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- I agree completely with their conclusion that VIX is not a hard number. Probably, this can be generalized beyond VIX:
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  - Modern financial econometrics tends to create estimates of estimates of estimates and treat them as data.
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  - Modern financial econometrics tends to create estimates of estimates of estimates and treat them as data.
  - In both cases, the entire structure is often a bit shaky.
- Morgenstern wrote a whole book about this half a century ago (Oskar Morgenstern (1950) *On the Accuracy of Economic Observations*. Princeton: Princeton University Press.) in which he quoted Norbert Wiener: "Economics is a one or two digit science"

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- If you have an informative prior, then you must weight with that also. If you are not a Bayesian, you will not go down this path.
- Grover and Shah (2014) implicitly use equal weighting of all instruments – they use the same weighting schemes that have been proposed for non noisy option prices.

# Optimal Aggregation of Noisy IVs

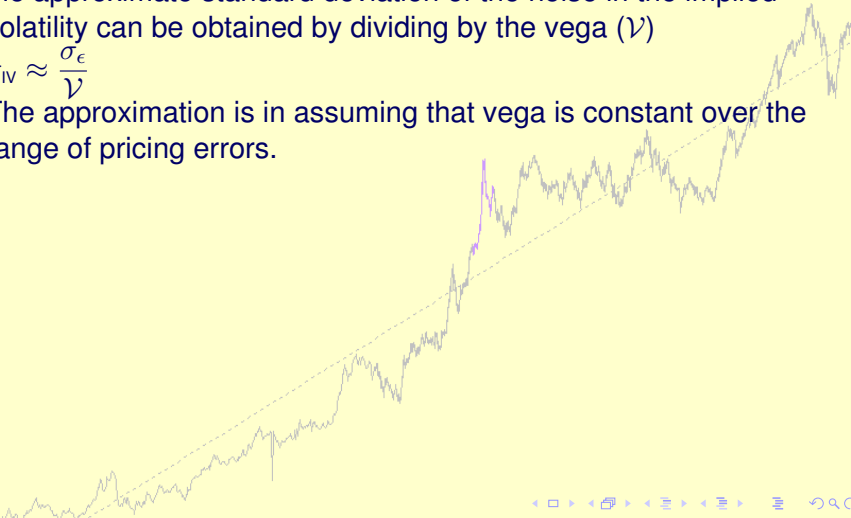


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- If the standard deviation of the noise in the option price is  $\sigma_\epsilon$ , then the approximate standard deviation of the noise in the implied volatility can be obtained by dividing by the vega ( $\mathcal{V}$ )

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The approximation is in assuming that vega is constant over the range of pricing errors.



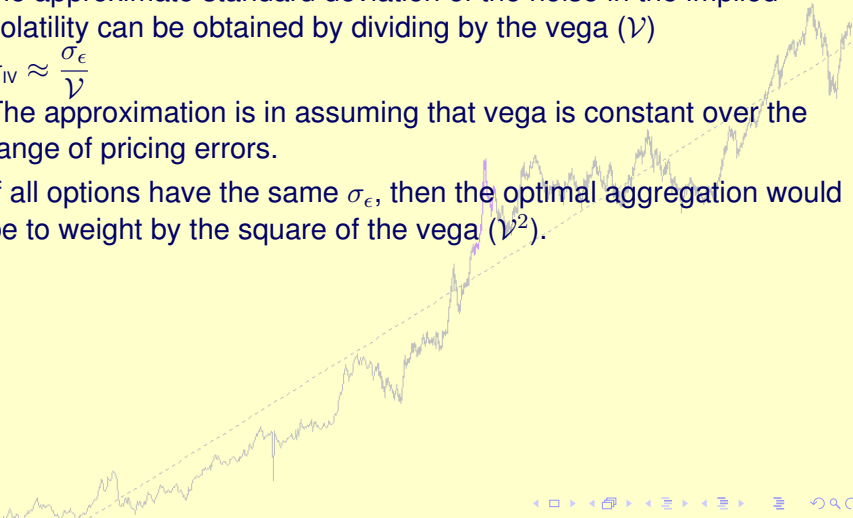
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- The superiority of the VVIX suggests that vega weighting is closer to the optimal than other weighting schemes. But weighting with the square or even higher powers of vega may be even better.

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- But then uniform sampling is not optimal. Some strikes are so liquid that they are highly likely to be in any plausible sample.
- Optimal sampling would be to sample with probabilities proportional to trading frequency or inversely proportional to inter-trade times.

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- “This measure of imprecision, of roughly 1.5 percentage points, is an economically significant one. For a sense of scale, the one-day change in VVIX is smaller than 1.5 percentage points on 62% of the days. This suggests that on 62% of the days, we know little about whether VVIX went up or down when compared with the previous day.” Grover and Shah, 2014



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- This is not necessarily true! **Counterexample:** Ten options are observed on both days and in each of them, the IV on the second day is higher than on the first day by amounts ranging from 0.1% to 3% and the VIX is higher by 1% (which is well below the imprecision of 1.5%). Yet, by the binomial test, we can say with 99.9% confidence that VIX is higher on second day.

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- Counterexample is contrived, but the key issue is one identified in Morgenstern’s book: the accuracy of the first difference of a noisy variable depends not only on the error variance but also (and more importantly!) on the autocorrelation of the noise.

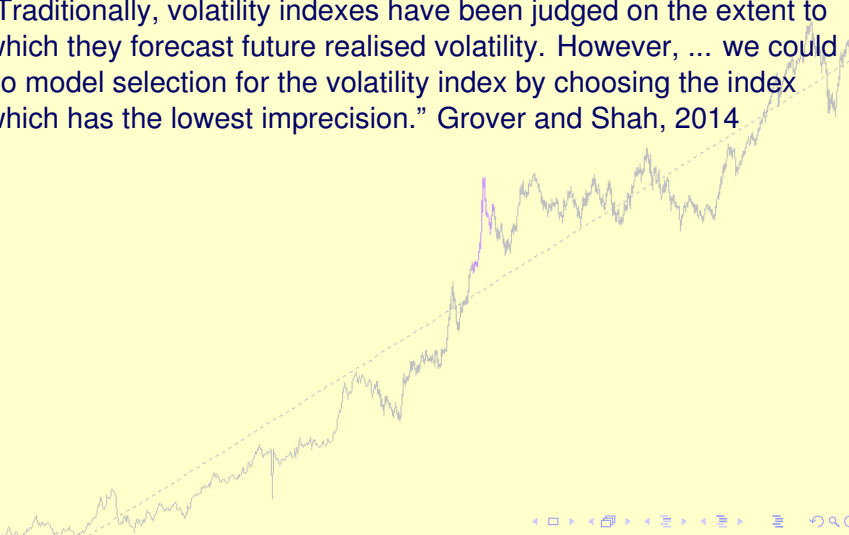


# Criteria for the best VIX estimator



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- It may be econometrically impractical, but to me the best VIX is the one that is most closely correlated with the first principal component of a basket of tail risk indicators.