NATIONAL RESEARCH UNIVERSITY
HIGHER SCHOOL OF ECONOMICS

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UPSIDE AND DOWNSIDE RISKS IN MOMENTUM RETURNS

BASIC RESEARCH PROGRAM

WORKING PAPERS

SERIES: FINANCIAL ECONOMICS
WP BRP 50/FE/2015

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UPSIDE AND DOWNSIDE RISKS IN MOMENTUM RETURNS[2]

I provide a novel risk-based explanation for the profitability of momentum strategies. I show that the past winners and the past losers are differently exposed to the upside and downside market risks. Winners systematically have higher relative downside market betas and lower relative upside market betas than losers. As a result, the winner-minus-loser momentum portfolios are exposed to extra downside market risk, but hedge against the upside market risk. Such asymmetry in the upside and downside risks is a mechanical consequence of rebalancing momentum portfolios. But it is unattractive for an investor because both positive relative downside betas and negative relative upside betas carry *positive* risk premiums according to the Downside-Risk CAPM. Hence, the high returns to momentum strategies are a mere compensation for their upside and downside risks. The Downside Risk-CAPM is a robust unifying explanation of returns to momentum portfolios, constructed for different geographical and asset markets, and it outperforms alternative multi-factor models.

JEL Classifications: G12, G14, G15.

Keywords: momentum, downside risk, downside beta, upside risk, upside beta, Downside-Risk CAPM.

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[2] The author is very grateful to Christopher Polk, Christian Julliard, Dong Lou, Andrea Vedolin, Lucio Sarno, Philippe Mueller, Anna Obizhaeva, Dmitri Makarov, Sergei Gelman, Andrei Simonov, Stefan Ruenzi, and the seminar participants at London School of Economics, Gaidar Institute for Economic Policy, New Economic School, National Research University Higher School of Economics, Mannheim University Business School, EFMA and MIFN meetings for their comments and suggestions. The article was prepared within the framework of the Academic Fund Program at the National Research University Higher School of Economics (HSE) in 2015-2016 (grant №15-01-0079) and supported within the framework of a subsidy granted to the HSE by the Government of the Russian Federation for the implementation of the Global Competitiveness Program.

1. INTRODUCTION

Since Jegadeesh and Titman (1993), the momentum anomaly has received a lot of attention. Buying past winners and selling past losers generates abnormal returns in the short run, which cannot be explained by conventional risk measures (e.g. the standard deviation and the market beta) and provide evidence for market inefficiency. Momentum strategies proved to be profitable around the world, at the level of national equity indices (e.g. Asness, Liew, and Stevens, 1997; Richards, 1997; Cenedese et al., 2013) and at the individual stock level (Rouwenhorst, 1998, 1999), among currencies (Okunev and White, 2003; Menkhoff et al., 2012), commodities, bonds and other assets (Gorton et al., 2008; Asness, Moskowitz, and Pedersen, 2013).

In this paper, I provide a novel risk-based explanation for the profitability of global momentum strategies. I show that the past winners and the past losers are differently exposed to the upside and downside market risks. Winners systematically have higher relative downside market betas and lower relative upside market betas than losers. As a result, the winner-minus-loser momentum portfolios are exposed to the downside market risk, but hedge against the upside market risk. Greater relative downside risk and lower relative upside risk of past winners are compensated by higher returns. Indeed, such asymmetry in upside and downside market risks explains the returns to the cross-section of global momentum portfolios well.

The importance of separating the overall market risk into the upside and downside risks for asset pricing was recognized in early papers (e.g. Roy, 1952; Markowitz, 1959; Bawa and Lindenberg, 1977) and was articulated in Ang and Chen (2002) and Ang et al. (2006) for the US stock market. As Ang at al. (2006) show, sorting stocks into portfolios in order of increasing relative downside betas produces a monotonically increasing pattern of portfolio average returns, whereas sorting stocks in order of increasing relative upside betas produces a monotonically decreasing pattern of returns. In other words, after controlling for the market risk, the relative downside beta carries a positive risk premium and the relative upside beta carries a negative risk premium. Therefore, separating the market risk into the upside and the downside components improves the performance of the CAPM significantly. More recently, Lettau et al. (2014) and Dobrynskaya (2014) provide further convincing evidence that the CAPM with the downside risk has greater explanatory power in the stock, currency, commodity and bond markets than the regular CAPM. They show that the exposure to the downside risk is a unifying explanation for returns in different asset markets.

Although numerous explanations for the momentum anomaly have been put forward, their upside and downside market risks has not been studied thoroughly. Harvey and Siddique (2000) note that momentum is (negatively) related to systematic co-skewness. Ang et al. (2001) find that the US momentum portfolio has positive and significant loading on a factor that reflects the downside risk, and that the downside risk factor explains some of the cross-sectional variation in returns to momentum portfolios. Lettau et al. (2014) consider six US Fama-French size-momentum portfolios and find some evidence that the returns are "broadly positively associated with the downside beta".

Building on these studies, I show that the downside risk alone does not fully explain the returns to the cross-section of momentum portfolios because the upside risk plays a significant role too and cannot be neglected. In fact, it is the difference in the downside and upside betas (beta asymmetry) which varies across momentum portfolios the greatest. For any cross-section of momentum portfolios considered, the difference in betas is monotonically increasing from past losers to past winners. As a result, the winner-minus-loser momentum portfolios are exposed to the downside risk, but hedge against the upside risk.

This finding is consistent with a recent study by Daniel and Moskowitz (2014), who show that the winner-minus-loser momentum portfolios tend to crash when the market rebounds after a decline. The momentum crashes occur during the market upturns because these portfolios appear to be long in the low-beta stocks and short in the high-beta stocks picked in the preceding formation period of the declining market. But if the formation period coincides with the growing market, on the contrary, the momentum portfolios appears to be long in the high-beta stocks and short in the low-beta stocks, what leads to their high exposure to the downside risk if the market turns down. Because the momentum portfolios are rebalanced periodically, and because the market changes its trend often, the momentum portfolios appear to have positive downside betas and negative upside betas mechanically. Recent studies by Barroso and Santa-Clara (2015) and Jacobs, Regele and Weber (2015) also show that past winner and loser portfolios have asymmetric return distributions and, as a result, the momentum portfolio returns exhibit significant negative skewness and high kurtosis. Such asymmetry in risks is not attractive for an investor and requires a risk premium.

In the cross-sectional tests, I show that the *relative* downside beta, which captures the *extra* downside risk and, hence, the downside-upside risk asymmetry, explains the returns to the momentum portfolios well, whereas the traditional beta has no explanatory power. The relative downside beta premium is approximately 3-4 percent per month, highly statistically significant and similar in magnitude to the estimates obtained for the stock and currency markets (Lettau et al., 2014; Dobrynskaya, 2014).

My findings are similar for all cross-sections of momentum portfolios in different geographical markets and asset classes. I study the US, Global, European, North-American and Asian-Pacific momentum portfolios of individual stocks, global momentum portfolios of country indices, currency momentum portfolios and Asness, Moscowitz and Pedersen (2013) momentum portfolios in different asset classes. I show that momentum is a global phenomenon indeed, and its upside-downside risk structure is similar around the world and in different asset markets. I confirm the findings of Asness, Moskowitz, and Pedersen (2013) that momentum strategies in different locations and asset markets share common risks. But the major contribution of this paper is to show that a microfounded theoretical asset-pricing model (namely, the Downside-Risk CAPM – DR-CAPM) previously used to explain stock and currency returns can also explain the momentum returns well.

As an extension, I consider the US short-term equity reversal portfolios and currency carry portfolios, and the same explanation applies. Coupled with findings of Lettau et al. (2014) about the validity of the DR-CAPM for currency, commodity and size-book-to-market portfolios, the different exposure to the upside and downside risks can be considered a unifying explanation of returns in various markets. The results are robust to different estimation methodologies (Fama-MacBeth, 1973, with constant and time-varying betas and Hansen's efficient GMM, 1982) and different periods of study.

The rest of the paper is organized as follows. In section 2, I describe the theoretical asset pricing models with downside risk to motivate my risk measures. Section 3 is devoted to the data description and portfolio formation. In section 4, I present the portfolio statistics and the results of the cross-sectional tests for different sets of momentum, reversal and carry portfolios. Section 5 concludes the paper. The appendix is devoted to a number of additional robustness checks.

2. CAPM WITH UPSIDE AND DOWNSIDE RISKS

The importance of upside and downside risks was recognized as early as the first theoretical asset-pricing models were developed. Roy (1952) suggests that economic agents care particularly about the downside risk. Markowitz (1959) proposes using semi-variance as a proper measure of risk. Bawa and Lindenberg (1977) provide an extended version of the CAPM where the market beta is separated into the upside beta and the downside beta. Longin and Solnik (2001) consider upside and downside correlations, and Ang and Chen (2001) propose a measure of correlation asymmetry and show that the asymmetric correlation is priced in the US equity market.

Ang et al. (2006) show how upside and downside risks may be priced cross-sectionally in an equilibrium setting. In a theoretical model with disappointment aversion, they show numerically that the traditional CAPM alpha is increasing in the relative downside beta, decreasing in the relative upside beta and, hence, increasing with the difference between the downside and upside betas (downside-upside beta asymmetry). Assets should have higher expected returns if they have higher relative downside betas because such assets perform poorly in bad states of the world when the marginal utility of wealth is high and asset returns are particularly important. In other words, the extra downside risk (on top of the regular beta risk) requires an additional positive risk premium. Assets with higher relative upside betas, on the contrary, carry a negative additional risk premium because the upside potential is, in fact, attractive for investors.

Ang et al. (2006) show that these relationships hold in the data indeed. Sorting US stocks into portfolios in order of increasing relative downside betas produces a monotonically increasing pattern of portfolio average returns, whereas sorting stocks in order of increasing relative upside betas produces a monotonically decreasing pattern of returns. In other words, the relative downside beta carries a positive risk premium and the relative upside beta carries a negative risk premium. It is important to note that, in all sorts, the regular betas of all portfolios are roughly the same; therefore, the differences in the portfolio returns are not attributable to the beta risk.

The authors also find in cross-sectional regressions for individual stocks that the upside and downside risks are priced differently, and that the two-beta CAPM has a much higher explanatory power than the traditional CAPM. Even after controlling for other risk factors (size, book-to-market, momentum, liquidity and volatility), the estimates of the downside risk premium are high and statistically significant whereas the estimates of the upside risk premium are not.

More recently, asset pricing models with the downside risk proved to be as successful in explaining returns in the currency, commodity and bond markets (Lettau et al, 2014; Dobrynskaya, 2014), as in the equity market. The downside risk is shown to be priced similarly in different asset markets around the globe. Different investor aversion to the upside and downside risks also has theoretical foundations (e.g. disappointment aversion in Gul, 1991, investor sentiment in Shleifer and Vishny, 1997, or funding risk in Filipe and Suominen, 2014).

3. DATA AND PORTFOLIO FORMATION

I consider a variety of momentum and reversal portfolios around the globe to show that the upside-downside risk asymmetry is a universal phenomenon.

Firstly, I consider 10 US equal-weighted and value-weighted momentum portfolios, which are formed by sorting NYSE, AMEX and NASDAQ stocks in month t by their total returns in months t-12 to t-2. The month prior to the sort date is excluded because of the short-term reversal. Portfolio 1 (low) is the past-loser portfolio, and portfolio 10 (high) is the past winner portfolio. I also construct the winner-minus-loser (WML) portfolios which have a long position in portfolio 10 and a short position in portfolio 1. The longest time series of data is available for these portfolios: from January 1927 until July 2013. The data is taken from the Fama-French data library.

Secondly, I consider global and regional momentum portfolios of *individual stocks*. These portfolios are formed by monthly sorts of stocks in the corresponding region by their previous-year (t-12 to t-2) performance. The data on these portfolios is also obtained from the Fama-French data library and covers the period from November 1990 until August 2013. I collect the raw data on 25 equal-weighted Global, European, Asian-Pacific, Japanese and North-American size-momentum portfolios and construct 5 momentum portfolios and 5-1 WML portfolio for each region. The Global portfolios consist of stocks from 23 countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Switzerland, Sweden, the UK, and the USA; the European portfolios consist of stocks from 16 countries; the Asian-Pacific portfolios consist of stocks from 4 countries; and the North-American portfolios consist of stocks from Canada and the USA.

The third set of momentum portfolios is formed by double sorts of individual stocks by their previous year performance and the market capitalization. I consider global 25 size-momentum portfolios form the Fama-French data library.

The fourth set of global momentum portfolios is formed by sorting *country indices* in month t by their total returns in US dollars in months t-12 to t-2. The portfolios are rebalanced every month. Following Richards (1997) and Cenedese et al. (2013), I use MSCI country indices as the base assets. These indices often represent a benchmark for country index ETFs, and hence they are traded assets which can be used to form such momentum portfolios in practice. There are 40 countries in the sample: Australia, Austria, Belgium, Brazil, Canada, Czech Republic, Denmark, Egypt, Finland, France, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, South Korea, Malaysia, Mexico, the Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Russia, Singapore, South Africa, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, the UK, and the USA. The sample period is from January 1983 until August 2013, the first sort is done in December 1983 and the first return is measured in January 1984. For 20 countries, the indices are available for the whole period, 12 indices start in December 1987, 4 indices start in December 1992 and 4 indices start in December 1994. I form 6 equally-weighted portfolios of indices, where portfolio 1 represents past loser countries and portfolio 6 represents past winner countries. Once new indices appear, they enter the portfolios a year later, and the portfolios become more diversified. I also form the 6-1 WML portfolio which represents a global momentum strategy.

The fifth set consists of 5 *currency* momentum portfolios which are formed by sorting currencies in month t by their exchange rate appreciation relative to the US dollar during the period t-12 to t-2 and held for 1 month. The sample consists of 45 currencies, but the actual number of currencies varies from 10 (November 1984) to 41 (December 1998) due to data limitations and creation of the Euro zone. The exchange rate data cover the period from October 1983 until August 2013, the first sort is done in October 1984 and the first portfolio returns are measured in November 1984. The end-of-month exchange rate data are collected from various data sources via Datastream.

I also consider short-term reversal portfolios of US stocks for the period from January 1927 until July 2013. The portfolios are sorted by the stock performance in the previous month and held for one month. The data is taken from the Fama-French data library.

I use the following risk factors in the analysis: the market factor (the US market index for the US portfolios and the developed countries World MSCI index for the global and regional portfolios), the market volatility factor (the squared market factor), the momentum factor (the Fama-French US momentum factor before November 1990, the Fama-French global momentum factor afterwards, which is formed by sorting individual stocks in 23 countries by their trailing previous-year performance), and the global size factor (the Fama-French global SMB factor).

4. RESULTS

4.1. US MOMENTUM PORTFOLIOS

I start the analysis of US momentum portfolios because the longest time series of data is available for these portfolios. Table 1 reports the return and risk characteristics of 10 value-weighted and 10 equal-weighted momentum portfolios, as well as the WML zero-cost portfolios.

The momentum effect is strong in the US; the zero-cost value-weighted (equal-weighted) momentum strategy generated an average return of 14.27 (9.80) percent per annum during 1927-2013. The past winner portfolios generally have lower return standard deviation, skewness and market beta than the past loser portfolios, but higher returns. A similar decreasing U-shaped pattern of market betas of momentum portfolios was already noted in Jegadeesh and Titman (1993). Therefore, the WML portfolios generate virtually risk-free returns, if these measures of risk are considered. This represents the well-known momentum anomaly.

Keeping the Ang et al. (2006) two-beta CAPM in mind, I estimate the upside and downside market betas of the momentum portfolios in the following time-series regression:

$$r_{it} = \alpha_i + \beta_i^- * r_{Mt} + \gamma_i * r_{Mt} * D_t + \varepsilon_{it}, \tag{1}$$

where r_{it} is the return on portfolio *i*, r_{Mt} is the US market return, $D_t = \begin{cases} 0, r_{Mt} \le 0 \\ 1, r_{Mt} > 0 \end{cases}$, β_i^- is the estimate of the downside beta[3], γ_i is the estimate of the upside-downside beta asymmetry, ε_{it} is an error term. The upside beta can be calculated as follows: $\beta_i^+ = \beta_i^- + \gamma_i$. Then, the relative downside beta is $(\beta_i^- - \beta_i)$, and the relative upside beta is $(\beta_i^+ - \beta_i)$, where β_i is the traditional beta, estimated in the regression of portfolio return on the market return. This approach to estimate the

[3] As defined here, the downside beta is conditional on the negative market return. Another way to define downside beta is to condition on the episodes when the market return is below its mean. This alternative specification produces similar results and it is not reported.

upside and downside betas jointly is superior to the one, used in Lettau et al. (2014), because no information regarding the upside is lost[4]. The relative downside beta measures *additional* market risk on the downside, after controlling for the overall market risk measured by the regular market beta. A portfolio may have lower market beta, but greater exposure to the downside risk, and hence may require higher returns, because investors care more about performance in downstates. This can only be seen after separating the overall market risk and the downside market risk.

Table 1 reports the relative downside betas, the relative upside betas and the beta asymmetry (defined as $\beta_i^- - \beta_i^+ = -\gamma_i$) of the US momentum portfolios. We observe a striking increasing pattern for the relative downside betas and decreasing pattern for the relative upside betas along the portfolio rank. Past winner portfolios have higher downside risk and lower upside risk than past loser portfolios. Therefore, the WML portfolios are exposed to the downside risk, but hedge against the upside risk. Since the downside risk is more important for an investor, the WML portfolios require risk premiums.

Because both the relative downside betas and the relative upside betas are different for past winners and past losers, there is an even stronger positive relationship between the beta asymmetry and portfolio rank. Past losers have higher upside betas than downside betas, whereas past winners have higher downside betas than upside betas. The beta asymmetry ranges from -0.71 to 0.99 and it is statistically significant for several top and bottom portfolios, as well as the WML portfolios. The results are similar in cases of value-weighted and equal-weighted portfolios.

Figure 1 illustrates the relationships between the relative upside betas, relative downside betas, beta asymmetry and portfolio rank (for the value-weighted portfolios). We observe clear monotonic relationships.

The differences in the upside and downside risks of momentum portfolios can explain the differences in their returns. Figure 2 plots the predicted versus realized returns of US momentum portfolios, where the predictions are made by the traditional CAPM (left-hand-side) and the two-

[4] Lettau et al. (2014) just pick the downside episodes and estimate the downside beta in that sub-sample.

beta CAPM (right-hand side). Indeed, the two-beta CAPM has very high explanatory power (R^2 of 0.93 and 0.94), whereas the traditional CAPM performs worse (R^2 of 0.46 and 0.66), and the beta premium is even negative.

I use the following specification of the two-beta CAPM for the cross-sectional regressions:

$$r_i - r_f = \beta_i \lambda + \left(\beta_i^- - \beta_i\right)\lambda^- + \mu + \varepsilon_i , \tag{2}$$

where λ is the traditional beta premium, λ^- is the extra downside beta premium, and μ is the common pricing error, which can be restricted to zero[5]. This specification nests the traditional CAPM if the extra downside risk is not priced or if the downside beta is equal to the traditional beta (and, hence, to the upside beta). This specification of the two-beta CAPM (called the Downside-Risk CAPM – DR-CAPM) was estimated in Lettau et al. (2014) for different asset classes, and it is alternative to the specification of Ang et al. (2006):

$$r_i - r_f = \beta_i^+ \lambda^+ + \beta_i^- \lambda^- + \mu + \varepsilon_i , \tag{3}$$

where λ^+ is the upside beta premium and λ^- is the downside beta premium. Since the traditional beta is a weighted average of the upside beta and the downside beta, we need to have any two betas of the three to fully specify the model. If the *relative* downside beta premium is positive, it means that the *relative* upside beta premium is negative. Specification (2) is more convenient because we can easily compare it with the traditional CAPM specification and see the contribution of the relative downside risk.

Table 2 reports the estimates of risk premiums in the cross-sectional tests of the traditional CAPM and the DR-CAPM with and without the constant. I employ two alternative methodologies to estimate risk premiums: the Fama-MacBeth (1973) and Hansen's (1982) two-step GMM. In the latter, the factor betas and risk premiums are estimated jointly, and the standard errors are corrected to account for the generated regressor problem. I use the identity weighting matrix in the first step,

[5] It is common in the recent literature to restrict the pricing error to zero (e.g. Burnside et al., 2011; Lustig et al., 2011; Cenedese et al., 2013).

and then re-optimize using the efficient weighting matrix. The moment conditions are specified as in Cochrane (2005):

$$\begin{cases} E(r_{jt} - \alpha_j - b_j f_t) = 0 \\ E(r_{jt} - \alpha_j - b_j f_t) \otimes f_t = 0 \\ E(r_{jt} - b_j \lambda - \mu) = 0 \end{cases} \tag{4}$$

where f_t is either a risk factor or a vector of factors, r_{jt} is the excess return on portfolio *j*, b_j is a factor beta, and λ is a factor risk premium. The first two moments estimate factor betas, and the third moment estimates factor risk premiums.

The traditional CAPM has negative R^2 in case of no constant, and negative beta premiums, significant intercepts and low R^2 in case with a constant. It is also rejected by the test for the over-identifying restrictions (J-statistics). Therefore, the traditional CAPM cannot explain the returns to the US momentum portfolios.

The DR-CAPM, on the contrary, performs very well in terms of both R^2 and J-statistics. The relative downside beta premium is about 2-4 percent and it is highly statistically significant irrespective of the estimation methodology[6]. Hence, the momentum return is a compensation for the extra downside risk. In case with a constant, the beta premium and the constant are insignificant in most cases, so that almost full explanatory power of the model comes from the downside risk component. These estimates should be taken carefully, though, because the US momentum portfolios are negatively exposed to the US market factor what generates a negative estimate of the market risk premium in some cases contrary to the model predictions. Using a broader spectrum of portfolios in the cross-section produces more economically plausible estimates. Therefore, I consider momentum portfolios in other geographical regions and other asset classes in the subsequent sections and perform joint tests which have more power.

[6] In an alternative specification of the two-beta CAPM with relative upside betas instead of the relative downside betas, the relative upside beta premium is negative and the explanatory power of the model is exactly the same by construction. These results are not reported because they are redundant.

My results differ from Lettau et al.'s (2014) results who do not find such a strong support for the DR-CAPM in the cross-section of six US size-momentum portfolios, although they write that the returns are "broadly positively associated with the downside beta". The reason is that they look at the downside betas instead of *relative* downside betas which measure downside-upside beta asymmetry. It turns out that the downside betas of these portfolios are similar and, hence, they cannot explain the differences in these portfolio returns. But the relative downside betas, relative upside betas and the downside-upside beta asymmetry vary across the portfolios significantly and are well aligned with the portfolio returns. Neglecting the upside component leads to misinterpretation of the results. I confirm the validity of the DR-CAPM for the cross-section of 25 global size-momentum portfolios in section 4.3.

4.2. GLOBAL AND REGIONAL MOMENTUM PORTFOLIOS

In this section, I consider global and regional momentum portfolios of individual stocks and show that the downside-upside risk asymmetry of momentum returns is a global phenomenon. Table 3 reports the returns and risks of 5 global, 5 European, 5 Asian-Pacific and 5 North-American momentum portfolios and the corresponding 5-1 WML portfolios. The momentum strategies are profitable in all regions with the highest momentum return in Europe (17.58 percent pa) and the lowest momentum return in the Asian-Pacific region (6.55 percent pa)[7].

In all regions, the high returns to the WML portfolios cannot be explained by the market factor because their global market betas are negative in all cases, as in Fama and French (2012). While the market betas are somewhat decreasing with the portfolio rank, the relative downside betas are monotonically increasing and the relative upside betas are monotonically decreasing. The past winner portfolios have greater exposure to the downside risk and lower exposure to the upside risk than the past loser portfolios. Consequently, the winner portfolios exhibit a greater degree of the downside-upside risk asymmetry (β^{-}-β^{+}). This asymmetry is statistically significant for the winner

[7] The exception is Japan where the WML portfolio is unprofitable (as in Asness, 2011, and Fama and French, 2012).

and WML portfolios in all regions[8]. In general, the global and regional momentum portfolios have similar risk structure as the US momentum portfolios despite the different base assets and different sample periods.

As in the US case, the DR-CAPM has a high explanatory power in the cross-section of momentum portfolios in all regions (figure 3). The predicted returns are very close to the realized returns with R^2 of 77-96 percent.

Table 4 reports the Fama-MacBeth (1973) and Hansen's (1982) GMM estimates of risk premiums in the CAPM and DR-CAPM specifications. In case of the CAPM, the beta premium is negative and insignificant, the intercept is highly significant, the adjusted R^2 is negative in most cases and the model is rejected by the J-statistics in case with a constant. As in case of the US, the traditional market factor alone cannot explain the returns to the global momentum portfolios. When the relative downside risk is also taken into account, the beta premiums become positive but insignificant, the intercepts become insignificant, and the relative downside beta premiums are highly significant in all cases. The DR-CAPM is never rejected by the J-statistics. The DR-CAPM has high explanatory power for all sets of momentum portfolios, and this explanatory power comes solely from the downside risk component which captures the downside-upside risk asymmetry.

4.3. SIZE-MOMENTUM PORTFOLIOS

The momentum portfolios have a strong factor structure, and one may argue that the downside risk factor may be spurious if it is at least slightly correlated with the true momentum factor. To break the factor structure of the momentum portfolios, I consider 25 double-sorted size-momentum portfolios in this section and short-term reversal and currency carry portfolios in subsequent sections.

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[8] In case of Japan, the difference in the upside and downside betas of its WML portfolio is statistically insignificant. Therefore, Japan is indeed an exception that proves the rule. The results for the Japanese momentum portfolios are available upon request.

Table 5 reports the returns, relative downside and upside betas and the beta asymmetry of the global size-momentum portfolios. The portfolio average returns are decreasing with size and increasing with the past returns. As a result, all SMB and WML long-short portfolios generate positive returns. Confirming previous studies (e.g. Jegadeesh and Titman, 1993), the momentum strategy is profitable for all size quintiles, and the momentum effect is stronger for small firms.

The relative downside betas are decreasing with size and increasing with the past returns. The relative upside betas, on the contrary, are increasing with size and decreasing with the past returns. Small winner stocks have the highest downside risk, the lowest upside risk and the greatest downside-upside risk asymmetry. Big loser stocks have the lowest downside risk, the highest upside risk and the lowest (negative) risk asymmetry. The WML portfolios have positive and statistically significant beta asymmetry for all size quintiles. The SMB portfolios have positive, but insignificant, beta asymmetry. Therefore, this risk asymmetry does not fully explain the size anomaly.

In figure 4, I plot predicted versus realized returns of the 25 global size-momentum portfolios where the predictions are made by the traditional CAPM, the three-factor CAPM with the market, size and momentum factors, and the DR-CAPM. The traditional CAPM has low explanatory power (R^2 is 0.35), and the market risk premium is negative. The three-factor CAPM explains the returns much better (R^2 is 0.70), but this result is not surprising given the size and momentum factors are derived from these portfolios. The DR-CAPM has an even higher explanatory power despite the lower number of factors (R^2 is 0.75). The asymmetry in betas is aligned well with the portfolio returns.

Table 6 reports the Fama-MacBeth risk premiums in alternative multifactor specifications. In the CAPM (column (1)), the beta premium is negative and the intercept is highly statistically significant. In the DR-CAPM (column (2)), only the relative downside beta premium is significant. This model outperforms the three-factor model (column (3)), where the beta premium is negative and the intercept is significant again. When all risk factors are included (column (4)), the downside risk factor has the highest statistical significance, although the size and momentum factors are significant too. Only the traditional beta is dead.

4.4 MOMENTUM PORTFOLIOS OF COUNTRY INDICES

In this section, I consider alternative set of global momentum portfolios, which are formed by sorting country indices instead of individual stocks. Country indices also exhibit momentum, and the WML portfolio of country indices generates high returns which cannot be explained by conventional risk factors (e.g. Richards, 1997; Cenedese et al., 2013).

Table 7 reports the return and risk characteristics of 6 momentum portfolios of country indices and the 6-1 WML portfolio. Both the returns in the local currencies and the returns in the US dollars are increasing with the portfolio rank. According to the Uncovered Equity Parity (Hau and Rey, 2006), equity return differential in the domestic currency should be offset by the depreciation of the domestic currency, but this is clearly not the case. Winner portfolios consistently generate higher exchange-rate adjusted returns in excess of the US returns, whereas loser portfolios generate negative excess returns (row 4 in table 7). This violation of the UEP has been documented in Cenedese et al. (2013), and it leads to the global momentum strategies being profitable. Such global momentum strategy WML had an average USD return of about 13 percent per annum in 1984-2013.

The profitability of this momentum strategy cannot be explained by conventional risk measures, like the standard deviation, skewness or market beta because all of them are similar for the 6 portfolios considered. As a result, the WML portfolio has no market risk and low volatility.

As in the previous sections, portfolios with higher rank have higher relative downside betas and lower relative upside betas. Whereas the loser portfolios 1 and 2 have symmetric upside and downside risks, the difference between the downside and upside betas is monotonically increasing with the portfolio rank and it is statistically significant for portfolios 3-6 and the WML portfolio. As a results, although the WML portfolio has the traditional beta of almost zero, it has a positive relative downside beta, a negative relative upside beta and a high beta asymmetry.

The last row of table 7 shows how the index momentum portfolios load on the Fama-French global momentum factor, which is formed by sorting individual stocks[9]. The loadings monotonically increase with the portfolio rank and are highly statistically significant for the loser and winner portfolios. The index-level momentum portfolios and the stock-level momentum portfolios have a similar risk structure and a similar exposure to downside and upside market risks.

Figure 5 plots realized versus predicted returns of the 6 momentum portfolios of country indices, where the predicted returns are estimated using the traditional CAPM and the DR-CAPM. The CAPM does not explain the returns to the momentum portfolios at all because the CAPM betas and, hence, predicted returns of all portfolios are similar while the realized returns differ significantly. The DR-CAPM, on the contrary, predicts the returns very well with R^2 of 0.91.

Table 8 reports the risk premiums in cross-sectional regressions. As before, the DR-CAPM has a much higher explanatory power than the CAPM, the relative downside beta premium is highly significant whereas the traditional beta premium is not. The estimates of the downside risk premium are similar to the estimates obtained for the global portfolios of individual stocks. Once again, we see that the downside-upside risk asymmetry of momentum portfolios is a global phenomenon and it is priced similarly around the world. It is crucial to account for this asymmetry to fully understand risks of momentum strategies.

4.5 CURRENCY MOMENTUM PORTFOLIOS

In addition to various equity momentum strategies, I consider currency momentum strategies as an out-of-sample test. A recent comprehensive study of currency momentum strategies by Menkhoff et al. (2012) provides strong evidence that currency momentum strategies are profitable, particularly for short holding periods (1 month), and the profits are mostly generated by the momentum in spot exchange rates rather than in forward discounts. The authors show that the currency momentum returns cannot be fully explained by transaction costs, business cycle risk, liquidity and volatility

[9] The momentum beta is estimated in a two-factor beta-momentum specification.

risks and other traditional risk factors, used in equity and currency literature. They conclude that although the FX markets are more liquid and efficient than the stock markets, “the properties of momentum strategies are fairly similar, which suggests that momentum profits in different asset classes could share a common root”.

To be consistent with my previous analysis of the equity market, I consider a currency momentum strategy with 11-month formation period and 1-month holding period. This strategy is one of the most profitable strategies out of 50 strategies considered in Menkhoff et al. (2012). Its average annual return was 6 and 7.6 percent in 1976-2010, depending on whether the spot rate changes or the total excess returns (including the interest rate differentials, or the forward discounts) were used to sort currencies into portfolios and to measure the subsequent returns. Since the spot rate changes exhibit greater momentum, I form 5 momentum portfolios by sorting currencies by their preceding spot rate appreciation relative to the US dollar. The winner portfolio includes 1/5 of currencies that have appreciated mostly and the loser portfolio includes 1/5 of currencies that have depreciated mostly.

Panel A of table 9 reports the returns and risk characteristics of the 5 currency momentum portfolios and the WML portfolio. Indeed, the average portfolio return is increasing with the portfolio rank, and the WML portfolio generated a return of 7.82 percent per annum during 1984-2013. This return is lower compared to the stock market, but still significant and it cannot be explained by the traditional risk measures such as standard deviation, skewness or the market beta.

The relative downside and upside betas exhibit similar patterns as in the stock market. The loser portfolio has the lowest relative downside beta and the highest relative upside beta whereas the winner portfolio has the highest relative downside beta and the lowest relative upside beta. The asymmetry in betas increases with the portfolio rank and it is high and statistically significant for the WML portfolio.

The last row in panel A shows how the currency momentum portfolios load on the global equity momentum factor. Although the loadings are not very high, they have predictable signs and are statistically significant for the winner, loser and WML portfolios. Therefore, momentum portfolios in different asset markets have a common component. My findings suggest that the relative downside risk can explain this common component because all momentum portfolios have similar exposure to the downside risk.

Panel B of table 9 shows the Fama-MacBeth and the efficient GMM risk premiums in the cross-sectional regressions. Since the intercepts are insignificant in all specifications and their inclusion does not affect point estimates significantly, they are dropped out. As before, the traditional CAPM has low explanatory power and the beta premium is negative. The DR-CAPM has higher explanatory power, which comes predominantly from the downside-risk component. The estimates of the relative downside beta premium are all statistically significant and similar in magnitude to the estimates obtained for the stock market.

4.6 ALL MOMENTUM PORTFOLIOS TOGETHER

As noted in Rouwenhorst (1998) and more recently in Asness, Moskowitz and Pedersen (2014), momentum portfolios in different geographical regions and asset classes are correlated and, perhaps, share a common component. In this section, I show that the different exposure to the downside and upside market risks is a unifying explanation of returns to momentum portfolios in different markets. I analyze all portfolios studied previously as a single cross-section. I have 48 portfolios in total: 10 US portfolios, 5 global, 5 European, 5 Asian-Pacific and 5 North-American portfolios of stocks, 6 global portfolios of country indices, 5 currency portfolios and 7 corresponding WML portfolios. The sample period is restricted to November 1990 – August 2013 since some portfolios were not available prior to that period.

The correlation matrix for returns of the 7 WML portfolios is presented in table 10. All portfolios have positive and statistically significant correlations with each other. The highest correlations are observed between portfolios of stocks (up to 0.9), and the lowest correlations are observed across asset classes. But the positive correlations suggest that all momentum portfolios may be exposed to the same risks, even if the exposures vary.

In figure 6, I plot predicted and realized returns of the 48 momentum portfolios. In the left-hand-side figure, the predictions are made by the CAPM. There are three clear clusters of momentum portfolios. The 7 portfolios in the oval cluster are the WML portfolios. The 5 portfolios in the rhombus cluster are the currency portfolios. The portfolios in the rectangle cluster are equity portfolios of stocks and country indices. Within each cluster, all predicted returns are similar whereas the actual returns vary significantly. The CAPM is not able to explain the momentum portfolio returns.

When the DR-CAPM is used to predict returns (the right-hand-side figure), all portfolios are scattered around the 45-degree line with R^2 of 57%. The currency portfolios are closer to the origin and the equity portfolios are further from it. But there are no visible clusters, and all WML portfolios are close to the 45-degree line. Therefore, the DR-CAPM has a high explanatory power for the single cross-section of 48 momentum portfolio.

Table 11 reports the Fama-MacBeth estimates[10] of cross-sectional regressions with alternative specifications. The traditional CAPM is rejected because the market risk premium is statistically insignificant in case with a constant and the R^2 is negative in case of no constant. When the market and momentum factors are included (column (3)), both are significant, the intercept becomes insignificant, and the adjusted R^2 increases from 16 to 49 percent. Therefore, inclusion of the momentum risk factor improves the explanatory power of the CAPM dramatically.

The DR-CAPM has an even higher adjusted R^2, and the both premiums are statistically significant, whereas the intercept is not[11]. The relative downside beta premium is 3-4 percent per month which can be considered a unifying estimate across different markets around the world.

[10] Since the GMM estimates are similar to the Fama-MacBeth ones for all asset classes, the GMM estimates are not reported in the remainder of the paper to save space.
[11] The intercepts in specifications (3)-(5) are statistically insignificant and can easily be dropped out without affecting the results.

Similar estimates of the downside beta premium were obtained in Dobrynskaya (2014) and Lettau et al. (2014) for equity portfolios sorted by other characteristics and currency carry portfolios.

Most importantly, inclusion of the global momentum factor (column (5)) does not improve the explanatory power of the DR-CAPM, and the momentum factor itself is statistically insignificant. After controlling for the downside-upside risk asymmetry, the momentum factor becomes redundant.

4.7 EXTENSIONS

4.7.1 CURRENCY MOMENTUM AND CARRY

Several recent studies have shown that the downside risk explains high returns to carry portfolios – portfolios with long positions in high-interest-rate currencies and short positions in low-interest-rate currencies (e.g. Dobrynskaya, 2014; Lettau et al., 2014). Given that the returns to currency momentum and carry portfolios are uncorrelated (Menkhoff et al., 2012), how can the same downside-risk-based explanation be valid in the both cases?

To answer this question, I form 5 carry portfolios by sorting the same 45 currencies, which were used to form the currency momentum portfolios studied in section 4.5, by the forward discounts. Sorting by the forward discounts is equivalent to sorting by the interest rate differentials if the covered interest parity is satisfied. I adopt this approach to be consistent with the recent literature on carry trades. Every month, 1/5 of currencies with the lowest forward discounts are allocated to portfolio 1, the next 1/5 of currencies in the ranking are allocated to portfolio 2, and so on. I also form the HML carry portfolio which has a long position in portfolio 5 and a short position in portfolio 1. The HML portfolio resembles the most aggressive carry trade strategy which exploits the largest interest rate differentials.

Table 12 reports the return and risk characteristics of the 5 currency momentum and 5 carry portfolios. Both the WML and the HML portfolios generate high excess returns (7.76% and 12.13% per annum, respectively). These returns are uncorrelated indeed, the correlation coefficient is -0.11.

The reason is that the both portfolios have different loadings on the global market factor. The WML portfolio has a market beta of -0.03 because the market betas of the past lower and past winner portfolios (and all other portfolios in the ranking) are almost the same. The HML portfolio, on the contrary, has a positive and statistically significant market beta of 0.14 because carry portfolios of higher rank have higher market betas.

When the regular market beta is separated into the upside and downside components, we observe surprising similarities between the momentum and carry portfolios. The downside betas of 5 momentum portfolios and 5 carry portfolios are increasing with the portfolio rank, and therefore, both the WML and the HML portfolios have positive exposure to the downside risk, although the downside beta of the HML portfolio is higher. The patterns of the *relative* downside betas of the currency momentum and carry portfolios are almost identical.

What is different between the momentum and carry portfolios is their behavior during the growing markets. The upside betas of the 5 carry portfolios are roughly the same, and that is why their returns can solely be explained by their downside risk exposure (Dobrynskaya, 2014). The upside betas of the momentum portfolios are monotonically decreasing with the portfolio rank, and the WML portfolio has a negative upside beta[12]. The different upside betas of the WML and the HML portfolios explain why these portfolios are uncorrelated and have different regular market betas. In fact, they are uncorrelated only in the growing markets, but they behave similarly in the falling markets.

Therefore, to price momentum portfolios, the differences in their exposure to the upside risk should also be taken into account[13]. The DR-CAPM with relative downside betas is a convenient model because the relative downside beta, by construction, reflects the relative upside beta and the asymmetry in betas. But despite the different upside betas, the *relative* upside betas and the *asymmetry* in betas of the momentum and carry portfolios are very similar.

[12] This is consistent with the findings of Moscowitz et al. (2015) about momentum crashes when the market rebounds.
[13] Lettau et al. (2014) could not find strong support for the downside risk explanation of momentum returns exactly because they neglected the upside risk component.

The upside and downside betas of the momentum and carry portfolios are illustrated in Figure 7. In the top diagrams, the patterns of the regular betas of the momentum and carry portfolios are different because their upside betas are different. But the bottom diagrams, which exhibit the *relative* upside and downside betas, look very similar and resemble figure 1 for the US stock portfolios. The HML portfolio has a greater asymmetry in risks than the WML portfolio, and it yields higher returns, what is consistent with the predictions of the DR-CAPM.

The predicted and realized returns of the momentum and carry portfolios assuming the CAPM and the DR-CAPM are plotted in Figure 8. The CAPM cannot explain the returns to either momentum or carry portfolios, and the WML and the HML portfolios are obvious outliers. DR-CAPM, as before, has a very high explanatory power for the both sets of portfolios. All portfolios are scattered close to the 45-degree line, and the HML and WML portfolios are priced rather precisely. But it should be noticed that all carry portfolios generally outperform all momentum portfolios, i.e. their risk-adjusted alphas are higher.

Table 13 reports the Fama-MacBeth cross-sectional estimation results for the momentum and carry portfolios separately and jointly. In all cases, the DR-CAPM performs much better than the traditional CAPM. The relative downside beta premium is always highly significant, whereas the beta premium is not. The intercepts of the DR-CAPM are all insignificant, and the R^2 is always much higher than in case of the CAPM. Most importantly, whereas the CAPM has some explanatory power for the carry portfolios and none for the momentum portfolios, the DR-CAPM has high explanatory power for the both sets of portfolios, because it takes into account the differences in their downside *and* upside risks. Therefore, the DR-CAPM is a unifying explanation for these seemingly unrelated portfolios because, in fact, they have similar downside-upside risk asymmetry.

4.7.2 SHORT-TERM REVERSAL PORTFOLIOS

As another extension, I analyze short-term reversal portfolios which have also been shown to generate abnormal returns. These portfolios are sorted by the previous month return and held for one month.

There is a strong short-term reversal effect. For instance, the value-weighted loser-minus-winner one-month reversal portfolio had an average return of 11 percent per annum during 1927-2013. Figure 9 plots the predicted versus realized returns of the equal-weighted and value-weighted reversal portfolios where the predictions are made by the traditional CAPM (left panel) and the DR-CAPM (right panel). As in the case of momentum portfolios, the traditional CAPM has weak explanatory power for the cross-section of reversal portfolios, but the DR-CAPM performs well again (the R^2 is 58 and 80 percent).

In the cross-sectional tests (table 14), the relative downside beta premium is lower in magnitude than in the case of momentum portfolios, but it is still statistically significant. The downside-upside risk asymmetry explains the returns to the short-term reversal portfolios as well[14]. The recent past loser portfolios generally have higher relative downside betas and lower relative upside betas (greater beta asymmetry) than the recent past winner portfolios and require risk premiums.

5 CONCLUSION

Momentum strategies generate high returns with insignificant overall market risk. Therefore, the momentum return is either evidence for market inefficiency, or a compensation for another risk factor. In this paper, I provide a novel risk-based explanation for momentum returns. I show that once we separate the overall market risk into the upside and downside risks, the momentum

[14] But the exposure to the upside and downside risks does not explain returns to long-term reversal (value) portfolios. The results for Asness et al. (2013) value portfolios are available upon request. Whereas the results for their momentum portfolios, reported in the appendix to this paper, are similar to the results for the Fama-French momentum portfolios reported in the main body, the returns to their value portfolios, sorted by 5-year preceding returns, cannot be explained by the DR-CAPM. The value premium remains a puzzle.

strategies appear to have asymmetric risk profile: they are exposed to the downside risk, but hedge against the upside risk. Since the upside and downside risks are priced differently, the momentum return is a compensation for this risk asymmetry.

I consider US, global and regional momentum and reversal portfolios of individual stocks and global momentum portfolios of country indices and currencies. I show that the asymmetry in upside and downside market risks explains all cross-sections of momentum portfolio returns well. The past loser portfolios have lower relative downside risk and higher relative upside risk, whereas the past winner portfolios have higher relative downside risk and lower relative upside risk and, hence, greater downside-upside risk asymmetry. For any set of momentum portfolios, the risk asymmetry is monotonically increasing with portfolio rank. The DR-CAPM explains the cross-section of momentum returns much better than the traditional CAPM. It is also a unifying explanation for returns of the seemingly unrelated currency momentum and carry portfolios. The estimates of the relative downside beta premium are always statistically significant and similar in magnitude to the estimates obtained for other asset markets. Therefore, the momentum portfolio returns are not anomalous, but rather a compensation for their upside and downside market risks.

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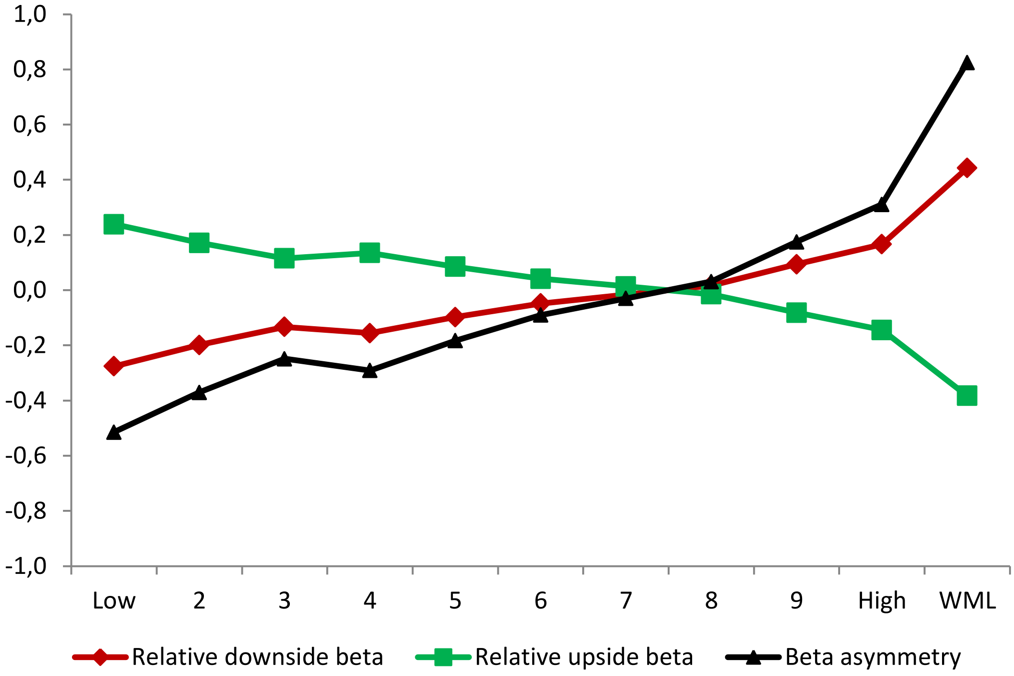
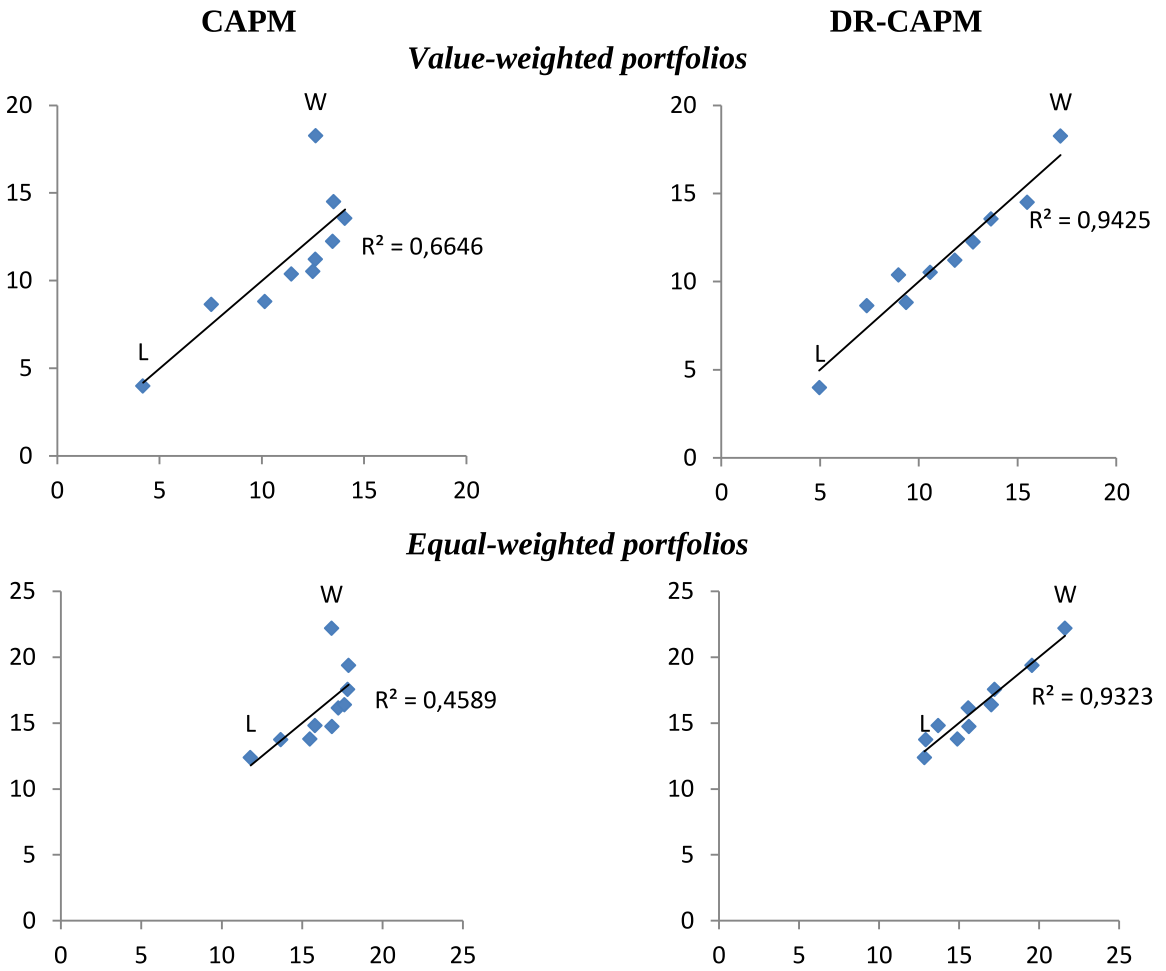
Figure 1. Relative upside and downside risks of US momentum portfolios



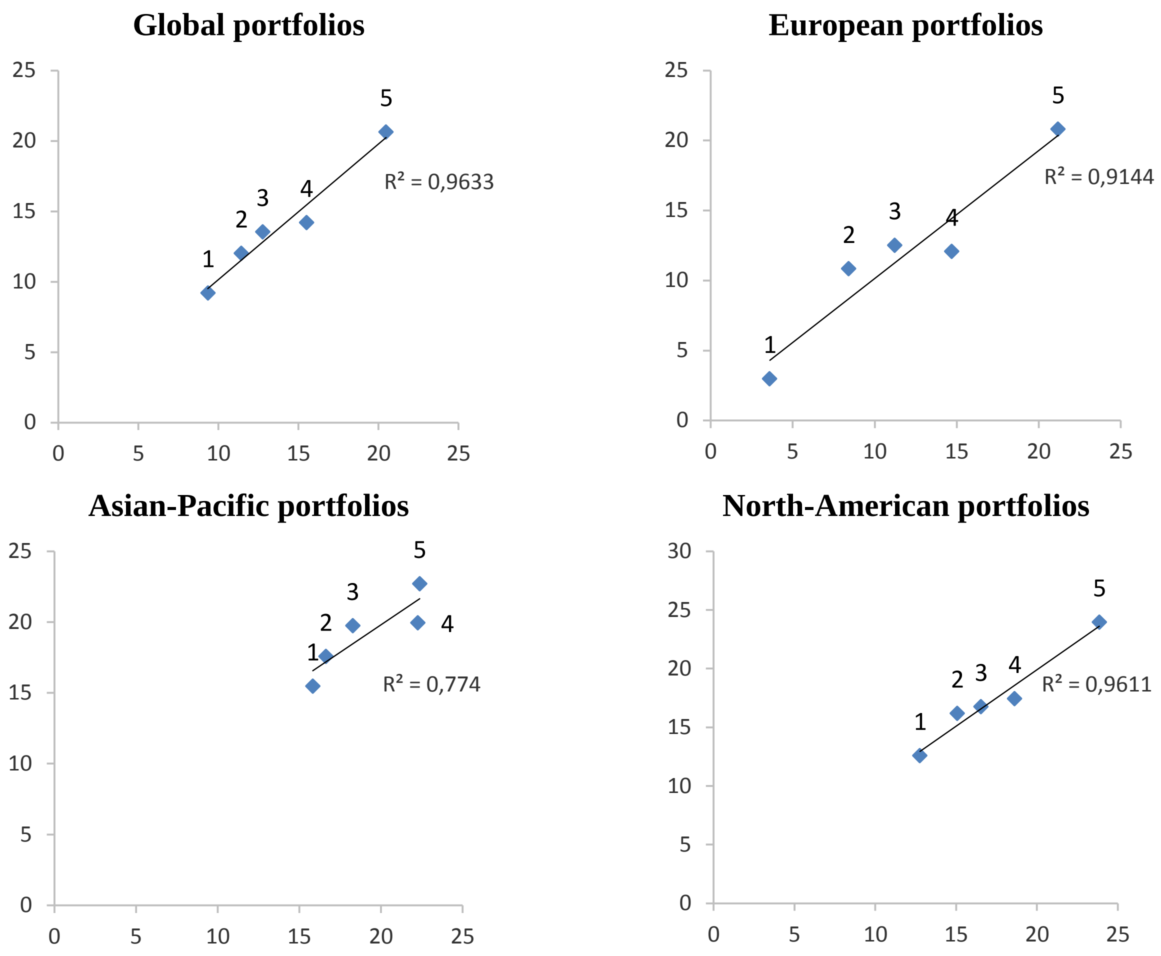
The figure shows the OLS estimates of relative downside and upside betas and beta asymmetry (β^{-}-β^{+}) of 10US value-weighted momentum portfolios, formed by sorting stocks at time t by their total return in time t-12 to t-2, and the winner-minus-loser (WML) portfolio. January 1927 - July 2013.

Figure 2. Predicted versus realized returns of US momentum portfolios



The figures show predicted (on the horizontal axis) versus realized (on the vertical axis) returns of 10 US momentum portfolios, formed by sorting stocks at time t by their total return in time t-12 to t-2.The predictions are made assuming the CAPM (left-hand side) and the DR-CAPM (right-hand side) using the OLS estimates. January 1927 - July 2013.

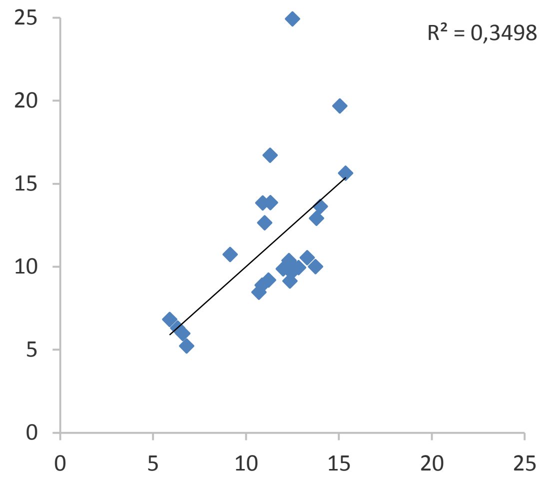
Figure 3. Predicted versus realized returns of global and regional momentum portfolios: DR-CAPM



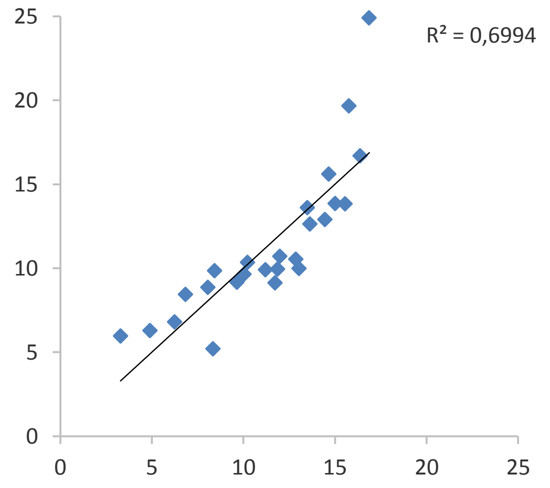
The figures show predicted (on the horizontal axis) versus realized (on the vertical axis) returns of global and regional momentum portfolios, formed by sorting stocks in the corresponding region at time t by their total return in time t-12 to t-2. The prediction is made assuming the DR-CAPM using the OLS estimates. Nov 1990 - Aug 2013.

Figure 4. Predicted versus realized returns of 25 global size-momentum portfolios

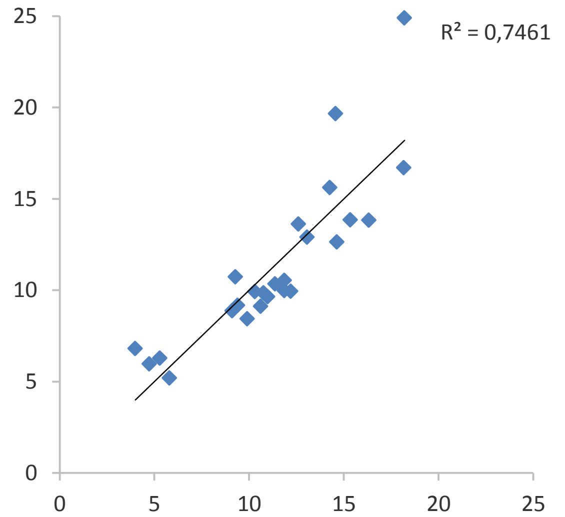
CAPM



3-factor CAPM with the market, size and momentum factors

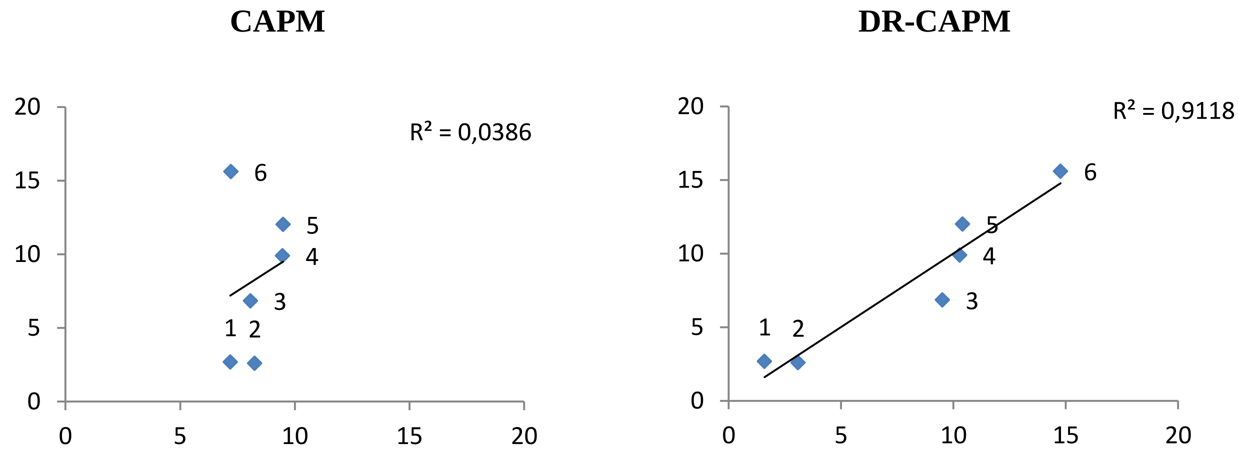


DR-CAPM



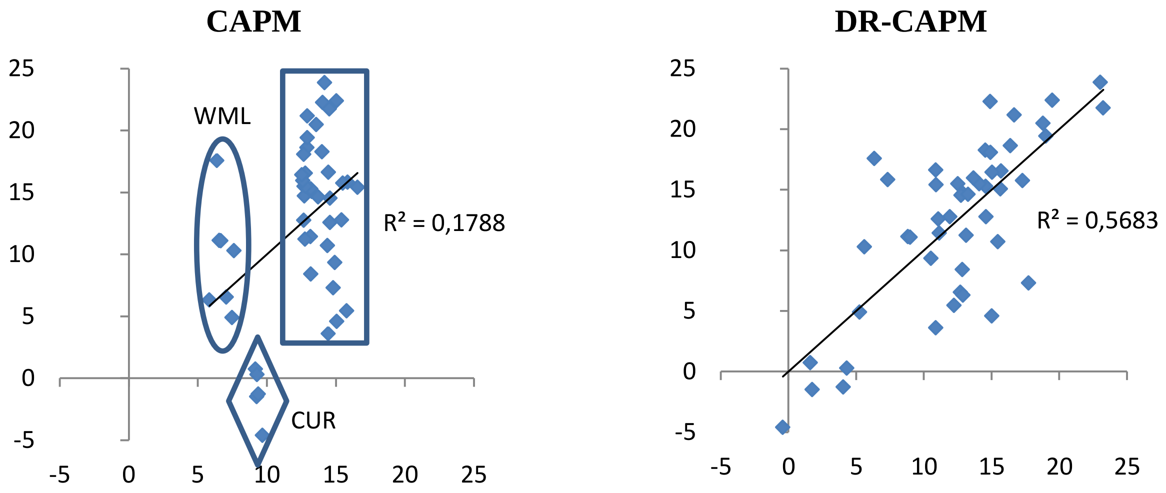
The figures show predicted (on the horizontal axis) versus realized (on the vertical axis) returns of 25 global double-sorted size-momentum portfolios. The predictions are made using alternative factor models and OLS estimates. Nov 1990 - Aug 2013.

Figure 5. Predicted versus realized returns of momentum portfolios of country indices



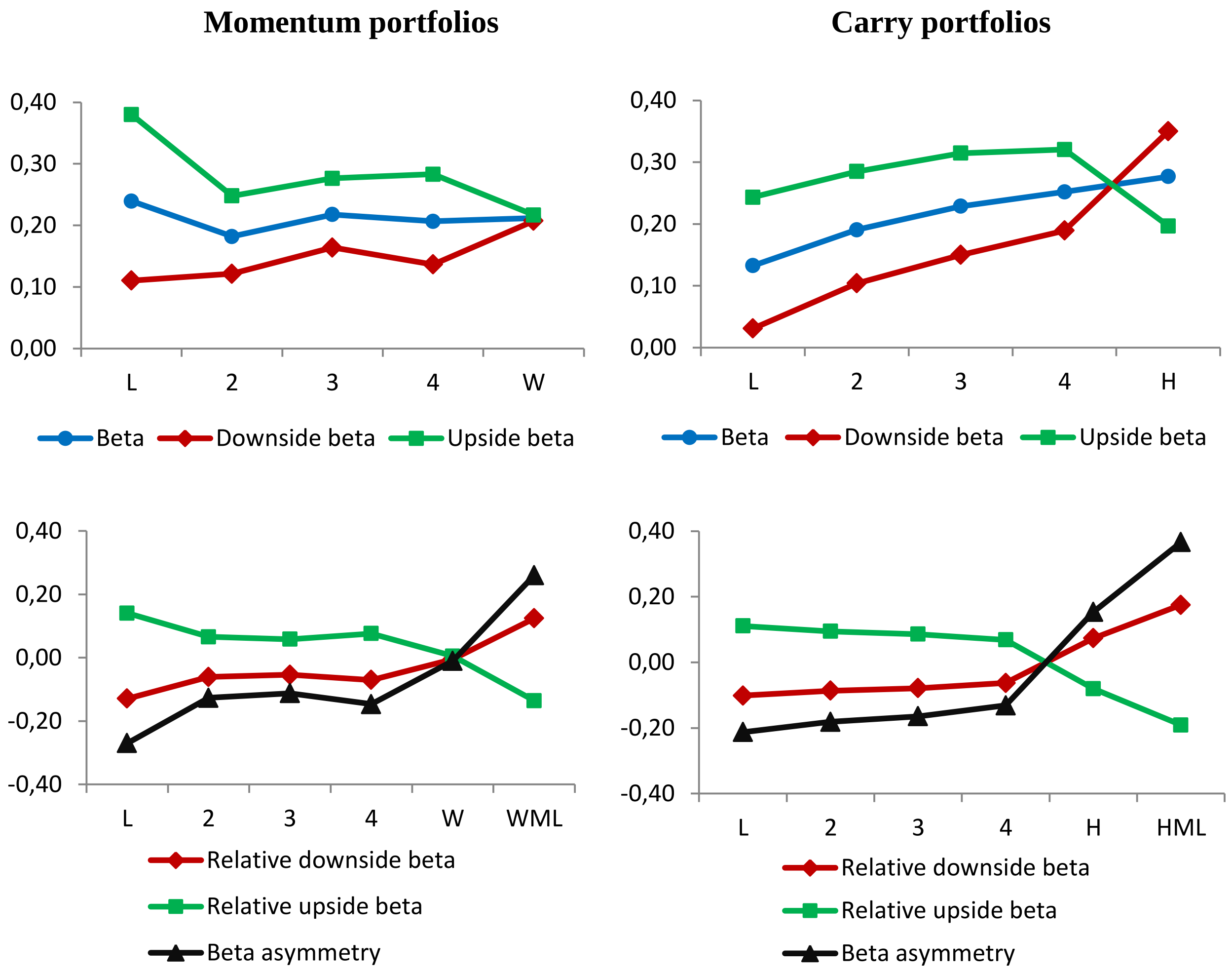
The figures show predicted (on the horizontal axis) versus realized (on the vertical axis) returns of 6 global momentum portfolios, formed by sorting 40 country indices at time t by their total return in time t-12 to t-2The predictions are made assuming the CAPM (left-hand side) and the DR-CAPM (right-hand side) using the OLS estimates. Jan 1984 - Aug 2013.

Figure 6. Predicted versus realized returns of 48 global and regional momentum portfolios



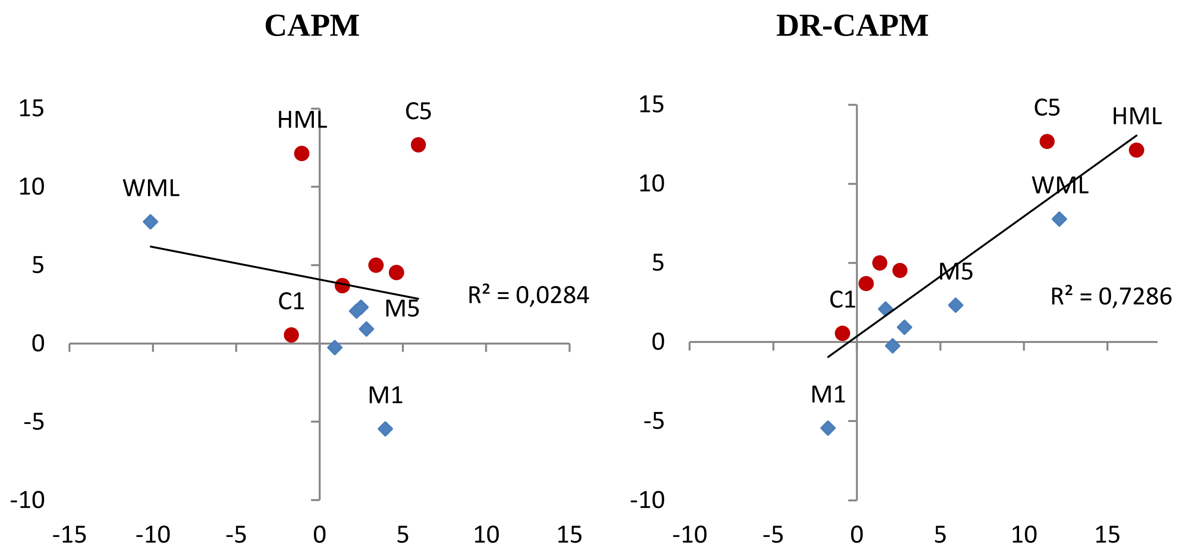
The figures show predicted (on the horizontal axis) versus realized (on the vertical axis) returns of 48 global and regional momentum portfolios (10 US portfolios, 5 global, 5 European, 5 Asian-Pacific and 5 North-American portfolios of stocks, 6 portfolios of country indices and 5 currency portfolios, and 7 corresponding WML portfolios). All portfolios are formed by sorting base assets at time t by their total return in time t-12 to t-2. The predictions are made assuming the CAPM (left-hand side) and the DR-CAPM (right-hand side) using the OLS estimates. Nov 1990 - Aug 2013.

Figure 7. Upside and downside risks of currency momentum and carry portfolios



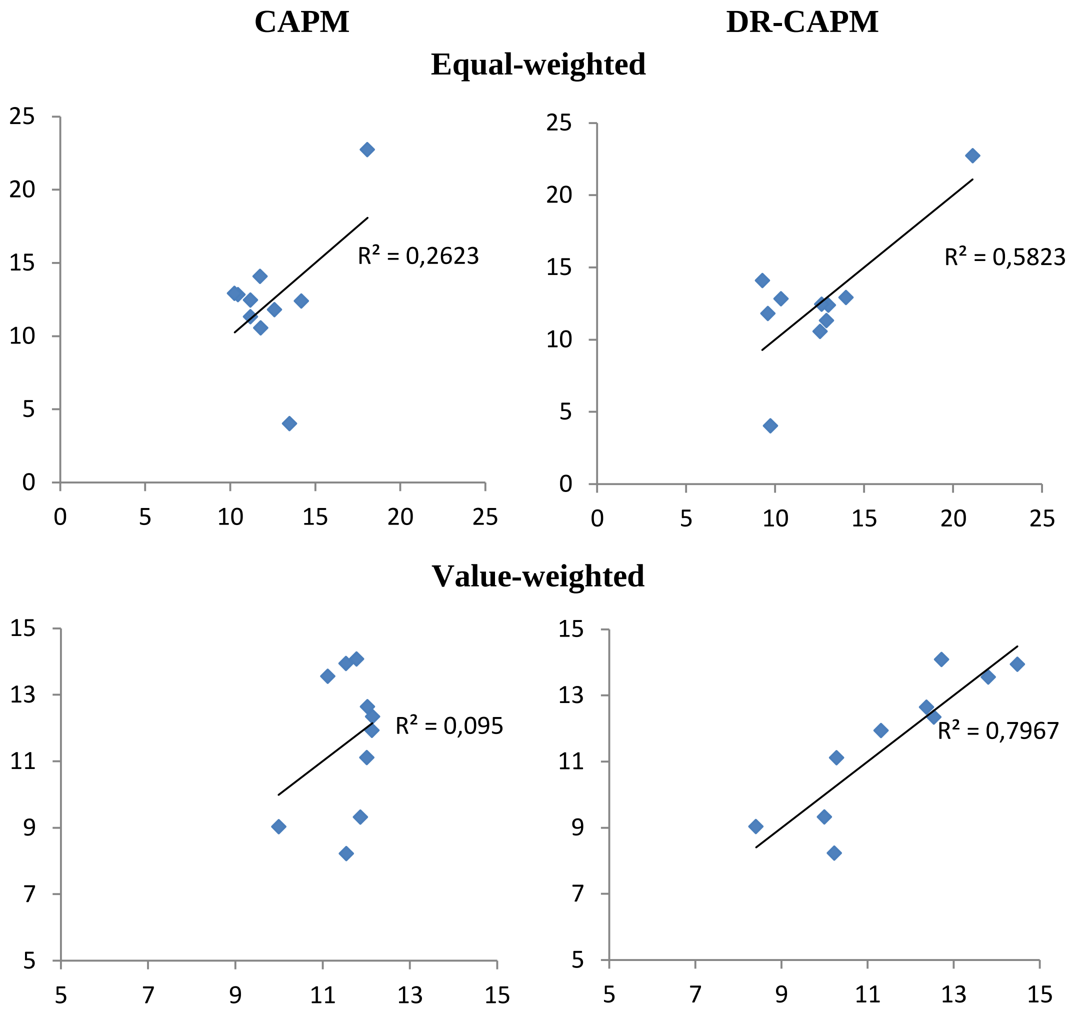
The figure shows the OLS estimates of the regular betas, downside and upside betas (in the top panel) and the relative downside betas, relative upside betas and beta asymmetry (in the bottom panel) of 5 currency momentum portfolios, formed by sorting currencies at time t by their returns in time t-12 to t-2 and held for 1 month (in the left-hand-side diagrams), and 5 carry portfolios, formed by sorting currencies by the interest rate differentials (in the right-hand-side diagrams). The WML and the HML are the corresponding long-short portfolios. Nov 1984 – June 2013.

Figure 8. Predicted versus realized returns of currency momentum and carry portfolios



The figures show predicted (on the horizontal axis) versus realized (on the vertical axis) returns of 5 currency momentum portfolios, formed by sorting currencies at time t by their returns in time t-12 to t-2 and held for 1 month (marked by rhombuses), and 5 carry portfolios, formed by sorting currencies by the interest rate differentials (marked by circles). The WML and the HML are the corresponding long-short portfolios. The predictions are made assuming the CAPM (left-hand side) and the DR-CAPM (right-hand side) using the OLS estimates. Nov 1984 – June 2013.

Figure 9. Predicted versus realized returns of US short-term reversal portfolios



The figures show predicted (on the horizontal axis) versus realized (on the vertical axis) returns of 10 US short-term reversal portfolios, formed by sorting individual stocks in month t by their return in month t-1. The predictions are made assuming the CAPM (left-hand side) and the DR-CAPM (right-hand side) using the OLS estimates. Jan 1984 - Jul 2013.

Table 1. Return and risk characteristics of US momentum portfolios

The table reports return and risk characteristics of 10 value-weighted and 10 equal-weighted US momentum portfolios, formed by sorting NYSE, AMEX, and NASDAQ stocks at time t by their total return in time t-12 to t-2, and the corresponding winner-minus-loser (WML) portfolios. The returns are annualized and expressed in percent. The reported betas are the OLS time-series estimates. The US market index serves as a proxy for the market portfolio. The momentum factor is the corresponding WML portfolio. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors. Jan 1927 – July 2013.

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**WML**
	Value-weighted										
Average return	3.99	8.64	8.81	10.37	10.52	11.22	12.24	13.56	14.50	18.26	14.27
Standard deviation	117.98	98.05	84.72	77.30	71.82	69.90	66.74	64.74	68.33	78.62	95.44
Skewness	1.82	1.79	1.48	1.46	1.24	0.69	0.12	0.00	-0.32	-0.50	-2.44
Market beta (β)	1.55	1.34	1.18	1.10	1.03	1.03	0.97	0.94	0.97	1.02	-0.52
	[18.34]	[16.16]	[17.58]	[23.61]	[21.37]	[35.25]	[45.72]	[45.46]	[29.33]	[15.14]	[-3.54]
Relative downside beta (β^{-}-β)	-0.28	-0.20	-0.13	-0.16	-0.10	-0.05	-0.02	0.02	0.09	0.17	0.44
Relative upside beta (β^{+}-β)	0.24	0.17	0.12	0.13	0.08	0.04	0.01	-0.01	-0.08	-0.14	-0.38
Beta asymmetry	-0.51	-0.37	-0.25	-0.29	-0.18	-0.09	-0.03	0.03	0.18	0.31	0.83
(β^{-}-β^{+})	[-2.67]	[-1.98]	[-1.76]	[-3.33]	[-1.45]	[-1.54]	[-0.55]	[0.71]	[2.23]	[2.37]	[2.64]
US momentum beta	-0.63	-0.39	-0.28	-0.19	-0.14	-0.05	0.02	0.10	0.17	0.37	1.00
	[-33.47]	[-17.06]	[-12.40]	[-12.04]	[-5.45]	[-2.72]	[1.46]	[7.02]	[10.88]	[19.67]	
	Equal-weighted										
Average return	12.38	13.73	13.78	14.80	14.73	16.15	16.39	17.56	19.38	22.18	9.80
Standard deviation	134.99	109.70	94.74	91.40	83.32	79.89	77.64	76.57	77.59	89.20	93.15
Skewness	2.85	3.12	2.08	2.53	1.74	1.44	1.07	0.94	0.10	0.11	-4.25
Market beta (β)	1.59	1.43	1.28	1.25	1.16	1.13	1.09	1.08	1.07	1.16	-0.43
	[16.26]	[14.09]	[19.86]	[15.89]	[21.45]	[24.08]	[26.40]	[22.62]	[28.40]	[17.77]	[-3.08]
Relative downside beta (β^{-}-β)	-0.38	-0.32	-0.18	-0.23	-0.11	-0.10	-0.03	-0.01	0.09	0.15	0.53
Relative upside beta (β^{+}-β)	0.33	0.28	0.16	0.20	0.10	0.09	0.02	0.01	-0.08	-0.13	-0.46
Beta asymmetry	-0.71	-0.60	-0.34	-0.42	-0.21	-0.19	-0.05	-0.02	0.17	0.28	0.99
(β^{-}-β^{+})	[-2.69]	[-2.15]	[-2.10]	[-2.23]	[-1.50]	[-1.64]	[-0.47]	[-0.16]	[1.74]	[1.81]	[2.81]
US momentum beta	-0.83	-0.50	-0.34	-0.29	-0.21	-0.14	-0.07	0.00	0.06	0.17	1.00
	[-24.65]	[-12.00]	[-15.84]	[-9.36]	[-7.47]	[-6.64]	[-3.52]	[-0.15]	[2.53]	[4.91]	

Table 2. Cross-sectional regressions for US momentum portfolios

The table reports the Fama-MacBeth and efficient GMM estimates of risk premiums (in percent per month) obtained for 10 value-weighted and 10 equal-weighted US momentum portfolios. The US market index serves as a proxy for the market portfolio. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors with 12 lags. J statistics for the over-identifying restrictions is also reported. P-value for J statistics is in parentheses. Jan 1927 – July 2013.

	Fama-MacBeth				GMM			
	CAPM		DR-CAPM		CAPM		DR-CAPM	
	Value-weighted							
Beta	0.53	-1.35	0.75	-0.19	1.11	-0.81	0.71	0.12
	[2.96]	[-3.71]	[4.20]	[-0.51]	[7.11]	[-2.31]	[3.93]	[0.15]
Relative downside beta			3.11	2.07			4.29	3.03
			[6.08]	[3.62]			[2.21]	[2.04]
Constant		2.15		0.99		1.57		0.65
		[6.37]		[2.95]		[4.76]		[0.79]
R^2 adj	-0.66	0.62	0.80	0.93				
J-stat					20.49	22.57	4.57	4.39
					(0.02)	(0.00)	(0.80)	(0.73)
	Equal-weighted							
Beta	0.83	-0.98	1.06	0.65	1.26	0.23	1.06	0.98
	[4.04]	[-2.28]	[5.18]	[1.34]	[7.28]	[0.62]	[4.78]	[1.36]
Relative downside beta			2.25	1.90			2.27	2.19
			[5.59]	[4.10]			[2.84]	[2.25]
Constant		2.25		0.48		0.84		0.10
		[5.18]		[1.02]		[2.37]		[0.13]
R^2 adj	-1.13	0.39	0.90	0.91				
J-stat					19.09	25.67	1.38	1.72
					(0.02)	(0.00)	(0.99)	(0.97)

Table 3. Return and risk characteristics of global momentum portfolios

The table reports return and risk characteristics of 5 global equal-weighted momentum portfolios (panel A) and 5 regional equal-weighted momentum portfolios (panels B-D), and the corresponding winner-minus-loser (WML) momentum portfolios. All portfolios are formed by sorting individual stocks in the corresponding region at time t by their total return in time t-12 to t-2. All returns are converted to USD, annualized and expressed in percent. The reported betas are the OLS time-series estimates. The MSCI global market index serves as a proxy for the market portfolio. The global Fama-French momentum factor is used to estimate the momentum betas. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors. Nov 1990 – Aug 2013.

	P1	**P2**	**P3**	**P4**	**P5**	**WML**
Panel A: Global momentum portfolios						
Average return (% pa)	9.35	11.43	12.76	15.50	20.48	11.13
Standard deviation	75.04	51.93	46.72	48.23	62.46	47.84
Skewness	0.07	-0.64	-0.90	-0.85	-0.94	-1.73
Global market beta (β)	1.15	0.86	0.78	0.79	0.93	-0.22
	[11.50]	[14.06]	[17.05]	[18.34]	[15.58]	[-2.06]
Relative downside beta (β^--β)	-0.04	0.03	0.07	0.08	0.18	0.22
Relative upside beta (β^+-β)	0.05	-0.04	-0.08	-0.09	-0.21	-0.26
Beta asymmetry (β^--β^+)	-0.10	0.07	0.15	0.17	0.39	0.49
	[-0.32]	[0.38]	[1.18]	[1.82]	[3.15]	[2.87]
Momentum beta	-0.44	-0.16	0.00	0.18	0.46	0.90
	[-3.38]	[-2.88]	[0.12]	[3.65]	[4.99]	[17.99]
Av. number of stocks	5545	2558	2204	2145	2932	
Panel B: European momentum portfolios						
Average return (% pa)	3.60	8.42	11.23	14.71	21.18	17.58
Standard deviation	74.19	56.98	52.79	53.09	61.65	48.30
Skewness	0.07	-0.89	-0.98	-0.82	-0.61	-1.47
Global market beta (β)	1.07	0.87	0.80	0.79	0.82	-0.25
	[9.41]	[11.08]	[11.86]	[12.36]	[12.03]	[-2.27]
Relative downside beta (β^--β)	-0.02	0.07	0.09	0.09	0.16	0.18
Relative upside beta (β^+-β)	0.02	-0.08	-0.10	-0.10	-0.19	-0.21
Beta asymmetry (β^--β^+)	-0.04	0.15	0.19	0.19	0.34	0.39
	[-0.13]	[0.60]	[0.99]	[1.18]	[2.07]	[2.26]
Momentum beta	-0.43	-0.17	-0.04	0.11	0.30	0.73
	[-3.50]	[-2.80]	[-0.76]	[2.31]	[4.58]	[8.99]
Av. number of stocks	1968	884	750	705	966	

Table 3 (Continued). Return and risk characteristics of global momentum portfolios

The table reports return and risk characteristics of 5 global equal-weighted momentum portfolios (panel A) and 5 regional equal-weighted momentum portfolios (panels B-D), and the corresponding winner-minus-loser (WML) momentum portfolios. All portfolios are formed by sorting individual stocks in the corresponding region at time t by their total return in time t-12 to t-2. All returns are converted to USD, annualized and expressed in percent. The reported betas are the OLS time-series estimates. The MSCI global market index serves as a proxy for the market portfolio. The global Fama-French momentum factor is used to estimate the momentum betas. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors. Nov 1990 – Aug 2013.

	P1	**P2**	**P3**	**P4**	**P5**	**WML**
Panel C: Asian-Pacific momentum portfolios						
Average return (% pa)	15.83	16.63	18.28	22.27	22.38	6.55
Standard deviation	102.75	79.77	72.61	74.89	91.98	56.46
Skewness	0.30	-0.06	-0.63	-0.53	-1.03	-2.22
Global market beta (β)	1.30	1.08	1.00	1.00	1.17	-0.13
	[9.22]	[10.27]	[12.48]	[12.02]	[11.46]	[-2.66]
Relative downside beta (β^{-}-β)	-0.15	-0.02	0.07	0.08	0.14	0.29
Relative upside beta (β^{+}-β)	0.17	0.02	-0.09	-0.09	-0.17	-0.34
Beta asymmetry (β^{-}-β^{+})	-0.32	-0.05	0.16	0.17	0.31	0.62
	[-0.73]	[-0.14]	[0.70]	[0.80]	[1.38]	[3.06]
Momentum beta	-0.19	-0.05	0.05	0.19	0.36	0.55
	[-1.04]	[-0.39]	[0.63]	[1.94]	[3.26]	[4.63]
Av. number of stocks	885	319	269	270	413	
Panel D: North-American momentum portfolios						
Average return (% pa)	12.77	15.07	16.54	18.63	23.86	11.09
Standard deviation	88.11	55.76	51.20	54.13	77.67	64.30
Skewness	0.31	-0.98	-1.04	-0.82	-0.28	-1.34
Global market beta (β)	1.23	0.88	0.80	0.82	1.03	-0.20
	[10.67]	[13.67]	[16.18]	[16.68]	[13.31]	[-3.07]
Relative downside beta (β^{-}-β)	0.02	0.12	0.14	0.15	0.25	0.22
Relative upside beta (β^{+}-β)	-0.03	-0.15	-0.17	-0.18	-0.29	-0.26
Beta asymmetry (β^{-}-β^{+})	0.05	0.27	0.31	0.33	0.54	0.49
	[0.16]	[1.49]	[2.37]	[2.94]	[2.88]	[2.08]
Momentum beta	-0.51	-0.14	0.05	0.25	0.66	1.18
	[-2.90]	[-2.60]	[0.91]	[3.73]	[4.22]	[18.29]
Av. number of stocks	1990	861	733	753	1124	

Table 4. Cross-sectional regressions for global momentum portfolios

The table reports the Fama-MacBeth and efficient GMM estimates of risk premiums (in percent per month) obtained for global and regional equal-weighted momentum portfolios (five in each case). All portfolios are formed by sorting individual stocks in the corresponding region at time t by their total return in time t-12 to t-2. The MSCI global market index serves as a proxy for the market portfolio. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors with 12 lags. J statistics for the over-identifying restrictions is also reported. P-value for J statistics is in parentheses. Nov 1990 – Aug 2013.

	Fama-MacBeth				GMM			
	CAPM		DR-CAPM		CAPM		DR-CAPM	
				Global				
Beta	0.96	-0.80	0.66	0.43	1.83	-0.09	1.20	-0.21
	[2.44]	[-1.14]	[1.61]	[0.65]	[5.47]	[-0.17]	[2.54]	[-0.11]
Relative downside beta			4.93	4.68			4.15	5.71
			[3.97]	[3.39]			[2.32]	[2.53]
Constant		1.63		0.22		0.84		0.95
		[3.61]		[0.50]		[2.44]		[0.80]
R^2 adj	-0.45	-0.18	0.94	0.93				
J-stat					7.83	16.31	3.89	3.02
					(0.10)	(0.00)	(0.27)	(0.22)
				European				
Beta	0.78	-3.49	0.12	0.90	2.10	-1.69	0.99	1.51
	[1.78]	[-3.65]	[0.25]	[0.68]	[4.91]	[-2.62]	[1.36]	[0.61]
Relative downside beta			8.36	9.62			5.58	5.90
			[5.56]	[3.68]			[2.43]	[2.19]
Constant		3.77		-0.78		2.02		-0.47
		[5.24]		[-0.66]		[4.09]		[-0.22]
R^2 adj	-0.28	0.38	0.87	0.83				
J-stat					8.11	95.78	1.42	1.40
					(0.09)	(0.00)	(0.70)	(0.50)
				Asian-Pacific				
Beta	1.18	-0.76	1.14	0.53	2.32	-0.66	0.53	0.81
	[2.36]	[-0.86]	[2.24]	[0.67]	[5.09]	[-0.96]	[0.44]	[0.40]
Relative downside beta			2.79	2.35			8.07	10.11
			[2.56]	[2.14]			[1.53]	[0.75]
Constant		2.17		0.69		1.98		-0.62
		[3.15]		[0.99]		[3.23]		[-0.18]
R^2 adj	-0.79	-0.15	0.63	0.55				
J-stat					8.01	13.42	1.92	1.83
					(0.09)	(0.00)	(0.59)	(0.40)
				North-American				
Beta	1.21	-0.42	0.56	0.49	2.04	13.25	0.61	0.40
	[3.13]	[-0.67]	[1.29]	[0.79]	[5.32]	[1.10]	[0.51]	[0.38]
Relative downside beta			4.80	4.69			5.78	4.12
			[3.57]	[2.78]			[2.02]	[2.05]
Constant		1.60		0.09		-9.58		0.44
		[3.64]		[0.16]		[-0.96]		[0.69]
R^2 adj	-0.66	-0.27	0.95	0.92				
J-stat					8.96	13.69	1.14	0.76
					(0.06)	(0.00)	(0.77)	(0.69)

Table 5. Returns and asymmetric betas of 25 global size-momentum portfolios

The table reports returns and betas of 25 global double-sorted size-momentum portfolios, the winner-minus-loser (WML) momentum portfolios and the small-minus-big (SMB) size portfolios. The returns are annualized and expressed in percent. The betas are the OLS time-series estimates. The global market index serves as a proxy for the market portfolio. T-statistics for the long-short portfolios are reported in brackets. Nov 1990 – Aug 2013.

	P1 - loser	P2	P3	P4	P5 - winner	**WML**
	Average returns, % pa					
P1 - small	10.72	13.61	15.62	19.67	24.91	**14.18**
P2	5.20	9.12	9.98	12.91	16.70	**11.51**
P3	6.80	9.18	9.92	10.54	13.83	**7.03**
P4	6.28	8.87	9.65	9.95	13.85	**7.56**
P5 - big	5.96	8.44	9.86	10.35	12.63	**6.67**
SMB	**4.76**	**5.17**	**5.75**	**9.32**	**12.27**	
	Beta asymmetry (β^--β^+)					
P1 - small	-0.03	0.14	0.23	0.24	0.43	**0.46 [3.17]**
P2	-0.21	0.04	0.10	0.17	0.43	**0.64 [3.53]**
P3	-0.30	-0.02	0.02	0.10	0.33	**0.64 [3.29]**
P4	-0.24	-0.04	0.06	0.12	0.28	**0.52 [2.52]**
P5 - big	-0.26	0.00	0.05	0.08	0.25	**0.51 [2.39]**
SMB	**0.23 [1.32]**	**0.14 [1.07]**	**0.18 [1.60]**	**0.16 [1.34]**	**0.18 [1.02]**	
	Relative downside beta (β^--β)					
P1 - small	-0.01	0.07	0.10	0.11	0.20	**0.21**
P2	-0.10	0.02	0.05	0.08	0.20	**0.29**
P3	-0.14	-0.01	0.01	0.05	0.15	**0.29**
P4	-0.11	-0.02	0.03	0.06	0.13	**0.24**
P5 - big	-0.12	0.00	0.02	0.04	0.11	**0.23**
SMB	**0.11**	**0.06**	**0.08**	**0.08**	**0.08**	
	Relative upside beta (β^+-β)					
P1 - small	0.02	-0.08	-0.12	-0.13	-0.23	**-0.25**
P2	0.11	-0.02	-0.06	-0.09	-0.23	**-0.35**
P3	0.16	0.01	-0.01	-0.06	-0.18	**-0.34**
P4	0.13	0.02	-0.03	-0.07	-0.15	**-0.28**
P5 - big	0.14	0.00	-0.03	-0.04	-0.13	**-0.28**
SMB	**-0.13**	**-0.08**	**-0.10**	**-0.09**	**-0.10**	

Table 6. Cross-sectional regressions for 25 size-momentum portfolios

The table reports the Fama-MacBeth and the efficient GMM estimates of risk premiums (in percent per month) obtained for 25 global double-sorted size-momentum portfolios. Alternative multi-factor models are estimated in columns (1)-(4). The global market factor, the global momentum factor and the global size factor are used as risk factors. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors with 12 lags. J statistics for the over-identifying restrictions is also reported. P-value for J statistics is in parentheses. Nov 1990 – Aug 2013.

	Fama-MacBeth				**GMM**			
	(1)	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
Beta	-1.30	0.07	-0.75	0.06	-3.99	0.81	-0.96	0.45
	[-2.69]	[0.14]	[-2.00]	[0.14]	[-7.64]	[0.69]	[-2.80]	[0.32]
Relative downside beta		3.61		5.57		5.67		5.27
		[2.64]		[5.12]		[2.03]		[5.19]
SMB beta			0.48	0.55			1.23	0.79
			[2.84]	[3.15]			[7.93]	[4.51]
Momentum beta			0.62	0.62			0.42	0.41
			[2.13]	[2.15]			[1.79]	[1.86]
Constant	1.95	0.50	1.12	0.34	4.71	-0.23	0.94	-0.32
	[4.90]	[1.23]	[3.51]	[0.90]	[8.90]	[-0.22]	[3.17]	[-0.35]
R2 adj	0.32	0.72	0.66	0.79				
J-stat					22.24	29.04	22.10	23.77
					(0.51)	(0.14)	(0.39)	(0.25)

Table 7. Return and risk characteristics of momentum portfolios of country indices

The table reports return and risk characteristics of 6 global momentum portfolios, formed by sorting 40 country indices at time t by their total return in time t-12 to t-2, the winner-minus-loser (WML) portfolio and the US market index. All returns are annualized and expressed in percent. The reported betas are the OLS time-series estimates. The MSCI global market index serves as a proxy for the market portfolio. The global Fama-French momentum factor is used to estimate the momentum betas. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors. Jan 1984 – Aug 2013.

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**WML**	**US ret**
Return in local currency	8.05	6.20	10.16	11.47	14.01	34.23	26.18	8.99
Exchange rate return	-1.37	0.38	0.67	2.42	1.99	-14.64	-13.26	
Return in USD	6.68	6.59	10.83	13.89	16.00	19.59	12.92	8.99
Return in excess of US return	-2.31	-2.40	1.84	4.90	7.01	10.60		
	[-0.58]	[-0.83]	[0.58]	[1.71]	[2.24]	[2.71]		
Standard deviation	80.69	70.23	69.72	66.83	68.26	85.43	69.32	53.38
Skewness	-0.31	-0.53	-0.67	-0.71	-0.71	-0.68	-0.05	-0.74
Global market beta (β)	1.12	1.08	1.08	1.02	1.02	1.12	0.00	0.87
	[14.68]	[16.47]	[22.40]	[20.29]	[18.63]	[13.19]	[-0.01]	[23.60]
Relative downside beta (β^{-}-β)	0.07	0.06	0.18	0.17	0.16	0.34	0.27	0.08
Relative upside beta (β^{+}-β)	-0.08	-0.06	-0.20	-0.18	-0.17	-0.37	-0.29	-0.08
Beta asymmetry (β^{-}-β^{+})	0.15	0.12	0.38	0.34	0.34	0.71	0.57	0.15
	[0.76]	[0.65]	[3.02]	[2.68]	[2.09]	[3.13]	[2.12]	[1.81]
Global momentum beta	-0.32	-0.15	0.04	0.05	0.08	0.13	0.45	-0.02
	[-4.22]	[-1.95]	[0.48]	[0.72]	[1.26]	[2.05]	[5.20]	[-0.56]

Table 8. Cross-sectional regressions for momentum portfolios of country indices

The table reports the Fama-MacBeth and GMM estimates of risk premiums (in percent per month) obtained for the 6 global momentum portfolios, formed by sorting 40 country indices at time t by their total return in time t-12 to t-2. The MSCI global market index serves as a proxy for the market portfolio. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors with 12 lags. J statistics for the over-identifying restrictions is also reported. P-value for J statistics is in parentheses. Jan 1984 – Aug 2013.

	Fama-MacBeth				**GMM**			
	CAPM		**DR-CAPM**		**CAPM**		**DR-CAPM**	
Beta	0.95	-1.69	0.35	-3.31	0.84	-45.28	0.00	-2.56
	[2.96]	[-0.95]	[1.06]	[-1.75]	[2.37]	[-0.31]	[-0.01]	[-0.87]
Relative downside beta			3.89	4.08			4.73	4.37
			[3.92]	[4.02]			[2.11]	[2.10]
Constant		2.84		3.90		49.33		2.80
		[1.55]		[2.06]		[0.31]		[0.94]
R^2 adj	-0.05	-0.21	0.72	0.90				
J-stat					13.42	5.59	9.23	6.09
					(0.02)	(0.23)	(0.06)	(0.11)

Table 9. Returns, risks and risk premiums of currency momentum portfolios

The table reports return and risk characteristics of 5 currency momentum portfolios, formed by sorting currencies at time t by their returns in time t-12 to t-2 and held for 1 month, and the 5-1 winner-minus-loser (WML) portfolio (panel A) and the Fama-MacBeth and efficient GMM estimates of risk premiums (panel B). The returns are annualized, whereas the risk premiums are expressed in percent per month. The reported betas are the OLS time-series estimates. The MSCI global market index serves as a proxy for the market portfolio. The global Fama-French momentum factor is used to estimate the equity momentum betas. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors with 12 lags. J statistics for the over-identifying restrictions is also reported. P-value for J statistics is in parentheses. Nov 1984 – Aug 2013.

	Panel A: Time-series regressions					
	P1	**P2**	**P3**	**P4**	**P5**	**WML**
Exchange rate return (% pa)	-5.47	-0.36	0.95	2.65	2.35	7.82
Standard deviation	34.27	27.51	30.66	29.78	29.07	36.55
Skewness	-0.70	0.30	-0.28	-0.31	-0.65	0.75
Global market beta (β)	0.24	0.18	0.22	0.20	0.21	-0.03
	[5.38]	[4.32]	[4.65]	[4.60]	[5.12]	[-0.68]
Relative downside beta (β^{-}-β)	-0.14	-0.07	-0.05	-0.09	-0.01	0.13
Relative upside beta (β^{+}-β)	0.17	0.08	0.06	0.11	0.01	-0.16
Beta asymmetry (β^{-}-β^{+})	-0.31	-0.15	-0.12	-0.19	-0.01	0.30
	[-2.22]	[-1.42]	[-1.03]	[-1.78]	[-0.12]	[2.43]
Global equity momentum beta	-0.10	-0.06	0.02	0.03	0.09	0.19
	[-2.51]	[-1.55]	[0.61]	[0.83]	[2.94]	[4.59]

	Panel B: Cross-sectional regressions			
	Fama-MacBeth		**GMM**	
	CAPM	**DR-CAPM**	**CAPM**	**DR-CAPM**
Beta	-1.56	-0.21	-1.91	1.10
	[-2.59]	[-0.27]	[-3.24]	[0.55]
Relative downside beta		3.97		4.74
		[2.80]		[2.42]
R^2 adj	0.15	0.47		
J-stat			7.91	7.99
			(0.09)	(0.09)

Table 10. Correlation matrix for winner-minus-loser momentum portfolios

The table reports the correlation coefficients of returns of 7 global and regional WML portfolios and the global Fama-French momentum factor. T-statistics are in brackets. Nov 1990 – Aug 2013.

	US	Global	European	Asian-Pacific	North-American	Country indices	Curren cies	FF mom factor
US	1.00							
Global	0.80	1.00						
	[21.68]							
European	0.56	0.81	1.00					
	[11.06]	[22.86]						
Asian-Pacific	0.39	0.56	0.29	1.00				
	[7.06]	[11.05]	[5.01]					
North-American	0.89	0.89	0.64	0.44	1.00			
	[32.34]	[32.63]	[13.60]	[7.97]				
Country indices	0.24	0.33	0.21	0.34	0.27	1.00		
	[4.01]	[5.76]	[3.53]	[5.93]	[4.69]			
Currencies	0.15	0.21	0.20	0.33	0.17	0.20	1.00	
	[2.49]	[3.55]	[3.35]	[5.67]	[2.92]	[3.42]		
Global FF mom factor	0.72	0.92	0.76	0.48	0.88	0.37	0.26	1.00
	[17.13]	[38.91]	[19.22]	[8.98]	[30.17]	[6.50]	[4.53]	

Table 11. Cross-sectional regressions for 48 global and regional momentum portfolios

The table reports the Fama-MacBeth estimates of risk premiums (in percent per month) obtained for 48 global and regional momentum portfolios. Alternative multi-factor models are estimated in columns (1)-(5). The global market factor and the global momentum factor are used as risk factors. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors. Nov 1990 – Aug 2013.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Beta	1.14	0.51	1.10	0.88	1.02
	[3.03]	[1.14]	[2.67]	[2.12]	[2.40]
Relative downside beta				3.94	2.79
				[3.99]	[2.06]
Momentum beta			1.04		0.44
			[3.39]		[1.02]
Constant		0.66	0.11	0.04	-0.01
		[3.75]	[1.08]	[0.43]	[-0.06]
R^2 adj	-0.21	0.16	0.49	0.55	0.57

Table 12. Returns and risks of currency momentum and carry portfolios

The table reports return and risk characteristics of 5 currency momentum portfolios, formed by sorting currencies at time t by their returns in time t-12 to t-2 and held for 1 month, and 5 carry portfolios, formed by sorting currencies by the interest rate differentials. The returns are annualized and expressed in percent. The reported betas are the OLS time-series estimates. The MSCI global market index serves as a proxy for the market portfolio. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors. Nov 1984 – June 2013.

	Momentum portfolios						**Carry portfolios**					
	P1	**P2**	**P3**	**P4**	**P5**	**WML**	**P1**	**P2**	**P3**	**P4**	**P5**	**HML**
Return	-5.45	-0.25	0.92	2.07	2.31	**7.76**	0.55	3.70	5.00	4.53	12.68	**12.13**
Beta (β)	0.24	0.18	0.22	0.21	0.21	**-0.03**	0.13	0.19	0.23	0.25	0.28	**0.14**
	[5.26]	[4.28]	[4.57]	[5.55]	[4.94]	**[-0.60]**	[4.74]	[4.62]	[5.01]	[4.67]	[5.39]	**[3.00]**
Downside beta (β^-)	0.11	0.12	0.16	0.14	0.21	**0.10**	0.03	0.10	0.15	0.19	0.35	**0.32**
	[1.16]	[1.58]	[1.76]	[2.13]	[2.48]	**[1.46]**	[0.62]	[1.35]	[1.73]	[1.65]	[3.45]	**[4.30]**
Rel. downside beta (β^--β)	-0.13	-0.06	-0.05	-0.07	0.00	**0.12**	-0.10	-0.09	-0.08	-0.06	0.07	**0.17**
Upside beta (β^+)	0.38	0.25	0.28	0.28	0.22	**-0.16**	0.24	0.29	0.31	0.32	0.20	**-0.05**
	[5.32]	[4.42]	[5.37]	[5.85]	[4.45]	**[-1.95]**	[7.09]	[5.48]	[5.52]	[5.66]	[3.16]	**[-0.88]**
Rel. upside beta (β^+-β)	0.14	0.07	0.06	0.08	0.01	**-0.14**	0.11	0.09	0.09	0.07	-0.08	**-0.19**
Beta asymmetry (β^--β^+)	-0.27	-0.13	-0.11	-0.15	-0.01	**0.26**	-0.21	-0.18	-0.16	-0.13	0.15	**0.37**
	[-1.95]	[-1.20]	[-0.95]	[-1.70]	[0.09]	**[2.19]**	[-3.11]	[-1.74]	[-1.43]	[-0.90]	[1.10]	**[3.46]**

Table 13. Cross-sectional regressions for currency momentum and carry portfolios

The table reports the Fama-MacBeth estimates of risk premiums (in percent per month) obtained for 5 currency momentum portfolios, formed by sorting currencies at time t by their returns in time t-12 to t-2 and held for 1 month, and 5 carry portfolios, formed by sorting currencies by the interest rate differentials. The MSCI global market index serves as a proxy for the market portfolio. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors with 12 lags. The sample period is Nov 1984 – June 2013.

	Mom pfls		**Carry pfls**		**Mom and carry pfls**	
	CAPM	**DR-CAPM**	**CAPM**	**DR-CAPM**	**CAPM**	**DR-CAPM**
Beta	-7.20	-2.36	5.57	1.85	4.40	0.68
	[-2.11]	[-0.83]	[6.24]	[1.87]	[4.75]	[0.57]
Relative downside beta		4.60		3.99		5.27
		[3.02]		[4.03]		[5.70]
Constant	1.20	0.47	-1.08	-0.07	-1.04	0.06
	[1.68]	[0.77]	[-5.24]	[-0.35]	[-4.85]	[0.19]
R^2 adj	0.09	0.55	0.62	0.94	0.11	0.55

Table 14. Cross-sectional regressions for reversal portfolios

The table reports the Fama-MacBeth estimates of risk premiums (in percent per month) obtained for 10 value-weighted US short-term reversal portfolios. The portfolios are formed by sorting stocks in month t by their return in month t-1. The US market index serves as a proxy for the market portfolio. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors with 12 lags. The sample period is Jan 1927 – July 2013.

	CAPM		**DR-CAPM**	
Beta	0.65	0.88	0.71	1.02
	[3.70]	[2.37]	[4.04]	[2.59]
Relative downside beta			1.62	1.67
			[2.35]	[2.35]
Constant		-0.26		-0.34
		[-0.69]		[-0.87]
R^2	0.18	0.19	0.35	0.38

APPENDIX

A1. FAMA-MACBETH ESTIMATION WITH TIME-VARYING BETAS

In the main paper, the upside and downside betas of the momentum portfolios were assumed to be constant. As a robustness check, I allow for the time-variation in the betas by estimating them in a five-year rolling window. I consider the US momentum portfolios of individual stocks for which the longest time series of data is available. Since the sample period for these portfolios starts in January 1927, the first betas are estimated in January 1932 for the preceding five-year window.

Figure A1 plots the relative downside betas of the US past winner and past loser portfolios over time. Even though the betas were rather unstable, the relative downside betas of past winners were almost always significantly higher than the relative downside betas of past losers. This means that the relative downside betas of the WML portfolio were always positive and rather high. Moreover, at times when the winners' relative downside betas were higher, the losers' relative downside betas were generally lower, and hence the WML's relative downside betas were even higher.

The Fama-MacBeth estimation of rolling cross-sectional regressions of portfolio excess returns on their previous betas and relative downside betas produce similar results as in the case of constant betas. The estimate of the beta premium is 0.22 and statistically insignificant. The estimate of the relative downside beta premium is 0.93 with the t-statistics of 2.40. The estimate of the constant term is 0.54 and statistically insignificant. The high explanatory power of the DR-CAPM for momentum portfolios is robust to the time-variation in the betas.

A2. RISKS OF MOMENTUM PORTFOLIOS IN SUB-PERIODS

As another robustness check, I study whether the asymmetry in the upside and downside betas of the US momentum portfolios was persistently observed in different longer periods of time. I split the whole time period into two equal sub-periods 1927-1969 and 1970-2013 and calculate the return and risk characteristics of the momentum portfolios in theses sub-periods. In addition, I consider a more recent sub-period 2000-2013 which is characterized by particularly high activity of institutional investors.

Table A1 reports the returns and betas of the momentum portfolios in the three sub-periods. The momentum strategy was always profitable, although the average WML return is much lower in 2000-2013. The reason is the crash in momentum profits during the recent financial crisis of 2008-9.

The market betas of the past loser portfolios were always higher than those of the past winner portfolios. Therefore, the market betas cannot explain the high returns to the WML portfolio in any sub-period. The relative downside betas and the beta asymmetry, on the contrary, were always increasing with the portfolio rank. In any sub-period, the past winner portfolios had higher relative downside betas and lower relative upside betas that the past loser portfolios. The asymmetry in the upside and downside betas was persistent in different periods of time.

A3. OTHER RISK FACTORS IN MOMENTUM RETURNS

Daniel and Moscowitz (2014) claim that the momentum crashes occur in times of high market volatility. Therefore, volatility risk can explain momentum returns. Pastor and Stambaugh (2003) and, more recently, Fontaine et al. (2014) argue that liquidity risk explains the cross-section of equity returns. In this section, I consider these alternative risk-based explanations for the US momentum portfolios. In addition to the downside risk explanation, I consider the Pastor-Stambaugh traded liquidity factor, the Fama-French US momentum factor and the squared global market return as a proxy for the market volatility risk factor. The period of study is limited to January 1968 – July 2013 because the liquidity factor is unavailable for the longer period.

In figure A2, I plot the 10 momentum portfolios' betas to alternative risk factors. For every risk factor considered (except the liquidity factor), there is a monotonic relationship between portfolio betas and returns. It should be noted that the cross-sectional correlation between the relative downside betas and the volatility betas is -1. Therefore, the relative downside risk and the volatility risk are very similar. But liquidity betas of all portfolios are close to zero, statistically insignificant and unlikely to explain momentum returns. Asness, Moskowitz, and Pedersen (2013) also find that the Pastor-Stambaugh market liquidity measure cannot explain momentum returns.

Table A2 reports the Fama-MacBeth estimates of alternative multi-factor specifications. In specifications (1)-(4), all risk factors except the market factor carry statistically significant premiums. The liquidity risk has the lowest explanatory power in terms of R^2.

In multi-factor specifications (5)-(9), the liquidity risk premium is always insignificant. The volatility risk premium also becomes insignificant once the relative downside risk is controlled for (columns (7) and (9)). The momentum risk premium and the relative downside risk premium are both statistically significant. Given the high degree of multicollinearity between the momentum betas and the relative downside betas, their explanatory power is shared. It is not surprising that the momentum factor has the strongest explanatory power because this factor is constructed from the same portfolios which are on the left-hand side. But out of all exogenous risk factors considered, the relative downside risk (and, hence, the risk asymmetry) has the highest explanatory power for momentum returns.

A4. ALTERNATIVE MOMENTUM PORTFOLIOS IN VARIOUS ASSET MARKETS

Whereas in the previous analysis the Fama-French stock portfolios were used as test assets, in this section I use an alternative set of momentum portfolios provided by Asness, Moskowitz and Pedersen (2013). These portfolios are constructed in ten asset classes: US stocks, UK stocks, Continental European stocks, global stocks[15], country equity index futures, currencies, government bonds, commodity futures, "global non-stock asset classes", "global all asset classes". In each category, the authors sort the respective assets by their preceding 1-year returns skipping the most recent month and form three portfolios: past loser, middle and past winner portfolios[16]. An advantage of using the AMP portfolios is the ability to test a model for many asset classes in the same setting. But a disadvantage is inability to test a model within one asset class because the authors form only three momentum portfolios in each asset class.

In addition to the portfolio returns, the authors also provide data on their market, momentum and value factors. The AMP market factor represents an equal-weighted portfolio of all global assets. The AMP momentum and value factors are zero-cost rank-weighted portfolios constructed by sorting all global assets by momentum and value, respectively. The AMP factors are different from the Fama-French equity factors because they capture common variation in momentum and value across asset classes and geographical markets. Asness, Moskowitz and Pedersen (2013) claim that these factors have higher explanatory power for the cross-section of global momentum and value portfolio returns, and that their three-factor model is superior to other common multifactor models.

Table A3 presents the returns and market betas of 30 AMP momentum portfolios. In all asset classes, the relative downside betas are increasing from losers to winners, the relative upside betas are decreasing and the regular betas are almost the same. Similarly to other momentum portfolios previously considered, past winners have higher downside risk, lower upside risk and greater differences between downside and upside betas than past losers. An exception is Continental Europe where the AMP WML exhibits a different risk profile. This finding is very strange, though, given that the Fama-French European WML portfolio has a high and statistically significant difference in the betas (see table 3). Apart from this exception, the AMP momentum portfolios in different asset classes and geographical locations have similar upside and downside risk structure as all the momentum portfolios considered in the previous sections. This confirms the robustness of my finding that momentum portfolios are differently exposed to the upside and downside market risks.

[15] Global stocks include Japanese stocks, but the Japanese momentum portfolios are not studied separately because the momentum strategy is not profitable there.
[16] See Asness, Moskowitz and Pedersen (2013) for portfolio details.

Table A4 reports the estimates of cross-sectional regressions for the 30 AMP momentum portfolios. I compare three asset-pricing models: the CAPM, the DR-CAPM and the AMP three-factor model. In all models, I use the AMP "all assets" market factor instead of the global equity factor used in the previous sections. Using this market factor, the regular CAPM performs surprisingly well[17]. But despite the high explanatory power of the CAPM *across* asset classes, it does not explain the momentum portfolio returns *within* each asset class because winner and loser betas are roughly the same. The DR-CAPM is an improvement again because it explains the returns within each asset class and has a higher explanatory power across asset classes. The AMP model has the highest R^2 which is not surprising given the factors are constructed from the same portfolios which are explained[18]. But the "value and momentum everywhere" factors are hard to interpret and they lack theoretical foundations. The DR-CAPM has theoretical micro-foundations and can be applied to portfolios sorted by other characteristics[19], but its explanatory power for momentum returns is lower. Therefore, which model is superior remains an open question.

[17] Its explanatory power is much lower if the global equity factor is used instead. It is also lower if the "local" market factors are used to estimate betas of momentum portfolios in different asset markets (as is done in Asness, Moskowitz and Pedersen, 2013).

[18] The value premium estimate is negative and statistically insignificant because the momentum portfolios are not exposed to this factor. We would need the value portfolios in the cross-section to estimate the value premium correctly.

[19] For example, Lettau et al. (2014) confirm the validity of the DR-CAPM for currency carry, commodity and size-book-to-market portfolio returns.

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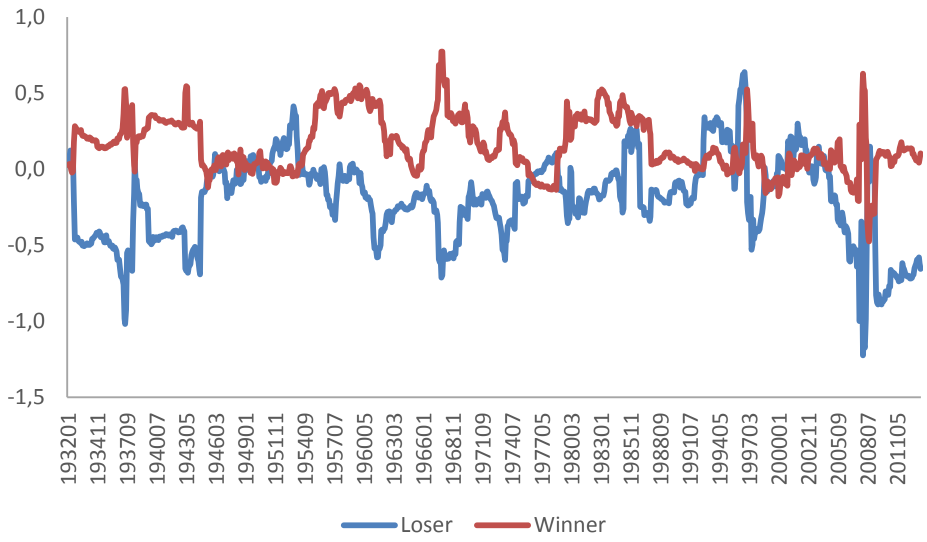
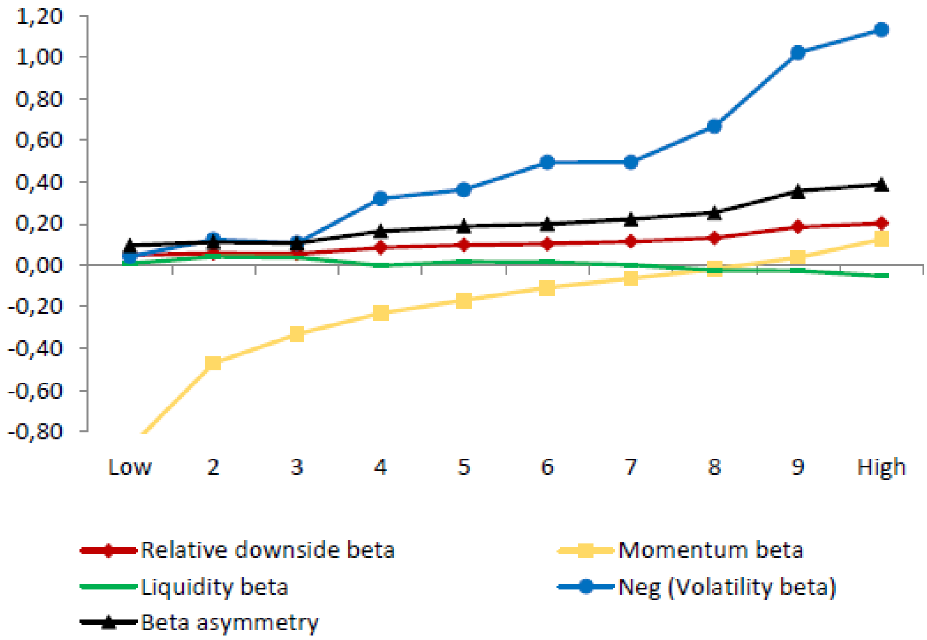
Figure A1. Relative time-varying downside betas of winner and loser US stock portfolios



The figure shows the dynamics of the 5-year rolling relative downside betas of the US past winner and past loser momentum portfolios, formed by sorting stocks at time t by their total return in time t-12 to t-2. January 1927 - July 2013.

Figure A2. Exposure of US momentum portfolios to other risk factors



The figure shows the OLS estimates of the relative downside betas, beta asymmetry (β^{-}-β^{+}), liquidity, volatility and momentum betas of 10 US equal-weighted momentum portfolios, formed by sorting stocks at time t by their total return in time t-12 to t-2. Because the volatility betas are all negative, the figure plots their absolute values, normalized to zero (shifted down) for the past loser portfolio. January 1968 - July 2013.

Table A1. Return and risk characteristics of US momentum portfolios in sub-periods

The table reports return and risk characteristics of 10 value-weighted US momentum portfolios, formed by sorting NYSE, AMEX, and NASDAQ stocks at time t by their total return in time t-12 to t-2, and the corresponding winner-minus-loser (WML) portfolios in sub-periods. The returns are annualized and expressed in percent. The reported betas are the OLS time-series estimates. The US market index serves as a proxy for the market portfolio. January 1927 – July 2013.

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**WML**
						1927-1969					
Average return	6.00	8.63	6.74	9.27	10.81	11.21	12.59	13.77	15.42	19.27	13.27
US market beta	1.60	1.43	1.26	1.18	1.10	1.08	1.02	0.95	0.97	0.95	-0.66
Relative downside beta	-0.34	-0.23	-0.13	-0.20	-0.12	-0.07	-0.02	0.03	0.11	0.21	0.55
Relative upside beta	0.28	0.19	0.10	0.16	0.10	0.06	0.01	-0.03	-0.09	-0.18	-0.45
Beta asymmetry (β^--β^+)	-0.62	-0.41	-0.23	-0.36	-0.22	-0.14	-0.03	0.06	0.20	0.39	1.00
						1970-2013					
Average return	2.01	8.66	10.85	11.47	10.23	11.22	11.90	13.34	13.60	17.26	15.25
US market beta	1.45	1.19	1.03	0.96	0.92	0.93	0.89	0.91	0.97	1.16	-0.29
Relative downside beta	-0.13	-0.12	-0.14	-0.06	-0.03	0.02	0.00	-0.01	0.07	0.06	0.19
Relative upside beta	0.12	0.12	0.13	0.06	0.03	-0.02	0.00	0.01	-0.06	-0.05	-0.18
Beta asymmetry (β^--β^+)	-0.25	-0.24	-0.27	-0.12	-0.06	0.04	0.00	-0.02	0.13	0.11	0.37
						2000-2013					
Average return	2.86	6.38	6.83	9.23	8.52	6.42	7.67	7.52	6.27	7.19	4.34
US market beta	1.95	1.41	1.14	0.98	0.88	0.84	0.78	0.78	0.86	1.08	-0.86
Relative downside beta	-0.45	-0.16	-0.20	-0.10	-0.15	0.05	-0.03	0.04	0.08	0.07	0.53
Relative upside beta	0.55	0.20	0.25	0.12	0.18	-0.06	0.04	-0.05	-0.10	-0.09	-0.64
Beta asymmetry (β^--β^+)	-1.00	-0.36	-0.45	-0.21	-0.33	0.11	-0.07	0.09	0.18	0.17	1.17

Table A2. Cross-sectional regressions for US momentum portfolios with other risk factors

The table reports the Fama-MacBeth estimates of risk premiums (in percent per month) obtained for 10 US value-weighted momentum portfolios, formed by sorting NYSE, AMEX, and NASDAQ stocks at time t by their total return in time t-12 to t-2. Alternative multi-factor specifications are reported in columns. The US market index serves as a proxy for the market portfolio. The market volatility is measured as the squared market return. The Pastor-Stambaugh traded liquidity factor and the Fama-French US momentum factor are used to measure the liquidity and momentum betas, respectively. T-statistics are in brackets, t-statistics are calculated using NW heteroscedasticity consistent standard errors. January 1927 – July 2013.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Beta	-0.25	-0.22	-0.63	0.91	-0.22	-0.19	-0.20	0.54	0.54
	[-0.49]	[-0.43]	[-1.13]	[1.87]	[-0.43]	[-0.37]	[-0.40]	[1.15]	[1.15]
Relative downside beta	5.02				5.42		3.69	1.91	2.22
	[3.73]				[3.85]		[2.41]	[1.85]	[1.88]
Volatility beta		-0.70				-0.76	-0.25		0.05
		[-3.75]				[-3.86]	[-0.73]		[0.13]
Liquidity beta			-7.97		0.79	0.76	0.83	0.26	0.25
			[-3.64]		[0.77]	[0.75]	[0.81]	[0.26]	[0.26]
Momentum beta				1.00				0.75	0.76
				[3.36]				[2.25]	[2.24]
Constant	0.96	0.85	1.92	0.51	0.88	0.77	0.84	0.62	0.63
	[2.51]	[2.21]	[4.18]	[1.30]	[2.48]	[2.14]	[2.27]	[1.78]	[1.74]
R^2 adj	0.95	0.94	0.71	0.98	0.94	0.94	0.93	0.99	0.99

Table A3. Return and risk characteristics of AMP momentum portfolios

The table reports return and risk characteristics of Asness, Moskowitz and Pedersen (2013) momentum portfolios in 10 asset markets and the corresponding winner-minus-loser (WML) portfolios. For any asset class, the assets are sorted into three portfolios by their preceding returns in time t-12 to t-2. The average portfolio returns are in excess of the 1-month US Treasury bill rate, annualized and expressed in percent. The reported betas are the OLS time-series estimates. The AMP all-assets equal-weighted index serves as a proxy for the market portfolio. January 84 - Dec 2010.

	P1	**P2**	**P3**	**WML**	**P1**	**P2**	**P3**	**WML**
	U.S. stocks				**U.K. stocks**			
Average excess return	9.70	9.57	13.04	**3.34**	7.48	12.75	15.85	**8.37**
Market beta	1.68	1.35	1.57	**-0.12**	2.06	1.92	2.00	**-0.07**
Relative downside beta	0.24	0.34	0.52	**0.27**	-0.12	-0.06	0.15	**0.27**
Relative upside beta	-0.19	-0.27	-0.41	**-0.21**	0.10	0.05	-0.12	**-0.22**
Beta asymmetry (β^--β^+)	0.44	0.60	0.92	**0.48**	-0.22	-0.11	0.27	**0.49**
	Europe stocks				**Global stocks**			
Average excess return	9.76	13.81	16.87	**7.11**	8.45	11.00	13.36	**4.90**
Market beta	2.27	2.00	2.03	**-0.25**	1.96	1.74	1.84	**-0.12**
Relative downside beta	0.41	0.43	0.34	**-0.07**	0.14	0.23	0.29	**0.15**
Relative upside beta	-0.32	-0.34	-0.27	**0.05**	-0.11	-0.18	-0.23	**-0.12**
Beta asymmetry (β^--β^+)	0.73	0.76	0.62	**-0.12**	0.24	0.41	0.52	**0.27**
	Country indices				**Currencies**			
Average excess return	2.52	6.03	10.58	**8.06**	0.50	1.94	3.54	**3.04**
Market beta	1.78	1.68	1.76	**-0.03**	0.60	0.65	0.51	**-0.09**
Relative downside beta	0.25	0.36	0.52	**0.27**	-0.22	-0.15	-0.03	**0.18**
Relative upside beta	-0.24	-0.35	-0.50	**-0.26**	0.21	0.14	0.03	**-0.18**
Beta asymmetry (β^--β^+)	0.49	0.71	1.01	**0.52**	-0.43	-0.29	-0.07	**0.36**
	Fixed income				**Commodities**			
Average excess return	3.64	3.15	3.56	**-0.08**	-1.64	2.66	9.22	**10.86**
Market beta	0.16	0.22	0.24	**0.08**	0.87	0.71	0.96	**0.09**
Relative downside beta	-0.17	-0.12	-0.07	**0.10**	0.07	0.29	0.43	**0.36**
Relative upside beta	0.16	0.12	0.07	**-0.10**	-0.07	-0.28	-0.42	**-0.35**
Beta asymmetry (β^--β^+)	-0.33	-0.24	-0.14	**0.20**	0.13	0.57	0.85	**0.72**
	Global other asset classes				**Global all asset classes**			
Average excess return	1.77	3.12	5.37	**3.59**	3.45	5.10	7.37	**3.92**
Market beta	0.69	0.67	0.71	**0.01**	1.01	0.94	0.99	**-0.02**
Relative downside beta	-0.18	-0.07	-0.04	**0.15**	-0.10	0.00	0.04	**0.15**
Relative upside beta	0.14	0.06	0.03	**-0.12**	0.08	0.00	-0.03	**-0.12**
Beta asymmetry (β^--β^+)	-0.32	-0.13	-0.07	**0.28**	-0.17	0.00	0.08	**0.27**

Table A4. Cross-sectional regressions for AMP momentum portfolios

The table reports the Fama-MacBeth estimates of risk premiums obtained for 30 Asness, Moskowitz and Pedersen (2013) momentum portfolios in 10 asset classes. The AMP all-assets equal-weighted index serves as a proxy for the market portfolio. The AMP all-assets value and momentum factors are used in the three-factor AMP model. T-statistics are in brackets, t-statistics are calculated using NW heteroskedasticity consistent standard errors. January 84 - June 2010.

	CAPM	**DR-CAPM**	**AMP model**
Beta	5.60	4.43	5.84
	[2.54]	[2.04]	[2.65]
Relative downside beta		5.31	
		[2.60]	
Momentum beta			4.07
			[3.25]
Value beta			-4.62
			[-1.70]
Constant	0.10	0.91	-0.31
	[0.08]	[0.70]	[-0.24]
R^2 adj	0.55	0.57	0.83

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