

Elasticity dynamics between VIX futures and ETPs: a quantile regression analysis of intraday and closing market behavior

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Abstract

Purpose – The authors investigate the elasticity between VIX exchange traded products (ETPs)–including ETNs (VXX, XIV and TVIX) and ETFs (VIXY, SVXY and UVXY)–and VIX Futures.

Design/methodology/approach – This study applies quantile regression to uncover nonlinear elasticity dynamics in the daily price interactions between ETPs and Futures.

Findings – Employing decile regressions on the S&P 500 VIX Short-Term Total Return Index (SPVXSTR), the authors find that elasticity of VIX Futures to ETP prices is lower at market close but higher intraday, potentially due to liquidity differences, with peaks at the distribution's extremes at close. VXX exhibits significantly higher elasticity than VIXY, likely due to its dominant, unhedged note structure, while XIV and SVXY show similar elasticity, and TVIX's elasticity is half that of UVXY, reflecting its reduced leverage. These findings suggest that intraday liquidity amplifies futures responsiveness, with implications for hedging strategies during volatile closes and portfolio construction favoring dominant instruments such as VXX.

Originality/value – The linear relations between VIX ETPs and VIX Futures are well documented in the literature using mean-regression approaches, here estimated elasticities are assumed constant across the distribution of VIX Futures and ETPs. This study extends the analysis by employing quantile regression to capture quantile-specific elasticities, allowing for a more nuanced examination of inverse and leveraged products, where elasticity dynamics remain largely unexplored.

Keywords Elasticity, VIX, Exchange traded products, Quantile regression

Paper type Research article

1. Introduction

Whaley (1993) predicted the rise of VIX derivatives a decade before their 2004 debut. Since then, ETPs, including asset- or futures-based ETFs and unsecured ETNs tracking benchmark indices, have emerged from the CBOE Volatility Index (VIX), enabling tailored volatility exposure for trading and hedging. VIX derivatives markets now compete with SPX and SPY options, with VIX Options and Futures showing significant influence, as O'Neill and Whaley (2023) analyze through the impact of nondiscretionary trading on futures prices, potentially highlighting mechanisms like price pressure in markets such as VIX Futures (O'Neill and Whaley, 2023).

Retail investors find ETPs appealing for their simplicity and liquidity (Broman, 2016), though they differ from traditional funds due to clientele effects (Agapova, 2011). VIX ETPs have grown popular for volatility management and access to derivatives markets (Whaley,



2013), despite risks like the “contango trap,” where futures curves slope upward 80% of the time (Shu and Zang, 2012; Gehricke and Zhang, 2018; Johnson, 2017; Hill, 2013; Alexander and Korvilas, 2013). Price discovery likely occurs in liquid, low-cost markets (Fleming *et al.*, 1996), influenced by factors like liquidity, latency, and high-frequency trading (Ozturk *et al.*, 2017; Benos and Sagade, 2016; Riordan and Storkenmaier, 2012), with O’Neill and Rajaguru (2023) investigating the directional influence of price movements between VIX ETPs and VIX Futures to uncover these dynamics (O’Neill and Rajaguru, 2023).

VIX, untradeable except at expiry (Zhu and Lian, 2012; Lin, 2007), relies on VIX Futures—cost-free and dominant in volatility trading—for forward expectations (Bollen *et al.*, 2017; Frijns *et al.*, 2016). VIX Options tie to Futures via put-call parity (Bollen *et al.*, 2017). The causal relations between VIX ETPs and Futures are well established (Frijns *et al.*, 2016; Shu and Zhang, 2012; Posselt, 2021; Bordonado *et al.*, 2017), with O’Neill and Rajaguru (2024) exploring how this causality varies across high and low volatility periods (O’Neill and Rajaguru, 2024), including inverse and leveraged ETPs (Fernandez-Perez *et al.*, 2018; Whaley, 2013; Park, 2015). We analyze key ETNs (VXX, TVIX, XIV) and ETFs (VIXY, UVXY, SVXY), supported by O’Neill and Rajaguru (2019), who develop a response surface analysis method to determine critical values for lead-lag ratios, applied to high-frequency, non-synchronous financial data for studying such temporal relationships (O’Neill and Rajaguru, 2019). However, the non-linear dynamic relationship between ETNs and ETFs are likely to be different across different quantiles.

We study elasticity of price changes in VIX ETPs to VIX Futures using quantile regressions. Decile regressions reveal that VIX Futures elasticity to VXX is high intraday but lower at close, with heightened sensitivity at the distribution’s extreme ends during closing periods; while XIV dominates elasticity end-of-day from 3:45–4:15 p.m., overall elasticity increases in higher deciles intraday, likely driven by liquidity differences and shifting hedging demands brought forward earlier in the day.

2. Data sources

We examine the intraday price movements of the SPVXSTR, alongside three VIX ETNs (VXX, XIV, TVIX) and three ETFs (VIXY, SVXY, UVXY), all tied to that index.

VXX, launched January 29, 2009, and VIXY launched March 1, 2011, both track SPVXSTR daily returns minus fees. XIV, launched November 29, 2010, and SVXY, launched October 3, 2011, inversely track SPVXSTR. TVIX, launched November 29, 2010, and UVXY, launched October 3, 2011, double SPVXSTR’s daily returns.

Data are sourced for these, along with the two nearest maturity VIX Futures contracts, Thomson Reuters Tick History (TRTH) via SIRCA, recorded to the millisecond.

The SPVXSTR, launched December 20, 2005, is a weighted series of the two nearest futures contracts, rebalanced daily for a 30-day maturity. SPVXSTR data were obtained from TRTH in five-second intervals.

Daily NYSE TAQ data for VXX, XIV, VIXY, SVXY, UVXY and TVIX were accessed via Wharton Research Data Services from their inception through March 31, 2018, capturing the February 5, 2018, liquidity event but ending February 15, before XIV’s delisting and leverage adjustments to UVXY and SVXY. More recent developments such as the introduction of Convexityshares Daily 1.5x Spikes Futures ETF Fund (SPKY), restrictions on short-VIX strategies, and adjustments to leverage rules may affect the generalizability of the findings. A brief comment in the main text or a footnote could effectively address this.

3. Methodology

As opposed to the OLS estimates where we minimize the sum of squared residual (i.e. $\min_{\beta} \sum_i (y_i - \mu(x_i, \beta))^2$), the quantile regression minimizes a weighted sum of absolute errors, assigning asymmetric weights to over- and under-predictions,

$$\min_{\beta} \left(\sum_{i: y_i \geq \eta} q |y_i - \eta(x_i, \beta)| + \sum_{i: y_i < \eta} (1 - q) |y_i - \eta(x_i, \beta)| \right)$$

where the weights depend on the specified quantile (see [Koenker, 2005](#); [Koenker and Hallock, 2001](#)).

In this study, we consider the following quantile regression models to estimate the elasticity of price changes in ETNs to VIX Futures:

$$\ln(\text{SPVXSTR}_t) = \beta_1^{(q)} + \beta_2^{(q)} \ln(\text{TVIX}_t) + \beta_3^{(q)} \ln(\text{VXX}_t) + \beta_4^{(q)} \ln(\text{XIV}_t) + e_t^{(q)}$$

The parameters $\beta_i^{(q)}$'s expected to vary for each q-th quantile within the range of $0 \leq q \leq 1$.

We have also considered VIXY, SVXY, and UVXY ETFs in place of ETNs VXX, XIV and TVIX:

$$\ln(\text{SPVXSTR}_t) = \beta_1^{(q)} + \beta_2^{(q)} \ln(\text{VIXY}_t) + \beta_3^{(q)} \ln(\text{UVXY}_t) + \beta_4^{(q)} \ln(\text{SVXY}_t) + e_t^{(q)}$$

4. Elasticity of VIX futures to ETPs

We now turn to assessing the elasticity of VIX futures to VIX ETP prices using a decile regression approach. [Table 1](#) (the corresponding graphs: [Figures 1](#) and [2](#)) summarizes the results of a decile regression of $\ln(\text{SPVXSTR})$ on various $\ln(\text{ETP})$ returns, based on the full sample of intraday 15-min log returns, excluding overnight returns. Panel A covers November 29, 2010, to February 15, 2018—when all ETNs (TVIX, VXX, XIV) traded concurrently—regressing the futures index return, $\ln(\text{SPVXSTR})$, on $\ln(\text{TVIX})$, $\ln(\text{VXX})$, and $\ln(\text{XIV})$. The coefficients, though small economically, are statistically significant at the 1% level across all deciles, confirmed by the Wald test (chi-square distribution, one degree of freedom). The constant, such as 0.096 in the first row of Panel A, indicates an SPVXSTR level of $\exp(0.096)$ or 1.10 when $\text{TVIX} = \text{VXX} = \text{XIV} = 1$. Panel B spans October 3, 2011, to February 15, 2018—when all ETFs (UVXY, VIXY, SVXY) traded concurrently—using all intraday data and the final 30 min before close. Elasticity, interpreted from the log coefficients, varies notably: in Panel A's first decile, a 1% VXX return yields a 0.568% SPVXSTR return, while the reverse effect of $\ln(\text{SPVXSTR})$ on $\ln(\text{VXX})$ is 1/0.568 or 1.761%, enabled by cointegration of all variables. Updated results reveal elasticity is lower at the close but higher intraday, possibly due to liquidity differences, and peaks at the distribution's extreme ends at close. For example, a 1% change in VXX corresponds to an 0.568% change in SPVXSTR during intraday trading and a 0.260% change at market close at the first decile. Similarly, a 1% change in VIXY corresponds to an 0.283% change in SPVXSTR during intraday trading and a 0.168% change at market close at the first decile. Comparing ETNs and ETFs, XIV and SVXY show similar elasticity, while TVIX's elasticity is half that of UVXY, consistent with TVIX's leverage ratio being halved. Notably, VXX exhibits much higher elasticity than VIXY, likely due to its dominance as an unhedged note structure, unlike ETFs. Sensitivity of SPVXSTR to XIV increases across Panel A's higher deciles intraday, though it diminishes at close, reflecting shifting hedging demands.

The research findings carry significant implications for understanding VIX futures and ETP dynamics. The observation that elasticity is lower at market close but higher during the

Table 1. Decile regression of VIX futures on VIX ETPs for the period November 29, 2010 through February 15, 2018

Panel A - VXX, TVIX and XIV ETNs with SPVXSTER

Full sample					3:45–4:15p.m.				
Decile	ln (TVIX)	ln (VXX)	ln (XIV)	Constant	Decile	ln (TVIX)	ln (VXX)	ln (XIV)	Constant
0.1	0.096	0.568	−0.183	0.096	0.1	0.048	0.260	−0.321	−0.0004
0.2	0.090	0.588	−0.197	0.090	0.2	0.037	0.216	−0.319	−0.0002
0.3	0.088	0.585	−0.207	0.088	0.3	0.030	0.153	−0.309	−0.00008
0.4	0.085	0.580	−0.219	0.085	0.4	0.023	0.094	−0.327	−0.00003
0.5	0.084	0.573	−0.228	0.084	0.5	0.023	0.094	−0.326	0.0000
0.6	0.084	0.568	−0.233	0.084	0.6	0.024	0.094	−0.324	0.00007
0.7	0.085	0.561	−0.236	0.085	0.7	0.030	0.153	−0.306	0.00008
0.8	0.087	0.551	−0.237	0.087	0.8	0.037	0.215	−0.314	0.0002
0.9	0.084	0.525	−0.245	0.084	0.9	0.048	0.255	−0.315	0.0004

Panel B - VIXY, UVXY and SVXY ETFs with SPVXSTER

Full sample					3:45–4:15p.m.				
Decile	ln (UVXY)	ln (VIXY)	ln (SVXY)	Constant	Decile	ln (UVXY)	ln (VIXY)	ln (SVXY)	Constant
0.1	0.264	0.283	−0.142	0.264	0.1	0.154	0.168	−0.243	−0.001
0.2	0.269	0.275	−0.165	0.269	0.2	0.172	0.169	−0.227	−0.0007
0.3	0.259	0.278	−0.185	0.259	0.3	0.136	0.156	−0.197	−0.0003
0.4	0.251	0.289	−0.191	0.251	0.4	0.065	0.146	−0.156	−0.00004
0.5	0.247	0.289	−0.198	0.247	0.5	0.048	0.156	−0.149	0.00000
0.6	0.246	0.286	−0.202	0.246	0.6	0.061	0.151	−0.158	0.00004
0.7	0.252	0.273	−0.201	0.252	0.7	0.132	0.159	−0.201	0.0003
0.8	0.255	0.266	−0.194	0.255	0.8	0.168	0.182	−0.226	0.0007
0.9	0.245	0.266	−0.187	0.245	0.9	0.161	0.184	−0.232	0.001

Note(s): Table shows the coefficients of a decile regression fitted with the dependent variable being ln (SPVXSTR) and the independent variables natural logarithm of 15 min ETP returns. The regression is fitted over the entire period. Panel A contains the results using November 29, 2010 through February 15, 2018—the period during which all ETNs were traded concurrently. Panel B contains the results using October 3, 2011 through February 15, 2018—the period during which all ETFs were traded concurrently. All estimated coefficients are significant at the one percent probability level

Source(s): Authors' own work

trading day, potentially due to liquidity differences, suggests that intraday trading conditions amplify the responsiveness of VIX futures to ETP price changes, offering traders opportunities to exploit these variations (O'Neill and Rajaguru, 2024). The heightened elasticity at the extreme ends of the distribution at close implies that during volatile closing periods, VIX futures may overreact to ETP movements, impacting hedging strategies in stress scenarios. The similar elasticity between XIV ETNs and SVXY ETFs indicates that structural differences between ETNs and ETFs may not significantly alter their influence on VIX futures, providing flexibility in instrument choice for investors. In contrast, the finding that TVIX ETNs exhibit half the elasticity of UVXY ETFs, aligning with TVIX's reduced leverage ratio, underscores how leverage adjustments directly shape market impact. Finally, the notably higher elasticity of VXX compared to VIXY ETFs, likely due to VXX's dominance and unhedged note structure, highlights its outsized role in driving VIX futures, relative to ETF counterparts, with implications for portfolio construction and volatility trading (O'Neill and Rajaguru, 2023).

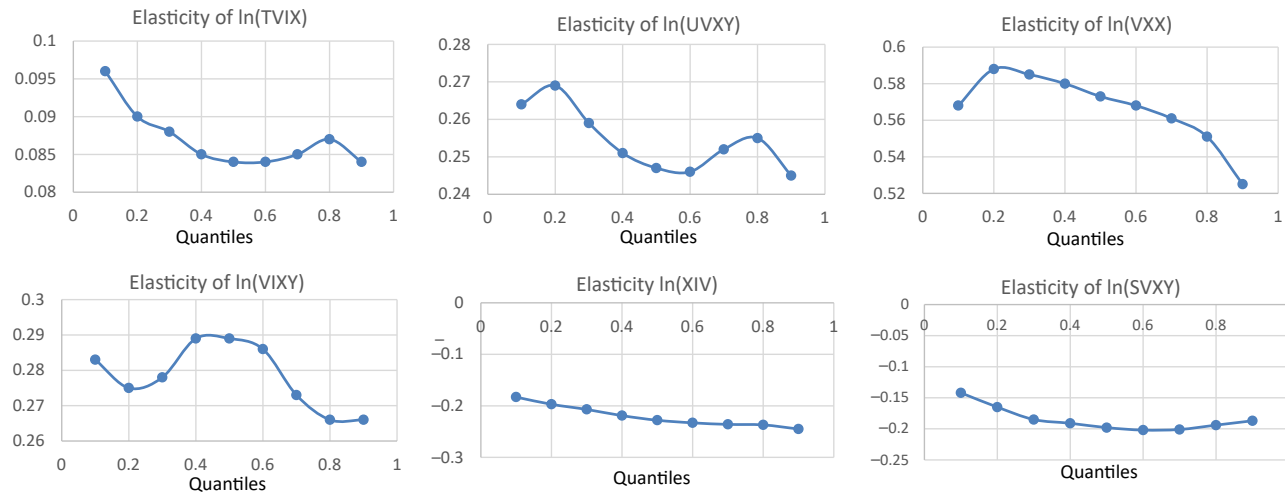


Figure 1. Full sample results: elasticities at different quantiles, dependent variable: $\ln(\text{SPVXSTR})$. **Note(s):** Figure shows the elasticities of a decile regression fitted with the dependent variable being $\ln(\text{SPVXSTR})$ and the independent variables natural logarithm of 15-min ETP returns. The regression is fitted over the entire period. **Source(s):** Authors' own work

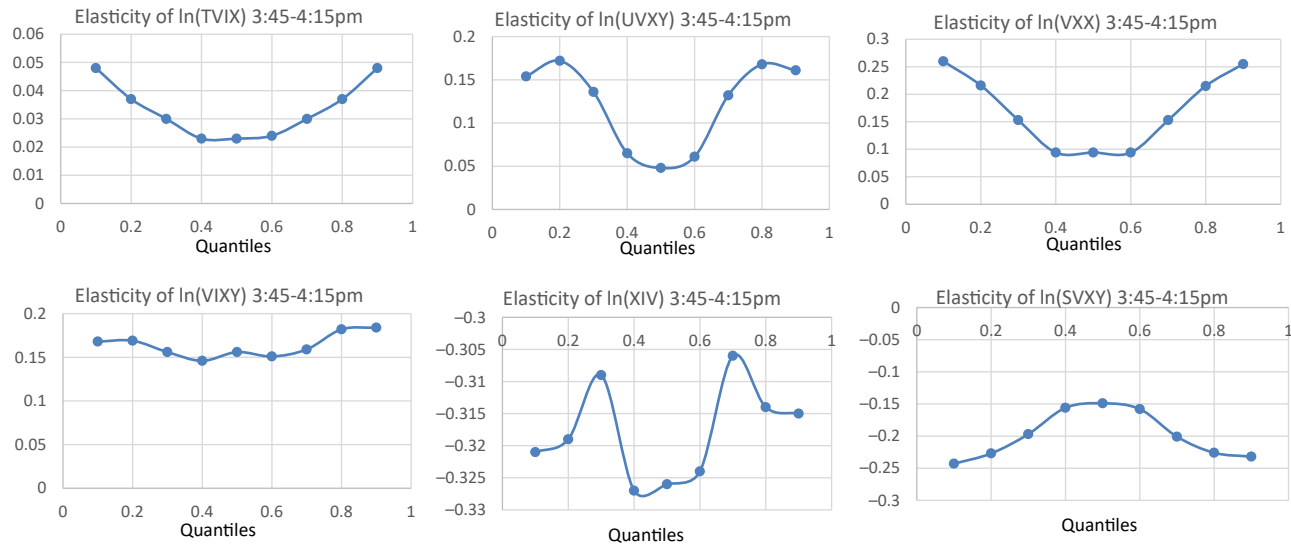


Figure 2. Closing sample results: elasticities at different quantiles, dependent variable: SPVXSTER. **Note(s):** Figure shows the elasticities of a decile regression fitted with the dependent variable being $\ln(\text{SPVXSTR})$ and the independent variables natural logarithm of 15-min ETP returns. The regression is fitted over the closing sample. **Source(s):** Authors' own work

5. Conclusion

This paper examines the elasticity dynamics between VIX ETPs and VIX Futures contracts. VIX product markets have expanded to rival SPX and SPY options as leading platforms for trading and hedging volatility. This surge in investor activity has been accompanied by evolving causal relationships between VIX Futures and ETPs over time.

Decile regressions highlight the sensitivity of VIX Futures prices to ETP prices and how these changes in different volatility environments. Results show that VIX futures, as proxied by SPVXSTR, are more responsive to VXX, than to TVIX and XIV except 3:45–4:15p.m. where XIV is dominant. Results also show increasing sensitivity of SPVXSTR to XIV across the full day (panel A) in higher deciles, where higher returns on VIX futures may well drive higher hedging demands for such products such that hedging is brought-forward earlier in the day. Similarly, the results for the associated ETFs, which are less actively traded, are more ambiguous. Practically speaking, the higher elasticity during the trading day means that intraday trading conditions amplify the responsiveness of VIX futures to ETP price changes. Traders may seek to exploit these variations. Similarly, elasticity is heightened at the extreme ends of the distribution at close. VIX futures may overreact to ETP movements and this has implications for calibrating hedging strategies in stress scenarios.

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