

Box 4

GAUGING STOCK MARKET UNCERTAINTY USING OPTION-IMPLIED DISTRIBUTIONS

After a long period of relatively low volatility and steadily rising stock prices, global stock markets were suddenly hit by a strong sell-off in late February 2007. On 27 February broad-based indices in the euro area and the United States dropped by 3% and 3.5% respectively, as measured by the Dow Jones EURO STOXX and the Standard & Poor's 500 indices. There are indications that the stock market turmoil reflected a sharp and sudden increase in global risk aversion and uncertainty, causing broad-based profit-taking in the light of the strong valuation gains accumulated over previous months. However, following a short period in which prices stabilised at lower levels, global stock markets to a large extent recovered the previous losses during the second half of March and early April. Despite the limited impact, it is important to look at how investors' risk perceptions evolved during that episode.

Option prices contain useful information about market participants' risk perceptions. In particular, by estimating what are known as option-implied distributions, it is possible to derive the probabilities that investors assign to possible future stock price developments. This box applies option-implied distributions to the recent stock market turmoil in order to examine two different aspects in more detail. First, an attempt is made to gauge the extent to which the February turmoil was seen by investors as an extreme event. Second, the box looks at whether investors, following the stock market correction, changed their view concerning future large swings in US stock prices. The analysis is applied to the US market, since a sufficiently wide range of actively traded options are available for the Standard and Poor's 500 index.

An option contract, such as a call option, can be seen as a bet that the underlying asset will at some point in the future exceed a certain level. By combining the information from several options that give a positive pay-off for different levels of the underlying asset, it is possible to recover the full set of probabilities that investors assign to all possible future stock price developments. These are often referred to as option-implied distributions. Several interesting statistics and applications can be derived from these distributions. First, the distributions can reveal potential asymmetries and therefore the "balance of risks" which the markets may perceive as regards future asset price developments. Second, by comparing the shape of the option-implied density functions before and after a specific event, it is possible to determine

more precisely the way in which that event has shaped market participants' views about the future.¹

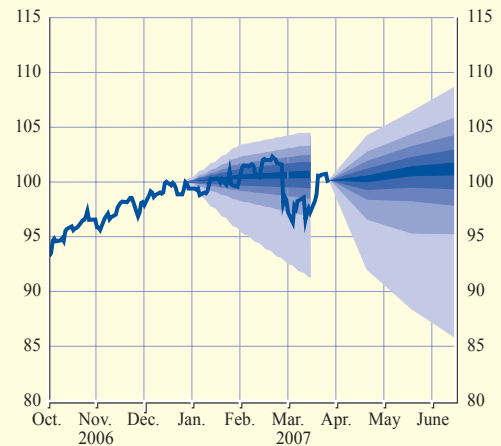
Furthermore, by using distributions based on options with various maturities, it is possible to derive a "fan chart" that reflects the distribution of future stock price developments as perceived by the markets. Using data on options on the Standard & Poor's 500 price index traded on the Chicago Mercantile Exchange, two fan charts are shown, one using data for late December 2006 and the other based on data for late March 2007, together with the actual performance of the Standard & Poor's 500 index. These fan charts are built up using option contracts that expire around one month, two months and three months ahead respectively. Each "fan" is composed of nine bands, with each band covering 10% of the probability mass of the option-implied distribution over the range of potential outcomes for future

stock price developments as perceived by market participants. The successive pairs of bands shown are drawn to cover 90% of the probability distribution. The depth of the shading of each band varies in proportion to its value or "height" of the probability distribution function such that, for example, the central band with the darkest shading covers the most likely event. The bands widen as the time horizon is extended, indicating increasing uncertainty about outcomes at more distant points in time.²

Three interesting features can be inferred from the chart. First, although the drop in US stock prices was relatively marked by late February, prices did not fall outside the 90% confidence bands derived from the option-implied distribution extracted two months earlier. In fact, only for a few days in late February and early March did US stock prices hover in the lower outer band covering outcomes with a probability between 5% and 15%. This suggests that by late December 2006 investors estimated that there was an approximately one in ten chance of a stock price correction as sharp as that actually observed. Second, the fan chart derived from options at end-March is wider than that derived from end-2006 options. This suggests that market participants have recently viewed the likelihood of there being a more volatile stock market environment as having increased. Third, judging from the asymmetry of the two fan charts at both points in time, the markets appear to have perceived strong declines in stock prices as being more likely than increases of similar magnitude. This asymmetry was more marked in the fan chart derived in March than in that computed at the end of December 2006. As a consequence of this reassessment, a stock price decline equally as strong as that observed in February was seen by market participants in late March as being somewhat more likely than it was three months earlier.

Option-implied distributions for the Standard and Poor's 500 index

(index: 27 December 2006 = 100; daily data)



Sources: Bloomberg and ECB calculations.

Notes: Fan charts as at 27 December 2006 and 29 March 2007. The fan charts depict the implied distribution of future stock price developments over the next two and a half calendar months.

1 For an application to stock market reactions to the September 11 terrorist attacks, see M. Andersson and M. Lomakka, "Evaluating implied RNDs by some new confidence interval estimation techniques", *Journal of Banking and Finance*, 2005, pp. 1535-1557. See also the article entitled "The information content of interest rates and their derivatives for monetary policy" in the May 2000 issue of the Monthly Bulletin for a fan chart of the three-month EURIBOR.

2 For a further description of fan chart interpretations, see R. Clews, N. Panigirtzoglou and J. Proudman, "Recent developments in extracting information from option markets", Quarterly Bulletin, Bank of England, February 2000.