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Beate Reszat*

Nobel Contingencies

This year, the Royal Swedish Academy of Sciences awarded the Nobel Prize in economics to Robert C. Merton of Harvard University and Myron S. Scholes of Stanford University for a pioneering formula for the valuation of stock options. The laureates developed their method in the early seventies in close collaboration with Fischer Black, who died in 1995. While sometimes the Academy's decision is greeted with harsh criticism, this time there seems to be nearly unanimous agreement on the winners' merits. Special emphasis is put on their work's practical use and its wide applicability. The praise must sound strange to those remembering recent losses and failures in derivatives trading. This raises the question of the rationale behind the Stockholm decision and the signals it is sending to the markets in a time of growing uncertainties and instabilities.

At the beginning of the seventies, the international financial markets were facing fundamental changes. After the collapse of the Bretton Woods system the exchange rates of major currencies, which were no longer kept within small bands by central bank interventions, started to fluctuate to a previously unknown extent. At the same time, the first post-war moves towards financial deregulation led to increased interest rate variability. As a result, a growing need was felt by firms, financial institutions and other agents to find a means of insuring against volatility and risk, as well as a growing demand for instruments allowing them to benefit from the inherent opportunities.

The financial services industry soon came up with new concepts to meet the challenge. Exchange-traded financial derivatives such as futures and options emerged, first in the United States and later on also in Europe and the Far East.¹ In 1972, the International Money Market (IMM) at the Chicago Mercantile Exchange (CME) began trading in foreign currency futures. In April 1973, one month before Fischer Black and Myron Scholes presented their famous formula,² the Chicago Board Options Exchange (CBOE) took up the trade with financial options. The timing of the publication of the Black-Scholes framework, to which Robert Merton vastly contributed in subsequent modifications and applications, was perfect.

As the Royal Swedish Academy emphasised, Black, Merton and Scholes laid the foundation for the

extraordinary growth of the derivatives markets during recent years.³ Nowadays, there are about 70 futures and options exchanges worldwide, with still more being developed, offering a wide array of instruments, and, even more important, there is a large over-the-counter (OTC) market. Their expansion is roughly illustrated in Table 1. Much of the development took place very recently. According to estimates by the International Swaps and Derivatives Association (ISDA) and the Bank for International Settlements (BIS) the notional amounts of exchange-traded instruments outstanding rose from 3.5 trillion US dollars in 1991 to more than 9.8 trillion at the end of 1996, and that of OTC instruments even from 4.4 trillion to over 24 trillion (Table 2).

There are three broad categories of financial derivatives: futures, swaps and options. Futures are standardised forward contracts traded on an exchange, i.e. contracts to buy or sell a standard quantity of a specific asset at a predetermined future date and price. Swaps are transactions in which, in principle, a spot and a forward trade, or a forward/forward trade, are both agreed upon simultaneously. Options are contracts sold for a premium that give the buyer the right, but not the obligation, to buy (in case

¹ Compare, for example, M. Goldstein, D. Folkerts-Landau, P. Garber, L. Rojas-Suárez und M. Spencer: International Capital Markets, Part I.: Exchange Rate Management and International Capital Flows, Washington, DC 1993.

² The decisive paper was: F. Black, M. Scholes: The Pricing of Options and Corporate Liabilities, in: Journal of Political Economy, Vol. 81, 1973, pp. 637-654.

³ For the following, see the background information given by the Academy via the internet under: <http://www.nobel.se/announcement-97/economy97.html>.

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of a call option) or sell (in case of a put option) a financial asset in the future at a specified price. In allowing an unbundling of price risks derivatives contracts have many advantages. For example, due to the leverage of those instruments firms can hedge their risk exposures at low cost and with a minimum of capital needed. However, leverage is a double-edged sword because, like profits, losses can become overproportionate.

In the beginning, it was in particular options trading which faced unsurmountable obstacles. The problem was how to value those contracts. In contrast to other financial instruments options are so-called contingent claims based on the insurance principle. The related risk is an asymmetric one. The worst that can happen to the buyer of a call option is that his expectations

are not fulfilled and that in not exercising his option he loses his premium. The seller who has the obligation to deliver if the option is exercised is in a different situation. If, for him, prices move in the wrong direction and he does not already own the underlying asset he needs to buy it in the market and his loss can, in principle, be unlimited.

The value of an option today depends on an uncertain future, namely on the unknown development of the price of the underlying asset – the share price, stock index, exchange rate or whatever – to the date of maturity. To capture this aspect, successive generations of researchers tried to make assumptions of investors' attitudes towards risk. The earliest reported attempt dates as far back as 1900 to the doctoral dissertation of the French mathematician Louis Bachelier. Until Black and Scholes published their formula it was widely thought that option valuation required to take into account an individual risk premium, in analogy to the way in which present values in the evaluation of physical investment projects with uncertain returns are calculated. However, risk premia are hardly observed in reality. Black and Scholes demonstrated that there is no need to consider them explicitly because they are already contained in the price of the underlying asset.

Table 1
The Evolution of Financial Derivatives

Year	Instrument
1972	Foreign currency futures
1973	Equity options
1975	T-bond futures
1981	Currency swaps
1982	Interest rate swaps, T-note futures, Eurodollar futures, Equity index futures, Options on T-bond futures, Exchange-listed currency options
1983	Options on equity index, Options on T-note futures, Options on currency futures, Options on equity index futures, Interest rate caps and floors
1985	Eurodollar options, Swaptions
1987	OTC compound options, OTC average options
1989	Futures on interest rate swaps, Quanto options
1990	Equity index swaps
1991	Differential swaps
1993	Captions, Exchange-listed FLEX options
1994	Credit default options

Source: P. Jorion: Value at Risk, Chicago 1997, Table 1-1.

Table 2
Markets for Selected Derivative Instruments¹

Instruments	1991	1996
Exchange-traded instruments	3,519.3	9,884.6
- Interest rate futures	2,156.7	5,931.1
- Interest rate options	1,072.6	3,277.8
- Currency futures	18.3	50.3
- Currency options	62.9	46.5
- Stock market index futures	76.0	198.6
- Stock market index options	132.8	380.2
Over-the-counter instruments	4,449.4	24,292.0
- Interest rate swaps	3,065.1	-
- Currency swaps	807.2	-
- Other swap-related derivatives	577.2	-

¹ Notional amounts outstanding at end-year, in billions of US dollars.

Source: Bank for International Settlements: 67th Annual Report, Basle June 1997, Table VII.5.

The Method

Black and Scholes derived their formula for the price of an option under the assumption that there are only two securities. The fact that, in the real world, there is an infinite number of states was accounted for by assuming continuous trading in the two securities throughout the life of the option. In this case, under certain additional assumptions the payoffs from the option can always be replicated by adjusting the portfolio composition of the two. For example, under continuous trading, increasing the frequency of trading in few long-lived securities leads to essentially the same result as increasing the number of securities but having only one trading round.⁴

As an example, consider a European call option⁵ that gives the right to buy a firm's share in three months at a strike price of US \$ 50. The higher the stock price of the share today, the higher is the

⁴ Compare for the details also: N. Strong, M. Walker: Information and Capital Markets, Oxford 1987, pp. 68-70.

⁵ A European-style option differs from an American-style one in that the latter can be exercised before expiration while the former can only be exercised at the expiration date. The following example is taken from the Royal Swedish Academy's internet home page. See footnote 3.

probability that the option will be exercised. An investor who already owns a number of shares of that firm and wants to hedge against undesired price changes can eliminate his risk by selling the option. Assuming that if the stock price goes up (down) by two dollars the option goes up (down) by one dollar he will have to write two options for every share he owns. Since in that case his portfolio is risk-free the capital invested must earn exactly the same return as the risk-free market rate on a three-month Treasury bill. If there were any difference between the two, arbitrage would set in instantaneously and eliminate it. With the expiration date approaching, and with stock prices going up and down, the relation between the option and the stock price is always changing and the investor is forced to permanently correct his portfolio composition to maintain a risk-free position.

The Black-Scholes formula for a European call option can be written as

$$C = SN(d) - Le^{-rt} N(d - \sigma\sqrt{t})$$

with

$$d = \frac{\ln \frac{S}{L} + (r + \frac{\sigma^2}{2})t}{\sigma\sqrt{t}}$$

C is the value of the option, S the share price today and L is the strike price. The option value is equal to the difference between the expected share value – the first term on the right-hand side – and the expected cost – the second term – if the option is exercised. The option value is higher, the higher the share price today, the higher its volatility measured as the standard deviation σ , the higher the risk-free interest rate r , the longer the time to maturity t , the lower the strike price, and the higher the probability that the option will be exercised. The probability is evaluated by the normal distribution function N .

The method Black, Merton and Scholes developed has become indispensable for companies, banks and other institutions in managing and evaluating risks. Thousands of traders and investors worldwide rely on the formula every day to value stock options. Its principles have also found wide applications in many other fields of the economy. Options are only one kind of so-called contingent claims. In principle, the value of a firm's shares, its loans or other debt instruments depends on its overall value in quite a similar way to the way in which the value of a stock option depends on the price of the underlying asset. In this sense, the Nobel laureates laid the foundation for a unified theory of the valuation of corporate liabilities.

There are other applications as well. A guarantee is comparable to an option in that it is exploited under certain circumstances. The same holds for an insurance contract. Investment decisions, too, involve contingencies: equipment can be designed to allow for more or less flexibility in utilisation. For example, in some cases production is more easily closed down and reopened under a changing economic environment than in others. Flexibility can be regarded as an option and valued accordingly.

Imponderabilities

In the formula all the components are observable except volatility. As a rule, financial time series have a non-constant variance showing different values, for example, for daily, monthly or yearly data as well as for different time periods. Thus, an estimate of future volatility is needed. In principle, this can be calculated in several ways either from historical data or by taking so-called "implied" volatilities from the observed option prices of other market participants. Each method has its drawbacks. For historical volatilities the results differ depending on the time series chosen and on if and how more recent observations are weighted. On the other hand, implied volatilities do not always exist, and if they do they may include non-price components such as transaction costs or risk premia.

Another obstacle to risk analysis results from the nonlinearity of the formula, which cannot easily be transformed into a linear relationship. As a consequence, it is not possible to calculate expected changes in value simply by multiplying estimated changes in one determinant by constant sensitivities of the positions as in traditional analyses. If one factor changes the new option value is given by the interplay of all influences in the way described by the formula. As a result, intuition and "feeling" for risk based on experience, which in traditional financial areas allowed one to look at a few key variables to understand the pricing process, have become worthless and even dangerous. At times, nonlinearity has bizarre effects. This can be illustrated by the results of simulations which were carried out for call options on the German DAX index.⁶

The simulated situation is as follows. At a certain point in time a dealer has simultaneously sold 10,000

⁶ The example is taken from R. Goebel: Ansätze zur Risikomessung und -steuerung des Derivategeschäfts in Kreditinstituten und Nichtbanken, in: A. Bertuch-Samuels und W. Störmann (Hrsg.): Derivate Finanzinstrumente: Nutzen und Risiken, Stuttgart 1995, pp. 65-67.

call options on the DAX and bought 20,000 call options at different strike prices for the same expiration date. In Table 3a there are three scenarios for the DAX and, at the same time, three different developments of volatility with both changing in steps of 10 per cent. The impression is positive throughout. Each change in whichever direction would have meant a profit for the dealer. In Table 3b the picture looks completely different. Here, a kind of fine tuning has taken place with smaller intervals of five per cent changes chosen for both the price of the underlying asset and the volatility. Two things are remarkable. First, in this case considerable potential losses show up which otherwise would have stayed undetected. Second, the largest losses did not occur in the worst-case scenario for the price of the underlying asset but in between at a five-per cent rise.

The example demonstrates how much option trading differs from more traditional financial market segments. The complexity of the pricing process makes a correct valuation method indispensable. To have provided economic agents with such a method is the achievement of Black, Merton and Scholes. However, as recent experience has shown, it is exactly this complexity and the related uncertainties which limit the use of the formula.

Barings and Co.

Recent years have seen some spectacular losses from derivatives trading in rapid succession. Shock waves went through the international financial markets when in February 1995 Barings Bank, one of the oldest British merchant banks, went bankrupt after one of its traders at Baring Futures (Singapore) Ltd, Nick Leeson, lost more than 1.3 billion dollars on the Singapore and Osaka futures exchanges.⁷ Part of the losses resulted from a strategy known as *straddle*, simultaneous sales of put and call options on the Nikkei 225, which essentially were a bet that the price of the index would trade only in a narrow range. The bet was lost when in January 1995 the Kobe earthquake made price volatility move against the trader's odds.

Barings was the most spectacular case, but by far not the only one. Table 4 lists the most famous losses made with trading in financial derivatives since the mid-eighties. Two points are remarkable. First, there is a strong increase of cases since 1993, when the loss

of Showa Shell in the foreign exchange forward market became known, with the number of firms catching the headlines being twice as many as in the previous ten years. Second, the extent of losses has risen dramatically. While during the 1980s and early 1990s the losses remained well below 400 million dollars, in most of the more recent cases the amounts by far exceeded one billion.

The reasons for the failures were manifold. In some cases, the culprits were rogue traders who deliberately used their positions for unauthorised

Table 3a
Profitable Options ...

Volatility	Price change of the underlying asset		
	-10%	0	+10%
+10% percentage points	185	55	530
0	205	0	230
-10% percentage points	205	155	105

Table 3b
... and their Loss Potential

Volatility	Price change of the underlying asset				
	-10%	-5%	0	+5%	+10%
+10% percentage points	185	125	55	140	530
+ 5% percentage points	200	140	-10	-10	375
0	205	180	0	-175	230
-5% percentage points	205	205	50	-365	130
-10% percentage points	205	205	155	-585	105

Table 4
Famous Financial Derivatives Losses

Company	Instrument	Amount (US \$ millions)
Between 1984 and 1994:		
Klöckner	Commodities futures	380
Allied Lyons	Currency options	275
Volkswagen	Foreign exchange futures	260
Nippon Steel	Foreign exchange derivatives	130
Showa Shell Sekiyu	Foreign exchange forwards	1,580
Since 1994		
Sumitomo Corporation	Commodities futures	1,800
Kashima Oil	Currency derivatives	1,450
Metallgesellschaft	Energy derivatives	1,340
Barings	Stock index futures	1,330
Codelco, Chile	Commodities futures	200
Procter&Gamble	Leveraged D-mark/ US dollar spread	157
National Westminster	Currency options	80

⁷ A detailed description of the case can be found in: J. Rawnsley: *Going for Broke*, London 1996. For this and other cases cf. also B. Reszat: *The Japanese Foreign Exchange Market*, London 1997.

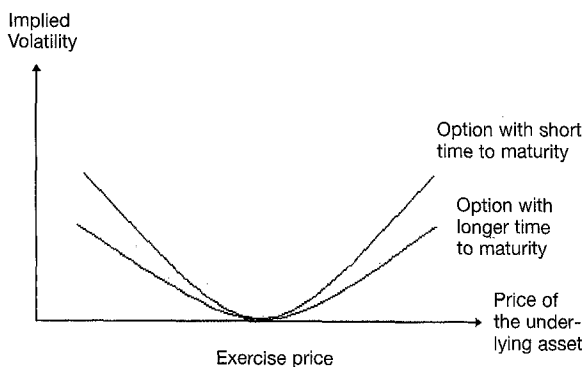
Source: David Shirreff: *Fill that Gap!* in: *Euromoney*, August 1994: p. 29; *Financial Times*, various issues.

activities. For example, in the Barings case, Nick Leeson was in charge of both trading and settlement which made it easy for him to cover his tracks. Often losses can only be explained by a lack of experience and overconfidence in computer facilities, models and one's own abilities to cope with an unexpected change in market sentiments. One example is the case of a British bank, NatWest, which lost £ 50 million on options trading earlier this year. The bank's trader was reported to have miscalculated volatility.⁸ Those miscalculations are said to happen frequently, but are hard to detect for two reasons.

One is "model risk". Often traders are allowed to use more sophisticated models than the controllers who check their books and therefore are not able to trace the basic assumptions behind their calculations. The second is a phenomenon known as "volatility smile". On the one hand, options which are far in or out of the money have much higher implied volatilities than others. On the other hand, options far in or out of the money with a short time to maturity are traded with a higher implied volatility than those with a longer one. Since markets for those options are highly illiquid implied volatilities cannot be observed and traders try to more or less guess these by taking the known volatility of liquid options and then adjusting the numbers respectively. The curve they derive in this way looks like a broad smile which explains the name (Figure 1).⁹

Black and Scholes did not take the smile effect into account. For their formula to hold they assumed that volatility neither depends on the time to maturity nor on an option's "moneyness". In addition, they made two other assumptions which are regularly violated by market developments: that of continuous trading and the absence of price jumps. They are the reason why the method cannot be trusted under all circumstances.

Figure 1
The Smil Effect



Experienced traders do not rely on the formula alone. They have various means of coping with the volatility smile and they use a range of sensitivity measures in addition to better judge the risks related to their strategies.¹⁰ Nevertheless, as recent losses have shown, the number of actors who lack experience, as well as the amounts they are willing to put at stake, have obviously grown. As far as the reason is overconfidence in computing facilities and models, the feeling that there is a formula to rely on, one which all other traders are using as well, even if most of them sitting at their screens have never even seen it, might well have contributed to their carelessness.

Conclusions

The accumulation of losses from derivatives trading in recent years throws a somewhat strange light on the decision of the Nobel Committee. How can it be that a method which is so dependent on very special assumptions and loaded with so many uncertainties is praised so highly? There is a danger that the decision might be misinterpreted as an approval of the current situation in the derivatives markets and as a call to shrug off any criticism of the existing practices of some banks and companies to take high risks and not care enough about risk management and control.

This was clearly not the Committee's intention. The prize must be regarded as an acknowledgement of the great progress the work of Black, Merton and Scholes meant for the financial markets and for wide areas of the economy. The development and successive modification of the Black-Scholes formula put derivatives trading in general on a solid basis. As a result, the markets grew strongly and the range of available instruments widened considerably, which allowed economic agents to hedge against many risks in a world of rising uncertainties and instabilities and to pursue their activities and make their decisions widely unhindered on the basis of reliable calculations. That the formula does not offer protection against all the possible calamities in a derivatives dealer's life is not the fault of the formula. The message from Stockholm is not that we should take the stability of the markets for granted.

⁸ See John Gapper: When the Smile is Wiped off, in: *The Financial Times*, 9 March 1997.

⁹ Compare in greater detail: Hans Peter Steinbrenner: *Bewertungen im professionellen Optionsgeschäft*, Stuttgart 1996, pp. 290-292.

¹⁰ See in greater detail B. Reszat: Sources of Increasing Systemic Risk in International Financial Markets, in: *INTERECONOMICS*, September/October 1997, pp. 4-5, and the references cited there.