Factor Investing: Long-Only versus Long-Short

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Abstract

Various studies recommend investing in factor premiums beyond the classic market risk premium, such as the small-cap, value, momentum, and low-volatility premiums. It is unclear, however, if factor investing can best be implemented using a long-only or a long-short approach. We empirically compare both approaches and find that although a long-short approach is superior theoretically, a long-only approach seems to be the preferred alternative in most scenarios, after accounting for practical issues such as benchmark restrictions, implementation costs and factor decay. In fact, we show that costs and decay may completely offset the value added of a long-short implementation. We conclude that investors should carefully consider the pros and cons of long-only and long-short approaches when implementing factor investing. The framework described in this paper is intended to help investors make that decision.

Keywords: factor premiums, factor investing, long-only, long-short, small-cap, value, momentum, low-volatility

JEL Classification: *C12, G11, G12, G14*

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1. Introduction

A growing body of academic literature argues for a so-called factor investing approach to setting up investment portfolios, i.e., to allocate strategically to well-established factor premiums, such as the small-cap, value, momentum, and low-volatility premiums. For an in-depth motivation for factor investing we refer to the work of Ang, Goetzmann, and Schaefer (2009) and Ang (2013). While studies such as these have triggered considerable interest in factor investing among professional investors, important questions on how factor investing should be implemented still remain unanswered. One of these key questions is whether a factor investing framework should be implemented using a long-only or a long-short approach.

While some studies advocate a long-short approach to factor investing [see, e.g., Bender, Briand, Nielsen and Stefek (2010) and Ilmanen and Kizer (2012)], other studies propose a long-only approach [see, e.g., Blitz (2012) and MSCI (2013)]. Investment vehicles that have been set up over the past years to offer investors explicit exposure to factor premiums are also predominantly long-only (e.g., index funds and exchange-traded funds based on small-cap, value and low-volatility indexes).

In this paper we empirically compare long-only versus long-short approaches to factor investing in order to determine which approach is preferable under various conditions. Our main result is that although the long-short approach is superior in theory, the long-only approach seems to be a better alternative in most scenarios that account for practical issues such as benchmark restrictions, implementation costs and factor decay. To cope with benchmark restrictions, an investor could apply a beta overlay to a long-short approach, but in that case most of the advantage compared to a long-only approach disappears. Perhaps even more importantly, the long-only approach is more robust to implementation costs and factor decay. In fact, we show that these issues may completely offset the value added of a long-short implementation. We also find that investors who are comfortable with a zero-beta approach to factor investing may consider simply hedging out the market exposure of a long-only factor investing strategy, e.g., by selling short liquid index futures rather than individual securities. We conclude that investors should carefully consider all pros and cons of long-only and long-short approaches when implementing factor investing. This paper provides a framework intended to help investors make that decision.

2. Data and factor returns

We consider factor investing strategies based on the most widely acknowledged factor premiums in the equity market: the market factor, the small-cap factor, the value factor, the momentum factor, and the low-volatility factor. We use monthly U.S. stock return series over the period July 1963 to December 2010. Most of the data for our analyses are from the webpage of French (2013). As a proxy for the market we take the Mkt-RF factor, which represents the value-weighted market return in excess of the risk-free rate for the entire CRSP stock universe. RF is the return on the one-month T-bill.

The proxies we use for the small-cap, value, and momentum factors are based on Fama and French (1993) 2x3 equally-weighted portfolios. As in Blitz (2012), we derive our proxies for the value and momentum factors by only considering the segment of the market that Fama-French refer to as the "Big" segment (i.e., stocks that have a market capitalization above the NYSE median).[1] By doing so, we make sure that the strategies we describe can be applied on a large scale, and that the results are not highly sensitive to market microstructure concerns. Specifically, our long-only value portfolio is the return on the Big/High book-to-market portfolio of French in excess of the risk-free rate. Throughout the remainder of our study, we refer to this factor as the Value-RF factor. For the long-short value strategy we take the return differential between the Big/High book-to-market and the Big/Low book-to-market portfolios. We refer to this factor as the HML (i.e., High-Minus-Low) factor. Likewise, we take the excess returns of the Big/High 12-1M return momentum portfolio of French, and the return differential between the Big/High momentum and the Big/Low momentum portfolio for the momentum factor strategies. We refer to these factors as the Mom-RF and the WML (i.e., Winners-Minus-Losers) factors, respectively. Our small-cap factor follows Blitz (2012) by taking the returns of stocks with a market capitalization between the 30^{th} and 70^{th} percentile of NYSE stocks for the long-only approach, and the return differential between this portfolio and the portfolio of stocks with a market capitalization above the 70^{th} percentile of NYSE stocks for the long-short approach. We refer to these factors as the Small-RF and SMB (i.e., Small-Minus-Big) factors, respectively.

[1] The average number of stocks in the Big segment of the market is around 800. At the end of our sample period, the NYSE median market cap threshold is at a market capitalization of around 1 billion USD.

For the low-volatility factor strategies we follow the procedure of Fama and French (1993) and construct 2x3 equally-weighted portfolios based on market capitalization and past 36-month return volatility for all common stocks in the CRSP universe. We then take the Big/Low-volatility portfolio (i.e., stocks with a market capitalization above the NYSE median and bottom tercile rank on volatility) as a proxy for the low-volatility factor for the long-only approach, and the return differential between the Big/Low volatility and the Big/High volatility portfolios as a proxy for the low-volatility factor for the long-short approach. We refer to the long-only and long-short low-volatility factors as the Lowvol-RF and SMV (i.e., Stable-Minus-Volatile) factors, respectively. To ensure that the low-volatility long-short factor is beta-neutral we give a weight to the Big/Low-volatility portfolio of 130 percent and a weight of 70 percent to the Big/High-volatility portfolios.[2] Since the betas of the Big/Low-volatility and Big/High-volatility portfolios are 0.8 and 1.5 respectively, this weighting scheme results in a long-short factor that is roughly beta-neutral, similar to the other long-short factors we consider in our study and similar to how Frazzini and Pedersen (2014) handle this issue.

3. Empirical results

In this section we discuss our empirical findings. In our first analysis we ignore benchmark restrictions, implementation costs, and factor decay. In the subsequent analyses, we discuss the impact of these practical issues on the performances of long-only and long-short approaches to factor investing.

3.1 Results without restrictions, implementation costs, and factor decay.

We compare three portfolios: the market portfolio, the long-only factor portfolio, and a long-short factor portfolio. The long-only factor portfolio is equally invested in each of the four factors, i.e. the small-cap, value, momentum, and low-volatility factor portfolios each receive a portfolio weight of 25 percent. We refer to this portfolio as the "Long-Only Beta 1" portfolio.[3] The first long-short factor portfolio we consider is equally invested in the corresponding long-

[2] The portfolio is 60% short in the risk-free rate in order to finance these positions.
[3] The estimated beta of this portfolio is 1.01 over our sample period.

short factors. More specifically, the SMB, HML, WML, and SMV factors each receive a portfolio weight of 25 percent. We refer to this portfolio as the "Long-Short Beta 0" portfolio. We first consider the returns, risks (i.e., volatilities), and Sharpe ratios for these portfolios, as well as for the underlying factors. The results are reported in Table 1.

[INSERT TABLE 1 ABOUT HERE]

In Panel A of Table 1 we observe that all factor portfolios have a higher Sharpe ratio than the capitalization-weighted market portfolio. Each of the long-only factor portfolios has a higher return, and the Lowvol-RF portfolio additionally has a lower risk. More specifically, the Small-RF portfolio has a Sharpe ratio of 0.31, the Value-RF portfolio has a Sharpe ratio of 0.49, the Mom-RF portfolio has a Sharpe ratio of 0.49 and the Lowvol-RF factor has a Sharpe ratio of 0.45, which compares to a Sharpe ratio of 0.27 for the Mkt-RF portfolio. Not surprisingly, therefore, the "Long-Only Beta 1" portfolio exhibits a higher Sharpe ratio than the market portfolio. The increase in Sharpe from 0.27 to 0.47 is quite substantial and illustrates the effectiveness of a factor investing approach. Furthermore, the combined factor portfolio has a Sharpe ratio which is higher than the average of all individual factor portfolios, reflecting the benefits of diversification across factor premiums.

We next consider the results for the long-short factor portfolios. For all long-short factor portfolios we observe positive Sharpe ratios, ranging from 0.24 for the SMB factor to 0.39 for the WML factor. When we consider the results for the "Long-Short Beta 0" portfolio we clearly see the diversification benefits of long-short factor investing: whereas the volatilities of the individual factor portfolios range from 6.9 for the SMB portfolio to 16.1 for the WML portfolio, the volatility of the "Long-Short Beta 0" portfolio amounts to only 5.9 percent per annum. The resulting Sharpe ratio of the "Long-Short Beta 0" portfolio is 0.73, significantly higher than the Sharpe ratio of the long-only factor portfolio.

However, it is premature to conclude that a long-short approach to factor investing is therefore superior to a long-only approach. A key difference between the long-only and the long-short approaches is that the latter approach relies heavily on shorting large numbers of stocks, as also shown in Panel B of Table 1. Many investors are reluctant to apply shorting on such a large scale. Constraints on the extent to which shorting is allowed may even render the long-short

approach effectively infeasible. Of course one might wonder if such a constraint should simply be relieved in order to be able to reap the benefits of a long-short factor investing approach. However, there are some valid reasons for restricting short-selling, as shorting involves various risks that are not captured by a conventional risk measure such as volatility. For instance, shorting is an OTC agreement which involves margin requirements and counterparty risk. In addition, it involves the risk of short squeezes, the potential risk of unlimited losses, and the risk of being forced to close down positions precisely at the moment when it is least desirable. Another caveat is that it may not be possible to enter into some of the most desired short positions. By contrast, the long-only approach involves none of these issues.

Apart from shorting constraints, there are additional important issues that need to be considered in the comparison between the long-only and long-short alternatives, in particular benchmark restrictions, implementation costs and factor decay. These issues are the subject of the following sections.

3.2 Benchmark restrictions

A long-short factor portfolio may not be very attractive for investors who are benchmarked against the market index. In order to illustrate this point we consider the following characteristics of the factor investing portfolios against the market portfolio: beta, outperformance, tracking error (i.e., standard deviation of outperformance), information ratio, and drawdown. The drawdown measures at each point in time the historical peak-to-through decline of a portfolio relative to the market, and in the table we report the average drawdown of a portfolio. Panel C of Table 1 shows that the "Long-Short Beta 0" portfolio has a poor performance relative to the market and also involves high levels of relative risk. The tracking errors of the long-only factors range from 7.0 percent (Lowvol-RF) to 8.8 percent (Value-RF), while the tracking errors of the long-short factors range from 15.3 percent (SMB) to 23.9 percent (WML). This means that the relative risk compared to the market portfolio is 2-3 times larger for the long-short factors. The drawdown statistics also indicate higher benchmark-relative risk for long-short factors, with two to ten times higher expected underperformance compared to the market portfolio (Mkt-RF). As a

result of higher returns and lower tracking errors, the information ratios of the long-only factors are much higher than the information ratios of the corresponding long-short factors.

Combined, the “Long-Only Beta 1” portfolio yields an outperformance of 3.6 percent per annum over our sample period, compared to only 0.1 percent for the “Long-Short Beta 0” portfolio. And while the “Long-Only Beta 1” portfolio has a tracking error of 4.9 percent per annum and an average drawdown of -3.0 percent, these figures are 17.7 and -49.1 percent respectively for the “Long-Short Beta 0” portfolio. The outperformances and tracking errors to the market portfolio of the “Long-Only Beta 1” and “Long-Short Beta 0” portfolios translate into information ratios of 0.72 and 0.01, respectively. As a consequence of the poor performance of the “Long-Short Beta 0” portfolio relative to the market portfolio, a long-only approach seems preferable over a pure long-short approach for investors who are directly or indirectly benchmarked against the market.

The benchmark issue raises various questions. First, one might wonder whether this is perhaps another example of a constraint that should be alleviated, e.g., by simply taking the benchmark much less seriously. We believe, however, that the benchmark should not be dismissed that easily. The benchmark, or market portfolio, reflects the consensus portfolio and is the only portfolio that is consistent with market equilibrium. Thus, an investor without any views on the market should hold this portfolio. The long-only factor portfolio deviates from the benchmark by tilting towards various factor premiums that have been strong historically, based on the view that these will persist in the future. In the unfortunate event that this view happens to be wrong, i.e., if the small-cap, value, momentum, and low-volatility premiums were to disappear in the future, not much is actually lost, as the long-only factor portfolio will still capture the equity market premium, thereby keeping pace with the benchmark return. The return of the long-short factor portfolio, on the other hand, is entirely dependent on the continued existence of the various factor premiums. Without positive factor premiums, the return of the long-short factor portfolio is zero. Thus, the long-short approach requires a much stronger belief in the continued existence of factor premiums than the long-only approach.

One way in which the relatively low return of the “Long-Short Beta 0” portfolio might be addressed is by simply levering the portfolio up, e.g., from 100 percent long plus 100 percent short to 200 percent long plus 200 percent short. In principle, this doubles the return as well as

the volatility of the strategy, thereby preserving the Sharpe ratio. The higher return takes care of the low-return issue, and although the volatility is higher as well, it may still be acceptable given the low base-case volatility. However, the drawback of this approach is that it amplifies the leverage and benchmark concerns discussed above. For instance, the already very high tracking error against the benchmark of 17.7 percent for the 100/100 long-short portfolio would double to over 35 percent for the 200/200 portfolio. We address this issue in more detail in the follow-up analyses in section 3.4.

Alternatively, investors could employ a market beta overlay, in order to increase the return of the long-short approach and simultaneously decrease its tracking error. For instance, one could take a 100 percent long position in the market portfolio next to the long-short positions in the factor portfolios. This could for instance be done by buying liquid index futures, which is, in contrast to shorting individual stocks, quite easy to implement in practice.[4] To investigate how the performance of a long-short approach with beta overlay compares to a long-only approach, we consider the performance of a second long-short factor portfolio that is 200/100 percent long/short invested. More specifically, the returns of this long-short portfolio are the sum of the returns of the Mkt-RF and the "Long-Short Beta 0" portfolios. We refer to this portfolio as the "Long-Short Beta 1" portfolio.[5] The performance of this factor portfolio is also presented in Table 1. As can be seen from Table 1, this portfolio has a beta close to one and levels of tracking error and drawdown that are comparable to those of the "Long-Only Beta 1" portfolio: while the "Long-Only Beta 1" portfolio has a tracking error of 4.9 percent per annum and an average drawdown of -3.0 percent, these figures are 5.9 and -2.5 percent for the "Long-Short Beta 1" portfolio, respectively. Because the relative risk levels of the Beta 1 portfolios are similar, an apples-to-apples comparison between the long-only and long-short approaches can now be made.

Once the beta overlay is applied it appears that most of the value added of a long-short approach over a long-only approach disappears. While the "Long-Short Beta 0" portfolio has a gross Sharpe ratio of 0.73, the Sharpe ratio of the "Long-Short Beta 1" portfolio is significantly lower at 0.54, which is much closer to the Sharpe ratio of 0.47 for the "Long-Only Beta 1"

[4] For US investors the S&P500 future is very liquid and available at low cost. Also for international equities liquid futures are available. Thus the step from "100/100" to "200/100" is relatively easy to do in practice by simply adding index futures to the long-short portfolio.

[5] Because the "Long-Short Beta 0" portfolio actually has a market beta of -0.07, we assign a weight of 1.07/1 to the Mkt-RF portfolio in our calculations to set the beta of the "Long-Short Beta 1" portfolio to one.

portfolio. This result can be attributed to the fact that most of the risk budget of the Beta 1 portfolios is consumed by the market factor, which diminishes the diversification benefits of the small-cap, value, momentum, and low-risk factors. We conclude that when a comparison is made between long-only and long-short approaches to factor investing in a Beta 1 context, the performance differential between both approaches is substantially smaller than when the long-short approach is allowed to exhibit extreme deviations from the market portfolio.

3.3 Implementation costs and factor decay

The next and perhaps most important consideration in our comparison of a long-only versus a long-short approach to factor investing is the sensitivity to implementation costs (e.g., transaction costs, borrowing costs, margin requirements and management fees), and potential decay in factor returns to reflect a more realistic forward looking expectation of factor premiums (e.g. see Harvey, Liu, and Zhu, 2013). We argue that a long-short approach is more sensitive to these important implementation issues since the long-short solution involves double the turnover of a long-only strategy; higher trading costs and shorting costs; and stronger dependence on the magnitude of factor premiums.

To investigate these sensitivities we analyze several scenarios in which we assume different levels of costs and decay in the factors premiums. For the base case scenario we assume that the annual costs for holding a long-only factor portfolio are 50 basis points per annum. These costs include costs of rebalancing portfolios, taxes, and management fees. We assume similar costs for holding the short side of the factor portfolios. In addition, we assume 100 basis points per annum for the shorting costs. We assume that there are no costs for holding the market portfolio.

Regarding the decay in factor premiums, we assume 100 basis points decay in performance for the market factor, 100 basis points decay for the difference in return between the long factor portfolios and the market, and 100 basis points decay for the difference in return between the short factor portfolios and the market. Since a long-only approach to factor investing also involves exposure to the market factor, this means we subtract 200 basis points from the gross return series. For the long-short approach we also subtract 200 basis points from the gross

return series since the long-short approaches have factor exposures both in the long and the short portfolios. We do make an exception for the SMB factor: since the SMB factor is short in large cap stocks and we assume that that there are no costs for holding (and shorting) the market portfolio, we subtract costs and decay only once for this factor portfolio. We also assume that shorting costs are zero for the SMB factor. We refer to this base case scenario as the "Neutral" scenario.

Next to our "Neutral" scenario, we consider two more optimistic and two more pessimistic scenarios. In our "Optimistic decay" ("Pessimistic decay") scenario, we assume decays of 50 basis points (150 basis points) per annum instead of the 100 basis points assumed in the base-case scenario, and in our "Optimistic costs" ("Pessimistic costs") scenario we assume costs to be 25 basis points (75 basis points) and shorting costs to be 75 basis points (125 basis points). All other assumptions in these scenarios are the same as in our base-case "Neutral" scenario. The results for the different scenarios are presented in Table 2.

[INSERT TABLE 2 ABOUT HERE]

Panel A of Table 2 shows the results of the Neutral scenario. As expected we observe that the impact of costs is larger for the long-short approach than for the long-only approach: while the Sharpe ratio of the "Long-Only Beta 1" portfolio drops from 0.47 to 0.31, the Sharpe ratio of the "Long-Short Beta 1" portfolio falls from 0.54 to 0.25. In other words, when costs and decay are taken into account the long-only factor investing approach appears to be slightly better than the long-short approach. Interestingly, even if we look at the two more optimistic scenarios with either lower decay in factor premiums (Panel B of Table 2) or lower costs (Panel D of Table 2), a long-short approach to factor investing does not generate higher Sharpe ratios than a long-only approach. Under our "Pessimistic decay" and "Pessimistic costs" scenarios, the value added of long-short factor investing versus the market portfolio even disappears almost entirely. For example, both the Mkt-RF portfolio and the "Long-Short Beta 1" portfolio have a Sharpe ratio of 0.17 in our "Pessimistic decay" scenario, and under our "Pessimistic costs" scenario the "Long-Short Beta 1" portfolio has a Sharpe ratio of 0.22 versus 0.20 for the Mkt-RF portfolio. The Sharpe ratios of the long-only approach, however, are significantly higher than those of both the the Mkt-RF and "Long-Short Beta 1" portfolios in all scenarios. We conclude that a long-only

approach to factor investing is more robust to implementation costs and factor decay than a long-short approach. Figure 1 gives an overview of our main findings.

[INSERT FIGURE 1 ABOUT HERE]

Another way to examine the impact of implementation costs is by evaluating the performance of investment vehicles that provide investors access to factor premiums. For long-only we can consider the literature that has evaluated the performance of passive funds that track a factor-based index, such as a value index or a low-volatility index. The conclusion of this stream of literature is that although such funds exhibit some implementation shortfall in comparison to the paper indexes they are designed to track, the extent of this implementation shortfall is small. Another relevant study in this regard is Huij and van Gelderen (2013), who find strong evidence that mutual funds with systematic tilts towards proven factors, be it intentional or unintentional, are able to generate above-average long-term returns. The extent to which long-short factor premiums can be captured efficiently in practice is unclear though, for the simple reason that the first such funds have only recently been introduced. This also argues for caution with regard to a long-short factor investing approach.

3.4 Follow-up analyses

In this section we discuss the results of various follow-up empirical analyses we performed. We first investigate the sensitivity of our results to the impact of trading costs on the momentum premium. To this end, we assume double the costs for both the long-only and the long-short momentum factors. All other settings are the same as in our "Neutral" scenario. In our second follow-up analysis, we derive our factor proxies by considering not only the "Big" segment of the market (i.e., stocks that have a market capitalization above the NYSE median), but also the "Small" segment of the market. More specifically, Value-RF is now the average return of Small/High book-to-market and Big/High book-to-market stock portfolios in excess of the risk-free rate, and HML is now the return differential between the average return of Small/High book-to-market and Big/High book-to-market stock portoflios, and the average return of Small/Low book-to-market and Big/Low book-to-market stock portfolios. Our momentum and low-risk factors are constructed in a similar fashion. Small-RF is return of stocks with a market

capitalization below the 30th percentile of NYSE stocks, and SMB is the return differential between this portfolio and the portfolio of stocks with a market capitalization above the 70th percentile of NYSE stocks. In our third analysis, we use value-weighted factor portfolios instead of the equally-weighted portfolio considered in the base-case analysis. And finally, in our fourth analysis, we assume that there are no additional costs involved with short selling. The results of these analyses are presented in Table 3.

[INSERT TABLE 3 ABOUT HERE]

We observe that the "Long-only Beta 0" portfolios earn higher returns and Sharpe ratios than the "Long-short Beta 0" portfolios in all scenarios, and that the "Long-only Beta 1" portfolios also earn higher returns and Sharpe ratios than the "Long-short Beta 1" portfolios in all scenarios. Thus, our conclusion that a long-only approach to factor investing tends to outperform a long-short approach after accounting for implementation costs and factor decay appears to be quite robust to methodological choices.

Finally, we investigate the impact of higher levels of leverage on the performance of the "Long-short Beta 1" portfolio under our "Neutral" scenario. To this end, we consider leverage levels ranging from 200/100 to 300/200. The results of this analysis are presented in Table 4. We observe that the use of higher levels of leverage helps to increase the expected return. However, it also exacerbates the portfolio's levels of counterparty risk, liquidity risk, and deviations from the market benchmark. Moreover, the increase in return is associated with an equally large increase in volatility, as a result of which the Sharpe ratio of the portfolio only very marginally increases with higher levels of leverage. We conclude that the use of higher levels of leverage is not very helpful in improving the performance of long-short factor strategies.

[INSERT TABLE 4 ABOUT HERE]

When we consider the results of our follow-up analyses all together, we conclude that a long-only approach seems to be the preferred alternative in most scenarios after accounting for practical issues such as benchmark restrictions, implementation costs and factor decay.

4. Concluding comments

Two important lessons can be inferred from our comparison of long-only and long-short implementations of factor investing.

First, the added value of a long-short approach to factor investing over a long-only approach is mainly observable in the zero-beta spectrum that is not a feasible alternative for investors who are benchmarked against the market. Once a beta overlay is applied to the long-short approach in order to cope with benchmark restrictions, the added value of long-short over long-only already becomes substantially smaller. At the same time, the long-short approach involves higher risks in the form of leverage, counterparty risk, and lower liquidity. One may wonder whether the outperformance over a long-only approach outweighs these additional concerns.

Second and most importantly, a long-short approach is more sensitive to implementation costs, such as transaction costs, borrowing costs, margin requirements, and factor performance decay. Accounting for these issues we find that the long-only approach tends to be superior to the long-short approach. In some scenarios we even find that the value added of a long-short implementation disappears altogether as a result of costs and decay.

Our results should not be construed to imply that we believe it is impossible for a long-short approach to improve on a long-only approach to factor investing. What our results do show is that the large apparent difference in risk-adjusted performance of a simple long-short approach versus a simple long-only approach comes with a number of important caveats. We conclude that investors should carefully consider all the pros and cons of long-only and long-short approaches on a forward-looking basis when implementing factor investing. Our framework is intended to help investors make that decision.

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Table 1. Long-only versus long-short approaches to factor investing.

	Long-only							Long-short					
	Mkt-RF	Small-RF	Value-RF	Mom-RF	Lowvol-RF	Long-only Beta 0	Long-only Beta 1	SMB	HML	WML	SMV	Long-short Beta 0	Long-short Beta 1
Panel A. Absolute performance characteristics													
Return	4.2	6.2	8.6	9.2	6.2	3.4	7.7	1.6	3.6	6.3	3.3	4.3	9.0
Risk	15.7	20.0	17.6	18.6	13.8	4.8	16.5	6.9	11.2	16.1	12.3	5.9	16.9
Sharpe	0.27	0.31	0.49	0.49	0.45	0.71	0.47	0.24	0.32	0.39	0.27	0.73	0.54
Panel B. Other risk characteristics													
Leverage	100/0	100/0	100/0	100/0	100/0	100/100	100/0	100/100	100/100	100/100	130/70	100/100	200/100
Counterparty risk	No	No	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Liquidity	High	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	Low	Low	Low	Low
Panel C. Benchnark-relative performance characteristics													
Beta	1.00	1.18	0.97	1.09	0.79	0.01	1.01	0.12	-0.21	-0.14	-0.04	-0.07	1.01
Outperf	-	2.0	4.4	5.0	2.0	-0.7	3.6	-2.5	-0.6	2.1	-0.9	0.1	4.8
Tracking error	-	8.1	8.8	7.7	7.0	16.3	4.9	15.3	21.8	23.9	20.4	17.7	5.9
Information ratio	-	0.25	0.50	0.65	0.29	-0.04	0.72	-0.17	-0.03	0.09	-0.04	0.01	0.82
Drawdown	-	-11.2	-5.5	-3.9	-5.5	-52.0	-3.0	-54.3	-56.9	-46.9	-47.4	-49.1	-2.5

Table 2. Long-only versus long-short approaches to factor investing under scenarios with different levels of decay and costs.

	Long-only							Long-short					
	Mkt-RF	Small-RF	Value-RF	Mom-RF	Lowvol-RF	Long-only Beta 0	Long-only Beta 1	SMB	HML	WML	SMV	Long-short Beta 0	Long-short Beta 1
Panel A. Neutral scenario													
Return	3.1	3.6	5.9	6.5	3.6	1.9	5.1	0.1	-0.5	2.2	-0.8	0.8	4.3
Risk	15.7	20.0	17.6	18.6	13.8	4.8	16.5	6.9	11.2	16.1	12.3	5.9	16.9
Sharpe	0.20	0.18	0.34	0.35	0.26	0.39	0.31	0.02	-0.04	0.13	-0.06	0.14	0.25
Panel B. Optimistic decay scenario													
Return	3.7	4.6	7.0	7.6	4.6	2.4	6.1	0.6	0.5	3.2	0.2	1.7	5.8
Risk	15.7	20.0	17.6	18.6	13.8	4.8	16.5	6.9	11.2	16.1	12.3	5.9	16.9
Sharpe	0.23	0.23	0.40	0.41	0.33	0.50	0.37	0.09	0.05	0.20	0.02	0.29	0.34
Panel C. Pessimistic decay scenario													
Return	2.6	2.5	4.9	5.4	2.5	1.4	4.0	-0.4	-1.5	1.1	-1.8	0.0	2.8
Risk	15.7	20.0	17.6	18.6	13.8	4.8	16.5	6.9	11.2	16.1	12.3	5.9	16.9
Sharpe	0.17	0.13	0.28	0.29	0.18	0.29	0.24	-0.05	-0.13	0.07	-0.14	-0.01	0.17
Panel D. Optimistic costs scenario													
Return	3.1	3.8	6.2	6.8	3.8	2.2	5.3	0.4	0.3	2.9	0.0	1.5	4.9
Risk	15.7	20.0	17.6	18.6	13.8	4.8	16.5	6.9	11.2	16.1	12.3	5.9	16.9
Sharpe	0.20	0.19	0.35	0.36	0.28	0.45	0.32	0.06	0.02	0.18	0.00	0.25	0.29
Panel E. Pessimistic costs scenario													
Return	3.1	3.3	5.7	6.2	3.3	1.7	4.8	-0.1	-1.2	1.4	-1.5	0.2	3.6
Risk	15.7	20.0	17.6	18.6	13.8	4.8	16.5	6.9	11.2	16.1	12.3	5.9	16.9
Sharpe	0.20	0.16	0.32	0.33	0.24	0.34	0.29	-0.02	-0.11	0.09	-0.12	0.03	0.22

Table 3. Follow-up empirical analyses I: Higher trading costs for momentum, value-weighted returns, and no shorting costs for long-short.

		Long-only						Long-short					
	Mkt-RF	Small-RF	Value-RF	Mom-RF	Lowvol-RF	Long-only Beta 0	Long-only Beta 1	SMB	HML	WML	SMV	Long-short Beta 0	Long-short Beta 1
Panel A. Neutral scenario													
Return	3.1	3.6	5.9	6.5	3.6	1.9	5.1	0.1	-0.5	2.2	-0.8	0.8	4.3
Risk	15.7	20.0	17.6	18.6	13.8	4.8	16.5	6.9	11.2	16.1	12.3	5.9	16.9
Sharpe	0.20	0.18	0.34	0.35	0.26	0.39	0.31	0.02	-0.04	0.13	-0.06	0.14	0.25
Panel B. Higher trading costs for momentum (Neutral scenario)													
Return	3.1	3.6	5.9	6.0	3.6	1.8	5.0	0.1	-0.5	1.1	-0.8	0.6	4.0
Risk	15.7	20.0	17.6	18.6	13.8	4.8	16.5	6.9	11.2	16.1	12.3	5.9	16.9
Sharpe	0.20	0.18	0.34	0.32	0.26	0.37	0.30	0.02	-0.04	0.07	-0.06	0.10	0.24
Panel C. Including micro-caps (Neutral scenario)													
Return	3.1	5.7	8.7	9.3	4.9	4.1	7.4	2.0	2.3	3.2	-1.1	2.3	5.9
Risk	15.7	22.7	18.4	19.6	12.3	8.1	17.3	14.4	10.6	14.6	11.1	6.0	16.2
Sharpe	0.20	0.25	0.47	0.47	0.40	0.50	0.43	0.14	0.22	0.22	-0.10	0.38	0.36
Panel D. Value-weighted factor returns (Neutral scenario)													
Return	3.1	3.8	3.9	4.9	1.6	0.5	3.7	1.2	-1.9	0.4	-3.0	-0.2	3.1
Risk	15.7	18.8	16.3	17.2	13.4	3.4	15.4	8.6	11.0	16.6	13.5	5.8	17.6
Sharpe	0.20	0.20	0.24	0.28	0.12	0.14	0.24	0.14	-0.17	0.02	-0.22	-0.03	0.18
Panel E. No shorting costs for Long-short (Neutral scenario)													
Return	3.1	3.6	5.9	6.5	3.6	1.9	5.1	0.1	0.5	3.2	0.2	1.6	5.1
Risk	15.7	20.0	17.6	18.6	13.8	4.8	16.5	6.9	11.2	16.1	12.3	5.9	16.9
Sharpe	0.20	0.18	0.34	0.35	0.26	0.39	0.31	0.02	0.05	0.20	0.02	0.27	0.30

Table 4. Follow-up empirical analyses II: different levels of leverage for long-short approaches to factor investing.

		Long-short Beta 1 (Neutral scenario)					
	Long-only Beta 1	A	B	C	D	E	F
Panel A. Absolute performance characteristics							
Return	5.1	4.3	4.5	4.6	4.7	4.9	5.0
Risk	16.5	16.9	17.1	17.4	17.8	18.2	18.8
Sharpe	0.31	0.25	0.26	0.26	0.27	0.27	0.26
Panel B. Other risk characteristics							
Leverage	100/0	200/100	220/120	240/140	260/160	280/180	300/200
Counterparty risk	No	Yes	Yes	Yes	Yes	Yes	Yes
Liquidity	Medium	Low	Low	Low	Low	Low	Low
Panel C. Benchnark-relative performance characteristics							
Beta	1.01	1.01	1.00	0.98	0.97	0.96	0.94
Outperf	1.9	1.2	1.3	1.5	1.6	1.7	1.8
Tracking error	4.9	5.8	6.9	8.1	9.3	10.4	11.6
Information ratio	0.40	0.20	0.19	0.18	0.17	0.16	0.16
Drawdown	-5.02	-6.5	-8.0	-9.6	-11.2	-12.8	-14.4

Figure 1. Sharpe ratios of long-only versus long-short approaches to factor investing under scenarios with different levels of decay and costs.