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QUANTICA CAPITAL

# QUARTERLY INSIGHTS

## WHEN TREND-FOLLOWING HITS CAPACITY
## A CASE STUDY ON COMMODITIES

Exploring the hidden opportunity costs of limited investment universe diversification

#21 | MARCH 2025

# Executive summary

In this research note, we analyze the relationship between the optimal size of an investment universe, its investment capacity, and the underlying market liquidity characteristics for a typical medium-term trend-following strategy, using commodities as a case study.

For most trend-following CTAs, commodities are a key part of their investment universe and can be a key contributor to performance. In fact, over the past five years, we estimate that commodities may have contributed approximately half of the trend-following CTA industry's total returns through December 2024. Among all asset classes, commodity futures present the broadest and most diverse range of investment opportunities for trend-followers as evidenced by their historically lower average cross-correlations in trend-following returns.

While commodities present on paper substantial diversification benefits, we find that these benefits are heavily influenced by the liquidity available in each commodity market. While we do not find any clear relationship between market liquidity and the historical profitability of trend-following after accounting for trading costs, we show that less liquid markets tend to exhibit weaker trend-following return correlations, while more liquid markets appear more strongly correlated. As a result, the expected theoretical Sharpe ratio of a broadly diversified trend-following strategy across 69 commodity markets can be nearly twice as high as that of a universe restricted to only the 10 most liquid commodity markets.

In practice, however, it is difficult to fully capitalize on these diversification benefits due to inherent market capacity constraints. Commodity futures liquidity is highly concentrated: out of a universe of 69 commodity futures, the 10 most liquid commodity markets account for approximately 70% of the total liquidity across all available commodity futures, with energy futures alone accounting for 55-65%. As the target investment capacity of a strategy increases, risk allocation must shift toward more liquid markets, leading to higher return correlations and hence a decline in the strategy's expected Sharpe ratio.

For a $1 billion target capacity for the commodity allocation in a medium-term trend-following program (corresponding to an approximately $3-4 billion capacity for the fully diversified program), the more concentrated risk allocation amongst fewer instruments can result in an estimated 17% Sharpe ratio deterioration, equivalent to an estimated -1.6% annual drag on returns (assuming a 12% p.a. target portfolio volatility), compared to the unconstrained case.

Additionally, the average historical per-market Sharpe ratio across a full universe of 69 commodity futures is around 0.15-0.2, fluctuating within a narrower range of approximately $\pm$0.1. As the risk allocation is concentrated in fewer markets, confidence in this number decreases, driven by the substantial dispersion in trend-following Sharpe ratios across markets, leading to greater variability in expected performance.

At the same time, our framework, built on our proprietary liquidity models, underscores the potential opportunity cost of trading fewer markets than the capital allocated to a strategy would theoretically permit. For example, trend-following ETFs, which have recently gained popularity due to their lower fees and ease of access, are structurally limited to trading only a fraction of the markets available to an unconstrained CTA. As a result of the lack of full diversification potential, the expected structural drag on performance can be as high as 4% per year before fees over the long term. This drag can potentially negate or even outweigh the benefits of lower fees when compared to more expensive, yet better-diversified implementations with more effective use of their investment capacity.

We conclude that the optimal number of commodity markets traded in a trend-following program is directly tied to its target investment capacity. Understanding and carefully evaluating the relationships between diversification benefits, implementation costs and investment capacity is essential to selecting an optimal investment universe that maximizes the performance potential of a trend-following strategy.

## Introduction

At its core, trend-following is built on a simple yet powerful assumption: persistent price trends occur repeatedly across all liquid financial and commodity futures markets, regardless of market conditions. By systematically capturing these trends, trend-following strategies aim to generate positive, uncorrelated returns over the long term. However, the timing and location of the next profitable trend remain unknown. This uncertainty underscores the importance of trading across the broadest and most diversified universe possible. Market diversification is fundamental to any successful trend-following strategy, ensuring exposure to a wide range of opportunities while reducing reliance on any single market or asset class.

Exchange-traded futures markets provide a great framework for implementing this approach. Their deep liquidity across multiple asset classes - including commodities, equities, fixed income, and currencies - enables capital-efficient risk deployment at scale on both the long and short sides.

Since the emergence of the first trend-followers, also known as Commodity Trading Advisors (CTAs), nearly 50 years ago, commodities have been a fundamental part of their investment universe, as the name implies[1]. This connection traces back to the origins of futures markets, which were initially created for commodity trading.

While each trend-following CTA selects its own investment universe, trend estimation approach, and risk allocation strategy, our research indicates that commodities have emerged as the leading

[1] While commodities have historically played a key role, CTAs also trade a wide range of asset classes, including equities, fixed income, and currencies.

contributor to trend-following CTAs performance over the past five years. When aiming to replicate average trend-following industry returns, as represented by a benchmark like the SG Trend Index (which, as of 2024, tracks nearly $60 billion in assets managed by 10 of the largest global trend-following programs), commodity futures are estimated to have contributed about half, or roughly 4.2% per annum, of the total gross performance over the period January 2020 and December 2024[2].

| 01.01.20 - 31.12.24 | Asset class | Annualized returns |
|---|---|---|
| Quantica generic trend-following model (hypothetical) | Equities | 0.2% |
| | Fixed Income & Rates | 2.3% |
| | Currencies | 1.2% |
| | Commodities | 4.2% |
| | Total (net total return) | 7.9% |
| SG Trend Index | Total | 7.8% |

Table 1: Estimated annualized asset-class gross return attribution and net total return (accounting for management fees of 1% per annum and annual performance fees of 15%, including the contribution from cash) to replicate the positions and performance of a trend-following industry benchmark, such as the SG Trend Index, for the period January 1, 2020 – December 31, 2024. This analysis is based on an internally developed generic medium-term trend-following model, incorporating realistic trading costs derived from Quantica's proprietary models. The correlation between the generic trend-following model and the SG Trend Index based on daily returns over the period is 0.9. For illustrative purpose only. The actual performance of any trend-following strategy may differ significantly from the estimates provided due to various market factors, model assumptions, and other variables. No assurance is given that any investment or trading program will achieve results similar to those of the SG Trend Index. The SG Trend Index is unmanaged, does not incur fees, and is not directly investable. Source: Quantica Capital, Societe Generale. HYPOTHETICAL RESULTS. PLEASE SEE IMPORTANT DISCLAIMERS ON PAGE 3.

Given their strong contribution to trend-following performance in recent years, this research note takes the opportunity to revisit the diversification benefits that make commodities an essential part of a trend-follower's investment universe. In particular, using an extensive and comprehensive universe of 69 commodity futures markets, we quantify how these benefits are affected by increasing capital allocations to the commodity universe within a generic trend-following modeling framework.

By incorporating investment capacity models for commodity futures markets (which estimate how much liquidity each market can absorb), we highlight the trade-offs between theoretically optimal portfolio diversification benefits and the practical constraints imposed by the uneven distribution of liquidity across the commodity futures universe.

After introducing our commodity investment universe, we begin by examining the distribution and concentration of available liquidity across different commodity sectors, including energy, precious and base metals, and agricultural futures.

In a first step, assuming unlimited investment capacity – allowing to allocate equal risk to all markets displaying the same trend strength regardless of their liquidity characteristics - we employ a simple model to quantify the theoretical diversification benefits as a function of the liquidity composition of the investment universe. Starting with the set of most liquid commodity futures, we progressively expand the investment universe by adding markets in decreasing order of liquidity to quantify the marginal diversification benefits of adding less liquid markets. We compare the resulting diversification profile to that of the three other major asset classes - equities, fixed income, and currencies.

In a second step, we impose an allocation constraint that limits the size of a position and trade in each market as a percentage of the market's available daily liquidity.

[2] Based on an internally developed trend following model designed to replicate the positions and returns of a typical trend-following benchmark such as the SG Trend Index. The SG Trend Index is designed to track 10 of the largest trend-following CTAs (by AUM) which meet a list of criteria (as defined by SG) and be representative of the trend-followers in the managed futures space. The SG Trend Index is equally weighted, and rebalanced and reconstituted annually. The Index is not directly investable and is presented for illustrative purposes only and does not represent the performance of any specific trading program, advisor, or fund. There are material differences between the index and any individual trading strategy, including but not limited to fees, execution costs, and risk management practices. Source: Société Générale.

Under such market capacity constraints, we analyze how increasing target strategy investment capacity - ranging from $1 million to $5 billion for the commodity allocation[3] - impacts portfolio diversification. Specifically, we seek to quantify the number of commodity markets, or the proportion of the total available universe that meaningfully contribute to diversification at each capacity level. This allows us to assess the relationship between investment capacity and the diversification benefits of commodities within a generic medium-term trend-following strategy. It enables us to estimate the theoretically expected deterioration in strategy Sharpe ratio as investment capacity increases, and at the same time to determine the number of instruments that may effectively contribute to the highest theoretically expected Sharpe-ratio for a given target investment capacity level.

## Only 10 commodity futures markets account for approximately 70% of all available commodity futures liquidity

Our analysis in this research note is based on a set of 69 exchange-traded commodity futures markets. While not exhaustive, we believe this selection represents the vast majority of globally available commodity futures liquidity and includes 20 energy, 33 agriculture, 4 precious metals, and 12 base metals & industrial futures contracts. Commodity futures markets with minimal open interest recorded across their lifetime, as well as all China commodity futures, are excluded[4]. Figure 1 provides an overview of the attribution of aggregate commodity futures liquidity[5] across sub-sectors since 2015, with values normalized to 1 in 2015. It is first worth observing that over the last 10 years aggregated commodity liquidity has doubled, reaching a peak in 2022, driven by a spike in market volatility[6]. Second, energy futures have consistently

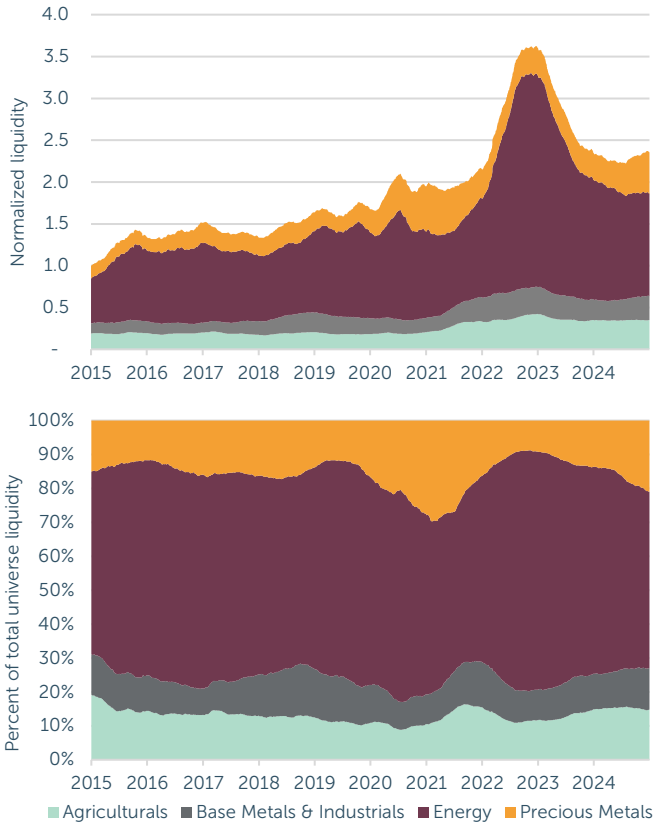



Figure 1: (Top) Distribution of commodity futures liquidity across sub-sectors and (Bottom) share of total available commodity futures liquidity by sub-sector. Period: 2015 – 2024. Market liquidity estimated based on a proprietary market liquidity models designed to measure the true available liquidity in risk terms for a trend-following CTA. Unlike traditional liquidity metrics such as average daily traded volume or open interest, which do not account for a contract's daily risk, it provides a more precise assessment of a market's capacity to absorb trend-following positions.
Source: Quantica Capital.

[3] All investment capacities referenced in here refer to the strategy deployed on the commodity universe only. Accordingly, in the case of a more diversified implementation of the strategy including equities, fixed income, and currencies, and allocating one-quarter or one-third of its risk to commodities, capacity numbers would have to be multiplied by a factor of 3-4, assuming the other asset classes offer greater capacity than commodities.

[4] Please feel free to contact Quantica if you would like to learn more about the complete list of futures markets used for the purpose of this research note.

[5] Estimated based on proprietary market liquidity models designed to measure the true available liquidity in risk terms for a trend-following CTA. Unlike traditional liquidity metrics such as average daily traded volume or open interest, it provides a more precise assessment of a market's capacity to absorb trend-following positions. The same market liquidity models were used as a basis to quantify the overall market participation of the trend-following industry in "The footprint of trend-following", Quantica Quarterly Insights, December 2022.

[6] Higher market volatility reduces the notional exposure required to achieve a given target risk level, thereby increasing the effective available liquidity for a trend-following CTA.

accounted for the majority of available liquidity, representing 55–65% of the total. Agricultural futures contribute approximately 10–20%, while precious metals make up to 15% of overall commodity liquidity.

The chart makes it clear that commodity liquidity is very unevenly distributed across sub-sectors and markets. As shown in Table 1, which lists the 15 most liquid commodity markets based on our proprietary liquidity metric over the period 2020 – 2024, four contracts – WTI & Brent crude oil, gold, and US natural gas – account for around 50% of total available commodity futures liquidity, with WTI oil being the most liquid, estimated to represent a quarter of all liquidity.

| Rank | Instrument | Sub-Sector | % of total liquidity | Cumulative % |
|---|---|---|---|---|
| 1 | WTI Crude 1 | Energy | 22% | 22% |
| 2 | Gold | Precious Metals | 11% | 33% |
| 3 | Brent Crude | Energy | 11% | 44% |
| 4 | Natural Gas (Henry Hub) | Energy | 6% | 50% |
| 5 | Silver | Precious Metals | 5% | 55% |
| 6 | Natural Gas TTF | Energy | 4% | 59% |
| 7 | Gasoline | Energy | 4% | 62% |
| 8 | Heating Oil | Energy | 4% | 66% |
| 9 | Soybeans | Agriculturals | 3% | 69% |
| 10 | Gasoil Low Sulfur | Energy | 3% | 72% |
| 11 | Copper 1 | Base Metals & Industrials | 3% | 75% |
| 12 | WTI Crude 2 | Energy | 3% | 78% |
| 13 | Copper 2 | Base Metals & Industrials | 3% | 81% |
| 14 | Corn | Agriculturals | 2% | 83% |
| 15 | Aluminium | Base Metals & Industrials | 2% | 85% |

Table 2: List of the 15 most liquid commodity futures markets out of a universe of 69 (excluding China commodity futures). Liquidity for each market is estimated based on a proprietary market liquidity models designed to measure the true available liquidity in risk terms for a trend-following CTA. The ranking is based on a median of this indicator for each market over the last 5-year period 2020 – 2024. The ranking is based on market liquidity scores which are based on proprietary models and is for illustrative purposes only. Liquidity estimates are subject to market conditions, model assumptions, and other variables that may impact market liquidity at any given time. Source: Quantica Capital.

More broadly, 10 of the 69 selected commodity futures markets account for around 70% of total available commodity futures liquidity, with the remainder spread across the other 59 markets.

Having provided a high-level overview of the liquidity characteristics of the commodity futures investment universe and having ranked the markets by their true available liquidity for a trend-following CTA, we turn to quantifying the relationship between the diversification potential and the underlying liquidity characteristics of the commodity futures for a generic medium-term trend-following strategy.

## A simple model to measure the diversification potential of commodities for trend-following

To quantify the diversification benefits of commodities, we rely on a model that we introduced in a previous Quarterly Insights note from December 2021[7].
In fact, the risk-adjusted return (or Sharpe ratio) of an equal-weighted portfolio of $n$ correlated (trend-following) return streams can be expressed as a function of three variables:

- the number $n$ of portfolio constituents,
- the average cross-correlation $\bar{\rho}$ of the constituents' (trend-following) return streams, and
- the average Sharpe ratio $\bar{s}$ of the $n$ (trend-following) return streams: $\bar{s} = \frac{1}{n}\sum_{i=1}^{n} \text{Sharpe}(R_i)$, where $R_i$ denotes the (trend-following) return stream of instrument $i$

$$\text{Sharpe}\left(\frac{1}{n}\sum_{i=1}^{n} R_i\right) = \bar{s} \cdot \frac{1}{\sqrt{\bar{\rho} + \frac{1-\bar{\rho}}{n}}} = \bar{s} \cdot m(\bar{\rho}, n)\,.$$

The proportionality factor or Diversification Multiplier $m(\bar{\rho}, n)$ only depends on the number of universe constituents and the average cross-

[7] "The value of diversification in trend-following", Quantica Quarterly Insights, December 2021.

correlation of their (trend-following) return streams and measures the pure diversification benefit obtained from adding instruments to the universe[8].
With this simple formula, the diversification potential of a given investment universe of commodities and the Sharpe ratio that may be generated by a medium-term trend-following strategy applied to such universe may be quantified by estimating the following two variables empirically:

- the average per-instrument Sharpe ratio, and
- the average cross-correlation $\bar{\rho}$ of the constituents' trend-following returns, which allows to compute the multiplier $m(\bar{\rho}, n)$.

To estimate these two variables, we will again use our proprietary generic medium-term trend-following model[9], which was designed to closely track the positions and returns of a typical trend-following benchmark such as the SG Trend Index.

**The average per-market trend-following Sharpe ratio across all commodities over the past 10 years does not appear to show a dependency on liquidity**

We begin by exploring the relationship between the average per-instrument medium-term trend-following Sharpe ratio of a pure commodity universe and the underlying liquidity characteristics of that universe.
For that purpose, we simulate the generic trend-following strategy applied to our universe of 69 commodity futures for the period from January 2015 to December 2024. Based on the simulated returns, we calculate the average per-market Sharpe ratio net of realistic trading costs[10] for investment universes of increasing size. The analysis starts with a single-instrument universe, consisting of the most liquid of the 69 markets, and progressively adds markets in descending order of liquidity, based on their average liquidity score over the full 10-year period.

The results, shown in Figure 2, clearly demonstrate the lack of a direct relationship between the expected per-market profitability of trend-following and the liquidity of the underlying market. Investors would not have been rewarded with higher trend-following returns on average in less liquid commodity markets over the past 10 years. Indeed, the hypothetical average per-market Sharpe ratio of a generic medium-term trend-following strategy has consistently ranged between 0.1 and 0.2 net of trading costs across all commodity universe constituents, irrespective of universe size. Less liquid markets may have historically exhibited more profitable trends than more liquid markets, but over the long term, higher trading costs appear to generally offset most of these advantages.

At the same time, the confidence in the average per instrument Sharpe ratio estimation increases as the investment universe expands. This is reflected in the 2.5% and 97.5% percentile confidence intervals of the estimated average Sharpe ratio, which become narrower as the investment universe is composed of more markets.
Over the past 10 years, individual commodity instruments have exhibited hypothetical trend-following Sharpe ratios ranging from -0.75 to +1.3 with a standard deviation of 0.4 In contrast, the

[8] The following two extreme scenarios may be highlighted:
- If $\bar{\rho} = 0$, then the formula reduces to $\bar{s} \cdot \sqrt{n}$ and we see that the Sharpe ratio can grow without bounds, proportionally to the square root of the number of instruments.
- If instead all the constituents are perfectly correlated, i.e. $\bar{\rho} = 1$, (or if $n = 1$), the multiplier $m(\bar{\rho}, n) = 1$, and the portfolio Sharpe ratio is equal to $\bar{s}$, and there is no diversification benefit at all.

[9] Our generic trend-following model measures trends based on an exponentially weighted moving average with a half-life of one calendar quarter. The strategy targets a long-term portfolio volatility of 12% p.a., with an equal long-term target risk allocation across instruments.
[10] Trading cost assumptions are market specific and derived from Quantica's proprietary execution models with higher costs for less liquid markets and lower costs for more liquid ones.

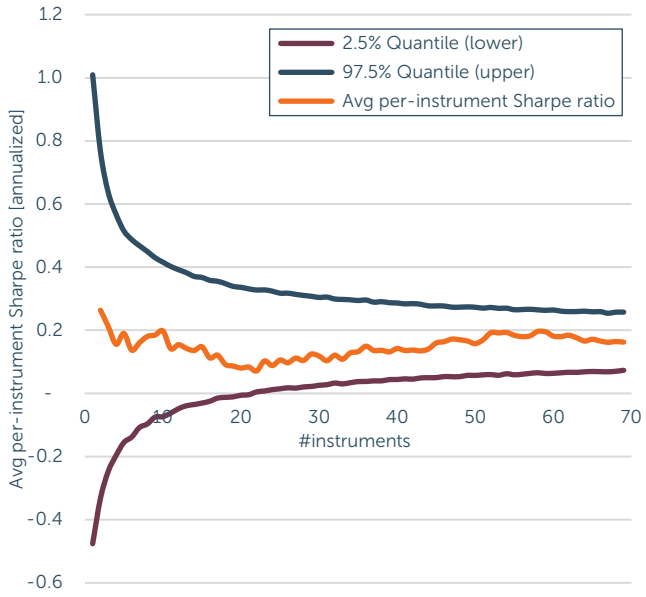



Figure 2: Average equal-weighted trend-following Sharpe ratio per instrument across investment universes of increasing sizes, incorporating additional markets in descending order of their liquidity, based on their average liquidity score over the period. The 2.5% and 97.5% percentiles are derived from random selections of *n* commodity markets out of a total of 69. Sharpe ratios are net of realistic trading costs but do not reflect the deduction of investment advisory fees and other expenses. Period of analysis: Jan. 2015 – Dec. 2024. Source: Quantica Capital. HYPOTHETICAL RESULTS. PLEASE SEE IMPORTANT DISCLAIMERS ON PAGE 3.

hypothetical average per-instrument trend-following Sharpe ratio across the full universe of 69 instruments has remained within a significantly narrower band of approximately $\pm 0.1$[11].

Next, we aim to quantify the relationship between the average cross-correlation of per-instrument trend-following returns across the constituents of a commodity investment universe and the underlying liquidity characteristics of that universe.

**The reward for accepting lower market liquidity is an increase in diversification benefits, rather than more profitable trends.**

As before, we conduct the analysis on commodity investment universes of increasing size, progressively incorporating less liquid markets. Specifically, we calculate the average quarterly cross-correlations on a rolling, non-overlapping quarterly basis over the past 10 years, and derive the associated 95% confidence intervals using bootstrapping[12]. To minimize temporal bias, the constituents of each investment universe of size *n* are updated daily, incorporating the *n* most liquid instruments based on their liquidity score from the preceding 12 months.

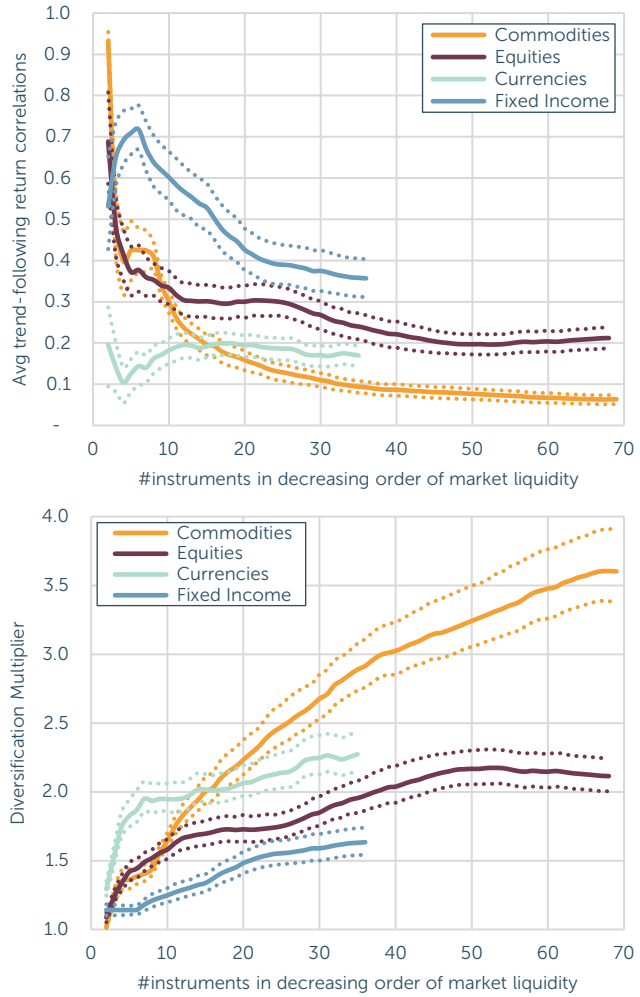
The results are presented in Figure 3, which also includes a comparison of the average cross-correlation of per-instrument trend-following returns across the three other major asset classes: equities, fixed income, and currencies[13].

Across commodities, the average cross-correlation of trend-following returns consistently decreases as less liquid markets are added to the universe. For example, the average trend-following return correlation for the 10 most liquid commodity futures markets (which as a reminder account for around 70% of total commodity futures liquidity) is 0.3. However, this correlation drops to just 0.06 when considering the full set of 69 instruments. Less liquid markets tend to exhibit weaker trend-following return correlations, while those with deeper liquidity are more strongly correlated. In other words, the reward for trading less liquid markets is an increase in diversification benefits, rather than more profitable market trends.

[11] While this is beyond the scope of this note, similar observations may be made on the other liquid asset classes (equities, fixed income, currencies). We don't see any empirical evidence or theorical justification that less liquid markets are more likely to produce more profitable trends compared to more liquid markets.

[12] To obtain the confidence interval of average quarterly cross-correlations, we begin by selecting a random starting point between 0 and 63, representing the starting day of a quarter. From the starting point, we construct a series of these statistics at quarterly intervals. We then resample this series with replacement to generate bootstrap samples and compute the mean for each sample. By repeating this procedure multiple times, we obtain a distribution of the mean based on the resampled data.

[13] Based on a comprehensive list of 68 equity index, 36 fixed income, and 35 currency instruments.




| Asset class | #instruments | Lowest avg cross-correlation | Highest Diversification Multiplier |
|---|---|---|---|
| Equities | 68 | 0.20 | 2.1 |
| Fixed income | 36 | 0.35 | 1.6 |
| Currencies | 35 | 0.17 | 2.3 |
| Commodities | 69 | 0.06 | 3.6 |

Figure 3: (Top) Average quarterly instrument trend-following return cross-correlations and (Bottom) corresponding "diversification multiplier", including 95% confidence intervals using bootstrapping, for investment universes of increasing sizes, with constituents being added in descending order of their liquidity. The constituents of each investment universe of size $n$ are updated daily, incorporating the n most liquid instruments based on their average liquidity score over the preceding 12 months. The Diversification Multiplier measures the diversification potential of a given investment universe and only depends on the number of universe constituents and their average cross-correlation. Analysis performed over the period Jan. 2015 – Dec. 2024 and based on a generic trend-following model developed by Quantica. Source: Quantica Capital. HYPOTHETICAL RESULTS. PLEASE SEE IMPORTANT DISCLAIMERS ON PAGE 3.

Applied to the full commodity universe, the Diversification Multiplier for a medium-term trend-following strategy can theoretically reach 3.6, a value almost twice as high as the Diversification Multiplier of 1.65 for the same strategy applied to a smaller universe composed of only the 10 most liquid commodity markets. Assuming an average per-instrument Sharpe ratio of 0.2, independent of the composition of the universe, the expected Sharpe ratio of the fully diversified commodity trend-following portfolio can reach 0.72 (0.2*3.6) or more than double the expected Sharpe-ratio of 0.33 for the highly liquid 10 instrument portfolio. We conclude that the potential to increase the portfolio's Sharpe ratio by adding less liquid commodity markets is significant.

## Of all major asset classes, commodities offer the strongest diversification benefits

More generally, among all major asset classes, commodities offer the strongest potential diversification benefits for trend-following strategies. Applying trend-following to less liquid markets lowers average return correlations across all asset classes, but the highest Diversification Multiplier for the broadest currency, equity, and fixed income universes are only 2.3, 2.1, and 1.6, respectively. Interestingly, any commodity universe with more than 20 liquid constituents delivers already a higher Diversification Multiplier. Finally, while the diversification benefits for equity market futures appear to plateau after the 45th market, no such limit seems to have been reached for commodities. This is consistent with theory as we have previously demonstrated[14] that the number $N_p$ of portfolio constituents needed to reach $p \in [0\%, 100\%]$ of the maximally achievable Diversification Multiplier is purely a function of the average cross-correlation $\bar{\rho}$ and is given by:

[14] "The value of diversification in trend-following", Quantica Quarterly Insights, December 2021.

$$N_p = \frac{1-\bar{\rho}}{\bar{\rho}} \cdot \frac{p^2}{1-p^2}.$$

Using a 95% threshold and the previously estimated average per-commodity-instrument trend-following return correlation of 0.06, the formula indicates that a generic trend-following approach could potentially and theoretically achieve further diversification benefits by expanding the investment universe to as many as 138 instruments.

Due to their higher intra-asset class cross-correlation, equity and bond markets require far fewer instruments than commodities to reach the maximum diversification threshold. Specifically, the $N_{95\%}$ threshold is met with just 38 equity and 17 fixed income instruments, due to the higher average correlation of the underlying returns

### The practical implementation limits to the theoretical diversification benefits

At this point, it is important to note that we made the assumption of a uniform long-term target strategic risk allocation across all 69 commodity markets, regardless for their ability to absorb the risk associated with any level of hypothetical capital allocation into the trend-following strategy. Hence, we assumed unlimited capacity in all underlying commodity markets.

Ignoring market capacity constraints, the optimal approach would be to trade all 69 instruments, allocating the same strategic target risk to each, as this could yield the highest theoretical expected Sharpe ratio for the given strategy configuration.

While a manager with a small capital allocation can easily implement an equal long-term strategic risk allocation across all commodity instruments, scaling up to a larger allocation - such as $5 billion - will clearly encounter market capacity constraints. Some of the less liquid markets won't simply be able to absorb the size of the targeted risk allocations. This forces the manager to choose between (1) narrowing down the investment universe to focus on a set of instruments that allows for an equal long-term strategic risk allocation, or (2) allocating more risk to the more liquid instruments at the expense of less liquid instruments. In the next section, we aim to quantify the impact of deviating from an ideal equal-risk allocation due to liquidity constraints on the weighted average trend-following return correlations, Diversification Multipliers, and the expected Sharpe ratio of the strategy.

### Target investment capacity and effective number of markets contributing to risk diversification

To account for the finite market capacity of futures markets, we further subject our generic trend-following strategy to liquidity allocation constraints. Specifically, each position and each trade in any market cannot exceed a fraction of the available daily liquidity for that market. We define market specific maximum exposure thresholds derived from Quantica's proprietary market liquidity models to ensure that trade sizes remain within levels that mitigate the risk of elevated execution costs and potential performance degradation due to market impact. Any excess capital that cannot be deployed due to these limits is allocated pro rata to the remaining markets with excess capacity until the overall portfolio risk target is met.

We then simulate this generic trend-following strategy including liquidity constraints over the 10-year period from 2015 to 2024, and for different hypothetical target investment capacities from $1 million to $5 billion for the commodity allocation[15].

Figure 4 shows the cumulative percentage of total portfolio risk explained by the number of

[15] The underlying exponentially weighted moving average used to measure trends in our generic trend-following strategy is based on a half-life of one calendar quarter and the strategy's portfolio volatility target is 12% per annum. Shorter half-lives (capturing shorter-term trends) or higher portfolio target volatilities would result in higher portfolio turnover and amplify the impact of liquidity constraints, while longer half-lives (reflecting longer-term trends) and lower portfolio target volatilities would reduce their effect.

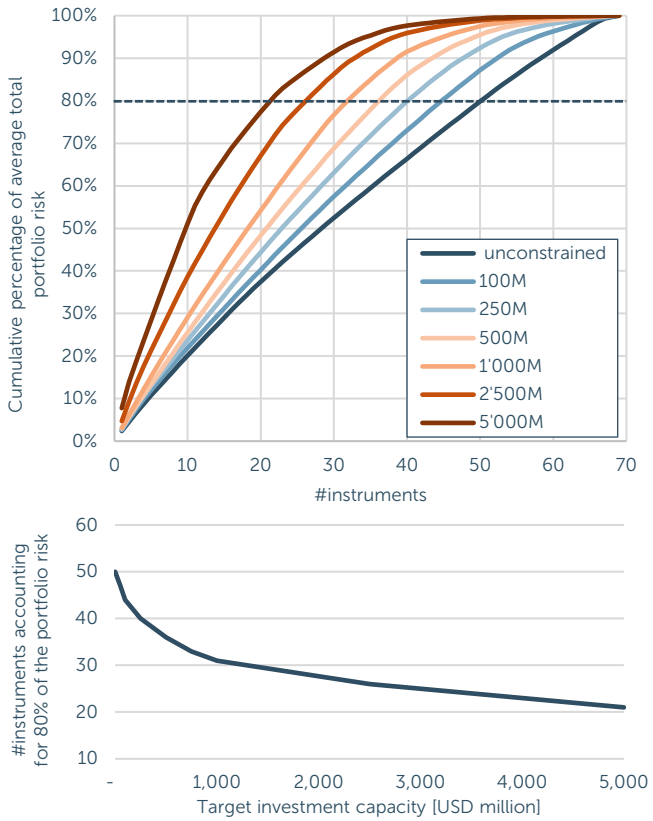



Figure 4: (Top) Cumulative percentage of average total portfolio risk explained by number of constituents in the investment universe in descending order of their individual contribution for different target investment capacities of an underlying generic medium-term trend-following strategy. Percentage of average total portfolio risk explained is calculated as the ratio between the 1-day Value-at-Risk (99%) of the group of instruments divided by the sum of 1-day Value-at-Risk (99%) across all instruments. (Bottom) Corresponding number of instruments accounting for on average 80% of the total portfolio risk realized. Analysis performed over the period Jan. 2015 – Dec. 2024. Source: Quantica Capital. HYPOTHETICAL RESULTS. PLEASE SEE IMPORTANT DISCLAIMERS ON PAGE 3.

constituents in the investment universe. For an unconstrained strategy (or for very small target investment capacities), the cumulative percentage of risk explained is almost linear in the number of instruments. A linearly shaped curve represents a portfolio that adheres to an equal long-term target strategic risk allocation across all instruments. Inversely, the more concave the risk allocation curve, the greater the deviation from the target equal strategic risk allocation profile, reflecting the impact of investment capacity constraints. The concave shape is the result of fewer and fewer instruments accounting for the bulk of the risk allocation. For an investment capacity of $5 billion, only one-third of all available commodity instruments will meaningfully contribute to portfolio diversification, accounting together for on average 80% of the total portfolio risk realized over the past ten years.

In a last step, we quantify the impact of higher investment capacities on strategy diversification in terms of theoretically expected strategy Sharpe ratio deterioration. For each target investment capacity level, we calculate *risk-weighted* trend-following return correlations[16], accounting for the unequal distribution of risk across instruments, along with their confidence intervals, using bootstrapping on a rolling, non-overlapping quarterly basis. This allows us to infer the associated risk-weighted Diversification Multiplier of our generic medium-term trend-following strategy (a proxy for its expected Sharpe ratio). As shown in Figure 5, for a $50 million target investment capacity, the average *risk-weighted* and *equal-weighted* trend-following return correlations, as well as the corresponding Diversification Multipliers, are nearly identical at 0.05 and 3.8, respectively. Assuming an average per-instrument Sharpe ratio of 0.2, this corresponds to an excepted theoretical strategy Sharpe ratio of 0.76 (i.e. 3.8*0.2).

As target investment capacity increases, maintaining a given level of portfolio risk exposure requires reallocating risk toward more liquid futures markets at the expense of less liquid ones. This shift in relative risk allocation between instruments leads to a gradual rise in average risk-weighted instrument return correlations and a decline in both the Diversification Multiplier and the theoretically expected Sharpe ratio.

[16] For an *unequally*-weighted portfolio, the variance of the portfolio can be expressed as a function of the individual volatility $\sigma$, the weightings $w_1, \dots, w_n$, and the weighted average cross-correlation $\bar{\rho} = \frac{1}{\sum_{i \neq j} w_i w_j} \sum_{i \neq j} w_i w_j \rho_{ij}$ by the formula $\mathrm{Var}(\sum_{i=1}^{n} w_i R_i) = \sigma^2 (\sum_{i=1}^{n} w_i^2 + \sum_{i \neq j} w_i w_j \bar{\rho})$.

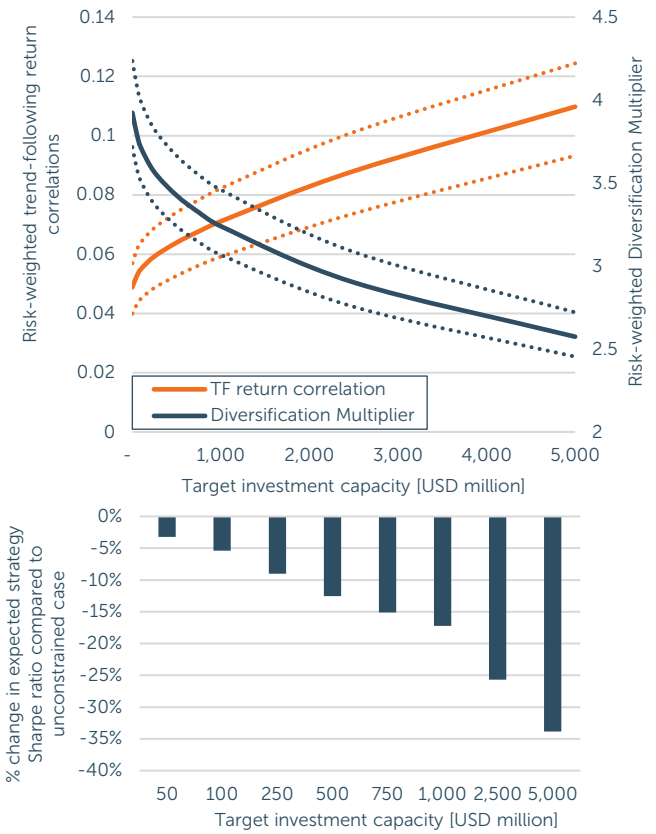



Figure 5: (Top) Average risk-weighted trend-following return correlations and corresponding Diversification Multiplier, including 95% confidence intervals using bootstrapping on a rolling, non-overlapping quarterly basis, for increasing target investment capacity levels of the underlying investment strategy. (Bottom) Corresponding % change in expected strategy Sharpe ratio. The Diversification Multiplier measures the diversification potential of a given investment universe, and for a portfolio of risky assets with unequal target risk allocation depends on the number of universe constituents, relative risk of instruments and their cross-correlation. Analysis performed over the period Jan. 2015 – Dec. 2024 and based on a generic trend-following model applied on a universe of 69 commodity futures markets, subject to maximum liquidity constraints per market. Source: Quantica Capital. HYPOTHETICAL RESULTS. PLEASE SEE IMPORTANT DISCLAIMERS ON PAGE 3.

For a medium-term trend-following strategy with a target volatility of 12% p.a. applied to a fully diversified commodities-only universe, a target investment capacity of $1 billion is expected to incur a theoretical Sharpe ratio reduction of 17% due to market capacity constraints, compared to an unconstrained, equal-risk implementation.

This translates to a decline of 0.14 Sharpe ratio points or an estimated 1.6% drag on the strategy's annualized returns, assuming an equal average per-instrument Sharpe-ratio of 0.2. At a capacity of $5 billion, the Sharpe ratio deterioration increases to 34%, equating to an annual performance drag of 2.7% under the same per-instrument Sharpe-ratio assumptions.

Once again, these theoretical results reflect the application of simplified, yet realistic, market-specific capacity constraints. While our trading cost assumptions are tailored to each market, we have intentionally chosen not to model them as a function of trade size. For larger portfolios, actual trading costs may be higher, potentially introducing an additional drag on expected returns. The demonstrated reduction in expected performance is a pure consequence of capacity constraints and does not yet reflect an expected increase in transaction costs.

## Balancing scale and diversification: The hidden opportunity costs with trend-following ETFs

Recently, a handful of trend-following strategies have emerged in the U.S. in the form of Exchange Traded Funds (ETFs). Promoters of these products highlight their simplicity and tradability, offering investors an accessible way to gain trend-following 'beta exposure' without the complexities of traditional CTAs or the scale required for a managed account. But most importantly, the key selling point of ETFs compared to traditional fund structures is their significantly lower fees compared to established and successful trend-following CTAs.

It is important to note that, given the low fees associated with ETF implementations, the manager's compensation is primarily driven by the assets raised. To make this a sustainable business model, the manager is constrained to implement a strategy with a high target investment capacity. As per our analysis above, this naturally limits the size of their investment universe to the most liquid futures markets. When it comes to commodities, this means that an ETF

may realistically allocate only among the very most liquid subset of commodity markets[17].

While a more concentrated universe provides for a larger investment capacity, it suffers from several limitations from an investor point of view:

1. The ETF doesn't capture the full scope of diversification potential offered by commodities (and other asset classes) for a trend-following approach. The weighted average correlation between universe constituents will typically be higher compared to those in a universe that is not subject to the ETF specific structural and operational constraints, translating into degraded return expectations.
2. While we believe the profitability of trends over the long-term to be similar across markets regardless of their liquidity level, the dispersion of such profitability across instruments and time is wide. As shown in Figure 2, a larger universe leads to smaller dispersion around the average expected realized Sharpe ratio per instrument, due to the low cross-correlations between instruments. In other words, an ETF with a limited number of instruments may experience a broader range of performance outcomes compared to a manager with a larger investment universe. Successfully navigating different market conditions may, therefore, require a higher degree of luck for an ETF implementation.

In reality, it is not uncommon for ETFs to offer trend following implementations with fewer than 10 commodity instruments. As shown in Figure 3, the Diversification Multiplier of the 10 most liquid commodity futures in our sample is 1.6, corresponding to an expected aggregate Sharpe ratio of 0.32, a value that is less than half of the theoretical maximum strategy Sharpe ratio that could be achieved with the optimal number of instruments with a target investment capacity of $1 billion. This can translate to an expected theoretical return drag of almost 4% per annum (assuming a strategy target volatility of 12% p.a.). While these results rely on several simplifying assumptions, they suggest that there may be significant opportunity costs associated with some trend-following ETF implementations, which may completely offset and even exceed any fee savings compared to more expensive but more effectively structured trend-following CTAs.

### More markets do not always lead to better results

At the other end of the complexity spectrum, trend-following programs that aim to trade hundreds of markets while managing billions of dollars in assets will likely experience a risk distribution that deviates from the theoretical optimal equal-risk allocation approach. While the prospect of accessing a broad range of investment opportunities may be appealing, many of these markets may contribute more to a marketing narrative than to the portfolio's risk allocation or overall performance, especially as the amount of capital managed increases.

In short, while incorporating the largest number of commodity futures markets is theoretically the most optimal approach, the reality is that each market can only absorb a finite amount of risk. Therefore, the optimal number of commodity markets for a trend-following program is directly tied to its target investment capacity. In order to select an optimal investment universe that maximizes the performance potential of a trend-following strategy, it is essential to understand and carefully evaluate the relationships between diversification benefits, implementation costs and investment capacity.

[17] Additionally, ETFs are subject to several structural limitations due to regulatory, liquidity and market-making requirements, which additionally limit the size of the tradeable universe. Futures contracts must be sufficiently liquid to support daily market-making (efficient creation and redemption of shares) without excessive slippage. ETFs must disclose holdings daily, which may impact execution and market impact in thinly traded markets.

## Conclusion

Among all asset classes, commodities provide the broadest and most diverse spectrum of investment opportunities for trend-following strategies. This is evidenced by the low average cross-correlation of trend-following returns across a representative set of 69 commodity markets used for this analysis, covering energy, agriculture and metals, and representing the vast majority of available global commodity futures liquidity. We have shown that the theoretical diversification benefit for a generic medium-term trend-following strategy is up to twice as high in commodities as it is in equities, fixed income, or currencies.

However, commodity futures liquidity is highly concentrated: the 10 most liquid commodity futures of these 69 markets make up 70% of total available liquidity. Crucially, we find no evidence linking lower liquidity to higher trend profitability, with the per-instrument trend-following Sharpe ratio for commodities averaging 0.15 - 0.20 over the past decade (a level that is not too dissimilar to the average per-instrument trend-following Sharpe ratio observed across other liquid asset classes).

Instead, we find a clear inverse relationship between market liquidity and diversification benefits: a fully diversified commodity universe can deliver almost twice the expected diversification benefits and trend-following Sharpe ratio compared to that of a universe restricted to the 10 most liquid markets. In short, trading in less liquid markets does not lead to the capture of stronger market trends. Instead, it leads to less correlated trend-following returns and thus higher risk-adjusted portfolio returns.

Achieving optimal diversification requires a sufficient long-term target risk allocation across all markets, yet in reality, each market can only absorb a finite and limited amount of risk.

As investment capacity increases, risk allocation must deviate from the ideal, concentrating in the most liquid markets. Taking into account such reasonable capacity constraints, we have shown that for a $1 billion medium-term trend-following strategy with a half-life of one calendar quarter and a target 12% annualized volatility, less than half of 69 commodities would have realized more than 80% of total portfolio risk over the past ten years. This effectively results in higher weighted average instrument cross-correlations that reduces the diversification potential of the commodity asset class. In such case, market liquidity constraints alone result in an expected 17% decline in the Sharpe ratio compared to the liquidity-unconstrained optimum, which is equivalent to a 1.6% drag on expected annualized performance if we assume a reasonable average per instrument trend-following Sharpe-ratio of 0.2 for each commodity market.

Moreover, a more limited number of instruments increases the range of expected performance outcomes, as the dispersion of trend-following profitability across instruments and time is significant. In fact, the resulting average per-instrument Sharpe ratio dispersion is expected to be twice as high for $1 billion capacity compared to the unconstrained portfolio.

Our results suggest that for a trend-following strategy with a pre-defined long-term portfolio risk exposure target, there is an optimal number of commodity markets that maximizes available diversification benefits, given a chosen target investment capacity. Conversely, by knowing the number of commodity markets traded by a strategy, the proposed framework allows to derive a realistic investment capacity that would maximise the theoretical diversification potential of its investment universe and compare it with the target investment capacity advertised by the manager of the trend-following program.

Since 2003, Quantica Capital's mission has been to design and implement the best possible systematic trend-following investment products in highly liquid, global markets. To the benefit of our investors and all our stakeholders.

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