Amundi Working Paper

WP-063-2017

April 2017

Factor Investing: The Rocky Road from Long-Only to Long-Short

Marie Brière, Head of Investor Research Center – Amundi

Ariane Szafarz, Université Libre de Bruxelles

Factor Investing: The Rocky Road from

Long-Only to Long-Short*

Marie Brière*

Head of Investor Research Center – Amundi

Paris Dauphine University

marie.briere@amundi.com

Ariane Szafarz

Université Libre de Bruxelles (ULB), Belgium

aszafarz@ulb.ac.be

* Corresponding Author: Address: Amundi, 91 bd Pasteur, 75015 Paris, France

The authors are grateful to Sohnke Bartram, Nicolas Fragneau, Emmanuel Jurczenko, Bruce Phelps, Simon Polbennikov, Thierry Roncalli, Bruno Taillardat, Paolo Sodini, and Mihail Velikov for suggestions and discussions.

About the authors

Marie Brière

Marie Brière is head of the Investor Research Center at Amundi. She is also an affiliate professor at Paris Dauphine University and an associate researcher at the Centre Emile Bernheim at Solvay Brussels School of Economics & Management. Dr. Brière began her career as a quantitative researcher at the proprietary trading desk at BNP Paribas. She also served as a fixed-income strategist at Crédit Lyonnais Asset Management and as head of fixed income, foreign exchange, and volatility strategy at Crédit Agricole Asset Management. Her scientific articles have been published in international academic journals including *the Financial Analyst Journal, Journal of Banking and Finance, Journal of International Money and Finance, World Development*, etc. She received the Markowitz award for her article with Zvi Bodie on "*Sovereign Wealth and Risk Management*", published in *the Journal of Investment Management*. She holds a PhD in economics from the University Paris X and graduated from ENSAE.

Ariane Szafarz

Professor Ariane Szafarz is a full professor of mathematics and finance at Solvay Brussels School of Economics and Management (SBS-EM), Université Libre de Bruxelles (ULB). She holds a PhD in Mathematics and an MD in Philosophy. Her research topics include microfinance (mission drift, governance issues), financial econometrics, international finance, epistemology of probability, and job market discrimination. She co-directs the doctoral programme in management sciences organised jointly by SBS-EM (ULB), the Faculté Warocqué (UMONS) and HEC Management School (ULg). She is also President of the Marie-Christine Adam Fund. She has been visiting Professor at Université de Lille II, Université Catholique de Louvain, and the Luxembourg School of Finance. She has published several books and scientific articles in *Econometric Theory, European Economic Review, Journal of Fixed Income, Journal of Empirical Finance,* etc.

Abstract

This paper examines how restrictions on short positions affect the financial attractiveness of factor investing. To fill the gap between unconstrained long-short allocations and restricted long-only portfolios, we consider two in-between strategies. The first imposes that only the market can be shorted; the second is the so-called "130/30" or "active extension" trading strategy, which caps total short exposure at 30%. The takeaways from our research are twofold. First, short sales contribute significantly to the mean-variance performance of efficient factor-based portfolios. Second, the factor portfolios built originally by Fama and French (1992) with the purpose of developing asset pricing are impressively clear-sighted when it comes to portfolio management. Indeed, combining these portfolios generates mean-variance performances similar to those of optimized long-short portfolios, except for low levels of volatility.

Keywords: Investment, asset allocation, factor investing, long-only, long-short, 130-30.
JEL classification: G11, G01, C58, D92

I. Introduction

Factor investing has emerged from the asset management world as the new paradigm for long-term investment (Cazalet and Roncalli, 2014; Jurczenko et al., 2015). It attracted fresh interest after the publication of a report on active portfolio management, produced by Ang et al. (2009) at the request of the Norwegian sovereign wealth fund. The first risk factor to be identified is the market factor, which delivers the so-called market premium. According to the capital asset pricing model (CAPM), the market premium is the only risk premium available to investors. However, a host of empirical work has uncovered additional factors that entail significant risk premia. The best-known of these relate to growth and value (Fama and French, 1992) and momentum (Carhart, 1997). Factor investing exhibits a remarkable propensity to beat the market in terms of enhancing expected returns for a given level of volatility. According to Israel and Moskowitz (2013), and Asness et al. (2014), both the long and short legs of factors contribute to overall financial performance.[1] Brière and Szafarz (2016) compare optimal portfolios made up of either the ten sector indexes in the Standard Industrial Classification (SIC) system, or the five long legs plus the five short legs of the factors proposed by Fama and French (2015). The results of that comparison suggest that the dominance of factor investing over sector investing relies on the possibility to make short sales. However, a sizeable literature on portfolio management suggests that shorting regularly to rebalance portfolios is difficult. The aim of this paper is to assess the actual dependence of the mean-variance performances of factor investing on short-selling restrictions.

[1] However, Blitz et al. (2014) show that, when transaction costs and strategy capacity are factored in, long-only factors are preferable to long-short ones.

Proponents of long-short investment strategies (e.g., Miller, 2001) stress that bans on short-selling deprive investors of transaction opportunities in overvalued stocks. We therefore refrain from using a strictly binary framework: a shorting ban versus unlimited shorting. Instead, we emphasize intermediate scenarios, which are in line with the practice of U.S. and foreign mutual funds. We consider two types of intermediate situation: the 130/30, or active extension trading strategy, and the situation where only the market can be shorted. By definition, an asset allocation strategy obeys the 130/30 rule if the total short position at any point in time is below 30% of the portfolio value, which automatically puts a 130% ceiling on the long position. While the 130/30 rule is routinely applied in fund and index management,[2] it is not commonly associated with factor investing.[3] By contrast, portfolios where only the market can be shorted are easy to implement by combining long-only portfolios with index derivatives or exchange traded funds (ETFs). This paper will investigate both the 130/30 rule and the combination of long-only factor and long-short market investing as two strategies that are midway between the two polar cases: long-only for all assets and unrestricted long-short.

In terms of portfolio composition, the long-short factors proposed originally by Fama and French for asset pricing, such as the "small-minus-big" (SMB) size factor, can be viewed as obeying an implicit 200/100 rule that combines the market (100%) with a 100% exposure in the long leg ("small") and a 100% short position in the short leg ("big").[4] While total exclusion of short sales is too restrictive for some investors, unlimited short-selling is mostly unrealistic. In particular, claiming that a 100% short position in factors is easily feasible is an overstatement, because

---

[2] MSCI produces 130/30 factor indices. (https://www.msci.com/eqb/methodology/meth_docs/MSCI_Factor_Index_Methodology_May12.pdf), and fund providers supply 130/30 strategies (https://personal.vanguard.com/pdf/icrloc.pdf).

[3] The paper by Lo and Patel (2008) is the exception.

[4] The relative share of short legs in optimal factor-based portfolios often surpasses the 100% threshold (see Section 3).

factors are not directly accessible to investors (Idzorek and Kowara, 2013), and factor-based ETFs typically offer exposure to long legs only. Therefore, we argue that judging the effectiveness of factor investing should take into account market characteristics such as the existence of legal restrictions and specific costs, which can significantly affect performance.

The empirical results suggest that: 1) any departure from the long-short strategy harms the mean-variance performances of factor-based portfolios, and 2) the performances of the factor portfolios that Fama and French (1992) built for asset pricing purposes are remarkably similar to those of optimized long-short portfolios, except for low levels of volatility.

2. Short-Selling and Factor Investing

Scholars who develop portfolio management theory and conduct empirical studies typically consider either the unconstrained situation where short-selling is unrestricted or the fully constrained situation where short sales are banned. The reasons for excluding short-selling pertain both to legal barriers and to cost issues. First, some countries forbid short sales, which can be executed only off-exchange or offshore. In a comprehensive international comparison of short-selling restrictions, Bris et al. (2007) show that 35 countries (out of 47) permit the practice, but their tolerance is often coupled with temporary restrictions during specific periods, such as the 2007-2008 subprime crisis (Bernal et al., 2014). In the U.S., Regulation T governs funds' cash accounts and the amount of credit that securities brokers and dealers may extend to their clients for the purchase of securities. It limits gross exposure (the total long position plus absolute value of total short position) to no more than twice the investment capital, and so caps short sales at 50% of the portfolio. In addition, many market participants do not take full advantage of legal tolerance for shorting, mostly because these sales typically require the borrowing of securities. For instance, U.S. mutual funds are forbidden to borrow money "unless authorized by the vote of a majority of its outstanding Voting Securities" (U.S. Investment Company Act, Section 13(a)). Short positions are more easily obtained through derivative contracts, such as total return swaps or contracts for difference. Europe's UCITS mutual funds are prohibited from taking physical short positions, and their borrowing is limited to 10% of net assets, and for temporary purposes only. However, leverage can be generated through the use of derivatives and repos.[5] In addition to regulatory constraints, restrictions can originate from funds' investment policies. Almazan et al. (2004) find that 30% of a large sample of U.S. equity mutual funds have the option to sell short, but only 3% actually do so.

Second, covered and uncovered short sales entail specific costs and risks. Covered (or traditional) short-selling involves borrowing the security and returning it to the lender at a given future date. The securities lending market is decentralized, so finding a lender can involve a costly search. Short-selling also exposes the trader to the risk of liquidity shortage and short squeezing (Jones and Lamont, 2002). By contrast, uncovered short-selling is carried out without borrowing. Under U.S. rules, the seller has three days to deliver the security to the buyer. Past this deadline, the sale can be considered as "manipulative," putting the trader at risk of legal action.

In sum, short-selling is both limited by law and costlier than regular stock purchases and sales. However, the typical factor-investing strategies rely heavily on short sales, and the bulk of the

[5] Under current UCITS regulation, funds' global leverage exposure can be measured in two different ways and the leverage constraints depend on the chosen methodology. In the commitment approach, which is appropriate for funds that do not use complex derivatives, the absolute values of the underlying exposures of the derivatives are aggregated to measure the fund's total leverage, which is restricted to 100% of the net asset value. A UCITS fund may alternatively choose to measure leverage based on a Value at Risk (VaR) approach. The absolute VaR limit depends on the risk profile of a fund, but the absolute maximum is 20% over a 20-day horizon for a confidence interval of 99%.

empirical literature on risk factors disregards the additional constraints associated with shorting. Factor indices rebalance individual stocks according to characteristics that change constantly. In fact, the extent of the changes varies with the type of factor. Factors such as value, size, profitability and investment are defined by means of stock characteristics with little variability, while momentum stocks change frequently. The rebalancing frequency adopted by Fama and French is yearly for the first group of factors (end-June) but monthly for the momentum portfolios. Considering a one-sided turnover resulting from averaging the values of purchased or sold assets, Novy-Marx and Velikov (2016) estimate that the turnover of the size and value long-short portfolios is around 2% per year and the associated transaction costs[6] are close to 5 bps per month, regardless of the size of the portfolio. For the momentum factor, the authors find a turnover of 25% per year and transaction costs of 50 bps per month. Asness et al. (2015) and Harvey and Liu (2015) argue that the return of the high-minus-low (HML) factor might be overstated because the strategy involves shorting very small stocks. Although the transaction costs of both the conservative-minus-aggressive (CMA) investment factor and the robust-minus-weak (RMW) profitability factor are still unexplored, we conjecture that their turnover is close to that of their size and value counterparts, which are also rebalanced on a yearly basis.[7] In addition, sophisticated transaction-cost models consider the break-even capacity of each investment strategy in terms of portfolio size. By definition, break-even capacity is reached when the transaction costs are equal to the gross returns of the strategy. Using data on real-life trades, Frazzini et al. (2014) estimate that the break-even capacities of the Fama and French long-short size, value, and momentum factors are USD 103 billion, USD 83 billion, and USD 52 billion,

[6] The authors estimate round-trip transaction costs related to bid-ask spreads, but do not account for the price impact of large trades (costs related to the change in price due to the trade).
[7] At the portfolio level, transaction costs raise additional difficulties as purchases and sales of stocks can net out. See also Israel and Moskowitz (2013) and Ang et al. (2017).

respectively. These figures far exceed those computed by Lesmond et al. (2004), and Korajczyk and Sadka (2004), who all rely on simple microstructure models. Still, accounting for the real costs of short-selling is well beyond the scope of this paper. Here, we acknowledge the relevance of the problem by considering investment strategies that rely relatively little on short-selling.

Despite cost issues, the performative contributions of short positions to portfolio diversification are often mentioned. According to Jacobs and Levy (1993b) and Miller (2001), replacing an optimal long-short portfolio by its long-only proxy[8] can entail a significant loss of efficiency.[9] For instance, the biases in financial analysts' recommendations, materialized by the imbalance between Buy and Sell, might represent a source of profit to those who can afford to take short positions. Excluding *ex ante* any short position can thus prove detrimental to investors. To relax the constraint, middle-of-the-road options, such as the 130/30 investment rules, are proposed in the literature. Lo and Patel (2008, p. 12) attribute the impressive growth of the 130/30 class of strategies to "both (…) the historical success of long-short equity hedge funds and the increasing frustration of portfolio managers at the apparent impact of long-only constraints on performance." An alternative, cost-conscious option consists in restricting short-selling to assets that are liquid enough so that the position is easy to reverse if needed, thus limiting the consequences of a short squeeze. This is why we also consider an investment option where factors are long-only but the market can still be shorted.

Our portfolios of interest are made up of the market index and the five historical factors for which data are available on French's website: size (SMB), value (HML), profitability (RMW),

[8] In a long-only investment universe, the second-best strategy is to underweight the assets otherwise shorted (Michaud, 1993)

[9] This statement concerns portfolios composed of any type of assets. Yet for factor-based portfolios, Israel and Moskowitz (2013) show that, the loss of efficiency can be less severe than expected since the long legs of factor styles typically generate over 50% of total performance. Blitz et al. (2014) underline that, on a net basis, long-short strategies do not necessarily dominate long-only ones.

investment (CMA), and momentum (MOM). By nature, these factors require short positions since each of them combines opposite positions on the two legs of the long-short position (e.g., "small" for the long leg, and "big" for the short leg). Thus, when it comes to investing in these factors, heavy dependence on short sales seems unavoidable. Investors may see this as a burden since factor investing is regarded as a long-term asset management strategy,[10] and constant rebalancing is especially costly when short-selling is involved. With this in mind, those same investors might wonder how costly it would be (in terms of investment performance) to adapt the factor analysis to situations where short-selling is fully or partly restricted. Our paper addresses this concern.

To relax the necessity of short-selling in factor investing, we proceed in two steps. First, we disentangle the long and short legs of the five historical factors. The ten resulting long-only factors provide additional flexibility in portfolio management. Second, short-selling restrictions, if any, are imposed separately on each of these ten factors. Last, we consider separately any short-selling restrictions on the market index to show that shorting the market is much easier to do (through derivative markets, for instance) than shorting any other factor. This exploratory strategy allows us to highlight the trade-off between limiting short sales and enlarging the set possible combinations of assets. We use as a benchmark the efficient frontier composed of portfolios that combine the market index with optimized proportions of the five historical long-short factors taken from Fama and French (2015), which we call the FF frontier,[11] and assess alternative investment rules, including the 130/30 option, with respect to this benchmark. Our derivations follow the line of logic proposed by Clark et al. (2004) and Sorensen et al. (2007),

[10] Ang (2014) argues that factor investing is especially relevant in a long-term perspective because it takes into account the occurrence of bad times.

[11] Accordingly, we qualify as "FF" any portfolio on this frontier.

who examine the consequences of imposing various realistic restrictions to portfolios, including short-selling limitations. The next section explains in more details how we proceed.

3. Data and Methods

3.1 Data

We use the five long-short risk factors proposed by Fama and French (1992, 2015) and Carhart (1997): size, value, profitability, investment, and momentum. From the monthly data retrieved from Ken French's website,[12] covering the period stretching from July 1963 to December 2015, we constructed the long and short legs of each factor separately (see Brière and Szafarz, 2016, for technical details). Working with classic factors (size, value, and momentum) is an advantage, since the literature is consensual about their relevance (Asness et al., 2013). The two additional factors—profitability and investment—are more controversial (Harvey et al., 2016), but they allow us to take into account stock characteristics otherwise missed (Novy-Marx, 2013; Hou et al., 2015).

The database is composed of historic series of returns for the ten long-only factors: (1) small, (2) big, (3) value, (4) growth, (5) robust profitability, (6) weak profitability, (7) conservative investment, (8) aggressive investment, (9) high momentum, (10) low momentum. In an optimized portfolio composition, we will let each leg have its specific exposure. Evidently, this optimization goes beyond Fama and French's original approach, which imposes opposite exposures on the two legs of the long-short position (e.g., small minus big). Still, we consider the five historical factors

[12] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html. The investment universe considered by Fama and French is made up of stocks with a CRSP share code and positive book equity data. Moreover, the data for year t are restricted to stocks for which market prices are available in June of year t and in December of year t-1.

as a benchmark in our analysis. Overall, we are dealing with 11 elementary styles (or factors): five short legs, five long legs, and the market. In unrestricted portfolios, each of these styles can be held long or short. By contrast, several types of short-selling limitations will be placed on restricted portfolios. The next section clarifies these limitations.

Tables 1 and 2 provide descriptive statistics and historical correlations, respectively. The factor annualized returns reported in Table 1 range from 7.95% (low momentum) to 16.43% high momentum). Volatilities lie between 15.00% (big) and 21.63% (low momentum). Skewness is negative for all factors, except low momentum. Kurtosis ranges from 4.71 (growth) to 6.44 (Value). Sharpe ratios are between 0.37 (low momentum) and 0.89 (high momentum). Table 2 presents pairwise factor correlations as well as correlations between factors and the market. Correlations between factors are homogeneously high, ranging from 0.74 (between low and high momentum) and 0.99 (between growth and aggressive investment). Unsurprisingly, the highest correlation with the market (0.99) is found for the "big" factor, composed of the large capitalizations, which drive the market index. The lowest correlation (0.87) corresponds to the low momentum factor, which picks underperforming stocks.

Table 1: Descriptive Statistics, July 1963 – December 2015

	Market	Small	Big	Value	Growth	Robust profitab	Weak profitab	Conservative invest	Aggressive invest	High mom	Low mom
Mean (%)	0.90	1.18	0.92	1.22	0.89	1.14	0.89	1.19	0.89	1.37	0.66
Ann. Mean (%)	10.78	14.17	11.08	14.63	10.72	13.63	10.66	14.29	10.67	16.43	7.95
Median (%)	1.23	1.59	1.26	2.00	1.00	1.41	1.30	1.47	1.23	1.85	0.55
Maximum (%)	16.61	27.12	16.66	26.00	18.00	20.26	21.21	20.21	21.08	17.49	40.13
Minimum (%)	-22.64	-29.55	-21.41	-24.00	-28.00	-25.80	-27.49	-25.54	-27.82	-27.87	-24.77
Std. Dev. (%)	4.43	5.81	4.33	4.90	5.48	4.91	5.53	4.93	5.62	5.32	6.24
Volatility (%)	15.35	20.12	15.00	16.97	18.97	17.00	19.17	17.07	19.48	18.42	21.63
Skewness	-0.50	-0.45	-0.42	-0.46	-0.46	-0.55	-0.48	-0.52	-0.50	-0.62	0.39
Kurtosis	4.94	5.46	4.89	6.44	4.71	5.36	4.91	5.23	4.75	5.28	7.08
Sharpe Ratio	0.70	0.70	0.74	0.86	0.57	0.80	0.56	0.84	0.55	0.89	0.37

Table 2: Correlations, Factors and the Market, July 1963 – December 2015

	Small	Big	Value	Growth	Robust profitab	Weak profitab	Conservative invest	Aggressive invest	High mom	Low mom
Market	0.89	0.99	0.89	0.95	0.96	0.93	0.94	0.96	0.92	0.87
Small		0.86	0.93	0.95	0.95	0.96	0.96	0.95	0.93	0.88
Big			0.90	0.92	0.95	0.91	0.92	0.93	0.89	0.86
Value				0.85	0.92	0.91	0.95	0.88	0.86	0.87
Growth					0.96	0.96	0.93	0.99	0.94	0.86
Robust profitab						0.92	0.95	0.97	0.94	0.88
Weak profitab							0.97	0.96	0.93	0.89
Conservative invest								0.94	0.92	0.88
Aggressive invest									0.94	0.88
High mom										0.74

3.2 Methods

In our universe of 11 elementary styles, each portfolio is defined by its vector of shares invested in each style *i*: $W = (w_i),\ i = 0, \dots, 10,$ with:

$$\sum_{i=0}^{11} w_i = 1. \tag{1}$$

For simplicity, we number the styles as follows: the market is style 0, the long legs have odd indices (1 = small, 3 = value, 5 = conservative investment, 7 = robust profitability, 9 = high momentum), and the (positive exposures to) short legs have even indices: (2 = big, 4 = growth, 6 = aggressive investment, 8 = weak profitability, 10 = low momentum). In addition, we add up the long and short exposures to compute the global short position (GSP) of portfolio *W*:

$$GSP(W) = \sum_{i\in\{0,1,\dots,10\}:x_i<0} |w_i| \tag{2}$$

Hence, mimicking the typical structure of the FF long-short factors (SMB, HML, CMA, RMW, and MOM) is easily done by imposing the constraint $w_i = -w_{i+1}$, for the odd values of index *i*.

Adding to that condition the restriction of a unitary exposure to the market, we obtain the constraints fulfilled by any FF portfolio:

$$w_0 = 1 \text{ and } \forall i \in \{1,3,5,7,9\}: w_i = -w_{i+1}. \quad (3)$$

Under the constraints in Eq. (3), Eq. (1) implies that $\sum_{i=1}^{11} w_i = 0$, which leaves $GSP(W)$ unrestricted. The only FF portfolio excluding short sales is the market (with $w_i = -w_{i+1} = 0,\ i > 0$). As soon as an FF portfolio has factors in its composition, it is leveraged and $GSP(X) > 0$. The total share of short positions is then: $GSP(W) = \sum_{i\in\{1,3,5,7,9\}} |w_i| = \sum_{i\in\{2,4,6,8,10\}} |w_i|$, but there is nothing to prevent a short position in a long leg or a long position in a short leg (if so, both cases occur together necessarily). The higher $GSP(W)$, the farther the FF portfolio from the market composition.

Using as a benchmark the efficient frontier built from the FF portfolios described in Eq. (3), we examine the consequences on mean-variance performances of imposing five sets of short-selling-based restrictions in the w_i's. Table 1 presents the four groups of portfolios of interest according to both market exposure and the maximal admissible short-selling level. Portfolios in Group 1 (global long-only) exclude any short position whatsoever. Group 2 (long-short market + long-only factors) puts no restriction on market exposure but excludes short positions in factors. The rationale is that easy access to index trading makes shorting the market easier and less costly than shorting factors, which are hardly tradable. Group 3 includes the typical 130/30 portfolios defined by the combination of a 130% long position and a 30% short one. Finally, in Group 4, no position is constrained.

Table 3: Portfolios of Interest

Portfolios / Characteristics	**FF benchmark portfolios**	**1. Global long-only**	**2. Long-short market + long-only factors**	**3. 130/30**	**4. Global long-short**
Exposure to market	$\boldsymbol{w_0 = 1}$	$w_0 > 0$	unconstrained	$GSP(W) \leq 0.3$	unconstrained
Exposures to styles	$\boldsymbol{w_i = -w_{i+1}}$, **for $\boldsymbol{i\ odd}$**	$w_i > 0,$ for $i > 0$	$w_i > 0,$ for $i > 0$		unconstrained

In each group of portfolios described in Table 3, we perform mean-variance optimization and subsequently draw the corresponding efficient frontier, i.e. the curve representing the optimized portfolios in the mean-variance plane. To assess the performance of these efficient frontiers, we define three benchmark portfolios on the FF frontier (see Eq. (3)) by means of their volatilities. First, the FF minimum-variance portfolio (*FFminvol*) has a volatility of 13.37%. Second, the FF market-volatility portfolio (*FFmktvol*) has a volatility of 15.35%. Last, we consider an FF portfolio with high volatility (*FFhighvol*). This portfolio is defined as the one that makes the volatility of the market equidistant from those of *FFminvol* and *FFhighvol*. The benchmark high volatility is thus equal to: 15.35% + (15.35% - 13.37%) = 17.33%. Table 4 gives the composition of the three benchmark portfolios. As expected, the magnitude of the short exposure increases with the level of volatility.

Table 4: The Benchmark Portfolios

	FFminvol	*FFmktvol*	*FFhighvol*
Ann. Return (%)	15.06	22.91	26.54
Volatility (%)	13.37	15.35	17.33
	Composition		
Market	1	1	1
Small	-0.25	0.16	0.35
Big	0.25	-0.16	-0.35
Value	0.04	0.13	0.18
Growth	-0.04	-0.13	-0.18
Robust profitab	0.34	0.93	1.21
Weak profitab	-0.34	-0.93	-1.21
Conservative invest	0.8	1.37	1.64
Aggressive invest	-0.8	-1.37	-1.64
High mom	0.12	0.39	0.52
Low mom	-0.12	-0.39	-0.52
Total share of long positions	2.54	3.99	4.90
Total share of short positions	-1.54	-2.99	-3.90

In line with the logic underlying the FF factors, optimization puts positive weights on long legs and negative ones on short legs in all cases but one: in the *FFminvol* portfolio, the long leg of the size factor has a negative coefficient (-0.25), which automatically imposes the symmetrical long position in the short leg. The total share of long positions in the portfolio, $\sum_{i\in\{1,3,5,7,9\}} w_i$, increases with portfolio volatility, as do the individual shares of each long leg. By contrast, the coefficient of the market is set at 100%, meaning that the role of the market decreases when the FF portfolio becomes more volatile. The increase is particularly impressive for the coefficient of the profitability factor, which goes from 0.34 for *FFminvol* to 0.94 for *FFmktvol*, and to 1.51 for *FFhighvol*. Likewise, the loading on conservative investment is almost double that on the market (193% versus 100%). Profitability and investment are the two most recent factors (Fama and French, 2015), suggesting that the risk premia associated with factors, sometimes referred to as anomalies, tend to erode after their discovery (McLean and Pontiff, 2016). While Table 1 indicates that the market annualized return over the period is 10.78%, the same-volatility FF portfolio, *FFmktvol*, reaches more than twice that figure (22.9%). Overall, the mean-variance performances of the three benchmark portfolios are remarkable, meaning that we set the bar fairly high.

We assess the financial performances of the efficient frontiers corresponding to the four groups of portfolios in Table 3 by comparing these frontiers to the benchmark FF portfolios by means of geometric tests. In fact, the common procedure here would have consisted in using spanning tests, but these are applicable to unconstrained portfolios only (Wang, 1998). By contrast, the geometric tests work well when constraints on the coefficients are imposed. More precisely, our assessment tools are based on distance computations in the mean-variance plan. The Basak et al. (2002) test, resp. the Brière et al. (2013) test, exploits the horizontal, resp. vertical, distance between a given portfolio and an efficient frontier.[13] In both cases, if the returns on the assets are jointly normal, under the null that distance is zero, the test statistics has an asymptotic normal distribution. The two tests complement one other usefully, as it may happen (and will happen in our analysis) that neither test is applicable because of the shape of the efficient frontier of interest. Intuitively, the null that the horizontal, resp. vertical, distance is zero means that the portfolios optimized within the given asset group match the volatility, resp. expected return, performances of the benchmark portfolio. By contrast, a significantly positive outperformance indicates that the group of portfolios in question performs better than the benchmark, while a negative score signals an underperformance. Better performance means higher returns for the horizontal distance, and lower volatility for the vertical one.

[13] More complex distances combining the two dimensions exist in the literature (Briec et al., 2004), but corresponding tests have not been developed yet.

Practically, we will apply both tests to each pair made up of one benchmark portfolio and the efficient frontier corresponding to one of the four cases described in Table 3. So, we will end up with (at most) six test results (two distances applied with respect to three benchmark portfolios) for every asset allocation scenario, the numerical results being supported by the graphical visualization of efficient frontiers. The overall objective of the exercise is twofold. First, we seek a global picture of the impact on portfolio performance of short-selling constraints with variable degrees of severity. Second, a more detailed analysis will investigate whether the performance losses resulting from restrictions on short-selling are mediated by portfolio volatility, a parameter driven chiefly by the investor's risk aversion. If so, the practical consequences of short-selling limitations would not affect all investors equally. Intuitively, one expects that a lower level of risk aversion makes an investor keener to go short and hence more sensitive to short-selling restrictions. The empirical results in the next section will check the relevance of this intuition.

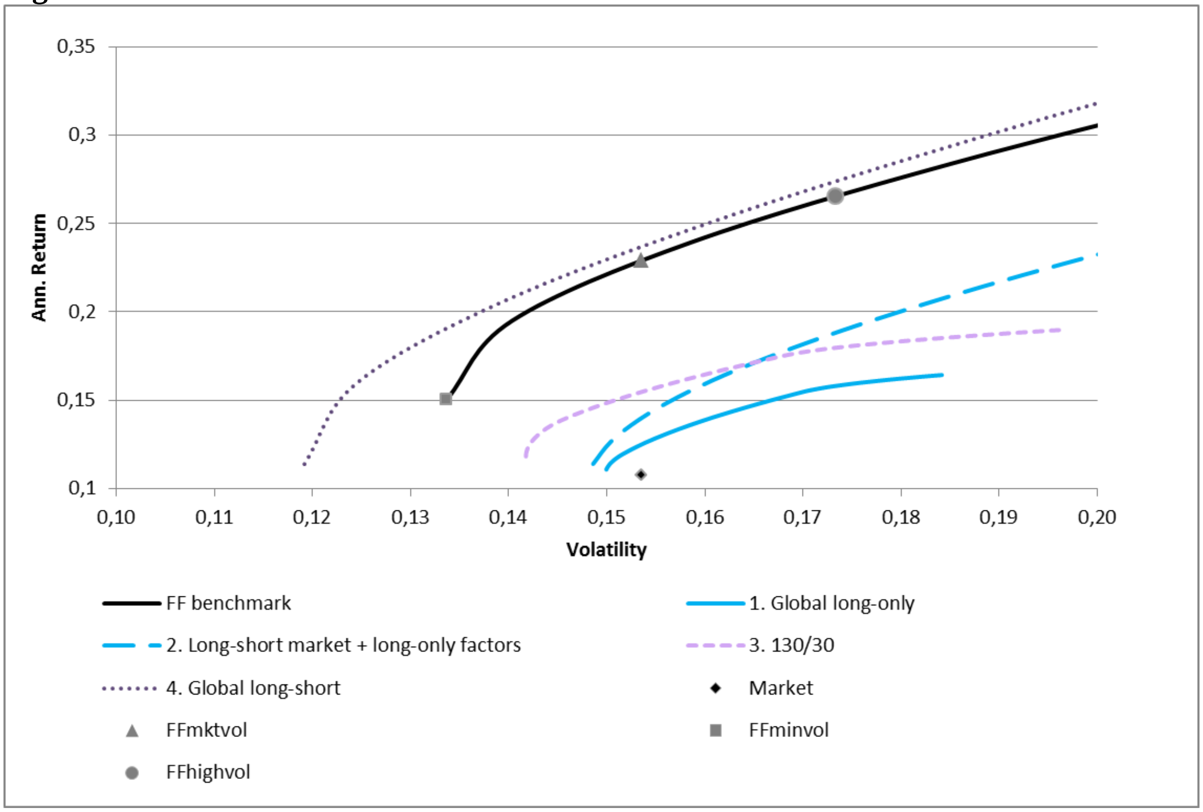
4. Empirical Results

4.1 Efficient Frontiers

Consistent with Table 3, we start by representing the five efficient frontiers of interest, namely the benchmark FF frontier as well as the frontier associated with the four groups of portfolios to be tested. From definitions, we expect that the frontier corresponding to the global long-short case (Group 4) dominates all the others, including the benchmark, since it allows fully unconstrained optimization. Likewise, the global long-only case (Group 1) is evidently more restrictive than both the cases of the long-short market + long-only factors (Group 2) and the 130/30 (Group 3). This implies that the frontier associated with Group 1 must be dominated by the other two. There is no clear dominance to be expected between the frontiers corresponding to Groups 2 and 3, since on the one hand the exposure to the market is unconstrained in Group 2 but constrained by the 130/30 restriction in Group 3, and the other factors can be shorted (to a certain extent) in Group 3 but not at all in Group 2. Hence, comparing the frontiers obtained for Groups 2 and 3 can bring insights into the trade-off arising from shorting the market only versus shorting single-legged factors. Given the specific constraints used to define the benchmark FF portfolios (see Eq. (3)), we have no priors on how the FF efficient frontier is located with respect to the efficient frontiers for Groups 1 to 3.

Figure 1 shows our five efficient frontiers. It reveals that the expected dominances are observed graphically. It also shows that the frontiers associated with Groups 2 and 3 do eventually intersect, and the intersection point has a relatively high volatility level of between 16% and 17%. One possible interpretation is that shorting the market is useful for decreasing the overall volatility of the portfolio, while shorting factors allows investors with low risk aversion to benefit from leverage effects that drive both higher volatility and higher expected returns.

Figure 1: Efficient Frontiers



Remarkably, the benchmark FF frontier seems to largely dominate the efficient frontiers derived for cases 1, 2, and 3, while there is no theoretical argument supporting these facts. Another, and perhaps more disturbing piece of evidence as far as theory is concerned relates to the position of the market portfolio on Figure 1. It is located below all our frontiers of interest, even the most restricted one (corresponding to Group 1), which bans any short sale. This could be viewed as contradicting the CAPM, which predicts that the market portfolio is efficient. Admittedly, from a statistical standpoint, the distance between the point representing the market portfolio and the Group 1 frontier can be (and probably is) insignificant. The formal tests in the next subsection will show that the results go in the opposite direction when the benchmark frontier is considered.

4.2 *Horizontal and Vertical Tests*

Tables 4 to 7 show the test results for the four groups of portfolios described in Table 1 and for which Figure 1 gives the efficient frontiers. In each table, a given group is tested by means of the Basak et al. (2002) horizontal test and the Brière et al. (2013) vertical test, both of which exploit distances in the mean-variance plan. Each test is run for three FF benchmark portfolios, namely *FFmktvol* that has market volatility, and the two portfolios symmetrically located on its left, *FFminvol*, and on its right, *FFhighvol*. Empty columns show that the tests are sometimes unfeasible because efficient frontiers may lack a portfolio with same expected return (for the horizontal test) or same volatility (for the vertical test) as a given benchmark portfolio. This problem shows up more frequently for frontiers that are relatively farther away from the FF benchmark frontier.

Table 4: Test Results for Group 1: Global Long-Only

Efficient frontier for Group 1	Excess return (horizontal test)			Excess variance (vertical test)		
Benchmark portfolio	*FFminvol*	*FFmktvol*	*FFhighvol*	*FFminvol*	*FFmktvol*	*FFhighvol*
Outperformance (expected return/variance)	-0.0008***	-	-	-	-0.0086***	-0.0089***
Composition of the efficient portfolio with same variance/expected return as the benchmark						
Small	0.00	-	-	-	0.00	0.00
Big	0.09	-	-	-	0.64	0.00
Value	0.52	-	-	-	0.29	0.37
Growth	0.00	-	-	-	0.00	0.00
Robust profitab	0.00	-	-	-	0.00	0.00
Weak profitab	0.00	-	-	-	0.00	0.00
Conservative invest	0.00	-	-	-	0.00	0.00
Aggressive invest	0.00	-	-	-	0.00	0.00
High mom	0.39	-	-	-	0.06	0.63
Low mom	0.00	-	-	-	0.00	0.00
Market	0.00	-	-	-	0.00	0.00
Total share of long positions	1.00	-	-	-	1.00	1.00
Total share of short positions	0.00	-	-	-	0.00	0.00

Preliminary examination of Tables 4 to 6 reveals that all the tests run for Groups 1, 2, and 3 exhibit underperformances (negative outperformances) that are significant at the 1% level, suggesting that the portfolios in the three groups fail to reach the performances of the FF benchmarks, in terms of expected returns as well as volatility. In consequence, the flexibility gained by disconnecting the weights of the long and short factor legs does very little to offset the performance advantages associated with the high levels of short positions in the FF portfolios. Even partially relaxing the short-selling restrictions in two different ways (on the market index only in Group 2, and by allowing 30% or less of short sales in Group 3) is largely insufficient to challenge effectively the performances of FF benchmark portfolios.

Table 5: Test Results for Group 2: Long-Short Market + Long-Only Factors

Efficient frontier for Group 2	Excess return (horizontal test)			Excess variance (vertical test)		
Benchmark portfolio	*FFminvol*	*FFmktvol*	*FFhighvol*	*FFminvol*	*FFmktvol*	*FFhighvol*
Outperformance (expected return/variance)	-0.0005***	-0.0012***	-0.0016***	-	-0.0074***	-0.0064***
Composition of the efficient portfolio with same variance/expected return as the benchmark						
Small	0.00	0.00	0.00	-	0.00	0.00
Big	3.59	6.57	7.92	-	3.15	5.04
Value	0.02	0.00	0.00	-	0.04	0.00
Growth	0.00	0.00	0.00	-	0.00	0.00
Robust profitab	0.00	0.32	0.52	-	0.00	0.08
Weak profitab	0.00	0.00	0.00	-	0.00	0.00
Conservative invest	0.04	0.21	0.26	-	0.00	0.15
Aggressive invest	0.00	0.00	0.00	-	0.00	0.00
High mom	0.52	1.51	1.95	-	0.37	1.02
Low mom	0.00	0.00	0.00	-	0.00	0.00
Market	-3.18	-7.61	-9.65	-	-2.57	-5.30
Total share of long positions	4.18	8.61	10.65	-	3.57	6.30
Total share of short positions	-3.18	-7.61	-9.65	-	-2.57	-5.30

The compositions of the efficient portfolios used in the comparisons with benchmark portfolios are visible in the lower part of each table (Tables 4 to 7). In Table 4, where short positions are forbidden, the reported compositions exclude, surprisingly, the “small” leg of the traditional size factor, as well as both legs of the newer factors, “profitability” and “investment”. These compositions are dominated by the “value” and “high momentum” factors, with a special role for “big” in the portfolio with the same expected return as the *FFmktvol*, probably because the market and the “big” leg of SMB are strongly correlated. The market itself is absent from the compositions. By contrast, Table 5 reports impressive short positions in the market index (between 257% and 965%). Since this index is the only style that can be shorted in the Group 2 configuration, these compositions, which are heavily loaded in short sales, indirectly illustrate just how binding the short-selling restrictions are. This is especially relevant given that the compositions reported in Table 6 for 130/30 portfolios allocate zero coefficients to the market. One interpretation could be that the 30% authorized share of short-selling is too precious to be dedicated to the market. Instead, it is fully attributed to “low momentum”, while positive coefficients are found for “big”, “value”, and “high momentum.”

In fact, short positions close to those originally imposed in the FF strategy are well designed to capture the risk premia associated with factors. Put differently, the way Fama and French built their factors for making their case in asset pricing holds up exceptionally well in the transition to portfolio management. This is an impressive accomplishment coming from a literature that, for decades, was devoted exclusively to asset pricing.

Table 6: Test Results for Group 3: 130/30

Efficient frontier for Group 3	Excess return (horizontal test)			Excess variance (vertical test)		
Benchmark portfolio	*FFminvol*	*FFmktvol*	*FFhighvol*	*FFminvol*	*FFmktvol*	*FFhighvol*
Outperformance (expected return /variance)	-0.0004***	-	-	-	-0.0062***	-0.0071***
Composition of the efficient portfolio with same variance/expected return as the benchmark						
Small	0.00	-	-	-	0.00	0.00
Big	0.53	-	-	-	0.44	0.00
Value	0.63	-	-	-	0.67	0.59
Growth	0.00	-	-	-	0.00	0.00
Robust profitab	0.00	-	-	-	0.00	0.00
Weak profitab	0.00	-	-	-	0.00	0.00
Conservative invest	0.00	-	-	-	0.00	0.00
Aggressive invest	0.00	-	-	-	0.00	0.00
High mom	0.14	-	-	-	0.19	0.71
Low mom	-0.30	-	-	-	-0.30	-0.30
Market	0.00	-	-	-	0.00	0.00
Total share of long positions	1.30	-	-	-	1.30	1.30
Total share of short positions	-0.30	-	-	-	-0.30	-0.30

Table 7 contrasts with the others since it reports positive outperformance. This is in line with the fact that it reports on the performances of efficient long-short portfolios compared to those of the FF benchmarks. As Figure 1 shows, the two frontiers are close to one other, especially with volatility above a threshold that sits visually around 14%. Table 7 provides formal confirmation of this intuition. It highlights that the global long-short frontier outperforms the FF minimal volatility portfolio, *FFminvol,* both in expected return and in volatility. More generally, highly risk-averse investors prefer freely optimized long-only portfolios over factor-based portfolios built according to the standard FF rule summarized in Eq. (3). Remarkably, however, those who tolerate medium to low levels of risk can safely avoid the inconvenience of tailoring their own portfolios and opt for the efficient FF portfolio that matches their desired level of volatility. Interestingly, Table 7 reveals that the total shares of short positions are high (in absolute value) along the efficient frontier, as expected, but eventually the variations prove to be modest. For instance, the benchmark *FFminvol* portfolio reaches a volatility of 13.37% with a short position of 154% (see Table 3), its same-variance counterpart on the group 7 efficient frontier has a total share of short positions equal to 483%, more than three times the benchmark value. Table 7 proves that the impressive amount of shorting is profitable in terms of excess returns. However, for riskier portfolios, discrepancies in total short positions and the resulting outperformances are smaller and mostly insufficient to recommend the global long-short strategy over the FF benchmark.

Table 7: Test Results for Group 4: Global Long-Short

Efficient frontier for Group 4	Excess return (horizontal test)			Excess variance (vertical test)		
Benchmark portfolio	*FFminvol*	*FFmktvol*	*FF17.3%vol*	*FFminvol*	*FFmktvol*	*FF17.3%vol*
Outperformance (expected return or variance)	0.0002***	0.0001*	0.0001*	0.0033***	0.0006	0.0007
Composition of the efficient portfolio (same variance/expected return as the benchmark)						
Small	2.25	1.25	0.79	1.73	1.15	0.68
Big	-0.03	-0.47	-0.67	-0.26	-0.51	-0.71
Value	-0.23	-0.21	-0.20	-0.22	-0.21	-0.20
Growth	-0.08	-0.37	-0.50	-0.23	-0.39	-0.53
Robust profitab	-0.35	0.46	0.83	0.06	0.54	0.92
Weak profitab	-0.83	-1.13	-1.27	-0.99	-1.16	-1.30
Conservative invest	-0.57	0.44	0.91	-0.05	0.54	1.02
Aggressive invest	-2.31	-2.49	-2.57	-2.40	-2.51	-2.59
High mom	-0.12	0.98	1.49	0.45	1.09	1.61
Low mom	-0.31	0.00	0.14	-0.15	0.03	0.18
Market	3.58	2.53	2.05	3.04	2.43	1.94
Total share of long positions	5.83	5.67	6.21	5.29	5.78	6.34
Total share of short positions	-4.83	-4.67	-5.21	-4.29	-4.78	-5.34

5. Conclusion

The main takeaways of this paper are twofold. First, short-selling enhances the performance of factor investing. Long-short strategies can exhibit attractive mean-variance performance. Our results contrast with those of Israel and Moskowitz (2013) and Asness et al. (2014), who instead consider investments in individual factors. This difference is probably due to the fact that we run optimal asset allocations (under a series of pre-defined constrained) that combine styles, which embody both the long and short legs of the FF factors. Second, the way Fama and French (1992) built factor portfolios in an asset pricing perspective was impressively clear-sighted in terms of portfolio management. These two-leg optimization-free portfolios are obtained from equal absolute weights of the long and short legs. Our tests results suggest that, except for low levels of volatility, the FF portfolios generate performances as good as those of optimized long-short portfolios.

Our paper contributes to the debate on the efficiency gains associated with relaxing the long-only restriction on portfolio optimization (Brush, 1997; Jacobs and Levy, 2005; Jacobs et al. 2007 and 2005) in the specific context of factor investing (Eun et al., 2010; Ang, 2014). Legal restrictions and specific costs aside, long-short strategies are evidently superior to long-only ones because they capture investment opportunities that are otherwise inaccessible. This point has been made repeatedly in the literature, along with various performance indicators such as higher alphas and lower tracking errors (Sorensen et al., 2007), diversification benefits (Krusen et al., 2008) and higher efficiency (Johnson et al., 2007). With respect to this literature stream, our methodological innovation stems from using intermediate situations which depart from both the highly restrictive long-only case and the (too?) permissive long-short rule.

References

Almazan, A., K. C. Brown, M. Carlson, and D.A. Chapman (2004). Why Constraint your Mutual Fund Manager? *Journal of Financial Economics* 73, 289-321.

Ang, A. (2014). *Asset Management – A Systematic Approach to Factor Investing*. Oxford: Oxford University Press.

Ang, A., W. Goetzmann, and S. Schaefer (2009). *Evaluation of Active Management of the Norwegian GPFG*. Norway: Ministry of Finance.

Ang A., R. Ratcliffe, and P. Miranda (2017). Capacity of Smart Beta Strategies: A Transaction Cost Perspective. Working Paper, Columbia Business School Research Paper No. 16-76.

Asness, C.S., T. Moskowitz, and L. Pedersen (2013). Value and Momentum Everywhere. *Journal of Finance* 68, 929-985.

Asness, C.S., A. Ilmanen, R. Israel, and T. J. Moskowitz (2015). Investing with Style. *Journal of Investment Management* 13, 27-63.

Asness C.S., A. Frazzini, R. Israel and T. Moskowitz (2014). Fact, Fiction, and Momentum Investing. *Journal of Portfolio Management* 40, 75-92.

Basak G., R. Jagannathan, and G. Sun (2002). A Direct Test for the Mean-Variance Efficiency of a Portfolio. *Journal of Economic Dynamics and Control* 26, 1195-1215.

Bernal, O., A. Herinckx, and A. Szafarz (2014). Which Short-Selling Regulation is the Least Damaging to Market Efficiency? Evidence from Europe. *International Review of Law and Economics* 37, 244-256.

Blitz D., J. Huij, S. Lansdorp, and P. van Vliet (2014). Factor Investing: Long-Only versus Long-Short, SSRN Working Paper No. 2417221.

Briec W., K. Kerstens and, J. Lesourd (2004). Single-Period Markowitz Portfolio Selection, Performance Gauging, and Duality: A Variation on the Luenberger Shortage Function. *Journal of Optimization Theory and Applications* 120, 1-27.

Brière, M., B. Drut, V. Mignon, K. Oosterlinck, and A. Szafarz (2013). Is the Market Portfolio Efficient? A New Test of Mean-Variance Efficiency when all Assets are Risky. *Finance*, 34, 7-41.

Brière M., and A. Szafarz (2016). Factor Investing: Risk Premia versus Diversification Benefits, SSRN Working Paper No. 2615703

Bris, A., W. N. Goetzmann, and N. Zhu (2007). Efficiency and the Bear: Short Sales and Markets around the World. *Journal of Finance* 62, 1029-1079.

Brush J. S. (1997). Comparisons and Combinations of Long and Long-Short Strategies. *Financial Analyst Journal* 53, 81-89.

Carhart, M.M. (1997). On Persistence in Mutual Fund Performance. *Journal of Finance* 52, 57-82.

Cazalet, Z., and T. Roncalli (2014). Facts and Fantasies about Factor Investing. SSRN Working Paper No. 2524547.

Clarke, R., H. de Silva, and S. Sapra (2004). Toward More Information-Efficient Portfolios. *Journal of Portfolio Management* 31, 54–63.

Eun, C.S., S. Lai, F.A. de Roon, and Z. Zhang (2010). International Diversification with Factor Funds. *Management Science* 56, 1500-1518.

Fama, E.F., and K.R. French (1992). The Cross-Section of Expected Stock Returns. *Journal of Finance* 47, 427-465.

Fama, E.F., and K.R. French (2015). A Five-Factor Asset Pricing Model. *Journal of Financial Economics* 116, 1-22.

Frazzini, A., R. Israel, and T. Moskowitz (2014). Trading Costs of Asset Pricing Anomalies. Fama-Miller Working Paper, Chicago Booth Research Paper No. 14-05.

Gilli, M., E. Schumann, G. di Tollo and G. Cabej (2011). Constructing 130/30-Portfolios with the Omega Ratio. *Journal of Asset Management* 12, 94-108.

Harvey, C. R., and Y. Liu (2015). Backtesting. *Journal of Portfolio Management* 42, 13-28.

Harvey, C. R., Y. Liu, and H. Zhu (2016). … And the Cross Section of Expected Returns. *Review of Financial Studies* 29, 5-68.

Hou, K., C. Xue, and L. Zhang (2015). Digesting Anomalies: An Investment Approach. *Review of Financial Studies* 28, 650-705.

Idzorek, T. M., and M. Kowara (2013). Factor-Based Asset Allocation vs. Asset-Class-Based Asset Allocation. *Financial Analyst Journal* 69, 1-11.

Israel R. and T. Moskowitz (2013). The Role of Shorting, Firm Size, and Time on Market Anomalies. *Journal of Financial Economics* 108, 275-301.

Jobson, J.D., and B.M. Korkie (1981). Performance Hypothesis Testing with the Sharpe and Treynor Measures. *Journal of Finance* 36, 889–908.

Jones, C.M., and O.A. Lamont (2002). Short-sale Constraints and Stock Returns. *Journal of Financial Economics* 66, 207-239.

Jacobs, B.I., and K.N. Levy (1993). Long Short Equity Investing *Journal of Portfolio Management* 20, 52-64.

Jacobs, B.I., and K.N. Levy (2007). 20 Myths about Enhanced Active 120-20 Strategies. *Financial Analysts Journal* 63, 19-26.

Jacobs, B.I., K.N. Levy, and H.M. Markowitz (2005). Portfolio Optimization with Factors, Scenarios, and Realistic Short Positions. *Operations Research* 53, 586-599.

Jorion, P. (1986). Bayes-Stein Estimation for Portfolio Analysis. *Journal of Financial and Quantitative Analysis* 21, 279-292.

Jurczenko, E., T. Michel, and J. Teiletche (2015). A Unified Framework for Risk-Based Investing. *Journal of Investment Strategies* 4, 1-29.

Korajczyk, R.A., and R. Sadka (2004). Are Momentum Profits Robust to Trading Costs? *Journal of Finance* 59, 1039-1082.

Krusen, C., F. Weber, R.A. Weigand (2008). 130/30 Funds: The Evolution of Active Equity Investing. *Journal of Portfolio Management* 1, 176-185.

Ledoit O. and M. Wolf (2004). Honey, I Shrunk the Sample Covariance Matrix, *Journal of Portfolio Management* 30, 110-119.

Lesmond, D.A., M.J. Schill, and C. Zhou (2004). The Illusory Nature of Momentum Profits. *Journal of Financial Economics* 71, 349–380.

Lo, A.W., and P.N. Patel (2008). 130/30: The New Long-Only. *Journal of Portfolio Management* 34, 12-38.

McLean, R.D., and J. Pontiff (2016). Does Academic Research Destroy Stock Return Predictability? *Journal of Finance* 71, 5–32.

Michaud R. (1993). Are Long-Short Equity Strategies Superior? *Financial Analysts Journal* 49, 44-50.

Miller E.M. (2001). Why the Low Returns to Beta and other Forms of Risk? *Journal of Portfolio Management* 27, 40-56.

Novy-Marx, R. (2013). The Other Side of Value: The Gross Profitability Premium. *Journal of Financial Economics* 108, 1-28.

Novy-Marx, R., and M. Velikov (2016). A Taxonomy of Anomalies and their Trading Cost. *Review of Financial Studies* 29, 104-147.

Sorensen, E.H., R. Hua, and E. Qian (2007). Aspects of Constrained Long-Short Equity Portfolios: Taking Off the Handcuffs. *Journal of Portfolio Management* 33, 12-22.

Wang, Z. (1998). Efficiency Loss and Constraints on Portfolio Holdings. *Journal of Financial Economics* 48, 359-375.

Chief Editors:

Pascal Blanqué

Deputy Chief Executive Officer

Global Head of Institutional Business

Group Chief Investment Officer

Philippe Ithurbide

Global Head of Research, Strategy and Analysis

Amundi Working Paper

WP-063-2017

April 2017

research-center.amundi.com