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Publication date
01-11-2015

Document Version
Accepted version

Citation for this work (American Psychological Association 7th edition)
Alexander, C., Kapraun, J., & Korovilas, D. (2015). *Trading and investing in volatility products* (Version 1). University of Sussex. https://hdl.handle.net/10779/uos.23432531.v1

Published in
Financial Markets, Institutions and Instruments

Link to external publisher version
https://doi.org/10.1111/fmii.12032

Trading and Investing in Volatility Products

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This Version: February 2015

ABSTRACT

Since the banking crisis the market for volatility exchange-traded products has developed rapidly as it opens to clients beyond the large institutional investor pool. Speculation is driven by increasingly complex leveraged and inverse exposures including those that attempt to trade on significant roll costs in volatility futures curves. Longer-term investors use these products for the purposes of equity diversification, driven by fears of an ongoing Eurozone crisis. We survey the burgeoning academic literature in this area and present a comprehensive and up-to-date comparison of the market and statistical characteristics of European and US exchange-traded volatility products.

JEL classification: G12, G15, G23

Keywords: VIX, VSTOXX, volatility futures, volatility ETPs, roll yield

† This paper is based on a part of Julia's dissertation submitted at WHU – Otto Beisheim School of Management in Vallendar.

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1. INTRODUCTION AND LITERATURE REVIEW

During the latter decades of the last century trading volatility was only possible through holding portfolios of options, by entering a variance swap or through the (less popular) volatility swaps. There is a large body of literature dealing with these over-the-counter instruments starting with Carr and Madan (1998) and Demeterfi et al. (1999). More recently Carr and Lee (2009) provide an extensive literature review on early volatility derivatives. Our study focuses on recent developments in the volatility exchange-traded products that are related to implied volatility indices.

In the last few years a wide range of volatility indices on different asset classes have been developed, each constructed using prices of standard European options. This followed classic papers by Whaley (1993) and Fleming et al. (1995), which themselves built on earlier work of Gastineau (1977), Galai (1979), Cox and Rubinstein (1985), Brenner and Galai (1989) and others. The first implied volatility index, the VIX, introduced by the Chicago Board Options Exchange (CBOE) was based on the S&P 100 index. The VIX is perceived as an important indicator of investor sentiment and, following Whaley (2000), it is now commonly referred to as the ``investor fear gauge''. The original VIX calculation methodology had several weaknesses which made the issuance of VIX-related derivatives difficult. Therefore, in 2003 the CBOE together with Goldman Sachs redefined the calculation methodology, to use prices of synthetic 30-day options on the S&P 500 index. Carr and Wu (2006) and Whaley (2009) motivate this change and describe the main modifications therein. The latest innovation by the CBOE, in October 2014, was to include some highly-liquid weekly options in the VIX calculation methodology, this way obtaining a more precise match to its 30-day constant volatility.

Many studies examine the empirical properties of the new VIX index. To name just a few: Baba and Sakurai (2011) argue that there are three distinct regimes in the VIX index dynamics; Qadan (2013) and Gonzalez-Perez and Guerrero (2013) investigate the day-of-the week effect on the VIX index and show that Mondays are associated with higher VIX values than other days of the week; and, more recently, Smales (2014) observes a strong negative relationship between changes in VIX and aggregated news sentiment; and Fernandes et al. (2014) provide a thorough analysis on the relationship between the VIX index and main financial and macroeconomic factors.

The new VIX methodology was soon widely accepted and adopted by other exchanges so that, by the time of writing, volatility indices exist on all major global stock indices as well as on several commodities, exchange rates and interest rates. A detailed overview of the publicly available volatility indices is provided, among others, by Lopez and Navarro (2012), and Siriopoulos and Fassas (2013). Several studies investigate the transmission of implied volatility across international markets. For instance, following Konstantinidi et al. (2008), Badshah (2012) and Sarwar (2012) show that there are significant spill-over effects across different equity volatility indices. More recently, Ding, Huang and Pu (2014) investigate the volatility linkage across the US, EU, German, Japanese and Swiss equity markets and find, in particular, a strong information transmission between VIX and other market volatility indices; and Jiang et al. (2014) examine the effect of news announcement on the volatility spillovers between US and European markets.

Other studies focus on volatility indices in less-developed or emerging markets. So for instance, Huang et al. (2013) study the information spillover effects of the Taiwan stock index futures, options trading volume and Taiwan VIX; Shaikh and Padhi (2014) examine the forecasting performance of implied volatility for Indian markets; Ryu (2012) and Lee and Ryu (2014) investigate the properties of the Korean volatility index VKOSPI; Siriopoulos and Fassas (2012) propose a model-free Greek implied volatility index; and Lee (2014) explores the relationship between the changes in the Japanese volatility index and Nikkei 225 returns.

Implied volatility indices across different asset classes allow one to investigate their volatility interaction. Among others, Daigler et al. (2014) examine volatility spill-over effects from equities to the foreign exchange (forex) market; Liu and Fan (2013) test the uncertainty transmission implied by crude oil, forex, gold and volatility indices; Badshah et al. (2013) observe strong spill-over effects from VIX to gold and exchange-rate volatility indices; Jubinski and Lipton (2013) find strong evidence that the returns of gold, silver and oil commodity futures are influenced by the VIX index; Lopez and Navarro (2013) analyze the European interest rate volatility by constructing a set of implied volatility indices on fixed-income derivatives; and Haugom et al. (2014) use the CBOE oil volatility index to forecast volatility for the WTI futures markets.

A further benefit of implied volatility indices is that they can be used as underlying instruments for derivative products. This potential was already recognized by Grünbichler and Longstaff (1996), who ranked futures and options on volatility among the ``fundamental types of derivatives securities''. The first successful issuance of volatility futures contracts on VIX index by CBOE took place in March 2004, followed by VIX options two years later. This novel derivatives class has, however, some features not shared by traditional equity derivatives. In particular, because the underlying VIX is not tradable, there is no usual cost-of-carry connection between the volatility index and its futures. Thus, volatility futures contracts do not track the underlying exactly and put-call parity does not hold for VIX options (see Dzekounoff (2010) for further details).

A growing body of literature has been since focused on modelling the VIX index and its derivatives and on analyzing their relationship. Among others, Zhang et al. (2010) establish a theoretical relationship between VIX futures prices and the VIX index within a mean-reverting variance model. They show that the VIX and VIX futures are highly correlated and the term structure of VIX futures prices is on average upward sloping. Fassas (2012) verifies this contango tendency but he also shows that the term structure is highly volatile and there is a strong relationship between changes in the VIX futures term structure and S&P 500 returns. A subsequent study by Fassas and Siriopoulos (2012) uses a panel regression approach to claim that VIX futures prices can be used as an efficient and unbiased estimator for the spot VIX. Asensio (2013) further explores the relationship between the VIX index and VIX futures by evaluating the information content of the VIX term structure. He finds that VIX futures are consistently overpriced and that the forecast bias is especially pronounced in short-term futures contracts.

To obtain a constant-maturity exposure to volatility futures, indices based on a rolling position in corresponding futures contracts have been disseminated since 2009. This way, issuance of volatility exchange-traded products (ETPs) linked to a direct, leveraged or inverse exposure to volatility futures indices was possible. Given the growing number of volatility products with extremely high daily trading volumes, several authors have addressed various aspects of investing in volatility ETNs and ETFs. Among others, Dash and Liu (2012) consider S&P VIX short-term and mid-term futures indices, on which the indicative values of most volatility ETNs are based. They show that these indices have very low beta with the VIX index primarily because they have experienced significant roll costs (ranging from 0.07% to 0.18% a day during the period 2005 - 2011). The roll cost is especially pronounced in the short-term futures index, eroding positive returns in more than 65% of the considered months. Accordingly, Hancock (2013a, 2013b) demonstrates empirically that ETPs based on the VIX futures indices have not performed well in recent years. With similar arguments, Whaley (2013) shows that most ETPs based on the VIX short-term index are not suitable as a buy-and-hold investment. He claims that from December 2005 to March 2012, direct investors had lost about $3.89bn, compared with only $57.4m for inverse ETPs, whereas the index, which tracks the negative exposure to VIX futures, achieved an annual return of 6% over the same period.

Alexander and Korovilas (2012) provide one of the most extensive studies in this area, examining the performance of the most active volatility ETNs. In particular, the first volatility ETN VXX, which tracks the performance of the S&P VIX short-term futures index, has lost more than 90% of its value since inception in 2009 due to the high roll cost during the contango markets, and a convexity effect. To assess the performance over a longer period of time the authors replicate indicative values of the main ETNs back to 2004 and also explain in detail how ETN issuers hedge their exposure against early redemption risk using VIX futures. In particular, they illustrate how the front-running of this hedging activity led to an incident on February 23, 2012, when the issuer of the TVIX ETN (which tracks 2x the VIX short-term index) suspended the on-tap issuance of the notes. The authors also highlight that these hedging activities affect the prices of the futures contracts by raising their volatility, an issue which should concern not only the issuers but also market makers and regulators. Similarly, Goltz and Stoyanov (2013) use the TVIX event to raise general questions about the potential hidden risks in trading volatility ETNs, which do not directly track the volatility index but its corresponding futures index. A subsequent study by Bollen et al. (2013) further investigates the price impact of the hedging demand from volatility ETN issuers, claiming that it affects not only VIX futures prices but also the volatility risk premium of S&P 500 options. In addition, Huskaj and Norden (2013) show that the extensive trading in VIX futures has an impact on total volatility and, therefore, also on VIX option prices.

To explain the overwhelmingly negative returns on VIX futures and their direct ETNs, Eraker and Wu (2013) propose an equilibrium model which produces an upward sloping term structure of VIX futures and a positive volatility risk premium. Many other studies apply advanced models to volatility indices or their futures prices to better describe volatility dynamics and to price volatility derivatives. Mean-reversion, stochastic volatility of volatility and volatility jumps are features considered to be important in these papers. For more recent studies in this area see, for instance, Kaeck and Alexander (2013), Drimus and Farkas (2013) and Baldeaux and Badran (2014) and references therein.

The literature cited above indicates a growing interest in volatility derivatives from both practitioners and academia. It also reveals considerable complexity in this novel asset class. Volatility markets develop rapidly and in this study of exchange-traded volatility products we contribute to the existing literature in two significant ways. First, we provide a comprehensive and up-to-date survey of all volatility indices -- not only the VIX -- and of the markets for their ETPs. Secondly, we present a thorough empirical analysis of the market and trading characteristics of volatility futures and their ETPs during the post-banking crisis period (January 2011 to December 2014). Here we compare the characteristics of the growing European volatility market with the US market related to the VIX index, providing several useful insights for potential traders and investors in volatility markets.

The remainder of this paper is organized as follows: Section 2 surveys the burgeoning market for volatility ETPs; Section 3 describes their market characteristics, describing how these have evolved as the market develops; Section 4 examines statistical properties and performance; Section 5 offers some concluding remarks.

2. TAXONOMY OF VOLATILITY PRODUCTS

2.1 Chronology of Implied Volatility Indices

The CBOE now provides daily quotes for a wide variety of equity volatility indices in addition to the VIX, including those for: different segments of the US stock markets, such as Dow Jones Industrial Average Volatility Index (VXD), Nasdaq-100 Volatility Index (VXN) and Russell 2000 Volatility Index (RVX); five highly liquid individual equities, i.e. Apple, Amazon, Google, Goldman Sachs and IBM; the VIX of VIX index (VVIX) which tracks the volatility of the VIX index calculated from a portfolio of VIX options; the CBOE S&P 500 3-Month Volatility Index (VXV); and, most recently, the VXST and the VXMT indices, which measure the very short-term volatility triggered by market events respectively mid-term volatility over a 6-month time horizon. Together with VIX and VXV these indices provide very useful information about the current implied volatility term structure.

The demand for quotes on equity volatility indices has now spread all over the world. In April 2005, Deutsche Börse AG recalculated VDAX, originally introduced in 1994, using the new CBOE VIX methodology. Further European volatility indices such as the VSTOXX (on the EURO STOXX 50), the VSMI (on the Swiss SMI), the VCAC (on the French CAC 40), the VBEL (on the Belgian BEL 20), the VFTSE (on the UK FTSE 100), and VAEX (on the Dutch AEX) were launched shortly after. Over the next few years many other developed and emerging countries with liquid financial markets introduced their own volatility indices. With four Asian volatility indices, namely Korean VKOSPI, Indian VIX on Nifty, Hong Kong's VHSI and Japan's VNKY, as well as with Australian SPAVIX, Russian RTSVX, South African SAVIT40, Canadian VIXC, Mexican VIMEX and several other unofficial indices, more than 30 equity volatility indices are now quoted on each trading day.

The universe of volatility indices has since expanded to other non-equity asset classes which have historically exhibited high options trading volumes. CBOE is the leading provider thereby, quoting over 20 indices on different sectors. Volatility indices have been designed on commodities, currency exchange-rates, and emerging and developed markets.[1] Instead of index option prices, these volatility indices are based on the market prices options on exchange-traded funds (ETFs). As such, they allow investors to monitor volatility of specific sectors of ETFs in their portfolios.

In June 2012, CBOE began quoting its first interest rate-based volatility index, the CBOE Interest Rate Swap Volatility Index (SRVX), which measures basis-point volatility in the interest rate swap market. This is one of the largest over-the-counter (OTC) derivatives markets in the world and its volatility is of considerable interest to investors. One year later the CBOE and Chicago Mercantile Exchange (CME) Group announced the issuance of a new fixed-income volatility benchmark index, the CBOE/CBOT 10-year US Treasury Note Volatility Index (VXTNY), which is the first volatility index based on US government debt. Table 1 summarizes details on the main implied volatility indices.[2]

Table 1: Overview of Significant Implied Volatility Indices

Ticker/Symbol	Underlying Asset	Index Provider	Inception
Equity indices			
VXO	S&P 100	CBOE	1993
VXD	DJIA	CBOE	1997
VXN	NASDAQ-100	CBOE	2001
VIXC	S&P/TSX 60	Montréal Exchange	2002
VIX	S&P 500	CBOE	2003
VDAX	DAX 30	Deutsche Börse	2003
RVX	Russell 2000	CBOE	2004
VSMI	SMI	SIX Swiss Exchange	2005
VSTOXX	EURO STOXX 50	STOXX Ltd.	2005
TAIEX OVI	TAIEX	TAIFEX	2006
VXV[1]	S&P 500	CBOE	2007

[1] See http://www.cboe.com/micro/volatility/ for the overview of all volatility indices calculated by the CBOE.
[2] A recent addition not included in the table is the IVSTOXX, a volatility index on forward implied volatility in a form which can be replicated directly. It uses VSTOXX sub-index levels based on EURO STOXX 50 options to determine the expectation of implied volatility for a period of three months with a start value in the future. See http://www.stoxx.com/download/indices/factsheets/ivstxtr_fs.pdf for detailed information on the index calculation.

VAEX	AEX	Nyse Euronext	2007
VBEL	BEL 20	Nyse Euronext	2007
VCAC	CAC 40	Nyse Euronext	2007
SAVIT40[1]	FTSE/JSE 40	Johannesburg Stock	2007
VFTSE	FTSE 100	Nyse Euronext	2008
VKOSPI	KOSPI 200	Korea Exchange KRX	2009
INVIXN	Nifty 50	NSE India	2010
SPAVIX	S&P/ASX 200	Australian Securities	2010
RTSVX	RTS	RTS Stock Exchange	2010
VHSI	HSI	Hang Seng indices	2011
VNKY	Nikkei 225	VNKY Research	2011
VVIX	VIX Volatility Index	CBOE	2012
FTSE 100 IVI	FTSE 100	FTSE	2013
IVMIB 30	FTSE MIB	FTSE	2013
VXST[1]	S&P 500	CBOE	2013
VXMT[1]	S&P 500	CBOE	2013
RVI[2]	RTS	Moscow Exchange	2013
Commodities/Currency/Fixed Income			
OVX	United States Oil Fund	CBOE	2008
GVZ	SPDR Gold Shares	CBOE	2008
EVZ	CurrencyShares Euro Trust	CBOE	2008
SAVI WM[1]	White Maize Options	JSE	2009
SAVI Dollar[1]	Rand/Dollar Options	JSE	2009
OIV	CBOE/NYMEX WTI options	CBOE	2010
GVX	CBOE/COMEX Gold Options	CBOE	2010
VXGDX	Market Vectors Gold Miners ETF	CBOE	2011
VXSLV	iShares Silver Trust ETF	CBOE	2011
VXXLE	Energy Select SPDR Fund	CBOE	2011
SIV	CBOT Soybean Options	CBOE	2011
CIV	CBOT Corn options	CBOE	2011
WIV	CBOT Wheat Options	CBOE	2012
SRVX	1y Swaptions on 10y USD Swaps	CBOE	2012
VXTYN	10y US Treasury Note Options	CBOE	2013
Single Stocks			
VXAZN	Amazon	CBOE	2011
VXAPL	Apple	CBOE	2011
VXGS	Goldman Sachs	CBOE	2011
VXGOG	Google	CBOE	2011
VXIBM	IBM	CBOE	2011
Emerging and Developed Markets			
VXEEM	iShares MSCI Emerging markets	CBOE	2011
VXFXI	iShares FTSE China 25 ETF	CBOE	2011
VXEWZ	iShares MSCI Brazil Index	CBOE	2011
VXEFA	iShares MSCI EAFE Index Fund	CBOE	2013

[1]All indices are based on 30-day vanilla options, except for VXV and SAVIT40, SAVI Dollar and SAVI White Maize indices, which are based on 3-months options, VXST index, which uses nearby and second nearby options with at least 1 day left to expiration and VXTM index with S&P 500 options that expire in 6 - to - 9 months.
[2] The new Russian market volatility index RVI is calculated based on actual RTS index option prices over 15 strikes while the calculation methodology for the RTSVX index uses Black-Scholes option pricing formula.

2.2. Volatility Futures and Options

The concept of a volatility index derivative was first introduced by Gastineau (1977) and extended by Brenner and Galai (1989). In fact, the potential for volatility derivatives to be ``one of the most important new financial innovations'' was recognized long ago by Grünbichler and Longstaff (1996). The first volatility futures were launched by the German Futures and Options Exchange (DTB) as VOLAX futures contracts on the three-month implied volatility of an at-the-money DAX option in January 1998. However, the contract failed to attract significant volume and was de-listed in December 1998.

The Chicago futures exchange (CFE) first listed VIX futures contracts on March 26, 2004. Futures for implied volatility on the Dow Jones Industrial Average (DJIA), the Nasdaq-100 and Russell 2000 indices were also launched in subsequent years but failed to reach the success of VIX futures and were de-listed a couple of years later.[3] European volatility futures on VDAX, VSMI, and VSTOXX, followed soon after, in September 2005, listed on EUREX. These also suffered from low trading volumes and were withdrawn in May 2009 and replaced by the VSTOXX mini-futures which have only 10% of the size of a standard futures contract.[4] The rapidly-growing Asian market followed with its own volatility futures in 2012. Now Hong Kong, Osaka, Indian and Korea exchanges offer futures contracts on VNKY, VHSI, VNIFTY and VKOSPI volatility indices, and listing of equity volatility futures on the Taiwan exchange is imminent at the time of writing.

Because volatility indices are not tradable, there is no unique closed-form, arbitrage free, cost-of-carry relationship connecting the volatility index with the price of a futures contract. As a result a sizeable difference between the index and its futures prices may be observed. Still, the futures price represents the risk-neutral expectation of the

[3] Futures contracts on the Nasdaq-100 and Russell 2000 volatility indices were re-launched in 2012 and 2013 respectively.
[4] VIX mini-futures contracts were also listed 2006 but due to lack of demand delisted 2014.

corresponding volatility index at maturity, and as such futures offer a volatility exposure that is still very highly correlated with the volatility index and with the rates on OTC variance swaps brokered by investment banks. Moreover, unlike variance swaps, the futures have no credit risk. Hence, the investment side of a commercial bank no longer needs to rely solely on OTC trades and take on unnecessary credit risk in order to gain exposure to volatility.

Table 2 summarizes the market specifications for volatility futures on VIX and VSTOXX. The settlement value of VIX futures is $1,000 times the point value of the VIX: for instance if the Special Opening Quote (SOQ) on VIX is 30%, the VIX futures settle at $30,000. The mini-futures are much smaller -- if the VSTOXX is at 30%, then the settlement value is 3,000 Euros. Apart from this, the main difference is that the final settlement value for VIX futures is based on the special opening quotation of VIX, whereas VSTOXX futures prices are based on the average of the VSTOXX index values between 11:30 and 12:00 CET on the last trading day. This way, the settlement value for VSTOXX is less prone to the large-scale manipulation -- popularly referred to as ``carpet-bombing'' -- that has been witnessed through large scale trading on S&P 500 options at the open of trading on the VIX futures settlement day.[5]

Building on the successful launch of VIX futures, CBOE introduced VIX options in February 2006. These derivative instruments became popular very quickly. They were named the ``Most Innovative Index Derivative Product'' at the Super Bowl of Indexing Conference in Phoenix, after more than 5 million contracts were traded in the first year. At the time of writing about 600,000 contracts are traded each day, and so far total volume peaked during February 2014 at 2,400,000 contracts traded per day.

[5] See http://onlyvix.blogspot.co.uk/2011/10/how-to-manipulate-vix-settlement-price.html

Table 2: Contract Specifications for Equity Volatility Futures

	VIX Futures	**VSTOXX Mini-futures**
Listing Date	26 March 2004	2 June 2009
Contract Multiplier	USD 1,000	EUR 100
Contract Months	Up to nine near-term serial months and five months on the February quarterly cycle	Up to eight months: The eight nearest successive calendar months
Trading Hours	07:00 - 15:15	08:50 - 17:30
Trading Place	CBOE	EUREX
Ticker/Symbol	VX	FVS
Minimum Price interval/ Value per tick	0.05 points (USD 50)	0.05 points (EUR 5)
Final Settlement Date	The Wednesday that is thirty days prior to the third Friday of the calendar month immediately following the month in which the contract expires	The Wednesday prior to the second last Friday of the respective maturity month
Final Settlement Value	Special Opening Quotation (SOQ) of VIX calculated from the sequence of opening prices of the options used to calculate the index on the settlement date	The average of the index values of the underlying on the Last Trading Day between 11:30 and 12:00 CET

Variance futures now provide a further possibility to trade volatility, and the convex (squared volatility) pay-off enhances gains and reduces losses relative to the linear volatility counterpart. In addition to the S&P 500 variance futures contracts which were re-listed by CBOE at the end of 2012, in April 2013 the CME Group announced the launch of nine new variance futures on commodities and currency pairs.[6] However, the variance futures market is not yet well developed and at the time of writing it is volatility derivatives that are growing most rapidly, now spreading to other asset classes. For instance, in 2011 the CBOE began listing volatility futures and options on Gold, Crude Oil, Emerging Markets and Brazil ETFs and in November 2014 CFE launched

[6] The CFE first introduced the S&P 500 3-month variance futures contracts in 2004, and the S&P 500 12-month variance futures in 2006. The 12-month contracts were first de-listed in 2011 and then re-launched one year later in December 2012. The 3-month variance futures were delisted in 2013. Among others, Zhang and Huang (2010) and Chang et al. (2013) empirically analyze the specialty of the S&P 500 variance futures.

futures on the CBOE/CBOT 10-year US Treasury Note Volatility Index opening a door to the interest rate volatility trading.[7] Table 3 shows the issuance time-line of volatility futures, and their traded contracts and open interest as of 31st of December 2014.

Table 3: Issuance Timeline of Volatility Futures

Inception	Corresp. Volatility Index	Provider	Traded Contracts[1]	Open interest[1]
Jan 98	DAX[2]	DTB	-	-
Mar 04	VIX	CFE	172,840	299,185
Apr 05	DJIA VI[2]	CFE	-	-
Sep 05	VDAX[2]	EUREX	-	-
Sep 05	VSMI[2]	EUREX	-	-
Sep 05	VSTOXX[2]	EUREX	-	-
Jul 07	NASDAQ 100 IV[2,3]	CFE	50	90
Jul 07	Russell 2000 IV[2,3]	CFE	0	48
Mar 09	VIX[2,4]	CFE	-	-
Jun 09	VSTOXX[4]	EUREX	21,522	171,411
Mar 11	Gold ETF IV	CFE	0	417
Jun 11	RTSVX	RTS	0	6
Jan 12	Emerging Markets ETF IV	CFE	80	121
Feb 12	Brazil ETF IV	CFE	30	215
Feb 12	Hang Seng VI	HKE	0	2
Feb 12	VNKY	OSE	636	7,461
Mar 12	Crude Oil ETF IV	CFE	2	134
Oct 13	S&P/ASX 200 VI	ASX	2	2
Feb 14	VNIFTY	NSE	90	86,400
Feb 14	VXST	CFE	8	45
Sep 14	RTSVX[5]	ME	0	4
Nov 14	VKOSPI-200	KRX	33	287
Nov 14	VXTYN	CFE	0	0

[1]Traded contracts and open interest as of 31 December 2014 or 30 December 2014 if the corresponding exchange was closed on 31/12/2014
[2]These futures contracts were de-listed
[3] CBOE re-launched the futures contracts on the Nasdaq-100 volatility index in May 2012 and contracts on Russell 2000 volatility index in October 2013.
[4] Mini-futures contracts which have one-tenth of the standard futures contract size.
[5] Futures based on the new Russian market volatility index RVI

The VIX mini-futures could not compete with the standard contracts and were de-listed in 2014, whereas the European VSTOXX mini-futures contracts are enjoying increasing demand. However, at the time of writing the number of traded futures

[7] See http://cfe.cboe.com/products/ for contract specifications.

contracts on the recently-launched Asian volatility and commodities ETF volatility indices remains negligible. Note that the open interest on VIX futures was roughly double the trading volume at this time. Since both buy and sell trades are recorded, this indicates that a VIX futures contract was being held for, on average, about four days. By contrast, VSTOXX mini-futures were being held for roughly 16 trading days, because the open interest was about 8 times the trading volume on 31st of December 2014. This indicates the presence of more short-term speculative trading on VIX futures. A similar comment applies to the other futures listed in Table 3: at least where open interest is not negligible, the contracts are being held for several weeks, on average. Whereas the average turnover time for a major equity index futures contract is much less than one day, even VIX futures are held for several days and the other volatility futures are held for a month or more, on average. This is too long for purely speculative investments, and because there is no traded cash product for which these futures provide a hedge, the main demand for these futures must be for diversification.

2.3. Exchange-Traded Products

Volatility Exchange-Traded Products (ETPs) have gained tremendous popularity during the last few years. The indicative value of volatility ETPs is linked to the market prices of the relevant futures indices. Thus, these products allow investors that are constrained against derivatives trading, or who wish to take smaller position sizes than those offered by futures, to take direct and inverse positions related to volatility futures. Compared to mutual funds, ETPs have a more transparent structure, can be traded daily and are tax and cost efficient. At the time of writing there are more than 40 ETPs on volatility with an overall market capitalization of about 4 billion USD and about 120 million contracts being traded every single day. Many of these products are highly liquid and some even have their own options, listed by the CBOE.

The cornerstone for volatility ETPs market was laid in January 2009, when Standard & Poor's (S&P) started to quote a term structure of S&P 500 VIX constant maturity futures series, in particular the S&P VIX short-term futures index (SPVXSP) and the S&P VIX mid-term futures index (SPVXMP). The VIX short-term index measures the return from a rolling position in the first and second month VIX futures contracts, maintaining a constant one-month maturity. Similarly, the mid-term futures index uses the fourth, fifth, sixth, and seventh month VIX futures contracts and captures a constant five-month maturity exposure. These indices provide now indicative values for numerous ETPs with a direct or inverse exposure to VIX futures.[8]

The first volatility futures ETNs to be issued were Barclays iPath S&P 500 VIX short-term (Ticker: VXX) and mid-term (Ticker: VXZ), launched at the beginning of 2009. Extolling the virtues of volatility as a new and effective equity diversifier, between January 2009 and May 2014 Barclays issued a total principal of $320bn on the VXX and $2.5bn on the VXZ ETNs. Then Velocity Shares, on behalf of Credit Suisse, followed in 2010 with 6 similar products, extending the ETNs universe with leveraged and inverse exposures to short- and mid-term VIX futures. The most popular of them, the Daily 2x VIX short-term ETN (Ticker: TVIX) is linked to twice the daily performance of the VIX short-term futures index.

ETRACS of UBS also tried to enter the volatility market by issuing 12 direct and inverse ETNs on VIX futures with a constant maturity of one to six months. However, these products failed to reach the success of their rival's products and were redeemed only one

[8] Meanwhile, there are several further volatility futures indices quoted by STOXX and S&P. See http://www.stoxx.com/download/indices/rulebooks/stoxx_strategy_guide.pdf or http://us.spindices.com for further details.

year after launch. The only remaining VIX ETN offered by UBS is the ETRACS Daily Long-Short VIX ETN (Ticker: XVIX), which takes a static long exposure in the mid-term and a short exposure in the short-term futures indices. The XVIX and its Barclays' rival XVZ, which dynamically allocates the long and short positions between the short- and mid-term VIX futures indices, were designed to take advantage of the convexity of the short end of the VIX futures curve.

Table 4: Taxonomy of Volatility ETNs

Ticker	Issuer	Inception	Underlying Index	Futures (m)	Leverage	Service fee[1]	Market Cap[2] ($m)
VXX[3,4]	Barclays	Jan-2009	VIX	1	1	0.89%	986.2
XIV[3]	Credit Suisse	Nov-2010	VIX	1	-1	1.35%	933.6
TVIX[3]	Credit Suisse	Nov-2010	VIX	1	2	1.65%	320.2
ZIV[3]	Credit Suisse	Nov-2010	VIX	5	-1	1.35%	124.1
VXZ[4]	Barclays	Jan-2009	VIX	5	1	0.89%	49.2
VSXX	Barclays	Apr-2010	VSTOXX	1	1	0.89%	22.1
XVZ	Barclays	Aug-2011	VIX	1 vs. 5	1	0.95%	18.5
VSXY	Barclays	Nov-2010	VSTOXX	5	1	0.89%	15.9
XVIX	UBS	Nov-2010	VIX	1 vs. 5	1	0.85%	12.0
VIIX[3,4]	Credit Suisse	Nov-2010	VIX	1	1	0.89%	11.2

1) All ETNs carry an extra redemption fee: 0.05% for Barclays and Credit Suisse, 0.125% for UBS
2) Market Cap in million USD as of 31/12/2014.
3) Split executed by the issuer: three 1:4 reverse splits on VXX in November 2010, October 2012 and November 2013 respectively, two 1:10 reverse split on TVIX in December 2012 and August 2013, 10:1 split on XIV and 8:1 split on ZIV occurred in June 2011, 1:10 reverse split on VIIX in August 2013.
4) Chicago Board Options Exchange (CBOE) offers options on these ETNs.

Table 4 provides an overview of the most prominent ETNs with a market cap of at least $10m, issued by iPath of Barclays, VelocityShares of Credit Suisse and ETRACS of UBS. Although most ETNs are currently based on the VIX short-term and mid-term futures indices, in 2010 Barclays issued ETNs for the European market. Two of the VSTOXX ETNs now rank among the 10 largest volatility ETNs by market capitalization. The exposure to volatility futures can be direct (also leveraged), inverse (XIV and ZIV), or a combination of direct and inverse on different maturities (XVIX and XVZ). Their performance is reduced by a service fee charged by the issuer. These fees are currently in the range of 0.85% - 1.65% per annum. For leveraged and inverse products the issuers charge significantly higher fees due to their hedging costs. A small redemption fee of 0.05% - 0.125% is also charged to the investor in case of early redemption.

With 98% of the overall market capitalization Barclays and Credit Suisse dominate the volatility ETNs market. With a market capitalization of $986m at the end of December 2014, the Barclays VXX alone covers about 40% of the total volatility ETNs market. For a security which steadily loses value, VXX is constantly in high demand. Its traded volume averages over 40 million shares per day and its market cap has remained at about $1bn for the last couple of years while its price has been adjusted three times due to dramatic loss in value since the inception. According to the prospectus, Barclays can initiate a 4 for 1 split if the indicative value is above $400 and a 1 for 4 reverse split, should the indicative value be below $25. One year after the third reverse split in November 2013, the VXX is again trading at levels around $30 and it is only a matter of time before the next 1:4 cut.

The introduction of ETNs has allowed any type of investor to gain exposure to volatility. However, these products have some adverse features not shared by futures. First of all, they retain the credit risk of the issuer, which has been more relevant for investors since the banking crisis.[9] Furthermore, a small investor may be trapped into an illiquid investment because the issuer will only redeem the shares early in large lots. Moreover, many ETNs have a callable feature whereby the issuer can call back the shares at any time, with a rather short call notice period. On the other hand, the early redemption fee and the annual service fee charged by ETN issuers are small relative to their hedging costs. Moreover, recent innovations in the volatility ETN market based on trading the term structure of VIX futures could make a diverse array of risk and return characteristics available at a reasonably low cost.

[9] Since 2011, Commerzbank offers secured VIX and VSTOXX ETNs, depositing securities with a very good credit rating for each ETN. However, at the time of writing, these ETNs are only rarely in demand. See http://warrants.commerzbank.com for further information on these products.

Unlike ETNs, Exchange-Traded Funds (ETFs) are assets of security funds and are, therefore, independent of the credit risk of the issuer. Table 5 gives details of the top 10 volatility ETFs sorted by the market capitalization as of 31st of December 2014. Again, most products are based on VIX futures.

With almost $1bn assets under management in ETFs, the main provider is ProShares. The market capitalization of its leveraged VIX short-term futures tracker UVXY (Ultra VIX short-term futures ETF) is greater than the equivalent ETN, i.e. Credit Suisse's TVIX. Their short-term and mid-term ETFs are now also listed on the Osaka Securities Exchange (OSE) and are enjoying increasing demand with a market cap of about $124m. The only European volatility ETF was launched in May 2011 by the Bank of America/Merrill Lynch (BofAML); this tracks the EURO STOXX 50 Investable Volatility Index (IVSTOXX).

Table 5: Taxonomy of Volatility ETFs

Ticker	Issuer	Inception	Underlying Index	Futures (m)	Leverage	Service fee[1]	Market Cap[2] ($m)
SVXY[2,4]	ProShares	03/10/2011	VIX	1	-1	0.95%	504.6
UVXY[2,3,4 4]	ProShares	03/10/2011	VIX	1	2	0.95%	346.3
1552	Kokusai	20/12/2010	VIX	1	1	0.36%	121.8
VIXY[2,3,4]	ProShares	03/01/2011	VIX	1	1	0.85%	111.8
VOOL	Lyxor	25/09/2012	VIX	1 vs. 5	1	0.60%	43.7
VIXM[2,4]	ProShares	03/01/2011	VIX	5	1	0.85%	29.5
HVU	BetaPro	16/12/2010	VIX	1	2	1.15%	24.4
VHTX	BofAMl	28/02/2011	IVSTOXX	3	1	0.80%	16.1
VIXS	Source	18/06/2010	VIX	1	1	0.60%	11.7
HVI	BetaPro	04/04/2012	VIX	1	-1	1.15%	11.7

[1] Market Cap in million USD as of 31/12/2014
[2] ProShares ETFs carry an extra redemption fee of 0.10%
[3] Split executed by the issuer: 1:6 split in March 2012, two 1:10 reverse splits in September 2012 and June 2013 respectively, 1:4 reverse split in January 2014 on UVXY, 1:5 reverse split on VIXY in June 2013; two 2:1 splits on SVXY in October 2012 and January 2014 respectively; 1:4 reverse split on VIXM in November 2014.
[4] Chicago Board Options Exchange (CBOE) offers options on these ETFs.

3. MARKET CHARACTERISTICS OF VOLATILITY PRODUCTS

3.1 Roll Costs on Futures

Figure 1 depicts the daily closing price ratio of the next-to-expire futures contract over the prompt futures, for the VIX (black line) and the VSTOXX (grey line) between 1 January 2011 and 31 December 2014. The value 1 indicates a flat term structure, greater than 1 is backwardation and less than 1 is contango, both at the short-end of the term structure. Both term structures are very often in contango. In fact, backwardation occurred in VIX futures on only 5% of the days between January 2012 and December 2014, compared with 15% for VSTOXX futures.

<Insert Figure 1 Here>

These rare and brief periods of backwardation are accompanied by a significant increase in trading volume on volatility futures associated with periods of exceptionally high equity market volatility. Trading volumes in USD terms are between 35% and 45% higher during backwardation periods than during periods of contango, on average. For instance, VIX futures trading volume during backwardation periods is about $800m more than it is during contango, on average per day. The volatility in the Eurozone has exceeded that in the US during the sample, and this is one reason why backwardation has been more frequent in the VSTOXX than in the VIX terms structure. Another reason why backwardation is becoming increasingly rare, particularly in VIX futures, is the front running of the hedging of volatility ETPs, a behaviour that is well documented and explained by Alexander and Korovilas (2012). This has the effect of pushing the VIX future term structure back into contango very swiftly after any backwardation is experienced.

Because of the predominance of contango a prevalent characteristic of the volatility futures market is a negative carry, i.e. a positive ``roll cost'' associated with rolling a contract over to the next maturity. To illustrate the effect of the negative carry on a long-term investment in volatility futures, Figure 2 displays the theoretical value of $100 invested in VIX and VSTOXX constant maturity short-term and mid-term futures indices. These indices replicate a position that rolls futures contracts on a daily basis maintaining a constant exposure to the one-month (short-term) or five-month (mid-term) futures contract. Starting in January 2011, a constant exposure to the one-month VIX future contract would generate a negative return of more than 95%.

<Insert Figure 2 Here>

Because of the convexity of the term structure (i.e. the slope of the term structure is greater at the short end) the roll cost for the mid-term VIX futures index is smaller than for the short-term futures. But it is still significant, eroding over 79% of the initial value over the sample period. Interestingly, this roll-cost differential is less evident for VSTOXX futures because the term structure of VSTOXX futures tends to be less convex than the VIX futures term structure. Typically, the VSTOXX term structure is less steep at the short end but more steep at the long end, compared with the VIX futures term structure. Hence, both the short-term VSTOXX futures and mid-term VIX futures indices have lost about the same amount over the holding period, i.e. about 80% of the initial investment.

These high roll costs translate into fairly large negative returns on volatility futures most of the time, yet trading volume has increased steadily so demand for these products as useful diversification instruments remains strong. Figure 3 depicts the average daily trading volume for the VIX and VSTOXX futures contracts since 2011 on the left scale. The average number of contracts traded each day on VIX and VSTOXX futures has more than quintupled between January 2011 and December 2014. A new record was set on 15 October 2014 when about 820,000 VIX and VSTOXX futures contracts with a value of more than $16.5bn in total were traded on a single day! Figure

3 displays the open interest on VSTOXX and VIX futures contracts. Since 2011, the number of open contracts on the VSTOXX mini-futures has tripled with a daily average of about 190,000 contracts, rising to 280,000 contracts during the last quarter of 2012. But in dollar terms this was still little more than 10% of the open interest on VIX futures.

<Insert Figure 3 Here>

3.2. Trading Costs and Turnaround Times of VIX and VSTOXX Futures

As a result of the lower liquidity, VSTOXX mini-futures contracts have higher trading costs: with bid-ask spreads currently about 90 basis points, they are roughly triple the spreads for VIX futures. This is evident from Figure 4 which depicts the price levels and average spreads for VIX and VSTOXX futures since January 2011. Also, since the EURO STOXX 50 index is less diversified than the S&P 500, the VSTOXX is usually above the VIX index. So VSTOXX mini-futures typically trade at prices that are about 20-30% above the level of VIX futures (see the right scale of the Figure 4).

<Insert Figure 4 Here>

Trading volumes record buy and sell as separate transactions, so the average number of trading days that a futures contract is held can be approximated using

$$\text{Average turnover time in days} = 2\text{x}\,\frac{\text{Average daily open interest}}{\text{Average daily trading volume}} \qquad (1)$$

Based on this calculation, Figure 5 depicts the average holding times for VIX and VSTOXX futures showing how these have evolved since 2011. Here again the results represent averages over a quarter. Over the period 2011 – 2014 the average turnover of VIX futures was never more than 9 days, whereas VSTOXX mini-futures are typically held for 2-4 weeks. This provides further support for our previous conclusion that it is the diversification demand for VSTOXX futures that dominates trading, whereas VIX futures are also transacted by day traders and other speculators that hold the contracts for a very short time, for instance in the front-running of futures hedges by issuers of ETPs.

<Insert Figure 5 Here>

3.3. Market Characteristics of Volatility ETNs and ETFs

The market for volatility ETNs and ETFs has soared during the last few years. Since 2009, over 40 ETNs and ETFs with a direct or inverse exposure to VIX and VSTOXX futures were issued. In the second quarter of 2012, the total market capitalization of volatility ETPs peaked at $6bn with more than $2.2bn assets under management alone for Barclays VXX ETN.[10] Figure 6 displays the market capitalization over all VIX and VSTOXX ETPs, showing how the quarterly average has changed since 2011. Total market capitalization peaked in Q2 2012, after which many investors redeemed their shares, apparently disappointed by the price development of direct volatility trackers. Since Q2 2012 the recovering international equity markets have reached new all-time highs and most long volatility products have lost more than 50% of their value since that time.

<Insert Figure 6 Here>

VIX-related products account for the large majority of volatility ETP market capitalization and secondary market trading on VIX-related ETNs has now become intense. Figure 7 depicts monthly average spread and volume data for the most popular of them, the Barclays short-term VXX ETN. Since 2011, the average spread has remained in the region of 10-20 bps, except during the Eurozone crisis in August 2011, when daily trading volume reached 30 million contracts with an average of about $2.5bn traded each day. On one single day, 8 August 2011, around $5bn was traded on VXX alone! Since then,

[10] Including the increasingly popular VQT ETN, which tracks the S&P 500 Dynamic VEQTOR index that allocates dynamically between the S&P 500, the VIX short-term futures index and cash.

the number of contracts traded per day has nearly quadrupled, reaching almost 157 million contracts in October 2014.

<Insert Figure 7 Here>

Participants in the ETN market can be categorized as speculators and investors. Speculators focus on intra-day trading, or have a maximum 2-3 days investment horizon and are particularly concerned with market liquidity and more specifically with the supply of ETN shares on behalf of the issuer. On the other hand, long-term investors are mainly concerned with the credit risk of the issuer. Therefore, there is a trade-off between the speculative demand and the credit risk that is relevant for medium- and long-term investors. Because of this ETNs may trade at a premium or a discount relative to their indicative value. Figure 8 depicts the market risk premiums for the Barclays short-term VXX and for the twice leveraged TVIX issued by Credit Suisse, quoted as the percentage difference of the market traded price relative to the indicative value of the ETN. Usually, VXX trades at a discount relative to its indicative value, i.e. the credit risk associated with the issuer dominates. The price trades at a premium only during periods of market uncertainty such as the Eurozone crisis in August 2011 or at the beginning of 2012, when the demand from investors has increased rapidly. By contrast, the TVIX premium is positive throughout, indicating a strong demand for the product from speculators relative to the supply of shares offered by Credit Suisse, the issuer of the note. Prior to February 2012 the premium was on average only slightly positive but when, on 23 February 2012, Credit Suisse announced it was suspending the issue of further shares, its market price initially rose to 15.41% above the indicative value.[11]

<Insert Figure 8 Here>

[11] Credit Suisse suspended issuance due to front-running of its hedging trades on VIX futures and only agreed to re-open the shares after making an agreement with VIX futures market makers that they guarantee the closing price on which the redemption value of ETNs are based -- see Alexander and Korovilas (2012) for further details.

The TVIX premium even reached a level of 89.43% on 21 March 2012 before Credit Suisse announced on 23 March 2012 that they would re-open issuance of new TVIX shares. Since then the situation has eased but the premium has not returned to its original level and remains in the region of 3-5%. Clearly, speculative demand for this twice leveraged, highly volatile product remains buoyant even after the TVIX lost more than 99% of its value. Issued originally at over $1,000 per share in November 2010, and after two 1:10 reverse splits in December 2012 and August 2013, by the end of December 2014 TVIX was trading below $5. Figure 9 depicts its market price and trading volume since inception in November 2010. Despite its dramatic loss of value, the number of traded contracts remains at very high levels and peaked at over 89 million on October 16th 2014, when over $450m was transacted on a single day. About 21 million contracts has been traded on TVIX daily, on average, since June 2014, with an average value of about $62m per day as the price per share dropped below the $5 mark (shown in the inset chart).

<Insert Figure 9 Here>

4. STATISTICAL PROPERTIES AND PERFORMANCE

International equity markets are becoming more integrated over time. As a result there is a high correlation between international equity volatility indices. The figures presented in Table 6 are averages based on weekly percentage changes over the period January 2008 to December 2014. Within Europe all volatility indices have correlations in the region of 0.8 to 0.9, except for the correlation between VSTOXX and VDAX which is even higher. The cross-continental correlation between the two most important volatility indices, US VIX and European VSTOXX, is also very high, almost 0.85. Asian equity volatility indices are less correlated. Over the same period the average weekly correlation is only about 0.50 and the Indian VIX (INVIXN) even has correlations under 0.4 with other equity volatility indices.

Correlations increase when based on synchronous daily quotes especially during the last few years. Correlations for the main CBOE volatility indices, calculated with daily data from March 2011 to December 2014, are displayed in Table 7. For example, between January 2011 and December 2014 the daily percentage changes on the VIX and the VXD indices had a correlation of 0.97. The VIX is also highly correlated with single-stocks volatility indices (daily percentage changes having a correlation of about 0.6 over the same period) and with the commodities and emerging markets ETFs (with similar correlations at around 0.7). By contrast, the CBOE Interest Rate Swap Volatility Index (SRVX) had a correlation near zero with all other CBOE volatility indices, based on daily percentage changes from June 2012 to December 2014, except for the new CBOE/CBOT 10-year US Treasury Note Volatility Index (VXTYN). This volatility index, firstly based on US government debt, was introduced in May 2013 and has also low correlations below 0.3 with other assets volatilities.

<Tables 6 and 7 Here>

Figure 10 depicts the evolution of four of the main international equity volatility indices: the VIX for the US, the VSTOXX for Europe, the VKOSPI for Korea and the SAVIT40 for South Africa. The series shown for VIX and VSTOXX are from January 2007 to December 2014, with the SAVIT40 starting in February 2007 and the VKOSPI starting only in April 2009. Apart from the evident high correlation which has just been discussed, the VIX is generally slightly lower than the other indices (except during 2010 when the VKOSPI was unusually low) and the VSTOXX has been particularly high since the Eurozone crisis began in the summer of 2011. By the end of the sample, as a few signs of recovery from the double-dip recession appeared, all indices were at the lower end of their normal range, between 15 and 25 volatility points compared with 50 to 80 points at the height of the banking crisis.

<Insert Figure 10 Here>

Table 8 displays the average, maximum and minimum levels of the main volatility indices between January 2008 and December 2014 in the first three columns. The more stocks in an index the greater the diversification effect and the lower the volatility, ceteris paribus. So, because the VIX is based on a 500-stock index, the average volatility index level is less than that for the VSTOXX, which is based on a 50-stock index. But less developed markets also tend to have higher volatilities than developed markets. For instance, the Russian index RTSVX, which is also based on a 50-stock index, is much higher than the VSTOXX, on average. At the onset of the financial crisis following the collapse of Lehman Brothers, RTSVX even reached about 200 volatility points, whereas the VSTOXX peaked at about 81 volatility points during the same period.

Table 8: Descriptive Statistics for Volatility Indices

	Average Level	**Max Level**	**Min Level**	**Ann Std Dev**	**Max weekly change**	**Min weekly change**	**Skew**	**Kurtosis**
VIX	22.33	79.13	10.32	100.1%	61.9%	-49.6%	0.60	4.94
VSTOXX	26.27	81.03	12.78	92.2%	67.7%	-36.5%	0.73	5.87
VFTSE	21.29	75.54	9.91	102.4%	69.0%	-39.1%	0.54	5.72
VHSI	25.96	87.19	11.53	78.0%	45.8%	-32.6%	0.50	4.73
VNKY	27.71	92.03	14.78	89.1%	75.7%	-36.4%	1.13	8.43
SPAVIX	21.26	63.95	9.61	88.0%	39.9%	-51.2%	-0.04	4.67
SAVIT40	23.72	56.23	12.31	43.0%	27.6%	-18.1%	0.42	4.20
VIMEX	23.29	67.00	10.14	64.1%	35.1%	-26.1%	0.57	4.74
VKOSPI	22.46	81.27	10.66	70.9%	55.3%	-27.2%	0.70	6.32
INVIXN	25.08	70.08	11.89	80.4%	41.1%	-44.0%	0.12	4.38
RTSVX	38.87	200.49	16.26	103.6%	71.3%	-53.6%	0.91	6.42

Descriptive statistics for the main implied volatility indices, calculated with weekly data from January 2008 to December 2014. Average, maximum and minimum levels are presented in percentage volatility points.

Except for the South African SAVIT 40, all volatility indices are highly volatile with the annual standard deviation of weekly changes reaching up to 100%. Positive skewness and high kurtosis levels also deviate substantially from the corresponding levels of the normal distribution and indicate higher probabilities for extreme weekly changes. This can also be seen from the wide range between the maximum and the minimum weekly changes in the levels. So for instance, the VIX index can increase in value by 62% or lose around 50% within one week.

Equity volatility indices may be used for indicative quotes on variance swap rates. Because these indices are highly negatively correlated with their underlying indices, they may offer diversification benefits for an equity investor, through OTC trades on variance swaps. However, here we are concerned with exchange-traded products, i.e. the futures and ETNs/ETFs on these indices, which, depending on their structure, have lower correlations with equity and different statistical characteristics than the volatility indices. Table 9 makes these differences immediately apparent by reporting summary statistics for returns on the main volatility ETNs. From January 2011 to December 2014 most of the ETNs had very large negative average daily returns and disastrous total returns. For instance, the VIX short-term VXX lost 94.6% and the twice leveraged TVIX even 99.5% of its value since 2011. In fact, a long volatility exposure was only profitable at the onset of the Eurozone crisis from August to December 2011 when the strong backwardation in the futures market generated a positive roll yield. Since 2012, recovering equity markets have eroded all previous positive returns on volatility. Even the strategic XVIX and XVZ, which were designed to take advantage of the VIX futures curve, could only slightly mitigate losses from the long position to VIX futures.

Table 9: Descriptive Statistics for Volatility ETNs

	Annualized Mean	Volatility	Max Daily Drawdown	Skew	Kurt	Total Return
VXX	-72.6%	61.4%	-14.2%	0.54	5.25	-94.6%
VXZ	-39.8%	30.5%	-8.6%	0.43	5.42	-79.8%
VSXX	-43.7%	53.3%	-14.4%	0.46	5.01	-82.7%
VSXY	-26.0%	29.2%	-8.5%	0.15	5.52	-64.8%
TVIX	-191.4%	115.4%	-35.4%	0.19	6.03	-100.0%
XIV	22.9%	63.0%	-22.3%	-1.04	6.51	151.5%
ZIV	27.5%	29.9%	-10.6%	-0.47	6.15	202.2%
XVZ	-14.9%	18.8%	-10.1%	2.30	37.32	-45.1%
XVIX	-11.4%	11.8%	-3.1%	0.06	4.30	-36.8%

Table reports the summary statistics for daily returns on the direct and inverse volatility ETNs issued by Credit Suisse, Barclays and UBS. Sample means and standard deviations are annualized based on 250 trading days per year. The sample is 3 January 2011 to 31 December 2014. * XVZ was issued in August 2011, prior to this date we replicate the value using S&P constant-maturity indices.

For comparison, over the same period the average changes in VIX levels were only slightly negative (-4.23% p.a.) and even positive for VSTOXX (+2.65% p.a.) with very high standard deviation (100% resp. 92%) and a high positive skewness (0.60 resp. 0.73). The returns on the (un-leveraged) volatility ETNs are, by contrast, less volatile and have lower skewness. At the same time inverse VIX ETPs have performed extremely well over the same period. For instance, the VelocityShares mid-term inverse ETN ZIV doubled in value between January 2011 and December 2014.

However, being positively correlated with equity, inverse volatility ETNs are more suitable for speculative short-term investments rather than for diversification purposes. Direct volatility ETNs, have, on the contrary, a large negative correlation with equity and therefore, despite negative returns, may still be optimal to diversify an equity portfolio. To see how equity-volatility correlations have increased in magnitude since the banking crisis, Figure 11 depicts 1-year rolling correlations for the SPY (the main passive ETF on the S&P 500) with the VIX short-term ETN VXX; and similarly for the Eurozone, the 1-year rolling correlations between the SX5EEX (the main EURO STOXX 50 ETF) with the VSTOXX short-term ETN VSXX are shown. The SPY-VXX correlation is strongly negative lying between -0.8 and -0.9 for most of the period. The European equity-volatility correlation was not quite so strong between January 2011 and December 2011, but in 2012 it has strengthened and since then it has remained around -0.8. Combining this with our previous observation that the roll cost for European volatility products is typically much lower than for similar products in the US, volatility ETPs may offer better diversification opportunities to European investors than those now available to US investors.

<Insert Figure 11 Here>

5. CONCLUSIONS

We have provided an extensive overview of implied volatility indices and their related exchange-traded products and the burgeoning literature in this field. A detailed study of their market and trading characteristics shows how the rapidly-developing volatility market has evolved over the last few years, a period which has been marked by the Eurozone crisis. Other sources have published partial information along the same lines but this has become out-of-date because the market has developing very rapidly in the years following the banking crisis. The fundamental volatility exchange-traded contracts that are currently traded are futures on volatility indices. Also, small investors, or those that are not allowed to trade futures, can now gain access to direct volatility trades via almost 40 related ETNs and ETFs. Exchange trading on these products continues to be high, despite the relatively tranquil equity markets during the past few years, with a market capitalization now exceeding $3m on VIX products alone. Transactions costs on the prompt futures contracts are now typically less than 5 bps, as trading continues in very high volumes. We have highlighted the similarities and differences between the US and the European volatility derivatives markets, providing several useful insights for potential investors in these products.

The average holding time for a VIX futures contract ranges from about one week for short-term contracts to about one month on longer-term contracts, and even short-term VSTOXX futures still have average holding periods a little greater than one month. The ETNs that are linked to VIX futures and those that track mid-term futures contracts are held, on average, for about 6 weeks. This shows that VIX futures and some ETNs are currently being held for diversification purposes. Indeed, all the evidence points to a large community of traditional capital asset investors that are holding these products as a means of diversification. Our up-to-date results on sustained high levels of roll costs, and the increasingly brief periods of backwardation that are experienced particularly in the US volatility futures term structures, should serve as a warning to this community.

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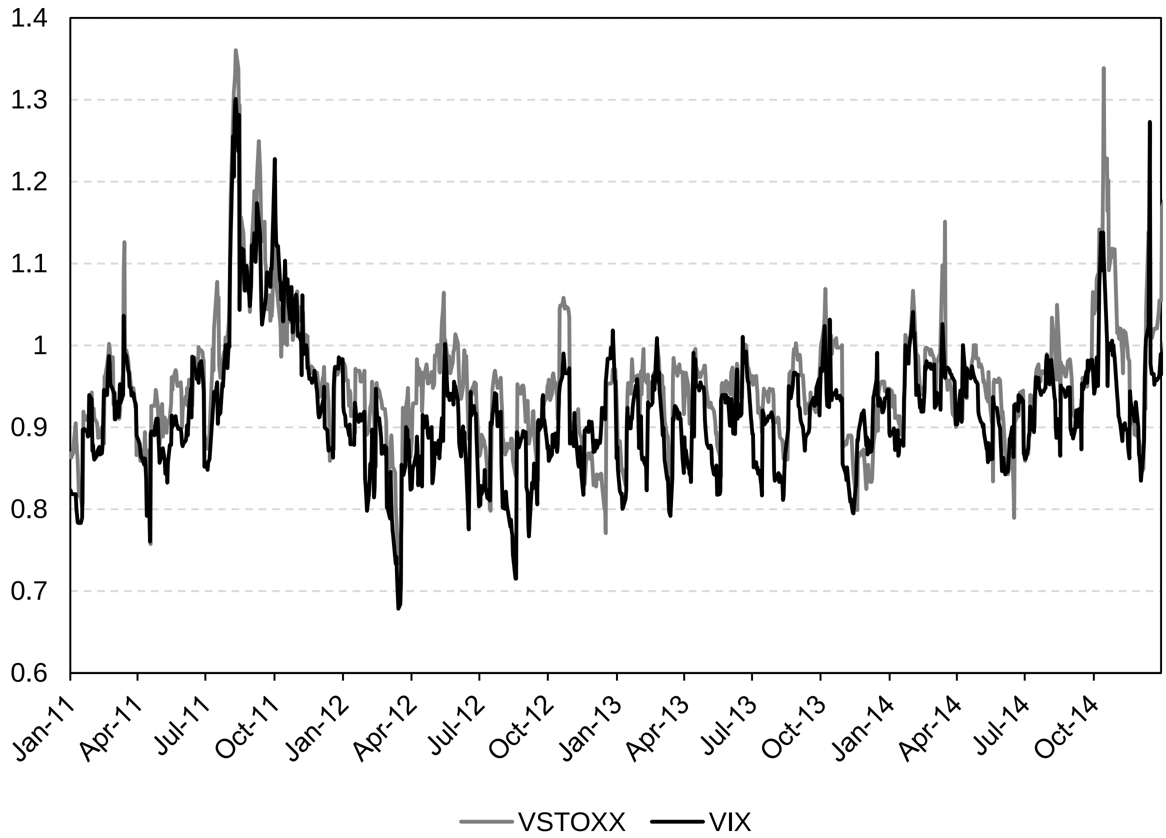
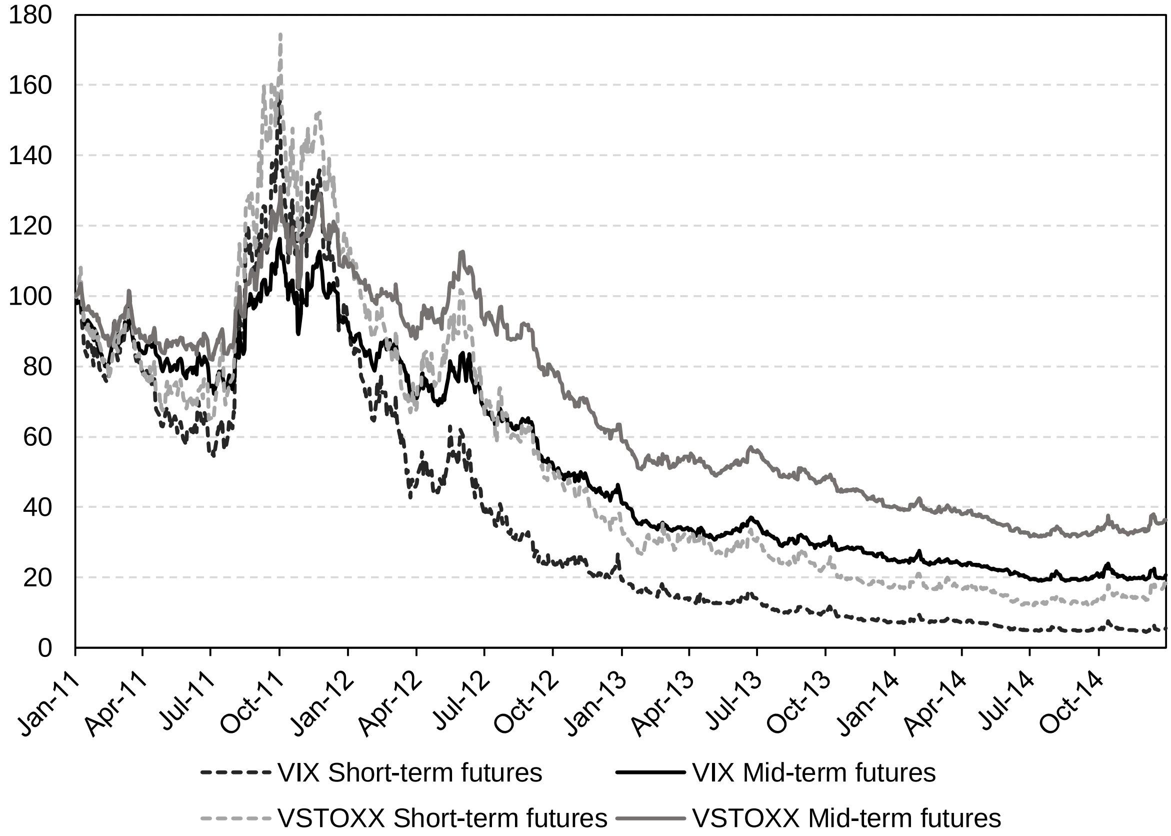
Figure 1: Slope of the Volatility Futures Term Structure



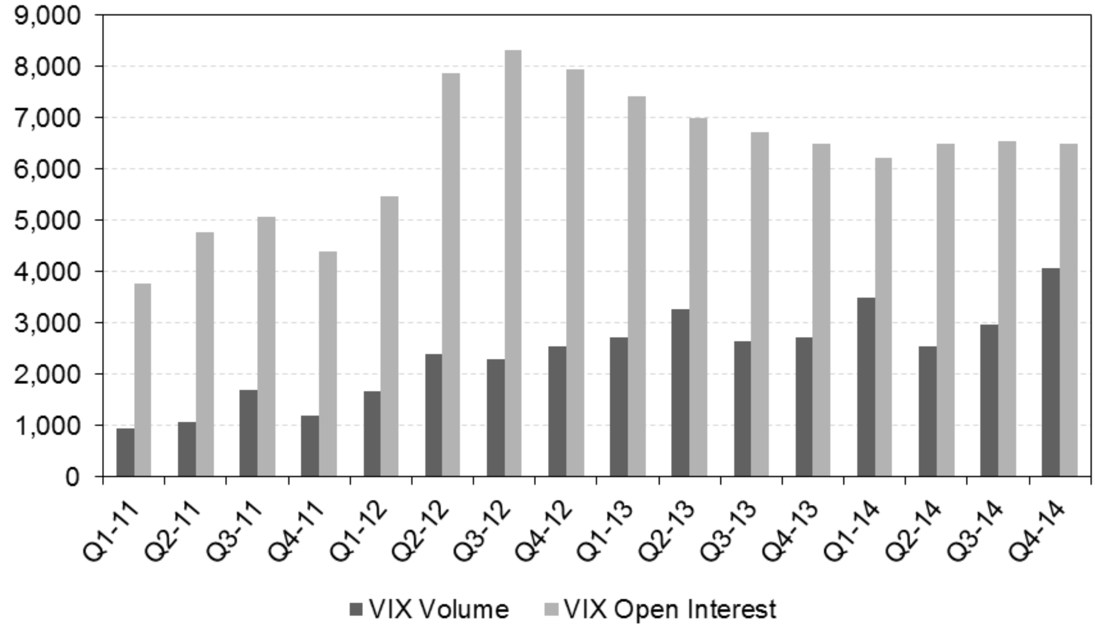
The graph shows the slope measure as the ratio of the closing daily price of the prompt futures contract to the equivalent price of the next-to-mature futures contract. So a value greater than one indicates backwardation and a value less than one indicates contango at the short-end of the term structure. The black (grey) line represents the slope of the VIX (VSTOXX) futures term structure.

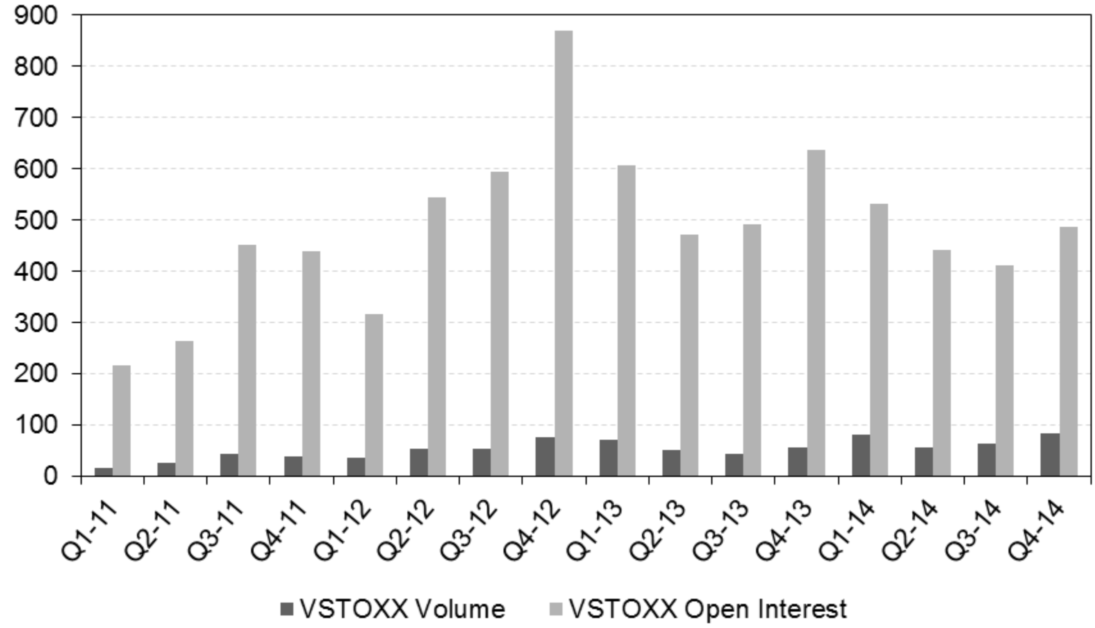
Figure 2: Constant-Maturity Futures Indices



Evolution of the constant-maturity VIX and VSTOXX futures indices, calculated by Standard & Poor's and STOXX. Short-term indices replicate the performance of a constant exposure to the corresponding 1-month volatility futures contract. Mid-term indices replicate the performance of a constant exposure to the corresponding 5-month volatility futures contract. The sample period is 3 January 2011 to 31 December 2014.

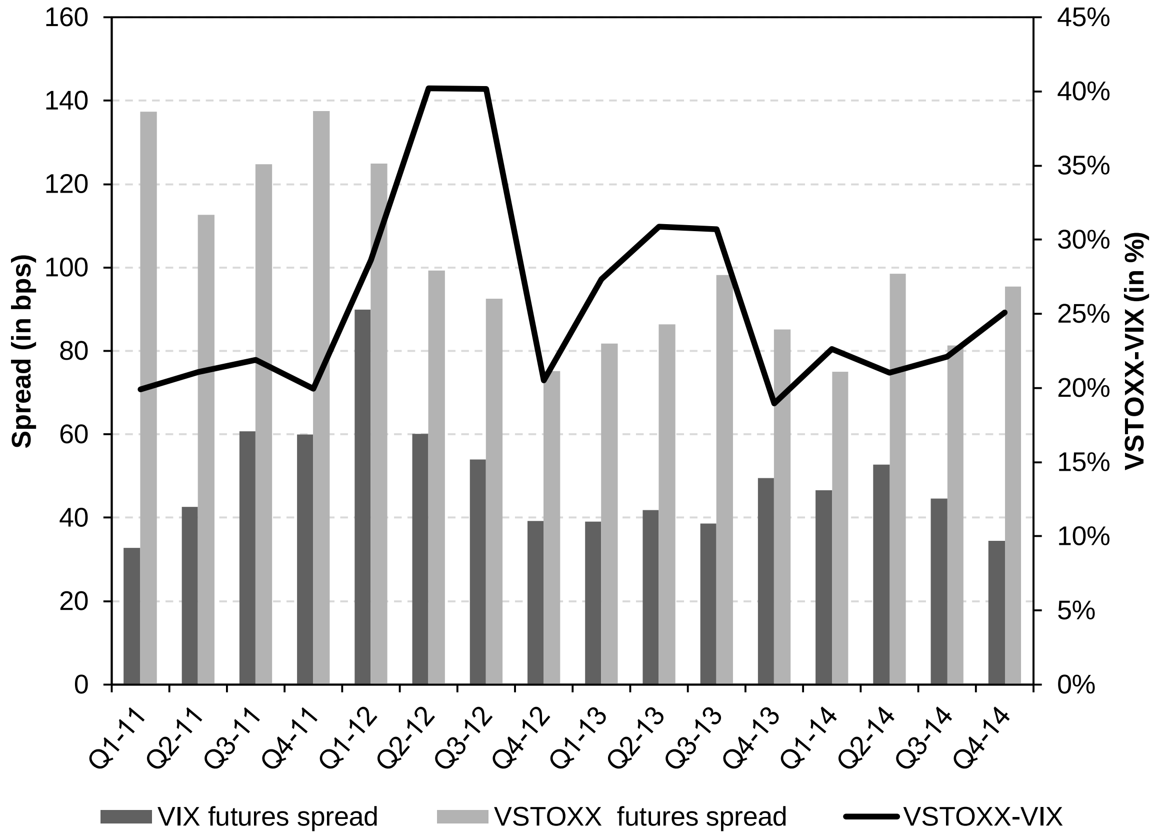
Figure 3: Volume and Open Interest of VIX and VSTOXX Futures





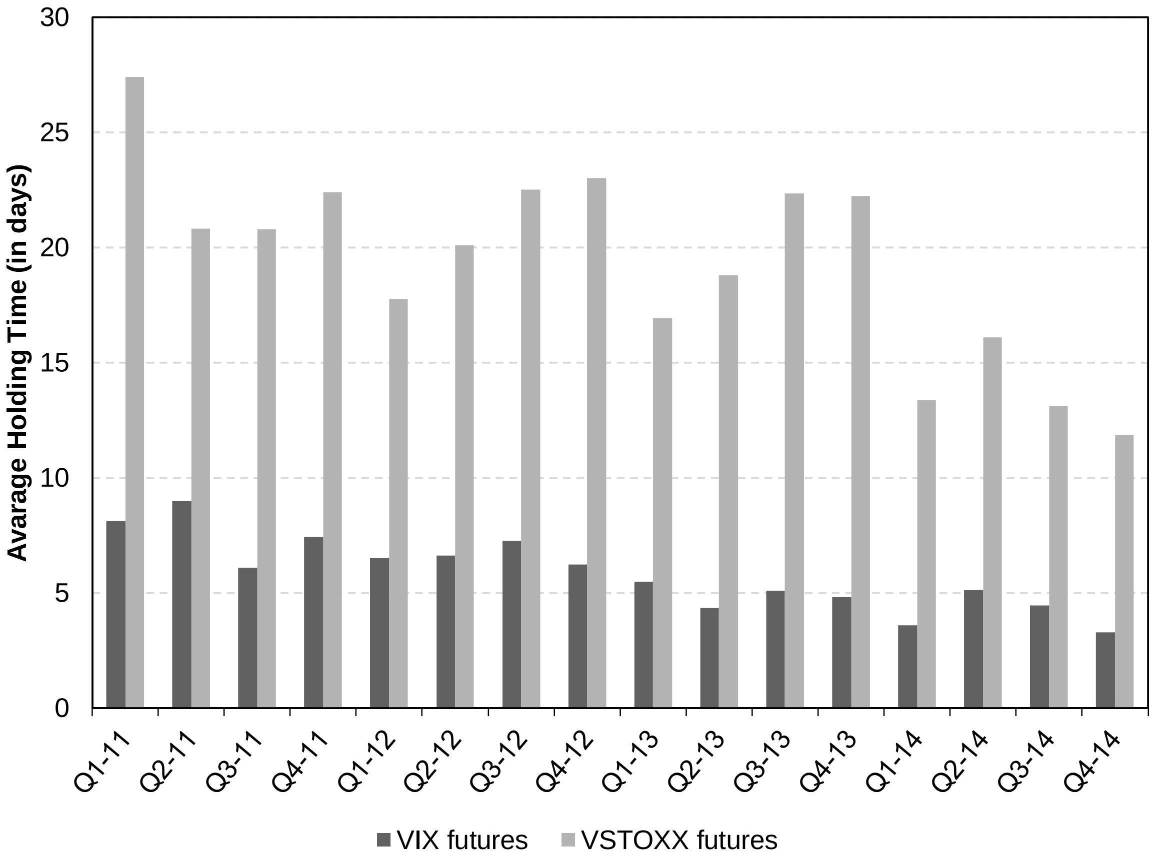
Average daily trading volume and open interest (in million USD) for VIX futures (top chart) and VSTOXX mini-futures (bottom chart).

Figure 4: Average Spreads and Differences in Levels for VIX and VSTOXX Futures



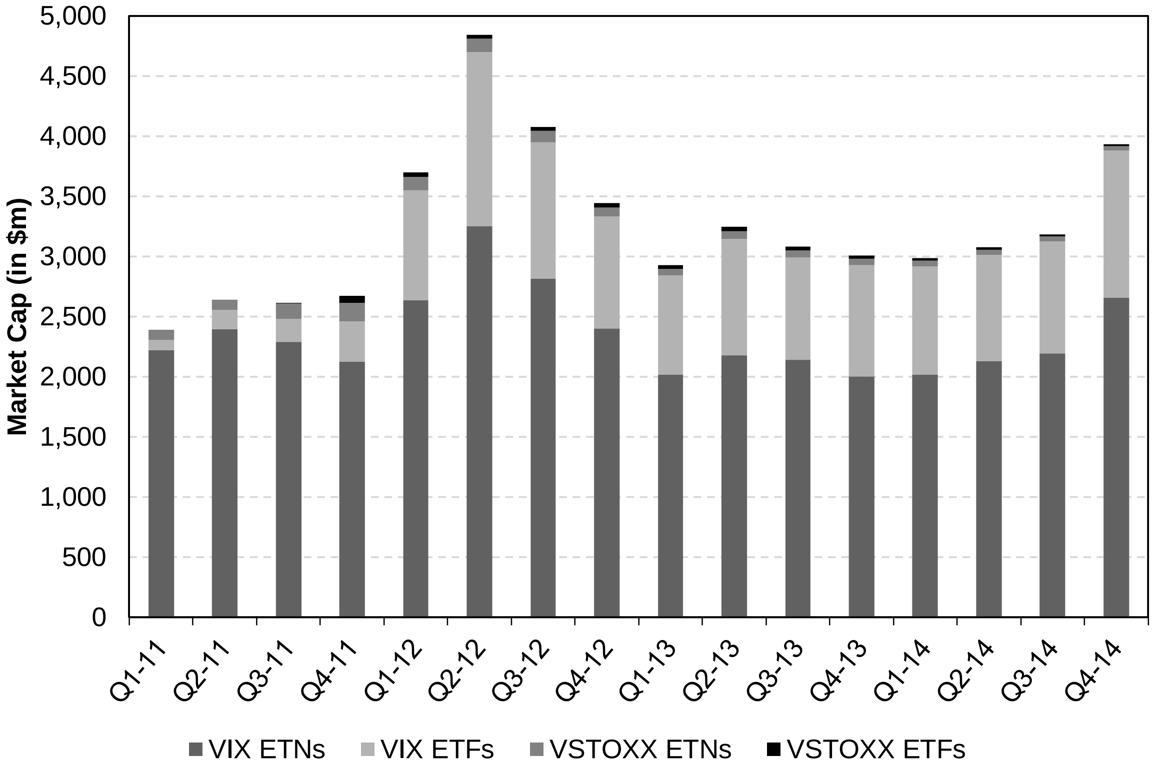
Spread (left scale, in bps) is the difference between the Ask and Bid prices as a percentage of the Mid price. VSTOXX-VIX (right scale, in %) is the relative difference in levels between VSTOXX and VIX front futures contracts. Numbers are averaged over the last quarter. The sample period is 3 January 2011 to 31 December 2014.

Figure 5: Average Turnover Times on Volatility Futures



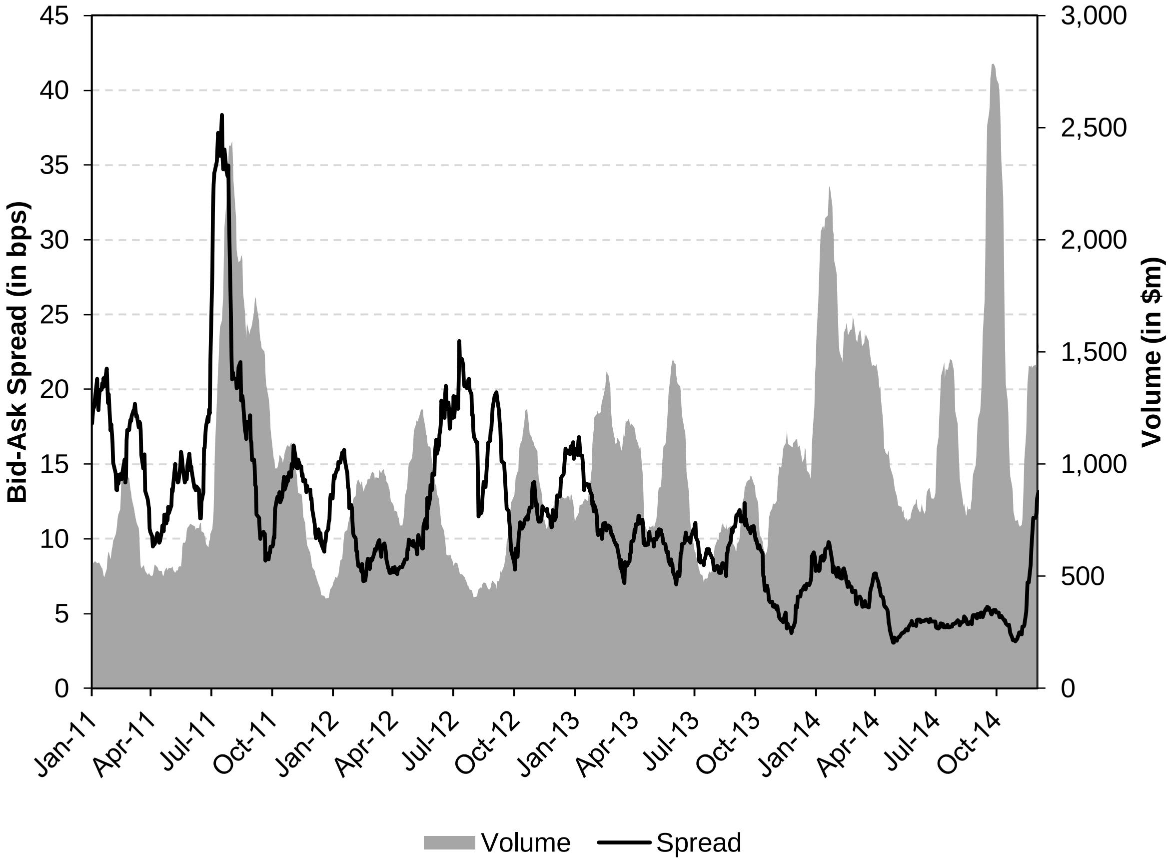
Average holding time of VIX and VSTOXX futures contracts, computed using (Eq. 1) and averaged over the last quarter. The sample period is 3 January 2011 to 31 December 2014.

Figure 6: Market Capitalization of Exchange-Traded Products



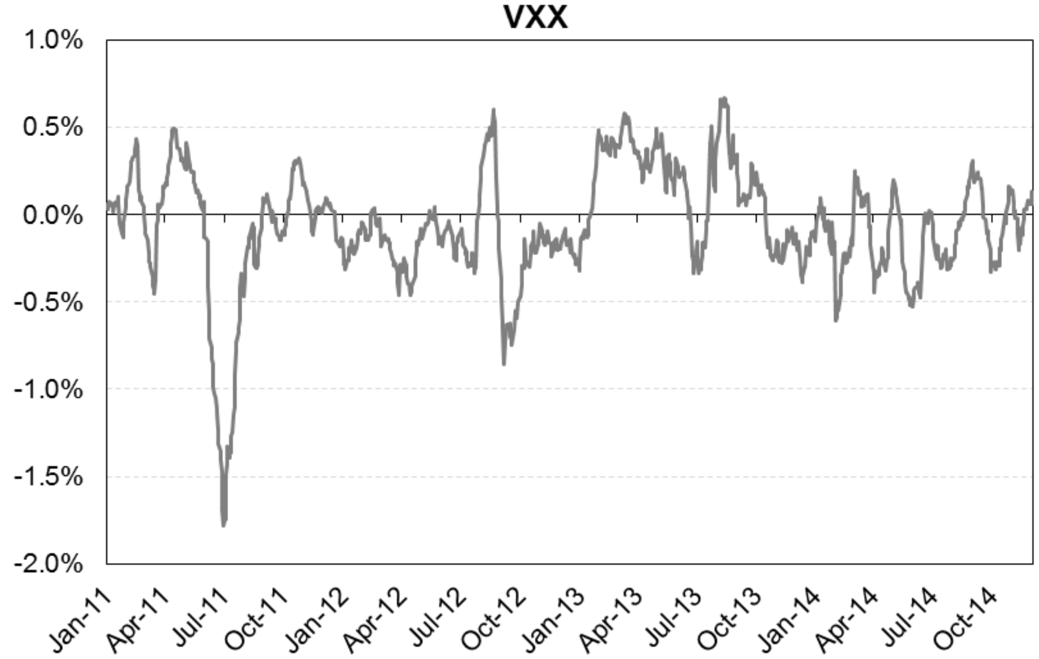
Market Capitalization of Exchange-Traded Products (in million USD) averaged over the last quarter. The sample period is 3 January 2011 to 31 December 2014.

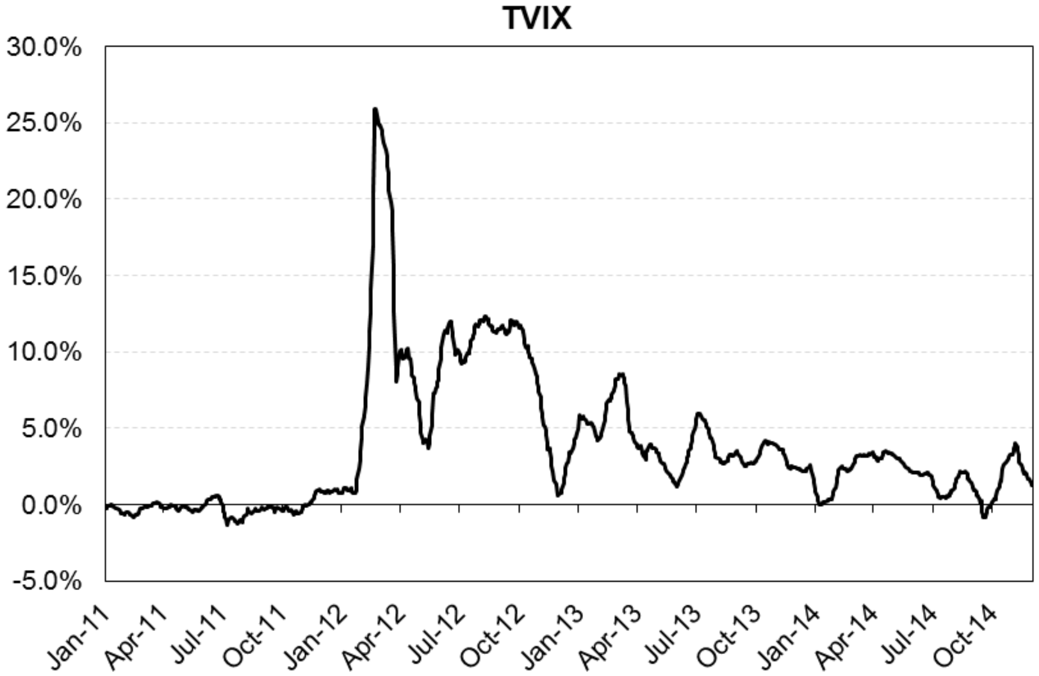
Figure 7: Spread and Trading Volume of VXX



Spread and Trading Volume of Barclays short-term ETN VXX. Spread (in basis points) is defined as the difference between the Ask and Bid prices as a percentage of the Mid price. Trading volume (in million USD) is the number of shares traded per day times the market price of the ETN. Series are smoothed by averaging over the last 22 trading days. The sample period is 3 January 2011 to 31 December 2014.

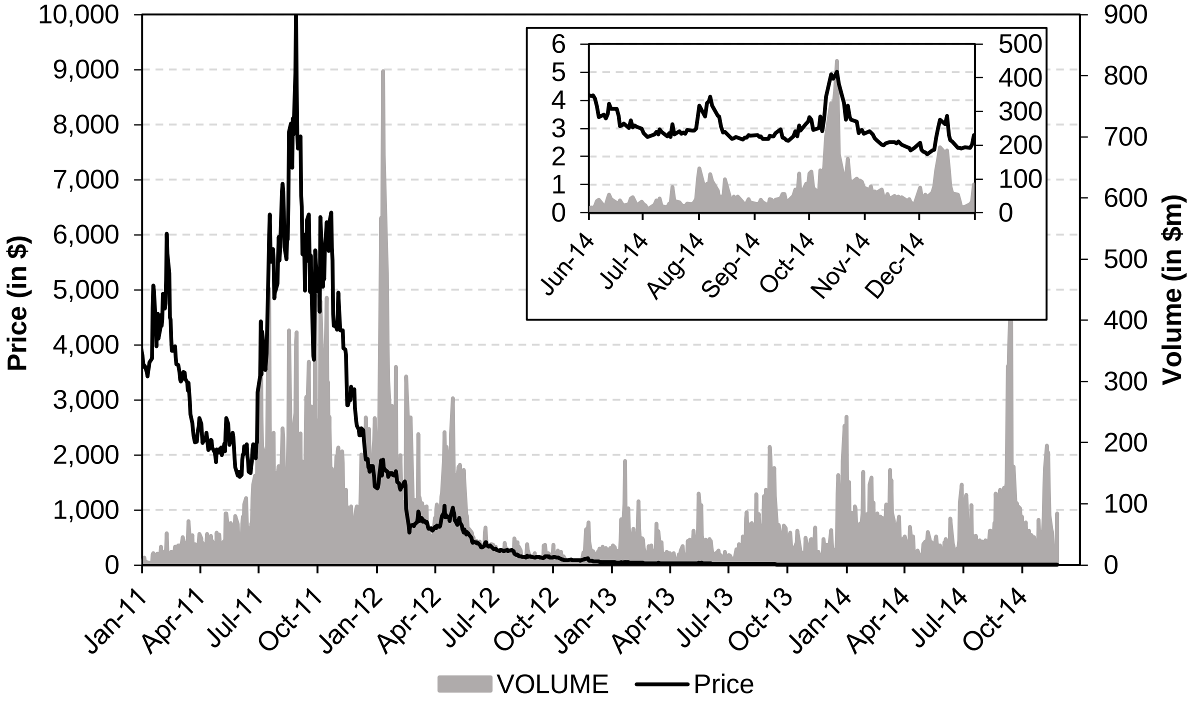
Figure 8: VXX and TVIX Market Risk Premiums





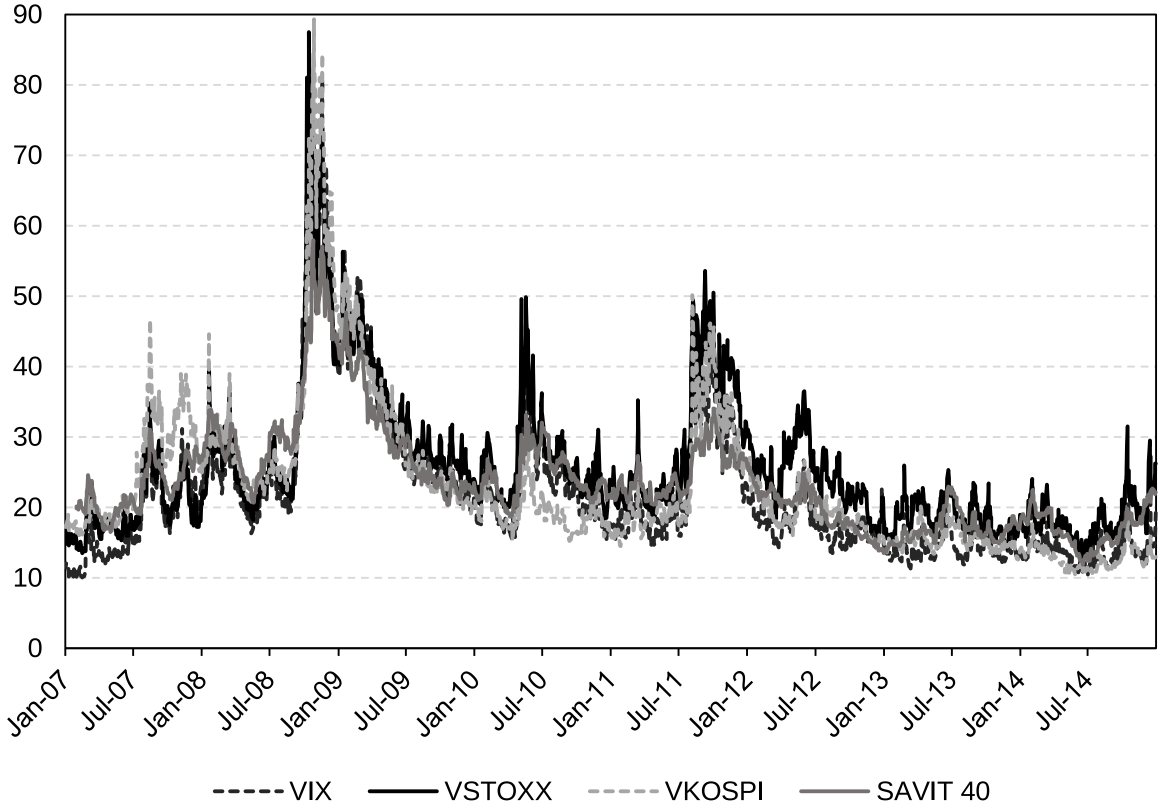
Premiums for VXX (top chart) and TVIX (bottom chart) are calculated as the percentage difference of the market traded price relative to the indicative value of the product at the end of the day. Series are smoothed by averaging over the last 22 trading days. In 2012, in the period from 22 February to 23 March, the premium of TVIX over its indicative value increased steadily and reached levels over 89% with the monthly average of up to 26%. The sample period is 3 January 2011 to 31 December 2014.

Figure 9: Price and Trading Volume of TVIX



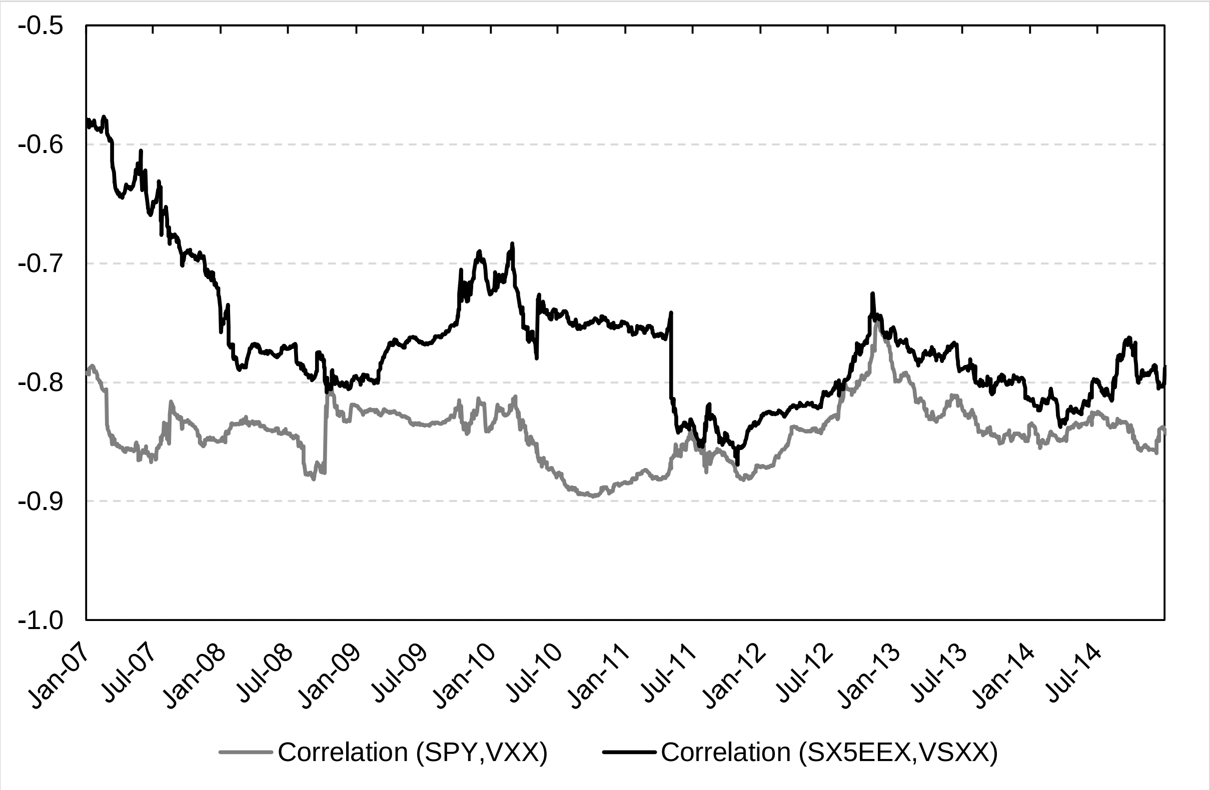
Daily price development and trading volume (in million USD) of TVIX since January 2011 (main chart) and since June 2014 (inset). Trading volume is the number of shares traded per day multiplied with the market price of the ETN. Series are adjusted for two 1:10 reverse splits occurring in December 2012 and August 2013.

Figure 10: Equity Volatility Indices



Evolution of a selection of volatility indices, quoted daily from 3 January 2007 to 31 December 2014.

Figure 11: Correlations between Equity Index and Volatility ETPs



1-year rolling correlations between Equity and Volatility ETFs: US S&P 500 ETF (SPY) and US short-term VIX ETN (VXX), EURO STOXX 50 ETF (SX5EEX) and European short-term VSTOXX ETN (VSXX). Correlations are based on the previous 250 daily returns, from 3 January 2007 to 31 December 2014.

Table 6: Weekly Correlation Matrix for Volatility Indices

	VIX	VSTOXX	VFTSE	VHSI	VNKY	SPAVIX	SAVIT40	VIMEX	VKOSPI	INVIXN	RTSVX
VIX	1.00										
VSTOXX	0.83	1.00									
VFTSE	0.79	0.87	1.00								
VHSI	0.53	0.59	0.57	1.00							
VNKY	0.51	0.55	0.57	0.64	1.00						
SPAVIX	0.56	0.55	0.59	0.64	0.60	1.00					
SAVIT40	0.53	0.55	0.49	0.52	0.47	0.47	1.00				
VIMEX	0.61	0.54	0.55	0.52	0.44	0.46	0.46	1.00			
VKOSPI	0.53	0.57	0.58	0.70	0.61	0.63	0.40	0.47	1.00		
INVIXN	0.32	0.33	0.28	0.42	0.29	0.35	0.25	0.28	0.35	1.00	
RTSVX	0.37	0.46	0.39	0.41	0.37	0.34	0.37	0.36	0.40	0.23	1.00

Correlations for the main equity volatility indices, calculated using weekly returns from January 2008 to December 2014.

Table 7: Daily Correlation Matrix for CBOE Volatility Indices

	VIX	SRVX	OVX	GVZ	EVZ	VXEEM	VXSLV	VXFXI	VXGDX	VXEWZ	VXXLE	VVIX	VXTYN
VIX	1.00												
SRVX	0.02	1.00											
OVX	0.56	0.05	1.00										
GVZ	0.42	0.07	0.42	1.00									
EVZ	0.43	0.14	0.32	0.36	1.00								
VXEEM	0.80	0.10	0.54	0.43	0.45	1.00							
VXSLV	0.42	0.04	0.39	0.74	0.29	0.43	1.00						
VXFXI	0.66	0.06	0.50	0.37	0.42	0.79	0.34	1.00					
VXGDX	0.53	0.01	0.45	0.55	0.37	0.56	0.55	0.51	1.00				
VXEWZ	0.68	0.06	0.50	0.39	0.41	0.78	0.37	0.73	0.54	1.00			
VXXLE	0.86	0.02	0.64	0.44	0.44	0.79	0.45	0.70	0.59	0.70	1.00		
VVIX	0.84	0.00	0.45	0.33	0.35	0.67	0.36	0.53	0.43	0.57	0.72	1.00	
VXTYN	0.26	0.38	0.21	0.25	0.29	0.27	0.17	0.21	0.17	0.24	0.21	0.23	1.00

Correlations for the main CBOE volatility indices, calculated with daily returns from 1 March 2011 to 31 December 2014.

The data for the Interest Rate Swap Volatility Index (SRVX) starts on 18 June 2012