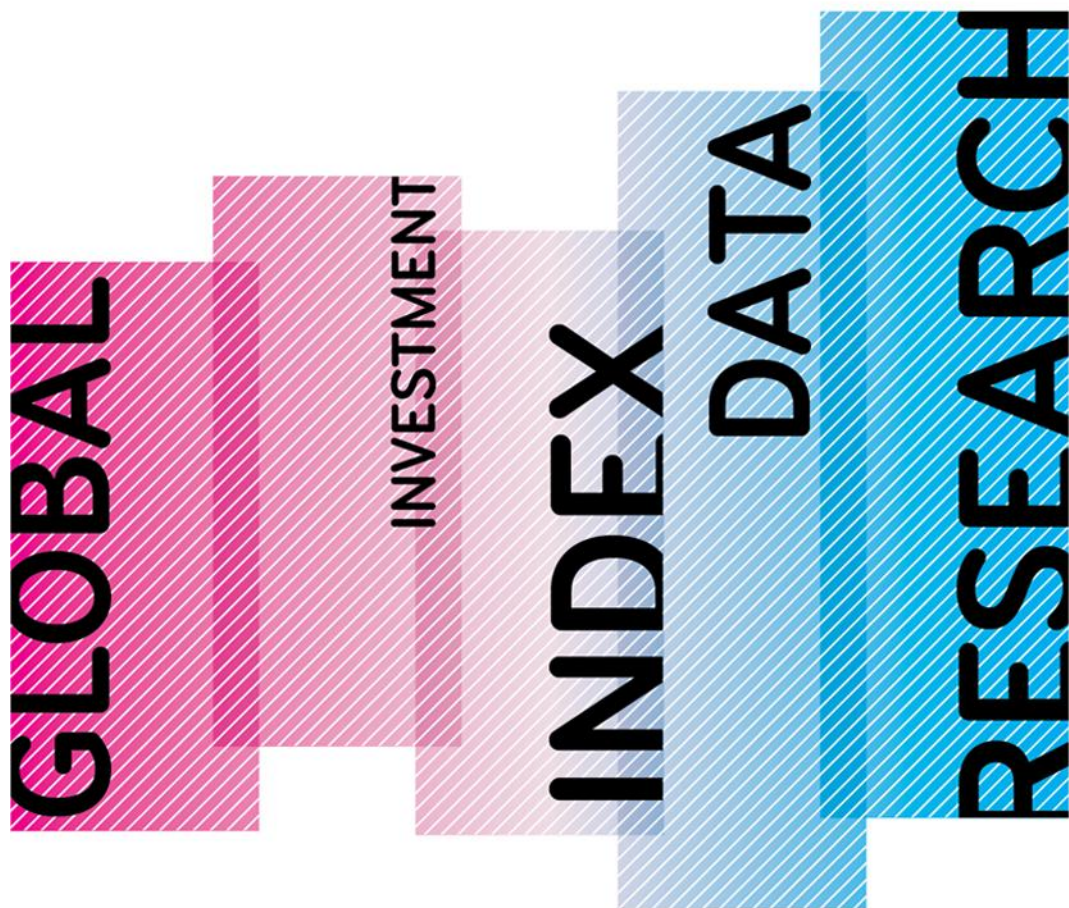


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# ISTOXX EUROPE FACTOR INDICES – AN INVESTABLE ACCESS TO FACTOR RISK PREMIA

Dr. Jan-Carl Plagge, Head of Applied Research, STOXX Ltd.



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# ISTOXX EUROPE FACTOR INDICES – AN INVESTABLE ACCESS TO FACTOR RISK PREMIA

## Abstract

The **iSTOXX Europe Single Factor** index family developed by STOXX in collaboration with Alpha Centauri<sup>1</sup> offers investors a unique and very innovative way to target and capture premia of six well-documented sources of systematic risk: value, carry, momentum, size, low risk as well as quality. In addition, the **iSTOXX Europe Multi-Factor** index aims at simultaneously capturing premia from the aggregate of factors rather than from just one source of risk alone.

The empirical results show that all iSTOXX Europe Single Factor Indices provide significant excess returns relative to their benchmark over a sample period of eleven years. With correlations to the benchmark index STOXX Europe 600 ranging from a minimum of -0.71 (low risk factor) to a maximum of 0.03 (value factor), factor returns are found to also serve as a great source of diversification when used in addition to an existing investment in a broad European benchmark index such as the STOXX Europe 600. Low correlations *among* factor returns further add to the diversification potential when investing in more than just one factor index.

However, risk premia are found to vary significantly over time. This observation as well as the low correlation among factor returns provide the grounds for the construction of the iSTOXX Europe Multi-Factor index. Its innovative methodology leads to lower risk and higher returns compared to a heuristic, e.g. equally weighted aggregation of single factor indices.

<sup>1</sup> Alpha Centauri is an independent multi-asset management boutique founded in 2005 and based in Hamburg, Germany. It is an investment manager specialized in innovative liquid alternative products, with factor investing at the core of its business. [www.alpha-centauri.com](http://www.alpha-centauri.com).

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## 1 Introduction

The traditional Capital Asset Pricing Model (CAPM) which goes back to the 1960s suggests only one risk factor, the market factor, to be systematically priced.<sup>2</sup> Over the following decades, however, empirical research observed the existence of additional factors in the attempt to explain equity returns. The first extension of the CAPM was brought forward by Fama and French (1992) who suggested an extension of the one-factor CAPM by two additional factors, size and value. They found that small-cap companies as well as companies that are relatively undervalued compared to their book value outperformed their respective counterparts. Carhart (1997) extended the “Three Factor Model” by a fourth factor, momentum. Next to these four factors, today’s models typically include a variety of additional factors such as carry or quality.

What all of these factors have in common is that they contribute to the explanation of equity returns. In other words, investors may harvest additional return, in terms of a premium, when exposing themselves to such risk factors.

The iSTOXX Europe Single Factor index family developed by STOXX in collaboration with Alpha Centauri offers investors a very unique and innovative way to target and capture these risk premia while simultaneously minimizing distortions, which may arise from other systematic sources of risk. In addition, the iSTOXX Europe Multi-Factor index aims at simultaneously capturing premia from various well-known risk factors rather than from just one single source of risk.

This paper starts off with an introduction into the construction of the iSTOXX Europe Single and Multi-Factor indices. In the following sections, the development of risk premia over time is analyzed from a single-factor as well as from a multi-factor perspective.

The empirical results show that all iSTOXX Europe Single Factor Indices provide significant excess returns relative to their benchmark over a sample period of eleven years. With correlations to the benchmark index STOXX Europe 600 ranging from a minimum of -0.71 (low risk factor) to a maximum of 0.03 (value factor), factor returns are found to also serve as a great source of diversification when used in addition to an existing investment in a broad European benchmark index such as the STOXX Europe 600. Low correlations *among* factor returns further add to the diversification potential when investing in more than just one factor index.

However, risk premia are found to vary significantly over time. This observation as well as the low correlation among factor returns provide the grounds for the construction of the iSTOXX Europe Multi-Factor index. Its innovative methodology leads to lower risk and higher returns compared to a heuristic, e.g. equally weighted aggregation of single factor indices.

<sup>2</sup> The CAPM goes back to William F. Sharpe, John Lintner and Jan Mossin who developed the model, independent from one another, in the 1960s. See, e.g., Sharpe (1964), Lintner (1965) and Mossin (1965).

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## 2 The Index Concept

iSTOXX Europe Factor Indices aim at capturing targeted risk premia while simultaneously minimizing the exposure to other systematic sources of risk. Available factors are value, carry, momentum, size, low risk as well as quality.<sup>3</sup> The underlying universe for the construction of all factor indices is the STOXX Europe Total Market Index. This index covers appr. 95% of the investable market capitalization of developed Europe.

In the selection process, the exposure of each company in the universe to each factor is assessed by a variety of fundamental measures.<sup>4</sup> In order to compose a single, company-factor-specific score, each measure is transformed into a normalized score, subject to industry specific level deviations, before being aggregated. Hereby, each variable is assigned the same importance, i.e. the same weight.

The selection of stocks, as well as the determination of corresponding weights, happen simultaneously based on an optimization approach.<sup>5</sup> The optimization hereby aims at maximizing the exposure to the respective targeted factor while subjecting itself to a series of constraints that are chosen in order to achieve the best tradeoff between tradability and factor replication. The constraints are as follows:

- maximum tracking error of three percent relative to STOXX Europe 600,
- maximum systematic risk contribution of ten percent to tracking error,
- targeted beta of one relative to STOXX Europe 600 with allowed maximum deviation of +/- 0.025,
- maximum deviation of component weights from those of the STOXX Europe 600 of +/- 1.5 percentage points,<sup>6</sup>
- targeted number of components between 50 and 120,
- components are capped at a maximum weight of 10%,
- industry weights cannot deviate from those of the STOXX Europe 600 by more than +/- 1.5%,
- one-way turnover per month is set to a maximum of 25%,
- liquidity constraint on constituent level: 100 mn times weight needs to be at most 15% of the average 20-day value traded.

In order to allow for the extraction of the pure factor premium net of the market, the optimization tries to achieve a beta of one relative to an easily tradable broad market index. In our case, one of Europe's most liquid indices in terms of derived products, the STOXX Europe 600, is used. Thus, a long investment in one of the iSTOXX Europe Factor indices while maintaining a short position in the STOXX Europe 600 index allows to easily hedge the market and extract the targeted risk premium.

The factor exploitation takes place within the allowed tracking error of three percent relative to the benchmark index. As this remainder, however, is influenced by a variety of systematic factors, the influence of these remaining factors is restricted to a maximum of ten percent, i.e. 0.3% (= 10% \* 3%) within the optimization process.

Unconstrained optimizations have two tendencies: on the one hand, they may derive very concentrated results. On the other hand, they may end up with a large number of components that have very small

<sup>3</sup> The iSTOXX Europe Multi-Factor Index aims at maximizing the overall exposure to the targeted risk factors.

<sup>4</sup> For an overview and explanation of the measures underlying the factor construction, please refer to Appendix A.

<sup>5</sup> The optimization is conducted using the APT Risk Model. FIS' investment risk solution (APT) provides award-winning investment technology for multi-asset class risk management, analytics and risk reporting, serving buy-side institutions globally. [www.fisglobal.com](http://www.fisglobal.com).

<sup>6</sup> For companies that are not part of the STOXX Europe 600, the reference weight is set to 0%.

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weights and thus, an insignificant contribution to the characteristics of the overall portfolio. In order to control for both effects, the optimization aims at a number of components that ranges between a minimum of 50 and a maximum of 120.<sup>7</sup> The specified maximum of 120 also aims at keeping the number of components at a reasonable level in order to facilitate trading. Further, the maximum weight on component level is set to 10% in order to prevent single components from dominating the index.

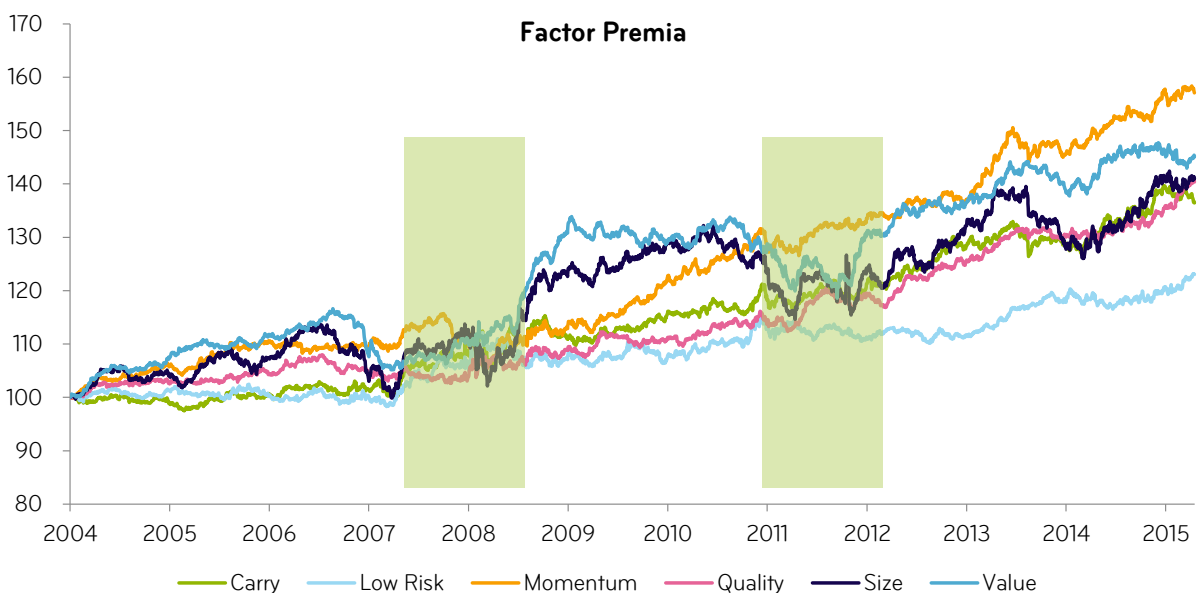
Lastly, the optimization process takes into account the industry allocation of the STOXX Europe 600 Index. Industry weights of the iSTOXX Europe Factor Indices cannot deviate by more than 1.5 percentage points from those of the benchmark. This step is necessary in order to increase the purity of the targeted premium when shorting the market via the STOXX Europe 600. Without industry constraints, sector deviations between the long and short positions, which remain in spite of the industry-specific normalization of factor scores and the targeted beta of 1 relative to the benchmark, may still lead to active sector bets or, in more general terms, to exposure to unwanted risk factors.

## 3 iSTOXX Europe Single Factor Indices

### 3.1 Factor Returns

In order to analyze the behavior of factor returns over time, we create long-short portfolios with a long position in the respective iSTOXX Europe Factor Index and a short position in the STOXX Europe 600 Index.<sup>8,9</sup>

Figure 1 displays the historical development of those factor premia over a time period ranging from Oct. 2004 to Mar. 2016. It is directly observable that the six sources of risk have been a significant source of return over the time period observed. Thus, investors would have been compensated for being exposed to those additional sources of risk.



<sup>7</sup> Please note that the actual number of components may be above or below the defined thresholds. However, the optimization procedure assigns a penalty for deviations. Thus, there needs to be a "good" reason for a breach of this criterion.

<sup>8</sup> The long-short-position is rebalanced on a monthly basis.

<sup>9</sup> Factor indices and -returns in this section always refer to a long position in an iSTOXX Europe Factor index and a short position in the STOXX Europe 600 index.

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Figure 1: Indexed excess returns of iSTOXX Europe Factor Indices over STOXX Europe 600 Index measured in EUR GR. Time period: Oct. 2004 – Mar. 2016.

The momentum factor hereby yielded the highest overall premium with an annualized return of 4.37% while the low risk factor showed the lowest return with 1.98% on an annualized basis (see column 2 of Table 1).

	Performance (p.a.)	Annualized volatility	Correl. to STX Europe 600
Carry	3.08%	4.17%	-0.37
Low Risk	1.98%	3.97%	-0.71
Momentum	4.37%	3.79%	-0.19
Quality	3.15%	3.24%	-0.28
Size	3.24%	6.49%	-0.24
Value	3.52%	4.54%	0.03
Multi-Factor	7.20%	4.08%	-0.40

Table 1: Annualized performance figures, standard deviations and correlations of factor returns to benchmark (STOXX Europe 600). All figures are based on EUR gross returns. Volatility and correlation figures are based on weekly returns. Time period: Oct. 2004 - Mar. 2016.

But apart from overall positive returns, the graphical representation of Figure 1 also indicates that factor returns vary over time. In times of market distress, as we see in this first graphical representation, factor returns have even been negative.

In order to analyze more closely the behavior of factor premia over time, we look at annual returns and compare them to those of the benchmark index STOXX Europe 600 (see Figure 2).

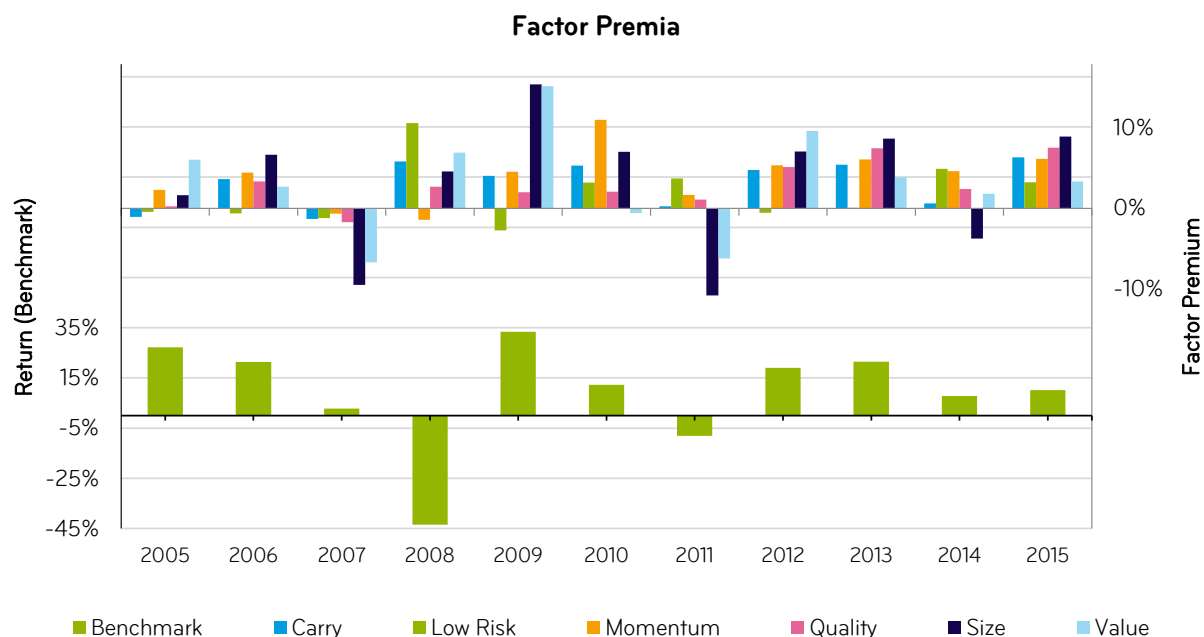


Figure 2: Annual return of STOXX Europe 600 and excess returns of iSTOXX Europe Factor Indices over STOXX Europe 600 measured in EUR GR. Time period: Jan. 2005 – Dec. 2015.

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In most of the eleven years observed, factor premia are found to be positive. In 2007, the year leading up to the financial crisis, and during the European debt crisis, which culminated in 2011, however, we find that especially small-cap and value stocks underperformed the broad market. But during the subsequent recovery periods in 2009 and 2012, both factors made up for their previous losses and showed the highest returns among all factors. It is important to point out that in 2008, the year when the financial crisis peaked and the STOXX Europe 600 lost 43%, all but the momentum factor yielded positive returns. Thus, next to a source of additional return, investing into factors may also be a good source of diversification - an assumption that will be investigated further in the next chapter.

## 3.2 Factor Correlations

Investors who consider a factor investment will typically have an existing exposure to a standard, i.e. market cap weighted broad market index. In our case, this may be the STOXX Europe 600. It is therefore of significant importance to understand how factor indices interact with a corresponding broad market investment.

To investigate these interactions, we look at correlations between factor premia and the STOXX Europe 600 Index (see Figure 3).

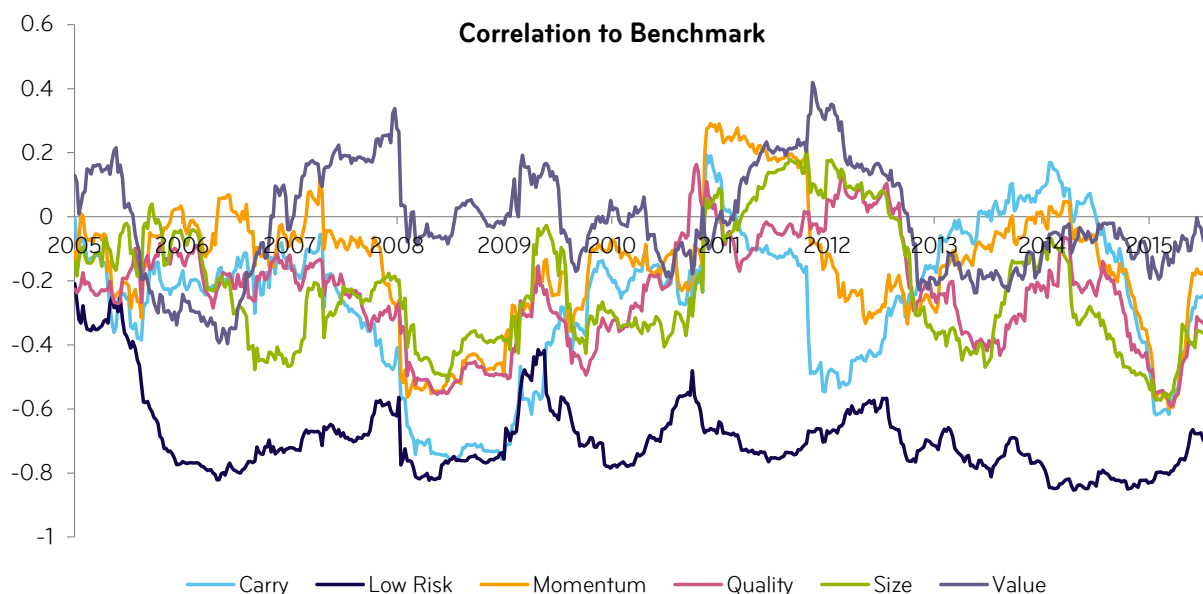


Figure 3: Correlations between factor returns and the STOXX Europe 600. Time period: Oct. 2004 – Mar. 2016. Correlations are based on weekly returns measured over a 52 week time period.

Time averages range from a minimum of -0.69 (Low-Risk factor) to a maximum of -0.01 (Value factor).<sup>10</sup> Thus, with correlations to the broad market being so low, factor returns indeed serve as a good instrument for diversification. However, when following correlations over time, it can be observed that this diversification potential fluctuates. While correlations to the STOXX Europe 600 sharply decreased during the bear market in 2007 / 2008, adding to diversification, they tend to increase again in times of recovery such as in 2009 and 2014, which mitigates their diversification.

<sup>10</sup> See also column 4 of Table 1 for correlations measured over the entire time period observed.



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So far, we have looked at correlations *between factor returns* and *returns of the broad market*. When adding one or more factor indices to an existing portfolio, however, it is important to understand the interactions, i.e. correlations, *among factors*. Table 2 provides correlations among factor returns measured over a time period ranging from Oct. 2004 to Mar. 2016.

	Carry	Low Risk	Momentum	Quality	Size	Value
Carry	-	0.41	0.58	0.45	0.50	0.13
Low Risk	0.41	-	0.34	0.34	0.35	0.08
Momentum	0.58	0.34	-	0.38	0.47	0.16
Quality	0.45	0.34	0.38	-	0.49	0.29
Size	0.50	0.35	0.47	0.49	-	0.51
Value	0.13	0.08	0.16	0.29	0.51	-
<i>Average</i>	<i>0.41</i>	<i>0.31</i>	<i>0.39</i>	<i>0.39</i>	<i>0.46</i>	<i>0.23</i>

Table 2: Correlations among factor returns measured based on weekly EUR gross returns. Time period: Oct. 2004 - Mar. 2016.

Correlations range from a minimum of 0.08 (Value and Low Risk) to a maximum of 0.58 (Carry and Momentum).<sup>11</sup> To put these figures into context: with an average correlation of 0.58 among developed market equity indices and an average correlation among developed markets' industries with about 0.77, style factors are found to be significantly less similar among each other<sup>12</sup>.

The value factor is hereby found to be the least similar among all six factors, with an average correlation to all other factors of just 0.23. This is noteworthy as it is this factor that displayed the highest correlation to the benchmark. Thus, in a portfolio exclusively based upon factor indices, the value factor has *the highest diversification potential*. By contrast, in a portfolio based on the STOXX Europe 600 and a single factor index, the value factor is found to have *the lowest diversification potential*. This conclusion is also supported when looking at volatilities of the actual iSTOXX Europe Factor Indices, rather than at the excess returns constructed by long-short positions (see column 3 of Table 3). With an annualized volatility of 20.07%, the iSTOXX Europe Value Index displays the highest level of total risk. The iSTOXX Europe Low Risk Index, on the other hand, is the combination of factor exposure and STOXX Europe 600 with the lowest level of total risk (16.73%).

	Performance (p.a.)	Annualized Volatility	Max. Drawdown
iSTOXX Europe Carry	9.98%	18.23%	-52.81%
iSTOXX Europe Low Risk	8.92%	16.73%	-53.59%
iSTOXX Europe Momentum	11.21%	19.10%	-58.40%
iSTOXX Europe Quality	9.93%	18.67%	-58.05%
iSTOXX Europe Size	9.94%	18.93%	-59.13%
iSTOXX Europe Value	10.12%	20.07%	-59.30%
iSTOXX Europe Multi-Factor	14.39%	18.10%	-50.43%
STOXX Europe 600	6.56%	19.48%	-58.37%

Table 3: Annualized performance figures and standard deviations of iSTOXX Europe Factor Indices and STOXX Europe 600. Volatilities are based on weekly returns. Returns are measured in EUR GR. Time period: Oct. 2004 – Mar. 2016.

<sup>11</sup> Correlations between factor returns may be higher compared to returns of indices that are constructed according to Fama-French. This is due to the fact that the Fama-French approach is mainly free from benchmark and tradability constraints and allows long-short positions *within* factor indices.

<sup>12</sup> Correlations among countries and industries are based on developed countries (classified according to the STOXX country classification system) and industries (classified based on the ICB industry classification) and measured over the time period: Sept. 2015 to June 2016.

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As stated, factor returns as well as correlations between factor returns and the STOXX Europe 600 Index fluctuate over time. This leads us to assume that correlations *among* factor returns may be subject to the same behavior. Figure 4 graphically displays average correlations *among all six factor premia*.<sup>13</sup> To view the behavior of correlations in a market context, the performance of the STOXX Europe 600 is also displayed.



Figure 4: Performance of the STOXX Europe 600 and average correlations among all six factor returns. Performance is measured in EUR GR. Correlations are based on weekly returns measured over a 52 week time period. Time period: Oct. 2004 - Mar. 2016.

As assumed, correlations vary significantly over time. In the years leading up to the financial crisis in 2008, they have been historically low with values around just 0.30. With the start of the crisis, however, correlations increased sharply, on average by about 20 percentage points before gradually decreasing again over the following four years. In recent years, correlations then started to pick up again and currently range at levels around 0.55. Thus, we find a certain dependency of factor returns on market-cycles. This behavior is important as it indicates that the quality of using multi-factor investments as an instrument for diversification varies over time. Especially in crises periods, factor returns have the tendency to become more similar which decreases their diversification potential.

### 4 iSTOXX Europe Multi-Factor Index

Given the variation of factor returns over time and in light of low correlations among those returns, it makes intuitive sense to consider an investment across more than just one factor for matters of diversification. But how to best combine single factor exposures in a multi-factor index?

<sup>13</sup> Average correlations are calculated as average of averages. In a first step, the average over all correlations between factor return x and all other factor returns is determined (which is repeated for each factor). In a second step, the average over all previously calculated average correlations is determined.

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The iSTOXX Europe Multi-Factor Index aims to maximize the aggregated exposure to all of the six factors - value, carry, momentum, size, low risk as well as quality. As we will see, this approach yields significantly better results than a mere heuristic, i.e. equal weighted combination of single factor indices.

Figure 5 provides median percentiles of company factor exposures from the perspective of each of the six single factor indices as well as from the perspective of the multi-factor index.<sup>14</sup>

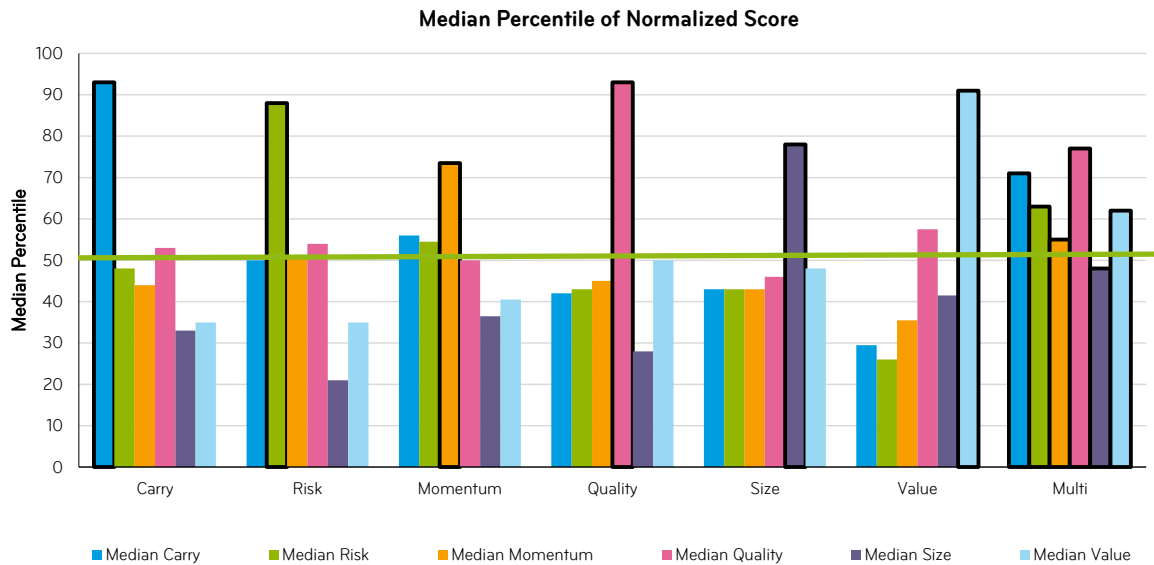


Figure 5: Median percentiles of companies selected into a respective factor index with regard to every one of the six specified factors.

As expected, companies selected into the single factor indices score highest on the factor in focus. The median percentiles to non-targeted factors are mostly below 50%.

With the exception of the size factor, median percentiles of companies selected into the iSTOXX Europe Multi-Factor Index, however, are found to be above 50%. Thus, the majority of companies selected into the multi-factor index belong to the top 50% with regard to more than just one factor. Hence, the iSTOXX Europe Multi-Factor Index tends to include companies that score relatively well across the majority of the factors rather than selecting those companies that score well in just one dimension but do badly in all the others. Here lies a significant difference compared to a mere combination of single factor indices.

To further illustrate the differences between the two approaches, Figure 6 provides a simplified graphical representation of two possible extremes of combining factors for the case of a hypothetical two-factor scenario with factors E and F.

<sup>14</sup> Percentiles are calculated relative to the universe index STOXX Europe Total Market Index. Cut-Off Date: Feb. 29, 2016.

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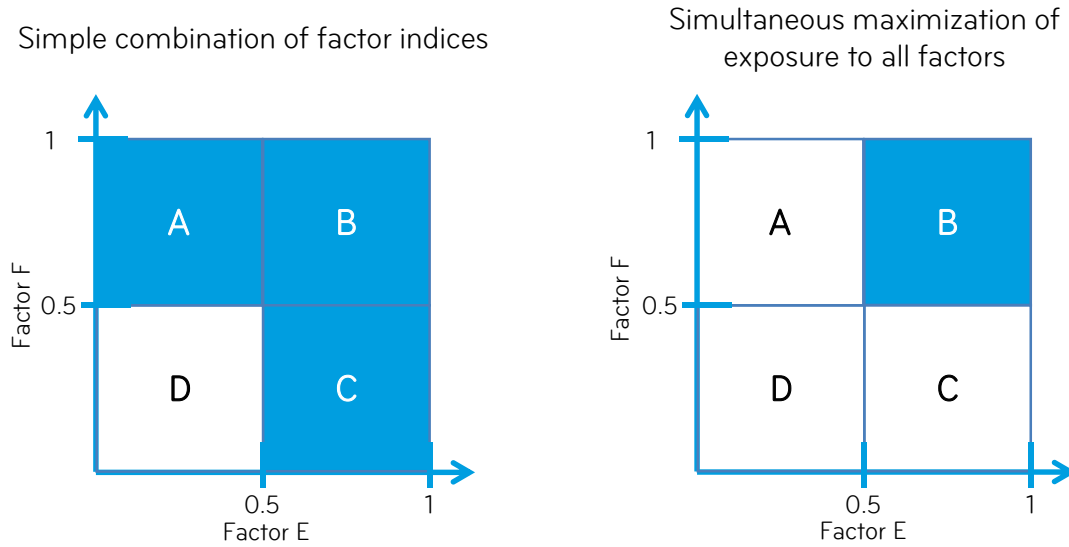


Figure 6: Simplified graphical representation of hypothetical two factors investment with factors E and F. The "index of indices" approach is displayed on the right hand side while a simultaneous maximization to both factors is displayed on the left hand side.

The "index of indices" approach, displayed on the left hand side of Figure 6, would lead to the inclusion of companies from quadrants A, B and C. Assuming that both factors E and F are independent from one another, companies that score high with regard to factor E (e.g. belong to the top 50%) could either have a very high (quadrant B) or very low (quadrant C) exposure to factor F. The same holds true from the perspective of factor F relative to factor E. Consequently, a combination of single factor indices would be a mix of companies with very different exposures to both factors.

The other extreme would be to include only those companies that score above the median with regard to both factors, E and F (quadrant B). As we have seen in Figure 5, the iSTOXX Europe Multi-Factor index tends to rather include those companies that score relatively well in both dimensions which would correspond with quadrant B (see right hand side of Figure 5).<sup>15</sup>

But how does this difference translate into performance? Figure 7 provides performance figures for both approaches, the "index of indices" concept as well as the methodology chosen for the iSTOXX Europe Multi-Factor Index.

<sup>15</sup> Please note that the selection process of the iSTOXX Europe Multi-Factor index does not explicitly require companies to fall into quadrant B. However, the empirical results indicate that the majority of companies selected into the index tend to score above the median in the majority of the targeted factors.

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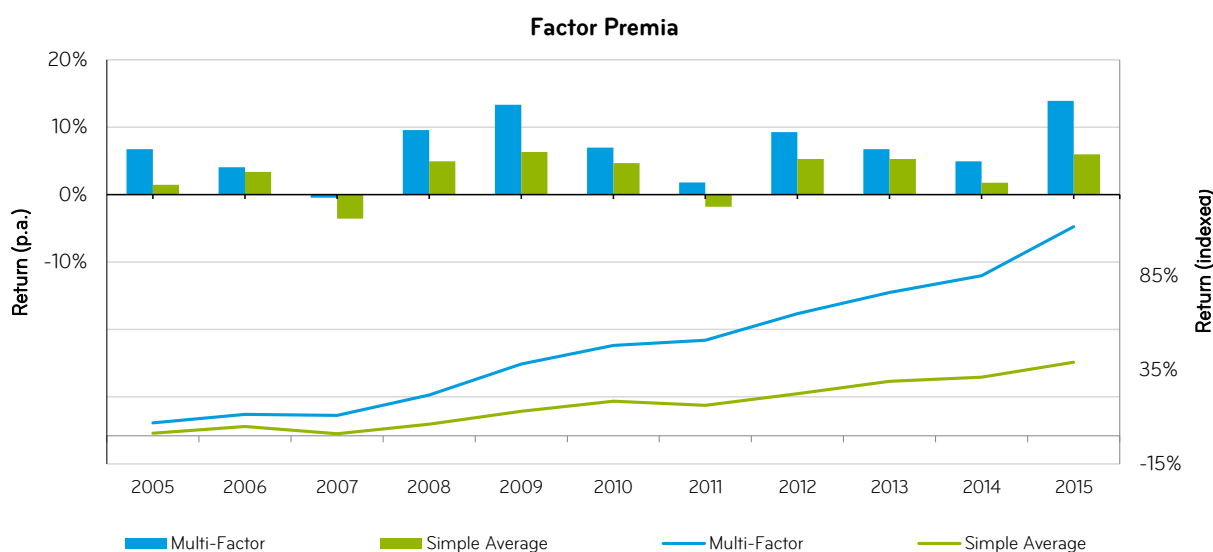


Figure 7: Annual and indexed returns of iSTOXX Europe Multi-Factor index as well as of equal-weighted combination of iSTOXX Europe Single Factor returns over STOXX Europe 600 measured in EUR GR. Time period: Jan. 2005 to Dec. 2015.

With an overall performance of 108.3% measured from Jan. 2005 to Dec. 2016, the iSTOXX Multi-Factor Index outperforms its equal-weighted benchmark, which generated a performance of "only" 38.4% over the 11 years observed, by a factor of 2.8 or 70 percentage points. More importantly, the superior performance does not only emerge in the long run. In fact, the iSTOXX Europe Multi-Factor Index outperformed its benchmark in every one of the eleven years observed. Thus, focusing on "hidden champions", i.e. those companies that score relatively well across more than one factor, rather than focusing on companies that score very well with regard to just one factor but poorly in the remaining factors, leads to better performance results.

As we have seen above, factor returns are found to have low correlation not only with the market but also amongst each other. Hence, an investment that combines a broad market investment with an investment across factors should provide significantly lower risk than an investment into the broad market alone. A comparison of volatility and maximum drawdown figures for those two alternatives supports this assumption (see columns 3 and 4 of Table 3). The iSTOXX Europe Multi-Factor index shows a total risk that is about 1.4 percentage points below that of a stand-alone investment into the STOXX Europe 600. Even more notably, the maximum drawdown of the iSTOXX Europe Multi-Factor index, measured over the entire period observed, is by as much as 13.5% or eight percentage points below that of the STOXX Europe 600.

## 5 Conclusion

The empirical results show that all iSTOXX Europe Single Factor Indices provide significant excess returns relative to their benchmark over a sample period of eleven years. With correlations to the benchmark index STOXX Europe 600 ranging from a minimum of -0.71 (low risk factor) to a maximum of 0.03 (value factor), factor returns are found to also serve as a great source of diversification when used in addition to an existing investment in a broad European benchmark index such as the STOXX Europe

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600. Low correlations *among* factor returns further add to the diversification potential when investing in more than just one factor index.

However, risk premia are found to vary significantly over time. This observation as well as the low correlation among factor returns provide the grounds for the construction of the iSTOXX Europe Multi-Factor index. Its innovative methodology leads to lower risk and higher returns compared to a heuristic, e.g. equally weighted aggregation of single factor indices.

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## Appendix A

### Metrics underlying the factor construction

#### A.1 Carry

The carry factor is a composite of four measures:

$$A.1.1 \text{ Price to dividend} = \frac{\text{Price}}{\text{dividend per share over the last 12 months}},$$

$$A.1.2 \text{ Internal growth} = \text{Return on equity} \times \text{Payout ratio} = \frac{\text{Earnings}}{\text{Book value}} \times \left(1 - \frac{\text{Dividend per share}}{\text{Earnings per share over the last 12m}}\right),$$

$$A.1.3 \text{ Earnings dispersion} = \text{Standard deviation of earnings; timeweighted forward 12 month},$$

$$A.1.4 \text{ Shares out reduction} = \frac{\text{Historical common shares decrease over last 24 months}}{\text{Common shares out}}.$$

#### A.2 Risk

The risk factor is a composite of three measures:

$$A.2.1 \text{ 3M volatility} = \text{Standard deviation of returns over 3 months},$$

$$A.2.2 \text{ 12M volatility} = \text{Standard deviation of returns over 12 months},$$

$$A.2.3 \text{ 12M semi volatility} = \text{Semi deviation of returns over 12 months}.$$

#### A.3 Momentum

The momentum factor is a composite of two measures:

$$A.3.1 \text{ 1M reversal} = -T \text{ Value of return index over 1 month},$$

$$A.3.2 \text{ 12M momentum} = T \text{ Value of return index over 12 months}.$$

#### A.4 Quality

The quality factor is a composite of five measures:

$$A.4.1 \text{ Operating income to common equity} = \frac{\text{Operating income}}{\text{Common equity}}, \text{ which becomes } \frac{\text{Operating income}}{\text{Total assets}} \text{ if } \text{Common equity} \leq 0,$$

$$A.4.2 \text{ Cash to current liabilities} = -1 \times \frac{\text{Cash and equivalent}}{\text{Current liabilities}},$$



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$$\text{A.4.3 Net external financing } 12M = -1 \times \frac{12M \Delta \text{ sh out} \times 12M \text{ average price} + 12M \Delta \text{ long debt} + 12M \Delta \text{ short debt} + 12M \Delta \text{ pref stocks}}{12M \text{ Average total assets}},$$

with,

$$12M \Delta \text{ sh out} = \text{Shares outstanding}_{t_0} - \text{Shares outstanding}_{t_0-12\text{month}},$$

$$12M \Delta \text{ long debt} = \text{Long debt}_{t_0} - \text{Long debt}_{t_0-12\text{month}},$$

$$12M \Delta \text{ short debt} = \text{Short debt}_{t_0} - \text{Short debt}_{t_0-12\text{month}},$$

$$12M \Delta \text{ pref stocks} = \text{Preferred stocks}_{t_0} - \text{Preferred stocks}_{t_0-12\text{month}},$$

$$12M \text{ average price} = \text{Average price in local currency with monthly observations},$$

$$12M \text{ Average total assets} = \text{Average total assets in local currency with quarterly observations},$$

$$\text{A.4.4 Coverage} = \text{Composite} \left( \frac{\text{EBIT}}{\text{Interest payments}}; \frac{\text{EBIT}}{\text{Total debt}}; \frac{\text{CFO}}{\text{Interest payments}}; \frac{\text{CFO}}{\text{Total debt}} \right).$$

$$\text{A.4.5 Accruals quality} = \frac{12M \Delta \text{ Net Operating Assets}}{\text{Total Assets}},$$

with,

$$12M \Delta \text{ net operating assets} = \text{Net operating assets}_{t_0} - \text{Net operating assets}_{t_0-12\text{month}},$$

with,

$$\text{Net operating assets} = \text{Total assets} - \text{Cash} - \text{Total liabilities} + \text{Short debt} + \text{Long debt}.$$

## A.5 Size

The size factor is a composite of two measures:

$$\text{A.5.1 Inverse MCAP} = -1 * \text{Market capitalization},$$

$$\text{A.5.2 Inverse EV} = -1 * (\text{Market capitalization at end of fiscal year} + \text{Preferred stocks} + \text{Minority interest} + \text{Total debt} - \text{Cash}).$$

## A.6 Value

The value factor is a composite of two measures:

$$\text{A.6.1 Forward } 12M \text{ earnings yield; replaced with } \frac{\text{Cash flows from operations}}{\text{Total assets}} \text{ if negative},$$

$$\text{A.6.2 Cash flow yield; replaced with } \frac{\text{Cash flows from operations}}{\text{Total assets}} \text{ if negative}.$$

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## Appendix B

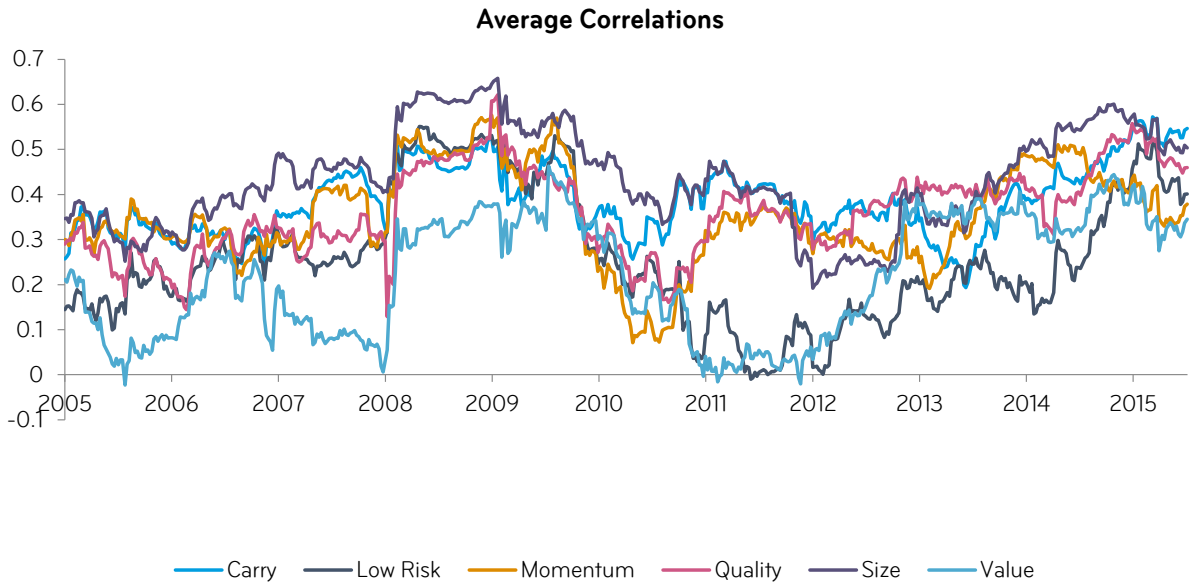


Figure A.1: Average correlations among factor returns from the perspective of each factor to all other five factors. Correlations are based on weekly EUR gross returns measured over a 52 week time-period. Time period: Oct. 2004 - Mar. 2016.

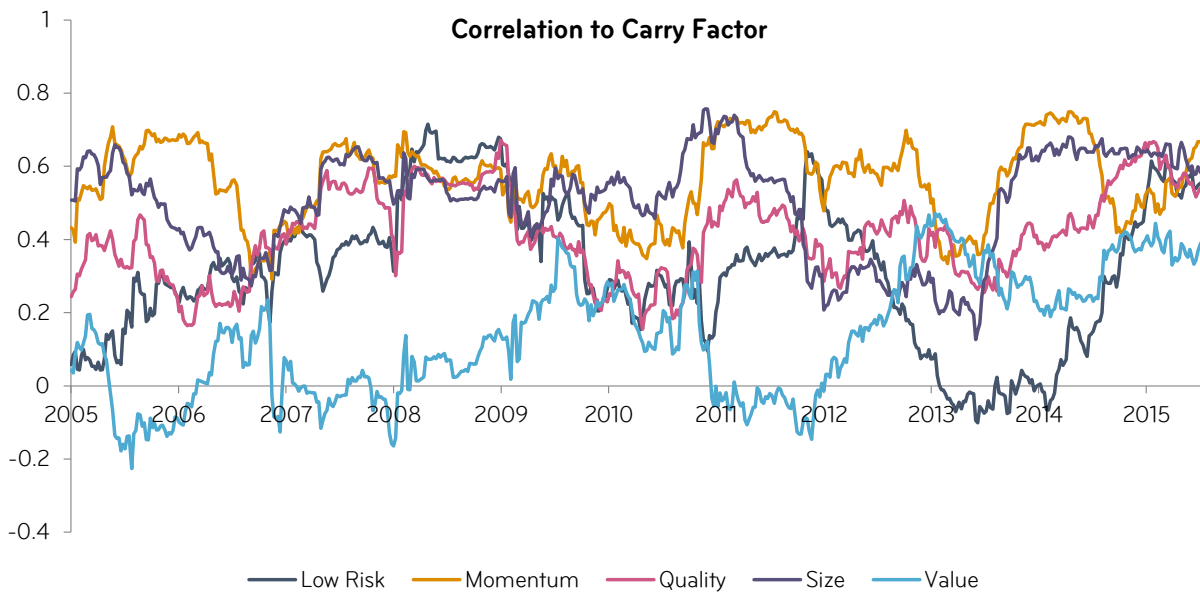
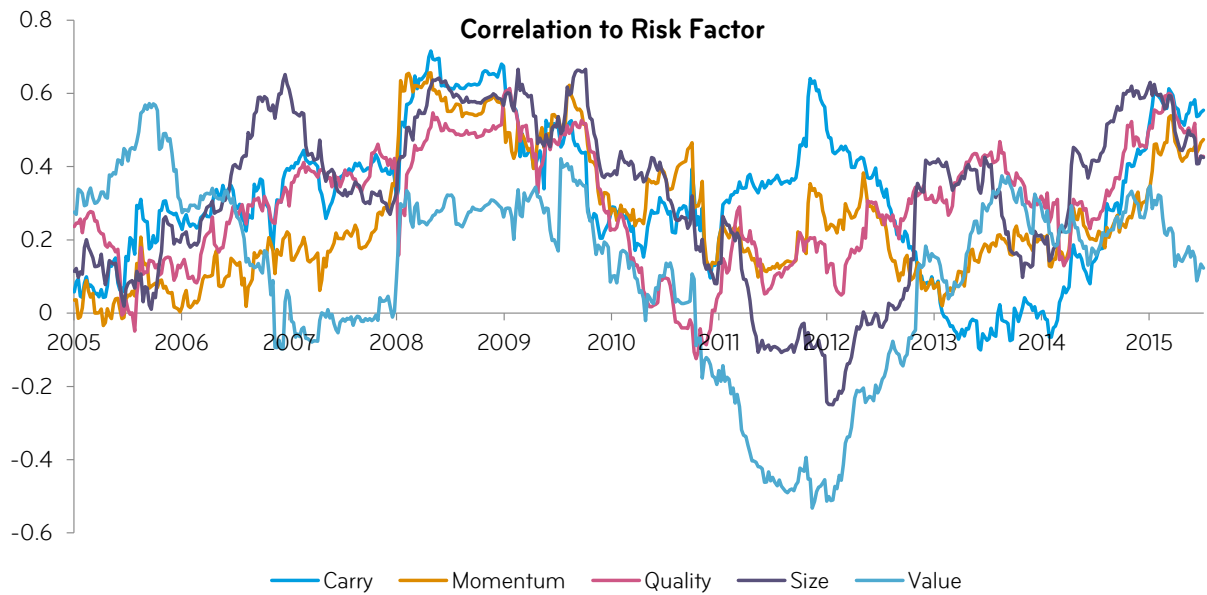


Figure A.2: Correlations of carry factor to all other factors. Correlations are based on weekly EUR gross returns measured over a 52 week time-period. Time period: Oct. 2004 - Mar. 2016.

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Low Figure A.3: Correlations of risk factor to all other factors. Correlations are based on weekly EUR gross returns measured over a 52 week time-period. Time period: Oct. 2004 - Mar. 2016.

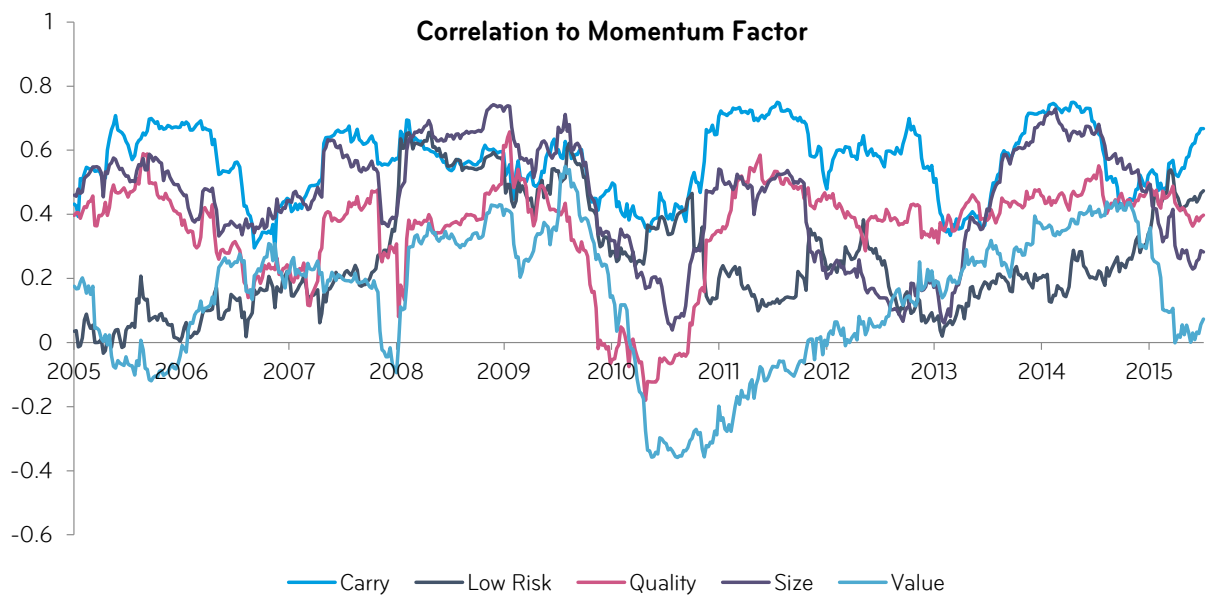


Figure A.4: Correlations of momentum factor to all other factors. Correlations are based on weekly EUR gross returns measured over a 52 week time-period. Time period: Oct. 2004 - Mar. 2016.

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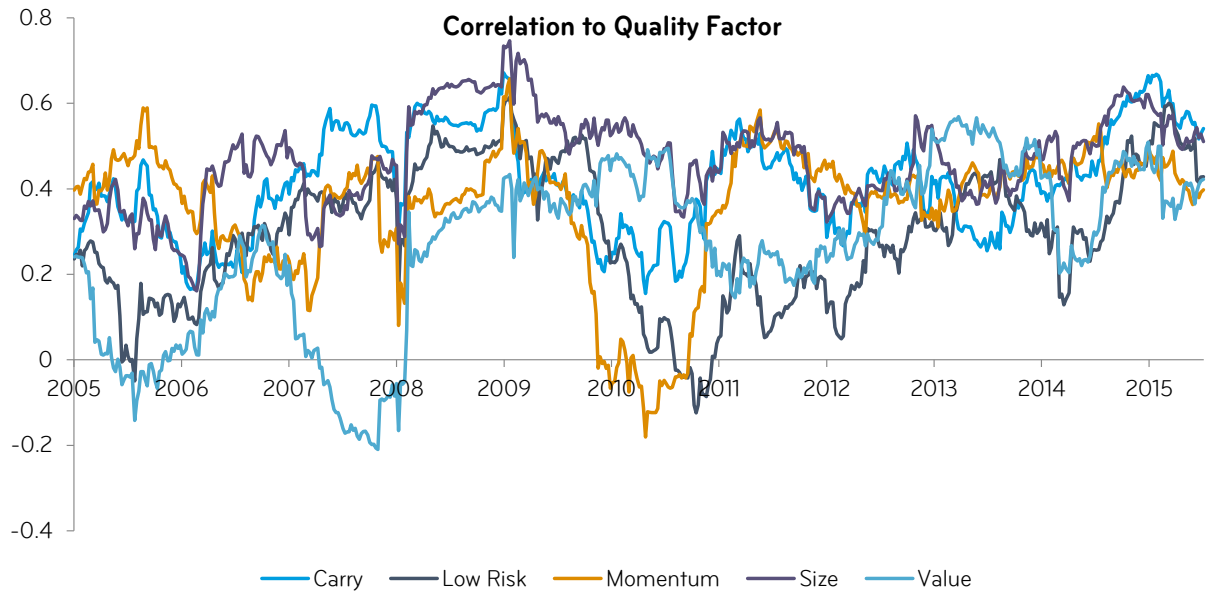


Figure A.5: Correlations of quality factor to all other factors. Correlations are based on weekly EUR gross returns measured over a 52 week time-period. Time period: Oct. 2004 - Mar. 2016.

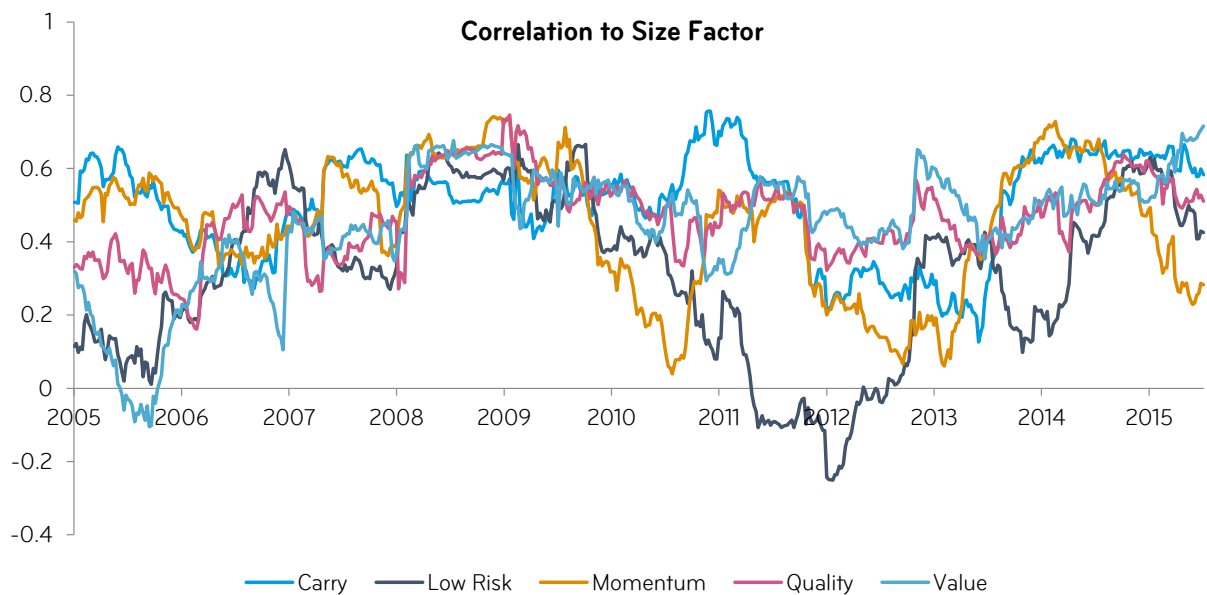


Figure A.6: Correlations of size factor to all other factors. Correlations are based on weekly EUR gross returns measured over a 52 week time-period. Time period: Oct. 2004 - Mar. 2016.

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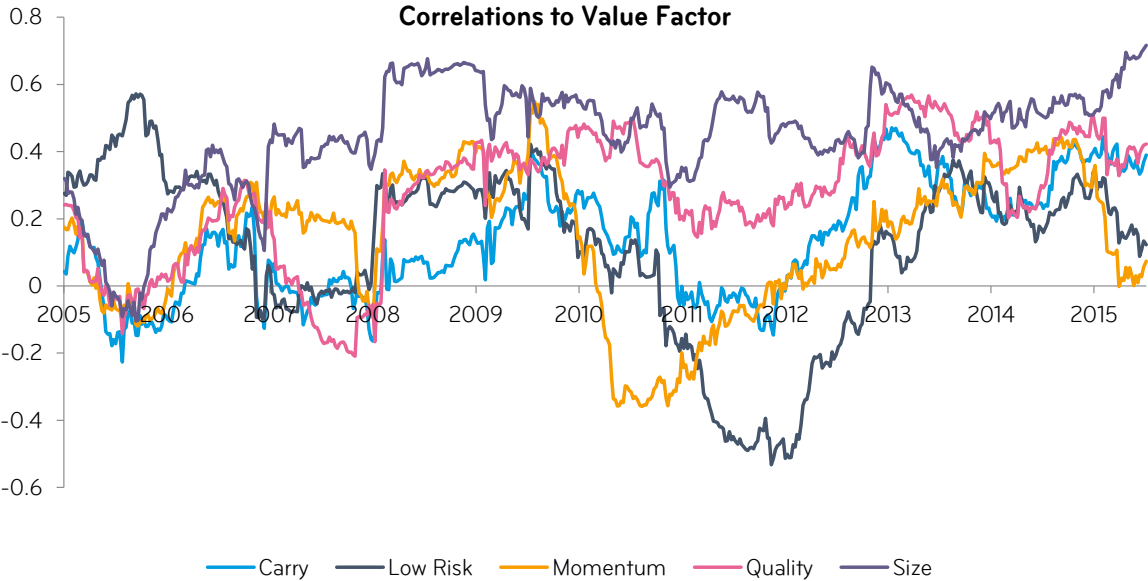


Figure A.7: Correlations of value factor to all other factors. Correlations are based on weekly EUR gross returns measured over a 52 week time-period. Time period: Oct. 2004 - Mar. 2016.

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## CONTACTS

Selnaustrasse 30  
CH-8021 Zurich  
P +41 (0)58 399 5300  
stoxx@stoxx.com  
www.stoxx.com

Frankfurt: +49 (0)69 211 13243  
London: +44 (0)20 7862 7680  
New York: +1 212 669 6426  
Singapore: +65 9189 7970  
Tokyo: +81-3-4578-6688 / 03-4578-6688

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