Do Derivative Instruments

Increase Market Volatility?

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August 1992

Chapter 12 in *Options: Recent Advances in Theory and Practice, Volume 2*
Ed: S D Hodges
Manchester University Press

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FORC Preprint: 92/19

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I Introduction

The October 1987 crash and other more recent hiccups have raised important questions about the volatility of security markets. These events occurred after a period of rapid growth in derivative instruments, and in the use of 'program trading' techniques, so it is hardly surprising that some observers have singled them out as a likely cause of recent high volatility.

A major report, *Market Volatility and Investor Confidence*, was published by the New York Stock Exchange in June 1990. Much of the report is concerned with attitudes to and the effect of program trading. The NYSE defines program trading as 'the simultaneous purchase or sale of 15 or more stocks with a total market value of at least $1 million', but misconceptions abound (for instance, that it means trading triggered by computers). Program trades can thus be either index arbitrage transactions, or transactions related to portfolio rebalancing that may or may not involve futures or options.

The subject of whether the introduction of derivatives tends to increase the volatility of the underlying market is therefore one of great topical interest. The purpose of this paper is to review what we know about this issue. The paper describes and synthesises both theoretical and empirical work.

The results of theoretical analysis are particularly important in the light of the difficulty of empirical work. The conventional academic view of derivatives is that they are in some sense redundant, as they can be replicated by means of dynamic trading strategies. The point of creating them is merely for administrative convenience and to reduce transactions costs. Under this view of the world the prices of the underlying securities, and hence also their volatility, will be unaffected whether derivatives are introduced or not. However, this is only the beginning of the story, for any one of a variety of possible market imperfections is sufficient to invalidate this view. Depending on what assumptions are made, arguments can be constructed to suggest that derivatives will either increase volatility or decrease it, depending on your taste. It will be for us to judge which assumptions are most appropriate, and whether and how empirical tests can be made to unravel the issues more clearly. At this stage we shall be forced to conclude that almost nothing has been proven. We may hope that in the future a strong basis of theory may lead to more conclusive empirical work.

The market imperfections considered can be regarded as consisting of two main types:

1. Constraints on how portfolios are constructed: these include constraints or costs on short selling in the absence of futures contracts, and margins and position limits on futures and options. We will also look at an example which illustrates some possible effects of market incompleteness in the absence of derivatives (for example, when jumps in stock prices or other factors would make exact replication of options impossible).
2. Imperfections in the information available to market participants: research here has mainly focused on the probable effects of portfolio-insurance-type investment-management strategies. Portfolio-insurance-type activities should have only a modest effect on market equilibrium, provided that such activities are anticipated by the market. Papers by Grossman (1988b) and Gennotte and Leland (1990) consider what further effects may occur if most investors are unaware of the magnitude of other investors' hedging plans. It turns out that this distinction can make a crucial difference to how markets behave. The institutional structure of a market may also affect the information available to participants sufficiently to influence the nature of the market.

A variety of empirical studies have been carried out, looking at different aspects of volatility and its relation to institutional structure and other variables. We shall consider these under the following headings:

1. Studies concerning whether the level of volatility in markets has changed, and also investigating linkages between markets, and determinants of volatility
2. Studies concerning what occurred during market crashes
3. Studies making international comparisons between markets, particularly in the context of market crashes
4. Studies investigating directly the impact of the introduction of derivatives on the volatility of the underlying market
5. Studies investigating expiration-day effects.

The evidence provided by individual studies is often rather weak, but taken together, elements of a consistent picture emerge. We shall see that there is little evidence to suggest any overall increase in volatility.

However, markets do seem to react in a quicker and more 'efficient' manner than formerly. For example, serial correlation in market movements has reduced. Concerns about 'episodic' volatility may have some validity. Our knowledge about the determinants of market volatility is very weak. For example, comparisons of the movements of different international markets in the 1987 crash reveal no significant relationships with market structure, the use of program-trading strategies or the presence of derivative markets. Most studies of the introduction of derivative instruments suggest that they lead to a slight fall in the average level of the volatility of the underlying security. Expiration days and even 'triple witchings' are hardly an exception to this. The evidence suggests only a tiny increase in volatility occurs on such dates. These results are broadly consistent with those of earlier work on commodity futures. For example, Cox (1976) suggested theoretical reasons and found empirical support for the view that the futures trading improves spot market efficiency (by reducing transactions costs and attracting additional speculative traders). Kamara (1982) provides an excellent survey of this literature.

II **Theoretical effects of portfolio constraints**

Under the 'classical' academic view, in a market with no imperfections, derivatives can be replicated by dynamic trading and therefore are entirely redundant. This means that introducing them makes no difference to market prices and does not affect volatility. In Sections II to IV we will discuss how various imperfections encountered in practice are likely to affect market volatility.

Without derivatives, short selling is often difficult or expensive. It is hard to speculate against a price that is thought to be too high. Futures provide a mechanism enabling speculators to bet either that the price is too high or that it is too low. We would expect this to reduce volatility and the likelihood of bubbles. Without futures, if short selling is either not available or costly, those investors who believe the market is too high are unable to put their money behind their beliefs. This type of view is hinted at by Brealey (1984).

More formally, we could develop a simple model in which investor j with relative market power k_j (related to the investor's size and risk tolerance) expects a future value of p_j for the market portfolio. The price p_0 of the market portfolio would then be:

$$p_0 = \frac{\sum_j k_j p_j - \sigma^2 m}{\sum_j k_j} \tag{1}$$

where σ is the (agreed) standard deviation of the future value, and m represents the supply of this asset.

In a market where short selling is costless, for example through writing futures contracts, the summation extends over all potential market participants. However, if no short selling is possible then the summation is restricted to a smaller set of j for which $p_j > p_0$. In this case, with the averaging over a smaller set, it is clear that the variation in p_0 with respect to changes in expectations would normally be larger than in the case with unrestricted short-selling. The term 'normally' is used advisedly: we could construct (rather pathological) examples in which the weights obtained by short sellers were sometimes high enough to make the short-selling equilibrium more volatile than the no-short-selling one.

Richer insights are provided by a model developed by Pliska and Shalen (1989) to investigate the effects of proposed regulatory changes on the margin requirements and speculative position limits for equity index futures. A dynamic model is developed in which the sequential arrival of information is perceived differently by diverse speculators due to noise. Futures traders are classified as either speculators or hedgers. Aggregate hedging demand, H_t, is specified exogenously. Speculators choose their futures positions so as to maximise the expected utility of future wealth subject to regulatory constraints. Mean-variance preferences are assumed. Two kinds of regulatory constraints are considered: margin requirements and speculative position limits. Hedgers are exempt from position limits (consistent with US practice). In each period t, some more information is revealed about the horizon date value of the index. The horizon value is the product of $\exp(s_t)$ terms, where s_t is distributed normally with zero mean and standard deviation σ_s. The value of s_t is revealed at the end of period t. Noise is introduced to generate speculative trades based on divergent expectations, so at the beginning of period t, the information available to the ith speculator is $s_t + \varepsilon_{it}$, where ε_{it} is normally distributed with zero mean and standard deviation σ_ε. Individual demands are calculated, and these are piecewise linear (because of the margin costs and position limits). Speculators do not draw any inferences from the futures price. The equilibrium futures price P_t which clears the market is obtained numerically.

Simulations were run using a market with seven speculators. The model was used to determine the response of trading volume, open interest and return volatility to different regulatory regimes. Margins affect expected volume and volatility through their effect on the shape and variation of the demand curves of speculators. Shocks are caused either by shifts in hedging demand or by the arrival of information. since the hedging demand is taken as exogenous in this model, the open interest and volume it generates are unaffected by the size of the margin requirement. On the other hand, open interest and volume generated by new information are unambiguously smaller, as speculators take smaller absolute positions as margins increase. The speculators' demand curves become steeper in a region of low prices and flatter in a region of high prices. This makes the *a priori* effect of higher margins on price volatility ambiguous. This ambiguity is also borne out by the simulation results and, if anything, volatility seems to increase as margins are increased. Thus, the results suggest that high margins are very effective in cutting speculative volume, but that this is not accompanied by greater price stability. Tighter speculative position limits have a relatively simple effect on investors' demand curves, and aggregate demand is unambiguously flattened. Stricter position limits again reduce volume and open interest, and are also destabilising.

III Derivatives and market completeness

The previous discussion has focused on the role of derivative instruments in providing cheap and convenient mechanisms for short selling, and for obtaining leverage. We will now turn to the equally important role of options and other contingent claims in making the market complete, so that any required contingent claim can be constructed. If price processes are continuous with known parameters and no frictions, then dynamic trading strategies can be constructed which exactly replicate option payoffs, and which therefore make options redundant securities. However, these assumptions are rather strong. Ross (1976) describes the role of options in making markets more complete. In this section we look at a simple discrete-time example, which illustrates possible price effects of derivatives in this role.

The example is inspired by the approach of Dybvig and Ingersoll (1982). It is set in a world containing two different classes of investor, which are differentiated in terms of their preferences (utility functions). The economy has three dates: date 0 (today), date 1 in which some information about the future value of the market portfolio is revealed, and date 2 in which it is all revealed. The investors are able to draw a probability tree for the date-2 possibilities, and this tree is partitioned by the information which arrives at date 1. The investors have given initial wealth, which can be invested in any proportions between the market portfolio and borrowing or lending at a zero real rate. The equilibrium price for the market portfolio is the one at which the market clears. We shall see how the equilibrium can be affected by the presence of derivatives making the market complete.

We give each (class of) investor an initial endowment of £500. For convenience of computation, the utility functions for each investor belong to the hyperbolic absolute risk-aversion (HARA) class. (See, for example, Ingersoll, 1987 or Huang and Litzenberger, 1988.) These utility functions, require two parameters a_i and b_i for each investor class i. The investor's absolute risk-aversion is given by

$$\text{ARA} = \frac{1}{a_i + b_i w} \qquad (2)$$

where w is the investor's wealth level. Separation theorems imply that we must choose b_1 different from b_2 in order to prevent the investors being content to hold the market portfolio and making derivatives redundant. We have chosen $a_1 = -300$, $b_1 = 1$, and $a_2 = 200$, $b_2 = 0$, so the utility functions are $U_1 = \ln(w-300)$ and $U_2 = -\exp(-0.005w)$ respectively. Individual 2 has constant absolute risk-aversion. In contrast, individual 1 becomes increasingly risk-averse at lower levels of wealth, and will defend a wealth level of £300. This means that individual 1 is likely to behave like a portfolio insurer. In constructing our example we wish to avoid a simple binomial tree with just pairs of branches, for in this case dynamic trading strategies will complete the market. However, the addition of a fifth branch with a low probability, to a conventional three-date, four-terminal-node tree, is sufficient to make the equilibrium dependent on whether derivatives trade or not.

The full example is shown in Figure 12.1, with some of the relevant numerical details in Table 12.1. The figure shows the nodes of the probability tree, together with the time-2 payoffs. It gives the equilibrium price for the market portfolio at times 0 and 1, first for the case where this is the only market-traded asset, and below in brackets for the case where markets have been completed. We should note that these equilibria are rational-expectations equilibria in the usual sense. The individuals are assumed to know each other's utility functions and agree on the probabilities and final payments on the tree. Conditional on what state occurs at time 1, the outcome at time 1 is precisely as each individual had expected.

We can tell the following story about this example. Without derivatives, investors whose risk-aversion increases fastest as their wealth falls (and who in this example seek to defend a particular future wealth level) are forced to withdraw from the equity market more quickly than they would really like after a market fall. The other investors pick up their former holdings, but since they too are risk-averse they demand a higher risk premium and the market fall is greater than it would have been, had derivatives made the market complete. Thus in our example, the volatility of the market portfolio is greater when the market is incomplete, because the investors are unable to share risks in an optimal way, and more risk is thrown on to one class of investor. In interpreting the completion of a market by derivatives it is worth considering that although options can

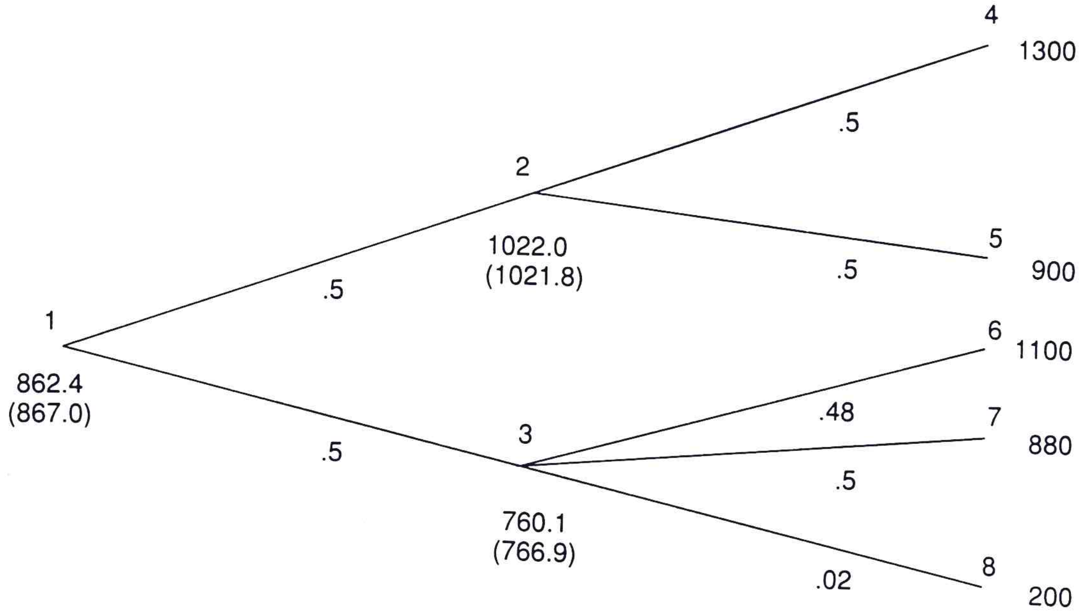

Figure 12.1 The effect of adding derivatives to a simple market. The figure shows equilibrium values first for an incomplete market, and below in brackets for a complete market.

play a unique role in a static context, in a dynamic one futures can also increase completeness by reducing market frictions so as to facilitate dynamic hedging. Note that the behaviour of our 'portfolio insurers' is entirely endogenous to the model, which itself is based within the classical expected-utility-maximisation paradigm. This contrasts with most other models of portfolio insurance behaviour which take the portfolio insurance *strategy* to be exogenous, so it is entirely unresponsive to the price behaviour encountered and also to the expected rates of returns available.

Two other points are worth mentioning. First, it is surprising just how little difference the derivatives make in this model. Both the prices and the variances are only changed by small amounts, despite the fact that some quite large portfolio rebalancings are involved. Second, the nature of the changes to equilibrium are not inevitable. It is equally possible to produce examples (though perhaps even more pathological ones) in which type-1 investors are frightened by an increase in expected variance even though this is accompanied by an increase in expected future market values. In such a case we can contrive to make the portfolio switching lead to an increase in market variance resulting from the introduction of derivatives.

Of course, dynamic trading strategies which move out of equities after a fall, followed in a systematic way will also tend to increase the volatility of the market. A paper by Brennan and Schwartz (1989) describes a model of a capital market in which a minority of investors follow portfolio-insurance policies. Under reasonable assumptions, although this increases

Table 12.1 Solution to probability tree example

Node	% of market held by Investor 1	Incomplete market: wealth of Investor 1	Incomplete market: wealth of Investor 2	Complete market: wealth of Investor 1	Complete market: wealth of Investor 2
1	35.0	500.0	500.0	500.0	500.0
2	58.8	555.9	603.7	554.7	600.1
3	27.2	464.1	433.5	464.6	435.3
4	—	719.5	718.1	718.1	714.9
5	—	484.1	553.4	483.1	549.9
6	—	556.5	681.1	590.7	642.3
7	—	496.7	520.9	473.7	539.3
8	—	311.9	25.7	313.0	20.0

market volatility, it does not do so very much, provided the other investors understand the plans and actions of the portfolio insurers. For example, in this model, even when 20% of investors are portfolio insurers, market volatility may only increase by 6% (e.g. from 17% to 18%) compared to when there are no portfolio insurers. Although they take the portfolio-insurance strategies as given exogenously, they also point out that the more widely followed the portfolio-insurance strategy is, the more costly it becomes. The popularity of such strategies should be self-limiting.

Finally, we may wish to question the appropriateness of assuming that investors are informed about each other's utility functions, and are thus able to anticipate what portfolio rebalancing will occur in future periods. It is precisely this problem which we will consider in the following section.

IV **Arguments concerning imperfect information**

Papers by Grossman (1988b) and by Gennotte and Leland (1990) analyse the problem that where dynamic hedging is planned it may not be communicated to the market and may cause extra volatility. The problem will tend to be reduced either by the market learning about this behaviour or by greater reliance on explicit options contracts instead of dynamic hedging. I will describe the results obtained by Gennotte and Leland.

The puzzle posed by the 1987 crash is how a market could fall by as much as 20% on an equity turnover, which although large, represented only about 0.2% of equity value, and when the amount of new information about fundamentals appeared to be rather modest. This suggests very inelastic demand (about 0.01), which is quite at odds with the predictions of the kinds of model we have so far discussed.

Gennotte and Leland develop a model in which the market is characterised as consisting of:

1. supply-informed funds (whose market-making capital accounts for about 0.5% of the market)
2. price-informed funds (whose market-timing capital accounts for about 2% of the market)
3. relatively passive investors who invest in the market 'for the long haul' (the remaining 97.5% of the market).

All three classes of investors are assumed to maximise expected utility of an exponential utility function $U = -\exp(w/a)$.

In this model there are two sources of uncertainty (and also of information). The initial fixed supply of securities is modified by a liquidity shock. The market makers are able to observe this, but only imperfectly because of noise. The other source of uncertainty concerns the true future price. The price-informed investors are able to observe this, but again imperfectly because of noise. The paper shows how the asset demands of each of the three classes of investor depend on the information received. It goes on to characterise the equilibrium price function, for a rational-expectations equilibrium, relating the current price to information about the future price, the unobserved liquidity supply and the observed liquidity supply. The model is then used to examine the effect of an increase in the supply of securities and also the presence of investors expectedly or unexpectedly pursuing portfolio-insurance strategies.

Choosing plausible values for the parameters of the model, Gennotte and Leland find the elasticity of demand is 17 when all investors are aware of an increase in supply, but it reduces to 0.16 when only the supply-informed market makers receive an accurate signal about it, and to 0.07 when no investors have information about the supply shock. They then investigate the possible destabilising effects of portfolio-insurance-type programs within this model. An additional deterministic supply function is introduced which represents the selling (or buying) of portfolio insurers as a function of market price. When all investors observe this additional supply, there is some increase in volatility (compared to the no-portfolio-insurance scenario) but crashes are unlikely (though possible). As with the previous analysis of a simple increase in supply, the effect becomes much more dramatic when either just the market makers, or no investors, have information about the portfolio-insurance activity. When this activity is unobserved, volatility increases because investors believe a change in fundamentals is more probable than a change in supply. They therefore see no reason to rush to take the other side of transactions generated by portfolio-insurance programs, and this magnifies the price response to other shocks. The model demonstrates that it is possible for a small change in information to trigger a discontinuity in price. An example is given in which the arrival of bad news triggers falls of 1%, 1.5%, or a crash of 30% depending on whether everyone, just the market makers, or no one at all is aware of the portfolio-insurance programs. In this model, the price does not bounce back if we now reverse the bad news: there is hysteresis in the relation between price and information. However, in other contexts upward jumps are certainly possible. The model would presumably show a bounce-back in price if we subsequently learned about the nature of the portfolio-insurance programs. In this respect it seems to have departed from the usual kind of rational-expectations equilibrium assumptions.

V Evidence on market volatility

We will turn to empirical work to review the main regularities which are revealed by a now dauntingly large (and often rather unfocused) empirical literature. The majority of work is for the US markets, but fortunately, despite some important institutional differences, few major differences have been found between the principal behaviour patterns in the markets of different countries. The review begins with general background concerning volatility and volatility relationships, before proceeding to the focus of the paper.

First, has there been any discernible increase in market volatility through time? A considerable number of papers have examined this. For example, see Schwert (1989, 1990) and Harris (1989). There is no evidence of any secular increase in the level of market volatility. Schwert (1990) studies monthly US equity returns from 1802–1989, daily returns from 1885–1989, and intra-day returns from 1983–9. He concludes that 'except for brief periods in October 1987, and recently on October 13, 1989, stock return volatility has not been unusually high in the 1990's'. He suggests that the high levels of the indices contributed to a perception of high volatility, as a given percentage shock represents a larger absolute change in the index. Periodically higher-than-average volatility is experienced. Schwert (1989) looks at the price movements before, during and after October 1987 in the context of 100 years of daily data. He concludes that while the 1987 crash was the largest one-day percentage change ever recorded, it was also remarkable in that stock-market volatility returned to low pre-crash levels quickly. Merville and Pieptea (1989) study implied volatilities from option prices on 25 stocks and the S&P 500 stock-index futures contract over the 10 years 1975–85. They conclude that 'volatility follows a mixed mean-reverting diffusion process with discrete white noise'.

It would be misleading to suppose that nothing has changed. There is evidence that markets' behaviour corresponds more closely than formerly to the random walk postulated by academic theorists for efficient markets. Froot *et al.* (1990) examine the short-run predictability of stock prices. Using intra-day NYSE data for the S&P 500 cash index from 1983 to 1989, they find that 'the predictability of short-term stock returns has declined markedly since 1983, contemporaneously with the growth in new institutional trading practices like portfolio and index futures trading'. In 1983 the autocorrelation of fifteen-minute returns was above 0.4; by 1989 it was practically zero. They analyse and reject the possibility that this change could be due either to 'bid-ask bounce' together with an increase in the synchronisation of buys or sells, or to non-trading effects. Further light on the nature of intra-day trading activity and price movements is provided by Harris *et al.* (1990). Steeley (1990), using daily data, provides an analysis of the behaviour of the UK Gilts market before and after Big Bang. He finds very similar reductions in the autocorrelation of price changes.

We now turn to consider studies which investigate various aspects of the relationship between volatility and other factors. Our selection will necessarily be rather selective. First, it is fairly well established that a security's volatility is related to trading volume. This itself is a complicated and abundant literature. A survey is provided by Karpoff (1987). We shall find later that volume effects are quite significant in the context of the introduction of derivative products. Possibly related to this, we have the idea and evidence that very little happens when markets are closed. French and Roll (1986), for example, provide evidence on just how small the variance per day of returns is over weekends, compared to that over trading days. Many researchers simply measure time in terms of trading days and ignore the heteroscedasticity that might be expected from some calendar time intervals being longer than others. Other papers, including Cheung and Ng (1990), document a U-shaped volatility pattern within the trading day.

A number of papers have examined the relationships between movements in the cash index and in futures prices. MacKinlay and Ramaswamy (1987) find that there is greater autocorrelation in the fifteen-minute changes in the spot index than in the index futures price. They attribute this to non-synchronous trading in the index stocks. Harris (1989), Stoll and Whaley (1990b) and some other studies find that changes in the index futures tend to lead changes in the index. Harris finds that this still appears to be the case even after allowance has been made for the effects of non-synchronous trading. Cheung and Ng (1990) examined the time-varying behaviour of volatilities on the S&P 500 index and the CME index future. Their methodology takes account of both the non-synchronous trading problem and the changing conditional variances. Using transactions prices from September 1983 until June 1987, they find that the futures market is more volatile than the spot market and that, although there is evidence that the variance of futures prices leads that of spot prices, the variance of spot prices does not seem to have predictive ability to forecast the variance of the movements in the futures price.

Other sets of studies have examined the impact of particular types of trading or changes in regime on the behaviour of stock prices. In the main, the evidence is either negative, or mixed. For example, Grossman (1988a), using ten months of daily observations on stock-market volatility and program trading on the NYSE in 1987 (including the 1987 crash period) was unable to find any significant association between program-trading intensity and volatility. He did, however, find a positive relationship between volatility and DOT (Designated Order Turnaround) system volume relative to NYSE volume, suggesting that the more volatile days are those when the retail-customer-generated DOT order flow is large. On the other hand Schwert (1990) mentions more recent studies by both the SEC and the NYSE which find positive relationships between program-trading volume and volatility.

Hsieh and Miller (1990) analyse whether Federal Reserve margin requirements on stocks have an effect on market volatility. They use daily and monthly data from 1934 to 1987. They find the expected negative relationship between margin requirements and the amount of margin credit outstanding, but find no convincing evidence that Federal Reserve margin requirements do anything to dampen stock-market volatility. The contrary conclusion expressed by some other work is attributed to flaws in its methodology. The paper also finds evidence that changes in margin requirements have tended to follow changes in market volatility.

VI **Market behaviour in market crashes**

Security price behaviour during the 1987 crash has been examined by many researchers, and it is beyond the scope of this paper to do more than mention one or two aspects of it. The studies by Katzenbach (1987), Brady (1988), Gammill and Marsh (1988), Greenwald and Stein (1988) and Miller (1988) all provide illuminating insights into what took place and into the relationships between the US stock and derivative markets. Mann, Shapiro and Sosebee (1990) document market activity on three other days of extreme market movements in October 1989.

Major price swings have invariably occurred on very high levels of trading volume. The high volumes have severely tested the abilities of the market to supply liquidity, and also the adequacy of their systems to cope with high volumes and fast movements. The issue of liquidity is both central and problematic. It is almost self-evident (and perhaps tautological) that liquidity was a problem. However, we have no adequate definition of what we mean by liquidity, or any consensus on how to measure it. A recent paper by Amihud *et al.* (1990), relates a number of liquidity measures such as bid–ask spread and change in the quote size on price changes.

In the 1987 crash, because stocks became illiquid and trading was sometimes also suspended, it is very difficult to compute what the 'true' spot index would have been with up-to-date prices. The reason why the futures always appeared to lead was largely due to the out-of-dateness of the spot index. As we have already mentioned, this phenomenon also contributes to the futures appearing more volatile than the spot.

In these market conditions, the usual high elasticity of demand in security markets clearly broke down. Markets no longer provided continuous prices, and investors were often unsure at what prices they could realistically execute trades. This particular problem is discussed in detail in Schwartz (1990) and Bronfman and Schwartz (1990). Despite the large volume of material which has been written about these occurrences, there remain puzzles as to why such large and comparatively isolated events occur, and whether or not the use of derivatives and derivative-related trading strategies made any real difference.

Portfolio-insurance-type strategies cannot have been the prime mover for the collapses, although it is possible that they may have helped to magnify the declines. Index arbitrage would be even less to blame. Miller (1990) points out that the view that 'the large price moves . . . might actually have been caused by index arbitrage, as one so often reads in the financial press, is a charge no academic researcher takes seriously. Arbitrage transactions, with a buy side in one market and a sell in the other, can have no substantial net effect on the price level.' Nevertheless, Miller does concede that, index arbitrage can create problems for other participants (and hence for the market as a whole), depending on how orders are processed, and how quotes are adjusted. An International Stock Exchange (1989) report highlights how different London is from New York. In the London market 'index arbitrage is normally only undertaken by a small number of firms that are market makers in a large proportion of the FT-SE 100 stocks'. The report concludes by emphasising the importance of encouraging the increased use of index arbitrage in the UK, as promoting liquidity, increasing the convergence of the equity and derivative markets, and as an effective low-risk strategy in equity investments.

VII **International comparisons**

Other insights may be obtained by making international comparisons of the events of October 1987. The study by Roll (1988), for example, performed multivariate regression analysis to try to determine what factors made the crash worse in some countries than in others. He concluded that the markets tend to display a consistent correlation with a world market index. A variety of institutional factors were examined, including the presence of options/futures trading, computer-directed trading, and the level of margin requirements. None of these was found to be significant.

Bertero and Mayer (1989) also studied this problem. They used an independent source of data on 23 stock markets around the world to examine the influence of the structure of the markets on their performance around the week of the crash. Ten of these markets traded index futures at the time of the crash. There was no evidence of any relation between the existence of index futures and the scale of the crash in the different markets. Only nine markets outside the USA use computers at some stage in their trading process. The existence of computer trading had no effect on performance during the crash.

VIII **The effects of introducing derivatives: empirical evidence**

A wide variety of empirical studies have now been reported on the effects of introducing equity options. None of this seems to support the hypothesis that derivatives increase volatility. Most seem consistent with an increase in volume and a weak reduction in volatility.

Early studies include Nathan (1974), Hayes and Tennenbaum (1979), Trennenpohl and Dukes (1979) and Klemkosky and Maness (1980). The Nathan Report looked at the volatility of 16 optioned stocks using weekly data for 53 weeks before the CBOE (Chicago Board Options Exchange) and 36 weeks after it. It compared the volatility of the optioned stocks to that of the market and to that of a random sample of 80 stocks. It concluded that the average volatility of the optioned stocks had reduced post-CBOE. Trennenpohl and Dukes used a sample of 32 optioned stocks and a random sample of 18 non-optioned NYSE securities. They looked at 30-month periods before and after CBOE listing. They too reported that the optioned securities decreased in volatility relative to the non-optioned random sample.

Klemkosky and Maness used a regression technique with a dummy variables for the pre-listing period to investigate whether the average beta had changed for securities belonging to three separate groups. Group 1 consisted of those 32 securities that were listed on the CBOE between April and October 1973. Group 2 consisted of those 32 securities that were listed on the CBOE between December 1974 and June 1975. Group 3 consisted of 39 securities that had options listed on the American Stock Exchange between January and June 1975. In each case they use 36 months of monthly stock returns before and after the period defining the sample. The results of this study were more equivocal. Roughly equal numbers of stocks experienced increases in beta as did declines. For the portfolios of each group, the betas of groups 1 and 2 declined slightly, while that of group 3 increased slightly. Calculating the change in the portfolio variances relative to that of the market index in the same periods reveals the same pattern. We can impute a reduction of between 6% and 9% in the variance of the group 1 and 2 portfolios, but an increase of 5% for group 3.

Nabar and Park (1988) looked at the effect of the introduction of options on 390 US stocks over a six-year period. They use an event study technique, calculating pre- and post-listing variances in thirty-day return periods before and after listing, and use another sample of 340 stocks as a control group. They found a small (4–8%) decline in volatility after options were introduced.

It is striking that all these authors reached broadly similar conclusions despite wide differences in their data sets and methods of analysis.

Another paper, by Skinner (1989), also worked with a large sample of stocks: 304 option listings (after omitting 58 firms for which adequate daily data was not available on the Centre for Research in Security Prices (CRSP) daily returns file). He finds that the introduction of options trading in a stock decreases volatility: the average market-adjusted variance decreases by 14% relative to the corresponding figure for a control sample, the median decreases by 9%. At the same time the median increase in volume was around 17% for the 297 firms with volume data available. After partitioning the sample into firms with volume changes above or below the median, it was found that the firms with the highest increase in volume have only a marginal decrease in volatility, while those with a smaller increase in volume show a substantial decrease.

In the UK, Gemmill (1989) found very similar volatility effects on a small sample of option introductions, and also on a controlled comparison of the volatilities of stocks with and without options. He used a regression approach to explain the average normalised share-price trading range in terms of the natural logarithm of daily volume and a dummy variable for options trading. Volume was positively associated with both the price range and (less strongly) with the presence of options trading. He concluded that volatility fell on average by 17% after options were introduced (but with a large standard error). The with/without comparison indicated a 4–12% lower volatility for shares without options.

One potential problem in these studies is that of sample bias. It is mentioned in Skinner's paper: 'The options exchanges choose those stocks for listing that rate highly in attributes such as investor interest, trading activity and *price volatility*' (italics in original). He reports that his results are robust when a variety of time periods prior to listing are used to estimate variance before listing. Given what we know about the degree of mean-reversion in risk measures, this problem deserves careful consideration. It is worth noting that Gemmill's two approaches are biased in opposite directions in this regard. A recent and important paper by Lamoureux (1990) attributes the whole of Skinner's decline in variance to this effect.

Two papers by Edwards (1988a, 1988b) look at the effect of equity-index futures and interest-rate futures on the volatility of the underlying. Edwards also concludes that there was no evidence that they had increased volatility over a period up to May 1987.

Using a quite different and more powerful methodology, Damodaran (1990) investigates whether the introduction of the S&P 500 futures contract in April 1982 affected the riskiness of those stocks in the index. The data used covered 1250 trading days immediately preceding and following the introduction of the futures contract. He finds evidence that stocks in the index had significantly but modestly higher betas and total variances after futures listing. The paper also provides evidence that these increases are related to trading activity variables, which reveal much heavier trading, and more noise after listing.

IX **Expiration day effects**

A number of authors have examined whether asset prices are more volatile on the expiration days of their derivatives. The consensus which emerges is that there is a significantly increased volume, but only fairly modest changes in price movements and volatility. Much of the folklore about the effect of triple witchings etc. seems misplaced. Stoll and Whaley (1987, 1990a) are good examples. The later paper examines expiration-day effects before and after June 1987, when the settlement of a number of important index contracts was changed from the close of trading to the open in an attempt to mitigate concern about occasional abnormal stock-price movements. Stoll and Whaley study all expiration days on NYSE stocks in the period January 1985 through to June 1989. The volume effects are substantial, and the change in settlement significant: at quarterly expirations the volume of trading in S&P 500 stocks in the opening half-hour rose from 6.6% of average two-day volume before June 1987, to 26.3% afterwards. The average volume in the closing half-hour fell from 20.8% to 9.4%. Price volatility at the open on quarterly expiration days increased after June 1987, and shows a price effect of about 0.3% in excess of the effect on non-expiration days: about the same as a typical quoted bid–ask spread for an active stock on the NYSE. Volatility at the close decreased after June 1987, but remained higher than normal. The price effects at monthly (non-quarterly) expirations are much less significant. Here, volatility effects cannot be reliably detected to show clear differences between index stocks and non-index stocks or between expiration days and non-expiration days.

For a contrasting methodology, a provocative study by Day and Lewis (1988) uses implied volatilities estimated from options prices to examine changes in volatility around expiration dates. The period analysed is from various dates in 1983 (corresponding to the introduction of new contracts) to December 1986. Day and Lewis examine daily price behaviour for four days either side of expiration dates, and find that the option prices reflect increases in the volatility of the underlying stock indexes around both quarterly and non-quarterly expiration dates. One problem with this approach is that the prices of the expiring call options used could well be biased relative to usual Black–Scholes valuations: either because of supply and demand effects in the market, or because of a tendency for fatter tails at short horizons.

Evidence on options expiration in the UK is provided by Pope and Yadav (1988). The time period used was from October 1982 to September 1987. After eliminating data that would have involved comparisons with three-week account periods, this gave 46 option expiration dates, and 465 expiries at the individual-firm level. Price behaviour was analysed using an event study methodology with daily data from 4 days prior to expiry to 5 days after. Volume data were only available after Big Bang (October 1986), but on a limited sample of 7 expiration dates showed a marked increase in trading volume before option expiry, and a marked decrease afterwards. Evidence is found for statistically significant downward price pressure immediately prior to option expiration, which amounts on average to 0.5%. Volatility of stock returns is examined by comparing the frequency with which the squared return in the event period exceeds that on the corresponding day in the control period. This test did not detect any change in returns volatility.

X Conclusions

This paper has presented a survey and review of theoretical and empirical work related to how the existence and use of derivative instruments affects the volatility of the underlying asset markets. There is strong evidence that derivatives lead to an increase in market volumes, both generally and also particularly just prior to expiry dates. Despite a general association between trading volume and volatility, the introduction of (or presence of) derivatives is often associated wih reduced levels of volatility. The theoretical analyses provide some insights into why this might be the case, but a number of puzzles remain.

The phenomenon of trading noise, which is identified in a number of studies, is still poorly understood. We know insufficient about how returns are generated, and about the determinants of trading volume and of price volatility. Periods of high volatility have stretched the capacities of markets to provide liquidity, and it is here particularly that our insights from theory are at their weakest.

The evidence, both theoretical and empirical, is quite different from much of the folklore. In analysing the effects of market structure on volatility we need to be exceedingly careful to use our words precisely. Program trading, for example, includes such diverse activities as dynamic trading strategies of a portfolio-insurance type, index arbitrage trading, and the use of computerised technical analysis to determine market timing decisions. If a number of large institutions act simultaneously in a similar way, albeit unconsciously, we can expect to see big price changes. When these occur, should we blame the computers or analysts that trigger the trades, should we blame the derivatives that they choose to trade in, should we blame the inadequacies of the markets in which they trade, or should we blame the structure of financial holdings which puts so much money under the control of so few hands?

Appendix A Recommendations of the NYSE Panel on Market Volatility and Investor Confidence

1. Coordinated 'circuit breakers' should be introduced to halt or limit trading in times of market stress. These measures should be mandatory across all domestic equity and equity derivative markets. Enhanced price and trade information should be made available during times when circuit breakers are triggered.
2. To enhance liquidity in times of market stress, the Securities and Exchange Commission (SEC) should ease existing constraints on the ability of corporations to repurchase their own common stock.
3. Other steps should be considered to increase market liquidity, such as removing obstacles that interfere with the ability of market makers to hedge their positions, encouraging the use of limit orders and improving credit arrangements on bank holidays.
4. Active efforts should be undertaken by the exchanges and other market professionals to work with the media to educate the public on how program trading, index arbitrage and the uptick exclusion actually work.
5. New products should be developed to enable individual investors to protect themselves from the extremes of intraday price swings.
6. The exchanges and their regulators should strive to improve their capabilities to detect intermarket trading abuses – in particular, by improving the quality of the audit trails of all markets.
7. Regulatory authority over the US equity and equity derivative markets should be consolidated under one federal agency.
8. The Panel recognizes that margins for individual securities should be higher than performance bonds on broad-based equity index futures. A

majority of the Panel believes that margin requirements for US equity and equity derivative instruments be set by the exchanges with government oversight consolidated in one federal agency.

A number of members disagreed with views expressed in recommendations 1, 7 and 8.

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