WHITEPAPER

Quantifying the challenge of market timing

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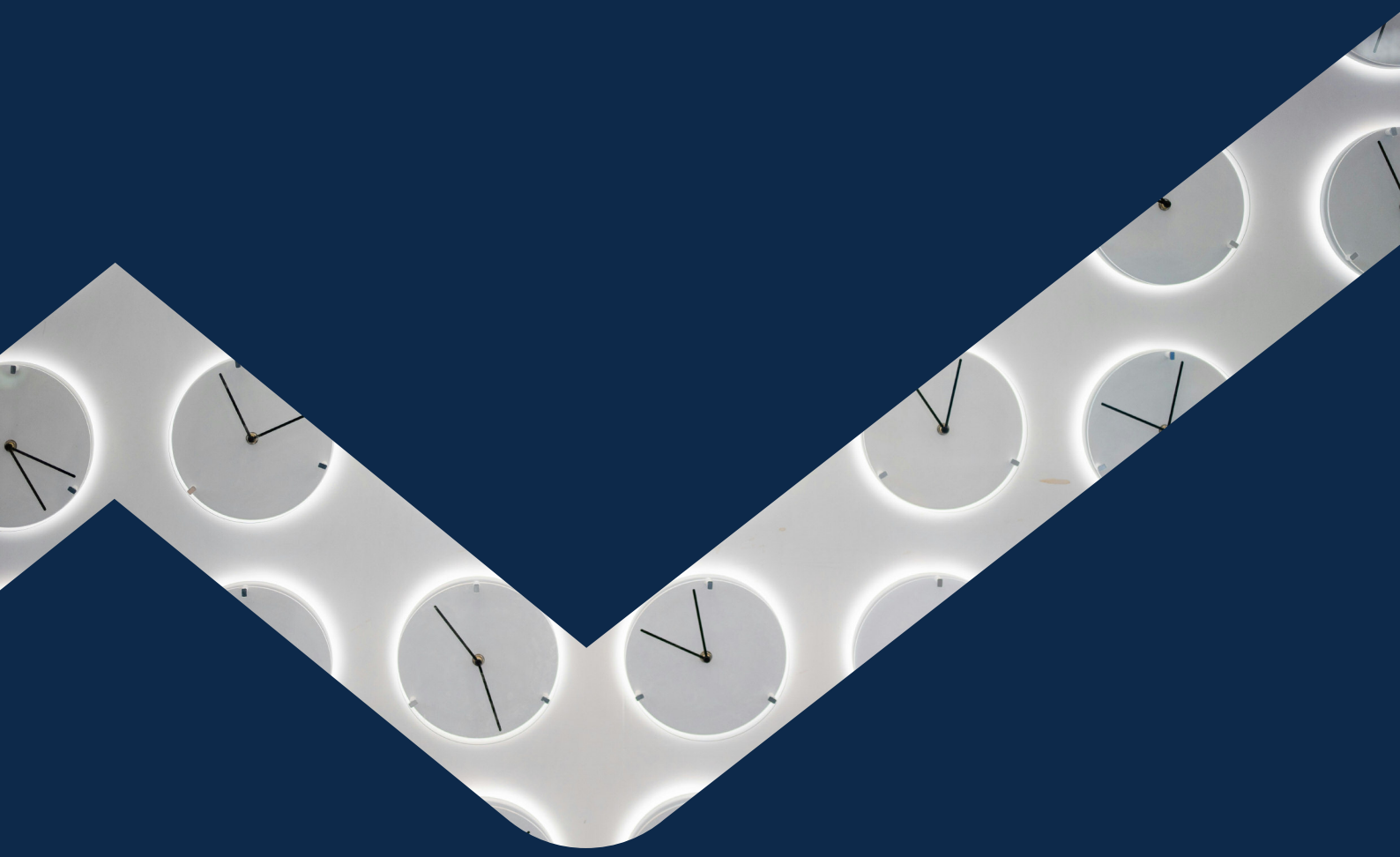

STOXX

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1. Introduction

In life, timing matters. In investing, even more so. The STOXX Global Artificial Intelligence Innovators (STOXX AI Innovators) is an example of this: the index's annualized historical performance from 2014–2024[1] was roughly 15%. However, by simply removing a single day's return per year, an investor could have created or destroyed nearly 5% of annualized performance.

Bodies of research have been dedicated to the art of timing investments, and put simply: while not impossible, it is difficult (Sharpe 1975). This difficulty is also related to the conventional wisdom for individual investors (as opposed to professional investors) to "stay invested." Research on the "performance gap" (Friesen 2007) and subsequent reports on the "investor return gap" highlight that, when entry/exit timing is included, retail investors' collective results lag buy-and-hold exposure. Despite the empirical evidence on the level of difficulty, though, the potential rewards for timing by individual investors – and indeed the temptation to reap them – are real.

If we accept that timing is difficult and perhaps best left to professional investors, we can also posit that some investments are more difficult to time than others. This paper aims to add to the research on timing by attempting to quantify the risk of market timing associated with different historical risk/return profiles.

We propose a new metric – **the tail-implied volatility spread** – to complement volatility, and help investors potentially better understand their risks.

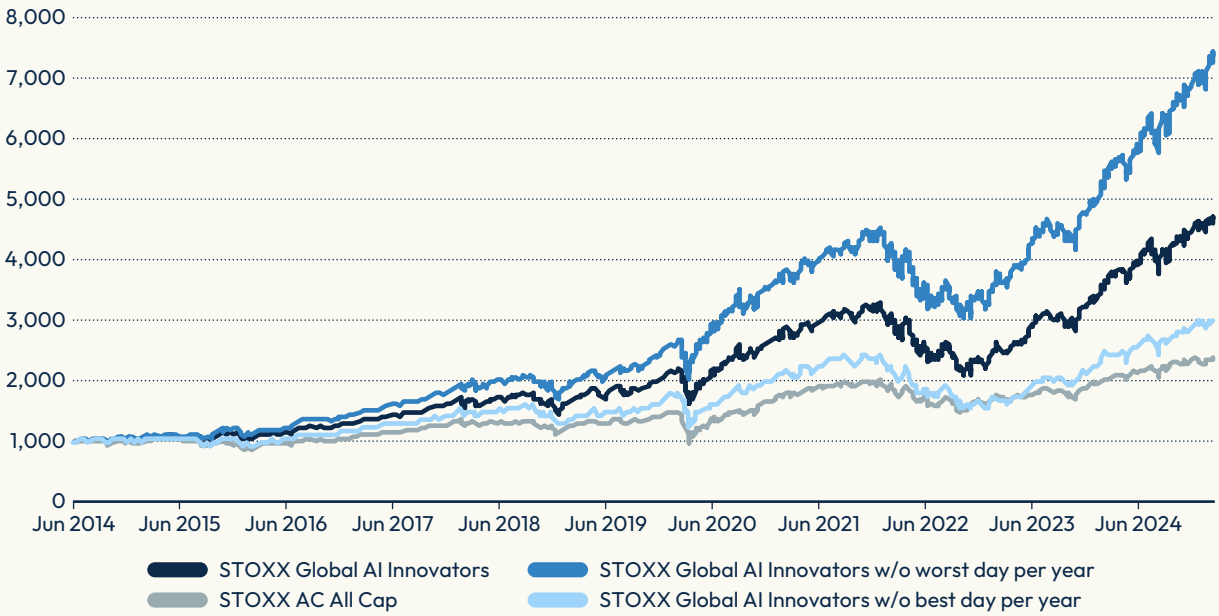
[1] USD net version, June 2014–December 2024. The history prior to the index launch on November 7, 2024, has been simulated.

2. Staying invested

Followers of the financial media and influencers may come across charts cautioning against timing by saying: "If you missed the best *X* days, you would have lost out on *Y%* of your return." This approach has come under withering criticism (Asness 2025)[2], on the basis that it is one-sided (not showing the rewards) and unrealistic (an extremely aggressive market timing strategy). This analysis and its flip side, however, are instructive in pondering the extremes of timing gone right and wrong.

Figure 1 below illustrates what would happen if – and of course it is a big "if" – investors had perfect foresight and were able to avoid the worst daily return per year, or had perfectly imperfect foresight and missed the best daily return per year.

Figure 1: STOXX AI Innovators – Expanded performance comparison



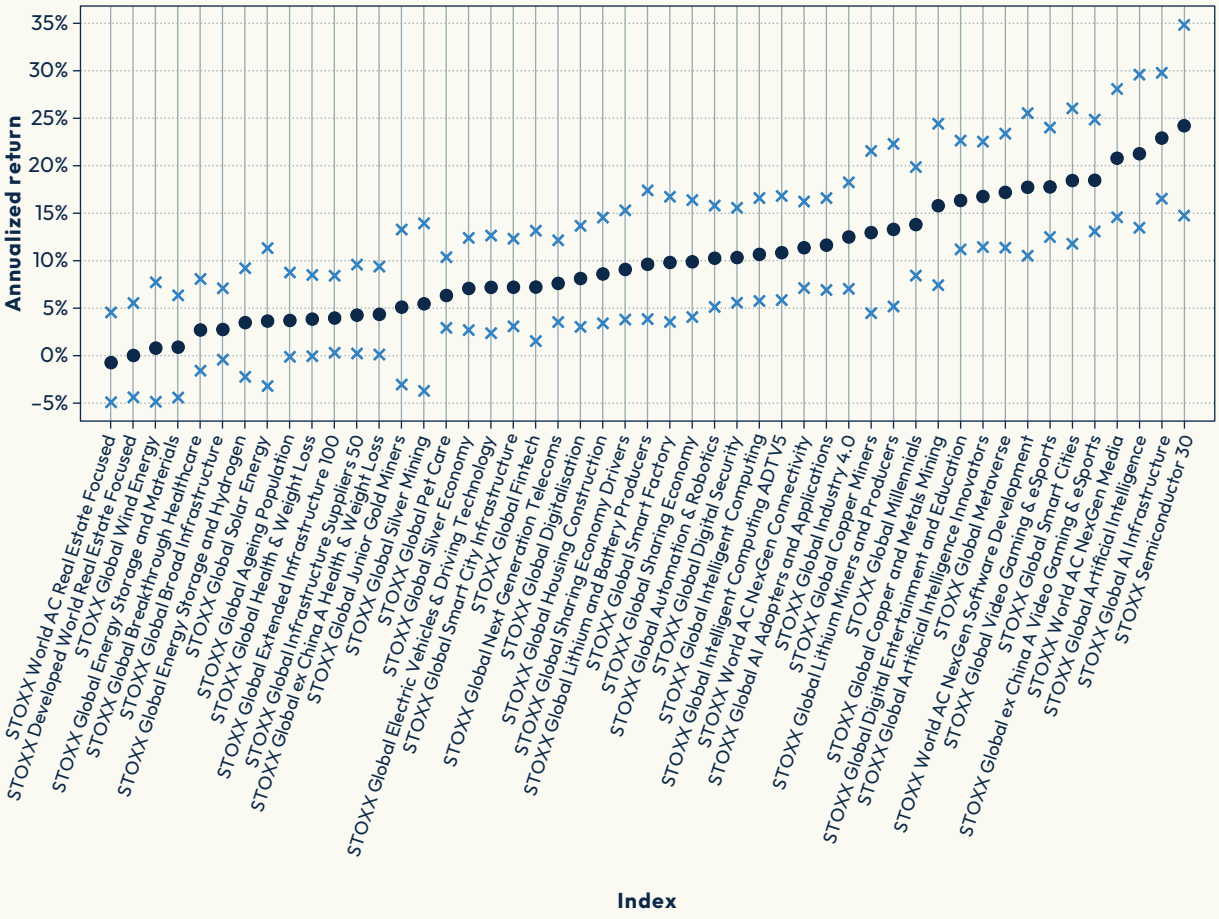
Source: STOXX. June 2014 – December 2024. USD net versions. The history prior to the index launch was simulated.

For the investor with perfect foresight, the index's performance rises 4.8%, to 20.5% per year. For the investor with perfectly imperfect foresight, the annualized performance is reduced by 4.6% per annum compared to the untimed strategy. This deflates returns to nearly those of the broad benchmark (the STOXX World AC All Cap) simply by removing a single day per year. Here, we do not use this illustration to promote a pro or anti-timing view, but rather call attention to how much an overall strategy's returns can rely on a small sample of days. As we will see in later sections, the portfolio's volatility hints at these outcomes, but does not give a complete picture.

[2] Asness does not promote market timing for most investors, but rather opposes the use of a flawed argument to deter it.

Looking at a broader cross section of indices (in this case the range of STOXX Thematic indices with global exposures) enables us to see how this best/worst day impact plays out across different themes. Figure 2 below shows the same type of what-if analysis, i.e., the performance that would be generated if either the best or the worst day of each calendar year were to be removed. The blue dots represent the annualized return for each index, while the light blue x's reflect the what-if performance.

Figure 2: Annualized return range with the best and worst days per year removed

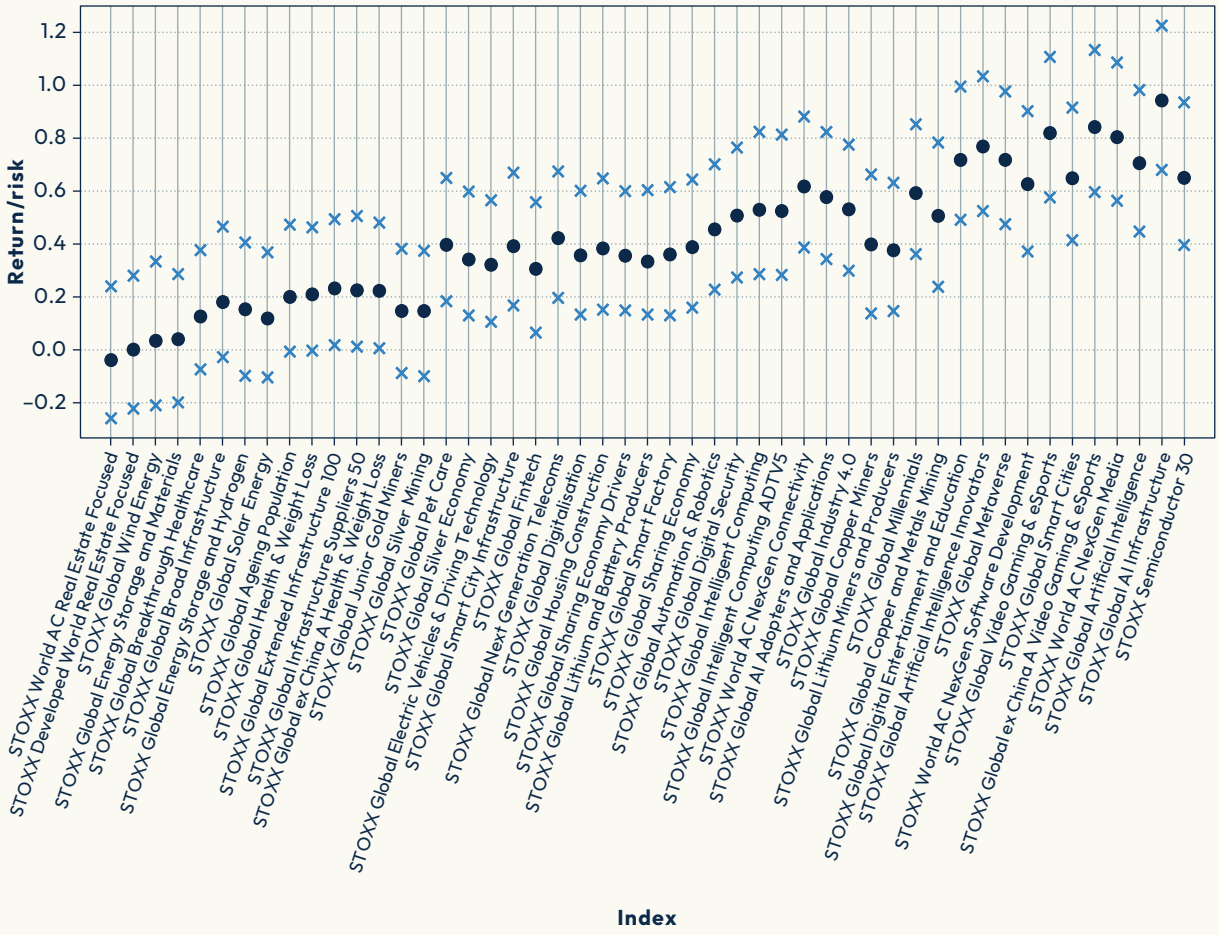


Source: STOXX. 2019–2024 annualized returns, USD net versions. The history prior to the index launch was simulated.

Although the ranges (i.e., the distance between the upper and lower x's) are clearly not uniform, volatility can be a guide to their size.

Figure 3 shows the same chart above (i.e., the indices are arranged in the same order) in risk-adjusted terms. This is achieved by dividing each of the annualized returns by the historical volatility over the same period. Here, we can see that the ranges are more uniform: in other words, incorporating risk can partially "normalize" the ranges.

Figure 3: Risk-adjusted return range with the best and worst days per year removed



Source: STOXX. 2019–2024 annualized risk and returns. USD net versions. The history prior to the index launch was simulated.

Figures 2 and 3 reveal two key observations. Firstly, when adjusting for risk, the indices with the best returns are not necessarily those with the best risk-adjusted returns (e.g., the STOXX Semiconductor 30, on the far right of the charts, had the highest return in Figure 2, but not the highest risk-adjusted return in Figure 3). Secondly, even after adjusting for risk, some ranges are still larger than others. This means that volatility alone does not tell the entire story of how reliant an index or portfolio's long-term returns are on single day performances.

In the upcoming sections, we will therefore define a metric that can complement volatility in estimating the impact of a strategy's best days. First, we will provide the intuition behind the metric, and then follow this with a refresher on volatility and, finally, the results of our metric.

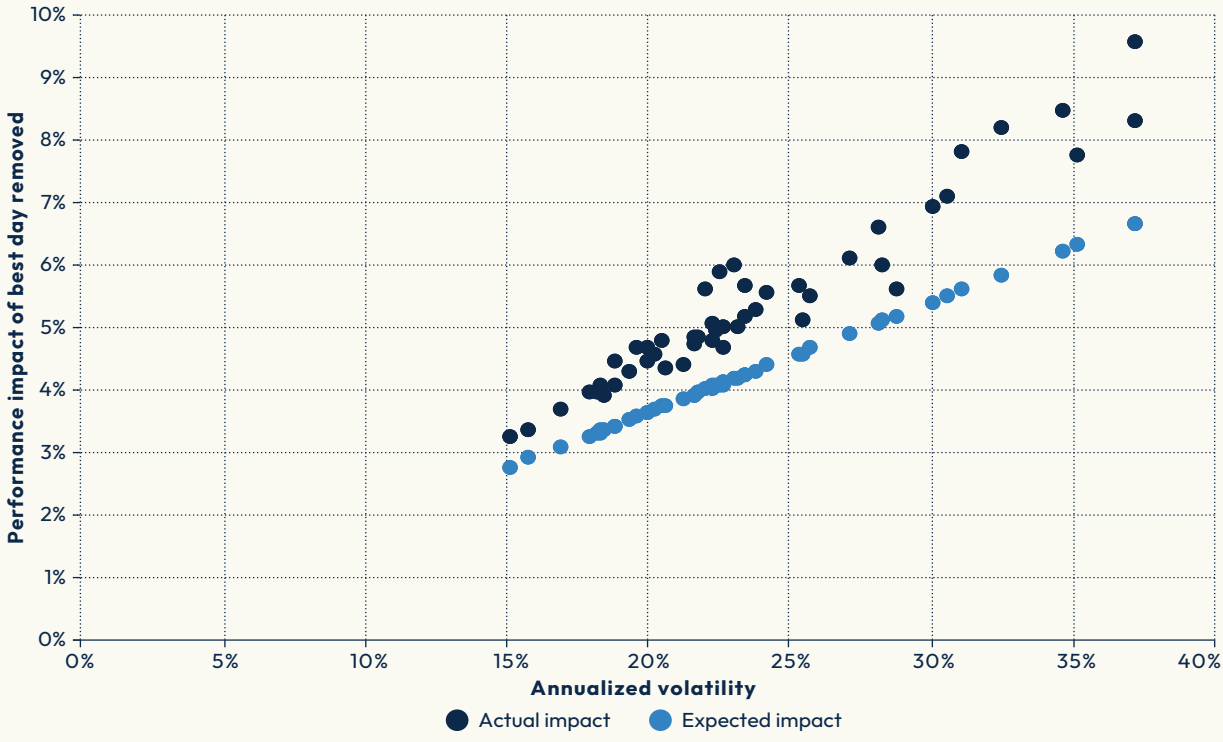
3. Estimating the max: theory and practice

If volatility were a perfect guide, we could estimate what the maximum daily return each year would be. The intuition behind this is as follows:

- There are (roughly) 252 trading days per year, meaning that the return on the best day will be better than those generated on the other 251 days.
- Using a branch of statistics called extreme value theory, we can estimate that, on average, the return of the best day in a 252 day year comes from the 99.76th[3] percentile of the daily return distribution.
- In a standard normal distribution, an observation with a probability of 99.76% is 2.82 standard deviations away from the mean.
- If we know the daily index volatility (which is one standard deviation), we know that the maximum daily return should be 2.82 multiplied by the standard deviation.[4]

To test this, Figure 4 plots the results of this intuition (the theory) against the historical data (the practice) using the dataset from Figures 2 and 3. The x-axis is the historical volatility. The y-axis is the performance impact[5] of the best day per year, with the expectation of the "theory" shown in light blue and the results of the "practice" shown in dark blue.

Figure 4: Comparison of theoretical and actual maximum daily returns



Source: STOXX. 2019–2024. The theoretical and expected returns are calculated based on the annualized returns for the time series with the best day per year removed compared to the standard time series. The history prior to the index launch was simulated.

[3] The maximum value of a random distribution with a sample size of *n* is itself a distribution. The expected value of the maximum can be estimated based on a formula developed by statistician Gunnar Blom (see the Appendix).

[4] Given the daily periodicity, we assume an average return of 0.

[5] To obtain the annualized performance impact, we solve for the return that would make the two time series (the standard series and the series without the best day per year) equivalent. See the Appendix for more details on the calculations.

This chart leads to two main observations. Firstly, in all cases, the actual performance impact of the best days is higher than the expected performance impact. This is evidence of "fat tails", which are known to correspond to equities and which we will explain in more detail in the next section. From a timing perspective, this means that the impact of missing the best return is uniformly higher than historical volatility would indicate.

Secondly, the relationship between the expected performance impact and volatility is linear – the more volatile the index, the higher the expectation. The relationship between the actual performance impact and volatility is not as neat, which points to the "real world" relationship between risk and return not being perfectly linear. Our metric accommodates these deviations, but first we will revisit volatility, its definitions and its limitations.

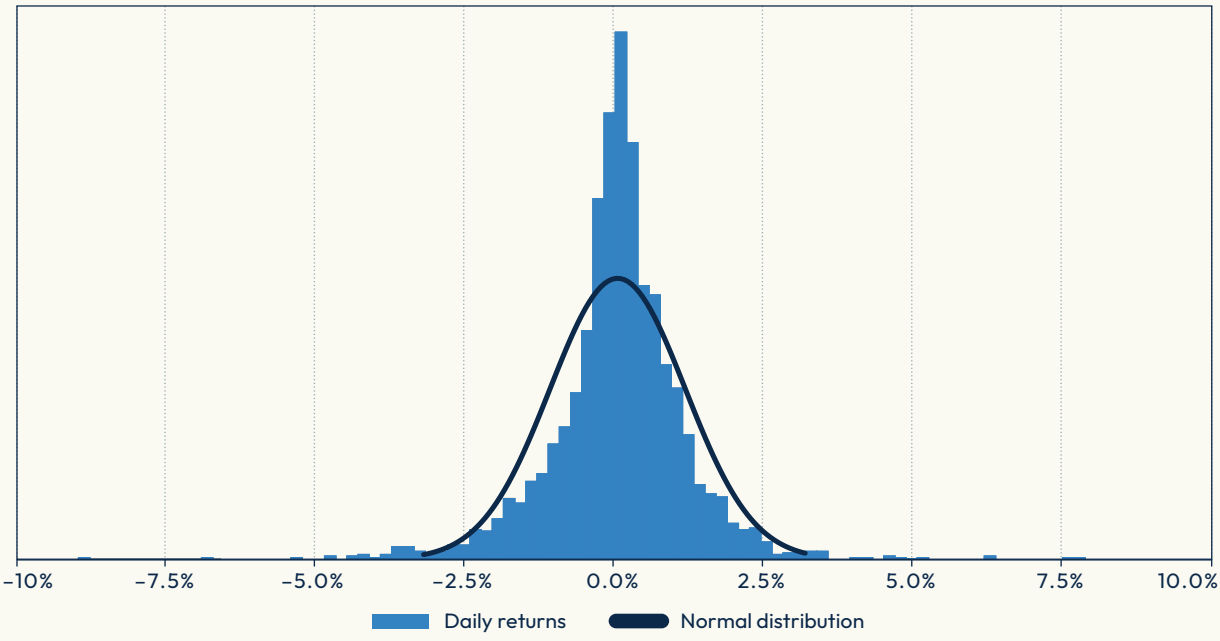
4. Volatility distributions and their moments

There are several different types of volatility that may be relevant to investors:

- **Realized volatility** – i.e., past volatility calculated using historical returns
- **Predicted volatility** – i.e., future volatility estimated using historical returns and a model
- **Implied volatility** – i.e., market-implied volatility modeled using option prices

Underpinning all these variants is the assumption that the logarithmic returns[6] of asset prices are normally distributed (this is also known as "Gaussian distribution"). To illustrate this visually, the distribution of the daily returns for the STOXX AI Innovators has been pictured below (Figure 5) and a "perfect" normal distribution superimposed on it.

Figure 5: Histogram of daily returns for the STOXX AI Innovators



Source: STOXX. June 2014 – December 2024, USD net versions. The history prior to the index launch was simulated.

[6] Asset prices are generally bounded by 0 and infinity, and are therefore said to be lognormally distributed.

This graph clearly shows that a perfectly normal distribution only approximates to the actual distribution of the returns. The differences can be quantified using what are known as the "higher moments" of the distribution:

- **Skewness** – which describes when the distribution is not symmetrical, and
- **Kurtosis** – which describes when some observations are further from the mean (these are also known as "fat tails")

Some level of skewness and kurtosis can be expected for the distribution of any set of financial returns. In addition, the results have been generated using historical data, which are not necessarily indicative of future results. They also make no distinction between "good" and "bad" volatility ("good" volatility resulting in positive returns and vice versa). This is why volatility must always be considered together with the assumptions made in connection with it.

While some argue that these limitations make Gaussian distributions inappropriate for financial returns, they are ubiquitous in finance, being used in everything from option pricing to performance measurement. As the maxim attributed to British statistician George Box says, "All models are wrong, but some are useful." In this spirit, the next section introduces our model.

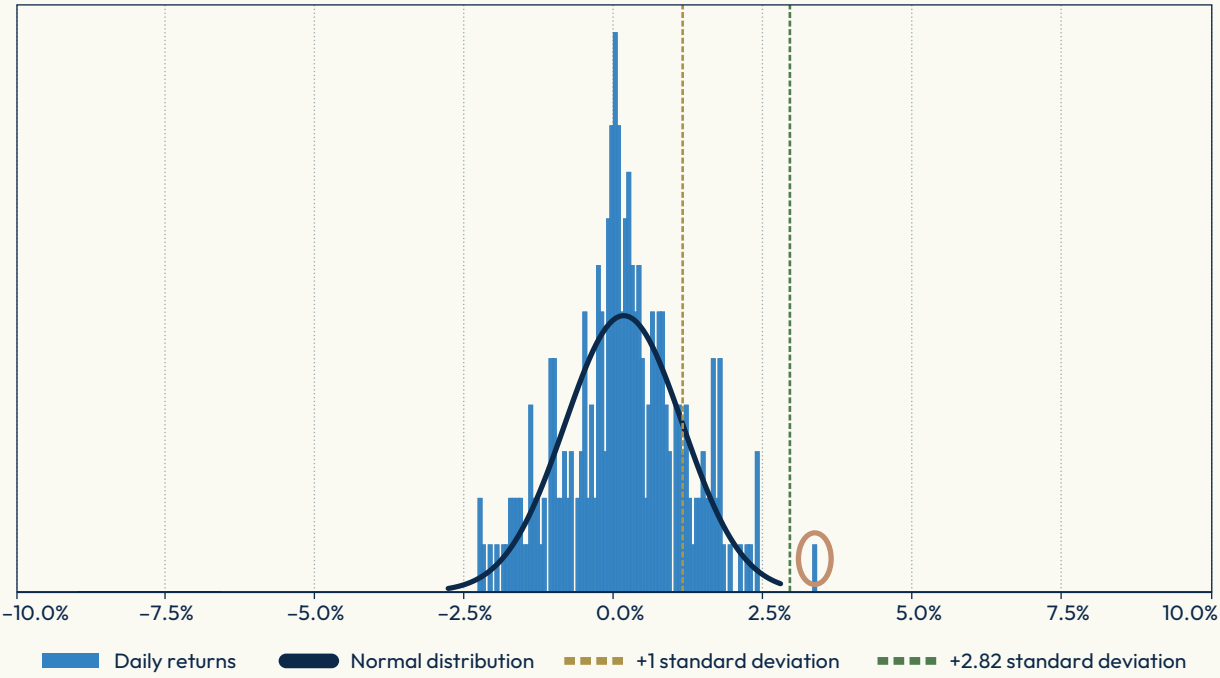
5. Introducing tail-implied volatility (TIV) and the TIV spread

Returning to the topic of how to understand market timing risk, we aim to create a metric that is low on complexity and high on intuition, and that is straightforward to calculate.

We do this by seeking to capture the difference between *theoretical* historical volatility – based on the performance impact of the best one day returns per calendar year – and *actual* realized volatility. In other words, we aim to capture the difference between expectations and reality.

Visually, an example is given below (Figure 6), which zooms in on the 2023 returns for the STOXX AI Innovators.

Figure 6: 2023 daily returns for the STOXX AI Innovators



Source: STOXX. December 2022 – December 2023, USD net versions. The history prior to the index launch was simulated.

The daily volatility is one standard deviation and is represented by the dashed brown line. Using our previous intuition, the maximum return we expect in a 252 day year is represented by the dashed grey line at 2.82 standard deviations from the mean. However, there is a one-day return beyond this point, which is circled in brown. We then posit what the one standard deviation would be **if** the maximum return (in the circle) were 2.82 standard deviations away?

We call this theoretical shift in the one standard deviation "tail-implied volatility" (TIV), and the difference between this and the actual volatility is the "TIV spread."

In simplified form (and assuming 252 trading days per year), the formula for (annualized) tail-implied-volatility is:

$$\frac{\text{Best day performance Impact}}{2.82} \times \sqrt{252}$$

where

$$\text{Best day performance impact} = \frac{\text{Annualized performance - annualized performance with best day per year removed}}{\text{Annualized performance with best day per year removed + 1}}$$

In this case, the tail-implied-volatility spread is: Tail implied volatility – realized volatility

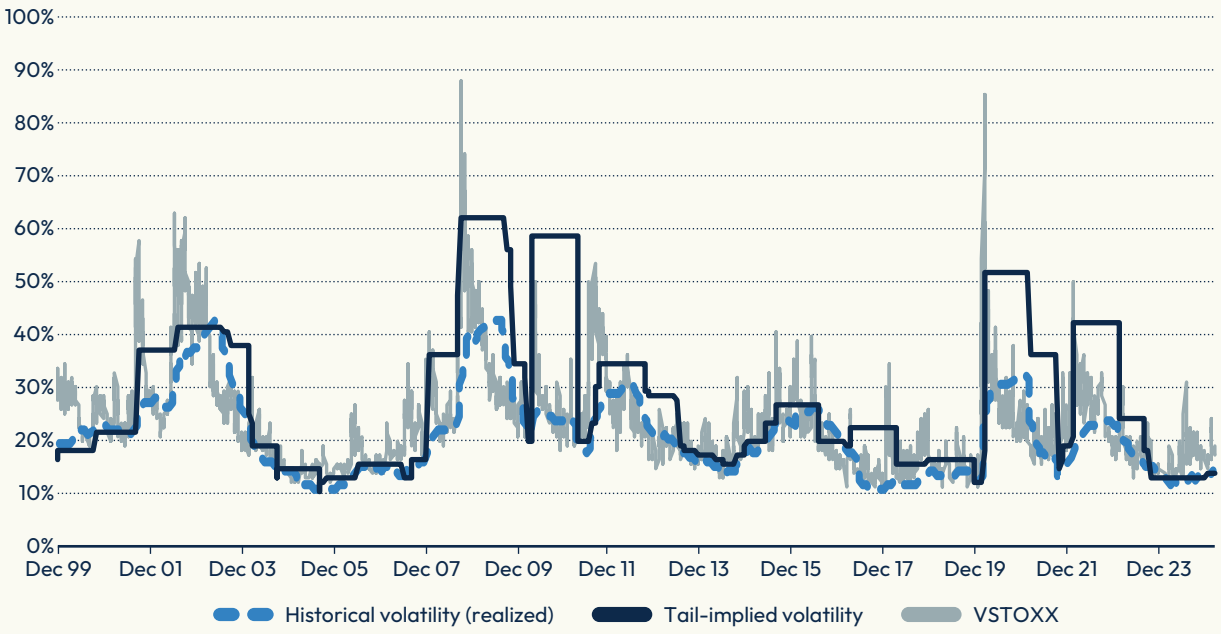
The full derivation is given in the appendix.

It is important to note that we do not represent the predictive power of this metric, but rather its use where history can be a guide.

One can think of the TIV spread as something akin to a "volatility bump" that an options trader can use to adjust their modeled option prices.[7] The higher the TIV spread, the more influenced the historical returns were by the best day per year, and thus the higher risk an investor may be exposed to when trying to time an investment. This also has the benefit of capturing "good" volatility that should not be missed, i.e., returns to the upside.

It is also possible to see how the metric evolves over time. For a deep history, and to include implied volatility, we turn to the flagship EURO STOXX 50 index. Below (Figure 7), we show the historical realized volatility, the implied volatility as measured by the forward-looking VSTOXX index[8] and, finally, the tail-implied volatility (TIV) as in our previous formulas.

Figure 7: EURO STOXX 50 volatility comparisons



Source: STOXX. 2019–2024. EUR price return versions. Historical volatility is annualized using the trailing 252-day period. The TIV is also based on the trailing 252 days. The history prior to the index launch was simulated.

The TIV and historical volatility are calculated using a rolling one-year time window and correspond neatly to spikes in implied volatility. During these periods of elevated uncertainty, an investor would have a heightened risk of missing out by trying to time the market. The TIV normalizes when the outsized return drops out of the window, due to the one-year look back.

[7] Option prices are guided by the volatility of the underlying asset, which is a key input in modeled option prices, such as those determined using the Black–Scholes formula. When making prices, traders may want to change the default volatility in their model to account for market conditions.

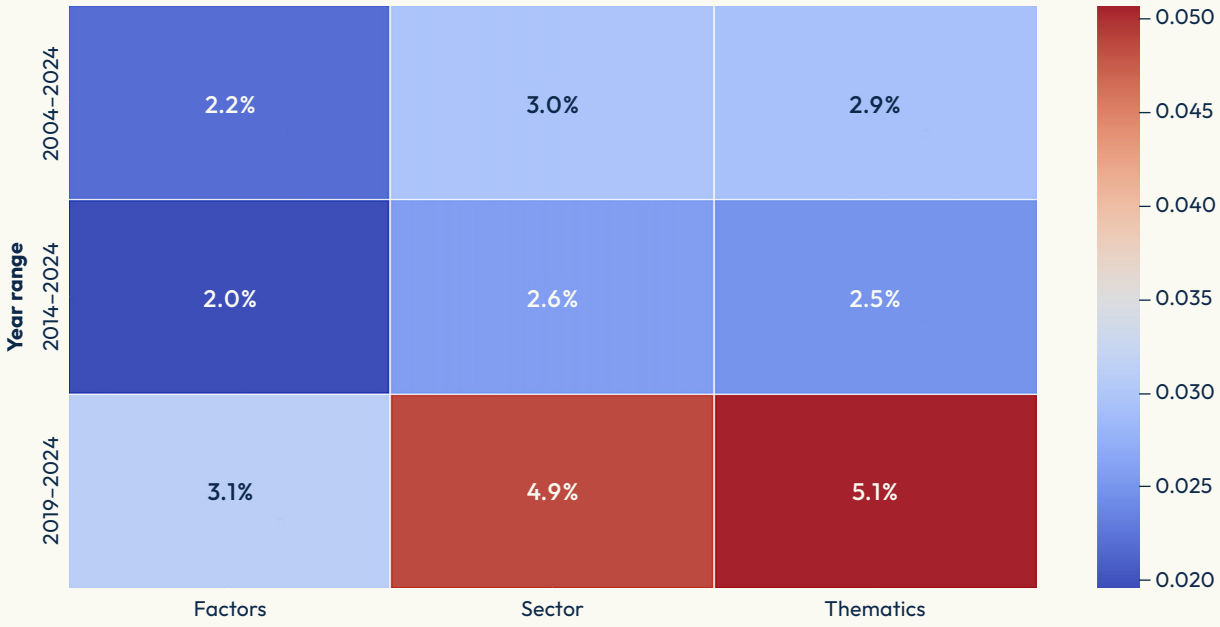
[8] The VSTOXX uses out-of-the-money options to measure the market's expectation of volatility 30 days out.

5.1 The TIV profile across indices

Applying this approach to a broader range of STOXX indices, we discover a number of patterns that potentially match our intuition. The heat map below (Figure 8) shows the median TIV spread across STOXX Thematic, Factor and Sector indices providing global exposure. These index families were chosen as they are known to be employed tactically. We can also show the metric over shorter and longer time horizons.

As previously discussed, the TIV spread is the difference between the theoretical volatility (based on the impact of removing the best day per year) and actual volatility. The higher the value produced, the more reliant the index performance is on its best days, after controlling for volatility.

Figure 8: STOXX Global indices



Source: STOXX. 2019–2024, USD net versions. The history prior to the index launch was simulated.

Figure 8 shows that the period most influenced by the COVID-19 pandemic required the most adjustments, with Thematics during that period requiring the biggest bump of all. In other words, when adjusting for realized volatility over the past five years, the median Thematic index relied most on its best days to drive overall performance.

Returning to our example of Thematic indices with global exposures, we can show the individual TIV spreads in descending order for the 2019–2024 period:

Figure 9: STOXX Thematic indices with global exposure

Index full name	Symbol	Annualized return	Annualized return (best removed)	Expected impact	Actual impact	Annualized standard deviation	TIV spread
STOXX Global Silver Mining	STXSILVV	5.5%	-3.7%	6.6%	9.5%	37.2%	16.4%
STOXX Global Copper Miners	STXCPPRV	13.0%	4.5%	5.8%	8.1%	32.5%	13.2%
STOXX Global Junior Gold Miners	STXGOLDV	5.1%	-3.0%	6.2%	8.4%	34.8%	12.6%
STOXX Global Copper and Metals Mining	STXCOPRV	15.8%	7.4%	5.5%	7.8%	31.2%	12.6%
STOXX Global Wind Energy	STXWINDV	0.8%	-4.9%	4.1%	5.9%	23.1%	10.3%
STOXX Global Energy Storage and Hydrogen	STXEGSTV	3.5%	-2.2%	4.0%	5.8%	22.7%	10.2%
STOXX Semiconductor 30	STXSEMIV	24.2%	14.7%	6.6%	8.2%	37.2%	9.2%
STOXX Global Solar Energy	STXSOLAV	3.6%	-3.2%	5.5%	7.1%	30.7%	9.1%
STOXX Global Energy Storage and Materials	STXERGMV	0.9%	-4.4%	3.9%	5.5%	22.2%	9.0%
STOXX Global Artificial Intelligence	STXAIV	21.3%	13.5%	5.4%	6.9%	30.1%	8.5%
STOXX Global Lithium Miners and Producers	STXLIMEV	13.3%	5.2%	6.3%	7.7%	35.3%	8.1%
STOXX World AC NexGen Software Development	STXSOFTV	17.7%	10.5%	5.0%	6.5%	28.3%	8.4%
STOXX Global Fintech	STXFTV	7.2%	1.5%	4.2%	5.6%	23.6%	7.9%
STOXX Global Smart Factory	STXSFCV	9.8%	3.5%	4.8%	6.0%	27.2%	6.8%
STOXX Global AI Infrastructure	STXAINFV	22.9%	16.5%	4.3%	5.5%	24.3%	6.5%
STOXX Global Sharing Economy	STXSECV	9.9%	4.1%	4.5%	5.6%	25.5%	6.0%
STOXX Developed World Real Estate Focused	SWRESV	0.0%	-4.4%	3.5%	4.6%	19.8%	6.2%
STOXX Global Housing Construction	STXHICV	8.6%	3.4%	4.0%	5.0%	22.4%	5.8%
STOXX Global Intelligent Computing	STXAAIV	10.7%	5.8%	3.6%	4.6%	20.1%	6.0%
STOXX Global Intelligent Computing ADTV5	STXAA5V	10.8%	5.8%	3.7%	4.7%	20.7%	5.9%
STOXX Global Metaverse	STXMETAV	17.2%	11.4%	4.3%	5.2%	23.9%	5.5%
STOXX World AC Real Estate Focused	STXRESV	-0.7%	-4.9%	3.4%	4.4%	19.0%	5.7%
STOXX Global Smart Cities	STXSCTV	18.4%	11.8%	5.1%	6.0%	28.4%	5.1%
STOXX Global Industry 4.0	STXIN4V	12.5%	7.0%	4.2%	5.1%	23.5%	5.2%
STOXX Global Digitalisation	IXDIGITU	8.1%	3.0%	4.0%	4.9%	22.7%	5.1%
STOXX Global Artificial Intelligence Innovators	STXAINNV	16.8%	11.4%	3.9%	4.8%	21.8%	5.1%
STOXX Global Automation & Robotics	IXAROBU	10.3%	5.1%	4.0%	4.9%	22.5%	4.9%
STOXX Global Digital Security	STXTDSV	10.3%	5.6%	3.6%	4.5%	20.4%	5.0%
STOXX World AC NexGen Media	STXMEDIV	20.8%	14.6%	4.6%	5.4%	25.9%	4.7%
STOXX Global ex China A Video Gaming & eSports	STXCVGEV	18.5%	13.1%	3.9%	4.8%	21.9%	4.9%
STOXX Global Video Gaming & eSports	STXVGEV	17.8%	12.5%	3.9%	4.7%	21.7%	4.7%
STOXX Global Millennials	STXMLNV	13.8%	8.4%	4.1%	5.0%	23.3%	4.6%
STOXX Global AI Adopters and Applications	STXAIAPV	11.6%	6.9%	3.6%	4.4%	20.2%	4.7%
STOXX Global Electric Vehicles & Driving Technology	STXELVV	7.2%	2.4%	4.0%	4.7%	22.4%	4.1%
STOXX Global ex China A Health & Weight Loss	STXCOBEV	4.3%	0.1%	3.5%	4.2%	19.5%	4.3%
STOXX Global Smart City Infrastructure	STXSCIV	7.2%	3.1%	3.3%	4.0%	18.4%	4.1%
STOXX Global Next Generation Telecoms	STXNGTV	7.6%	3.5%	3.2%	3.9%	18.0%	4.1%
STOXX World AC NexGen Connectivity	STXCONNV	11.4%	7.1%	3.3%	4.0%	18.4%	3.9%
STOXX Global Infrastructure Suppliers 50	SXGISS1V	4.3%	0.2%	3.4%	4.0%	19.0%	3.7%
STOXX Global Health & Weight Loss	STXOBEV	3.8%	-0.1%	3.3%	3.9%	18.3%	3.6%
STOXX Global Digital Entertainment and Education	STXDEEV	16.3%	11.2%	4.0%	4.6%	22.8%	3.3%
STOXX Global Sharing Economy Drivers	STXSEDV	9.1%	3.8%	4.5%	5.1%	25.5%	3.1%
STOXX Global Silver Economy	STXSLVV	7.1%	2.7%	3.7%	4.3%	20.7%	3.3%
STOXX Global Extended Infrastructure 100	SXGISSV	4.0%	0.3%	3.0%	3.6%	17.0%	3.5%
STOXX Global Breakthrough Healthcare	IXBRHLTU	2.7%	-1.6%	3.8%	4.4%	21.4%	3.1%
STOXX Global Lithium and Battery Producers	STXLIBV	9.6%	3.8%	5.1%	5.6%	28.8%	2.5%
STOXX Global Ageing Population	IXAGPOPU	3.7%	-0.1%	3.3%	3.8%	18.5%	3.1%
STOXX Global Pet Care	STXPCV	6.3%	2.9%	2.8%	3.3%	15.9%	2.7%
STOXX Global Broad Infrastructure	STXGBIV	2.8%	-0.4%	2.7%	3.2%	15.2%	2.7%

Source: STOXX. 2019–2024, USD net versions. The history prior to the index launch was simulated.

We can observe that the TIV spread does not depend on the original volatility or return levels. It is also interesting that the more commodity-centric thematics are at the top of the list, which means that these indices have more timing risk than their historical volatility levels would suggest. The Global AI Innovators we looked at previously is in the middle of the pack.

5.2 The TIV profile – Additional results

Turning back to the broader set of STOXX Sector, Thematic and Factor indices, we can now look across the 2014–2024 period and include regional indices as well. The top and bottom five in this selection are shown below.

Figure 10: Top five – All indices in selection

Index full name	Symbol	Annualized return	Annualized return (best removed)	Expected impact	Actual impact	Annualized std. dev.	TIV spread
STOXX Canada 240 Health Care	S24C40V	–27.8%	-35.7%	9.3%	12.4%	52.2%	17.3%
STOXX Eastern Europe 300 Automobiles & Parts	EE330V	6.0%	-1.1%	5.3%	7.2%	29.6%	10.7%
STOXX Europe Total Market Semiconductors	T9576V	13.1%	5.3%	5.7%	7.4%	32.1%	9.8%
EURO STOXX Total Market General Industrials	T2720U	7.1%	0.7%	4.6%	6.3%	25.9%	9.4%
EURO STOXX Total Market Electronic & Electrical Equipment	T2730U	10.7%	4.4%	4.4%	6.1%	24.9%	9.4%

Source: STOXX. 2014–2024, USD net versions. The history prior to the index launch was simulated.

Using the TIV spread as a guide, the risk of missing out on the best day's performance of these indices with a market timing strategy is much higher than their volatilities implied. As already mentioned in this section, the TIV spread is independent of returns and historical volatility. This is borne out by the indices with the highest values above, as the returns and volatilities vary dramatically within this subset.

Figure 11: Bottom five – All indices in selection

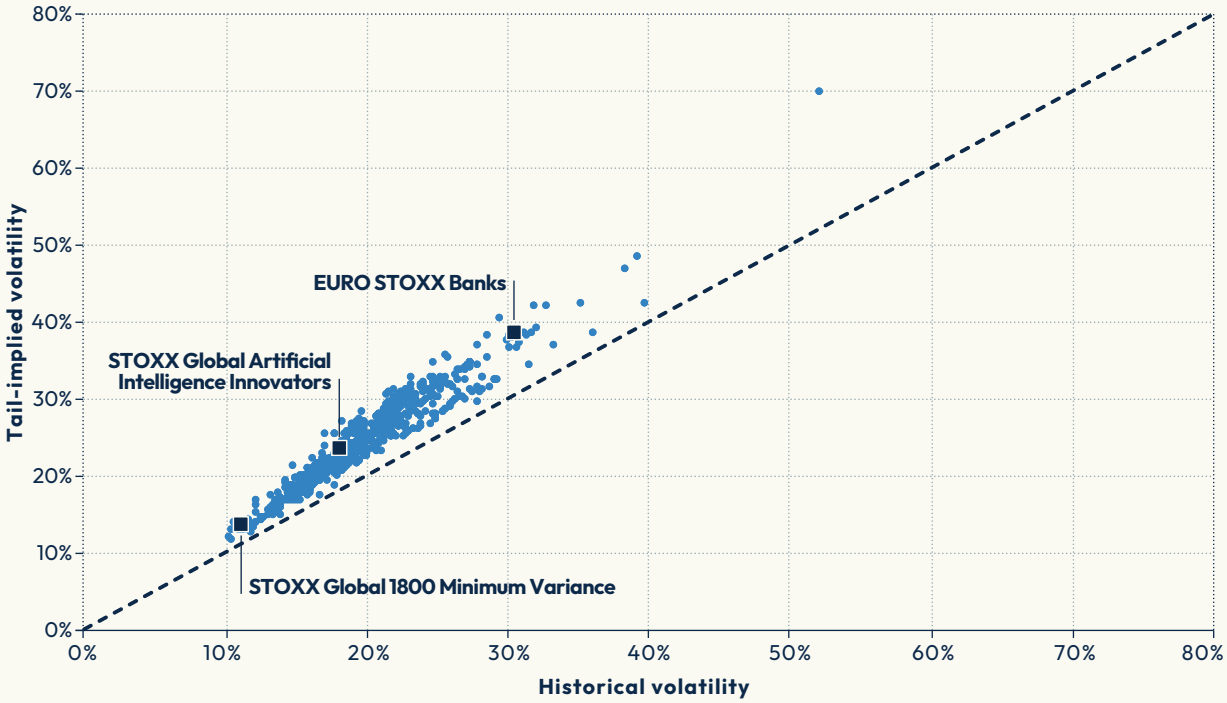
Index full name	Symbol	Annualized return	Annualized return (best removed)	Expected impact	Actual impact	Annualized std. dev.	TIV spread
STOXX International Developed Markets Health Care	SWDU20V	4.5%	1.9%	2.5%	2.6%	14.1%	0.4%
STOXX USA Select 50 USD	SXUSSEV	5.4%	2.3%	3.0%	3.0%	16.8%	0.3%
STOXX Australia 150 Minimum Variance Unconstrained	SA1AUNV	4.6%	1.4%	3.1%	3.2%	17.6%	0.3%
STOXX Australia 150 Minimum Variance	SA1AMVV	4.7%	1.4%	3.2%	3.2%	17.9%	0.1%
STOXX Eastern Europe 300 Real Estate	EE860V	–3.6%	–7.7%	4.8%	4.4%	27.3%	–2.7%

Source: STOXX. 2014–2024, USD net versions. The history prior to the index launch was simulated.

Only one index in this selection has a negative TIV spread, meaning that the performance impact of removing the best day per year here was actually *less* than expected. It is also interesting to note the presence of two minimum variance indices: The median TIV spread of a minimum variance index across the sample is 2.2%, whereas the result for the fuller sample is 3.7%. Whether minimum variance indices also reduce timing risk is a potential area for future exploration.

Figure 12, which shows the full sample of indices, looks similar to Figure 4, which highlighted only Thematics for the 2019–2024 period. The dotted line shows where the tail-implied volatility is equal to historical volatility, and the TIV spread can be inferred by how far each dot is from this line.

Figure 12: All indices in selection



Source: STOXX. 2014–2024, USD net versions. The history prior to the index launch was simulated.

6. Other metrics

As one might expect, the issue of returns being less than perfectly normally distributed is not a novel one, and the investment/statistics community already has an array of metrics to help navigate this. Figure 13 below provides a cursory overview of some popular approaches.

Figure 13: Comparison of metrics

	Description	Complexity to calculate[9]	Intuition
Skewness and kurtosis	Symmetry and tails of the distribution	Low	A positive skew indicates occasional large gains and frequent small losses, while a negative skew indicates the opposite. Positive kurtosis indicates the presence of "fat tails," while negative kurtosis indicates the opposite.
Statistical normality tests	Likelihood that series is normally distributed	Low/medium	Provides a sanity check on how realistic normal distribution assumptions are.
Implied volatility	Model implied volatility from options market	Medium	Uses forward-looking, option-implied market expectations instead of historical data.
Sortino and Calmar ratios	Adjusting Sharpe ratios that focus solely on downside volatility or the maximum drawdown	Low	These use normal distribution assumptions but distinguish between "good" and "bad" volatility.
VaR	Estimated maximum loss: In (x%) of cases, you can expect losses to exceed (y%)	Varies depending on inputs	Uses normal distribution assumptions but estimates the minimum loss at a certain threshold.
CvaR	The expected loss beyond VaR threshold	Moderate	Similar to the above, but looks at the total potential loss, not just a minimum number.
GARCH	Volatility forecast	High	A potentially more accurate estimate of future volatility, considering that volatility tends to cluster.

Source: STOXX.

While each of these metrics has their strengths and weaknesses, the primary limitation we can see from this brief survey is the education and knowledge needed to apply them, compared to their utility in understand timing risk. While finance industry professionals may live and breathe some of these, an average individual investor is unlikely to do so. The TIV spread can bridge the gap in helping understand the profile of historical returns without a crash course in statistics, balancing simplicity and insight.

[9] Using Excel or Python, for example.

7. Variations in the TIV spread

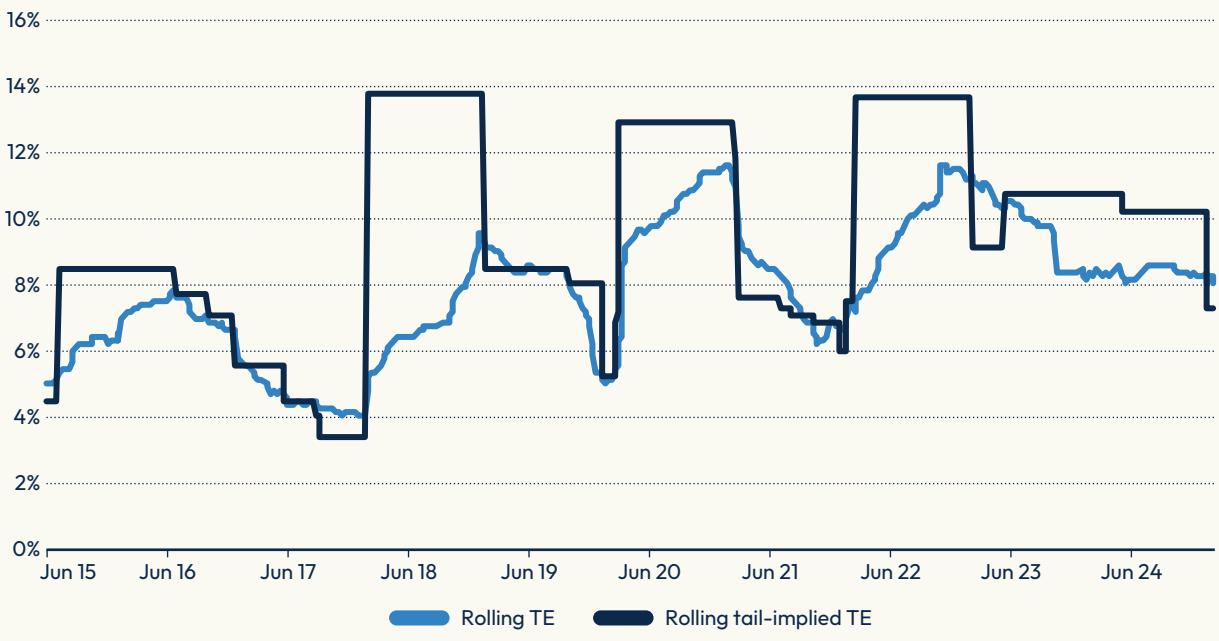
Since several parameters are selected when constructing the TIV spread, there are several ways in which this metric can be customized for more specific insights:

- **Varying look back period** – We chose to remove the best one-day return per year, as calendar year returns are commonly used in strategy evaluation. However, both the rolling window and the look back period can be varied. For example, in Figure 7 we used a rolling look back window.

- **Number of returns removed** – For simplicity, we removed just the best day per calendar year. However, multiple days per year could be removed to further increase robustness. In this case the calculation becomes slightly more complex, as the probability for each return (e.g., second-best, third-best) needs to be calculated independently.

- **Type of volatility used** – We used the volatility of returns, but the metric also works in the active space, i.e., relative to a benchmark. Tracking error is the volatility of benchmark-relative returns, so a tail-implied tracking error statistic could also be generated using the same methodology. As an example, the chart below uses a one-year look back window and substitutes active returns for returns in the TIV calculation.

Figure 14: Tail-implied tracking error (TE) for the STOXX AI Innovators



Source: STOXX. 2014–2024, USD net version. Benchmark: STOXX AC All Cap. A 252-day rolling window was used. The history prior to the index launch was simulated.

A look at this example shows that the story is similar in the active space, meaning that active (benchmark-relative) returns may be concentrated as well. The periods showing this highlight the times where investors run an increased risk of missing out on substantial benchmark-relative returns.

The extensibility of this metric is a potential area for future research.

8. Conclusions

The tail-implied volatility (TIV) spread that we propose in this paper is a tool allowing investors to compare investments from the standpoint of timing risk. An index with a historical volatility of 15% may seem like less of a risk to time than one of 20%; our metric aims to help assess whether this was historically the case. For portfolios with similar volatilities, the higher the TIV spread, the more concentrated the daily opportunity set was – i.e., the greater the risk of a timing strategy to miss the best day.

The right call on timing, of course, is only part of the equation for investors. While timing matters, sizing matters as well. This is the rationale behind the venture capital industry – there, it isn't how often you are right that matters, but how much you make when you are. Equally, volatility is not always a bad thing, since volatility can result in positive or negative returns. Higher risk can also correspond to higher returns and, when combined with the power of diversification, can result in powerful and robust portfolios.

Nevertheless, as Yogi Berra reputedly said, "it's tough to make predictions, especially about the future." If we accept the conventional wisdom that investments are difficult to time for individual investors, we can also understand that some are more difficult to time than others. Since volatility is an imperfect guide to the risks and opportunities, we have introduced this complementary and easy-to-understand metric to help investors better understand the timing risk of comparable investments.

9. Appendix

The TIV spread derivation, in annualized terms and assuming daily returns, is expressed as:

- Tail implied volatility – realized volatility, with

  Tail implied historical volatility: $\frac{\text{Best day performance impact}}{\text{z-score of n}^{\text{th}}\text{ day}} \times \sqrt{n}$, with

  Best day performance impact[10] = $\frac{\text{Annualized performance - annualized performance with best day per year removed}}{\text{Annualized performance with best day per year removed + 1}}$ and

  z-score of n^{th} day = $\phi^{-1}\left(\frac{n - \frac{\pi}{8}}{n - \frac{\pi}{4} + 1}\right)$, *with*

  ϕ^{-1} as the inverse cumulative distribution function,[11] and
  n days per year

- Annualized realized volatility = $\sqrt{\frac{1}{n-1} \times \sum_{i=1}^{n} \text{log returns}^2} \times \sqrt{n}$, *with*
  n days per year

[10] This solves for the return which, if applied to the annualized return of the series with the best day per annum removed, would equal the return of the regular series.

[11] This returns the number of standard deviations away from the mean that we expect for a given probability. Given the daily time frame, we assume a mean of 0. To normalize, we use a standard deviation of 1.

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