dipartimento
economia
Marco Biagi

DEMB Working Paper Series

N. 103

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December 2016

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Moment Risk Premia and the Cross-Section of Stock Returns

22-12-2016

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Abstract

The aim of this paper is to assess the existence and the sign of moment risk premia. To this end, we use methodologies ranging from swap contracts to portfolio sorting techniques in order to obtain robust estimates. We provide empirical evidence for the European stock market for the 2008-2015 time period. Evidence is found of a negative volatility risk premium and a positive skewness risk premium, which are robust to the different techniques and cannot be explained by common risk-factors such as market excess return, size, book-to-market and momentum. Kurtosis risk is not priced in our dataset. Furthermore, we find evidence of a positive risk premium in relation to the firm's size.

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1. **Introduction**

The financial literature proposes several approaches in order to compute moment risk premia. First, they can be computed as the difference between physical and risk-neutral moments. This method is model-free and relies on a swap contract in which the two counterparties agree to exchange at maturity the fixed swap rate against the floating realized rate. Second, moment risk premia can be investigated by using portfolio sorting techniques. The underlying rationale is that if a risk factor is priced in the market, stocks with different sensitivity to innovations in the risk factor will show different future returns (Chang et al. 2013). These studies are based on an extension of the Merton (1973) Intertemporal Capital Asset Pricing Model (ICAPM), by taking into account time-variation in the moments as risk factors.

The evidence relating to the existence and the sign of moment risk premia is mixed. The majority of the papers using the model-free approach (see e.g. Zhao et al. (2013), Elyasiani et al. (2016)) report the existence of negative variance and kurtosis risk premia and a positive skewness risk premium. On the other hand, in the cross-section of stock returns, the evidence is less clear. In particular, Ang et al. (2006) and Adrian and Rosenberg (2008), find that volatility risk is priced in the cross-section of stock returns. A positive innovation in volatility is associated with a deterioration of the investment opportunity set, pointing to a negative volatility risk premium. This is also supported by Carr and Wu (2009), who find that investors are averse to increases in market volatility, which are perceived as unfavourable shocks to the investment opportunity set. Chang et al. (2013) extend their analysis by investigating the time-variation in higher moments of the risk-neutral distribution such as skewness and kurtosis. Their results for the US stock market for the period 1996-2007 point to a negative statistically and economically significant skewness risk premium, while the results for both

volatility and kurtosis risk premia are weak. Moreover, most of the studies focus on the US market and the empirical evidence for the European stock markets is scant.

Against this backdrop, the aim of this paper is to apply different techniques to assess the existence and the sign of moment risk premia and provide empirical evidence for the European stock market in the period 2008-2015. The methodologies used to estimate the moment risk premia range from swap contracts to portfolio sorting techniques and are meant to obtain a robust estimate for the risk premia.

Several results are obtained. We find a negative volatility risk premium in line with previous studies in Ang et al. (2006) and Adrian and Rosenberg (2008). On the other hand, unlike Chang et al. (2013) and Bali and Murray (2013), but consistently with Kozhan et al. (2013), Elyasiani et al. (2016), we find evidence of a positive skewness risk premium. The kurtosis risk premium is not a priced factor in our dataset. The results for the sign of the volatility and the skewness risk premium are robust to different estimation methodologies (model-free and ICAPM based) and cannot be explained by common risk factors such as market excess return, book-to-market, firm size and momentum. Moreover, we find evidence of a positive risk premium for the firm size: stocks with low market capitalization earn in general higher returns than stocks with high market capitalization. Furthermore, the results show that taking into account the innovations in the implied moments as risk factors greatly improves the explanatory power of Fama-MacBeth regressions.

Our findings demonstrate that innovations in implied moments (volatility and skewness) are priced risk factors in the cross-section of stock returns and play an important role in asset pricing. This result is important for investors and financial institutions who should take into account the variability in higher moments of the risk-neutral distribution in order to improve portfolio strategies.

The paper proceeds as follows. In section 2 we provide a description of the dataset and the methodology used to obtain the risk-neutral moments and the other risk factors. In section 3 we present

the two different approaches adopted in order to assess the existence and the sign of the moment risk premia. The last section concludes.

2. Data and methodology

The dataset used in order to compute the implied moments consists of closing prices on EURO STOXX 50-index options (OESX), recorded from 02 January 2008 to 30 December 2015. OESX are European options on the EURO STOXX 50, a capital-weighted index composed of fifty of the largest and most liquid stocks in the Eurozone. The index was set up on 26 February 1998 and its composition is reviewed annually in September. As for the underlying asset, closing prices of the EURO STOXX 50 index recorded in the same time-period are used. The EURO STOXX 50 index is adjusted for dividends as follows:

$$\hat{S}_t = S_t e^{-\delta_t \Delta t} \tag{1}$$

where S_t is the EURO STOXX 50 index value at time t, δ_t is the dividend yield at time t and Δt is the time to maturity of the option. As a proxy for the risk-free rate, Euribor rates with maturities of one week, one month, two months, and three months are used: the appropriate yield to maturity is computed by linear interpolation. We also collect the closing prices of individual stocks listed on the STOXX Europe 600 Index from 31 January 2005 to 29 January 2016. We use the STOXX Europe 600 stocks data in order to obtain a wider basket of shares allowing us to implement portfolio sorting techniques. The dataset for the OESX is obtained from IVolatility, whereas the time series of the EURO STOXX 50 index and the STOXX Europe 600 individual stocks, the dividend yield and the Euribor rates are obtained from Datastream. We provide a graphical comparison between the EURO STOXX 50 index and STOXX Europe 600 index in Figure 1. It may be seen that the two market indices display a similar pattern in the period under investigation; in particular the correlation

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coefficient between EURO STOXX 50 and STOXX Europe 600 market returns is close to 96%, pointing to an almost perfect correlation between the two markets. This allows us to use the innovations in the risk-neutral moments of the EURO STOXX 50 as risk factors priced in the STOXX Europe 600 stocks.

In order to compute risk-neutral moments of the EURO STOXX 50 return distribution, we apply several filters to the option dataset in order to eliminate arbitrage opportunities and other irregularities in the prices. First, we eliminate options close to expiry (options with time to maturity of less than eight days) because they may suffer from pricing anomalies that occur close to expiry. Second, following Ait-Sahalia and Lo (1998) only at-the-money option and out-of-the-money options are retained. These include put options with moneyness (X/S, where X is the strike price and S the index value) lower than 1.03 and call options with moneyness higher than 0.97. Third, option prices violating the standard no-arbitrage constraints are eliminated. Finally, in line with Carr and Madan (2005), in order to avoid arbitrage opportunities, we check that butterfly spread strategies are non-negatively priced.

We compute the risk-neutral variance, skewness and kurtosis for the EURO STOXX 50 index by using the methodology adopted by Bakshi et al. (2003). The results are interpolated in order to obtain a 30-day forward-looking measure and subsequently annualized. Model-free measures of implied moments (volatility (*VOL*), skewness (*SKEW*) and kurtosis (*KURT*)) for the EURO STOXX 50 index return distribution are depicted in Figure 2. It may be seen that implied volatility is in general high in the period 2008-2012, which is characterized by a sharp decline in the EURO STOXX 50 level, due to both the subprime (2008-2009) and the European debt crises (2011-2012). On the other hand both the risk-neutral skewness and kurtosis present more peaks in the last part of our dataset, when market volatility is lower.

In line with Chang et al. (2013), we compute daily innovations for volatility by using first differences and, for higher order moments, we fit an autoregressive moving average (ARMA) model to the time series of both skewness and kurtosis in order to remove autocorrelation in the data. We compute the market excess return (MKT, as the difference between the daily performance of the STOXX Europe 600 index and daily risk-free rate) and other commonly used risk factors that account for characteristics of the firm such as size and book-to-market proposed in Fama and French (1993, 1996) and momentum introduced in Carhart (1997). The size factor "small-minus-big" (SMB) aims to capture the return compensation for additional risk attached to stocks characterized by low market capitalization levels and for this reason more exposed to economic and financial shocks. The book-to-market factorb "high-minus-low" (HML) measures the difference in return between stocks with high book-to-market (value stocks) and low book-to-market (growth stocks). Last, the momentum factor "up-minus-down" (UMD) accounts for the momentum of the stock prices, as proposed by Jegadeesh e Titman (1993). To elaborate, stocks characterized by high past returns (winners) tend to have a better future performance if compared to stocks with low past returns (losers). Hereafter we will refer to these factors as Carhart (1997) four factors.

In Table 1 we report the average values of the factors, the parameters for the ARMA (1,1) model, the correlation coefficients among innovations in option implied moments, along with Carhart (1997) four factors: market excess return (MKT), size (SMB), book-to-market (HML) and momentum (UMD). Several observations are in order in this connection. First, it may be seen that innovations in volatility are strongly negative related (-0.69) with market excess return. Second, innovations in market skewness are negatively related to market excess return (-0.20); on the other hand innovations in market kurtosis display a positive relation with MKT factor (0.07).

Third, the relation between innovations in skewness and kurtosis is strongly negative (-0.85). This result was expected: a low value in risk-neutral skewness points to a pronounced left tail, and is

therefore reflected in a high value of kurtosis. The high correlation between innovations in higher order risk-neutral moments may affect our analysis making it hard to distinguish between the effects of innovations in skewness from the effect of the innovations in kurtosis. To address this issue we adopt the methodology proposed in Chang et al. (2013), who orthogonalize the innovations in kurtosis as follows:

$$\Delta KURT_t = \beta_0 + \beta_1 \Delta SKEW_t + \varepsilon_t \tag{2}$$

where $\Delta KURT_t$ and $\Delta SKEW$ are the innovations in risk-neutral kurtosis and skewness, respectively. Throughout the paper we use the residuals of regression (2) as the innovations in kurtosis. This allows us to remove most of the correlation between the two measures, as shown in the right-hand side of Table 1 that reports the post-orthogonalization correlations. Innovations in kurtosis are still negatively related with innovations in market volatility.

Innovations in implied volatility, skewness and kurtosis are depicted in Figure 3. It is evident that, unlike volatility, innovations in higher order moments present more higher values in the last part of the dataset, which is characterized by lower values in both volatility and innovations in volatility.

3. Moment risk premia

In this section we adopt two different methodologies for the estimation of volatility, skewness and kurtosis risk premia. First, following Zhao et al. (2013), we use the model-free methodology and compute volatility, skewness and kurtosis swaps. Second, we investigate the pricing of moment risk by using the cross-section of stock returns: in line with Chang et al. (2013) we exploit different approaches such as multivariate sorting, four-way sorting and Fama-Macbeth (1973) regressions.

3.1 Swap contracts

It is worth recalling that in a variance swap, at maturity, the long side pays a fixed rate (the variance swap rate) and receives a floating rate (the realized or physical variance). The payoff, at maturity, for the long side is:

$$N(\sigma_R^2 - VRS) \tag{3}$$

where N is a notional Euro amount, σ_R^2 is the realized variance (computed at maturity), VRS is the fix variance swap rate, which is equal to the implied variance at the beginning of the contract. The payoff of the swap is equal to the variance risk premium, i.e. the amount that investors are willing to pay in order to be hedged against peaks of variance. Zhao et al. (2013) extend the variance swap to higher order moments and propose two new types of contract: the skewness and the kurtosis swap. In the latter the option-implied moment is the fixed leg and the realized moment is the floating one.

In order to compute variance, skewness and kurtosis risk premia each day we compute the implied moment from EURO STOXX 50 option prices and the realized moments from daily EURO STOXX 50 log-returns by using a rolling window of 30 calendar days. In this way, the realized moments refer to the same time-period covered by the risk-neutral counterparts. For the ease of the reader and consistently with the analysis in the next sections, we report results for volatility instead of variance. The average values for risk-neutral and realized (physical) moments are reported in Table 2. We can observe that the risk-neutral distribution of market returns is more volatile, negatively skewed, and fat-tailed than its corresponding realized one, which is almost symmetrical. The evidence points to the existence of risk premia for each moment of the return distribution. In particular, both the volatility and the kurtosis risk premia are negative and statistically significant. On the other hand, the skewness risk-premium is positive and statistically significant. This suggests that investors are willing to pay a

premium in order to be hedged against peaks of variance and kurtosis or against negative peaks in skewness. In Table 2 we present also the correlation coefficients between moments' risk premia. We can see that while the volatility and skewness risk premia are unrelated, the kurtosis risk premium is strongly correlated (-0.902) with the skewness one. Moreover, skewness and kurtosis are also strongly correlated, since fat tails are normally associated with asymmetry in the distribution. This points to the evidence that higher order moments are driven by a common source of risk and this will be carefully addressed in the next section.

3.2 Multivariate sorting

In this analysis, we are interested in assessing whether the moment risk is a priced factor in the cross-section of stock returns. In order to address this issue we use STOXX Europe 600 index data, instead of EURO STOXX 50, since we need a large number of stocks in order to implement the portfolio sorting strategies.

The first empirical exercise we propose aims to test the relation between future returns and the exposure of the stock to innovations in option-implied volatility, skewness and kurtosis in an out-of-sample framework. The analysis proceeds as follows. First, we estimate on a monthly basis, the β coefficients of each stock with respect to the risk factors by performing the following regression on the cross-section of stock returns:

$$R_{i,t} - R_{f,t} = \beta_0^i + \beta_{MKT}^i (R_{m,t} - R_{f,t}) + \beta_{\Delta VOL}^i \Delta VOL_t + \beta_{\Delta SKEW}^i \Delta SKEW_t + \beta_{\Delta KURT}^i \Delta KURT_t + \varepsilon_{i,t} \qquad (4)$$

where, in the month under investigation, $R_{i,t}$, $R_{f,t}$ and $R_{m,t}$ are the return on the i-th stock, the risk-free asset and the market portfolio, respectively and ΔVOL_t, $\Delta SKEW_t$ and $\Delta KURT_t$ are the innovations in the first, the second, and the third moment, respectively, at day t. Second, we create five equally-

weighted portfolios based on quintiles of the sensitivity to each risk factor: $\beta^i_{\Delta VOL}$, $\beta^i_{\Delta SKEW}$ and $\beta^i_{\Delta KURT}$.

The first (fifth) portfolio holds the stocks with the lowest (highest) value of the beta. Third, we compute the monthly return of each portfolio in the subsequent month. This procedure allows us to avoid spurious effects (correlation between the estimated exposures and returns), in line with previous studies in Ang et al. (2006), Agarwal et al. (2009) and Chang et al. (2013).

The rationale underlying the analysis is that if a risk factor is priced in the market, stocks with different sensitivity to innovations in the risk factor will show different future returns. To elaborate, if a positive innovation in market volatility (an increase in volatility) is perceived by investors as a deterioration of the investment opportunity set, stocks with low or positive exposure to innovations in market volatility act as a hedge against volatility risk. As a result they are desirable for investors since they provide positive or slightly negative returns when market volatility increases (usually associated with a decrease in market returns), resulting in a lower expected return for such assets. On the other hand, stocks with negative exposure to innovations in volatility should earn high future returns in order to compensate investors for the higher risk: we therefore expect the volatility risk premium to be negative. An a-priori expectation for the sign of the risk premium for skewness and kurtosis risk is provided by the correlation between the higher moments and market returns (Chang et al. (2013)). However, relying on the correlation coefficient only, we discard the investors' preference about skewness and kurtosis risk. In terms of investor preference, the rationale for kurtosis risk should be similar to that for volatility innovation. In fact an increase in kurtosis means that the risk-neutral distribution becomes more fat-tailed and as result the probability of extreme events increases. If the investors are risk-averse we can suppose that they consider an increase in market kurtosis as an unfavorable shock for the investment opportunity set. As a result, similarly to volatility, we could expect a negative price of kurtosis risk. Finally, a positive innovation in skewness (risk-neutral skewness increasing or becoming less negative) indicates a lower probability of realizations in the left tail of the distribution. To take this

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further, an increase in market skewness is associated to a lower downturn risk for the market and this could be interpreted as a positive shock for the investment opportunity set. On the other hand, negative innovations in market skewness are related to an increase in the probability of downside jumps in the market and can therefore be viewed as a negative shock to the investment opportunity set. In particular, stocks characterized by a negative exposure to market skewness innovations ensure positive returns when market skewness decreases and they act as a hedge against market skewness risk. Conversely, stocks with a positive exposure to market skewness innovations react negatively to a decrease in risk-neutral skewness; therefore, they should earn higher future returns in order to compensate their riskiness. We can thus expect the market price of skewness risk to be positive. However, this is in contrast with the results in Chang et al. (2013), who find both the skewness risk premia to be negative in the American stock market in the period 1996-2007, in line with Chabi-Yo (2012) who propose an intertemporal extension of the three-moment and four-moment CAPM (where the price of market skewness and kurtosis risk depend on the fourth and fifth derivative of the utility function, which are hard to assess).

In order to assess whether the effect of innovations in implied moments persists after controlling for the Carhart (1997) factors, we compute the "four-factor alpha" for each of the five portfolios plus the (Q5-Q1) by estimating the following equation:

$$R_{j,t} = \alpha^j + \beta^j_{MKT} MKT_t + \beta^j_{SMB} SMB_t + \beta^j_{HML} HML_t + \beta^j_{UMD} UMD_t + \varepsilon_{j,t} \tag{5}$$

where $R_{j,t}$ is the portfolio return (post-ranking) in day t, for $j=1,...,6$ and MKT_t, SMB_t, HML_t and UMD_t are the factors used to evaluate the robustness of the intercept (which is referred to as the "four-factor alpha"). Fifth, we compute the return of high minus low portfolios as the difference between the return of the portfolio characterized by the highest exposure to the risk factor and the one characterized

by the lowest exposure. Finally, we repeat the procedure each month by rolling the estimation window over to the next month.

We report the results for portfolios sorted on exposure to innovations in volatility, skewness and kurtosis in Table 3, Panel A, Panel B and Panel C, respectively. Starting from volatility exposure, if an increase in volatility is associated with a deterioration of the investment opportunity set, we expect average returns to have a decreasing pattern from the first quintile (Q1) characterized by the lowest exposure to volatility to the fifth quintile (Q5) characterized by the highest exposure to volatility. As a result, we expect a negative return and a negative alpha for the high-low portfolio (Q5-Q1). Moreover, we could also expect a monotonic pattern in both the average returns and the alphas for portfolios sorted in terms of their exposure to volatility risk. The results (reported in Table 3, Panel A) show that both the average return and the alpha for the long-short portfolio (Q5-Q1) are negative and significant. Moreover both the average returns of the equally weighted portfolios and the associated four-factor alphas present a monotonic decreasing pattern from the portfolio with the lowest exposure (Q1) to the one with the highest exposure (Q5). This pattern is also detectable in Figure 4, where the relation between average returns, Carhart four-factor alphas and the portfolio exposures to the risk factor is depicted.

This evidence points to a significant negative volatility risk premium priced into the cross-section of stocks returns, in line with previous findings in Ang et al. (2006), but in contrast with Chang et at. (2013) where the volatility risk premium is not robust to the choice of the model. In particular, stocks with low exposure ($\beta^i_{\Delta VOL}$) to innovations in market volatility earn higher future returns with respect to stocks with high exposure to volatility risk in order to compensate investors for the higher level of risk. Moreover, this result is consistent with the negative sign for the volatility risk premium obtained in Section 3.1 by using the volatility swap contract, suggesting that investors are averse to increases in

market volatility and are willing to pay a premium reflected in a lower return for stocks that act as a hedge against market volatility risk.

The results for portfolios sorted with respect to exposure to innovations in market skewness are reported in Table 3, in Panel B. We can see that the average return and the alpha statistics of the different portfolios present a monotonic (increasing) pattern with the sole exception of the third quintile portfolio. Moreover, the four-factor alpha for the long-short portfolio is positive and statistically significant, suggesting a positive skewness risk premium, in line with the evidence obtained in the previous section. As a result, we find that market skewness risk is also a factor priced into the cross-section of stock returns: investors are averse to negative changes in market skewness, and accept a lower future return for stocks that act as a hedge against skewness risk (stocks with low $\beta^i_{\Delta SKEW}$). This appears to be in contrast with previous findings in Chang et al. (2013), who document a robust negative skewness risk premium, reflected in a decreasing pattern in average returns and alphas from Q1 to Q5. One possible explanation is that this result reflects the difference in the institutional features between the two markets (European versus US) and in the different time period under investigation (2008-2015 versus 1996-2007). In Figure 4 it may be seen that the alpha and the average return generally increase when the exposure (beta) to skewness risk increases.

Finally, we report the cumulative return for portfolios with different exposure to innovations in kurtosis in Table 3, Panel C. We can see that both the return and the Carhart four-factor alpha for the Q5-Q1 portfolio are not statistically different from zero. Moreover, we cannot detect any monotonic pattern in both the average returns and the alpha statistics (see Figure 4). Therefore the results indicate that kurtosis risk is not priced into the cross-section of stock returns, in contrast with the result in Table 2. It is worth recalling that we have orthogonalized innovations in kurtosis with respect to innovations in skewness in order to remove the high correlation between the two variables. This may be the reason

why kurtosis risk is not significant in the portfolio analysis: given the high correlation between the two, they may capture the same source of risk.

In Figure 5 we report the cumulative return for portfolios with different exposure to innovations in the risk factors. It may be seen that while the performance of the portfolios with different exposure to volatility risk displays a pronounced spread (portfolios with low exposure to volatility display a higher return than portfolios with high exposure to volatility risk), there is no striking evidence for portfolios sorted with respect to exposure to kurtosis risk. Portfolios sorted by exposure to skewness risk display an intermediate results, where the only evidence regards the difference between Q1 (the worst performer) and Q5 (the best performer).

To sum up, the empirical evidence based on multivariate portfolio sorting confirms the results obtained in Section 3.1 for volatility and skewness. On the other hand, once ortogonalized by skewness, kurtosis risk is not priced into the cross-section of STOXX Europe 600 stock returns.

3.3 Four-way sorting

One drawback of the previous analysis is the difficulty in separating the effect of each risk factor due to the correlation between the exposures to the different factors (in particular the strong negative correlation between market excess returns and innovation in volatility). In order to address this issue, we adopt the methodology proposed in Chang et al. (2013), who perform a four-way sorting that allows them to isolate the pricing effects of the different risk factors. In contrast with Agarwal et al. (2009) who use a three-way sorting, we find a high correlation between innovations in volatility and market excess returns (-0.71) that has to be filtered out.

The procedure is based on the following steps. First, each month we sort the stocks into three different sub-samples based on their exposure to the market excess return factor. The first (third) group is

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formed by the stocks with the lowest (highest) estimate of β_{MKT}^i in that period. Second, within each group, we again sort the stocks characterized by a low, medium and high exposure to volatility risk, respectively. Third, we repeat the procedure within each of the previous nine groups by sorting again on the basis of the different exposure to innovations in skewness (high, medium or low), in this way we obtain 27 groups. As a last step, we sort again according to innovations in kurtosis (high, medium or low). In this way we obtain 81 groups of stocks ranked by high, medium or low exposure to market, volatility, skewness and kurtosis risk.

We compute the return of equally-weighted portfolios within each group over the next month. Finally, in order to have portfolios exposed to a single risk factor and neutral to the other risk factors, we take a long position on the 27 portfolios with the highest exposure to that factor and a short position in the 27 portfolios with the lowest exposure to the same risk factor, as follows:

$$
\begin{aligned}
FMKT &= (1/27)(R\beta_{\Delta MKT,H} - R\beta_{\Delta MKT,L}) \\
FVOL &= (1/27)(R\beta_{\Delta VOL,H} - R\beta_{\Delta VOL,L}) \\
FSKEW &= (1/27)(R\beta_{\Delta SKEW,H} - R\beta_{\Delta SKEW,L}) \\
FKURT &= (1/27)(R\beta_{\Delta KURT,H} - R\beta_{\Delta KURT,L})
\end{aligned}
\tag{6}
$$

where $FMKT$, $FVOL$, $FSKEW$ and $FKURT$ are the average returns of factor portfolios for exposure to excess return, volatility, skewness and kurtosis, respectively; $R\beta_{\Delta MKT,H}$ $R\beta_{\Delta VOL,H}$, $R\beta_{\Delta SKEW,H}$ and $R\beta_{\Delta KURT,H}$ are the sum of the returns of the portfolios characterized by the highest exposure to the specific risk factor and $R\beta_{\Delta MKT,L}$, $R\beta_{\Delta VOL,L}$, $R\beta_{\Delta SKEW,L}$ and $R\beta_{\Delta KURT,L}$ the sum of the returns of the portfolios characterized by the lowest exposure to the specific risk factor.

The average returns of the four factor portfolios represent the investors' compensation for time-varying market excess return, volatility, skewness and kurtosis risks. For instance, the return of the $FVOL$ portfolio reflects the return of a zero-cost portfolio which is exposed only to volatility risk and is

neutral to the other risk factors. Therefore, each average return of four factors can be viewed as the risk premium for being exposed to that risk factor.

The average returns and the Carhart alphas for the four factor portfolios are shown in Table 4. We can see that the average monthly volatility risk premium is equal to -0.47% (equal to -5.64% if annualized), which is statistically significant. This result is consistent with previous analysis based on the volatility swap and the multivariate portfolio sorting revealing a negative risk premium for volatility. The estimated risk premium for skewness risk, shown in Table 4, column 3-4, is equal to 0.16% on a monthly basis (annualized skewness risk premium is equal to 1.92%), positive and weakly significant. As a result, the four-way sorting analysis confirms the results, although weakly, obtained in the previous sections. The average return for the high-low portfolio sorted with respect to kurtosis risk is not statistically different from zero. Again, the results show that kurtosis risk is not priced into the cross-section of stock returns.

The cumulative returns for the factor portfolios based on innovations in volatility, skewness and kurtosis are presented in Figure 6. It is interesting to note that the return of the $FVOL$ portfolio (the one that captures the volatility risk premium) was positive during the 2008 market decline, suggesting a positive risk premium in that specific period. This evidence is consistent with a realized volatility higher than the implied one, during the market decline: in the most acute phase of the financial crisis, stocks that act as a hedge with respect to volatility risk achieved a better performance with respect to those exposed to volatility risk. This pattern, though less evident, can be detected also during the European debt crisis (2011-2012). Both the skewness and the kurtosis risk premiums do not vary significantly in the sample period: the skewness risk premium remains positive and the kurtosis risk premium negative.

In Table 5 we report the average monthly returns for the factor portfolios $FVOL$, $FSKEW$, $FKURT$, the Carhart risk factors and the correlation coefficients between the risk factors. In particular, we can see

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that only the SMB factor, capturing the excess return of low market capitalization firms with respect high market capitalization firms, is statistically significant and equal to 0.49% on a monthly basis (5.88% annualized). The positive price of size risk suggests that stocks characterized by low market capitalization levels earn higher returns than those characterized by high market capitalization levels. The cumulative returns for the Carhart (1997) four factor portfolios based on market excess return, size, book-to-market and momentum are depicted in Figure 7. We can see that the size factor is the only one that provides a constant positive performance over the entire sample period.

3.4 Fama-MacBeth regressions

In order to evaluate the robustness of the results, we compute the price of market, volatility, skewness and kurtosis risks by means of Fama and MacBeth (1973) regressions. In order to have a sufficient number of stocks in any sub-group we choose to use 25 Fama-French portfolios formed each month on Size and Book-to-Market.

Fama and Macbeth (1973) regressions rely on two different steps. First, we estimate the betas on six month[1] daily returns by running the most general model: the Carhart model augmented with innovations in volatility, skewness and kurtosis:

$$
\begin{aligned}
R_{i,t} - R_{f,t} &= \beta_0^i + \beta_{MKT}^i (R_{m,t} - R_{f,t}) + \beta_{\Delta VOL}^i \Delta VOL_t + \beta_{\Delta SKEW}^i \Delta SKEW_t + \\
&\quad \beta_{\Delta KURT}^i \Delta KURT_t + \beta_{SMB}^i SMB_t + \beta_{HML}^i HML_t + \beta_{UMD}^i UMD_t + \varepsilon_{i,t}
\end{aligned}
\tag{7}
$$

Second, in order to compute the price of the risk factors, we use the estimated betas as regressors in the following equation:

$$
\begin{aligned}
E[R_i] - R_f &= \lambda_0 + \lambda_{MKT} \beta_{MKT}^i + \lambda_{\Delta VOL} \beta_{\Delta VOL}^i + \lambda_{\Delta SKEW} \beta_{\Delta SKEW}^i \\
&\quad + \lambda_{\Delta KURT} \beta_{\Delta KURT}^i + \lambda_{SMB} \beta_{SMB}^i + \lambda_{HML} \beta_{HML}^i + \lambda_{UMD} \beta_{UMD}^i
\end{aligned}
\tag{8}
$$

---

[1] We find similar results when we estimate betas by using 60- and 90-days portfolios returns.

and estimate the equation on the next-month, where $E[R_i]$ is proxied by the next-month return of each of the 25 portfolios. The procedure is repeated by rolling the estimation window over to the next month.

In order to compare the pricing performance of the most general model with the one of the nested models, we also estimate by means of Fama and Macbeth (1973) regressions the following Carhart model (FFC4 model):

$$R_{i,t} - R_{f,t} = \beta_0^i + \beta_{MKT}^i (R_{m,t} - R_{f,t}) + \beta_{SMB}^i SMB_t + \beta_{HML}^i HML_t + \beta_{UMD}^i UMD_t + \varepsilon_{i,t}$$

$$E[R_i] - R_f = \lambda_0 + \lambda_{MKT}\beta_{MKT}^i + \lambda_{SMB}\beta_{SMB}^i + \lambda_{HML}\beta_{HML}^i + \lambda_{UMD}\beta_{UMD}^i \tag{9}$$

and the Four-Moment CAPM model:

$$R_{i,t} - R_{f,t} = \beta_0^i + \beta_{MKT}^i (R_{m,t} - R_{f,t}) + \beta_{\Delta VOL}^i \Delta VOL_t + \beta_{\Delta SKEW}^i \Delta SKEW_t + \beta_{\Delta KURT}^i \Delta KURT_t + \varepsilon_{i,t}$$

$$E[R_i] - R_f = \lambda_0 + \lambda_{MKT}\beta_{MKT}^i + \lambda_{\Delta VOL}\beta_{\Delta VOL}^i + \lambda_{\Delta SKEW}\beta_{\Delta SKEW}^i + \lambda_{\Delta KURT}\beta_{\Delta KURT}^i \tag{10}$$

Table 6 shows the average estimates for lambdas obtained by using the three different models. If the pricing model is correct, the value of the intercept should not be significant.

In the Carhart model augmented with innovations in volatility, skewness and kurtosis, we find that both the lambda coefficients for volatility and skewness are statistically significant, suggesting that volatility risk and skewness risk are priced factors in portfolios returns. The prices of volatility (negative) and skewness (positive) risks support the results obtained in previous sections about the sign of the risk premiums, suggesting that investors are averse to increases in volatility and decreases in risk-neutral skewness and are willing to accept a lower return on stocks that act as a hedge against these risks. On the other hand, we can see that the lambda coefficient for kurtosis risk is not statistically significant, suggesting that kurtosis risk is not a factor priced into the cross-section of stock returns, in line with previous results. Moreover, we find that the size factor lambda is positive and statistically significant,

in line with the results in Section 3.3. Investors expect higher returns on small market capitalization stocks with respect to high market capitalization stocks in order to be rewarded for their higher level of risk. Last, we can see that the complete model (8) is able to explain a large part of the portfolio returns (80%), suggesting that the introduction of innovations in market volatility, skewness and kurtosis greatly improves the explanatory power of the standard four-factor Carhart model. On the other hand, when we consider the Four-Moment CAPM model (10) we obtain a worse fit, indicating that the Carhart factors are important in the explanation of the cross-section of future returns. This is evident also from regression (9) where the size factor is the only significant one. As in the previous analysis outlined in sections 3.2 and 3.3, the skewness risk is priced once we take into account the size factor.

To sum up, we investigated the pricing of moment risk by using four different approaches and we checked the results by using common risk factors such as market excess return, size, book-to-market and momentum. We found robust evidence that volatility risk is priced both in the EURO STOXX 50 option market and in the cross-section of STOXX Europe 600 stock returns. In particular, the results point to a negative volatility risk premium: investors are averse to increases in market volatility and are willing to pay a premium (reflected in a lower return for stocks providing a hedge against volatility) in order to be hedged against peaks of volatility in the market. This result is consistent with previous evidence in the US market (see e.g. Ang et al. (2006) and Carr and Wu (2009)). Furthermore, by investigating the skewness swap contract, we find strong evidence of a positive skewness risk premium in the EURO STOXX 50 option market, which is reflected, albeit weakly, in a positive skewness risk premium also in the cross-section of STOXX Europe 600 stock returns. This result, in contrast with previous findings in Chang et al. (2013) for the US market, suggests that investors are averse to negative peaks (drops) in risk-neutral skewness and expect a higher return for stocks characterized by a positive exposure to skewness risk (high $\beta^i_{\Delta SKEW}$). Finally, we found that the size factor is the only

Carhart factor priced into the cross-section of stock returns, indicating that investors perceive stocks with low market capitalization levels as riskier and expect higher future returns on these stocks.

4. Conclusions

In this paper we investigated moment risk premia in the European stock market, using two different approaches. The first one was based on the swap contracts proposed in Zhao et al. (2013), and it was model-free. The second approach relied on an extension of the ICAPM model, where the innovations in risk-neutral moments were considered as risk factors, in line with Chang et al. (2013). The analysis was motivated by the fact that there is no consensus on the existence and sign of the moment risk premiums and that there is no evidence in the literature on the European stock market.

We obtained several results. First, the volatility risk premium was found to be negative, in line with Ang et al. (2006) and Adrian and Rosenberg (2008), suggesting that investors perceive an increase in market volatility as an unfavorable shock to the investment opportunity set. Therefore stocks that act as a hedge against volatility risk earn on average lower returns. Second, we found evidence of a positive skewness risk premium, in contrast with the results obtained in Chang et al. (2013), but in line with the findings of Kozhan et al. (2013) in the US market. In particular, investors are averse to decreases in market skewness and expect higher returns on stocks with high and positive beta, i.e. high exposure to skewness risk in order to be compensated for their higher riskiness. Third, the results for the volatility and the skewness risk premiums are robust to different estimation methodologies and to the inclusion of other risk factors such as market excess return, size, book-to-market and momentum. Fourth, there appears to be a positive risk premium for the size of the firm in the European market: stocks with low market capitalization levels earn on average higher future return than stocks with high market capitalization. Finally, when taking into account the innovations in the implied moments as risk factors,

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we found that the explanatory power of the regression on future portfolios' returns increased significantly.

Our findings demonstrate that innovations in volatility and skewness are priced risk factors in the cross-section of stock returns and play an important role in asset pricing. This result is important for investors and financial institutions, reflecting the need to take into account the variability in higher moments of the risk-neutral distribution in order to improve portfolio strategies.

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Table 1 – Risk factors

Factor	AR(1)	MA(1)	Mean	(pre-orthogonalization)			(post-orthogonalization)		
				ΔVOL	$\Delta SKEW$	$\Delta KURT$	ΔVOL	$\Delta SKEW$	$\Delta KURT$
ΔVOL	0.974	-0.037	-3.792e-05	1.00	0.13	-0.17	1.00	0.13	-0.08
$\Delta SKEW$	0.945	0.381	-1.031e-03		1.00	-0.85		1.00	0.00
$\Delta KURT$	0.937	-0.371	1.024e-03			1.00			1.00
MKT			6.589e-07				-0.69	-0.20	0.07
SMB			2.328e-04				0.13	0.05	0.00
HML			-3.773e-05				-0.37	-0.11	0.05
UMD			3.980e-05				0.25	0.06	0.02

Note: the table shows the average value for the risk factors of the cross-section of STOXX Europe 600 returns, the parameters for the ARMA (1,1) model and the correlation coefficients among the different factors. In the right-hand side of the table, innovations in implied kurtosis are orthogonalized with respect to innovations in implied skewness.

Table 2 – Results for the moment swap contracts

	Volatility	Skewness	Kurtosis				
Physical	0.1816	0.0019	3.0004				
Risk-neutral	0.2650	-0.4729	3.6016				
Risk premium	-0.0835	0.4749	-0.6011				
					VRP	SRP	KRP
				VRP	1.000	0.029	-0.078
				SRP		1.000	-0.902
				KRP			1.000

Note: the table shows the average values for the physical and risk-neutral moments of the EURO STOXX 50 distribution, the moment risk premia and the correlations among volatility risk premium (VRP), skewness risk premium (SRP) and kurtosis risk premium (KRP).

Table 3 – Statistics for portfolios sorted on exposure to innovations in implied moments

	Quintile					
Panel A	Q1	Q2	Q3	Q4	Q5	Q5-Q1
$\beta_{\Delta VOL}$	-0.66	-0.25	-0.045	0.14	0.54	
Avg. Ret.	0.86%	0.63%	0.37%	0.30%	0.15%	-0.70%
						(-2.88)
Alpha	0.56%	0.40%	0.14%	0.06%	-0.15%	-0.71%
						(-2.87)
	Quintile					
Panel B	Q1	Q2	Q3	Q4	Q5	Q5-Q1
$\beta_{\Delta SKEW}$	-0.14	-0.04	0.00	0.05	0.13	
Avg. Ret.	0.35%	0.40%	0.38%	0.44%	0.73%	0.38%
						(1.67)
Alpha	0.03%	0.17%	0.16%	0.20%	0.45%	0.42%
						(1.83)
	Quintile					
Panel C	Q1	Q2	Q3	Q4	Q5	Q5-Q1
$\beta_{\Delta KURT}$	-0.10	-0.03	-0.00	0.03	0.10	
Avg. Ret.	0.45%	0.53%	0.36%	0.47%	0.51%	0.06%
						(0.25)
Alpha	0.13%	0.28%	0.12%	0.24%	0.22%	0.09%
						(0.38)

Note: the table shows the results for portfolios sorted on exposure to volatility (Panel A), skewness (Panel B) and kurtosis (Panel C). Quintile 1 (5) collects stocks with the lowest (highest) values of β, Q5-Q1 portfolios are obtained combining a long position in Quintile 5 and a short position in Quintile 1. For each portfolio we report the average return and the Jensen alpha computed with respect to the Carhart (1997) four-factor model (t-stats are in brackets).

Table 4 – Portfolios sorted on the exposure to market excess return and innovations in implied moments

	$R_m - R_f$		ΔVOL		$\Delta SKEW$		$\Delta KURT$	
	Avg. Ret.	Alpha	Avg. Ret.	Alpha	Avg. Ret.	Alfa	Avg. Ret.	Alfa
L	0.51%	0.29%	0.71%	0.44%	0.37%	0.19%	0.43%	0.22%
M	0.52%	0.27%	0.45%	0.40%	0.50%	0.28%	0.50%	0.29%
H	0.37%	0.06%	0.24%	0.11%	0.53%	0.30%	0.47%	0.27%
H-L	-0.14%	-0.23%	-0.47%	-0.47%	0.16%	0.18%	0.05%	0.05%
	(-0.45)	(-1.22)	(-1.92)	(-2.34)	(1.65)	(1.80)	(0.53)	(0.55)

Note: the table reports the average return and the alpha computed with respect to the Carhart (1997) four-factor model in the factor portfolios obtained by using the four-way sorting method (t-stats are in brackets).

Table 5 – Factor portfolio statistics

Factors	Avg. Ret.	FVOL	FSKEW	FKURT	MKT	HML	SMB	UMD
FVOL	-0.47% (-1.92)	1.00	-0.05	0.09	-0.03	-0.61	0.04	0.14
FSKEW	0.16% (1.65)		1.00	-0.03	-0.03	-0.01	-0.04	0.03
FKURT	0.05% (0.53)			1.00	-0.12	-0.11	-0.00	0.09
$R_m - R_f$	-0.01% (-0.02)				1.00	0.73	0.09	-0.16
HML	-0.08% (-0.17)					1.00	0.09	-0.30
SMB	0.49% (2.47)						1.00	0.11
UMD	0.09% (0.26)							1.00

Note: the table shows the average risk premium for each factor and the correlation coefficients computed between the different risk factors (t-stats are in brackets).

Table 6 – Estimation output of Fama-Macbeth (1973) regressions

	FFC4 model (i)	Four-Moment CAPM (ii)	Augmented FFC4 model (iii)
λ_0	0.0055 (1.0376)	0.0093 (1.3012)	0.0088 (1.5330)
λ_{MKT}	-0.0025 (-0.3074)	0.0183 (0.9070)	-0.0052 (-0.5405)
$\lambda_{\Delta VOL}$		-0.0751 (-1.7517)	-0.0633 (-2.3279)
$\lambda_{\Delta SKEW}$		0.1212 (0.9852)	0.2360 (2.6596)
$\lambda_{\Delta KURT}$		-0.3455 (-1.3633)	0.1257 (0.9510)
λ_{SMB}	0.0013 (0.2124)		0.0018 (0.3029)
λ_{HML}	0.0062 (2.6312)		0.0060 (2.5492)
λ_{UMD}	0.0043 (1.0889)		0.0011 (0.2357)
R^2 (Adj.)	57.73%	44.17%	80.36%

Note: the table shows the estimated price of risk by applying the two-pass Fama-Macbeth (1973) regression method to the 25 Fama and French (1993) portfolios sorted on market capitalization and book-to-market. We test three different models:

(i) $\quad E[R_i] - R_f = \lambda_0 + \lambda_{MKT}\beta_{MKT}^i + \lambda_{SMB}\beta_{SMB}^i + \lambda_{HML}\beta_{HML}^i + \lambda_{UMD}\beta_{UMD}^i$

(ii) $\quad E[R_i] - R_f = \lambda_0 + \lambda_{MKT}\beta_{MKT}^i + \lambda_{\Delta VOL}\beta_{\Delta VOL}^i + \lambda_{\Delta SKEW}\beta_{\Delta SKEW}^i + \lambda_{\Delta KURT}\beta_{\Delta KURT}^i$

(iii) $\quad E[R_i] - R_f = \lambda_0 + \lambda_{MKT}\beta_{MKT}^i + \lambda_{\Delta VOL}\beta_{\Delta VOL}^i + \lambda_{\Delta SKEW}\beta_{\Delta SKEW}^i + \lambda_{\Delta KURT}\beta_{\Delta KURT}^i + \lambda_{SMB}\beta_{SMB}^i + \lambda_{HML}\beta_{HML}^i + \lambda_{UMD}\beta_{UMD}^i$,

t-stats are in brackets.

Figure 1 - European market performance during the sample period
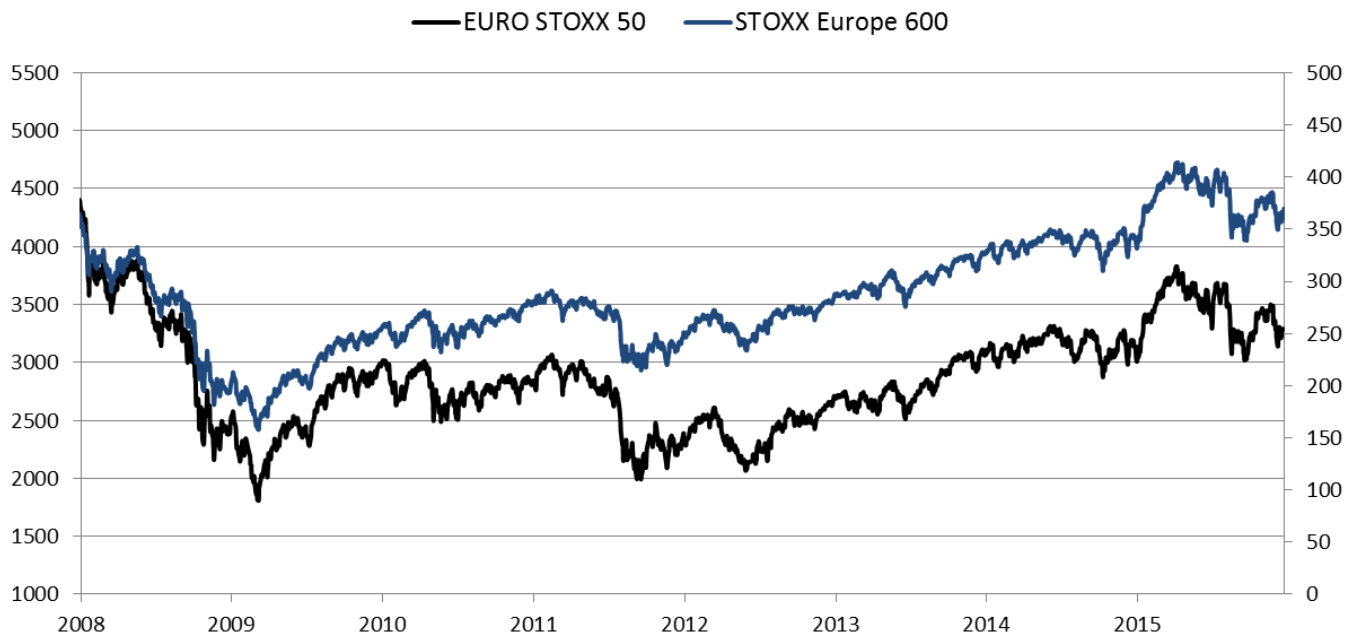
Note: EURO STOXX 50 index refers to the left axis, while STOXX Europe 600 refers to the right axis.

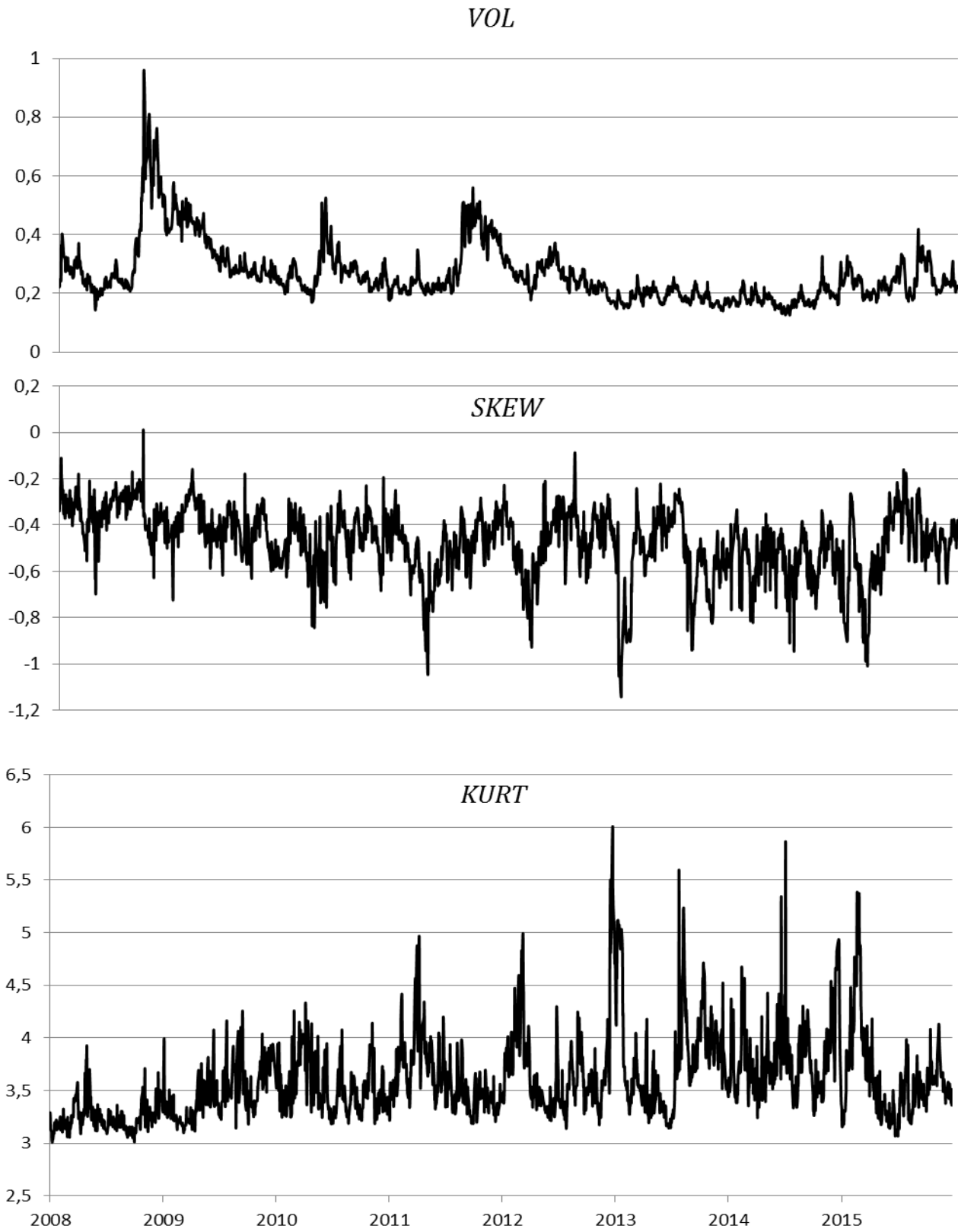Figure 2 – Daily implied volatility, skewness and kurtosis of EURO STOXX 50 index returns.

Figure 3 – Daily innovations in option implied moments
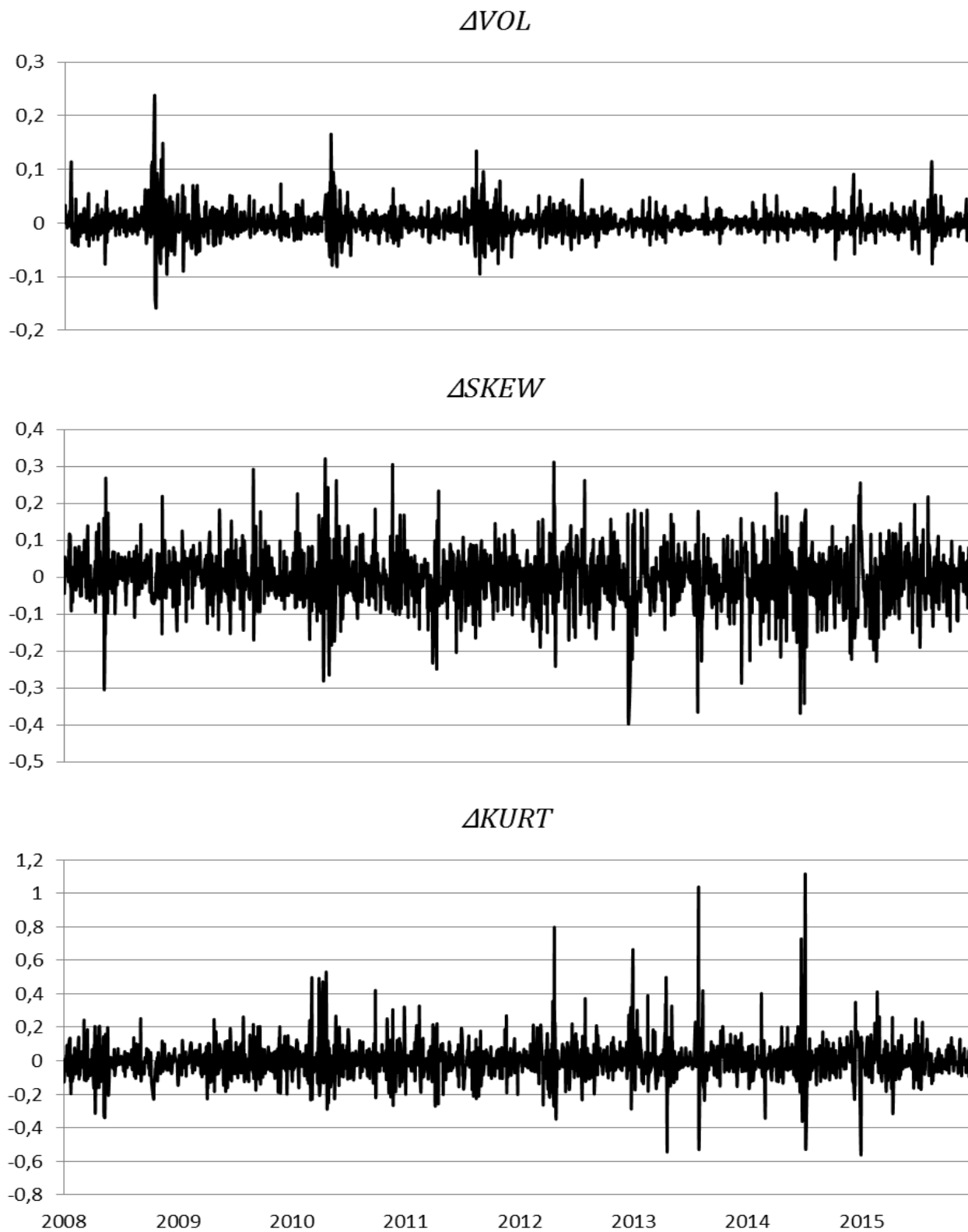
ΔVOL

ΔSKEW

ΔKURT

Figure 4 – Relation between portfolios average return and exposure to innovations in implied moments
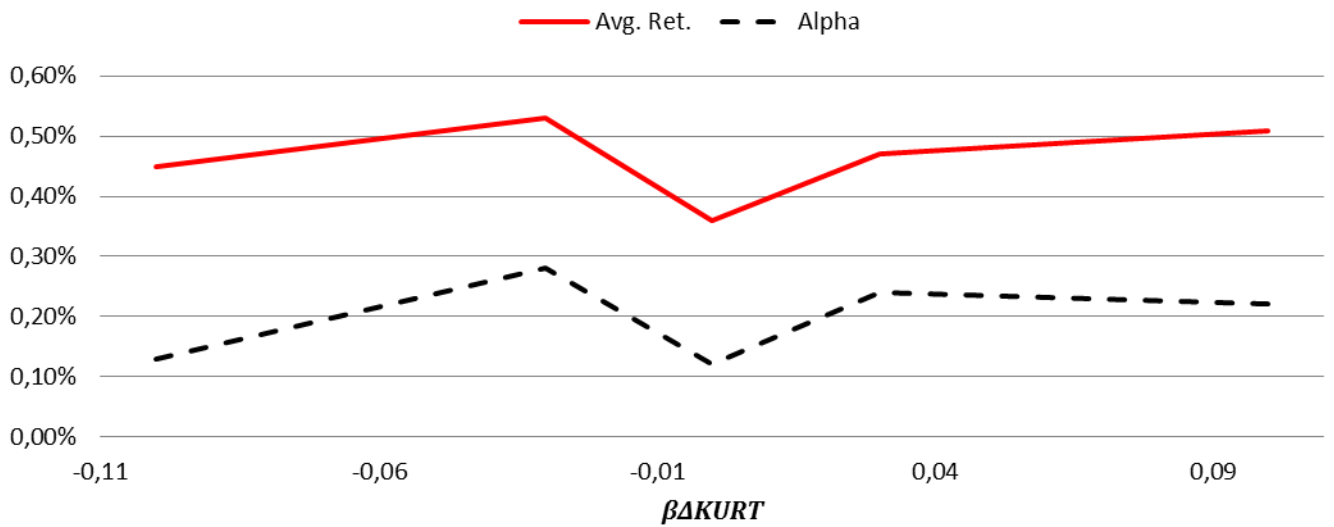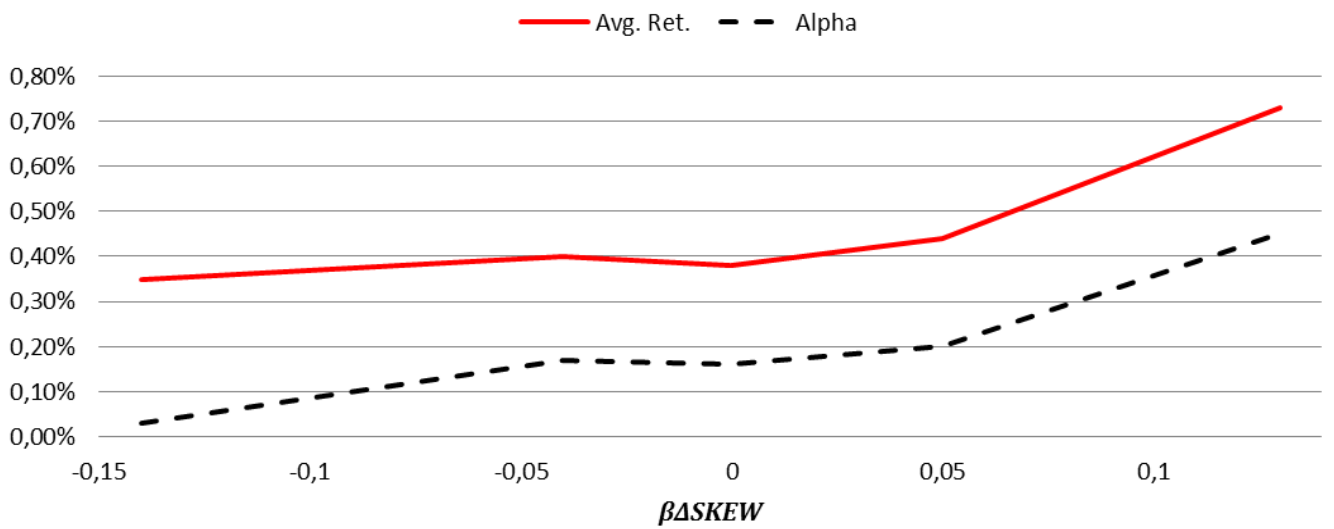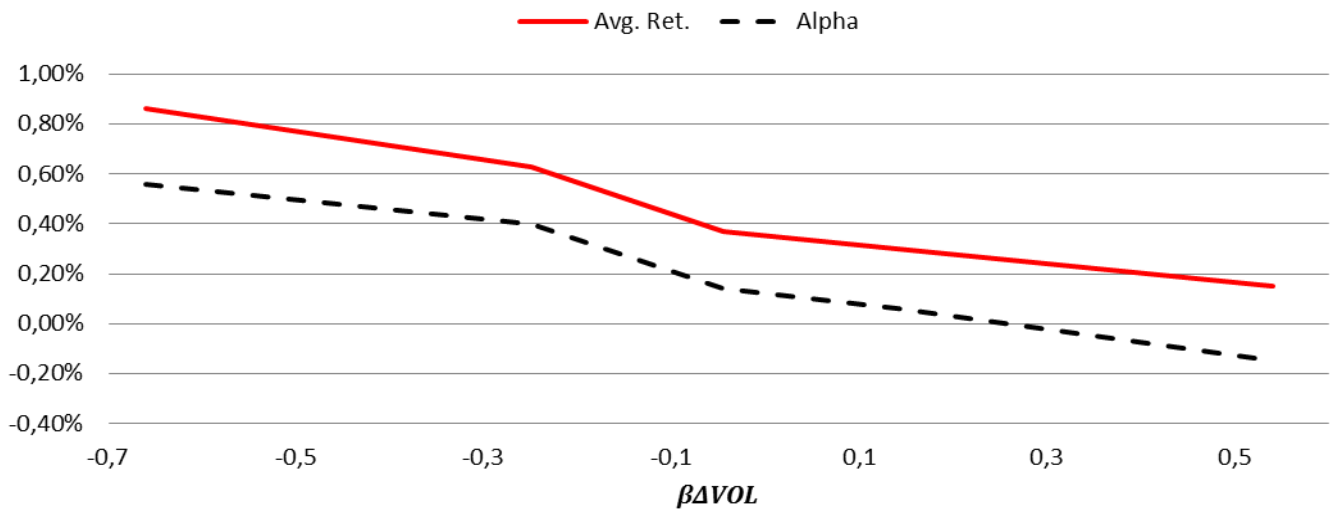
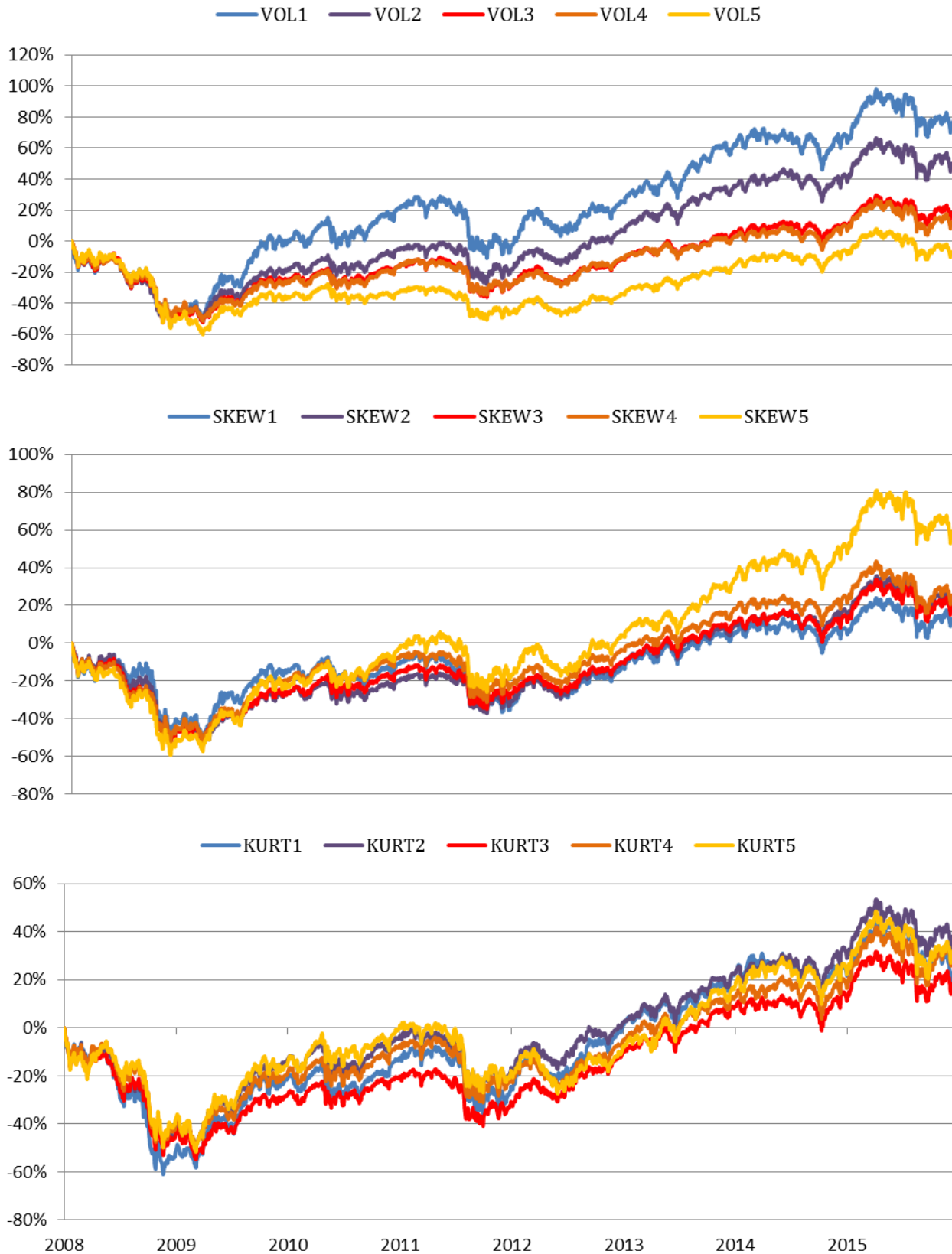Figure 5 – Cumulative performance of portfolios sorted on exposure to innovations in implied moments

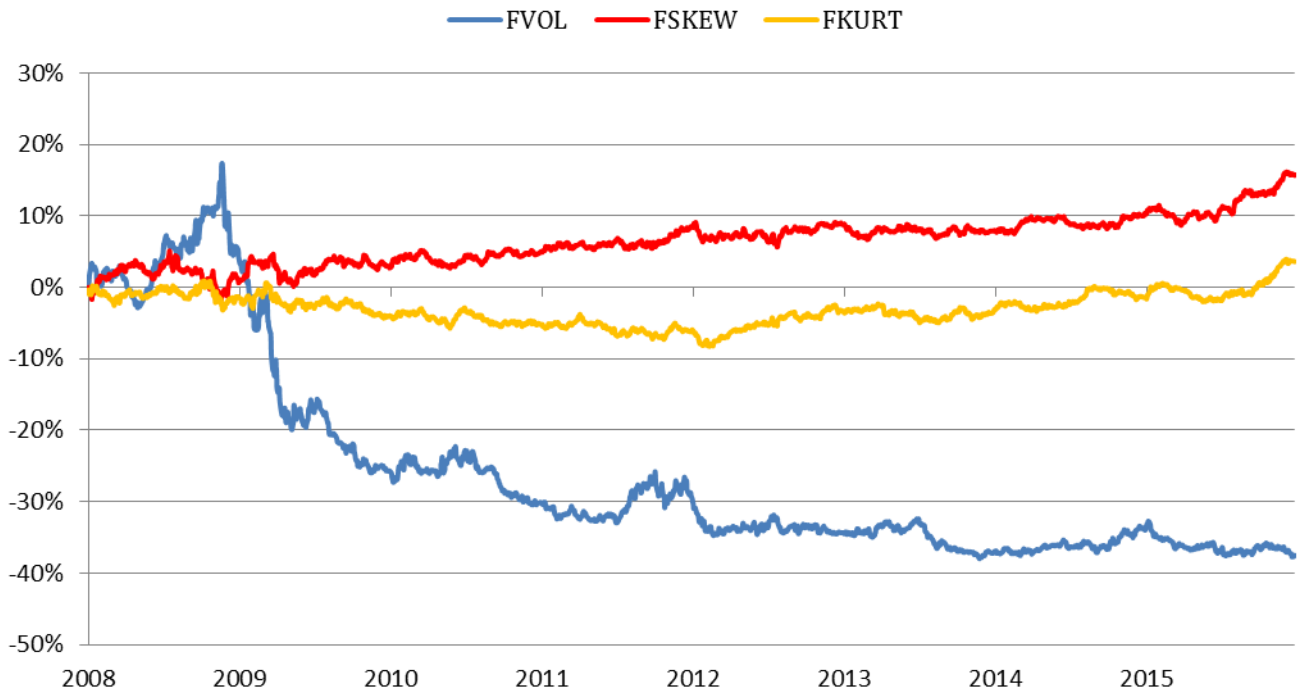Figure 6 – Cumulative performance on factor portfolios for exposure to moments risk

Figure 7 – Cumulative performance on Carhart (1997) factor portfolios