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HEIGHTENED VOLATILITY IN EARLY FEBRUARY 2018: THE IMPACT OF VIX PRODUCTS

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Risks &
Trends

On Friday February 2, a macroeconomic statistic that was the source of fears of a risk of a rise in interest rates in the United States led to a sharp correction on US equity markets (-6% over two days) and, above all, a spectacular spike in volatility: the VIX, which over the preceding months fluctuated between 10 and 15 points, soared as high as 50 points in just a few days before falling off again. The VSTOXX and VCAC indices followed the same trend.

This spike in volatility took the market by surprise, in terms of its sheer magnitude and rapidity. It appears to have resulted less from fundamental causes than technical factors linked to the derivatives indexed to the VIX, notably from the impact of products that bet on a drop in this index.

The first section of this report presents the main products that are concerned (I), followed by an analysis of their behaviour during the drop in equity markets (II): the study shows that investors in French collective investments were not significantly exposed to VIX-related strategies. The report proceeds to focus on the transmission mechanism of volatility shocks on the equities markets: while overall these products indexed to the VIX do not appear to have had a significant impact on equity prices, nevertheless they played a self-feeding role in the rise of the VIX futures, notably at the end of the session (III).
Lastly, part four addresses the suspicions raised by a whistleblower following these events of the possible manipulation of VIX futures, and explains the unlikelihood of the VCAC or the VSTOXX being exposed to a similar risk (IV).

The analysis shows that French investors in collective investment schemes have not been significantly exposed to strategies involving the VIX and have not been significantly impacted.

Despite the sudden movements observed in their prices (in some cases leading to their early liquidation), products indexed to the VIX benefited from significant new inflows following this episode, in a context of lower volatility.

Fears of a recurrence of this type of event appear to be high, first of all based on fundamental reasons: indeed, the persistent appetite for risk leading to a probable overvaluation of assets increases the risk of another market correction. Combined with the knock-on effects of these products, further sudden shifts in volatility could take place.

In addition to VIX derivatives, the large number of strategies based on volatility calls for vigilance, notably emphasising the usefulness of protection mechanisms against the most aberrant price swings, such as circuit breakers.

1. THE VIX AND ITS DERIVATIVES: A GROWING POPULARITY OF STRATEGIES BASED ON VOLATILITY

Based on the implicit volatility of option prices, the "Volatility Index", or "VIX", represents, in theory, the sum of future expected volatility and the volatility risk premium. Since end-2015 and a sustained period of low volatility, this risk premium has remained positive, encouraging the extensive growth in the use of the VIX futures market. Over the same period, a growth in the Assets under management (AUM) of funds with strategies based on volatility trends can be observed.

1.1. THE VIX AND ITS USE

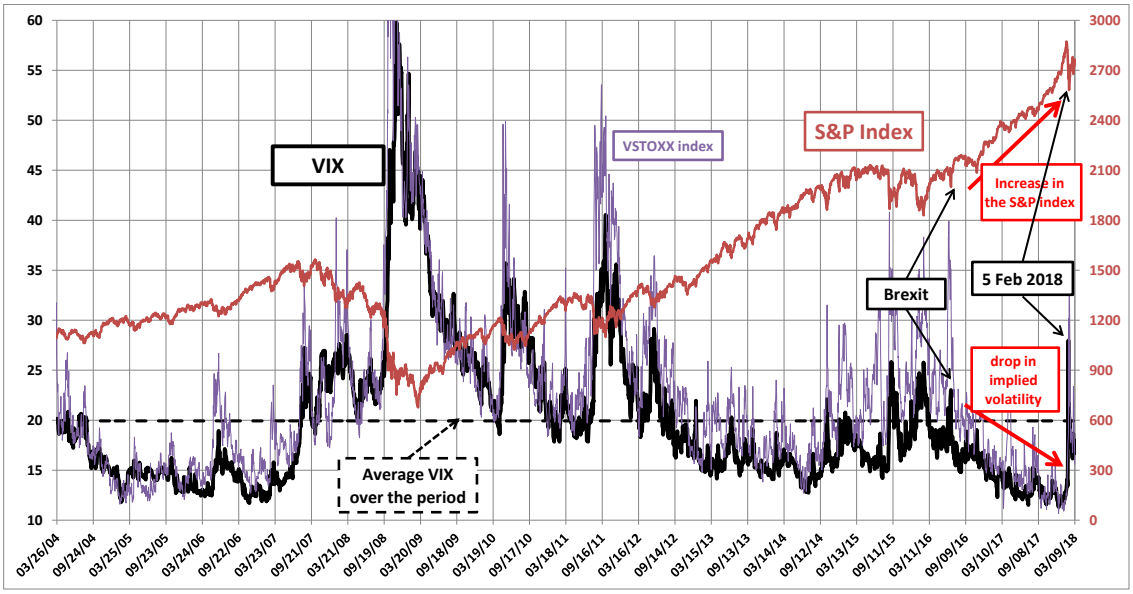
The VIX is an index that measures the implied volatility of S&P 500 index options with a 30-day rolling maturity[1]. It was introduced in 1993 by the Chicago Board Options Exchange (CBOE) and is published every 15 seconds (see Figure 1). **It is calculated based on the prices of options listed on this platform** using the formula provided in appendix[2]. Basically, if investors expect the S&P 500 to fluctuate by an average of 1% per day over the following month, the VIX will hover around 20 - its long-term average - while a level of 40 implies expectations of moves of 2%.

The index measures the expectations of the 30-day future volatility of US equity markets and its reading can be interpreted as an instant gauge of investors' perceived market risk. Since the index is highly sensitive to market stress, it is also referred to as the "fear index"; although a high VIX does not necessarily lead to future negative performance. The popularity of this indicator can be explained by the fact that, since its creation, changes in the VIX have on average been negatively correlated to changes in the prices of equities; investors thus buy put options on the S&P500 to hedge their positions in periods of market turbulence. Moreover, it can be observed that on average the VIX exceeds realised volatility, as investors are ready to pay a significant premium to acquire an exposure to this future volatility (Andersen and Bondarenko, 2007)[3]. Since November 2015, this risk premium has been systematically positive, underlining the increased interest of investors in this type of exposure.

Since end-2008, a decline in volatility has been observed, but with more frequent and violent fluctuations. These movements can be explained by the nature of political and macroeconomic shocks, but also by the growing popularity of volatility-based products, which can have, through negative convexities, significant effects on the index in the event of a downturn.

[1] A "Mid-Term VIX", with a six-month rolling maturity, is also published by the CBOE. As this index is far less volatile that the 30-day VIX, and is less used as a benchmark index, it has not been included in this report. The ratio of the 10-day realised volatility of these two indices has been 2.75 on average (between 1.5 and 5.5) over the past 5 years.
[2] The constant 30-day maturity is obtained by interpolating the measures on maturities within this set 30-day period.
[3] Andersen, T. G. and O. Bondarenko (2007). "Construction and interpretation of model free implied volatility", NBER Working Paper No. W13449.

Figure 1: Trend in the VIX and the S&P 500 index since March 2004 (the emergence of VIX derivatives)



Source: Thomson-Reuters

Prior to the creation of VIX derivatives, investors could not buy or sell the VIX itself. **The VIX was nevertheless used as an indicator of the price of overall risk**, or as a general proxy for investors' risk aversion (Adrian et al. 2016)[4]. Empirical literature also underlines the fact that there are strong correlations between the index and macroeconomic trends:

- Rey (2015)[5] demonstrates that global capital flows, global credit growth and the price of global assets move closely in line with the VIX.
- Longstaff, Pan, Pedersen and Singleton (2011)[6] believe that the price of sovereign risk is strongly correlated to the VIX.
- Adrian, Crump and Vogt (2015)[7] show that a non-linear function of the VIX can forecast market and bond returns.
- Lastly, monetary policy stance and the pricing of risk also react to the movements of the VIX (Bekaert, Hoerova and Duca (2013))[8].

Nevertheless it is worthy of note that, for empirical economists, although a drop in volatility over a long period can be an indicator of increased risk-taking (and thus a leading indicator of a financial crisis), it is not the level of volatility that serves as the indicator, but rather the unexpected occurrence of a high or low level of volatility[9].

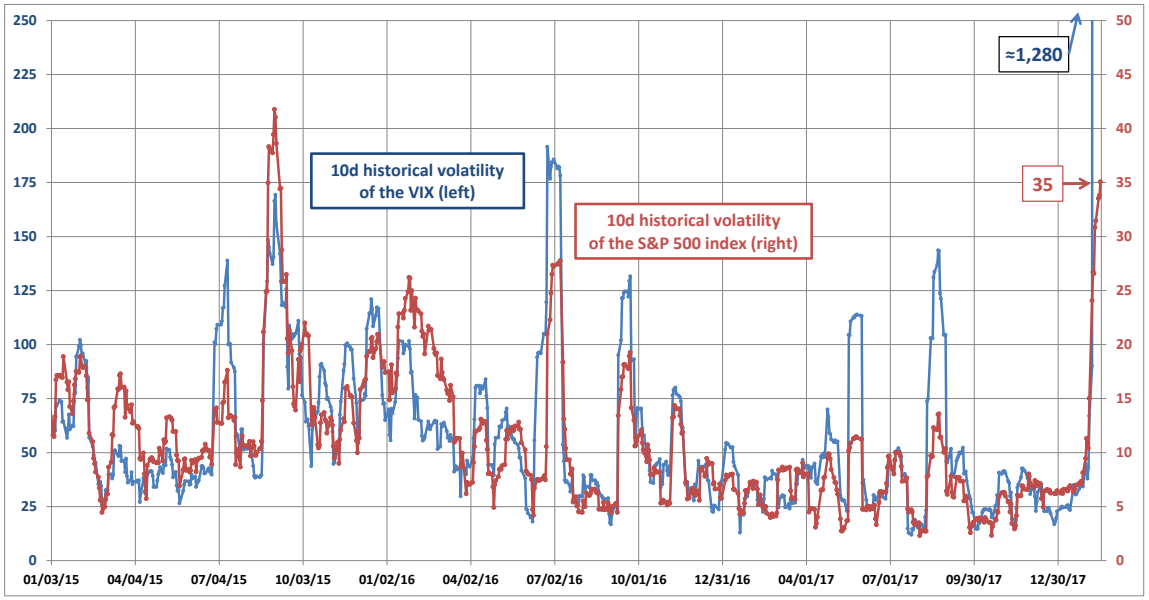
[4] Adrian T., D. Stackman and E. Vogt (2016), "Global Price of Risk and Stabilization Policies", August 2016 Number 786.
[5] Rey, H. (2015): "Dilemma not trilemma: the global financial cycle and monetary policy independence", Discussion paper, National Bureau of Economic Research.
[6] Longstaff, F. A., J. Pan, L. H. Pedersen, and K. J. Singleton (2011): "How Sovereign Is Sovereign Credit Risk?," American Economic Journal: Macroeconomics, 3(2), 75–103.
[7] Adrian, T., R. Crump, and E. Vogt (2015), "Nonlinearity and flight to safety in the risk-return trade-off for stocks and bonds," Federal Reserve Bank of New York Staff Report, 723.
[8] Bekaert, G., M. Hoerova, and M. L. Duca (2013): "Risk, uncertainty and monetary policy", Journal of Monetary Economics, 60(7), 771–788.
[9] See Danielsson, J, M Valenzuela, and I Zer (2015), "Learning from History: Volatility and Financial Crises", SSRN, an empirical analysis carried out using market data from 1800 to 2010 and covering 60 countries. It confirms Minsky's statement (1977) that: "stability is destabilizing".

1.2. LISTED DERIVATIVES LINKED TO THE VIX AND THEIR POPULARITY

Futures having the VIX index as underlying (VIX Futures) have been listed on the CBOE since 2004 and is quoted at $1,000 per index point. Options were introduced in 2006 and are quoted at $100 per index point. The daily settlement price of VIX futures is the last listed price at 4:15pm (New York time, i.e. 15 minutes after the closing of US cash and options markets).

The volatility of the VIX, which is thus a measure of the "volatility of volatility" is on average 10 times higher than that of the underlying index. **If we acknowledge that a financial instrument is measured by its volatility, then all derivatives based on the underlying VIX are by construction extremely risky.**

Figure 2: Volatility of the VIX compared to that of the S&P 500



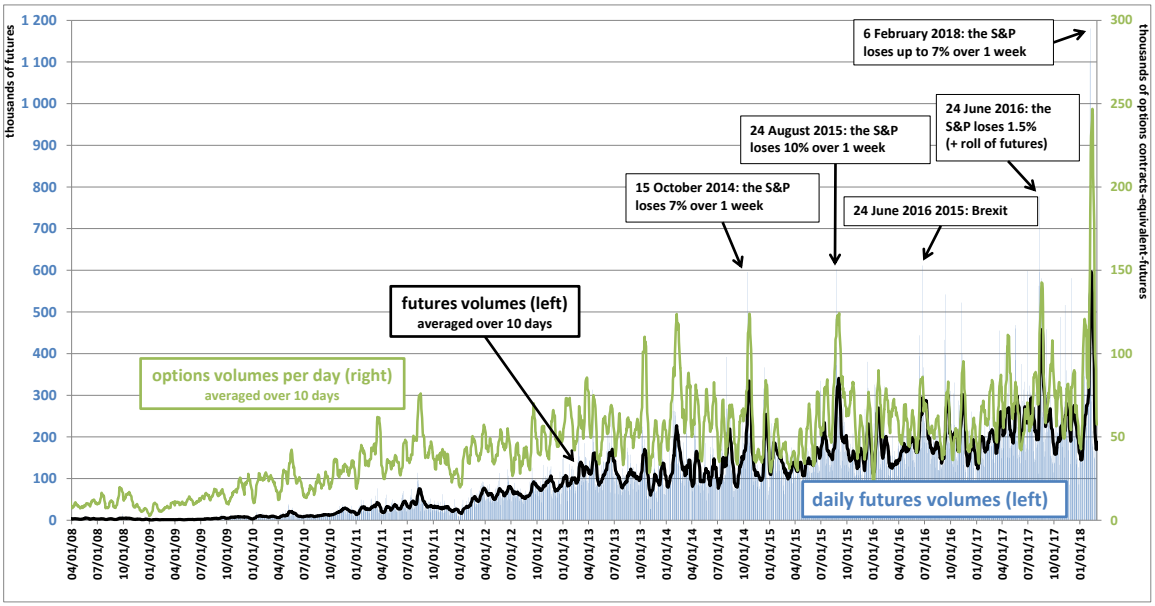
Source: Thomson Reuters

Volumes traded on VIX derivatives remained negligible up until end-2009 before gradually gaining popularity, reaching 260,000 contracts traded daily on average in January 2018. **Peaks in volume can be observed, each time in growing amounts, that coincide with the days of increased volatility presented in figure 3** (for example, for futures, volume peaks have increased from 100,000 in 2011 to 800,000 in 2017 and were around 1.2m at the beginning of February 2018).

One of the main reasons for the growing interest in these products is that positions on VIX derivatives can be used to provide protection against the volatility of the S&P500 index, particularly during periods of economic slowdown. VIX derivatives allow investors to obtain exposure to the volatility of the S&P500 at a lower cost than with traditional derivatives on the stock market index[10].

[10] Rhoads (2011) shows that it is often less expensive to be long with calls on the VIX that are out of the money than to buy puts that are out of the money on the S&P500. See Rhoads, R. (2011), "Trading VIX derivatives: trading and hedging strategies using VIX futures, options and exchange traded notes". New York: John Wiley and Sons.

Figure 3: Volumes traded in VIX futures (front and second month maturities) and options[11]



Source: Thomson Reuters.

1.3. AN ASSET THAT HAS BECOME ACCESSIBLE TO THE BROADER PUBLIC VIA INDEXED FUNDS

In parallel with the rise in volumes on listed derivatives, **Exchange-Traded Products (ETPs) indexed to the VIX future[12] such as Exchange-Traded Funds (ETFs) / Exchange-Traded Notes (ETNs), and thus accessible to the general public, were introduced on US markets** (and to a marginal extent in Europe and Asia). The fundamental difference between an ETF and an ETN is that an ETF holds the underlying products (or swaps, which replicate the performance of the assets, in the case of a synthetic ETF). ETNs, on the other hand, are **a debt instrument, the performance of which is defined by a formula guaranteed by the issuer. ETNs thus do not hold the assets whose performance it replicates**, but track a benchmark index. However, in practice, ETN providers hedge their positions at the end of the day, and this hedging can be expected to resemble that of an ETF holding VIX futures (but here the hedging instrument will be held on their own behalf, unlike in the case of ETFs).

Long products benefit from an increase in volatility, typically in periods of market stress. With the prolonged drop in volatility following Brexit, these funds have clearly underperformed, thus representing small amounts of AUM at end-January 2018. For example, the long VIX ETN (VXX) issued by Barclays has lost 87% of its value over two years, despite doubling its valuation between February 1 and 8 2018 (Figure 4).

[11] Futures trade at $1,000/index point and options at $100, the volumes of the latter have been divided by 10.
[12] As the index cannot be traded or easily replicated, VIX futures systematically serve as the benchmark for these funds.

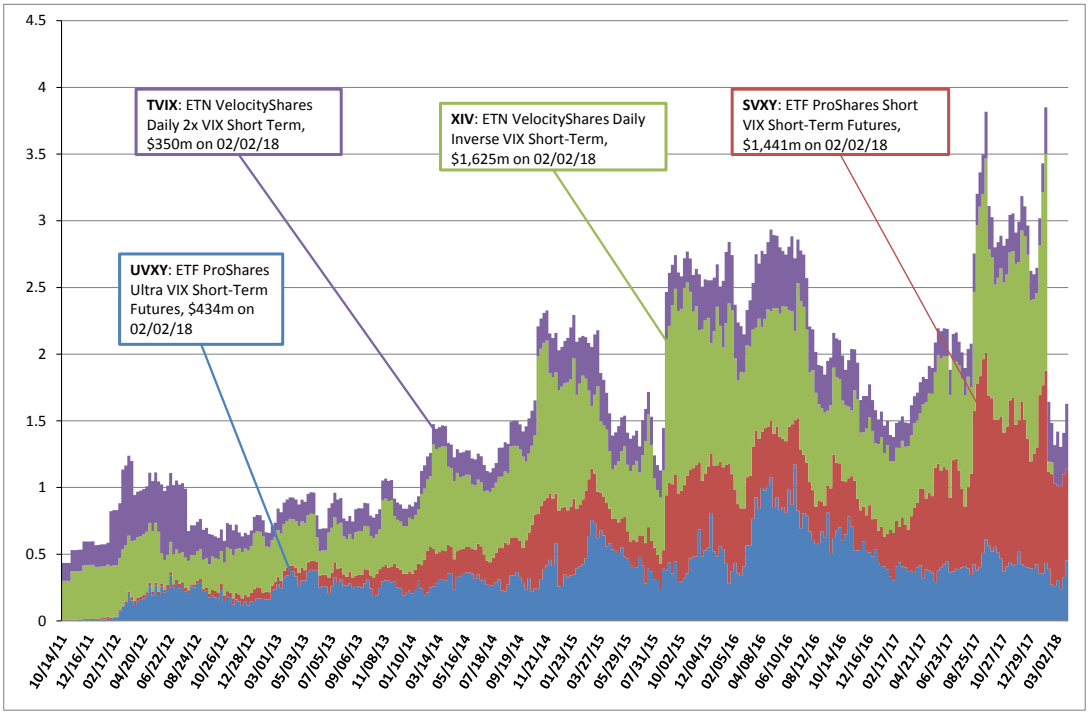
Figure 4: Example of the performance of a short-term long VIX ETN (VXX)

Source: Thomson Reuters.

Conversely, *short* products, which bet on a decrease in volatility, benefited from this trend of declining volatility. *Short* VIX AUM stood at $3.7bn at end-January 2018 (half of which were in the XIV fund, see Figure 5). This amount fell to $936m on February 13 2018, following the market stress spell.

In all, in 2013, Alexandre and Korovilas (2013) identified about 50 VIX ETNs for total AUM of 3 billion dollars, with daily trading volume peaks of 5 billion for certain products[13]. At end-2017, the AUM of the four largest *short* VIX ETNs and ETFs represented 2.6 billion dollars, which is relatively low compared to the ETP market.

Figure 5: Trend in the AUM of the four main volatility products (in USD bn)



Source: Bloomberg, last point on 23 March 2018.

[13] Alexander, C. and D. Korovilas (2013). "Volatility exchange-traded notes: curse or cure?", The Journal of Alternative Investments 16, 52–70.

1.4. MORE GENERALLY, A VERY SHARP INCREASE IN PRODUCTS BETTING ON VOLATILITY

While the AUM of VIX ETFs / ETNs thus may seem rather small, the universe of products using volatility in their strategy is sufficiently broad to cause concerns about spillovers from any movement in volatility. According to IMF estimates, this universe stands at about 500 billion dollars[14]. This universe of strategies implicitly linked to volatility can be valued at over 1,000 billion dollars, taking into account: "risk parity funds" (funds in which each asset class contributes equally to the risk of the portfolio, with a target level of volatility, with AUM estimated at between $400 billion and $600 billion in 2016[15]); "volatility-targeting funds", with estimated AUM of $500 billion[16]; and Commodity Trading Advisors (CTA), alternative funds that trade futures with the help of algorithmic decisions incorporating volatility movements in their selection of positions (AUM of $250 billion[17]). In Europe, the most popular volatility-targeting funds are the "minimum volatility" funds[18]. At the start of 2018, Morningstar listed 106 products of this type in Europe, including 47 ETFs and 59 traditional open-ended funds, with almost $200 billion in AUM.

According to market participants, these estimates are conservative, as they do not take products that implicitly or explicitly target volatility into account. Artemis Capital, for example, estimates these strategies at 2,000 billion dollars, notably by incorporating overwriting pension funds (pension funds that round out a traditional strategy by selling speculative options, and which in 2012 were estimated by Deutsche Bank at 32 billion dollars), and "risk premia" funds (which, like hedge funds, target absolute returns via long/short positions on various categories of assets, and were estimated in 2016 by the Economist Intelligence Unit at 300 billion dollars). These two strategies resemble short option positions, in the sense that their performance is optimal when volatility is low, but they can be subject to non-linear losses in the event of a market downturn[19].
The amount of AUM using volatility is significant: this means that volatility itself is a factor for risk-taking and a source of additional returns. This can lead to fears of a feedback loop between the volatility of assets and the financial products that distribute the risk as a function of this volatility.

2. DESCRIPTION OF THE PERFORMANCE OF VIX PRODUCTS IN EARLY FEBRUARY 2018 AND FRENCH/EUROPEAN IMPACTS

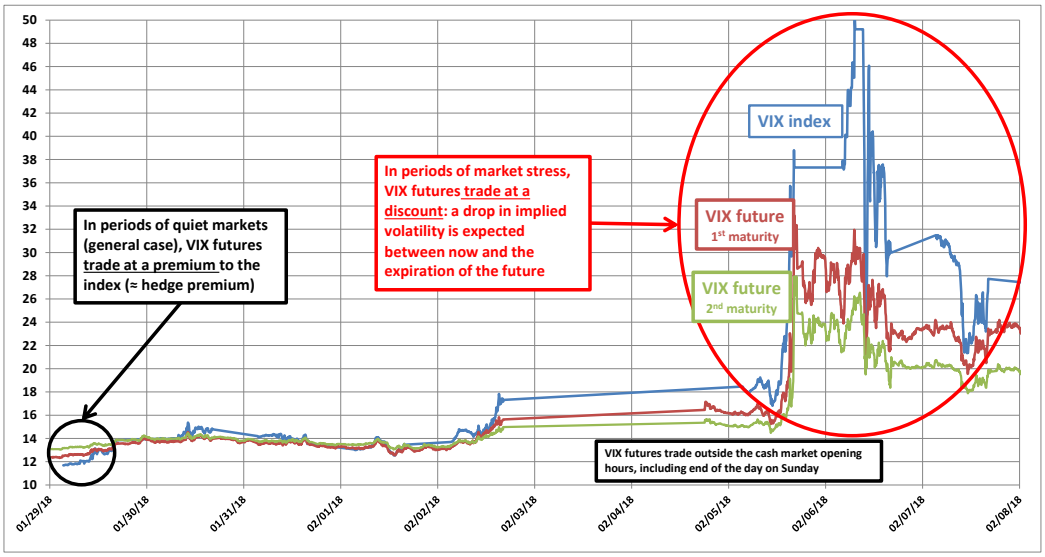
On Monday February 5, the S&P fell 4.2% while the VIX rose by 20 points, meaning the magnitude of the rise exceeded what one could have expected based on its historical relationship with the S&P 500 index. The significant losses of *short* VIX ETPs did not seem to have warded off investors. However, the exposure of French and European investors to these risks remained limited.

[14] M. Johnson (2017), "IMF warns volatility products loom as next big market shock", Financial Times, October.
[15] R. Wigglesworth (2016), "Little-known trading strategy exacerbates market turmoil", Financial Times, October.
[16] S. Verma (2018), "Volatility-Targeting Funds Could Sell $225 Billion of Stocks", Bloomberg, February.
[17] D. Burger (2018), "Map to the Underworld: $2 Trillion of Volatility Trades Here", Bloomberg, February.
[18] These funds select and weight securities on the basis of their historical volatility and the level of decorrelation to the securities in the replicated index. Morningstar underlines the fact that these funds, despite having succeeded on average in obtaining lower volatility than the average of their category, are not risk-free: they generally replace market risk with exposure to other potentially undesirable risk factors. See V. Baselli (2018), "Low Volatility": efficace, mais il faut être patient", Morningstar analysis of February, and Morningstar (2017), "Low volatility: searching for a durable edge", May.
[19] Artemis Capital Management (2017), "Volatility and the alchemy of risk".

NOTE : the difference in the movement of the VIX and VIX futures

Although the VIX index is often cited as a benchmark by economists or journalists, market participants can only trade VIX futures. Moreover, VIX futures follow a different trend from the index itself: when markets are calm, the futures trade above the index (risk premium), while in situations of high volatility, the futures rise less quickly than the index as, on average, traders expect the shock to be temporary and that the implied volatility of the options on which the VIX future is based will decrease again before the maturity of the futures[20].

Figure 6: Trend in the VIX vs. VIX futures for the first two maturities between January 29 and February 7 2018



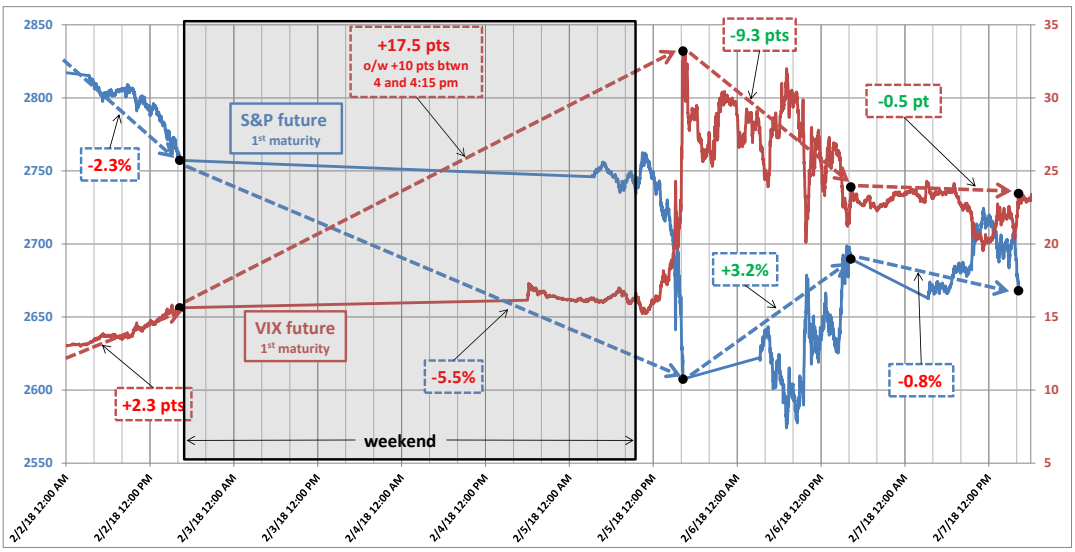
Source: Thomson-Reuters

2.1. EQUITY MARKETS CONTEXT ON FEBRUARY 5 2018 AND THE CASE OF THE "XIV" ETN

On Friday February 2, US monthly employment figures revealed wage growth of a magnitude that has not been seen since 2009, triggering fears of a rise in interest rates. The S&P index then started to fall, with the downward trend continuing in a marked manner on the following day (February 5). **Over the entire session, the S&P 500 index lost 4.2 %** and even suffered two mini flash crashes at the end of the day (see below).

[20] VIX futures allow investors to trade a level of implied volatility in S&P options at a future date (at maturity of the future) while the VIX reflects the valuation of an option position with a 30-day maturity. Moreover, gains or losses generated by an option position depend on the realised volatility of the S&P index over the next 30 days.

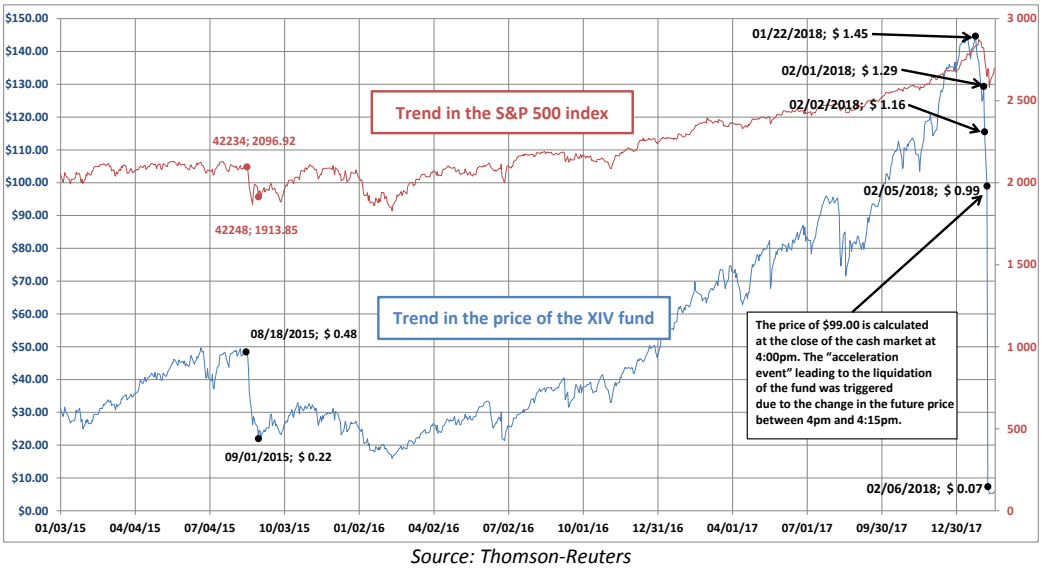
Figure 7: Trend in the VIX futures and S&P futures during February 2, 5, 6 and 7[21]



Source: Thomson-Reuters

The "XIV" ETN issued by Credit Suisse (full name: "Inverse Vix Short Term ETN") appears to be emblematic of the movements on February 5, being the biggest ETN indexed to the inverse daily performance of the VIX[22] (AUM of 1.9bn dollars on February 1, 2018). This AUM, which is significant for such s risky product, can notably be explained by the fund's performance between the Brexit vote on June 24, 2016 and February 1, 2018 (+487%). However, the fund lost 94% of its value over three sessions at the start of February (96% over five days) and the issuer has since closed the fund.

Figure 8: Comparison of the trend in the S&P 500 index and the price of the XIV fund between January 1, 2015 and February 14, 2018



Source: Thomson-Reuters

[21] The price of the S&P future corresponds to the price of the E-Mini S&P 500 Future. The price of the VIX future corresponds to the price of the front-month VIX future (code Thomson Reuters: VXc1).

[22] More specifically, replicating these indices via VIX futures (see below). Since 2 December 2010 Crédit Suisse issues several short products, including the "XIV" ETN (full name: « Inverse Vix Short Term ETN ») which replicates the daily performance of the basket of the front month and second-month VIX futures (VXc1 and VXc2), the weights of which are adjusted to replicate the VIX as closely as possible.

In fact, unitholders cannot lose more than their invested capital, but as the fund is invested in short positions, potential losses are theoretically unlimited and guaranteed as a last resort by the issuer. This is why it is stipulated in the prospectus that if the value of the ETN were to lose more than 80% of its value from the previous day, an "acceleration event" would be triggered and the fund liquidated. Investors are then refunded at the NAV calculated at a later date (in this case on February 15, 2018).

Three days after the announcement of the liquidation of the XIV fund, its rival ETF, SVXY[23] recorded record inflows of capital: 300 million dollars in just one day. Despite a logically similar performance to that of XIV at the beginning of February, this ETF did not have to be liquidated[24], which enabled it to attract new investors. The AUM of the three main products stood at 1.6 billion dollars on March 23, 2018.

The massive return of investors to this type of fund is notably linked to the rise in implied volatility following this spell, which offers a most attractive entry level given the past performance when volatility was markedly lower. This shows that investors appear to have considered the rise in volatility to be a relatively temporary event that would correct itself in the near term. This was a good bet, as the VIX then fell back, settling at around 15 points on March 12, 2018.

2.2. WHAT WAS THE IMPACT OF THESE MARKET MOVEMENTS ON EUROPEAN/FRENCH INVESTORS?

In Europe there is a handful of funds that bet on volatility: only 11 products, 2 of which still exist, are listed by Lipper[25]. In France, there were very few UCITS that explicitly bet on volatility[26], all of which have been dissolved since 2016. Two Irish funds, now dissolved, were also marketed as UCITS[27]. At present, there are only two products left in Europe: an Irish ETP (€5m in AUM at end-2017) and one Luxembourg ETF (AUM of €28m) [28], which are not distributed in France.

However, it is recognised that other funds, with strategies that are not focused on volatility, may use derivatives on VIX options. In order to observe which funds could have suffered from these holdings, an analysis of the discounts to net asset values from February 1 to February 9 was carried out. About 40 fund units saw their NAV drop by more than 10% over the period. The explanations for this can be divided into three categories:

[23] Its full name is "ProShares Short VIX Short-Term Futures ETF"
[24] This fund also lost 95% of its value between 2 and 5 February, however, unlike the XIV ETN, which included an acceleration event in its prospectus, the manager of the SVXY ETF has more flexibility to manage its fund dynamically in the case of absolute necessity, and announced on 6 February that the fund's performance was "in line with its investment objective and reflected the trends of the underlying index".
[25] Extraction at 12 March 2018 on all ETFs with the VIXX or VSTOXX as the underlying index. It is nevertheless non-exhaustive by nature, as the database, based on fund reports, is incomplete.
[26] Lyxor UCITS ETF UNLEVERAGED S&P 500 VIX FUTURES ENHANCED ROLL, authorised in January 2013, dissolved in November 2016, net assets of €8.6m; LYXOR ETF S&P 500 VIX FUTURES ENHANCED ROLL, authorised in April 2011, merged with another ETF in 2013, net assets of €46.6m; THEAM QUANT VOLTIMUM, authorised in June 2007, dissolved in October 2013, net assets of €348,000.
[27] SOURCE S&P 500 VIX FUTURES UCITS ETF, dissolved in November 2017, and ETFX BOFAML IVSTOXX ETF, dissolved in June 2015.
[28] An Irish ETP, Boost S&P500 VIX ST Futures 2.25x Leverage Daily ETP and a Luxembourg ETF, Lyxor S&P 500 VIX Futures Enhanced Roll UCITS ETF C-E.

- employee savings funds for which performance is linked to that of a company that suffered from a discount over the period (due to the drop in the CAC or Eurostoxx[29]): this is the case for 21 funds representing net assets of €2.4bn at the beginning of February;
- leverage funds that seek to replicate the daily performance of the underlying index (often the CAC40 or the Eurostoxx) several times and which thus suffered from bigger discounts than the indices during the period: 11 funds representing net assets of €868m at the beginning of February;
- dedicated funds with strategies that enable significant use of leverage and that invest heavily in derivatives: this is the case for 10 funds representing net assets of €625m at the beginning of February.

According to the analysis carried out by the AMF, investors in French collective investments were not significantly exposed to VIX-related strategies. However, other products using volatility may be distributed, which is a point to which attention should be drawn.

3. ASSESSMENT OF THE RISK OF TRANSMISSION FROM VOLATILITY PRODUCTS ON THE LEVEL OF VOLATILITY AND THE S&P: A CLEAR IMPACT ON THE VIX, INDIRECT AND LOW ON THE S&P

The effect of VIX ETPs on the spike in volatility on markets on February 5 appears to be key. According to the BIS[30], "market developments on February 5 were another illustration of how synthetic leveraged structures can create and amplify market jumps, even if the core players themselves are relatively small. For investors, this was also a stark reminder of the outsize risks involved in speculative strategies using complex derivatives".

This assessment points a finger at the influence of these products, which despite their low AUM, had an impact on the VIX and could have led to abrupt market movements. **The mechanisms seemingly coming into play here are: (i) the rebalancing mechanism of ETPs, which created a feedback loop with the index itself; (ii) the role of other participants in pushing up the prices of VIX futures, in anticipation of (i).**

While the impact of short VIX ETPs on the VIX futures trend appears clear, an analysis of the correlations between VIX futures and S&P futures highlights the strong probability of transmission between VIX futures and S&P futures. Under normal market conditions, given the amounts traded on the S&P, the direction of the transmission generally seems to be from the S&P futures toward VIX futures, while this relationship appears to have inverted at the very end of the day on February 5.

For other volatility products (options on VIX futures and the S&P), it is impossible to study their amplifying effect at the end of the day due to the unavailability of open positions on VIX derivatives that have expired or the breakdown of open positions between players hedging their delta or not at the end of the day[31].

[29] While the declines in the CAC40 (-1.48%) and the EuroSTOXX50 (-1.58%) on February 5 seem minor compared to the movements in the S&P, certain stocks dropped significantly (Air France, Fiat, Wells Fargo, Bonduelle, etc.).
[30] Bank for International Settlements, (2018), "Volatility is back", Quarterly Review, March 2018.
[31] See also appendix 2. End-clients could also have sought to cash in on VIX option premiums (overwriting) to play implied volatility that would remain low (in this case the volatility-making counterparties would be "long gamma"), or buy options in the aim of hedging a structurally short VIX position.

3.1. THE ETP REBALANCING MECHANISM: THE FEEDBACK LOOP

Inverse volatility ("short VIX") ETPs take short positions in VIX futures so as to allow investors to bet on lower volatility with maximum losses limited to their initial investment. To maintain their target exposure, the issuers of leveraged and inverse ETPs rebalance their portfolios on a daily basis by trading VIX-related derivatives, usually right at the end of the trading day. **Their risk coverage is by nature pro-cyclical: if VIX futures are up, the rebalancing of their hedging at the end of the day requires buying futures at the closing price,** and, inversely, if the futures drop (see focus below).

Even though the aggregate positions in these instruments are relatively small, even a slight change in the futures price can have a significant market impact, due to ETPs' required purchases of VIX futures to maintain their target leverage, which can magnify the trend observed.

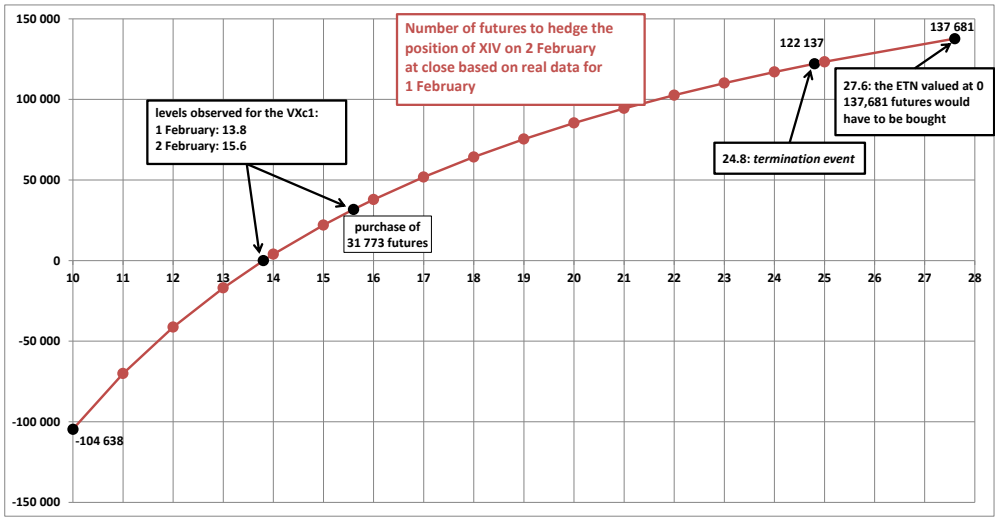
Illustration of the pro-cyclical impact of the hedging of the XIV ETN[32] on February 2

The ETN had $1.9bn in AUM on February 1, 2018. To replicate the inverse performance of the basket of VIX futures, Crédit Suisse must hold a $1.9bn short notional futures position.

On February 1, 2018, VIX futures[33] stood at 13.75. In order to replicate the expected performance of the ETN, Crédit Suisse, had to have a short position of $1.9bn and thus sell [1.9bn / (13.75 points * $1,000/point)] = 137,681 futures[34]. On February 2, VIX futures rose 13% to 15.6. Based on an equal number of units, the AUM of the fund decreased to $1,652bn. Now, in order to replicate the daily performance of VIX futures the next day, the issuer had to reduce their position at the end of the day to: $1,652bn/(15.6 * $1,000) = 105,909 futures. Crédit Suisse thus had to buy 31,772 futures, theoretically at the exact closing price at 4:15pm.

The chart below illustrates this result by plotting the number of futures that should have been executed on February 2 according the level reached at close. An explanation of the amplifying effect on trends linked to the volatility market is also provided in appendix 2.

Figure 9: Number of futures that should be executed by the issuer of the XIV ETN at the end of the day in function of the closing price of the VIX on February 2



[32] The figures provided in this example can be multiplied by two to obtain an estimate of the impact of all short products indexed to the VIX.
[33] The VIX futures price corresponds to that of the VXc1 (the futures contract with the nearest maturity).
[34] By proxy, the reasoning holds for the VXc1 future.

It is likely that certain players may seek to take advantage of the flows linked to this rebalancing by anticipating[35] these flows ahead of the close: the more marked the trend is at the end of the day, the higher the flows on the VIX futures linked to the short ETPs, which are public funds, will be and hence, the greater their impact. **In addition, the closing of the VIX futures market is 15 minutes after the close of equity markets in New York, i.e. at a time when the market is overall less liquid.** The day of February 5 presented a market configuration that favoured an acceleration in the trend at the end of the day, with a market that was trending down for fundamental reasons.

It is interesting to note that an issuer of a short VIX ETN would have been particularly well placed to take advantage of the rebalancing of the hedging of its ETN. Remember that, with ETNs, hedging transactions are traded on the issuer's own behalf as an ETN intrinsically does not hold assets[36].

Thus, by fractioning its purchases of VIX futures in the minutes preceding the close, the issuer could have both:

(i) **acted in the interest of its clients**: by buying a part of the contracts required for its hedging before the close, it limits its impact on the 4:15 closing price and thus avoids hampering the performance of the ETN (calculated based on this closing price).

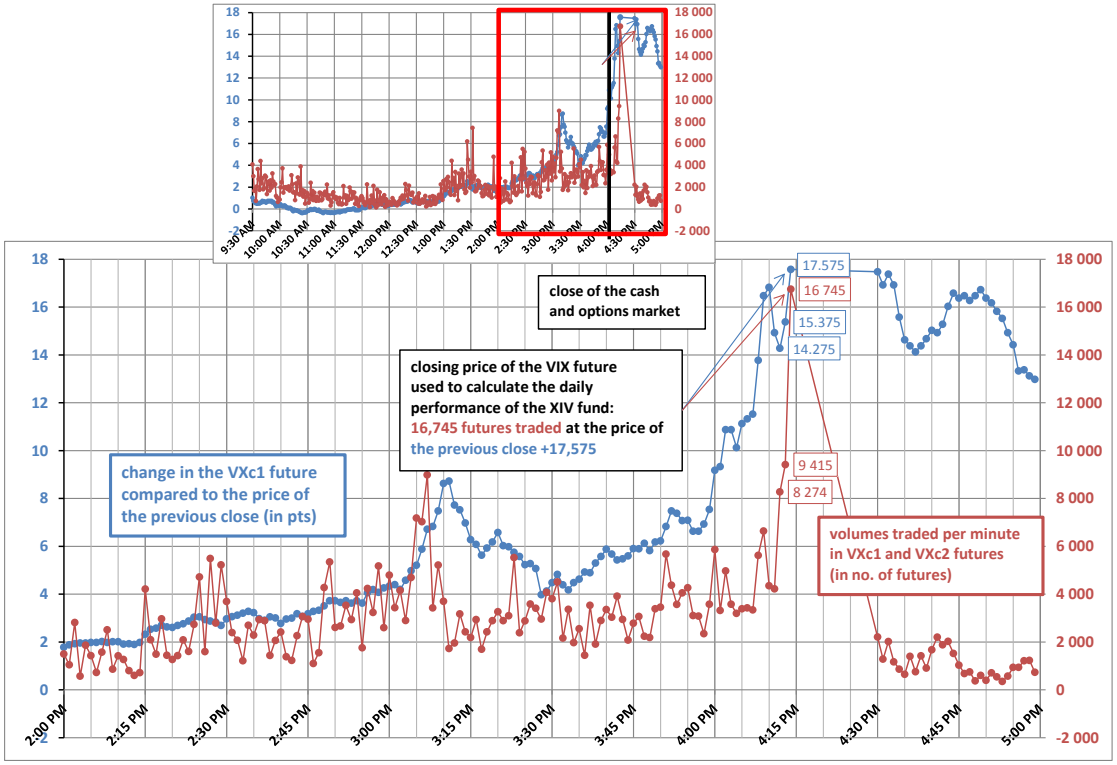
(ii) and **itself benefited**: by buying ahead of the close, futures that are assumed to rise before the close, and as these contracts are purchased on its own behalf, the issuer can ensure a profit by "theoretically selling" these futures to its ETN at the closing price and make a profit from the difference. Thus, by keeping a sufficient number of contracts to execute at the close in order to make an impact on the price, it can thus ensure itself a profit. Nevertheless, this impact must remain inferior to the impact that would have been generated by buying its entire hedging at the close, so that it can record a better performance, as explained in (i).

If all volumes observed over the final three minutes of the session of February 5 had been purchases made on behalf of one same player, its profits would have been around $48m[37].

The chart below shows the trend in the price of VIX futures and the volumes traded during the day of February 5: it can be observed that following the close of cash and options markets at 4:15pm, the price of the futures rose amid increasingly high volumes; during the last 3 minutes, volumes traded were at their highest on the day.

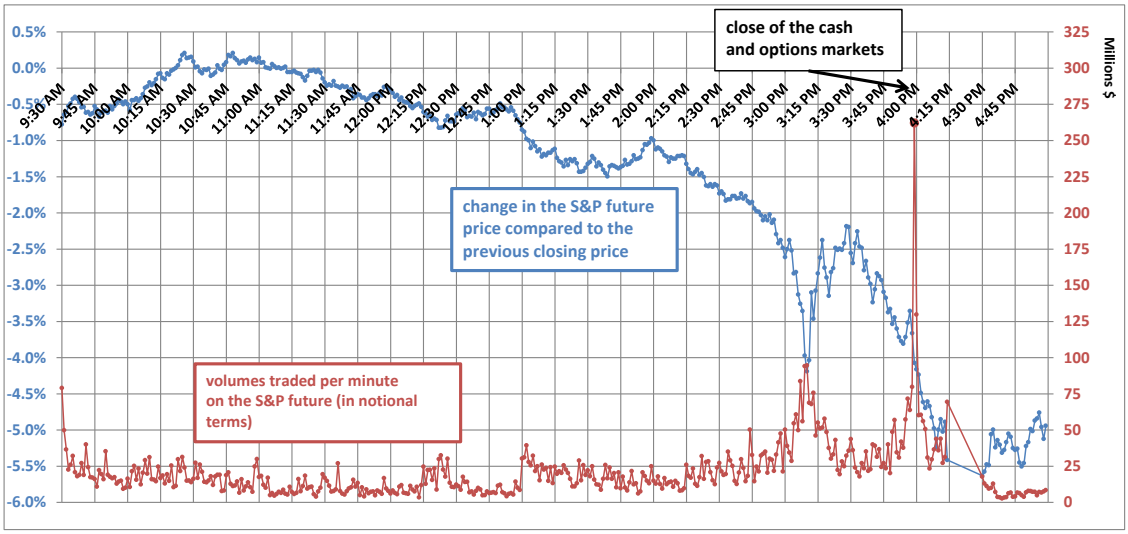
[35] This term is not to be understood as potential market abuse.
[36] A close reasoning could apply to an ETF issuer, which could replicate this strategy in anticipation of flows at the end of the day, but would have to sell them back to its fund at the close.
[37] Details of the calculation: $1,000 * [8,274 * (17.575 – 14.275) + 9,415 * (17.575-15.375)].

Figure 10: Trend in VIX futures and volumes traded (in no. of contracts)
February 5 2018



Source: Thomson Reuters

Figure 11: Trend of the mini S&P future and volumes traded per minute (in notional terms)
February 5 2018



Source: Thomson-Reuters

3.2. THE CONTAGION OF VIX FUTURES TOWARDS S&P FUTURES IS ONLY MINOR

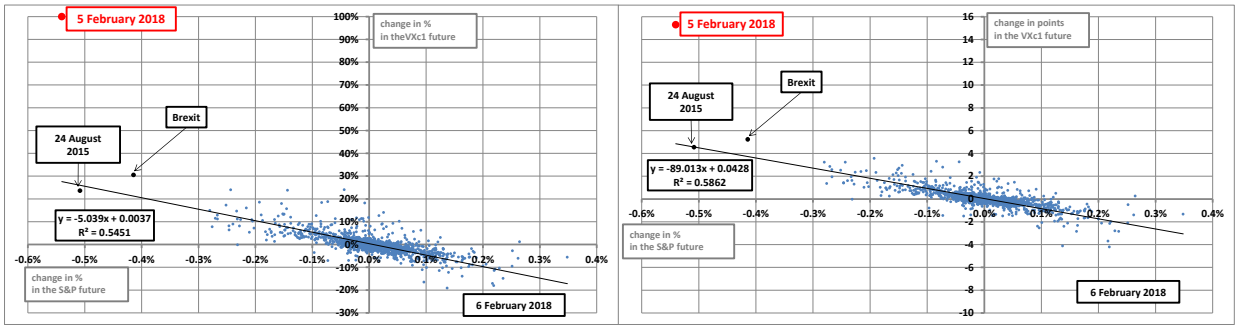
The correlation coefficient between the VIX and S&P indices calculated over the past five years is -0.85 with a coefficient of determination (R^2) of 0.72[38]. Given the volumes traded on their respective derivatives contracts[39], it is generally acknowledged that the VIX follows the fluctuations in the S&P. However, the flows at the end of the day impacting VIX futures on February 5 could have temporarily inverted this relationship after the close of the cash and options markets, with an S&P future price that would have been impacted by the variations observed in the VIX future price.

The spillover of the market impact of one instrument to another is necessarily linked to statistical arbitrage activity[40] carried out by market players. In the case studied, arbitrage consists of pair trading between these two assets. The strategy involves playing the spread between two assets that in principle move in a similar way and taking advantage of any increase in this price spread.

Moreover, the analysis of the fluctuations in the price of S&P and VIX futures shows that over a long period[41], the change in the VIX future price has a linear relationship with that of the S&P future, whether expressed in index points ("points approach", chart 12) or percentage ("percentage approach")[42].

Figure 12: Change in the VIX future vs. the change in the S&P future (March 2013 - March 2018).

"percentage approach" **"points approach"**



Source: Thomson Reuters

We again find the negative correlation between S&P and VIX futures.
Over a long period (5 years), this linear relationship presents an R^2 that is lower than the one obtained when underlying indices are considered. It is nevertheless accentuated when we look at the intraday price variations, especially on February 5, 2018[43].

Over the day of February 5, 2018, the linear relationship between VIX and S&P futures is particularly clear when the cash and options markets are open (see right-hand figure below); a -1% change in the S&P future (compared

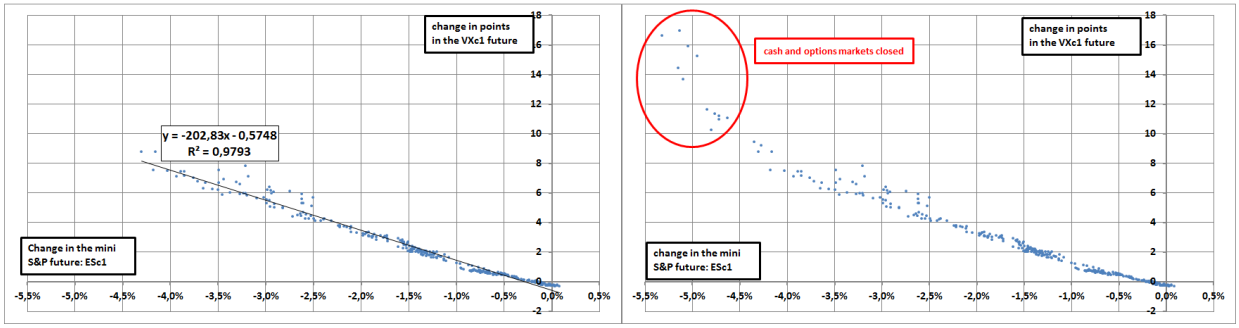
[38] Source: Bloomberg
[39] 100 times more S&P futures contracts are traded than VIX futures on average over one month.
[40] A winning arbitrage strategy "on average", as opposed to a systematic inter-market arbitrage.
[41] Methodology note: as the VIX and S&P indices cannot be traded, the futures prices are used in order to be consistent with the market. To replicate the VIX, the first two VIX future maturities need to be used, and the average of the two futures are used. The advantage of this method is that it also smooths out the valuation of the VXc1 when it expires and rolls into the second maturity.
[42] The change in VIX futures is generally expressed in points, unlike the S&P, which is expressed in percentage. The two approaches are proposed to make sure that using one or other of these approaches does not affect the results. Given the neutral effect of the approach used on the results obtained, the rest of the analysis will be based on the "points approach".
[43] This linear relationship was also observed on other days; however, when there is less volatility, an intraday adjustment is necessary: all other things being equal, VIX futures appear to drop during the day (see appendix 3 for a detailed explanation).

to its previous day closing price) corresponds to a +2.02-point change in the VIX future. The R^2 thus works out at 0.98. In terms of arbitrage, this means that, on average, over this day, for the sale of one VIX future, an arbitrageur would sell $202 000 in S&P futures (or an equivalent product)[44].

Furthermore, the natural flows affecting VIX futures on February 5, 2018 were long positions and the amounts in question were such that the resulting arbitrage described above could have temporarily impacted the price of S&P futures. If observations are made outside opening hours of the cash and options markets until the close of the VIX futures market (between 4pm and 4:15pm), "outliers" appear, which also reflect potential variations resulting from this arbitrage mechanism.

Figure 13: Change in the VIX future in points (x axis) as a function of the S&P future on February 5, 2018

Cash and options markets open | **Market open + 15 minutes**



Source: Thomson Reuters

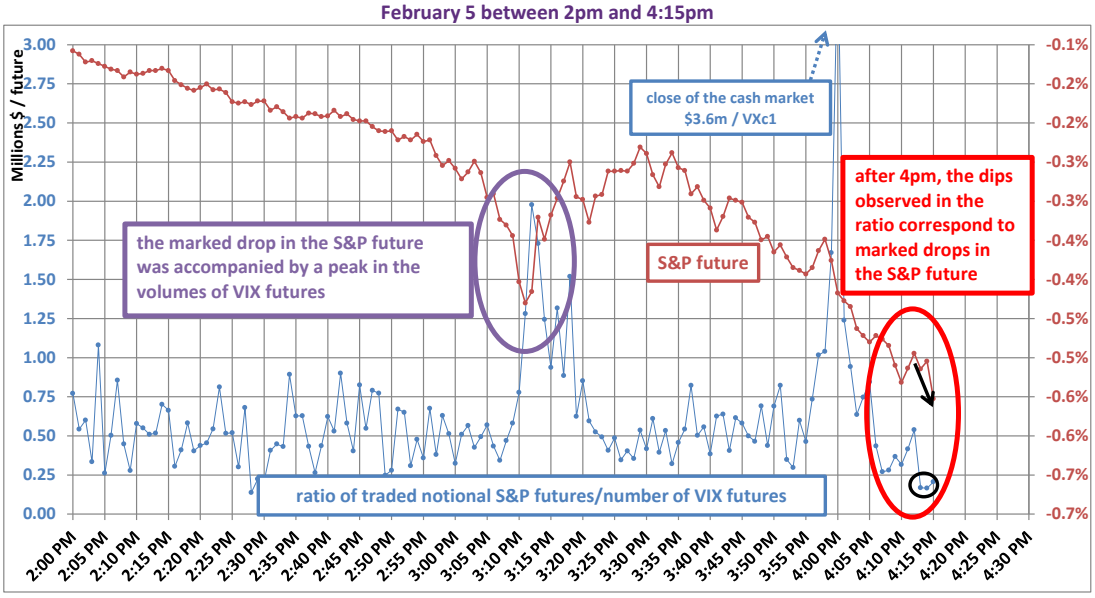
The following charts would seem to confirm these observations. Figure 14 represents, minute by minute, the ratio between the notional amount traded on the S&P future as a function of the number of VIX futures, and Figure 15 the respective volumes traded on these two contracts.

The following observations can be made:

- A first mini flash crash is observed between 3pm and 3:15pm. The ratio then increases sharply to reach $2m. This rise is explained by a peak in volumes of S&P futures that is proportionally greater than that observed on the VIX future. **The drop in price observed in the S&P 500 future at this moment is thus mainly caused by the activity on the S&P future while the VIX follows the trend**.
- The ratio then sees little change until the close of the cash and options market at 4pm, when the peak is observed, once again driven by the volumes on the S&P future.
- Over the last three minutes preceding the close of the VIX future, the ratio falls back once again to its low point of the day (below $202 thousand per VIX future). An analysis of the volumes shows that in this case, this rise is generated by a marked increase in VIX future volumes, with close to 35,000 contracts traded in the last three minutes. At the same time, the S&P future loses a further 0.7%: **The relationship between the price of the VIX future and that of the S&P future appears to have inverted over these few minutes. And despite the briefness of this inversion, given the high volumes, the impact on the S&P future seems to have been significant.**

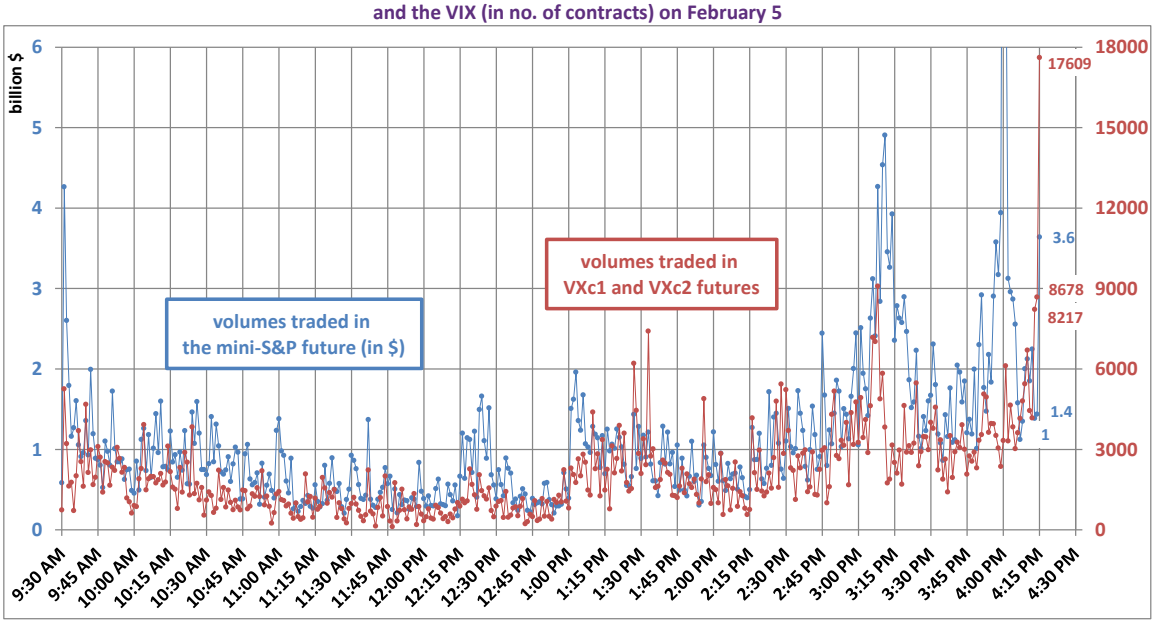
[44] VIX and S&P futures trade in the same direction due to their negative correlation.

Figure 14: Trend in the ratio of the traded notional value of S&P futures to traded VIX futures February 5 between 2pm and 4:15pm



Source: Thomson Reuters

Figure 15: Trend in volumes traded in the S&P future (in notional terms) and the VIX (in no. of contracts) on February 5



Source: Thomson Reuters

In conclusion, the volumes traded in the VIX do not seem to have been able to have a significant impact on the trend of the S&P future during most of the day on February 5, except for the last three minutes of trading of the VIX future (i.e. between 4:12pm and 4:15pm) when the relationship was inverted; over this period, the S&P future lost 0.7% (out of a total 5.5% drop over the day).

3.3. THE IMPACT OF OTHER VOLATILITY PRODUCTS: AN UNREALISED RISK AT THIS STAGE

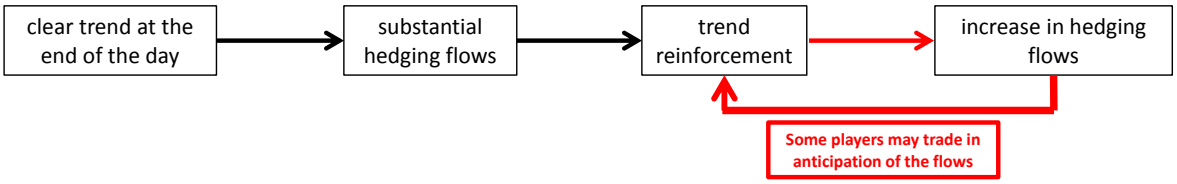
During the day of February 5, other products using volatility in their strategy do not seem to have played a role. We can note that investment strategies betting implicitly on volatility, unlike VIX ETPs, have diverse strategies, and thus cannot make reallocations at the same pace (in particular, not daily). Nevertheless, most of these funds - risk parity funds, for example - are pro-cyclical by nature, as their strategy consists of selling their risky assets when volatility increases.

Unlike VIX ETPs, the impact of other products targeting volatility in movements in the VIX and the S&P are difficult to quantify at this stage. However, the large amount of assets of all products using volatility targets or volatility products in their strategies is a point that merits close attention in future. **The pro-cyclical nature means that new turbulence in terms of volatility could lead to rebalancing movements of significant scale.**

In all, this event highlights the risks created by short volatility strategies, which not only hedge pure option strategies (such as vanilla options or structured products), but also created by "inverse" products such as the XIV ETN. Indeed, **in the event of an abrupt market downturn, these types of strategies can amplify the already existing price movements in a self-feeding process**:

- hedging flows increase with the trend, thus increasing their influence on the market of the underlying (appendix 2);
- certain players may seek to take advantage of these hedging flows by buying into the trend before the close before reselling to the natural buyers. They thereby magnify the trend and increase the volumes that will have to be executed by products with short volatility strategies.

Figure 16: Negative feedback loop mechanism as observed on the VIX future on February 5 2018



This type of market event ultimately does not contribute to the price formation process, as these price movements are more linked to mechanical effects than to decisions made on the basis of fundamentals, and **can thus hamper the proper functioning of markets.**

Thus, the rise in short volatility strategies calls for a certain amount of vigilance, and draws attention to **the usefulness of protection mechanisms against the most excessive price swings, such as circuit breakers.**

4. SUSPICIONS OF MANIPULATION OF THE VIX FUTURES MARKET LINKED TO ITS CALCULATION METHOD

Following the sudden collapse of the XIV ETN, a whistleblower, said to have held a senior position in one of the largest international investment banks, told US regulators that the price of VIX futures were being recurrently manipulated. The purpose of this manipulation was supposedly to influence the settlement price of the future when it expires. It is alleged to have generated several billions of dollars in profits, and thus an equal amount of losses for the counterparties.

This manipulation is said to have been possible by the methodology used by the CBOE for this calculation. It is unlikely that this type of manipulation would be possible on the French VCAC or the pan-European VSTOXX.

4.1. CALCULATION METHOD AND ALLEGED MANIPULATION SCHEME

While the VIX is continuously calculated using the prices of options on the underlying S&P 500 index, the final settlement price of the VIX future is calculated on the basis of transactions executed at the opening prices on the maturity date (the calculation is thus made based on a single point in time). This opening price is calculated via a special procedure specifically put in place to this end: the "Hybrid Opening System".

The rules of this procedure are the following:

- Options taken into account in the calculation of the settlement amount of the future are those traded on the CBOE only.
- Opening prices of transactions are used to calculate the future contract's settlement value.
- If no transactions are executed at the opening, the first mid-quote communicated immediately after opening is used.
- Market-on-open (OPG) orders of market makers (i.e. that are only validated at market opening) are automatically cancelled if unexecuted. It is for this reason that CBOE rules stipulate that the prices communicated by the CBOE immediately after the end of this procedure may differ from those communicated during the Hybrid Opening System.

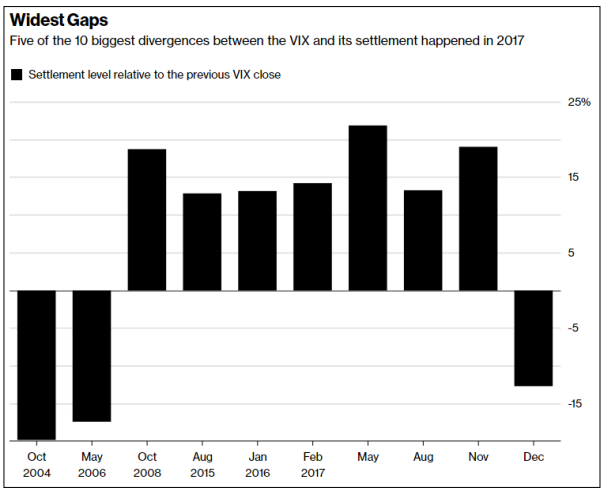
Several studies[45] and articles have already highlighted in the past the suspicious behaviour of VIX futures on their maturity date (see charts 16 and 17 below). According to the whistleblower, the manipulation is made easier and less risky by the fact that it does not necessarily involve actually trading options, but by simply placing orders, it is possible to manipulate the market.

[45] See Griffin J., A. Shams (2017), "Manipulation in the VIX?", The Review of Financial Studies, Volume 31, Issue 4, 1 April 2018, Pages 1377–1417.

Figure 17: illustration of a hypothetical manipulation on VIX futures

Source: Bloomberg

Figure 18: illustration of possible manipulations on VIX futures on several maturities



Source: Bloomberg

4.2. IS THIS MANIPULATION SCHEME POSSIBLE IN FRANCE OR EUROPE?

In France, Euronext publishes an index that is similar to the VIX, the VCAC, for which the calculation method is identical to that of the VIX[46]. However, since the VCAC is not an underlying of listed derivatives, **a manipulation scheme on the VCAC index similar to the alleged VIX manipulation may thus be ruled out.** Furthermore, since no products reference this index[47], the probability of manipulation is extremely slight.

In Europe, the benchmark index for measuring implied volatility is the VSTOXX index (the "EURO STOXX 50 Volatility Index") which is based on the quotations of options for which the underlying is the Eurostoxx 50 and also has a 30-day rolling maturity. Although theoretically co-developed by Deutsche Börse and Goldman Sachs, the VSTOXX index appears to use exactly the same methodology as the VIX.

[46] https://www.euronext.com/fr/content/indices-de-volatilit%C3%A9: "AEX® Volatility, BEL 20® Volatility and CAC 40® Volatility indices follow the current VIX® methodology, a sentiment indicator for the US market based on the S&P500 index option prices listed on CBOE. This methodology is currently used as the basis for many such indices and has become a standard throughout the world".

[47] Verification made using AMF databases, notably the FIRDS database from January 2018, which can exclude certain OTC traded products.

The VSTOXX index is the underlying of liquid derivatives (options and futures) that are listed on the Eurex. In 2017, 13.4m VSTOXX futures contracts were traded on the Eurex (i.e. a notional amount of €22.8bn) as well as 8m options (€16.5bn).

The final settlement price of the **VSTOXX future** is calculated based on the average of the prices of the VSTOXX index between 11:30am and 12. **As the index is calculated every 15 seconds, 61 points are used in calculating the settlement price of the future (as opposed to a single point for the VIX).** Given the liquidity of Eurostoxx 50 options at this time of the day, **it would thus appear much more difficult and costly to manipulate VSTOXX futures.**

APPENDIX 1: VIX CALCULATION FORMULA

The VIX is an instant gauge of the implicit market risk perceived by investors. For a given maturity, it is calculated based on the quotations of all options with this maturity and synthesises all the information in a single figure. As the VIX has a 30-day rolling maturity, the calculation is made by interpolating the two listed maturities that structure this theoretical maturity.

VIX calculation formula for a given maturity

$$\sigma^2 = \frac{2}{T}\sum_i \frac{\Delta K_i}{K_i^2} e^{RT} Q(K_i) - \frac{1}{T}\left[\frac{F}{K_0} - 1\right]^2$$

σ: value of the VIX
T: time to maturity (in calendar days)
F: forward price of the index calculated based on the options prices (call-put parity formula)
R: the risk-free rate
K_0: the first strike price under the forward price
K_i: the second strike price under the forward price (out-of-the-money options only)
$Q(K_i)$: the mid-price of the option

APPENDIX 2: DERIVATIVES MARKET-CASH MARKET TRANSMISSION MECHANISM

Derivatives are often presented as hedging instruments available to investors, but in reality these risks are transferred or externalised to other counterparties, which thus will accumulate a short volatility position that they hedge dynamically (usually daily).

This appendix aims to describe in greater detail through which mechanism this transfer of risks can lead to, in periods of market downturn, negative feedback loops.

1. IMPLIED VOLATILITY MARKET

Financial volatility measures the dispersion or variability of the price or return of an asset over time. In practice, it is calculated by analysing past volatility (standard deviation of returns of an asset over a given period of time) to obtain actual or past volatility, or by calculating the implied volatility based on options prices, which enables to observe the expected volatility of an asset.

The most commonly used calculation methods for options (such as Black and Scholes) rely partially on implied volatility[48]: indeed, market participants must forecast the future volatility of the underlying assets, while hedging against price fluctuations.
Implied volatility is thus found in all instruments of vanilla-type option (calls and puts) and more complex, or "exotic", products[49], which can be found, for example, in formula funds[50].

This means that a very high number of market participants "sell" or "buy" volatility without using a volatility index like the VIX. Moreover, many market participants hold short positions through complex volatility positions, such as risk parity funds or volatility-targeting funds, as described in section 1.4.

[48] "Implied volatility" is a parameter needed to price all derivative products that do not move linearly to the price of their underlying: it is used to model all possible paths that the underlying could take up to its maturity. This path is often represented as a binomial tree (or equivalent more sophisticated model).
[49] Only vanilla options are considered below.
[50] For these funds, implied volatility is not generally expressed as a single variable but by a function describing a "volatility surface". Indexed funds with guaranteed capital fall under this category.

2. MARKET PARTICIPANTS

Participants in the options market can be put into two main categories:

- **End-clients** are typically fund managers, who reason in terms of an option "premium" and not volatility. They use options to, for example:
  - **hedge risks**[51] by buying put options[52] (sell options) as protection against a discount in the underlying;
  - **improve performance.** An "overwriting" strategy is a strategy that consists of selling options to cash in a premium. This term is often used when talking about the sale of short-term calls (1 to 3 months) that are slightly "upside" (102% to 105% depending on the maturity) against an existing position on the underlying or on an index reflecting an overall exposure to a market; in this case, its performance is limited. The sale of upside calls sometimes serves to finance the purchase of hedging with puts.
    - **invest with greater leverage by limiting the risk on the premium invested.**

- **Market makers**, who manage their option position in terms of "Greeks" (delta, gamma, vega, theta and rho). These are described in greater detail below.

3. RISKS ASSOCIATED WITH AN OPTION POSITION FROM A VOLATILITY MARKET-MAKER'S PERSPECTIVE: THE "GREEKS"

Market participants are said to be "volatility players" if they hedge their directional position (their delta) on a regular basis. Generally, market makers hedge the delta of each of their transactions individually, while the delta linked to the position of the day before is only hedged once at the end of the day. The risks linked to an option position are only expressed indirectly with respect to the price of the underlying via its "Greeks":

- **Delta** corresponds to the rate of change between the price of the option and the change in the price of the underlying. The delta of an option position is generally expressed as a number of underlying securities (or in euros by multiplying this number by the price of the underlying security). For a single option, the delta is expressed as a percentage: between 0 and 100% for calls and between -100% and 0 for puts.
- **Gamma** of an option position corresponds to the rate of change between the delta of the position and the change in the price of the underlying. It reflects that fact that when there is a change in the price of the underlying, the absolute delta of the position increases, making it more exposed to a directional risk. The gamma of an option, whether a call or put, is always positive. It indicates that the higher the volatility of the underlying, the higher the chance of a winning position; the hedging of a long gamma position is counter-cyclical (for example, if the market drops, the trader must buy securities to return to a neutral delta position).
- **Vega** is the amount an option's price changes when the implied volatility increases by 1 point.
- **Theta** corresponds to the decrease in the price of an option over one day. It can translate into the cost of carry of a long gamma position.
- **Rho** corresponds to the exposure of the option position to a change in the interest rate. It is systematically hedged and generally only represents a residual risk.

[51] "Transfer risks" would in fact be more appropriate.
[52] A short position on the underlying can also be covered by buying calls.

4. IMPACT OF OPTION POSITIONS ON THE MARKET OF THE UNDERLYING ASSET

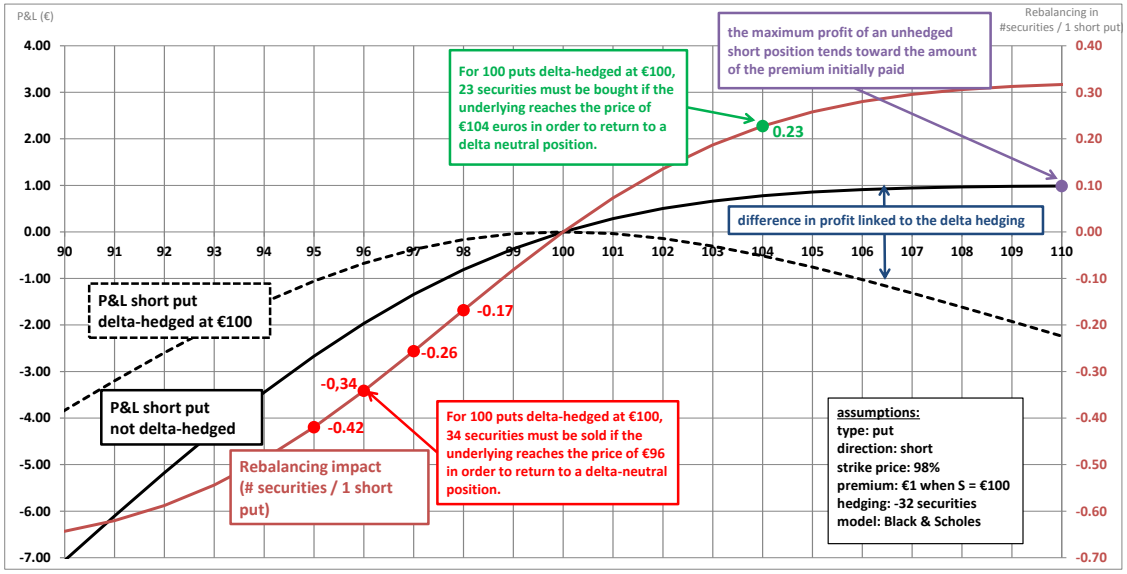
The fundamental difference between "end-clients" and "volatility players" market makers is that the latter trade on the securities market at the end of the day, while end-clients do not; in other words, the sum of the delta hedging positions of market makers at the end of the day is not offset by their non-market maker counterparties.

A market is "short volatility" (or "short gamma") if the overall sum of the gamma risks of all volatility market makers is negative for a given instrument. This type of configuration is recognised *ex-post* when there is a continuing clear market trend in the last minutes of the day and at the fixing at the close, i.e. when "volatility players" **hedge their positions. The clearer the market trend is at the end of the day, the greater the impact of the hedging of the market makers on the closing price (the trend will be magnified if the market is short gamma, and reduced in the opposite case).**

The chart below illustrates the short volatility position of a volatility market maker that holds a put with a maturity of 1 month, a strike price equal to 98% of the price of the underlying, and with implied volatility of 16%. These conditions are similar to a real position on the S&P index at end-January 2018 (for a put). The chart presents, all else being equal:

- The change in the valuation of an option position, delta hedged and unhedged, as a function of the change in the price of the underlying (the theta is not represented).
- The change in delta of this position as a function of the change in the price of the underlying; this curve thus reveals the pro-cyclical nature of an option position that will only be hedged at the end of the day, with a more significant market impact the greater the fluctuation in the price (the delta changes pretty much in a linear manner to the change in the price of the underlying between -6% and +4%).

Figure 19: Change in the profit and delta hedging of a short put option position with a maturity of 1 month, a strike price of 98% and volatility of 16% as a function of the change in the price of the underlying, all else being equal.



This example thus illustrates the mechanism by which the hedging of a position by an investor translates into a "short gamma" position from the perspective of their counterparty and can thus have an accelerating effect in the event of a drop in markets that is not related to fundamentals; when the end-client's initial investment is €100 (for the purchase of 100 put options), the "volatility players" counterparty must sell 32 securities to hedge their position (€3,200, corresponding to the delta of the option, calculated using a Black and Scholes model). Then, all else being equal, if the underlying loses 4% over the day, the sell pressure from the counterparty's hedging would be 34 securities (€3,264).

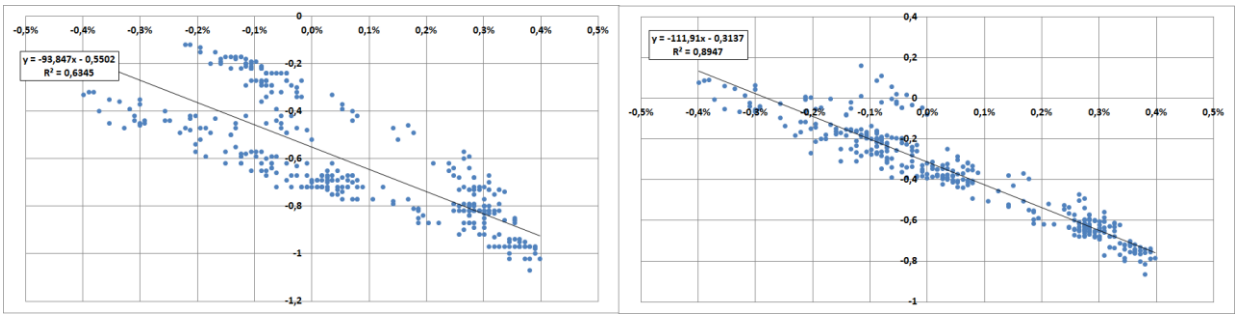
APPENDIX 3: THE LINEAR RELATIONSHIP BETWEEN THE FLUCTUATIONS IN S&P AND VIX FUTURES

In the body of the study, we introduced the existence of a visible linear relationship between VIX futures and S&P futures during the day. To represent this linear relationship, one must take into account the continual drop in the VIX future over the day. This drop is notably explained by the fact that the level of the VIX future must converge towards its underlying index, as the two must be equal on the maturity date of the future. This mechanism is comparable to the decrease in the time value of options (the "theta").

The charts below illustrate the intraday drop in the VIX future, all else being equal: the left-hand chart represents the change in the VIX future in points as a function of the change in the S&P future, without taking account of the theta; in this case the linear relationship between the two futures does not clearly stand out. When we take account of a continual decrease in the VIX future over the day (of 0.45 point here), the linear relationship is clearer[53].

Figure 20: Change in the VIX future as a function of the change in the S&P future with and without a linear decrease in the VIX future over the day

No adjustment | **With a linear drop of 0.45 point over the day in the VIX future**



[53] With respect to February 5, not factoring in this element only marginally affects the results obtained.