free profit (the term of art is an arbitrage opportunity).

Consider the euro forward contract described earlier. At maturity, the exporter has to pay €100 million and receives \$118 million. A replicating portfolio can be constructed as follows: borrow the present value of €100 million and invest the present value of the payment to be made on the forward contract, \$118 million, in Treasury bills that mature when the forward contract matures. At maturity, you have \$118 million dollars and have to pay back the borrowed euros plus interest, which amounts to €100 million. The forward contract must be priced so that the exporter is indifferent between using the forward contract or the replicating portfolio. If one approach is cheaper than the other, any investor could make money for sure by buying dollars against euros using the cheap approach and selling dollars against euros using the expensive approach.

The value of a forward contract changes over time. If the euro appreciates unexpectedly by 10 percent, the replicating portfolio makes a loss: the present value of the euro debt of the portfolio increases unexpectedly, but the value of the Treasury bills does not increase commensurately. Since the replicating portfolio has the same payoff as

the forward contract, the loss means that the value of the forward contract has become negative.

The replicating portfolio strategy is trickier to devise and implement for options. Consider the option to buy 100 shares of Upside at \$50 per share. If the price of the stock exceeds \$50 at maturity, the value of the option is 100 times the difference between the value of the underlying and \$50; otherwise, the option is worth nothing. The replicating portfolio must therefore be worth zero at maturity if the stock price is less than \$50 and 100 times the difference between the stock price and \$50 otherwise. At inception of the replicating strategy, one must purchase shares partly with borrowed money. However, the number of shares held has to increase as the stock price increases because it becomes more likely that the option holder will exercise, and it has to fall as the stock price falls since the option becomes more likely to expire worthless. In the former case, the shares acquired are financed with more borrowing; in the latter case, the proceeds from selling shares are used to pay back money borrowed. Fischer Black and Myron Scholes, in their path-breaking work provide a mathematical solution for the option price, the Black-Scholes (1973) formula, and for the number of shares held in the replicating portfolio at any time during the life of the option.

Derivatives Markets and Their Growth

Derivatives have been traded for centuries. Some of the earliest derivatives markets are the market for options on tulip bulbs in seventeenth-century Holland and the futures market for rice in Japan in the same century. But derivatives markets were small

until the 1970s, when economic conditions and developments in the pricing of derivatives laid the basis for the spectacular growth in derivatives markets we have experienced since then. The volatility of interest rates and exchange rates increased sharply in the 1970s, making it imperative for firms and investors to find ways to hedge these risks. Other changes in the economic environment, such as the deregulation of several industries and the spectacular growth in international trade and finance, increased the demand for financial products to manage risk further.

Development of the Black-Scholes (1973) formula in the early 1970s changed the trading of derivatives forever. Almost immediately, the approach used by Black and Scholes to price options together with critical contributions from Merton (1973) was found useful to price, evaluate the risk of, and hedge most derivatives, plain vanilla or exotic. Financial engineers could even invent new instruments and find their value with the Black-Merton-Scholes pricing method. The growing speed and power of computers made it easier to price derivatives using that method.

Until the 1970s, the trading of derivatives took the form mostly of option, forward, and futures contracts. Futures contracts are similar to forward contracts, but they are standardized contracts that trade on exchanges. Except for futures contracts on commodities, the trading of derivatives was done over the counter (OTC trading), which means that two parties agree on a trade without meeting through an organized exchange. In 1972, the Chicago Mercantile Exchange started trading futures contracts on currencies. The Chicago Board Options Exchange, where stock options are traded, was founded in 1973. In the late 1970s and early 1980s, the swaps market took off. Swaps and exotic

derivatives, whose growth started in the 1980s, are traded over the counter. So are forward contracts.

Estimating the size of the OTC derivatives markets is difficult. After all, an over-the-counter market is decentralized and unregulated, and the parties are not required to report their transactions. However, an OTC derivative trade typically involves a bank or a broker, and so it is possible to estimate the size of the OTC market for derivatives by surveying financial firms. The Bank for International Settlements (BIS) has conducted such surveys of financial firms since 1998. It surveys 60 major derivatives dealers and eliminates double counting among the reporting institutions.

The BIS reports the size of the OTC derivatives market by adding up the notional amounts of outstanding derivatives. In June 2003, the total notional amount of derivatives was \$169.7 trillion. The notional amount represents a proxy for the value of the underlyings against which claims are traded in the derivatives markets. For example, the euro forward contract we discussed earlier has a notional value of \$118 million and the interest rate swap had a notional amount of \$200,000. Interest rate swaps represent 56 percent of the market.

Derivatives markets have expanded dramatically in recent years. According to an earlier BIS survey, outstanding OTC derivatives had a total notional amount of \$94 trillion in June 2000, which implies that the size of the OTC derivatives market increased by more than 80 percent from 2000 to 2003. The International Swap and Derivatives Association (ISDA), a trade association, provides a longer time-series for notional amounts of currency swaps, interest rate swaps, and interest rate options. In 1987, the notional amount outstanding of these instruments was \$865 billion and in 2003 it was

\$124 trillion. By this measure, the market grew at the rate of 36 percent per year over 16 years.

The market for exchange-traded derivatives is not as large as the OTC market. The BIS, surveying organized derivatives markets across the world, reports that the notional amount of futures contracts was \$13.9 trillion in the middle of 2003 and the notional amount of options was \$24.3 trillion. The total market for exchange-traded derivatives is therefore \$37.8 trillion. The earliest data available for exchange-traded derivatives is for December 1986, when the total notional amount outstanding was \$615.7 billion. The market for exchange-traded derivatives is therefore 61 times in 2003 what it was in 1986, corresponding to an annual growth rate of 27 percent.

Adding up the OTC market and the exchanges, the notional amount of derivatives was \$208 trillion at the end of June 2003. To put this number in perspective, the capitalization of the markets for corporate debt and equity in the world was \$31 trillion at the end of 2003.

Using notional amounts, the size of the derivatives market is huge, but the estimate has to be treated with care. On the one hand, the total is artificially inflated because of the way derivatives contracts are often closed. Suppose that Widget Inc. wants to close a swap contract with JP Morgan Chase, where it makes floating rate payments and receives fixed rate payments. The best way for Widget Inc. to close that contract is to call up a number of banks and find out the most advantageous swap contract with the same terms where it pays a fixed rate and receives a floating rate. After entering the second contract, the floating payments it receives match the floating payments it has to make, so that it is no longer affected by the swap contract with JP Morgan Chase. As

Widget Inc. effectively closed its contract with JP Morgan Chase, it increased the notional amount of the derivatives markets by the notional amount of the new swap it entered into! On the other hand, the BIS estimate has a downward bias because it misses a number of derivatives contracts. For example, it misses derivatives where no counterparty is a reporting institution included in the survey – although the quantity of derivatives missed because of this reason should be small. More important, the survey ignores securities sold in the markets that are claims on underlying assets or include such claims, and hence are also derivative assets. Consider a mortgage banker. As its portfolio of mortgages grows, it might put the mortgages in a trust and issue securities against the assets of the trust. This process is called securitization. There are trillions of dollars of securitized mortgages.

A second way to look at the size of the derivatives market is as follows: Suppose that the whole world had to write off all derivatives contracts. For each swap contract, one party would write off an asset, the positive value of the contract at that time, and the counterparty would write off a liability. Now, just add up the positive value of all contracts at that time. By this measure, the aggregate value of OTC derivatives outstanding in June 2003 was \$7.9 trillion according to the BIS. This amount is large, but not compared to the notional amount of contracts outstanding.

A third way to look at the size of the derivatives markets is to measure how much trading takes place. Information on trading volume is regularly available for only some derivatives. According to the BIS, financial futures contract positions for \$624 trillion in notional value changed hands in 2003. The BIS conducts triennial surveys of foreign exchange and derivatives markets. The most recent survey, for April 2001, reported an

average daily trading volume of \$489 billion for interest rate derivatives in the OTC derivatives market. By comparison, the estimate for April 1995 was \$151 billion.

The benefits of derivatives

We saw that derivatives are priced by constructing a replicating portfolio. This suggests that derivatives are redundant assets. So, why the fuss? If it is true that everybody can replicate derivatives perfectly, banning derivatives would change nothing – as long as the disclosure requirements for replicating portfolios are the same as for derivatives. Instead of buying a call option on Upside Inc., Smith would simply manufacture the option on her own. The assumption of pricing models that financial markets are frictionless is a powerful simplifying assumption. The reason it makes sense to typically use that assumption is that firms with large trading operations can trade often enough and cheaply enough to manage replicating portfolios well enough for derivatives on underlyings trading in very liquid markets. These firms can also make markets in derivatives so that they match buyers and sellers. When they do so, they do not have to hedge.

For individuals and non-financial firms, derivatives are almost never redundant assets. There are three reasons for this. First, individuals and non-financial firms face much higher trading costs than the most efficient financial institutions. In general, for most investors and firms, replicating closely the payoff of a derivative such as a call option will be prohibitively expensive. Second, for derivatives that include option features, the replicating portfolio strategy typically requires trades to be made whenever

the price of the underlying changes. Otherwise, the replicating portfolio works only approximately. Third, identifying the correct replicating strategy is often a problem. For instance, the strategy may differ depending on the dynamics of the price of the underlying, so that estimation error may affect the performance of the replicating strategy and make that approach risky. Because of these issues, individuals and firms will be willing to pay financial institutions to provide them with a derivative instead of attempting to manufacture it on their own.

The main gain from derivatives is therefore to permit individuals and firms to achieve payoffs that they would not be able to achieve without derivatives or could only achieve at much greater cost. Because individuals and firms could not obtain the payoffs of derivatives efficiently by manufacturing them on their own, derivatives make markets more complete – i.e., they make it possible to hedge risks that otherwise would be unhedgeable – for these individuals and firms. When individuals and firms can manage risk better, risks are born by those who are in the best position to bear them and firms and individuals can take on riskier but more profitable projects by hedging those risks that can be hedged. As a result, the economy is more productive and welfare is higher.

A second important benefit from derivatives is that they can make underlying markets more efficient. First, derivatives markets produce information. For instance, in a number of countries, the only reliable information about long-term interest rates is obtained from swaps because the swap market is more liquid and more active than the bond market. Second, derivatives enable investors to trade on information that otherwise might be prohibitively expensive to trade on. For instance, short sales of stocks are often difficult to implement. This slows down the speed with which adverse information is

incorporated in stock prices and makes markets less efficient. With puts, investors can more easily take advantage of adverse information about stock prices. Though derivatives can make underlying markets more efficient, observers have long been concerned that they can also disrupt markets because they make it easier to build speculative positions. Overall, there does not seem compelling evidence at this time that the introduction of derivatives trading on an underlying increases permanently the volatility of the return of the underlying. For instance, Conrad (1998) finds that the introduction of option trading on a stock trading reduces the volatility of the underlying stock and Bollen (1998) finds no effect.

Who Uses Derivatives and Why?

I now turn to some evidence on who uses derivatives and why.² I first look at non-financial firms, then financial firms, and conclude with individuals.

Non-financial firms

The Bank of International Settlements survey reports that over-the-counter foreign exchange contracts for a notional amount of \$5 trillion and OTC interest rate contracts for a notional amount of \$15 trillion had non-financial firms as counterparties. The most comprehensive study of the use of derivatives by non-financial firms is by Bartram, Brown and Fehle (2004), who examine 7,292 non-financial firms from 48 countries using annual reports published in 2000-2001. They find that 59.8 percent of firms use derivatives. Since 64 percent of U.S. firms use derivatives, they are slightly

² Stulz (2003) provides a detailed analysis of the main economic theories of risk management by firms.

more likely to use derivatives than firms from other countries. The most frequently used derivatives are foreign exchange derivatives, which are used by 43.6 percent of firms. Interest rate derivatives are used by 32.5 percent of firms and commodity derivatives by 10 percent. Swaps and forwards are used much more frequently than options.

The Bartram, Brown and Fehle (2004) study also provides evidence on why firms use derivatives. The firms that use foreign currency derivatives have foreign currency transactions and firms that use interest rate derivatives have higher leverage. They find further that firms with higher leverage and lower balance sheet liquidity are more likely to use derivatives to hedge, which is consistent with a body of evidence that firms with higher costs of financial distress are more likely to hedge (however, they also find that more profitable firms are more likely to hedge, which runs counter to the financial distress motivation for hedging).

If firms use derivatives to hedge, the stock return volatility of firms and the stock return exposure to market risks should fall after they start using derivatives. In finance, the exposure or sensitivity of a stock to a market risk, say the yen-dollar exchange rate, is typically measured as the regression coefficient on the rate of change of the yen-dollar exchange rate in a regression of the return of the stock on the return of the stock market and the rate of change of the yen-dollar exchange rate. Guay (1999) shows that when firms start using derivatives, their stock return volatility falls by 5 percent, their interest rate exposure falls by 22 percent, and their foreign exchange exposure falls by 11 percent. Clearly, firms do use derivatives for hedging, although if firms hedged systematically, they would use derivatives much more (Guay and Kothari, 2003).

Firms use derivatives for other reasons, too. In a survey by Bodnar, Hayt, Marston and Smithson (1995, p. 108), 28 percent of the firms state that minimizing accounting earnings volatility is their primary motivation for using derivatives. Although theoretical research has paid little attention to the role of derivatives in smoothing earnings, there is empirical evidence that firms with a smoother flow of income are valued more (see Barth, Elliott, and Finn, 1999). There also exists evidence showing that firms use derivatives to reduce the present value of their tax liabilities (Graham and Rogers, 2002). The nature of management compensation affects the extent to which firms hedge. In general, firms for which options are a more important component of managerial compensation are less likely to hedge (Rogers, 2002; Tufano, 1996). After all, in many (but not all) situations managers who hold options benefit from increases in volatility, since their options will be worth more if the stock price rises, but the option will never be worth less than zero if the stock price falls. Finally, firms sometimes use derivatives to speculate.

Recent papers investigate whether using derivatives increases firm value. This issue is tricky, since derivatives' use could proxy for firm characteristics like astute management that are associated with higher firm value. Nevertheless, Allayannis and Weston (2001) and Bartram, Brown, and Fehle (2003) use Tobin's q as a measure of firm valuation and show that firms that use derivatives have a higher Tobin's q , when controlling for a wide range of firm characteristics. These results should be treated with caution but, according to these papers, the extent to which firms using derivatives are worth more varies, depending on the specification, from 4 percent to 12 percent.

Financial Firms

Banks and investment banks make markets in derivatives, but they also take positions in derivatives to manage risk. In the third quarter of 2003, the banks with the 25 largest derivatives portfolios held 96.6 percent of the derivatives for trading purposes and 3.4 percent for risk management needs (Office of the Controller of the Currency, Bank Derivatives Report, Third Quarter of 2003).

Purnanandam (2003) investigates banks' use of derivatives for risk management. He concludes that larger banks are more likely to use derivatives for risk management and that banks that use derivatives for that purpose do so to reduce the probability of financial distress.

Individuals

Little is known about derivatives use by individuals. The evidence there is, though, points to the fact that individuals tend to leave money on the table when faced with exercise decisions. Mortgages have an embedded option – a homeowner has the option to prepay the mortgage, which is a valuable right. Typically, mortgage holders exercise this option later than can be justified by theoretical models of option pricing (see Green and Lacour-Little, 1998). Perhaps even more striking is the result in Poteshman and Serbin (2003) that individual investors exercise stock options too early, while traders in large investment houses do not. Shiller (2003) makes an important point concerning the use of derivatives by individuals, which is that the opportunities for individuals to hedge risks that matter to them with derivatives are extremely limited. For instance,

individuals cannot hedge through derivatives the risks associated with the value of their house or the value of their human capital.

The Risks of Derivatives at the Firm Level

In this section, I consider the risks of derivatives for the firms that use them. In the following section, I turn to the risks they pose for financial institutions and the financial system.

How Well Do We Know What A Derivative Is Worth?

Derivatives that trade in liquid markets can always be bought or sold at the market price, so that models are not required to value them. Valuation issues are much more complex when trading is illiquid and available prices, if any, do not offer a good measure of the price at which a derivative can be traded. In this case, models have to be brought to bear to value derivatives – a procedure called marking them to market. In the words of a skeptical Warren Buffett: “In extreme cases, mark-to-model degenerates into what I would call mark-to-myth.” This may help explain why Warren Buffett, at a speech at the Harvard Business School, said that his problems with derivatives were with OTC derivatives and not exchange-traded derivatives.

Suppose you want to value a stock option using the Black-Scholes formula. The Black-Scholes formula assumes: 1) markets have no frictions; 2) the stock price is lognormally distributed; 3) interest rates are fixed; and 4) trading is possible all the time. With these assumptions, the stock price moves smoothly over time – it never jumps.

Further, the distribution of the stock return has a constant volatility. In the real world, departures from these assumptions are significant. One tell-tale sign that the model does not entirely hold is that if derivatives are priced by arbitrage, the supply for derivatives would be perfectly elastic at the theoretical price. This is not the case. Put options on the S&P 500 stock index, which can be used to insure portfolios (by assuring the right to sell at a certain price in the future even if the market declines below that level), become more expensive as demand increases (Bollen and Whaley, 2004). Though the shortcomings of the Black-Scholes formula are widely recognized, there is no general agreement on a better model.

Even relatively simple derivatives contracts can be misvalued substantially. Chase Manhattan had egg on its face when it discovered in 1999 that a foreign exchange trader had misvalued forward contracts to the tune of \$60 million (Silverman, 1999). In January 2004, the National Australian Bank reported currency option losses in excess of A\$ 360 million (approximately U.S. \$280 million) that were attributed to rogue traders and risk management failures and involved incorrect valuations and misreporting. It is much harder to value more complicated derivatives.

Two interesting studies show substantial disagreement among experts on the value of derivatives. The Bank of England (see Walmyn and Byres, 1997) asked dealers to value a number of different derivatives and found that while the dealers had similar numbers for the most actively traded derivatives, they were sometimes far apart for more complicated derivatives. Bernardo and Cornell (1997) had access to data for an auction of 32 mortgage derivatives securities. The average percentage by which the highest bid price exceeded the lowest bid price was 63 percent.

These issues appear even tougher when you remember that large organizations are valuing sometimes thousands of derivatives, some of which may be quite exotic. Regardless of the practical difficulties, current U.S. accounting rules, specified in Statement #133 issued by the Financial Accounting Standards Board (FASB) in June 1998, require firms to mark to market derivatives positions on their balance sheet. Before Statement #133, derivatives that did not require an upfront payment (for instance, swaps) were off-balance sheet items. This meant that there was a considerable difference, from an accounting and disclosure perspective, between holding the derivative and its replicating portfolio; the replicating portfolio would be on the balance sheet, but not the derivative. This difference has now disappeared.

How Liquid Are Derivatives Markets?

Part of the reason Warren Buffett was discussing derivative markets in the 2002 annual report of Berkshire Hathaway is that he had bought a reinsurance company, General Re, with a derivatives dealer subsidiary. He did not want that subsidiary, but was unable to sell it at his desired price. He then decided to close the subsidiary and get out of the derivatives contracts. But he explains that “closing down a derivatives business is easier said than done. It will be a great many years before we are totally out of this operation (though we reduce our exposure daily). In fact, the reinsurance and derivatives businesses are similar: Like Hell, both are easy to enter and almost impossible to exit.”

If a firm buys a commonly traded plain vanilla derivative – say, a put option on the euro with maturity and exercise price common in the marketplace – it is generally easy to find a buyer for this derivative. However, it can be harder to get out of long

maturity contracts and out of complicated derivatives. First, it is much more likely that there is risk involved in the replicating strategy for such derivatives – there may be uncertainty about the model to use and/or the inputs to use. Second, a complicated derivative only appeals to a small number of counterparties who both want that particular set of risk characteristics and are confident that they understand what they are receiving.

Transparency and Reliability of Accounting Statements

Enron had a huge portfolio of derivatives, including many contracts with extremely long maturities.³ For example, consider a 30-year swap contract where Enron delivers gas at regular intervals and receives fixed amounts of cash over time. The value of this contract has to be marked to market each quarter for accounting purposes. However, it can be tempting to tweak assumptions – say, about the growth in the storage cost of gas over the next thirty years – in a way that has a substantial impact on present profits. Warren Buffett (2003) correctly points out: “As a general rule, contracts involving multiple reference items and distant settlement dates increase the opportunities for counterparties to use fanciful assumptions.” Enron was not reluctant to tweak assumptions that way. Further, the accounting treatment of derivatives is sufficiently complex that canny use of derivatives can decrease or increase reported earnings. Freddie Mac, a corporation that guarantees and securitizes mortgages, got in trouble in 2003 because it used derivatives to hide billions of dollars of profits to achieve a smoother earnings path.

³ For a discussion of Enron’s situation in this journal, see the “Symposium on Enron and Conflict of Interest” in the Spring 2003 issue.

Though concerns disclosures about derivatives positions have increased, the information disclosed typically focuses on the stand-alone risks of derivatives, rather than on how derivatives are used. If a firm uses derivatives to hedge, it could take on a large amount of derivatives risk, yet become less risky as a result. Although disclosure requirements for derivatives are not much help in seeing how they are used, some firms do report the impact of their hedging activities on various risks. Another problem is that it is impossible for a firm to describe all the details of its derivatives risks. For example, Enron had complicated derivatives with “credit rating triggers,” which require payments to be made (or the derivatives positions to be closed) if the firm’s credit rating falls below a trigger level. Once Enron’s credit rating fell and these triggers were activated, the firm could no longer survive because the payments it owed were too large.

Does derivatives trading create perverse incentives?

The sale of a derivative produces revenue. A wise trading firm will typically proceed to hedge the derivative that it has sold. But placing a value on the derivative that is sold and on the corresponding hedge can be difficult and subject to judgment when the derivative is not traded in a very liquid market. Senior management does not always have strong incentives to side with risk managers who want to value derivatives conservatively against traders who prefer a more aggressive approach. When a conservative valuation of derivatives would cause a firm to make a loss, leading the stock price to fall and rendering executives’ stock options worthless, top executives may not support a conservative risk manager.

Derivatives trading does not require much cash investment. For instance, swaps have no value at initiation, so that a firm with a good credit rating can build a portfolio of swaps without writing checks, using its good credit as collateral. As a result, derivatives trading can look very profitable when its revenue is compared to the required cash investment. Yet, derivatives trading generates revenue by assuming additional risks. Derivatives may look profitable using traditional accounting, but when the cost associated with the increase in risk is properly taken into account, they may not be. Proper evaluation of the profitability of derivatives requires taking into account the capital required to support the risks of derivatives. The major commercial and investment banks have developed approaches that allow them to do just that. Other firms, though, are more likely to ignore the cost associated with the increase in risk brought about by derivatives trading, which leads them to overstate its profitability.

Do Firms Know the Risks Involved in the Derivatives They Use?

In 1994, a firm in Cincinnati, Gibson Greetings, lost one year's profits from its operations on derivatives. One of its derivative contracts worked like this: A swap specified that starting on April 5, 1993, and until October 5, 1997, Gibson would pay Bankers Trust six-month LIBOR [the London Interbank Offering Rate, a commonly used interest rate] squared divided by 6 percent times \$30 million and Bankers Trust would pay Gibson 5.50 percent times \$30 million. Such transactions have raised the concern that some parties involved in exotic contracts do not fully understand the risks they are taking.

Since 1994, regular users of derivatives have made considerable progress in measuring the risks of derivatives portfolios. The two most popular approaches are a risk measure called value-at-risk (or VaR) and stress tests (see Stulz, 2003). Value-at-risk is a quantile of the distribution of the change in value of the portfolio over a day. For instance, a 5 percent value-at risk of \$100 million for a bank means that there is a 5 percent chance the bank will lose \$100 million or more. With a stress test, the firm computes the value of its derivatives portfolio using scenarios of interest. For instance, it might compute the value of its portfolio if the Russian crisis events of 1998 were to occur again. Many firms with large portfolios of derivatives report their value-at-risk and may also report the outcomes of various stress tests. With these tools, firms that use derivatives regularly know their risks reasonably well. But these measurement tools do not always work well; for example, during the Russian crisis banks exceeded their VaRs more than they theoretically should have.

Who gets hurt with derivatives losses?

Derivatives are useful for firms, but at times firms have reported large derivatives losses. Who gets hurt by these losses? Often, a loss associated with a derivative is the flip side of a large gain on the hedged exposure. When a hedge is designed to eliminate all the risk associated with an exposure, it necessarily follows that the hedge will make a loss when the exposure hedged is profitable. For instance, in our example of the exporter hedging a euro exposure, the forward contract makes a loss when the euro appreciates unexpectedly. However, sometimes, derivatives losses are not the random byproducts of well conceived hedges, but the outcomes of poorly conceived derivatives positions. With

a derivative, somebody's loss is somebody else's gain. So, for a derivatives' loss to create a social loss, there must be deadweight costs. In many cases, the deadweight costs of derivatives losses are small or nonexistent. Sometimes they are not. Derivatives losses can lead to financial distress at the firm level, and as discussed in the next section, can in exceptional circumstances have more pervasive effects on the economy. However, firms have learned a lot about how to use derivatives, making foolish uses of derivatives less likely and productive uses more frequent.

Derivatives and Systemic Risks

Would the failure of an especially large derivatives dealer pose a systemic risk that could spread throughout the financial system? Could the collapse of a derivatives user with large positions have systemic implications? The collapse of the hedge fund Long-Term Capital Management provides a case study.

The Derivatives Risks of Financial Institutions

In the third quarter of 2003, insured commercial banks in the U.S. had derivatives positions with a total notional amount of \$67.1 trillion (OCC Bank Derivatives Report, Third Quarter 2003). There were 575 commercial banks with derivatives positions, but 96 percent of the total notional amount was held by seven banks.

Banks generally report the "market risk" of their trading positions. By market risk, they mean the risk associated with changes in financial prices and rates. For instance JP Morgan Chase reported a value-at-risk of \$111 million on December 31, 2002, which

means that there was a 1 percent chance that JP Morgan Chase would make a one-day loss on its trading portfolio in excess of \$111 million. Of course if the bank started actually making a parade of such losses, it would cut down its risk. For comparison, the trading revenue of JP Morgan Chase in 2002 was \$2.5 billion and total revenue was \$29.6 billion. Stockholders' equity was \$41 billion. By any standard, these risks seem manageable. Banks also manage to control the risk of their trading operations fairly well; they are generally successful in maintaining their value-at-risk within reasonably tight bands over time.

A large bank might make significant losses because if one or several of its large derivatives counterparties default. However, participants in financial markets have strong incentives to control counterparty risk and are doing so. The International Swap and Derivatives Association reports that 65 percent of plain vanilla interest rate swaps were collateralized in 2001. Parties also put triggers in derivatives contracts, forcing the counterparty to post more collateral as it becomes less creditworthy. We saw that the gross market value of over-the-counter derivatives is \$7.9 trillion. The BIS also produces a different number, which is the gross credit exposure, estimated at \$1.75 trillion. This much smaller number measures the amount that would be lost after taking into account the credit protections, such as collateral, incorporated in derivatives contracts and shows that these protections play a large role in practice. In the U.S., the Office of the Controller of the Currency provides information on credit losses on derivatives. Charge-offs for commercial banks from derivatives are small compared to charge-offs from commercial loans.

Is it possible that the risks of derivatives are substantially underestimated? Two issues are worth considering. First, if large losses at the level of one firm would impose large costs on the financial system, firms have little incentives to take these externalities into account on their own. This leads firms to pay less attention to extreme tail risks than is probably socially optimal. Second, though existing risk measures capture most risks, they don't capture risks we do not know matter. In 1998, liquidity risk – the risk associated with the cost of selling a position quickly rather than over time – was crucially important, but it was not included in most models. Now, models pay more attention to this risk. While it is impossible to answer the question of whether unknown risks are large, the conventional measures suggest that no large bank or investment bank is seriously at risk because of its derivatives holdings.

What Would Happen If A Major Dealer Or User Of Derivatives Collapsed?

Bankruptcy law contains an “automatic stay” provision that prevents creditors from requiring immediate payment and makes it possible for the claims of creditors to be resolved in an orderly fashion. Interest rate swaps and some other derivatives are exempted from this “automatic stay.” Instead, the parties to a swap contract use a master agreement which specifies how termination payments are determined in the event that a party defaults. Without the exemption from the automatic stay, default on derivatives contracts would present a considerable problem since counterparties might have to wait, perhaps for years, for their claims to be adjudicated, leaving them with mostly unhedgeable risks.

Consider a bank that experiences a default on a derivative contract. It chooses to ask for termination of the contract and is due a payment equal to the market value of its position at termination. If the position was hedged, the bank has only the hedge on its books after the default without having the contract it was trying to hedge. The bank's risk has increased and it may not have received cash payments that were promised. The bank may then lack the liquidity to make payments it owes, which leads to further problems. Under normal circumstances, markets are sufficiently liquid that the bank can quickly eliminate the risk created by the default for a wide range of derivatives. As long as exposures to single counterparties are small and well controlled, a default is unlikely to create a major problem for a bank as long as markets are reasonably liquid.

The situation may be direr if the default occurs in a period of economic turmoil. In that case, derivatives markets as well as markets for underlyings can lose liquidity, so that it might become harder to offset, hedge, or replace contracts. A bank may suddenly end up with more risk than intended precisely when other banks are already trying to reduce their risk. If many banks are measuring risk in similar ways, and all are trying to reduce risk, they all end up stuck with their risks because there is only a limited market for the positions they are trying to sell. In such a situation, the Federal Reserve would have to step in to provide liquidity. Given the central role of treasuries in dynamic hedging, it may also have to actively intervene to settle down the Treasury market.

Crash Fears: The LTCM Collapse

The collapse of the hedge fund Long-Term Capital Management (LTCM) is often given as an example of a crisis linked to derivatives that could perhaps have led to a meltdown of the financial system.⁴ At the end of July 1998, LTCM held assets worth \$125 billion, which were financed with about \$4.1 billion of its own capital and the rest with borrowing. It had derivatives with a total notional amount in excess of \$1 trillion. Many strategies employed by LTCM involved taking long positions in bonds that LTCM perceived to have too high of a yield given their risk and hedging these positions against interest rate risk with short positions in treasuries or derivatives. However, as Russia defaulted on its debt in 1998, there was a general “flight to safety” by investors around the globe. Interest rates on treasuries fell, but the yields on the bonds held by LTCM did not fall as much as the interest rates on treasuries, so that LTCM made losses on its hedges not matched by gains on the hedged bonds.

LTCM’s losses created a vicious circle for it. As it made losses, it sold some assets, which put pressure on prices, but more importantly the market perceived that liquidation of its positions became more likely. Traders who knew about LTCM’s portfolio could position themselves so that they would not get hurt by a liquidation and might even benefit from it. Their actions put pressures on prices, reducing further the value of LTCM’s portfolio, which made liquidation more likely and hence created incentives for a new round of trading. Further, as prices moved against LTCM and liquidity in the markets was drying up, counterparties were trying to maximize the collateral that they could obtain from LTCM on their marked-to-market contracts by marking positions as much as possible in their favor so that a forced liquidation would

⁴ For more detailed accounts of LTCM, see Marthinsen (2004) or Stulz (2000).

not hurt them in less liquid markets. This generated further marked-to-market losses for LTCM, imperiling its situation further. Finally, investors and banks which under normal times would have bid for assets in the event of an LTCM liquidation were facing problems of their own, as they had also made losses on their positions. Some were forced to sell assets that LTCM also held, putting further pressure on prices. By mid-September, LTCM could only avoid default by closing its positions or receiving an infusion of capital.

Closing LTCM's positions was easier said than done, since it had more than 50,000 derivatives contracts and securities positions in markets where liquidity was low both because of these positions and because of events not under its control. For creditors, the most efficient solution was to avoid a fire sale, take over, inject some cash, and liquidate the portfolio slowly, or find a buyer for the portfolio. A buyer showed up, Warren Buffett with AIG and Goldman Sachs bid \$4 billion for the portfolio. Had the bid succeeded, Berkshire Hathaway would have invested \$3 billion in LTCM. The solution that prevailed was instead one where creditors injected \$3.6 billion in the fund and took control with the LTCM partners retaining some ownership. There was no default; there was no public bailout; the creditors eventually took more money out than they put in. We will never know what would have happened had LTCM defaulted and entered bankruptcy. The fund itself was chartered not in the United States, but in the Cayman Islands, which complicated matters. But the lesson is that when a market participant that is large relative to the markets gets in trouble, its difficulties may affect prices adversely, which makes its situation worse – a fact that does not play a role in models that treat economic agents as price takers.

Before August 1998, LTCM was able to borrow on terms almost similar to those of major investment banks and in many ways was not different from the most efficient investment banks. These banks have extremely high leverage. They can pursue strategies that replicate derivatives payoffs with traded securities and borrowing. So could LTCM. Had LTCM not had as easy access to derivatives, it could have manufactured them on its own. This would have decreased its profits some and might have been too expensive for some types of derivatives, but LTCM would still have been very highly levered, would still have made extremely large losses in September 1998, and might still have collapsed then. It is difficult to say whether the risk to the economy would have been greater or smaller had LTCM been restricted from using derivatives. Its leverage would have been lower, but in replicating derivatives on its own, it might have needed to trade more in illiquid markets.

Conclusion

We have seen that derivatives allow firms and individuals to hedge risks and to take risks efficiently. They also can create risk at the firm level, especially if a firm uses derivatives episodically and is inexperienced in their use. For the economy as a whole, a collapse of a large derivatives user or dealer may create systemic risks. On balance, derivatives help make the economy more efficient. However, neither users of derivatives nor regulators can be complacent.

Firms have to make sure that derivatives are used properly. This means that the risks of derivatives positions have to be measured and understood. Those in charge of taking

derivatives positions must have the proper training. It also means that firms must have well-defined policies for derivatives use. A firm's board must know how risk is managed within the firm and which role derivatives play.

Regulators have to make sure to monitor carefully financial firms with large derivatives positions. Though regulators seem to be doing a good job in monitoring banks and brokerage houses, the risks taken by insurance companies, hedge funds, and government sponsored enterprises such as Fannie Mae and Freddie Mac are not equally well understood and monitored.

So, should we fear derivatives? The answer is no. We should have a healthy respect for them. We do not fear planes because they may crash and do not refuse to board them because of that risk. Instead, we make sure that planes are as safe as it makes economic sense for them to be. The same applies to derivatives. Typically, the losses from derivatives are localized, but the whole economy gains from the existence of derivatives markets.

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