Keep Up The Momentum*

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Abstract

The momentum risk premium is one of the most important alternative risk premia alongside the carry risk premium. However, it appears that it is not always well understood. For example, is it an alpha or a beta exposure? Is it a skewness risk premium or a market anomaly? Does it pursue a performance objective or a hedging objective? What are the differences between time-series and cross-section momentum? What are the main drivers of momentum returns? What does it mean when we say that it is a convex and not a concave strategy? Why is the momentum risk premium a diversifying engine, and not an absolute return strategy?

The goal of this paper is to provide specific and relevant answers to all these questions. The answers can already be found in the technical paper "*Understanding the Momentum Risk Premium*" published recently by Jusselin *et al.* (2017). However, the underlying mathematics can be daunting to readers. Therefore, this discussion paper presents the key messages and the associated financial insights behind these results.

Among the main findings, one result is of the most importance. To trend is to diversify in bad times. In good times, trend-following strategies offer no significant diversification power. Indeed, they are beta strategies. This is not a problem, since investors do not need to be diversified at all times. In particular, they do not need diversification in good times, because they do not want that the positive returns generated by some assets to be cancelled out by negative returns on other assets. This is why diversification may destroy portfolio performance in good times. Investors only need diversification in bad economic times and stressed markets.

This diversification asymmetry is essential when investing in beta strategies like alternative risk premia. On the contrary, this diversification asymmetry is irrelevant when investing in absolute return strategies. However, we know that generating performance with alpha strategies is much more difficult than generating performance with beta strategies. Therefore, beta is beautiful, but convex beta is precious and scarce. Among risk premia, momentum is one of the few strategies to offer this diversification asymmetry. This is why investing in momentum is a decision of portfolio construction, and not a search for alpha.

Keywords: Momentum, trend-following, diversification, payoff.

JEL classification: C50, C60, G11.

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Key Takeaways

- The performance of momentum strategies depends on three main parameters:
  - The absolute value of Sharpe ratios
  - The correlation matrix of asset returns
  - The moving average duration to estimate the trends
- Time-series momentum likes zero-correlated assets. This is why time-series momentum makes sense in a multi-asset framework.
- Cross-section-momentum likes highly correlated assets. This is why cross-section momentum makes sense within a universe of homogenous assets, e.g. a universe of stocks that belong to the same region.
- Short-term momentum is more risky than long-term momentum. Therefore, the cross-section dispersion of short-term momentum returns is broader than the cross-section dispersion of long-term momentum returns.
- The Sharpe ratio of long-term momentum is higher than the Sharpe ratio of short-term momentum.
- The choice of the moving average estimator is more crucial for short-term momentum than for long-term momentum.
- Too much leverage can be harmful for the strategy, since momentum portfolios are not homothetic transformations with respect to the portfolio's leverage.
- The payoff of a trend-following strategy is a long straddle option profile. Therefore, trend-following strategies exhibit a convex payoff.
- Trend-following portfolios are not absolute return strategies. In the long-run, trend-following strategies present a low moderate correlation with traditional asset classes. However, it is an illusion due to long-term averaging, since they present either a high positive or a high negative beta.
- The main motivation of momentum investing is diversification, not performance. The convexity of trend-following strategies mitigates the risk of diversified portfolios in bad times. This is why momentum strategies must be located in diversifying buckets, and not in absolute return buckets. Therefore, analysing the risk/return trade-off of momentum strategies on a standalone basis does not make sense.
- It follows that momentum risk premium is key for building an alternative risk premia portfolio.

1 Defining momentum strategies

Momentum is one of the oldest and most popular trading strategies in the investment industry. For instance, momentum strategies are crucial to commodity trading advisors (CTAs) and managed futures (MFs) in the hedge funds industry. They also represent the basic trading rules that are described in the famous Turtle trading experiment conducted by Richard Dennis and William Eckhardt in 1980s[1]. Momentum strategies are also highly popular among asset managers. For instance, the four-factor model of Carhart (1997) is the standard approach for analysing the performance of equity asset managers. Another important fact concerns the relationship between options and momentum. Indeed, it is well-known that the manufacturing of structured products is based on momentum strategies. Hedging demand from retail and institutional investors is therefore an important factor explaining the momentum style.

The momentum investment style is often opposed to the contrarian investment style. In the first approach, the investor follows the market or the current trend of some assets. This is why we also speak about trend-following strategies. In the second approach, the investor goes against the market or the current trend of some assets. This investment style is also known as the mean-reverting or reversal strategy. Contrarian investors think that financial markets overreact and crowd behaviour leads to a mispricing of assets. Therefore, value investing is generally classified as a contrarian strategy. It consists calculating the fundamental (or fair) value of the security, comparing this intrinsic value to the market value, and buying (or selling) the security if it is underpriced (or overpriced) by the market. Momentum investors are generally seen as lazy investors that demonstrate herding behaviour[2]. On the contrary, contrarian and value investors are perceived as smart people that "think outside the box". It is no coincidence that the most famous book on value investing is "The Intelligent Investor" written by Benjamin Graham. Therefore, momentum investors feel a sense of inferiority and often hide that they follow the crowd. In a nutshell, "*value and contrarian investing are gratifying while momentum investing is shameful*". However, it's not as simple as that, because all investors cannot be value or contrarian investors, even if they pretend that they are. For instance, by analysing the quarterly portfolio holdings of 155 equity mutual funds between 1974 and 1984, Grinblatt *et al.* (1995) found that "*77% of these mutual funds were momentum investors*".

As for value, there is a gap between the concept of momentum investing and the momentum risk premium. For instance, in a series of articles in the 1990s, Fama and French clearly defined the value risk factor and specified the quantitative metrics to measure the value of a stock. For momentum, we have to make the distinction between two generic strategies: time-series and cross-section. These two risk premium strategies assume that the past trend is a predictor of the future trend. In the case of the time-series momentum risk premium, the portfolio is long on assets with a positive past trend and short on assets with a negative past trend, whereas the cross-section momentum strategy consists in building a portfolio that is long on assets that have outperformed and short on assets that have underperformed. Thus, the time-series momentum is called the trend-following strategy or the trend-continuation strategy, because it assumes that assets with a current positive trend will continue to have a future positive trend and assets with a current negative trend will continue to have a future negative trend. A cross-section momentum is called a winners-minus-losers strategy. It as-

[1] See `http://www.investopedia.com/articles/trading/08/turtle-trading.asp`.

[2] The academic research community has often laughed about momentum strategies, which were classified as cooking recipes for amateur investors. All this has changed with the publication of Fung and Hsieh (2001). In fact, momentum can be easily explained by behavioural finance theory formulated by the recent Nobel Prize winner Richard Thaler and his co-authors.

sumes that the current winners will continue to outperform the current losers in the future. As a consequence, the net exposure of a time-series momentum is not equal to zero, whereas the net exposure of a cross-section momentum is equal to zero. The time-series momentum strategy is intensively used by CTAs with a multi-asset universe and is generally implemented with equity, bond, currency and commodity futures contracts. The cross-section momentum strategy is one of the pillars when a fund manager builds an equity multi-factor portfolio by mixing size, value, momentum, low risk and quality stocks. In the sequel, when the type of strategy is not specified, we systematically refer to the time-series momentum.

2 Why do investors pay so much attention to momentum risk premia?

Momentum is no longer taboo with the emergence of alternative risk premia, and is under the scrutiny of sophisticated institutional investors, including pension funds and sovereign wealth funds that are contrarian investors[3]. Therefore, Roncalli (2017) supports the view that carry and momentum are the most relevant alternative risk premia since they are present across different asset classes, and must be included in a strategic asset allocation. Since the main objective of alternative risk premia is to build a better diversified portfolio than a traditional stock-bond asset mix policy, one could have trouble understanding the link between momentum and diversification. Indeed, in one sense, momentum strategies are the opposite of diversification strategies because they follow the market. In fact, there is a misconception of diversification that we will explain later.

It is obvious that alternative risk premia revisit portfolio construction in two directions. First, in terms of the investment universe. For a long time, strategic asset allocation was mainly related to the concept of asset classes. The idea was to group individual securities to form a homogenous investment universe called an asset class. These asset classes can be broadly defined by distinguishing stocks, bonds, currencies and commodities or more specifically by considering US equities, European equities, Japanese equities, EM equities, etc. This type of approach is the foundation of strategic asset allocation, but is limiting in terms of security selection, because it is based on the capitalization-weighted portfolio. The idea of alternative risk premia is to group individual securities in another way in order to define new risk factors (Ang, 2014). Thus, alternative risk premia allow us to extend the building blocks of a strategic asset allocation, by completing the investment universe with risk premia strategies.

Nevertheless, the introduction of these new risk factors forces the investor to change his framework of asset allocation. For many decades, these new risk factors were extensively used by hedge funds and active managers under the name "absolute return" or alpha strategies. This concept suggests that they are independent from traditional asset classes. In this context, portfolio allocation consists in building two portfolios, a beta portfolio and an alpha portfolio, and mixing them in order to benefit from the performance and the diversification of the alpha portfolio. Improving the Sharpe ratio is then the "raison d'être" of absolute return strategies.

However, this magic formula has been put under pressure by the Global Financial Crisis in 2008 and afterwards. These risk factors have therefore been seen as dependent on traditional asset classes. The reason is that most of them are beta strategies, meaning that their performance also depends on the performance of the market. If alternative risk premia

[3]For instance, the strategic asset allocation of these investors is generally defined as a constant-mix portfolio, which is a typical contrarian investment approach.

are beta strategies, and not alpha strategies, the traditional diversification approach is not appropriate. As explained by Burgues *et al.* (2017), it must then be replaced by the payoff diversification approach for two main reasons. First, volatility is not the right risk measure of long-term investors, which are more sensitive to expected drawdowns. In other words, volatility risk is a tactical asset allocation decision, whereas skewness risk is a strategic asset allocation decision. Second, relationships between risk premia become highly non-linear. In this case, correlation is time-varying. This is why the values taken by the correlation must be interpreted with respect to the state of the market.

By differentiating convexity and concavity in the portfolio, alternative risk premia reshuffle the notion of "bad" and "good" diversification. A bad diversification consists in adding an asset that will help in bad times, but that will also destroy performance in good times. In this case, we risk ending up with a non- or low-performing portfolio. This is the example of systematically buying put options. This type of behavior is contrary to the long-run investment mindset, because it assumes that there are no positive risk premia in the long-term. A good diversification consists in adding an asset that will help in bad times without compromising the long-run performance. This can only be achieved with a risk premium strategy that exhibits a time-varying beta: a positive beta in good times and a negative beta in bad times. This is exactly the beta profile of momentum risk premia.

Most alternative risk premia portfolios include carry and momentum. What is the rationale? Like many risk premia, carry has a concave payoff like a short put option profile. The motivation behind carry is then different. The underlying idea is to improve the performance of traditional risk premia or to generate income. Therefore, the issue is not to accumulate only concave payoffs or short put payoffs, because it is too risky. This is why the momentum risk premium plays a central role in diversified portfolios, because it is one of the few convex strategies that can mitigate the risk of the rest of the portfolio, including also the traditional risk premia.

In summary, diversification is the main objective of long-term investors when investing in momentum, whereas performance is the main objective of long-term investors when investing in carry[4].

3 Risk-return analysis of trend-following strategies

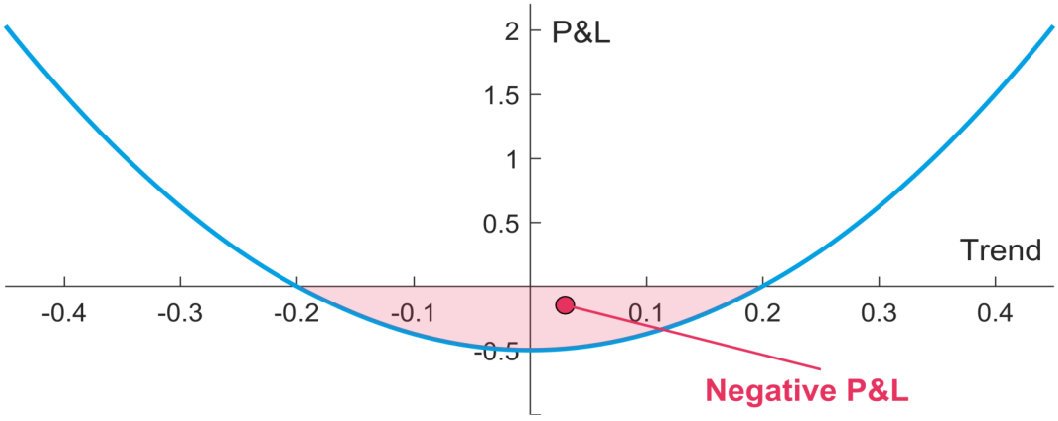
Jusselin *et al.* (2017) demonstrate that the payoff of the trend-following strategy is convex and is similar to a long exposure on a straddle option (see Figure 1). This result was already found by Fung and Hsieh (2001) and Bruder and Gaussel (2011). The convexity of the payoff implies that the strategy has a positive skewness. Roncalli (2017) classifies alternative risk premia into two families:

1. Skewness risk premia
   The investor is rewarded in good times for taking a skewness risk in bad times.

2. Market anomalies
   They correspond to trading strategies that have delivered good performance in the past, but their performance cannot be explained by the existence of a systematic risk in bad times. Their performance can only be explained by behavioral theories.

[4]We must not confuse volatility diversification and skewness diversification. Mixing several carry strategies with traditional risk premia reduces the volatility risk, which is a high-frequency diversification measure. At low frequencies, carry does not diversify.

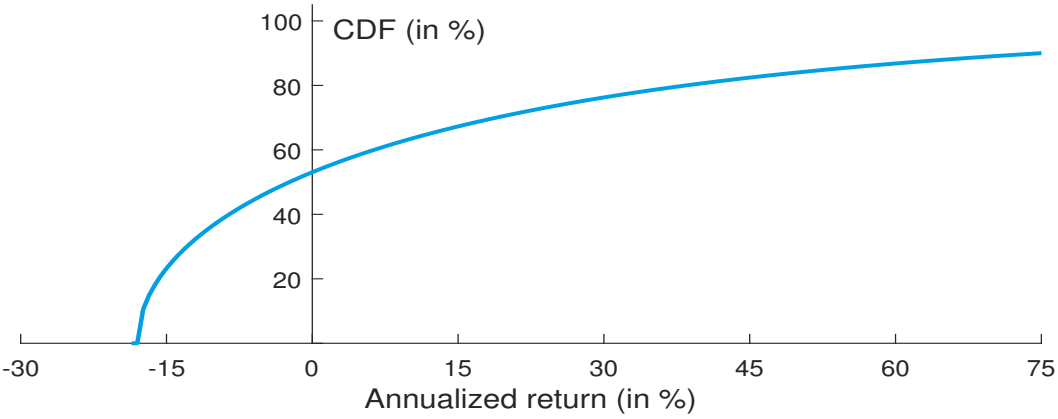
Figure 1: Payoff of the trend-following strategy



Following Roncalli (2017), trend-following strategies can only be market anomalies. This is confirmed by the cumulative distribution function of the P&L, which is reported in Figure 2. We notice that the loss is bounded, but the gain may be infinite, even if the asset has a zero Sharpe ratio. These generic results are impacted by three main parameters:

- the duration of the moving average that estimates the trends;
- the Sharpe ratio of the assets that compose the investment universe;
- the correlation matrix of asset returns.

Figure 2: Cumulative distribution function of the P&L when the Sharpe ratio of the asset is equal to zero



The effect of the moving average frequency is interesting. Indeed, the P&L of short-term trend-following strategies has a larger volatility than the P&L of long-term trend-following strategies. This result is not so obvious, because we may have the feeling that risk management of short-term trading is easier than risk management of long-term trading. In fact, this result is related to the fact that short-term trends are more difficult to estimate

than long-term trends. This explains that short-term trend-following strategies are more sensitive to trading recipes, proprietary models and the "savoir-faire" of the management team. This result is also confirmed by the broader dispersion of returns that is observed between Short-term CTAs than between long-term CTAs.

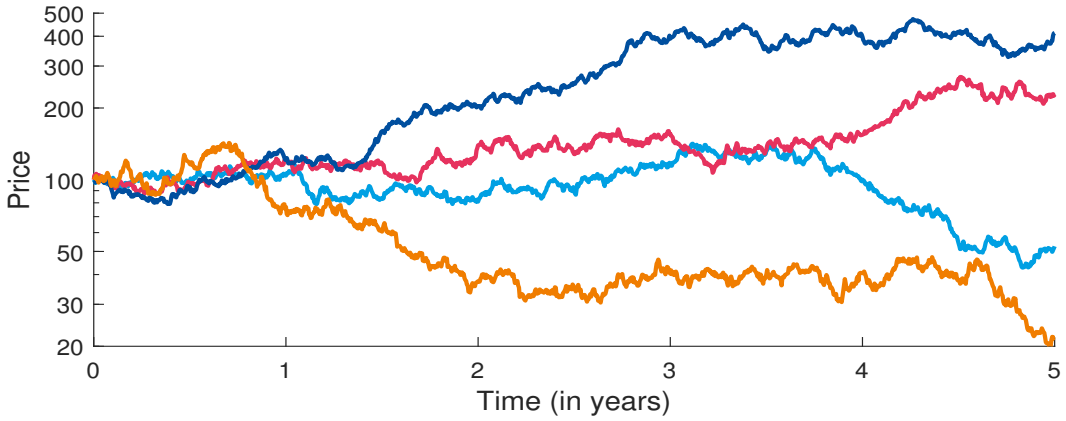
The convexity of the payoff is due to the impact of the Sharpe ratio. Indeed, the performance of the trend-following strategy does not depend on the sign of the Sharpe ratio, but only on its absolute value. Therefore, we obtain a symmetry property: a negative Sharpe ratio has the same impact than a positive Sharpe ratio. This property explains the rationale between long-only portfolios and long/short portfolios. When building a long-only portfolio, the investor needs to be strongly convinced about the (positive) risk premium of asset classes that are included in the investment universe. When considering a momentum strategy, the investor needs to be convinced that assets in the investment universe will exhibit trends, whatever the direction. This explains that the investment universe of a buy-and-hold or constant-mix portfolio is generally composed of stocks and bonds, whereas the investment universe of a momentum portfolio also includes currencies and commodities that are not risk premia.

The Sharpe ratio is a statistic that combines the trend and the volatility. In order to perform, momentum strategies need significant trends compared to the volatility. What does it mean? In fact, we can show that momentum strategies have a negative vega, implying that the investor pays a systematic premium because of the short exposure on the short-term volatility. This is why the momentum risk premium does not like that the volatility increases. Therefore, the Sharpe ratio is a relative measure of the strength of the trend, and a strong trend with high volatility is not necessarily better than a medium trend with very low volatility. In Figure 1, we notice that there is an area that corresponds to a negative P&L. In this area, the trend is too low to generate a sufficient return that will offest volatility trading costs. Like the theory of options, the theory of momentum is then based on several trade-offs: trend versus volatility, delta gain versus gamma cost, long-term volatility versus short term-volatility. The trade-off gain versus loss is particularly interesting. Indeed, "*trend followers lose more often than they gain*" as shown by Potters and Bouchaud (2006). This is due to the fact that big trends are not so frequent in financial markets. Most of the time, gamma costs dominate implying that the performance of the momentum strategy is poor, but sometimes there is a big trend and the momentum strategy posts an outstanding performance.

By comparing momentum and long-only (buy-and-hold or constant mix) strategies, Jusselin *et al.* (2017) find that the momentum strategy has a better Sharpe ratio than a long exposure when the Sharpe ratio of underlying assets is lower than 35%. Again, we face here a new asymmetry, which is quite understandable. It is obvious that a momentum portfolio will do a better job than a long portfolio if the asset's Sharpe ratio is negative. This is also the case when this latter is low, because the asset can exhibit temporary (negative and positive) trends. For instance, when we simulate a Geometric Brownian motion with a zero Sharpe ratio, we are surprised that we observe statistical trends. An illustration is given in Figure 3 with four simulated paths – we use a semi-logarithmic plot for the y-axis in order distinguish the relative performance. The maximum trend of each simulation is respectively equal to $+84\%$, $+73\%$, -56% and -48%. On the contrary, when the Sharpe ratio is sufficiently high, the long portfolio does a better job than the momentum portfolio, because the performance of the latter portfolio is not impacted by the gamma trading costs.

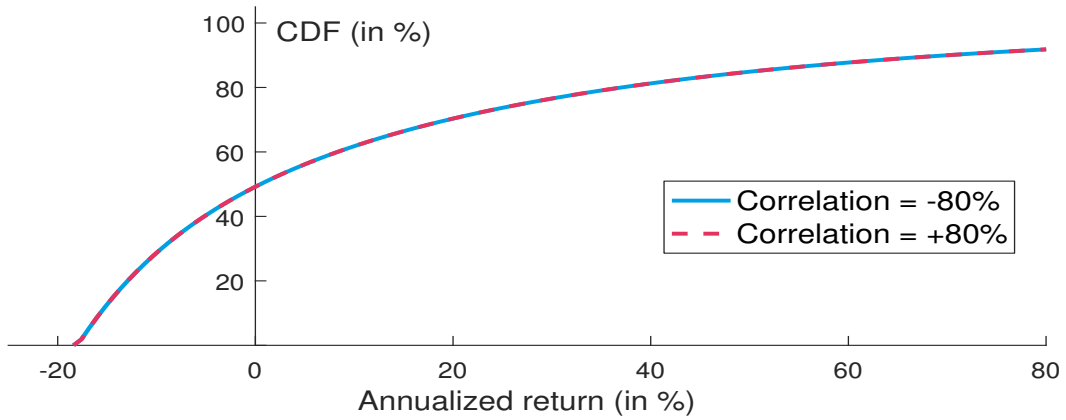
The third important parameter is the correlation between asset returns. When the Sharpe ratio is equal to zero, Jusselin *et al.* (2017) find a curious result: the P&L of the trend-following strategy does not depend on the sign of the correlation. As shown in Figure

Figure 3: Geometric Brownian motions exhibit trends



4, a correlation of −80% is equivalent to a correlation of +80%. This result contrasts with the traditional diversification approach. In the case of a long-only investment portfolio, the best case for diversification is when some assets are negatively correlated to other assets. This explains why the stock/bond asset mix policy is certainly the most well-known diversified portfolio. In the case of a long/short investment portfolio, the case of negative correlation is symmetric to the case of positive correlation. For instance, if we consider the two extreme cases, a correlation of +100% between two assets is equivalent to a correlation of −100% in a long/short momentum portfolio. In this later case, if we observe a positive trend on one asset, this implies a negative trend on the second asset. Therefore, the portfolio will be long on this asset and short on the second asset. However, the portfolio is not diversified, because it is exposed to the same trend. Thus, the best case is when the correlation is equal to zero, because we have two independent trends. In fact, the concept of diversification is more complex for momentum than for long-only portfolios. In particular, we must distinguish time-series and cross-section momentum.

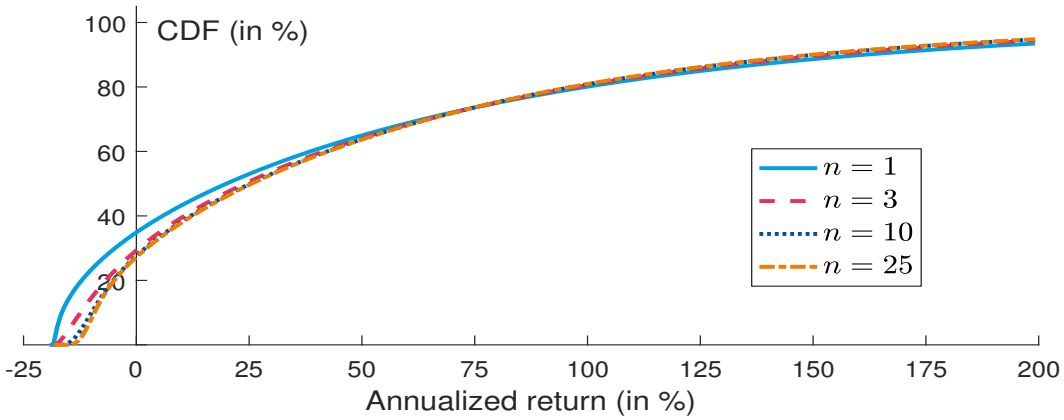
Figure 4: The correlation symmetry puzzle when the Sharpe ratio is equal to zero



4 Time-series versus cross-section momentum

In the previous section, we have presented results concerning the traditional trend-following strategy or the time-series momentum risk premium. However, as we indicated before, there are two momentum risk premia that present different behaviours. For instance, in Figure 5 we have represented the cumulative distribution function of the trend-following strategy when the cross-correlation is equal to 80% with respect to the number of assets that make up the investment universe. We notice that the diversification gain is limited when we consider more than three assets. This result confirms that the time-series momentum does not like (positively or negatively) correlated assets.

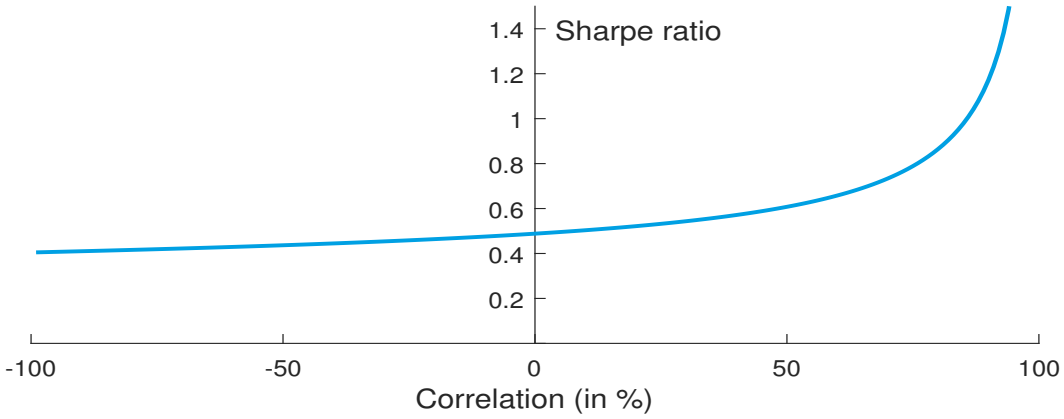
Figure 5: Correlation is not the friend of time-series momentum



With cross-section momentum, it is another story. In Figure 6, we have represented the Sharpe ratio of the cross-section momentum strategy with respect to the correlation between asset returns. We notice that the Sharpe ratio of the strategy increases with the correlation. Correlation is then the friend of cross-section momentum. How do we explain this big difference between the two momentum risk premia? We have seen that time-series momentum is a beta strategy. The dependence between the strategy return and the asset return increases with the magnitude of the trend. Therefore, having a zero correlation helps to reduce the volatility of the trend-following strategy. In the case of the cross-section momentum, the return of the portfolio depends on the relative difference between asset trends. If assets are weakly correlated, the dispersion of the P&L is very high. The outcome of the strategy is then very uncertain. This is why cross-section momentum likes highly correlated assets.

This difference between time-series and cross-section momentum is well known by hedge fund managers. This is the same issue as the difference between long/short matching and long/short managing. For instance, equity market neutral strategies aim to build a short exposure that is correlated to the long exposure. This is particularly true when fund managers use pairs trading. They expect that the performance will come from long/short matching. In this case, one pair is seen as one investment bet, not two investment bets. When implementing cross-section momentum, the investor has a similar approach. He expects that the performance comes from long/short matching. When implementing time-series momentum, the investor expects that the performance comes both from the short and long exposures. Thus, cross-section momentum is more a relative value (or an alpha) strategy whereas time-series momentum is typically a beta strategy.

Figure 6: Correlation is the friend of cross-section momentum



This distinction has major implications when designing a strategy. Time-series momentum makes sense for a multi-asset universe, including equity, fixed-income, currency and commodity futures contracts, in order to have a diversified investment universe. Cross-section momentum makes sense for a universe of homogeneous securities, for instance the stocks of an equity index that is focused in one country or one region. If we consider commodities, it is then better to implement time-series momentum at the global level and cross-section momentum at the category level (agricultural, energy, livestock, metals, etc.).

5 Hidden risks of momentum strategies

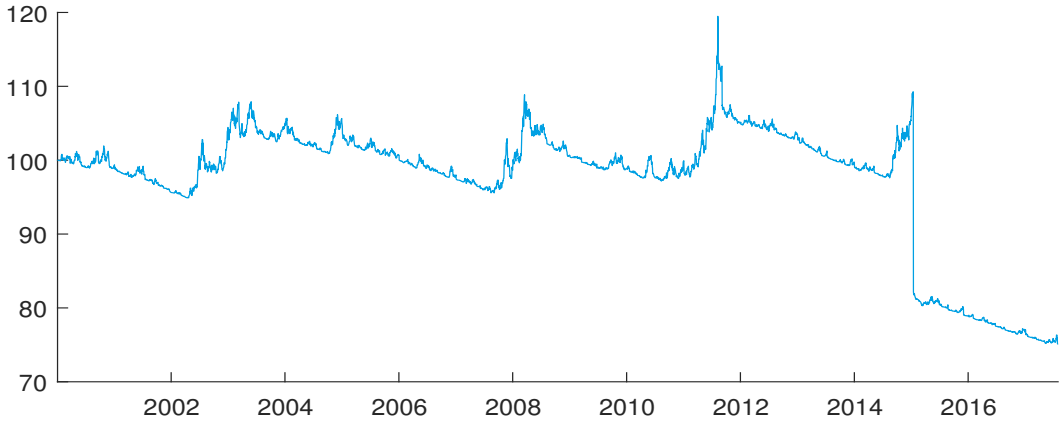
The concept of an "all weather fund" is a marketing idea that is difficult to achieve in practice. It is a little bit different from the concept of an absolute return strategy. The two portfolios have the same objective: they claim to perform reasonably well during both good and bad times. However, they do not use the same approach. Absolute return portfolios are based on alpha strategies that are weakly correlated to traditional risk premia. All weather portfolios are based on beta exposures, and diversification is the main driving force to achieve good performance in bad times. However, it is extremely difficult to find the magic formula. The behavior of a diversified portfolio in bad times is not easy to predict. With the emergence of alternative risk premia, it would be illusory to think that diversification will completely protect the investor from bad times. As explained by Ang (2014), each (traditional and alternative) risk premia has its own bad times. Of course, diversification helps to mitigate drawdown risks, but it cannot eliminate them.

Momentum strategy is not an exception. We have seen that its loss is bounded. This result has been obtained under two conditions. The first one assumes that the momentum strategy uses a reasonable leverage. It would be wrong to think that the leverage only impacts the sizing of long/short exposures, implying that there is a linear relationship between the level of leverage, and the return and volatility of the portfolio. The problem comes from the costs induced by gamma trading, which are not linear with respect to portfolio's leverage. In particular, we can show that too much leverage can be harmful for the strategy.

The second condition assumes that there is no jump or discontinuity in asset prices. Without this assumption, the payoff is not necessarily convex and the loss is not bounded. For instance, we think that there is a misconception about CTAs. Many people think that

CTAs are good strategies for hedging the skewness risk of the stock market. In reality, trend-following strategies help to hedge drawdowns due to volatility risk. For instance, CTAs did a very good job in 2008, because the Global Financial Crisis is more a high-volatility event than a pure skewness-risk event. However, it is not obvious that CTAs may post similar performances when facing skewness events. For instance, the performance of CTAs was disappointing during the Eurozone crisis in 2011 and the Swiss CHF chaos in January 2015. In Figure 7, we have reported the cumulative performance of the trend-following strategy applied to the CHF/USD currency. On January 15$^{\text{th}}$, 2015, we observed a large drawdown. This illustration shows that time-series momentum may also suffer in case of market discontinuities.

Figure 7: Cumulative performance of the CHF/USD trend-following strategy



Another important risk concerns trend reversals. This point has been already observed by Daniel and Moskowitz (2016), who showed that investors may face momentum crashes, especially when they use a cross-section implementation. This risk is related to the coherence between the duration of the trend and the duration of the moving average. Finally, we always verify that there is no free lunch in finance.

Since cross-section momentum is implemented using securities (stocks or bonds), the investor also faces a transaction cost risk. Indeed, the turnover of cross-section momentum is much higher than the turnover of other risk factors (value, quality, etc.). More generally, the liquidity of the asset universe is a key parameter when considering momentum strategies.

6 How do momentum strategies benefit from traditional risk premia?

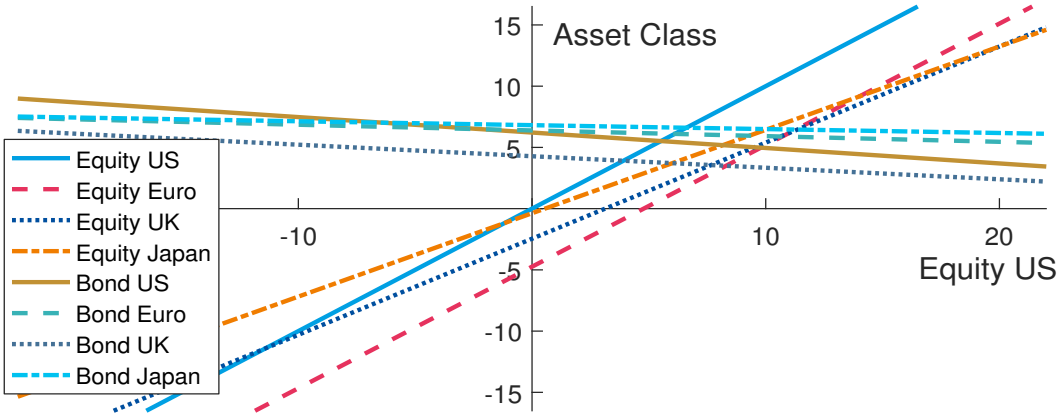
When we consider trend-following strategies, we generally think that their good performance comes from their ability to be long and short. And we imagine that the short exposure is of the same magnitude than the long exposure on average. This is not true. Most of the time, a trend-following strategy is net long. This is particularly true for equities and bonds. For instance, Jusselin *et al.* (2017) find that the average exposure for a trend-following strategy, whose volatility is comparable to the asset volatility, is equal to 58% for bonds, 52% for equities, 23% for commodities and 10% for currencies. We notice that there is a large difference between bonds and equities, and the other assets. Therefore, we can

wonder if the momentum strategy benefits from trend patterns or risk premia? In the case of bonds, Jusselin *et al.* (2017) show that risk premium is the most important effect, since about 70% of exposure is long. An interesting point is that the magnitude of short exposure is comparable to the magnitude of long exposure. This is not the case for equities. On average, the size of long exposure is twice the size of short exposure. Again, the momentum strategy benefits from the equity risk premium. For commodities and currencies, we obtain an opposite effect. The main contribution comes from trend patterns. This result is obvious since it is generally accepted that currencies and commodities do not exhibit risk premia. This explains that there is a symmetry between long and short exposures for currencies and commodities, but not for equities and bonds.

The case of equities demonstrates that the momentum risk premium comes also from the capacity to leverage or deleverage traditional risk premia. And it is not obvious that short management contributes more than leverage management. There is certainly a myth about short selling in CTA strategies. Many people believe that the good performance of CTAs in 2008 is due to their short equity exposure. However, on average, CTAs were 15% net short on equities in 2008. Why such a small value? Because it is extremely difficult to have a big exposure when the volatility is so high[5]. This explains that CTAs have more difficulties to be short on equities than long on equities, because negative trends are associated with high volatility regimes whereas positive trends are observed in low volatility regimes.

How to explain the good performance of CTAs in 2008? One of the reason is the stock/bond correlation. We should reiterate here that a negative correlation is equivalent to a positive correlation in long/short portfolios, because it corresponds to the same bet. However, this result assumes that there are no volatility differences between normal and stressed markets. If two assets are highly negatively correlated, and if we observe a negative trend in the first asset, the trend-following strategy has the choice between being short of the first asset and/or being long on the second asset. In 2008, the negative trend on equities has been primarily implemented by trend followers as a big long exposure on bonds, and a small short exposure on equities.

Figure 8: Payoff function with respect to the S&P 500 Index

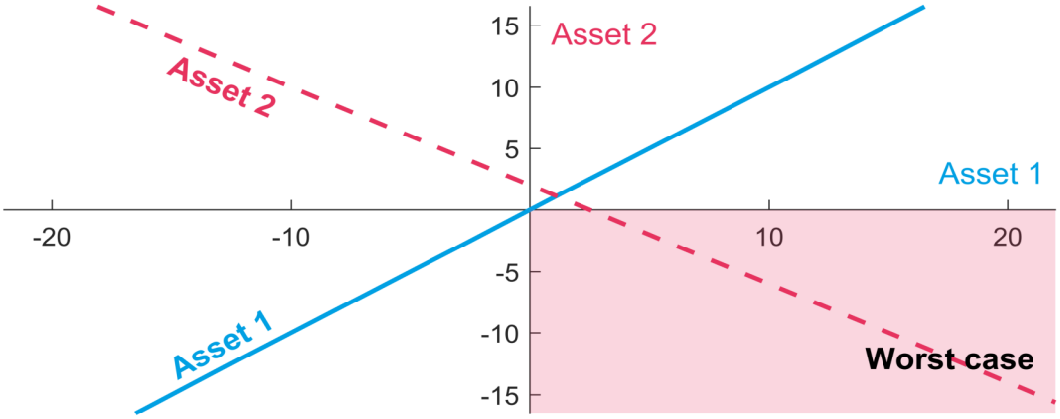


[5]We remind that the VIX index peaked at 80% in October 2008.

7 To trend is to diversify

The concept of diversification has been extensively discussed by Burgues *et al.* (2017), who differentiate the "correlation diversification" approach and the "payoff diversification" approach. In Figure 8, we report the payoff function of several asset classes by considering that the reference asset is the S&P 500 index. The payoff function has been estimated for the period from January 2000 to December 2016 by assuming a constant correlation.

Figure 9: Worst diversification case



We notice that the payoff of equity asset classes is an increasing affine function, because of their high cross-correlations. On the contrary, the payoff of bond asset classes is a decreasing affine function, because of the negative stock/bond correlation. However, it is remarkable that equity and bond payoffs are crossing within the top right quadrant. As said previously, the worst case of diversification is obtained when the good return of one asset is offset by the bad return of the other asset (see Figure 9). Therefore, a long-only diversified portfolio of stocks and bonds really makes sense, because bonds diversify equities in bad times and they are also performance assets in good times.

Figure 10: Stylized payoff of some strategies

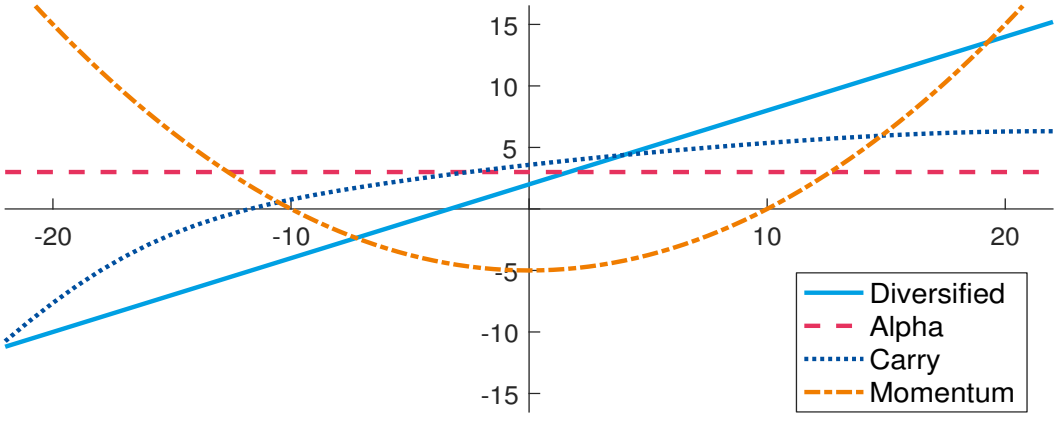
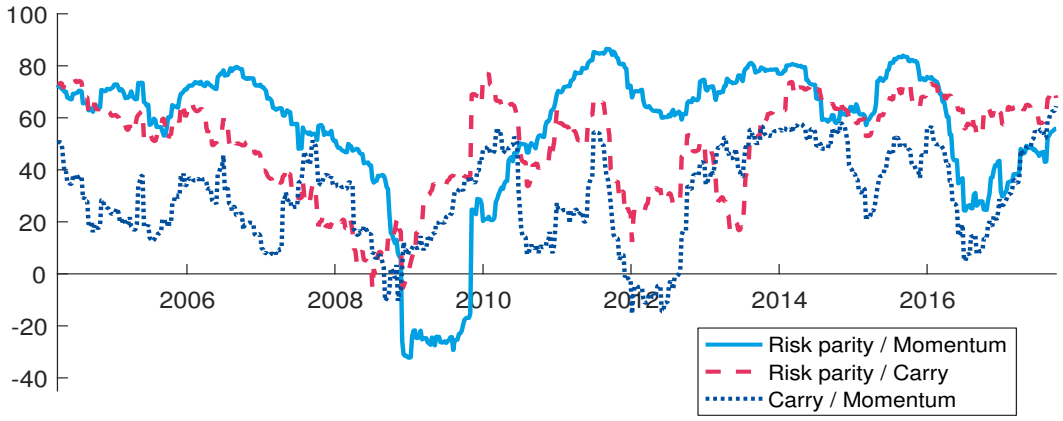


Figure 10 represents the generic payoff of some strategies: diversified risk parity, alpha, carry and momentum. By construction, an alpha or absolute return strategy is uncorrelated to traditional asset classes. It helps to improve the risk/return profile of a diversified fund, but its diversification power is limited. Carry may suffer in bad times. Therefore, carry may diversify at a high-frequency time scale (daily or weekly), but its diversification power is limited at a lower frequency time scale (yearly or more). The case of momentum is more interesting. As explained by Burgues *et al.* (2017), it helps to mitigate risk in bad times. But its payoff is very different from a long exposure in bonds (see Figures 8 and 10). And like bonds, the worst diversification case is avoided because of the convexity. Indeed, momentum strategies also generate performance in good times, even if they drag compared to a constant-mix portfolio.

In this context, momentum investing could not be motivated by the search for alpha, because it is a beta strategy, more precisely a time-varying beta strategy. We can now understand why Burgues *et al.* (2017) say that traditional portfolio optimization is not adapted when building a portfolio of alternative risk premia or when including ARP in a diversified portfolio. In the long run, the correlation between momentum strategies and diversified portfolios is close to zero. As such, portfolio optimization considers momentum as an alpha strategy and selects it in order to reduce the volatility. In the short run, we obtain two cases. After good times, momentum is generally not selected by portfolio optimization, because it has a high beta with performance that is lower than that of a simple constant-mix strategy. After bad times, portfolio optimization overweights the allocation in momentum because of its good performance. Portfolio optimization is therefore not adapted when allocating between alternative risk premia, because it is totally blind to convexity and concavity.

Figure 11: One-year historical weekly correlation between risk parity, momentum and carry



To illustrate why diversification cannot be reduced to volatility mitigation, we report the correlation between risk parity, momentum and carry strategies[6] in Figure 11. The long-term historical correlation is respectively equal to 50% between risk parity and momentum, 50% between risk parity and carry and 30% between carry and momentum. Since the correlation are positive, we may conclude that diversification is limited. However, it is perfectly normal that we obtain positive correlations because they are beta strategies. If we had got negative

[6]The risk parity corresponds to an ERC portfolio between equities and bonds; the momentum is implemented using a universe of bonds, equities and currencies; the carry strategy is a mix of three portfolios: fixed-income "roll-down", currency "forward rate bias" and volatility carry.

correlations, we would certainly be in the worst diversification case. Therefore, positive long-term correlations are fine in order to generate long-term performance. But we also notice that these correlations vary over time and may be negative in bad times. This is good news, because investors do not need diversification at all times. They need diversification in bad times, and particularly when they invest in beta strategies like alternative risk premia[7].

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[7] When Burgues *et al.* (2017) say that diversification is multi-faceted, they also include other directions than payoff functions. For instance, time horizon is another important factor of diversification. This makes short-term risk factors (e.g. cross-section momentum) and long-term risk factors (e.g. value) complementary.

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