Do Hedge Funds Hedge?
New Evidence from Volatility Risk Premia Embedded in VIX Options

**Anmar Al Wakil**¹,²  **Serge Darolles**¹

¹University of Paris-Dauphine, PSL Research University, France
²Natixis Investment Managers

**XIIth Financial Risks International Forum**

Paris, March 19, 2019
Motivation
- Background
- Our Paper
- Main Findings
- Main Contributions

Methodology

Implementation

Results

Conclusion
Figure 1: **A culture of secrecy.** Understanding complex hedge funds strategies has become crucial to explain hedge fund performance, managers’ skills, and compensation scheme.
Figure 2:  Penny-by-penny gains before big losses. This scatterplot exhibits monthly returns between Hedge Fund Global Index and S&P 500 Put Write Index over the period from January 1998 to June 2017.
Background
Alpha or Beta?

”Hedge funds may have strategies that yield payoffs similar to those of a company selling earthquake insurance; that is, most of the time the insurance company makes no payouts and has a nice profit, but from time to time disaster strikes and the insurance company makes large losses that may exceed its cumulative profits from good times. (...) Others have described hedge fund strategies as picking up pennies in front of a steamroller.”

”A hedge fund that implements a strategy akin to selling earthquake insurance and whose risk is not captured well by commonly used risk factors will have a significant positive alpha—until the quake hits.”

Exotic risks are also referred to as “advanced”, “alternative”, or “smart” beta in the literature (e.g., Carhart et al. 2014). In our taxonomy, we separate premium-bearing risks into those that are generally available through liquid, low-cost, and transparent investment vehicles such as index mutual funds or ETFs (traditional beta) from those that can typically only be obtained through hedge funds (exotic beta).”

Our Paper

- HF are not just selling put options but this example is interesting

- The PNL of the strategy is (at least) impacted by two factors
  - When PRICE drops, Put Premium increases, PNL is NEGATIVE
  - When VOL spikes, Put Premium increases, PNL is NEGATIVE

- Under the standard Black-Scholes framework, the two factors are not treated in the same manner
  - (log)-PRICE Variations are stochastic (return distribution)
  - (log)-VOL is a parameter (potentially time-varying)

- How to take into account the stochastic nature of the VOL?
Generally, HF use derivatives to "hedge" some risks, and then are exposed to VOL (distribution).

What is the impact of the stochastic nature of VOL (distribution) on:

- Portfolio/Investment decisions?
- In turn, the cross-section of HF returns?

Already been investigated in Agarwal, Arisoy, Naik (JFE, 2017) paper

BUT

- They implicitly assume that the (log)-VOL is normally distributed
- They build an investment strategy to get an exposure to the VOL of the (log)-VOL distribution
- They use this factor in an asset pricing exercise

Can we extend the study to higher-order moments (SKEW, KURT) of the (log)-VOL distribution?
Our Paper

We solve several technical issues:

1. **The data issue:**
   - How to filter from VIX option market data some information about the *implied distribution* of VOL?
   - How to filter from VIX spot returns a proxy for the *historical distribution* of VOL?

2. **The investable factor issue:**
   - How to build an investable strategy exposed to VOL of VOL?
   - How to build an investable strategy exposed to SKEW of VOL?
   - How to build an investable strategy exposed to KURT of VOL?
Main Findings

1 - HF are particularly VOL sensitive

HF are exposed to VOL risk, and the VOL risk premia are instrumental determinants of HF performance

2 - VOL sensitivity substantially arises from VOL of VOL

HF are particularly negatively exposed to VOL of VOL. This is especially true for Relative Value and Equity Hedge during crises when uncertainty is high

3 - HF are also exposed to higher-order moments of VOL

Relative Value and Directional are positively exposed to SKEW of VOL. Global Macro are positively exposed to SKEW of VOL. Merger Arb are positively exposed to KURT of VOL during crises
First Contribution - Evidence from HF Performance

- Volatility is instrumental in both time-series and cross-section
- Does HF alpha arise from volatility strategies?
- Use of multiple option-based dynamic trading strategies

Existing literature

- Extract VOL risks in HF from nontradable risk measures, or standard and fragmentary option-based strategies

Our contribution

- Extract VOL risks from multiple tradable VOL risk premia
- As decomposed into VOL, SKEW and KURT of VOL strategies
- Shows they are instrumental determinants in HF performance
Second Contribution - Evidence for Risk Premia Strats

- Most HF styles sell crash insurance, but VOL risk exposures across HF styles are complex.
- Depend on specific trading strategies they use to "hedge" risk exposures.

Existing literature

- Evidences on profitable divergence trading strategies to monetize compensation for higher-order risks.

Our contribution

- Evidences that divergence swaps are widely traded by HF.
- Shows VOL, SKEW, KURT of VOL risk premia are mimicking portfolios for VOL risk premia harvested by HF.
1 Motivation

2 Methodology
   • Multifactor Models
   • Volatility Risk Premia
   • Mimicking Portfolios

3 Implementation

4 Results

5 Conclusion
Multifactor Models

- HF returns exhibit **option-like payoffs** replicable by option-based factors.
- We use the same approach with new factors related to the volatility distribution:

\[
R_{it} = \alpha + \sum_{j=1}^{m} \beta_{jt} F_{jt} + \sum_{k=1}^{n} \beta_{kt} F_{kt}
\]

where \(R_{it}\) is returns of \(i\)-th HF strategy.

- **Control variables:** Fung–Hsieh factors (2004)
- **VOL risk premia:** tradable, option–implied
Volatility Risk Premia

- Existing literature usually captures VOL risk from a unique exposure: doesn’t reflect the full extent of volatility strategies [see e.g. Bondarenko (2004), Carr and Wu (2009), Bollerslev et al. (2009)]

**VOL (of VOL) risk premium**

- Widely traded to exploit pricing discrepancies between risk-neutral and realized volatilities (of volatility):

\[ \text{VoV}_{t,t+\tau,T} \equiv E_t^P [\sigma_{t,t-\tau,T}] - E_t^Q [\sigma_{t,t+\tau}] \]

where VoV is the difference between ex-post realized volatility and ex-ante risk-neutral expectation of future volatility

- Correspond to the payoff of a volswap on volatility
Volatility Risk Premia

Let $IV_{t,T}$ volatility smirk at time $t$ for maturity $T$ and moneyness $\xi$. Assume three-dimensional representation of $IV$:

$$IV_{t,T}(\xi) = \begin{cases} 
\gamma_{0,t,T} & \text{Black–Scholes: flat smile} \\
\gamma_{0,t,T} \left[1 + \gamma_{1,t,T} \xi \right] & \text{Skewed IV smile} \\
\gamma_{0,t,T} \left[1 + \gamma_{1,t,T} \xi + \gamma_{2,t,T} \xi^2 \right] & \text{Smirked IV smile}
\end{cases}$$

Figure 3: Smile dynamics contains market price of risk. VOL risks are embedded in level $\gamma_{0,t,T}$, slope $\gamma_{1,t,T}$, and curvature $\gamma_{2,t,T}$.
Mimicking Portfolios

(Using Zhang-Xiang (2008) asymptotic approximations)

\[
\begin{align*}
\gamma_{0,t,T} & \approx \left[1 - \frac{1}{24} (RN Kurt_{t,T} + 3)\right] RNVol_{t,T}, \\
\gamma_{1,t,T} & \approx \frac{1}{6} RN Skew_{t,T}, \\
\gamma_{2,t,T} & \approx \frac{1}{24} [RN Kurt_{t,T} + 3]
\end{align*}
\]

Extending volswaps to higher-order risks gives:

\[
\begin{align*}
VoV_{t,T} &= RD Vol_{t} - RNVol_{t,T} & \text{Volatility Factor} \\
SoV_{t,T} &= RD Skew_{t} - RN Skew_{t,T} & \text{Skewness Factor} \\
KoV_{t,T} &= RD Kurt_{t} - RN Kurt_{t,T} & \text{Kurtosis Factor}
\end{align*}
\]

Volatility risk premia can be replicated by distinct delta-vega-neutral portfolios of European call and put options:

\[
\Pi_{Kurt} = C(S_t, K_2) + \frac{\nu C_2}{\nu P_2} P(S_t, K_2) - C(S_t, K_3) - \frac{\nu C_3}{\nu P_1} P(S_t, K_1) \\
- \left[\Delta C_3 + \frac{\nu C_3}{\nu P_1} \Delta P_1 - \Delta C_2 - \frac{\nu C_2}{\nu P_2} \Delta P_2\right] S_t
\]
1 Motivation

2 Methodology

3 Implementation
   • Estimation

4 Results

5 Conclusion
Implementation

**Risk-neutral estimators**: \( RNVol, RNSkew, \) and \( RNKurt \)
- From market **VIX option prices**, provided by OptionMetrics
- **Model-free** approach of Bakshi, Kapadia, and Madan (2003)

**Realized estimators**: \( RDVol, RDSkew, \) and \( RDKurt \)
- From **high-frequency VIX spot prices**, provided by Bloomberg
- **Two-Scales Realized** measure of Ait-Sahalia, Mykland and Zhang (2005)
- **Bias-corrected** measure using subsampling and averaging to control for market microstructure noise

**VOL risk premia**: \( VoV, SoV, \) and \( KoV \)
- On a **daily** frequency, over **2008-2013**
- Risk premia are highly **ephemeral**: monthly calculations are inappropriate
- Constraint: length of **high-frequency** dataset
### Implementation

#### Panel A: Levels of Option-Implied Risk Premia

<table>
<thead>
<tr>
<th></th>
<th>30 Days Maturity</th>
<th>60 Days Maturity</th>
<th>90 Days Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VoV</td>
<td>SoV</td>
<td>KoV</td>
</tr>
<tr>
<td>Nb. Observations</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Mean</td>
<td>-0.193</td>
<td>-0.718</td>
<td>-6.027</td>
</tr>
<tr>
<td>Median</td>
<td>-0.242</td>
<td>-0.849</td>
<td>-2.680</td>
</tr>
<tr>
<td>Max</td>
<td>1.361</td>
<td>3.031</td>
<td>4.855</td>
</tr>
<tr>
<td>Min</td>
<td>-1.280</td>
<td>-4.555</td>
<td>-35.560</td>
</tr>
<tr>
<td>Standard Dev.</td>
<td>0.397</td>
<td>1.437</td>
<td>8.073</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.736</td>
<td>0.047</td>
<td>-1.437</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>4.017</td>
<td>2.457</td>
<td>4.322</td>
</tr>
<tr>
<td>LBQ Test</td>
<td>79.14*</td>
<td>0.01</td>
<td>0.12</td>
</tr>
<tr>
<td>ADF Test</td>
<td>-8.57**</td>
<td>-14**</td>
<td>-12.07**</td>
</tr>
<tr>
<td>Student Test</td>
<td>-8.41**</td>
<td>-8.66**</td>
<td>-12.93**</td>
</tr>
</tbody>
</table>

#### Panel B: First Differences of Option-Implied Risk Premia

<table>
<thead>
<tr>
<th></th>
<th>30 Days Maturity</th>
<th>60 Days Maturity</th>
<th>90 Days Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VoV</td>
<td>SoV</td>
<td>KoV</td>
</tr>
<tr>
<td>Nb. Observations</td>
<td>299</td>
<td>299</td>
<td>299</td>
</tr>
<tr>
<td>Mean</td>
<td>0.000</td>
<td>-0.094</td>
<td>0.025</td>
</tr>
<tr>
<td>Median</td>
<td>-0.016</td>
<td>-0.032</td>
<td>0.055</td>
</tr>
<tr>
<td>Max</td>
<td>1.166</td>
<td>5.826</td>
<td>30.593</td>
</tr>
<tr>
<td>Min</td>
<td>-1.443</td>
<td>-5.247</td>
<td>-35.141</td>
</tr>
<tr>
<td>Standard Dev.</td>
<td>0.393</td>
<td>2.029</td>
<td>11.543</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.051</td>
<td>0.017</td>
<td>0.059</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>3.687</td>
<td>2.687</td>
<td>3.528</td>
</tr>
<tr>
<td>LBQ Test</td>
<td>49.88*</td>
<td>61.45*</td>
<td>96.49*</td>
</tr>
<tr>
<td>ADF Test</td>
<td>-26.32**</td>
<td>-28.05**</td>
<td>-32.7**</td>
</tr>
<tr>
<td>Student Test</td>
<td>0</td>
<td>-0.03</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Table 1: **VOL risk premia embedded in VIX options**
Figure 4: VOL risk premia embedded in VIX options
Motivation

Methodology

Implementation

Results
- Data
- First Result - HF are VOL sensitive
- Second Result - VOL sensitivity arises from VOL of VOL
- Third Result - HF exposed to higher-order moments

Conclusion
Data

Multiple datasets

- **HF indices**, on a **daily** frequency, from HFR: Global, Directional, Equity Hedge, Macro, Merger Arbitrage, and Relative Value
- **Fung-Hsieh** seven factors on a **daily** frequency, i.e. MKT-RF, SMB, term spread $\Delta$, credit spread $\Delta$, and trend-following factors
- **VOL risk premia**, priced on a **daily** frequency, over 2008-2013

Our approach

- Over 2008-2013, we regress 5 **daily HF indices** on Fung-Hsieh factors and the 3 volatility risk premia
- To understand HF performance on a **daily** frequency
First Result - HF are VOL sensitive

<table>
<thead>
<tr>
<th></th>
<th>Factor Beta Quantiles</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 [Low]</td>
<td>2</td>
<td>3 [High]</td>
<td>High - Low</td>
</tr>
<tr>
<td>Panel A: VOL of VOL Premia in the Cross-Section</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average VOL of VOL Beta</td>
<td>-0.216% [-18.35]</td>
<td>-0.026% [-3.37]</td>
<td>0.091% [11.47]</td>
<td>0.307% [28,88]</td>
</tr>
<tr>
<td>Average Excess Return</td>
<td>0.0057 [0.16]</td>
<td>0.0051 [0.15]</td>
<td>-0.1113 [-2.4]</td>
<td>-0.117*** [-2.38]</td>
</tr>
<tr>
<td>Panel B: SKEW OF VOL Premia in the Cross-Section</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average SKEW OF VOL Beta</td>
<td>-0.019% [-6.49]</td>
<td>0.035% [14.33]</td>
<td>0.059% [18.28]</td>
<td>0.078% [16.7]</td>
</tr>
<tr>
<td>Average Excess Return</td>
<td>0.001 [0.01]</td>
<td>-0.024 [-0.6]</td>
<td>0.008 [0.18]</td>
<td>0.008 [0.15]</td>
</tr>
<tr>
<td>Panel C: KURT OF VOL Premia in the Cross-Section</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average KURT OF VOL Beta</td>
<td>-0.003% [-9.1]</td>
<td>0.005% [17.3]</td>
<td>0.009% [21.91]</td>
<td>0.012% [31.74]</td>
</tr>
<tr>
<td>Average Excess Return</td>
<td>0.0028 [0.07]</td>
<td>-0.0185 [-0.52]</td>
<td>-0.0832 [-1.79]</td>
<td>-0.086*** [-1.86]</td>
</tr>
</tbody>
</table>

Table 2: Quantile portfolios sorted by VOL risk premia betas
After controlling for Fung-Hsieh factor loadings, we form 3 quantile portfolios (high, medium, low beta) of cross-sectional HF index returns, sorted on loadings of each VOL premium:

- HF that significantly load on VOL OF VOL (KURT OF VOL) premia substantially outperform low-beta funds by nearly 11.7% (8.6%) per year.
- This finding sheds light to what extent HF alpha arises actually from volatility strategies.
- Nevertheless, HF that significantly bear SKEW OF VOL premia were not compensated by excess returns.
Table 3: HF sensitivity to VOL of VOL over 2008-2013
Second Result - VOL sensitivity arises from VOL of VOL

<table>
<thead>
<tr>
<th>Investment Style</th>
<th>Nb. Obs</th>
<th>Intercept</th>
<th>MKT-RF</th>
<th>SMB</th>
<th>dTERM</th>
<th>dCREDIT</th>
<th>PTFSBD</th>
<th>PTFFX</th>
<th>PTFSCOM</th>
<th>VoV</th>
<th>SoV</th>
<th>KoV</th>
<th>R-Square/Adj. R-Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>71</td>
<td>0.0007</td>
<td>0.0003***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[1.51]</td>
<td>[6.54]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[-3.41] [1.65] [0.59]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0571</td>
<td>0.1044***</td>
<td>-0.0100</td>
<td>0.0136</td>
<td>0.0288</td>
<td>0.0116*</td>
<td>1.6329</td>
<td>-0.0002</td>
<td>-0.0032***</td>
<td>[-3,01]</td>
<td>0.0004</td>
<td>0.0000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.74]</td>
<td>[5.3]</td>
<td>[-0.24]</td>
<td>[0.46]</td>
<td>[0.75]</td>
<td>[1.91]</td>
<td>[0.08]</td>
<td>[-1.58]</td>
<td></td>
<td></td>
<td></td>
<td>0.46</td>
</tr>
<tr>
<td>Directional</td>
<td>71</td>
<td>0.0012</td>
<td>0.2318***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[1.35]</td>
<td>[9.49]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[-1.33] [2.47] [0.73]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1378</td>
<td>0.207***</td>
<td>-0.0845</td>
<td>0.0725</td>
<td>0.0684</td>
<td>0.0146</td>
<td>-32.9334</td>
<td>-0.0004**</td>
<td></td>
<td></td>
<td></td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[1.05]</td>
<td>[5.33]</td>
<td>[-1.24]</td>
<td>[1.49]</td>
<td>[1.07]</td>
<td>[1.45]</td>
<td>[-0.97]</td>
<td>[-2.23]</td>
<td></td>
<td></td>
<td>0.0009</td>
<td>[1.91] [0.4]</td>
</tr>
<tr>
<td>Equity Hedge</td>
<td>71</td>
<td>0.0010</td>
<td>0.207***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[1.4]</td>
<td>[9.47]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1467</td>
<td>0.2303***</td>
<td>-0.0033</td>
<td>0.0464</td>
<td>0.0741</td>
<td>0.0182*</td>
<td>5.4085</td>
<td>-0.0002</td>
<td>-0.0039**</td>
<td>[-2,16]</td>
<td>0.0005</td>
<td>0.0000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[1.26]</td>
<td>[7.4]</td>
<td>[-0.05]</td>
<td>[1.03]</td>
<td>[1.27]</td>
<td>[1.98]</td>
<td>[0.17]</td>
<td>[-1.26]</td>
<td></td>
<td></td>
<td></td>
<td>0.60</td>
</tr>
<tr>
<td>Macro</td>
<td>71</td>
<td>-0.0005</td>
<td>-0.0637***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[-0.73]</td>
<td>[-3.12]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.0006</td>
<td>-0.0372</td>
<td>-0.0290</td>
<td>-0.0616*</td>
<td>-0.0339</td>
<td>-0.0027</td>
<td>-40.9889</td>
<td>-0.0002</td>
<td></td>
<td></td>
<td></td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[-0.069]</td>
<td>[-1.43]</td>
<td>[-0.54]</td>
<td>[-1.69]</td>
<td>[-0.72]</td>
<td>[-0.34]</td>
<td>[-1.33]</td>
<td>[-1.43]</td>
<td></td>
<td></td>
<td>-0.0017</td>
<td>[-1.89] [0.14]</td>
</tr>
<tr>
<td>Merger Arbitrage</td>
<td>71</td>
<td>0.0012***</td>
<td>0.1244***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[2.64]</td>
<td>[8.39]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3553***</td>
<td>0.1129***</td>
<td>-0.0527</td>
<td>0.0978***</td>
<td>0.1321***</td>
<td>0.0058</td>
<td>-19.6823</td>
<td>-0.0001</td>
<td></td>
<td></td>
<td></td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[3.62]</td>
<td>[6.1]</td>
<td>[-1.35]</td>
<td>[3.52]</td>
<td>[3.62]</td>
<td>[1.01]</td>
<td>[-1.01]</td>
<td>[-0.78]</td>
<td></td>
<td></td>
<td>-0.0001</td>
<td>[-0.81] [2.28]</td>
</tr>
<tr>
<td>Relative Value</td>
<td>71</td>
<td>0.0012*</td>
<td>0.064***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[1.68]</td>
<td>[2.8]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0037</td>
<td>0.0662**</td>
<td>0.0199</td>
<td>0.0477</td>
<td>0.0481</td>
<td>0.0191**</td>
<td>31.5392</td>
<td>-0.0001</td>
<td>-0.0042**</td>
<td>[-2,52]</td>
<td>0.0009</td>
<td>0.0000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.78]</td>
<td>[2.16]</td>
<td>[0.31]</td>
<td>[1.04]</td>
<td>[0.8]</td>
<td>[2.02]</td>
<td>[0.98]</td>
<td>[0.82]</td>
<td></td>
<td></td>
<td>0.0009</td>
<td>[2.02] [0.32]</td>
</tr>
</tbody>
</table>

**Table 4: HF sensitivity to VOL of VOL over crisis periods**
Second Result - VOL sensitivity arises from VOL of VOL

At **HF investment style** level, after controlling for Fung-Hsieh factors, we estimate time-series OLS regressions:

- A one-standard deviation increase in **VOL of VOL** premia is associated with a substantial decline in aggregate HF returns of **25.2% annually**
- **Relative Value** and **Equity Hedge** are the most negatively exposed strategies to **VOL of VOL**, particularly during crises when volatility swap returns are the highest

- Relative Value are usually considered as the last insurer against tail risks, executing risk transfer from financial institutions
- Whereas Equity Hedge usually overlay hedge long positions; the 2 payoff return profiles equal to buying a call hedged by **selling realized volatility**
Table 5: HF sensitivity to SKEW/KURT of VOL over 2008-2013
Table 6: HF sensitivity to SKEW/KURT of VOL over crisis periods
Third Result - HF exposed to higher-order moments

At **HF investment style** level, after controlling for Fung-Hsieh factors, we estimate time-series OLS regressions:

- **Relative Value and Directional** are the most positively exposed to SKEW of VOL, since they are usually skewness-buyers strategies.
- **Relative Value** are not completely insurance-sellers strategies, since they partially hedge VOL of VOL exposure by buying SKEW of VOL.
- **Whereas Global Macro** are usually negatively exposed to SKEW of VOL

Relative Value and Directional profit from VOL of VOL: Relative Value is long gamma, and trend-followers aim to buying max lookback straddles. It equals to **buying realized skewness**. Alternatively, Global Macro takes contrarian bets on tail risks, i.e. **selling realized SKEW** during crises: convergence trades based on long term macro-trends
Conclusion

- Provides a new evidence for volatility risk in HF performance
- Showing it is an instrumental determinant in both time-series and cross-section
- To what extent HF alpha actually arises from volatility exposure
- Decompose HF volatility risk from multiple and tradable option-based strategies
- Decomposed into volatility, skewness, and kurtosis risk premia
- Indeed, divergent swaps are now widely used by HF managers
- Most HF styles sell volatility
- But VOL risk exposures across HF are widely distinguishable, depending on specific strategies
Thank you