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Risk-asymmetry indices in Europe

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Abstract: The objectives of this study are threefold. First, we introduce for the first time a skewness index (SKEW) for each European country. Second, we compute an alternative measure of asymmetry (RAX) based on corridor implied volatilities to assess whether it outperforms the standard skewness index in measuring tail risk. Third, we investigate the properties of the proposed indices by uncovering the contemporaneous linear relationship among skewness, volatility, and returns and the information content of skewness on future returns, which is highly debated in the literature. Last, we propose two aggregate indices of asymmetry to monitor the risk of the EU financial market as a whole. To deal with the limited availability of option-based data for European countries, that represent the main obstacle for the construction of such indices in the EU, we delineate a country-specific procedure.

Several results are obtained. First, all the asymmetry indices are on average higher than 100, indicating that the risk-neutral distribution is in general left-skew for the 12 EU countries under investigation. Second, the relation between changes in asymmetry indices and contemporaneous market returns in positive, indicating that asymmetry indices are not able to capture the same fear effect captured by volatility indices. Third, the results for the relationship between asymmetry and volatility (future returns) are mixed both in terms of magnitude and significance and do not allow us to delineate general conclusions. Last, the aggregate asymmetry index based on the RAX methodology is the only one able to forecast future negative returns for all the EU countries in our dataset when it reaches very high levels.

Keywords: skewness index, risk-neutral skewness, corridor implied volatility, returns, European market.

JEL classification: G12, G13, G17

1. Introduction

The paper takes as its starting point the fact that in the EU countries, there is a lack of instruments to measure the risk of each financial market and the risk of the EU financial market as a whole. Only a few countries (mainly from northern and central Europe, the most developed ones) adopt a volatility index traded in the internal stock market. Moreover, none of the EU financial markets is provided with a more advanced index to measure additional tail risk (such as the Chicago Board Options Exchange SKEW index). The CBOE SKEW index has been listed on the CBOE since February 2011 to measure the tail risk not fully captured by the VIX index (CBOE (2010)) in the US market. While VIX measures the overall risk in the 30-day S&P500 log-returns without disentangling the probabilities attached to positive and negative returns, the skewness index (CBOE SKEW) is designed to measure the perceived tail risk, i.e., the probability that assigns to extreme negative returns. Recent empirical evidence shows that asymmetry indices outperform the standard volatility index in forecasting future market returns in both high and low volatility periods (Elyasiani et al. (2018a)).

The importance of accounting for option-implied skewness in asset pricing and portfolio management is highlighted by a high number of contributions (Bali and Murray (2013), Chang et al. (2013), Conrad et al. (2013), Elyasiani et al. (2020)). Also, Seo and Wachter (2019) find that option prices reflect the risk of rare economic events, such as consumption disasters, providing additional evidence for their importance in asset pricing. Despite the key role attributed to option implied skewness as a measure of risk, the literature investigating the properties of asymmetry indices is scant and limited to the US (Faff and Liu (2017)) and the Italian (Elyasiani et al. (2018a, 2018b)) market. On the other hand, for most of the European markets, a measure of the asymmetry in the return distribution and tail risk has yet to be introduced.

The only contribution that investigates a variety of European markets (AEX (Netherlands), CAC (France), DAX (Germany), FTSE (the United Kingdom), IBEX (Spain), MIB (Italy), OMX (Sweden) and SMI (Switzerland)) is Foresi and Wu (2005). Nevertheless, their analysis is limited to the simple estimation of the steepness of the implied volatility curve. More specifically, they show that out-of-the-money put options are more expensive than the corresponding out-of-the-money call options, i.e., risk-neutral distributions for these index returns are heavily skewed to the left. Moreover, the majority of the contributions focus on a period characterized by stable markets and low volatility, before the subprime bubble burst (2008-2009) and the European debt crisis from (2010-2012). Finally, none of the previous contributions compare the behavior of asymmetry measures in several markets and whether these risk indices could be useful to understand the risk transfer mechanisms among different countries.

To fill this gap, the paper aims to develop and analyze asymmetry risk indices for 12 index options market in the EU during the 2007-2017 period. The index option markets under investigation include AEX (Netherlands), BEL (Belgium), CAC (France), DAX (Germany), FTSE (the United Kingdom), HEX (Finland), IBEX (Spain), MIB (Italy), OMX (Sweden), and SMI (Switzerland), and for a brief period due to the limited availability of option data also ATX (Austria) and PSI (Portugal). Our dataset is a suitable framework for investigating the behavior of tail risk measures because it is characterized by the occurrence of both the subprime crisis (2008-2009) and the European debt crisis (2011-2012). The presence of high volatility periods in the sample allows us to investigate and contrast the proprieties of the skewness index in various market conditions and economies under stress, such as EU peripheral countries.

To this end, we take the following steps. First, we introduce, for the first time, a skewness index for each European market and two different maturities (30-day, 60-day), along the lines used to construct the *CBOE SKEW* index, to serve as a benchmark for measuring risk-neutral skewness. Second, since the role of the CBOE SKEW index as an indicator of “market fear” has been questioned in the literature (Liu and Faff (2017)), we exploit the concept of upside and downside corridor implied volatility to compute an alternative measure of asymmetry: the risk-asymmetry index (RAX) based on Elyasiani et al. (2018a). To this end, we delineate a country-specific procedure to overcome the limited availability of option-based data for European countries, that represent the main obstacle for the construction of such indices in the EU.

Third, we compare the properties of the obtained skewness indices in the different European markets, and we assess the relationship between the risk indices and market returns. In fact, the relation between skewness and future returns is still debated in the literature, and the evidence on market indices (in particular European ones) is scant. Bali and Murray (2013) and Conrad et al. (2013) find a negative relation between risk-neutral skewness and future stock returns, in line with an investors' preference for positively skewed assets. On the other hand, several other studies find a positive relation between the same variables, suggesting that informed investors trade first in options and only subsequently the information is embedded in asset prices (Cremers and Weinbaum (2010), Xing et al. (2010), Yan (2010), Stilger et al. (2017), Elyasiani et al. (2018a)). Finally, we propose two aggregate indices of asymmetry based either on the SKEW and the RAX methodology to monitor the risk of the EU financial market as a whole.

Several results are obtained. First, all the asymmetry indices show an average value higher than 100, indicating that the risk-neutral distribution is on average left-skewed for each country and both the maturities under investigation (30 days, 60 days). Thus, we confirm this phenomenon (well-known for the US) also for the 12 European markets under investigation. However, differently from the US, EU asymmetry indices also attain values lower than 100, suggesting that during the sample period, the risk-neutral distribution has been right-skewed in some cases. The reason for the dissimilarity could be related to the different institutional features of the European markets compared to the US. The differences include dissimilarity in market depth (US markets are deeper) and in sectoral diversification (European markets are concentrated on financial stocks); for a more detailed discussion, see, e.g., Elyasiani et al. (2020).

Second, the risk-neutral distribution for the 60-day maturity is, in general, more volatile and more skewed to the left than the 30-day risk-neutral distribution (both SKEW and RAX are higher for the 60-day maturity than for the 30-day maturity), suggesting that investors are more feared by tail risk in the medium-term than in the short-term. Third, we find, for almost all the countries in our dataset, evidence of a positive and significant relation between changes in asymmetry indices and contemporaneous market returns, suggesting that asymmetry indices act more as a measure of market greed (fear of losing opportunities) than as a measure of market fear (fear of losing money), in line with the literature on the US market (Faff and Liu (2017)). This also means that asymmetry indices are not able to gauge the current level of fear in the market, as occurs for the majority of the volatility indices, that show a strong negative relationship with market returns. Moreover, the low R-squared values indicate a poor level of association between returns and changes in asymmetry.

Fourth, regarding the debated relation between changes in volatility and changes in asymmetry (Faff and Liu (2017)), the results are mixed both in term of sign and significance, and largely depends on the country taken into consideration. A possible explanation is the existence of a significant difference between the European markets. For instance, heterogeneity in market depth and sectoral diversification might affect investor behavior and their perception of volatility and skewness risks. As a consequence, the debated relation between changes in volatility and skewness may have arisen from the use of different datasets (both in terms of markets and period).

Fifth, also the relation between country-specific market indices and future returns is mixed both in terms of magnitude and significance and does not allow us to draw a general conclusion about the possibility of exploiting asymmetry indices for forecasting market realization.

An exception is represented by the Italian market, since high (low) values in asymmetry indices are associated with low (high) future FTSE MIB returns, in line with Elyasiani et al. (2018a). The strong predictive power of asymmetry indices on the Italian stock market can be related to the Italian market contribution to the instability of the EU financial market in our sample. To elaborate, informed traders in the Italian stock market, worried about the spread dynamics between the Italian and the German government debt returns, conveyed this additional information in MIBO option prices.

Last, while the aggregated skewness index based on the CBOE methodology fails to signal positive or negative future returns, the proposed EU-RAX index provides crucial information to investors. In particular, when the aggregate index based on the RAX methodology reaches its top levels, future negative returns are expected for all the 12 EU countries. This result is of paramount importance for improving the forecast of left tail events and to avoid large portfolio losses.

2. The construction of the European skewness indices

The standard market practice adopted to compute risk-neutral skewness, in line with the CBOE procedure (CBOE (2010)), is the Bakshi et al. (2003) model-free skewness formula:

$$SK(\mathrm{t},\tau) \equiv \frac{E_t^q\left\{\left(R(\mathrm{t},\ \tau)-E_t^q\left[R(\mathrm{t},\ \tau)\right]\right)^3\right\}}{\left\{\left(E_t^q(R(\mathrm{t},\ \tau)-E_t^q\left[R(\mathrm{t},\ \tau)\right]\right)^2\right\}^{3/2}} = \frac{e^{r\tau}W(\mathrm{t},\tau)-3e^{r\tau}\mu(\mathrm{t},\tau)V(\mathrm{t},\tau)+2\mu(\mathrm{t},\tau)^3}{\left[e^{r\tau}V(\mathrm{t},\tau)-\mu(\mathrm{t},\tau)^2\right]^{3/2}}. \quad (1)$$

In this specification, $R(\mathrm{t},\ \tau)$, $\left[R(\mathrm{t},\ \tau)\right]^2$ and $\left[R(\mathrm{t},\ \tau)\right]^3$ are the payoffs of the contracts at time *t* with maturity τ, based on first, second and third moment of the distribution, respectively and $\mu(\mathrm{t},\tau)$, $V(\mathrm{t},\tau)$, $W(\mathrm{t},\tau)$ and $X(t,\tau)$ are the prices of the contracts, at time t with maturity τ, based on first, second, third and fourth moment of the distribution, respectively. Their value is computed as:

$$\mu(t,\tau) \equiv E^q \ln\left[S(t+\tau)/S(t)\right] = e^{r\tau} - 1 - \frac{e^{r\tau}}{2}V(t,\tau) - \frac{e^{r\tau}}{6}W(t,\tau) - \frac{e^{r\tau}}{24}X(t,\tau) \quad (2)$$

$$V(t,\tau)=\int_{S(t)}^{\infty}\frac{2\left(1-\ln\left[K/S(t)\right]\right)}{K^2}C(t,\tau;K)\,dK+\int_{0}^{S(t)}\frac{2(1+ln\left[S(t)/K\right]}{K^2}P(t,\tau;K)\,dK \tag{3}$$

$$\begin{aligned}W(t,\tau)=&\int_{S(t)}^{\infty}\frac{6\ln\left[K/S(t)\right]-3\left(ln\left[K/S(t)\right]\right)^2}{K^2}C(t,\tau;K)\,dK+\\&-\int_{0}^{S(t)}\frac{6\ln[S(t)/K]+3ln\left([S(t)/K]\right)^2}{K^2}P(t,\tau;K)\,dK\end{aligned} \tag{4}$$

$$\begin{aligned}X(t,\tau)=&\int_{S(t)}^{\infty}\frac{12\left(\ln\left[K/S(t)\right]\right)^2-4\left(ln\left[K/S(t)\right]\right)^3}{K^2}C(t,\tau;K)\,dK\\&+\int_{0}^{S(t)}\frac{12\left(\ln[S(t)/K]\right)^2+4\left(ln[S(t)/K]\right)^3}{K^2}P(t,\tau;K)\,dK\end{aligned} \tag{5}$$

where $C(t,\tau;K)$ and $P(t,\tau;K)$ are the prices of a call and a put option at time t with maturity τ and strike K, respectively, $S(t)$ is the underlying asset price at time t.

In line with the CBOE procedure (CBOE (2010)), to compute a measure with a 30-day (60-day) fixed maturity, two option series, a first option series with a maturity of less than 30 days (60 days) and a second option series with time to maturity greater than 30 days (60 days), are used:

$$SK=wSK_{near}+(1-w)SK_{next} \tag{6}$$

with $w=(T_{next}-\tau)/(T_{next}-T_{near})$, T_{near} (T_{next}) is the time to expiration of the near- and next term options, τ is equal to 30 or 60, on the basis of maturity choice, and SK_{near} and SK_{next} are the skewness measures, which refer to the near and next term options, respectively. Moreover, in line with the CBOE procedure (CBOE, 2010), we compute the skewness indices for each European country as:

$$SKEW=100-10\times SK \tag{7}$$

where *SK* is obtained in equation (1). Given that the risk-neutral skewness attains typically negative values for equity indices, formula (7) enhances the interpretation of the SKEW index. For symmetric distributions, risk-neutral skewness is equal to zero, and the SKEW index will be equal to 100. This value is a threshold level for the skewness index since values higher (lower) than 100 mean that the risk-neutral distribution is asymmetric to the left (right). Moreover, a high value of the SKEW index indicates that buying protection against market downturns (put options) is more expensive.

The CBOE SKEW index is meant to supplement the information contained in the CBOE volatility index (CBOE VIX), which measures the overall risk in the 30-day S&P500 log-returns. Despite its critical role in describing the return distribution, the CBOE SKEW index has not acquired the same outstanding reputation as the CBOE VIX index (Elyasiani et al. (2018b)). This may be, at least partially, due to the positive relationship between changes in the CBOE SKEW index and those of the market returns (see, e.g., Faff and Liu (2017)), that associate a positive change in the CBOE SKEW index to an increase in market returns. Moreover, while the volatility index (CBOE VIX) spikes during periods of market downturn, the skewness measure (CBOE SKEW) is known to spike in both calm and turmoil periods. These two points raise questions about the usefulness of the CBOE SKEW index as an indicator of US market fear (Faff and Liu (2017), Elyasiani et al. (2018b)), namely a barometer that spikes during periods of high volatility and market downturn. The poor performance of the SKEW index in measuring market fear calls for alternative asymmetry measures that are better suited to describe market fear.

3. Alternative measure of asymmetry obtained from option prices

To account for the asymmetry in the risk-neutral distribution, i.e. the fact that investors like positive spikes while they dislike negative spikes in the returns, the concept of upside and downside corridor implied volatility measures is exploited to obtain alternative indicators of risk. Corridor implied volatility can be computed as the square root of corridor implied variance (*CIV*), that is obtained from model-free implied variance due to Britten-Jones and Neuberger (2000) by truncating the integration domain between two barriers (see Carr and Madan (1998) and Andersen and Bondarenko (2007)):

$$\hat{E}\left[CIV(t,\tau)\right] = \hat{E}\left[\frac{1}{T}\int_t^T \sigma^2(t,\ldots) I_t(B_1B_2)\,dt\right] \tag{8}$$

where $I_t(\ldots)$ is an indicator function that accumulate variance only if the underlying asset lies between the two barriers (B_1 and B_2). According to Demeterfi et al. (1999) and Britten-Jones and Neuberger (2000), it is possible to compute the expected value of corridor implied variance (CIV), under the risk-neutral probability measure, by using a portfolio of options with strikes ranging from B_1 to B_2, as:

$$\hat{E}\left[CIV(t,\tau)\right] = \frac{2e^{r\tau}}{\tau}\int_{B_1}^{B_2} \frac{M(K,\tau)}{K^2}\,dK \tag{9}$$

where $M(K,\tau)$ is the minimum between a call or put option price with strike price K and maturity τ, r is the risk-free rate, and B_1 and B_2 are the barrier levels within which the variance is accumulated. Downside corridor implied variance is obtained by setting B_1 equal to zero and B_2 equal to the forward price, F_t, on the other hand, upside corridor implied variance is computed by setting B_1 equal to the forward price, F_t, and B_2 equal to infinity (∞).Downside and upside corridor implied volatility (σ_{DW}) are the square root of downside and upside corridor implied volatility (σ_{UP}), respectively:

$$\sigma_{DW}(t,\tau) = \sqrt{\frac{2e^{r\tau}}{\tau}\int_{t}^{F_t} \frac{M(K,\tau)}{K^2}\,dK} \tag{10}$$

$$\sigma_{UP}(t,\tau) = \sqrt{\frac{2e^{r\tau}}{\tau}\int_{F_t}^{\infty} \frac{M(K,\tau)}{K^2}\,dK} \tag{11}$$

and $F_t = K^* e^{r\tau} * difference$, where K^* is the reference strike price (i.e. the strike at which the $difference$ in absolute value between the at-the money call and put prices is the smallest)[1].

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[1] Following Elyasiani et al. (2018a), corridor implied volatility is computed as a discrete version of equations (10) and (11) with integration domain equal to [$K_{\min}$, F] and [F, $K_{\max}$], where $K_{\min}$ and $K_{\max}$ correspond to the minimum and maximum strike price ensuring an insignificant truncation error (for more details see Muzzioli (2015)).

Corridor implied volatility has been exploited in Elyasiani et al. (2018a) to compute an alternative asymmetry measure for the risk-neutral distribution: the RAX index, which is meant to capture the investors' pricing asymmetry towards upside gains and downside losses. Following Elyasiani et al. (2018a), we aggregate upside and downside corridor implied volatilities into the risk-asymmetry index (RAX), which measures the difference between upside and downside corridor implied volatilities standardized by total volatility. In particular, the numerator is standardized by total volatility, in this way, the RAX index is not influenced by the level of volatility in bullish or bearish market periods:

$$RAX\left(t,\tau\right)=\frac{\sigma_{UP}\left(t,\tau\right)-\sigma_{DW}\left(t,\tau\right)}{\sigma_{TOT}\left(t,\tau\right)} \tag{12}$$

where $\sigma_{TOT}\left(t,\tau\right)$ is the sum of the upside and downside corridor implied volatilities and coincides with model-free implied volatility. To get a constant 30-day (60-day) measure for the risk-asymmetry index, the RAX index is obtained by using the same linear interpolation procedure of the near- and next- term options adopted for the SKEW (equation 6). Moreover, the transformation in equation 7 is applied also to the daily values of the RAX index for ease of comparison with the SKEW index. Therefore, a value of the RAX higher than 100 indicates that the volatility of the left side of the distribution (σ_{DW}) is higher than the one of the right side (σ_{UP}), indicating that investors attach a higher (risk-neutral) probability to negative returns.

4. Application of the asymmetry measures to the European market

Our data set consists of closing prices of index options in 12 different countries, recorded from 2 January 2007 to 29 December 2017 based on availability[2]. The options data set, the dividend yield and the Euribor rates are obtained from OptionMetrics (IvyDB Europe). As for the underlying assets, the time series of

[2] Available option series start from February 7, 2014, for ATX (Austria) and from June 15, 2016, for PSI (Portugal).

the underlying assets are obtained from Bloomberg. Options are of European type. Following Muzzioli (2013a, 2013b), whether the underlying of the option series is an asset that pays dividends we compute its adjusted value as:

$$\hat{S}_t = S_t e^{-\delta_t \Delta t} \tag{13}$$

where S_t is the underlying asset 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.

Several filters are applied to the options data set to eliminate arbitrage opportunities and other irregularities in the prices. First, in line with the computational methodology of other indices (such as the CBOE SKEW), we eliminate options with time to maturity of less than eight days. Second, following Ait-Sahalia and Lo (1998), being in-the-money options infrequently traded compared to the other types of options and being their prices notoriously illiquid, only at-the-money and out-of-the-money options are retained. Following Elyasiani et al. (2018a) we consider 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. Moreover, in order to have a one-to-one correspondence between strikes and implied volatilities, we average the implied volatilities of options that correspond to the same strike price. Finally, we eliminate option prices violating the standard no-arbitrage constraints are eliminated.

However, the main obstacle for the construction of indices based on option prices in the EU is still the limited availability of option-based data for European countries. In particular, equation (1) and equations (10-11) require the existence of a continuum of strike prices ranging from zero to infinity, an assumption that is not fulfilled in the reality of the options market. While this assumption can be mitigated for the US market by the high number of option prices traded (usually around 120 per day), for peripheral European markets which are characterized by a limited number of strike prices traded (Elyasiani et al.

(2018b)), truncation and discretization errors can be expected to be very high. To this end, we delineate a country-specific procedure to nearly eliminate truncation and discretization errors and to greatly improves the precision of the skewness estimate.

First, after having applied the filters described above, we create a table of available strike prices and implied volatilities, which is our initial input. Second, to achieve a sufficient number of strike prices, we follow an interpolation-extrapolation methodology (see Jiang and Tian (2005)). Implied volatilities are interpolated between two adjacent knots using cubic splines to keep the function smooth in the knots and extrapolated outside the traded domain of strike prices. More specifically, we suppose constant volatility for strike prices higher than the maximum strike price traded and lower than the minimum strike price traded. The constant volatility used in the left (right) part of the extended smile is set to be equal to the volatility of the lowest (highest) strike price traded. This ensures to avoid negative implied volatilities (Muzzioli et al. (2018)). Last, from the interpolated-extrapolated smile, we compute missing implied volatility and strike prices by using a country-specific space interval (details are reported in Table 1) to ensure insignificant truncation errors. On the other hand, truncation errors are mitigated by computing a matrix of strike prices and implied volatility in the interval $S/(1+u) \le K \le S(1+u)$, where is the underlying asset value, and u is a parameter equal to 2 for all countries.

The obtained implied volatilities are finally converted into option prices and used in equation (1) to construct the model-free skewness measure based on Bakshi et al. (2003) and in equations (10-11) to obtain the corridor volatility measures. Therefore, our procedure for computing the European skewness indices is designed to follow the CBOE methodology to the point possible, while departing from it in the interpolation-extrapolation step, which is country-specific and essential for coping with the limited number of strike price available. Finally, to better understand the properties and the behavior of the obtained asymmetry measures, we compute, for each country, also a model-free volatility measure as the sum of corridor implied volatilities described in equations (10)-(11).

5. Properties of the European asymmetry indices

5.1. Descriptive analysis

By performing the methodology described in Sections 3-5, we compute for each of the 12 countries in our dataset, four asymmetry indices (two indices for each maturity, i.e., $SKEW_{30}$, RAX_{30}, $SKEW_{60}$, and RAX_{60}) and two volatility indices (VOL_{30}, and VOL_{60}). We thus obtain about 2870 daily closing values for the proposed risk indices. The descriptive statistics for the asymmetry and the volatility indices computed using options with a 30-day (60-day) are reported in Table 2, left panel (right panel). Several considerations can be drawn. First, all the asymmetry indices show an average value higher than 100, indicating that the risk-neutral distribution is on average left-skewed for each country and both the maturities under investigation. Second, the minimum values for the asymmetry indices are, in many cases, lower than 100, suggesting that during the sample period, the risk-neutral distribution has also been right-skewed. This result is in contrast with the SKEW index listed for the S&P500, which has always show values higher than 100 in the same period. The reason for the dissimilarity could be related to the different institutional features of the European markets compared to the US. More specifically, dissimilarity in market depth (US markets are deeper) and in sectoral diversification (European markets are concentrated on financial stocks) may have influenced investors' perception of asymmetry risk (see, e.g., Elyasiani et al. (2020) for a more detailed discussion).

Third, the average value for both the asymmetry indices (SKEW, RAX) is higher for the 60-day horizon than for the 30-day horizon for all the countries, suggesting that risk-neutral skewness declines (becomes more negative) for longer maturities. Fourth, also, the average implied volatility during the sample period has been higher for longer maturity. Therefore, the 60-day risk-neutral distribution is, in general, more volatile and more skewed to the left than the 30-day risk-neutral distribution. Last, implied volatility is higher for peripheral countries (Spain, Italy), which suffered the most from the European debt crisis, and it is quite low for Switzerland, which played as a safe haven during the crisis. The low average value achieved by ATX (Austria) and PSI (Portugal) are due to the limited sample period for these countries.

5.2. Role of the asymmetry indices

The objective of this section is to investigate the properties of the asymmetry indices proposed for the 12 European countries under investigation. There is mixed evidence in the literature regarding the relationship between skewness on the one hand, and returns and volatility on the other. To address this issue, several hypotheses are tested. First, in order to understand whether the skewness indices can be considered as a measure of fear (fear of losing money) or greed (fear of losing opportunities) in the market, we assess the relationship between changes in the skewness indices on one side and underlying asset returns on the other. Second, we uncover the relationship between changes in asymmetry and changes in volatility for the different EU countries under investigation. Third, we investigate the relative explanatory power of volatility and skewness on contemporaneous returns. In particular, the study of the contemporaneous relationship between changes in the skewness indices and returns is important to assess whether the skewness index contains information about investors' fear of future downturns (see, e.g., Faff and Liu (2017)).

5.3. Relation between contemporaneous changes in asymmetry indices and market returns

Theoretical literature provides little guidance in understanding the expected relationship between changes in skewness measures and market returns. Chabi-Yo (2012) shows that the price of market skewness depends on the fourth derivative of the utility function, which is hard to sign. Therefore, the relation between returns and changes in skewness remains mainly an empirical question (Chang, Christoffersen, and Jacobs (2013)).

To test whether the skewness indices can be considered as an indicator of market fear or market greed, i.e., whether thy measure more investors' excitement than investors' fear, we estimate the following regression:

$$R_t = \alpha + \beta \Delta index_t + \varepsilon_t \tag{14}$$

where $index_t$ is proxied alternatively by the daily changes in the asymmetry indices ($SKEW_{30}$, $SKEW_{60}$, RAX_{30}, and RAX_{60}). For the sake of comparison, also volatility indices are included in the analysis (in this case $index_t$ is proxied by VOL_{30}, and VOL_{60}).

The results, reported in Table 3, show the existence of a positive and significant relationship between changes in the $SKEW_{30}$ index and the daily underlying asset returns for all the countries with the only exceptions of Austria and Portugal (Panel A). When we consider the 60-day measure of skewness ($SKEW_{60}$), the relationship is positive and significant for all the countries (Panel B). This result suggests that the SKEW index acts more as a measure of market greed (fear of losing opportunities) than as a measure of market fear (fear of losing money), in line with the literature on the US (Faff and Liu (2017)). Similar results, although weaker, are obtained by the RAX index (Panels C and D). A notable exception is represented by the RAX index computed for the FTSE 100 index, which attains a negative and significant relation with market returns in terms of daily changes. In general, the explanatory power of changes in skewness on returns is quite low (none of the adjusted R-squared is higher than 10%), it is higher for the 60-days maturity and more liquid option markets (DAX, SMI).

On the other hand, changes in volatility indices display a negative and significant relationship with the underlying asset returns, with the only exception of Belgium. The negative relation between volatility and returns (leverage effect), a well-known result in the literature (see, e.g., Whaley (2000), Giot (2005)), indicates that volatility indices act as a fear indicator also in the European stock market. Once again, the explanatory power of changes in volatility on current returns is, in general, higher for the 60-day time horizon.

5.4. *Relation between contemporaneous changes in asymmetry indices and in volatility*

As a second step, to better investigate the relationship between asymmetry and volatility, which is highly debated in the literature, we estimate, for each country, the following regression (Faff and Liu (2017)):

$$\Delta VOL_t = \alpha + \beta \Delta index_t + \varepsilon_t \tag{15}$$

where ΔVOL is proxied by daily change in the volatility indices (VOL_{30}, and VOL_{60}), and $index_t$ is proxied alternatively by the daily changes in asymmetry indices ($SKEW_{30}$, $SKEW_{60}$, RAX_{30}, and RAX_{60}).

The results, reported in Table 4, are mixed both in terms of sign and significance and present country-specific patterns. In particular, a positive (negative) relation between changes in volatility and skewness is detected for the Netherlands, Austria, Finland, and Sweden (France, Spain, Switzerland), while for Italy, the sign of the relation depends on the maturity. On the other hand, the RAX_{30} index shows a positive relationship with volatility in terms of daily changes for all the countries with the exceptions of Austria (non-significant) and France (negative relation). For both the asymmetry measures, the relation with changes in volatility weakens for the 60-day maturity.

The results we obtain suggest that the relation between volatility and skewness is highly dependent on the specific feature of the market and the maturity under investigation. In particular, the European market presents many dissimilarities not only if compared to the US market, but also in the countries that are part of it. Heterogeneity in market depth and sectoral diversification might affect investor behavior and their perception of volatility and skewness risks. Therefore, the controversial results obtained in the literature for the relationships between volatility and skewness may have arisen from the analysis of different markets.

5.5. *Combined relation between changes in asymmetry and volatility indices on market returns*

To assess the relative information content embedded by the skewness and the volatility indices about investors' fear of current market downturns, we investigate the combined explanatory power of changes in volatility and changes in asymmetry indices on contemporaneous returns, by exploiting the model adopted in Elyasiani et al. (2018b):

$$R_t = \alpha + \beta_1 \Delta VOL + \beta_2 \Delta index_t + \varepsilon_t \qquad (16)$$

where ΔVOL are the daily changes of volatility indices (VOL_{30}, and VOL_{60}) and $\Delta index$ is proxied alternatively by daily changes in the asymmetry indices ($SKEW_{30}$, $SKEW_{60}$, RAX_{30}, and RAX_{60}). The results of the model (estimated for each of the 12 countries) are reported in Table 5. In all the countries with the only exception of Belgium (BEL), the volatility index attains a negative and significant relation with market returns in terms of daily changes, indicating that volatility indices act as measures of market fear. On the other hand, the asymmetry indices display a positive and significant relation with market returns for all the markets, with the only exception of Portugal (PSI). Therefore, in the European stock markets, a positive relationship prevails between asymmetry and European market returns, qualifying the European asymmetry indices more as measures of market greed (fear of losing opportunities) than market fear (fear of losing money).

However, the incremental contribution of asymmetry changes in the explanation of contemporaneous market returns is still limited compared to the one attributable to changes in volatility. A possible explanation is that the information content of option-implied measures, which reflect the investors' expectation over the next 30-day (60-day), should be investigated on a more appropriate time horizon, i.e., the next month (two months). This hypothesis will be investigated in the next section.

6. The relation between asymmetry and future market returns

The relation between skewness and future returns is still highly debated in the literature, especially regarding the sign. A first strand of literature (see, e.g. Bali and Murray (2013), Conrad et al. (2013) and Amaya et al. (2015)), find a negative relation between risk-neutral skewness and future market returns, suggesting that assets with a more pronounced left-skewed risk-neutral distribution earn higher future returns to compensate for their higher left-tail risk. On the other hand, the second strand of literature (Xing et al. (2010), Cremers and Weinbaum (2010), Yan (2011), Faff and Liu (2017), Stilger et al. (2017), Elyasiani et al. (2018a)) find a positive relation between risk-neutral skewness (or other proxies for skewness) and returns, since informed investors trade first in the option market and only subsequently the information is reflected in stock prices in the spot market. In particular, according to Lin and Lu (2015), options traders receive tips from analysis such as upcoming recommendation changes or earnings forecast revisions. A theoretical explanation for the empirical results cited above is provided by the general equilibrium model developed in Sasaki (2016), who finds a significantly positive relation between the jump risk and future aggregate index market return. It is worth noting that none of the contributions listed above investigates a variety of markets, being the empirical analysis performed on a single asset or, at most, on the constituents of a market index.

6.1. The level of risk and future market returns

To establish whether the index values are associated with positive or negative future returns, thus highlighting the possibility of profits or losses in the underlying market, we estimate the model proposed in Rubbaniy et al. (2014) for each of the 12 markets under investigation:

$$R_{t,t+n} = \alpha + \beta_1 index_{t,n} + \varepsilon_t \tag{17}$$

where $index_t$ is alternatively proxied by levels of the asymmetry indices ($SKEW_{30}$, $SKEW_{60}$, RAX_{30}, RAX_{60}) and the volatility indices (VOL_{30}, VOL_{60}) for the sake of comparison; $R_{t,t+n}$ is the underlying asset log-return computed between day *t* and day *t+30 (t+60)*, in order to have the same time horizon of the right-hand-side measure of risk.

The results, reported in Table 6, show on average low adjusted R-squared, in line with previous contributions that investigate the relationship between risk indices in terms of levels and market returns (Rubbaniy et al. (2014), Elyasiani et al. (2018a)). The only exception is represented by ATX (Austria), probably being affected by the short sample available (from February 7, 2014, to December 29, 2017).

Regarding the sign and the significance of the relationship, the results show country-specific patterns, i.e., they largely depend on the country and the maturity under investigation. In general, the relationship between the asymmetry indices for the UK and the future returns of the FTSE 100 index is negative and significant, suggesting that high levels in the asymmetry indices are associated with low future market returns. Similar results, although weaker, are found for Finland (HEX) for the 60-day maturity. For the same maturity, also, the FTSE MIB returns (Italian market) are negatively associated with the levels of the RAX index, while no forecasting power of the SKEW index is detected in this market. These findings are in line with Elyasiani et al. (2018a), who find a negative relation between asymmetry indices and future market returns, that is stronger in the medium term than in the short term and for the RAX index if compared to the SKEW index.

However, leaving apart the cases of ATX and PSI (due to the limited number of observations), there exist few exceptions for the negative relation between asymmetry indices and future market returns. These are OMX (Sweden) and BEL (Belgium), for which the relation between index levels and future returns is positive and significant, suggesting that high (low) levels of the risk indices are associated with high (low) future market returns. The OMX index suffered from a small market decline compared to other European countries during the sample, and it is characterized, along with the BEL index, by a low level of volatility on average (see Table 2, Panels E and F). These features might have affected the investor behavior in these markets and their perception of skewness risks. Finally, evidence about the sign and the significance of the relation is mixed for the French market (CAC).

The results for the relation between levels of volatility and future market returns, reported in Table 6, Panels E and F, display a positive and significant association in two (five) different markets for the short-term (medium-term) maturity. These positive sign for the relation between volatility and future market returns is consistent with the capital asset pricing model, predicting that if volatility is high, investors require a higher return in order to be compensated for the higher risk. A significant positive medium-term relation between volatility indices and future stock returns is also documented in Rubbaniy et al. (2014) and in Elyasiani et al. (2018a).

Although these results could be a starting point to understand the sign and the significance of the relationship between asymmetry indices and their behavior for the different countries in our dataset, the forecasting performance of asymmetry indices on future returns is found to be quite poor, leaving investors without clear signals for their investment choices.

6.2. The information content of extreme values of the asymmetry indices

An alternative perspective for investigating the relationship between asymmetry indices and future market returns is proposed in Rubbaniy et al. (2014), who estimate the relation between different levels of implied volatility indices (index values higher than the 90%, 95%, and 99% percentiles or lower than the 1%, 5%, and 10% percentiles) and the corresponding future index returns. The underlying rationale is that high, or very high, implied volatility levels may indicate an oversold market and, as a result, possible positive future returns for long positions in the underlying market (Giot (2005)).

Previous empirical results on volatility indices suggest that very high levels of volatility are related to positive future market returns, in line with the suggestion in Giot (2005). By exploiting the same model proposed in Rubbaniy et al. (2014), Elyasiani et al. (2018a) detect a negative relation between very high levels in the RAX index and future returns in the Italian market, suggesting that the RAX could be used by investors as an early warning about future market returns.

The procedure proposed in Rubbaniy et al. (2014) that analyze the sub-samples at extremes level, suffers from a significant drawback. More specifically, when the regression model described in equation (17) is estimated on the sub-samples that consider only extreme index values, the number of observations in each sample could be very low[3]. To avoid this issue, we adopt an alternative test based on a trading strategy, that takes a long position in the underlying asset (the index to which the risk measure is referred) when the asymmetry (SKEW or RAX) index level is lower (higher) than its 1%, 5%, and 10% (90%, 95%, and 99%) percentiles. In line with Elyasiani et al. (2018a), we investigate the profitability of the strategy for both, short (30-day) and medium-term (60-day) holding periods and report the results in Table 7 (Table 8) for index levels lower (higher) than its 1%, 5% and, 10% (90%, 95%, and 99%) percentiles.

When asymmetry indices are very low, future market returns are in general positive and significant for Finland (HEX), Spain (IBEX), Italy (MIB), and Portugal (PSI). Similar results are found for the UK (FTSE) when extremely low values of the asymmetry indices are considered, and also for Germany (DAX) and France (CAC), when considering very low values for their RAX_{30} (RAX_{60}) index, respectively. Weak evidence of a relationship between low RAX index levels and positive future market returns is also detected for Switzerland (SMI). Last, a few exceptions for the relation between low levels of asymmetry indices and future market returns are found for the Netherlands (AEX), Belgium (BEL), and Sweden (OMX), that display negative and significant returns in some cases. In general, we find evidence of a positive and significant relation between country-specific asymmetry indices and future

[3] When the lowest and the highest percentiles are considered (index values lower than the 1% percentile or higher than the 99% percentile), the number of observations for a sample consisting of 10 years of daily data is around 25. Therefore, standard regression assumptions can be questioned.

market returns, especially for the largest European markets in terms of market capitalization. On the other hand, the results for very low volatility levels, reported for the sake of comparison, are mixed both in terms of sign and magnitude, and do not allow strong conclusions.

When we consider very high values for the asymmetry indices (Table 8), the results are quite confusing, and it is not possible to detect a clear pattern. Very high values of asymmetry can anticipate future negative returns for Italy (MIB), in line with previous findings in Elyasiani et al. (2018a), and for Finland (HEX), if a 60-day measure of asymmetry is adopted. On the other hand, many countries (Austria, Belgium, Germany, Sweden, and Switzerland) show on average positive future returns when their asymmetry indices reach very high levels. Finally, we obtain mixed results for Portugal and the Netherlands, depending on the asymmetry indices used as a signal (SKEW or RAX), and for France. Therefore, relying on these results, it is not possible to draw general conclusions for the relation between very high values of asymmetry indices and future market returns. Also, for very high volatility levels, the sign of future market returns is mixed and largely depends on the specific country taken into consideration.

Possible explanations for the latter results can be related to the country-specific feature of options markets and the nature of the shocks that affected the European markets in the period under consideration. First, despite the interpolation-extrapolation methodology, some countries are characterized by a lower number of strike prices traded (Finland, Belgium, Austria and Portugal), producing a larger noise in the final estimate of asymmetry indices. Second, it is interesting to note that very low (high) values of asymmetry indices correctly predict positive (negative) future market returns for Italy, which is one of the countries that contribute the most to the financial instability and market downturns in the European area during the sample. Elyasiani et al. (2017) find results consistent with the hypothesis that information embedded in option prices is higher when the reasons for the crisis are within the market itself. More specifically, informed traders in the Italian stock market were extremely worried about the spread dynamics between the Italian and the German government bond returns, and they conveyed this information in option prices. On the other hand, the same information may not have been priced in other European markets.

Given the high level of association between the daily returns among the markets in our dataset (average correlation = 80%), a possible solution to deal with these issues is to aggregate the information embedded in the 12 asymmetry indices in a unique index of asymmetry for the European market. This point will be the focus of the next section.

7. Towards an aggregate index of asymmetry for the European market

In this section, we propose a first attempt to compute a unique asymmetry index to monitor the risk of the EU financial market as a whole. We believe that aggregating the information content of the 12 asymmetry indices could be useful to convey all the information about tail risk arising from the different countries and, at the same time, could help in making asymmetry index series more regular and stable. To account for the relative importance of the different markets in our dataset, we collect the daily data on market capitalization (in Euro) for each of the 12 countries under investigation. Total market capitalizations and relative market capitalization during the sample are reported in Figure 1. While the first (reported in the upper panel) is highly time-varying, especially during the 2007-2009 financial crisis, the latter (reported in the lower panel) is quite stable during the whole sample, indicating that also the composition of the aggregate index has not drastically changed in time. The major contribution is from the UK (30% on average), followed by France, Germany, and Switzerland. The contribution of the UK has increased in the period following the financial crisis, due to the faster recovery of the FTSE 100 index compared to other EU markets.

Each day, the aggregate index of asymmetry is computed as:

$$agg\_index = \frac{\left[w_1, w_2, ..., w_n\right] \cdot \left[s_1, s_2, ..., s_n\right]}{\sum_{i=1}^{n} w_i} \tag{18}$$

where w_i is the daily market capitalization[4] for the i-*th* market and s_i is the estimate for asymmetry for country $i=1,...,n$ obtained before the transformation applied in equation (7).

Finally, in order to compare the results with single country asymmetry indices, we applied the transformation in equation (7) using the aggregate index (agg_index) as input. We obtain two aggregate indices of asymmetry (we call them EU-SKEW and EU-RAX) based on the estimate for asymmetry (based on the SKEW or on the RAX methodology) used to plug-in equation (17).

The aggregate indices of asymmetry obtained using the SKEW (RAX) methodology are depicted on the top (bottom) of Figure 2. All the aggregate asymmetry indices have been higher than 100 during the sample period, indicating that the resulting asymmetry is negative, i.e., investors are in general concerned about future negative returns. The main differences between the aggregate indices based on the SKEW methodology (EU-SKEW$_{30}$, EUSKEW$_{60}$) and the ones based on the RAX methodology (EU-RAX$_{30}$, EU-RAX$_{60}$) is that the first ones reach the highest values in the final part of the sample, while the latter present many peaks also during the worst phase (the 2008-2009 and the 2010-2011 market declines). Moreover, the EU-RAX$_{30}$ index is the only one that presents a significant peak on June 23, 2016, the day of the Brexit referendum, correctly capturing the investors' fear about future market returns. As a result, we expect the EU-RAX$_{30}$ index to provide useful information about future market returns when reaching very high values.

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[4] The value of *w* is set equal to zero until February 7, 2014, for ATX (Austria) and until June 15, 2016, for PSI (Portugal), due to the limitation in the available data.

7.1. Extreme values of aggregate asymmetry indices and future market returns

In order to assess whether the proposed unique asymmetry indices for the EU market can outperform country-specific asymmetry indices in forecasting future market returns, we evaluate their forecasting performance using the same strategy proposed in Section 6.2. In particular, we investigate, for each country, the profitability of a strategy that takes a long position in the underlying asset when the asymmetry index level is lower (higher) than its 1%, 5%, and 10% (90%, 95%, and 99%) percentiles. The results for the relationship between very low values of asymmetry indices (values lower than its 1%, 5%, and 10%) and future market returns (reported in Table 9) are, in general, weak for the 30-day maturity. On the other hand, very low values of the asymmetry indices are associated with positive and significant market returns for Austria, Italy, and Portugal in the medium term (Panels B and C). At the same time, the SKEW (RAX) index is able to forecast positive returns also for Spain (Belgium, France, Finland, and Switzerland). However, the results are not robust to the different samples (percentiles) and tend to weaken for extremely high values of asymmetry indices.

The results for the relationship between very high values of asymmetry indices (values higher than their 90%, 95%, and 99% percentiles) and future market returns are reported in Table 10. When the aggregate index of asymmetry obtained using the CBOE SKEW methodology (EU-SKEW) reaches very high values, it does not display any forecasting power on future market returns, either over the near-term (Panel A) or the medium-term (Panel B). On the other hand, when the aggregate risk-asymmetry index (EU-RAX) hits very high values, the majority of European indices suffer from negative future returns, especially over the next 30 days. Moreover, when the EU-RAX_{30} index reaches extremely high values (values higher than its 99% percentiles, Panel C), future market returns are negative and statistically significant for all the markets taken into consideration. This result can be important for investors, who can use the EU-RAX_{30} index to avoid large portfolio losses and improve the forecast of left-tail risk.

7.2. Extreme values of aggregate volatility indices and future market returns

In the previous section, we have shown that it is possible to aggregate different asymmetry indices in a single measure of risk to improve the forecast about future market returns. To assess whether it is helpful to aggregate the information content also for volatility, we compute an aggregate volatility index for each of the two maturities under investigation ($EU\text{-}VOL_{30}$, $EU\text{-}VOL_{60}$) using the same methodology adopted for asymmetry indices (equation (18)).

The results for the relationship between very low values of the aggregate volatility index (values lower than its 1%, 5%, and 10% percentile) and future market returns are reported in Table 9 (Panels E, F). When the aggregate volatility index is lower than its 1% percentile, future market returns over the next 30 days are positive and significant for 7 of the 12 countries under investigation, including the Netherlands, Austria, Belgium, France, Germany, Spain, and Portugal. For the remaining five countries, returns are not statistically significant. On the other hand, very low values of the aggregate volatility index obtained using options with 60-day time to maturity (Panel F) are not useful to predict future market returns. The results can be interpreted as follows. When volatility across EU countries is extremely low, positive market returns are expected only in the short term. In fact, given the mean-reverting nature of volatility, investors cannot expect volatility to remain very low for a long time.

The opposite pattern is detected when we look at the results for the relationship between very high values of the aggregate volatility index (values higher than its 90%, 95%, and 99% percentile) and future market returns, reported in Table 10 (Panels E, F). When the aggregate volatility index reaches extremely high values, negative and significant future returns are expected for many countries and, in particular, for the 60-day maturity (Panel F). The only exceptions are represented by Sweden and the UK, that present on average positive and significant returns after volatility peaks. Given that both the countries use alternative currencies to the Euro and we converted returns in Euro terms, this result could be explained by the volatility of the currency market during market stress periods.

8. Conclusions

The Chicago Board Options Exchange (CBOE) has developed and quoted the volatility index (VIX) of the US stock market, which was later complemented with the SKEW index, to measure the tail risk not fully captured by the former (CBOE (2010)). On the other hand, among the EU countries, only a few adopt a volatility index traded in the internal stock market, and for most of the European markets, a measure of the asymmetry in the return distribution has yet to be introduced. To fill this gap, we develop and analyze for the first-time asymmetry risk indices for 12 countries in the EU during the 2007-2017 period. These countries include the Netherlands, Belgium, France, Germany, the UK, Finland, Spain, Italy, Sweden, Switzerland, Austria, and Portugal.

The measures of asymmetry introduced in the paper are based on the CBOE SKEW index methodology (to serve as a benchmark for measuring risk-neutral skewness) and on the risk-asymmetry index (RAX) introduced in Elyasiani et al. (2018a). To cope with the limited availability of option-based data for European countries that represent the main obstacle for the construction of such indices in the EU, we propose a country-specific procedure that involves interpolation among the existing strike prices and extrapolation outside of them. We compute the daily series of the two asymmetry measures for two different maturities (30-day, 60-day) to investigate the behavior of asymmetry both in the short- and in the medium- term.

Several results are obtained. First, in line with the prevailing literature, all the asymmetry indices show an average value higher than 100, indicating that the risk-neutral distribution is on average left-skewed for each country and for both the maturities under investigation (30 days, 60 days). However, differently from the US, asymmetry indices attain also values lower than 100, suggesting that during the sample period, the risk-neutral distribution has been right-skewed in some days. The reason for the dissimilarity could be related to the different institutional features of the European markets compared to the US (Elyasiani et al. (2020)), such as dissimilarity in market depth (US markets are deeper) and in sectoral diversification (US markets are more diversified).

Second, according to both the asymmetry measures (SKEW and RAX), the risk-neutral distribution for the 60-day maturity is, in general, more volatile and more skewed to the left than the 30-day risk-neutral distribution, suggesting that investors are more feared by tail risk in the medium-term than in the short-term. Third, we find, for almost all the countries in our dataset, evidence of a positive and significant relation between changes in asymmetry indices and contemporaneous market returns, suggesting that asymmetry indices act more as a measure of market greed (fear of losing opportunities) than as a measure of market fear (fear of losing money), in line with the literature on the US market (Faff and Liu (2017)). This result also suggests that, unlike volatility indices (which are strongly and negatively associated with market returns), asymmetry indices are not able to gauge the current level of fear in the market.

Fourth, regarding the debated relation between changes in volatility and changes in asymmetry (Faff and Liu (2017)), the results are mixed both in term of sign and significance, and largely depends on the country taken into consideration. We expect the heterogeneity in market depth, and sectoral diversification among EU countries might have affected investor behavior and their perception of volatility and skewness risks. Therefore, the debated relationship between volatility and skewness is largely dependent on the market under investigation.

Fifth, also the relation between country-specific market asymmetry indices and future returns is mixed both in terms of magnitude and significance, not allowing us to draw a general conclusion about the possibility of exploiting asymmetry indices for forecasting market returns. However, one notable exception is represented by the Italian market, for which high (low) values in asymmetry indices are associated with low (high) future FTSE MIB returns.

Last, while the aggregated skewness index based on the CBOE methodology fails to signal positive or negative future returns, the proposed EU-RAX index provides crucial information to investors. More specifically, when the aggregate index based on the RAX methodology reaches its top levels, future negative returns are expected for all the 12 EU countries. Similar results, although weaker, are detected for extremely high values of the aggregate volatility index, suggesting that investors can combine the information provided by the two aggregate indices (VOL and RAX) to get more confident signals about future market returns.

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Table 1 – Average number of strike prices available in the 12 European countries under investigation

Index (Country)	(i)	(ii)	(iii)	(iv)	(v)
AEX (Netherlands)	02-01-2007	72	37	0.25	4500
ATX (Austria)	07-02-2014	53	32	1.50	5100
BEL (Belgium)	02-01-2007	37	23	2.00	4300
CAC (France)	02-01-2007	71	22	2.50	4800
DAX (Germany)	02-01-2007	172	53	5.00	4500
FTSE (UK)	02-01-2007	119	37	2.50	6600
HEX (Finland)	02-01-2007	49	30	4.00	5300
IBEX (Spain)	02-01-2007	93	23	5.00	5500
MIB (Italy)	02-01-2007	60	27	1.00	6000
OMX (Sweden)	02-01-2007	64	38	0.50	6600
PSI (Portugal)	15-06-2016	62	38	2.00	6800
SMI (Switzerland)	02-01-2007	145	81	5.00	4200

Note: The table reports:

i) the initial date of the sample for each country under investigation;

ii) the average number of strike prices available before filters;

iii) the average number of strike prices available after filters;

iv) the country-specific parameter ΔK chosen to make discretization errors negligible;

v) the average number of strike prices (after the interpolation-extrapolation procedure) used to plug-in formulas in equations (2)-(5) and (8)-(11).

Table 2 – Descriptive statistics for the asymmetry and the volatility indices

	Avg.	Median	Min.	Max.	Std. Dev.	Avg.	Median	Min.	Max.	Std. Dev.
	Panel A: SKEW $_{30}$					Panel B: SKEW$_{60}$				
AEX	105.67	104.84	100.30	154.28	4.19	107.51	106.81	100.84	149.25	3.48
ATX	102.61	102.50	94.34	110.03	2.07	103.55	103.07	97.87	119.93	2.29
BEL	103.28	103.22	86.20	129.26	1.82	104.84	104.78	84.09	122.86	2.00
CAC	104.00	103.83	101.12	110.28	1.14	105.42	105.26	96.82	124.17	1.55
DAX	104.59	104.28	100.86	119.52	1.63	106.11	105.91	103.14	116.17	1.45
FTSE	105.29	104.85	100.82	118.99	2.18	107.22	106.83	102.08	125.33	2.44
HEX	101.71	101.75	95.49	106.68	1.09	102.21	102.13	94.12	110.33	1.47
IBEX	102.66	102.54	97.53	108.76	0.91	104.09	103.82	100.32	114.49	1.45
MIB	103.76	103.29	100.73	129.33	1.98	104.60	104.36	101.78	122.85	1.44
OMX	104.65	103.66	96.33	130.14	3.16	105.64	105.21	86.58	130.17	2.48
PSI	104.78	104.36	99.57	111.10	2.01	106.78	106.57	101.31	112.94	1.56
SMI	106.28	105.34	100.42	129.36	3.40	106.86	106.52	102.76	123.74	2.02
	Panel C: RAX $_{30}$					Panel D: RAX $_{60}$				
AEX	102.36	102.31	100.72	104.96	0.46	102.60	102.55	100.72	103.87	0.38
ATX	101.39	101.51	94.17	103.57	0.98	101.63	101.55	98.91	104.28	0.65
BEL	101.95	102.00	98.19	104.77	0.57	102.15	102.20	99.81	104.35	0.52
CAC	102.27	102.25	100.58	104.99	0.40	102.42	102.42	101.15	103.81	0.33
DAX	102.27	102.26	101.16	103.72	0.39	102.47	102.47	101.37	103.98	0.32
FTSE	102.51	102.50	100.34	104.34	0.54	102.74	102.75	100.85	104.62	0.44
HEX	101.24	101.26	95.85	105.66	0.74	101.30	101.23	96.70	105.45	0.81
IBEX	101.80	101.75	100.22	105.05	0.50	102.03	101.99	100.67	104.05	0.51
MIB	101.82	101.78	99.95	103.94	0.42	102.01	102.00	100.71	103.94	0.36
OMX	102.10	102.11	98.00	105.47	0.58	102.25	102.26	98.38	104.44	0.47
PSI	102.26	102.37	98.36	103.95	0.89	102.49	102.56	99.08	103.54	0.63
SMI	102.37	102.33	100.38	104.01	0.44	102.48	102.46	101.33	103.61	0.36
	Panel E: VOL $_{30}$					Panel F: VOL $_{60}$				
AEX	22.03	19.91	8.97	93.20	10.31	22.75	20.79	10.53	82.94	9.85
ATX	19.23	18.59	12.49	36.13	3.60	19.25	18.52	13.64	33.21	3.10
BEL	20.77	18.30	7.14	88.71	8.77	21.10	18.83	9.81	70.54	8.21
CAC	23.33	21.24	5.73	86.76	9.18	23.76	22.01	10.48	79.12	8.41
DAX	22.99	20.61	10.20	93.82	9.24	23.50	21.45	12.35	80.47	8.48
FTSE	19.82	17.39	8.67	95.91	9.18	20.44	18.38	9.52	77.37	8.51
HEX	22.46	20.21	12.30	72.14	8.55	22.57	20.42	12.36	72.12	8.30
IBEX	26.05	24.16	8.11	81.21	9.24	26.30	24.38	13.14	77.17	8.56
MIB	26.70	24.57	10.99	81.20	9.29	26.73	24.78	11.17	70.06	8.59
OMX	21.38	19.22	7.05	88.75	8.87	21.68	19.73	6.07	70.57	8.30
PSI	17.32	16.72	9.81	32.61	3.59	18.55	18.44	12.41	31.59	3.43
SMI	18.99	16.59	6.94	97.66	8.45	19.38	17.14	10.26	76.10	7.84

Note: The table reports, for each EU country under investigation, the descriptive statistics of the risk-neutral skewness index, the risk-asymmetry index and the implied volatility index computed using option with 30- and 60- day maturities.

Table 3 – Regression output for linear regression models in equation (14)

	α	β		R^2 adj.	α	β		R^2 adj.
	Panel A: $\Delta SKEW_{30}$				Panel B: $\Delta SKEW_{60}$			
AEX	0.00003	0.00019	***	0.29%	0.00003	0.00050	***	1.03%
ATX	0.00028	0.00078		0.15%	0.00027	0.00299	***	2.56%
BEL	-0.00003	0.00129	***	0.88%	-0.00004	0.00326	***	4.00%
CAC	-0.00002	0.00485	***	4.49%	-0.00002	0.00134	***	1.50%
DAX	0.00024	0.00223	***	2.46%	0.00024	0.00402	***	4.40%
FTSE	-0.00024	0.00173	***	1.26%	-0.00024	0.00092	***	0.49%
HEX	-0.00001	0.00208	***	0.41%	-0.00001	0.00337	***	2.04%
IBEX	-0.00013	0.00423	***	3.08%	-0.00013	0.00133	***	0.82%
MIB	-0.00024	0.00153	***	1.73%	-0.00024	0.00302	***	3.87%
OMX	0.00011	0.00072	***	1.14%	0.00011	0.00152	***	2.56%
PSI	0.00061	0.00059		0.31%	0.00062	0.00128	**	1.02%
SMI	0.00007	0.00176	***	3.88%	0.00006	0.00479	***	9.85%
	Panel C: ΔRAX_{30}				Panel D: ΔRAX_{60}			
AEX	0.00003	0.00679	***	1.83%	0.00003	0.01579	***	3.36%
ATX	0.00028	-0.00120		0.08%	0.00028	0.00026		0.00%
BEL	-0.00004	0.00002		0.00%	-0.00004	0.00658	***	1.21%
CAC	-0.00002	0.00745	***	0.84%	-0.00002	0.00599	***	0.52%
DAX	0.00024	0.00793	***	1.03%	0.00024	0.01016	***	1.26%
FTSE	-0.00024	-0.00674	***	0.96%	-0.00024	-0.00699	***	0.66%
HEX	-0.00001	-0.00123		0.06%	-0.00001	0.00200		0.20%
IBEX	-0.00013	0.00962	***	1.70%	-0.00013	0.00321	***	0.18%
MIB	-0.00024	0.00976	***	1.86%	-0.00023	0.02550	***	5.05%
OMX	0.00011	0.00324	***	1.23%	0.00011	0.00873	***	4.71%
PSI	0.00060	-0.00137	*	0.36%	0.00060	-0.00090		0.00%
SMI	0.00007	0.00656	*	0.96%	0.00006	0.01775	***	2.78%
	Panel E: ΔVOL_{30}				Panel F: ΔVOL_{60}			
AEX	0.00003	-0.00513	***	51.90%	0.00003	-0.00772	***	62.56%
ATX	0.00025	0.00000	***	34.16%	0.00025	-0.00842	***	34.75%
BEL	-0.00004	-0.00078		7.32%	-0.00004	-0.00152		10.66%
CAC	-0.00003	-0.00501	***	50.44%	-0.00002	-0.00737	***	59.95%
DAX	0.00024	-0.00506	***	49.75%	0.00023	-0.00719	***	57.61%
FTSE	-0.00024	-0.00589	***	43.29%	-0.00025	-0.00824	***	48.81%
HEX	-0.00001	-0.00414	***	15.50%	-0.00001	-0.00333	***	7.90%
IBEX	-0.00013	-0.00636	***	50.06%	-0.00013	-0.00650	***	43.38%
MIB	-0.00023	-0.00513	***	32.87%	-0.00023	-0.00675	***	31.80%
OMX	0.00012	-0.00370	***	26.65%	0.00012	-0.00642	***	34.95%
PSI	0.00050	-0.00278	***	22.86%	0.00041	-0.00474	***	31.05%
SMI	0.00007	-0.00486	***	49.93%	0.00007	-0.00772	***	60.50%

Note: The table presents the estimated output of the following regressions: $R_t = \alpha + \beta \Delta index_t + \varepsilon_t$, where *index* is proxied alternatively by daily changes in skewness ($SKEW_{30}$, $SKEW_{60}$, RAX_{30}, and RAX_{60}) and volatility indices (VOL_{30}, and VOL_{60}). R_t is the daily underlying asset log-return. All the regressions are run by using Ordinary Least Squares (OLS), with the Newey-West (1994) heteroscedasticity and autocorrelation consistent (HAC) covariance matrix. Significance at the 1% level is denoted by ***, at the 5% level by **, and at the 10% level by *.

Table 4 – Regression output for linear regression models in equation (15)

	α	β		R^2 adj.	α	β		R^2 adj.
	Panel A: $\Delta SKEW_{30}$				Panel B: $\Delta SKEW_{60}$			
AEX	-0.00068	0.11030	***	5.89%	-0.00059	0.01486		0.01%
ATX	-0.00565	0.24747	***	2.14%	-0.00505	-0.08207		0.08%
BEL	-0.00127	-0.17499		0.10%	-0.00098	-0.61838	**	1.16%
CAC	-0.00135	-0.47852	***	2.16%	-0.00151	-0.09938	***	0.38%
DAX	-0.00020	0.00579		0.00%	-0.00024	-0.24069	***	0.78%
FTSE	-0.00095	-0.00052		0.00%	-0.00092	-0.05635		0.12%
HEX	-0.00026	0.56977	***	3.64%	-0.00040	0.12191		0.26%
IBEX	-0.00008	-0.19235	***	0.48%	-0.00009	-0.12870	***	0.61%
MIB	0.00117	0.06527	***	0.22%	0.00110	-0.10131	**	0.32%
OMX	0.00102	0.21642	***	5.36%	0.00099	0.01357		0.00%
PSI	-0.03842	0.00464		0.00%	-0.03931	-0.14213		0.27%
SMI	-0.00022	-0.12316	***	0.87%	0.00012	-0.45171	***	4.12%
	Panel C: ΔRAX_{30}				Panel D: ΔRAX_{60}			
AEX	-0.00098	1.54135	***	4.86%	-0.00055	-0.35266		0.05%
ATX	-0.00583	0.67675	***	5.14%	-0.00549	0.39574	*	0.62%
BEL	0.00110	2.32613	**	2.56%	-0.00074	-1.07078		0.24%
CAC	-0.00151	-0.84497	***	0.52%	-0.00150	-0.65130	***	0.29%
DAX	0.00003	1.96210	***	3.32%	-0.00012	1.19146	***	0.88%
FTSE	-0.00134	2.07268	***	7.51%	-0.00104	1.54069	***	2.66%
HEX	-0.00024	1.18004	***	9.78%	-0.00035	0.62643	***	2.47%
IBEX	-0.00005	-0.02983		0.00%	-0.00007	-0.22506		0.05%
MIB	0.00123	1.16852	***	2.14%	0.00116	0.15965		-0.02%
OMX	0.00107	0.86984	***	4.67%	0.00098	-0.14850		0.03%
PSI	-0.03317	0.66067	*	4.58%	-0.03603	0.33559		0.39%
SMI	-0.00079	0.95502	**	0.96%	-0.00019	-0.57860		0.11%

Note: The table presents the estimated output of the following regressions: $\Delta VOL_t = \alpha + \beta \Delta index_t + \varepsilon_t$, where ΔVOL is proxied by daily change in the volatility indices (VOL_{30}, and VOL_{60}), and $index_t$ is proxied alternatively by the daily changes in asymmetry indices ($SKEW_{30}$, $SKEW_{60}$, RAX_{30}, and RAX_{60}). All the regressions are run by using Ordinary Least Squares (OLS), with the Newey-West (1994) heteroscedasticity and autocorrelation consistent (HAC) covariance matrix. Significance at the 1% level is denoted by ***, at the 5% level by **, and at the 10% level by *.

Table 5 - Regression output for linear regression models in equation (16)

	α	β_1		β_2		R^2 adj.	α	β_1		β_2		R^2 adj.
				Panel A: $\Delta SKEW_{30}$						Panel B: $\Delta SKEW_{60}$		
AEX	0.00003	-0.00556	***	0.00080	***	57.65%	0.00003	-0.00788	***	0.00086	***	65.69%
ATX	0.00025	-0.00575	***	0.00221	***	36.03%	0.00023	-0.00901	***	0.00481	***	41.37%
BEL	-0.00004	-0.00077		0.00116	***	8.02%	-0.00004	-0.00148		0.00299	***	14.00%
CAC	-0.00003	-0.00489	***	0.00251	***	51.61%	-0.00002	-0.00753	***	0.00210	***	63.70%
DAX	0.00024	-0.00506	***	0.00226	***	52.30%	0.00024	-0.00717	***	0.00392	***	61.81%
FTSE	-0.00025	-0.00589	***	0.00173	***	44.56%	-0.00025	-0.00831	***	0.00136	***	49.96%
HEX	-0.00001	-0.00444	***	0.00461	***	17.57%	-0.00001	-0.00382	***	0.00486	***	12.01%
IBEX	-0.00013	-0.00627	***	0.00302	***	51.62%	-0.00013	-0.00682	***	0.00293	***	47.37%
MIB	-0.00023	-0.00520	***	0.00187	***	35.47%	-0.00023	-0.00684	***	0.00333	***	36.53%
OMX	0.00012	-0.00411	***	0.00161	***	32.14%	0.00012	-0.00655	***	0.00186	***	38.82%
PSI	0.00051	-0.00278	***	0.00060		23.26%	0.00042	-0.00471	***	0.00105		31.74%
SMI	0.00006	-0.00477	***	0.00118	***	51.64%	0.00006	-0.00740	***	0.00198	*	62.07%
				Panel C: ΔRAX_{30}						Panel D: ΔRAX_{60}		
AEX	0.00003	-0.00562	***	0.01546	***	61.12%	0.00002	-0.00789	***	0.02069	***	68.35%
ATX	0.00025	-0.00575	***	0.00269	***	34.97%	0.00024	-0.00903	***	0.00735	***	37.29%
BEL	-0.00004	-0.00080		0.00188	*	7.49%	-0.00004	-0.00153		0.00700	***	12.04%
CAC	-0.00003	-0.00499	***	0.00324	***	50.59%	-0.00002	-0.00794	***	0.02123	***	66.62%
DAX	0.00024	-0.00538	***	0.01848	***	55.33%	0.00024	-0.00759	***	0.02235	***	63.67%
FTSE	-0.00024	-0.00610	***	0.00591	***	43.98%	-0.00025	-0.00849	***	0.00730	***	49.51%
HEX	-0.00001	-0.00447	***	0.00405	***	16.41%	-0.00001	-0.00377	***	0.00561	***	9.55%
IBEX	-0.00013	-0.00635	***	0.00943	***	51.71%	-0.00013	-0.00679	***	0.01153	***	46.06%
MIB	-0.00023	-0.00543	***	0.01610	***	37.90%	-0.00023	-0.00728	***	0.03527	***	41.31%
OMX	0.00012	-0.00407	***	0.00678	***	31.92%	0.00012	-0.00663	***	0.01052	***	41.79%
PSI	0.00050	-0.00281	***	0.00049		22.73%	0.00042	-0.00486	***	0.00181		31.42%
SMI	0.00006	-0.00498	***	0.01131	***	52.84%	0.00006	-0.00772	***	0.01790	***	63.34%

Note: The table presents the estimated output of the following regressions: $R_t = \alpha + \beta_1 \Delta VOL + \beta_2 \Delta index_t + \varepsilon_t$, where ΔVOL is proxied by daily change in the volatility indices (VOL_{30}, and VOL_{60}), and $index_t$ is proxied alternatively by the daily changes in asymmetry indices ($SKEW_{30}$, $SKEW_{60}$, RAX_{30}, and RAX_{60}); R_t is the daily underlying asset log-return. All the regressions are run by using Ordinary Least Squares (OLS), with the Newey-West (1994) heteroscedasticity and autocorrelation consistent (HAC) covariance matrix. Significance at the 1% level is denoted by ***, at the 5% level by **, and at the 10% level by *.

Table 6- Regression output for linear regression models in equation (17)

	α		β		R^2 adj.	α		β		R^2 adj.
	Panel A: $SKEW_{30}$					Panel B: $SKEW_{60}$				
AEX	-0.00277		0.00004		0.00%	-0.14505		0.00137		0.28%
ATX	-0.41590	***	0.00412	***	3.00%	-0.57834	***	0.00571	***	3.60%
BEL	-0.27984	*	0.00271	*	0.70%	-0.60536	**	0.00576	**	1.91%
CAC	-0.40326	*	0.00388	*	0.56%	0.32024	*	-0.00304	*	0.53%
DAX	0.00888		-0.00003		0.00%	-0.28155		0.00275		0.19%
FTSE	0.21476	*	-0.00211	*	0.32%	0.74606	***	-0.00721	***	1.03%
HEX	0.39228		-0.00384		0.27%	0.61083	**	-0.00591	**	0.89%
IBEX	0.07347		-0.00068		0.07%	0.18515		-0.00170		0.40%
MIB	0.03864		-0.00038		0.00%	0.22711		-0.00222		0.11%
OMX	-0.12896	*	0.00126	*	0.50%	-0.44810	***	0.00429	***	1.93%
PSI	0.38817	**	-0.00359	***	4.28%	0.49701	*	-0.00447	*	2.45%
SMI	-0.03467		0.00034		0.04%	-0.08780		0.00085		0.05%
	Panel C: RAX_{30}					Panel D: RAX_{60}				
AEX	0.44616		-0.00435		0.06%	-0.72932		0.00714		0.04%
ATX	-0.73636	***	0.00733	***	2.04%	-2.67443	***	0.02645	***	6.25%
BEL	-0.40956		0.00401		0.12%	-2.15540	***	0.02109	***	1.68%
CAC	1.47637	*	-0.01444	*	0.94%	1.37508		-0.01343		0.60%
DAX	0.26641		-0.00255		0.00%	-1.40868		0.01385		0.24%
FTSE	2.15874	***	-0.02124	***	1.51%	4.10648	***	-0.04034	***	2.04%
HEX	0.51268		-0.00505		0.12%	2.17997	**	-0.02141	**	1.44%
IBEX	-0.06340		0.00064		0.00%	0.55061		-0.00533		0.11%
MIB	0.58365	*	-0.00576	*	0.51%	1.10376	**	-0.01090	**	1.04%
OMX	-0.79044	**	0.00776	**	0.66%	-3.79434	***	0.03715	***	5.33%
PSI	1.14072	***	-0.01104	***	7.55%	0.47261		-0.00442		0.13%
SMI	0.35798		-0.00348		0.10%	0.71605		-0.00696		0.18%
	Panel E: VOL_{30}					Panel F: VOL_{60}				
AEX	0.00284		-0.00008		0.00%	-0.00375		0.00027		0.06%
ATX	-0.09209	***	0.00514	***	14.69%	-0.18163	***	0.01010	***	21.20%
BEL	0.00933		-0.00046		0.54%	0.00982		-0.00052		0.24%
CAC	-0.00033		0.00012		0.01%	-0.00756		0.00032		0.20%
DAX	-0.00018		0.00025		0.11%	-0.00930		0.00083		0.68%
FTSE	-0.02342	**	0.00072		0.87%	-0.05258	***	0.00164	***	1.93%
HEX	-0.02151	**	0.00075	*	1.22%	-0.05068	***	0.00174	***	2.81%
IBEX	-0.00703		0.000439		0.74%	-0.01395	*	0.000834	**	1.30%
MIB	0.01317		-0.00058		0.68%	0.01730		-0.00077		0.52%
OMX	-0.00976		0.00057		0.90%	-0.02484	***	0.00135	***	2.30%
PSI	-0.00893		0.00119		1.33%	-0.00451		0.00130		0.93%
SMI	0.00560		-0.00021		0.13%	0.01292		-0.00054		0.43%

Note: The table presents the estimated output of the following regressions: $R_{t,t+n} = \alpha + \beta_1 index_t + \varepsilon_t$, where *index* is proxied alternatively by daily changes in skewness ($SKEW_{30}$, $SKEW_{60}$, RAX_{30}, and RAX_{60}) and volatility indices (VOL_{30}, and VOL_{60}). $R_{t,t+n}$ is the underlying asset return computed as $R_{t,t+n} = \ln(index_{t+n} / index_t)$ where *n* is equal to 30 days or 60 days depending on the maturity of $index_t$. All the regressions are run by using Ordinary Least Squares (OLS), with the Newey-West (1994) heteroscedasticity and autocorrelation consistent (HAC) covariance matrix. Significance at the 1% level is denoted by ***, at the 5% level by **, and at the 10% level by *.

Table 7 – Average returns for a long position in the underling market when the when the country-specific index (SKEW, RAX, VOL) is lower than its 1%, 5% and 10% percentiles.

	1% percentile	5% percentile	10% percentile	1% percentile	5% percentile	10% percentile
	Panel A: $SKEW_{30}$			Panel B: $SKEW_{60}$		
AEX	-0.02963	-0.03299	-0.01932	-0.03360	-0.06550**	-0.08036***
ATX	-0.00820	0.00550	0.00386	0.00045	0.00677	0.00900
BEL	0.01399	-0.00528	-0.01691	0.01541	-0.01533	-0.04156**
CAC	-0.02633	-0.01581	-0.00836	0.02033	0.02012*	0.00780
DAX	0.01116	0.00895	0.01007	0.01884	-0.02044	-0.01376
FTSE	0.03928***	0.01378	0.00672	0.06789***	0.02945	0.01520
HEX	-0.00106	0.01381**	0.01482***	-0.00297	0.02295***	0.02579***
IBEX	0.03852**	0.02243**	0.01029	0.04420***	0.05228***	0.03718***
MIB	0.05009*	0.04056***	0.02842***	0.02929	0.05504**	0.03597**
OMX	-0.01092	-0.02324	-0.01655	0.00949	-0.01888	-0.03472**
PSI	0.04280***	0.04697***	0.04607***	0.01433***	0.06041***	0.06431***
SMI	0.00650	0.01283	0.00866	0.00979	0.01208	0.01284
	Panel C: RAX_{30}			Panel D: RAX_{60}		
AEX	0.02289	-0.00121	-0.00223	0.01427	-0.00239	-0.01661
ATX	-0.00920**	0.01027	0.00193	-0.00932	0.00614	0.00575
BEL	0.01275	-0.00046	-0.00230	0.01938	-0.00760	-0.01098
CAC	-0.01371	-0.01205	0.00256	0.02816**	0.02271**	0.12248
DAX	0.02960***	0.02814**	0.01251	-0.03388	-0.01204	-0.01149
FTSE	0.04360***	0.01220	0.00337	0.05609***	0.02073	0.01640
HEX	-0.00889	0.01283*	0.01525***	0.00043	0.02157***	0.02322***
IBEX	0.03135	0.01730*	0.00786	0.05573***	0.04298***	0.02794***
MIB	0.02073	0.02358**	0.02162***	0.02818	0.01807	0.02318**
OMX	-0.00499	-0.00017	-0.00920	-0.01349	-0.01251	-0.02351*
PSI	0.06237***	0.04850***	0.03638***	0.01433***	0.02810**	0.02996***
SMI	0.00624	0.00124	0.00866*	-0.00707	-0.00143	0.01124**
	Panel E: VOL_{30}			Panel F: VOL_{60}		
AEX	0.01087*	-0.00261	-0.00267	0.00409	0.00115	0.00268
ATX	-0.00897	-0.02935**	-0.02533**	-0.00303	-0.00630	-0.01540
BEL	0.00684	-0.00663	-0.00094	-0.01014	-0.00171	0.00201
CAC	0.00170	-0.01451	-0.01119	0.00312	-0.00720	-0.00829**
DAX	0.00267	-0.00235	-0.00291	-0.01453*	-0.00614	0.00058
FTSE	-0.00157	0.00073	0.00113	-0.00352	-0.00345	-0.00323
HEX	-0.00674	0.00973**	0.00694*	-0.00036	0.01589***	0.01163**
IBEX	-0.00642	-0.00854*	-0.00613	-0.00722	-0.01978***	-0.01281**
MIB	-0.00956	-0.00767	-0.01006*	-0.00959	-0.01823**	-0.01384
OMX	-0.00736	-0.00491	-0.00440	0.00782	-0.01043*	-0.00722
PSI	0.03519	0.01675	0.01847*	-0.00607	0.03092**	0.02055*
SMI	-0.00820**	-0.00054	-0.00199	-0.00163	0.00303	0.00315

Note: All the series are tested for significance by using the Newey-West (1994) heteroscedasticity and autocorrelation consistent (HAC) covariance matrix. Significance at the 1% level is denoted by ***, at the 5% level by **, and at the 10% level by *.

Table 8 – Average returns for a long position in the underling market when the when the country-specific index (SKEW, RAX, VOL) is higher than its 90%, 95% and 99% percentiles.

	90% percentile	95% percentile	99% percentile	90% percentile	95% percentile	99% percentile
	Panel A: $SKEW_{30}$			Panel B: $SKEW_{60}$		
AEX	-0.00070	-0.00414	-0.00012	0.00150	0.00815*	-0.00317
ATX	0.03069***	0.03646***	0.03239***	0.04509***	0.04222***	0.05306***
BEL	0.00904*	0.01844***	0.03136***	0.00642	0.00054	0.05480***
CAC	0.00931**	0.01002	0.01526*	-0.00421	-0.00129	-0.01076
DAX	0.01116**	0.01021*	0.00935	0.02125***	0.01695**	0.02286*
FTSE	-0.00261	-0.00248	0.00482	-0.00747	-0.00896**	0.00293
HEX	0.00537	0.01078	0.02952	-0.01956	-0.03949**	-0.06558**
IBEX	-0.00835	-0.00157	0.00063	-0.01162	0.00552	0.00091
MIB	-0.00818*	-0.00932*	-0.01006	-0.01610**	-0.02477***	-0.01835**
OMX	0.00946**	0.00979*	0.01352	0.01678**	0.02517**	0.02363
PSI	0.01064	0.00377	0.01910***	0.00514	-0.00529*	-0.00668***
SMI	0.00507	0.00735*	0.01313	0.01107**	0.02023***	0.02457***
	Panel C: RAX_{30}			Panel D: RAX_{60}		
AEX	-0.00871	-0.00319	-0.00106	-0.00826	-0.03230**	-0.05551*
ATX	0.02910***	0.03613***	0.05231***	0.04437***	0.04792***	0.05114***
BEL	-0.01237	-0.01547	0.00941	0.00106	-0.00580	0.03419***
CAC	-0.02096**	-0.01498	0.02977***	-0.00580	-0.01091	-0.02562
DAX	0.01572***	0.01953***	0.02036***	0.00559	0.01765*	-0.02338
FTSE	0.00322	0.00081	-0.01050	-0.00121	0.00050	-0.00920
HEX	-0.00004	-0.00905	-0.05424***	-0.02255*	-0.04804***	-0.11546***
IBEX	-0.01505*	-0.00063	0.00776	-0.02046	-0.03038	-0.01407
MIB	-0.01008*	-0.01345	0.01367	-0.03120**	-0.04048**	-0.05731***
OMX	0.00819	0.01157*	0.01815	0.03673***	0.03560***	0.04648***
PSI	0.01342	0.01727	0.01443	0.02211***	0.02649***	0.02453*
SMI	0.00309	0.00772	0.01511***	-0.00285	-0.01019	-0.02606
	Panel E: VOL_{30}			Panel F: VOL_{60}		
AEX	-0.00510	-0.03305*	-0.02680	0.01255	-0.01875	-0.02193
ATX	0.04109***	0.05616***	0.08303***	0.07351***	0.09374***	0.11663***
BEL	-0.01443	-0.03738**	-0.04240***	-0.01570	-0.02544	-0.05017***
CAC	-0.01614*	-0.01403	-0.01281	0.00127	-0.00577	-0.01056
DAX	0.00733	0.01331	-0.01089	0.03064**	0.01489	-0.00684
FTSE	0.00510	-0.00074	0.02257*	0.01599	0.00385	0.03916***
HEX	0.00749	-0.02611*	-0.07369***	0.00617	-0.02344	-0.08895***
IBEX	0.01500	0.01372	0.01115	0.03378**	0.02150	0.02812*
MIB	0.01055	0.01896	-0.04102***	0.02001	0.00667	-0.06953***
OMX	0.01259	0.01696	0.02053	0.03955***	0.04052**	0.03856***
PSI	0.03823***	0.03846***	0.06693***	0.03350***	0.06426***	0.07974***
SMI	-0.00330	-0.01539	-0.02556**	-0.00364	-0.01311	-0.04105***

Note: All the series are tested for significance by using the Newey-West (1994) heteroscedasticity and autocorrelation consistent (HAC) covariance matrix. Significance at the 1% level is denoted by ***, at the 5% level by **, and at the 10% level by *.

Table 9 – Average returns for a long position on the underlying indices in our dataset when the aggregate index (EU-SKEW, EU-RAX, EU-VOL) is lower its 1%, 5%, and 10% percentiles.

Regression output for indices values lower than their						
	1% percentile	5% percentile	10% percentile	1% percentile	5% percentile	10% percentile
		Panel A: $SKEW_{30}$			Panel B: $SKEW_{60}$	
AEX	-0.00687	-0.00549	-0.00797	0.00491	-0.00579	-0.01257***
ATX	0.00270	0.01056	0.00694	0.02522	0.01984**	0.00651
BEL	-0.00541	-0.00407	-0.00678	0.01569*	-0.00743	-0.01252*
CAC	0.00020	0.00348	-0.00129	0.01744	0.00214	-0.00404
DAX	-0.00193	-0.00448	-0.01067*	-0.00026	-0.01039	-0.01823***
FTSE	0.00171	0.00374	0.00282	0.01364	0.00116	0.00151
HEX	-0.00947	-0.00366	-0.00632	0.03190	0.00439	-0.00287
IBEX	-0.01229	-0.00177	-0.00103	0.02615**	0.01798***	0.01582**
MIB	-0.01815	-0.00180	-0.00467	0.02837**	0.02271***	0.01463
OMX	-0.00056	-0.00274	-0.00567	0.01541	-0.00583	-0.01493*
PSI	-0.02179*	0.00815	0.00295	0.02453**	0.02364**	0.01597
SMI	-0.00807	-0.00731	-0.00335	-0.00327	-0.01077	-0.01174*
		Panel C: RAX_{30}			Panel D: RAX_{60}	
AEX	0.02516	-0.01106	-0.01642	0.12200	0.07160	0.02311
ATX	0.09203	0.08897**	0.06207**	0.22312***	0.17930***	0.10141**
BEL	0.02164	0.00241	0.00146	0.14503	0.10734***	0.05081
CAC	0.05064	0.01778	0.00480	0.13651	0.10086**	0.04550
DAX	-0.00363	-0.03043	-0.02939	0.08073	0.04021	-0.00765
FTSE	0.05019	0.01402	-0.00085	0.09316	0.02076	-0.00679
HEX	0.01207	0.01398	0.00965	0.17380	0.13419**	0.07466*
IBEX	0.06824	0.04753	0.01729	0.05754	0.09028	0.05495
MIB	0.05262	0.02641	0.01537	0.20978	0.19284***	0.13072**
OMX	-0.02286	-0.01603	-0.01737	-0.06959	-0.03149	-0.04420
PSI	-0.00291	0.00899	0.01147	0.04897	0.10962***	0.05492
SMI	-0.00528	-0.01171	-0.01367	0.17978*	0.08394**	0.03299
		Panel E: VOL_{30}			Panel F: VOL_{60}	
AEX	0.14173***	-0.00969	-0.00235	-0.02455	0.04489	0.03339
ATX	0.31550***	0.04281	0.00778	0.23773*	0.09919	0.03570
BEL	0.15558**	-0.02117	0.00655	-0.03697	0.01252	0.03184
CAC	0.14019***	-0.05134	-0.04031	-0.09947	-0.03085	-0.04680
DAX	0.11707***	-0.02613	-0.02062	-0.17099*	-0.03165	-0.02124
FTSE	0.09089	0.002421	-0.00581	-0.00306	-0.01277	-0.01394
HEX	0.10662	-0.01448	0.00493	0.06954	-0.01592	0.02088
IBEX	0.12653**	-0.07319**	-0.03478	-0.08755	-0.12822	-0.07054
MIB	0.19197	-0.04087	-0.00889**	0.07202	0.03275	0.01068
OMX	0.04006	-0.04878	-0.02049	-0.24536	-0.06970	-0.01571***
PSI	0.34808***	-0.04992	-0.04394	0.19409*	-0.07038	-0.10961
SMI	0.03252	-0.02744	-0.00068	-0.05664	0.00654	0.01920

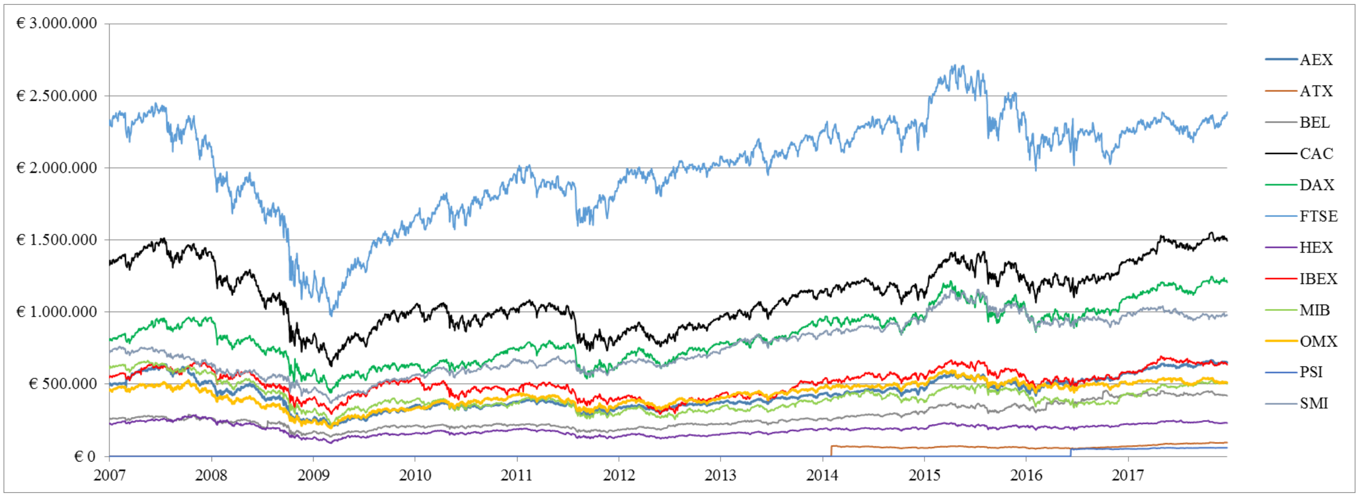
Note: All the series are tested for significance by using the Newey-West (1994) heteroscedasticity and autocorrelation consistent (HAC) covariance matrix. Significance at the 1% level is denoted by ***, at the 5% level by **, and at the 10% level by *.

Table 10 – Average returns for a long position on the underlying indices in our dataset when the aggregate index (EU-SKEW, EU-RAX, EU-VOL) is higher than its 90%, 95%, and 99% percentiles.

Regression output for indices values higher than their						
	90% percentile	95% percentile	99% percentile	90% percentile	95% percentile	99% percentile
	Panel A: $EU\text{-}SKEW_{30}$			Panel B: $EU\text{-}SKEW_{60}$		
AEX	0.02747	0.07970	0.48273	0.07109	0.14540	0.06245
ATX	0.04224	0.11214	0.60918	0.11109	0.21689	0.12654
BEL	0.02853	0.05210	0.49411	0.07950	0.14789	0.08007
CAC	-0.01416	-0.01136	0.24406	0.03245	0.05731	-0.01788
DAX	-0.01144	-0.00039	0.24985	0.02568	0.05740	-0.03629
FTSE	-0.01479	0.01025	0.23600	0.01898	0.04404	-0.05663
HEX	-0.00313	-0.01941	0.07775	0.07529	0.10803	0.00471
IBEX	-0.03043	-0.02474	0.29230	0.00981	0.02431	-0.05224
MIB	-0.03090	-0.05606	0.22140	0.03892	0.04958	-0.06853
OMX	-0.01759	-0.00662	0.24843	0.01340	0.05785	-0.04409
PSI	0.03613	0.03490	0.31413	0.06896	0.08856	0.00328
SMI	-0.01933	-0.02837	0.15863	0.01626	0.02929	-0.02038
	Panel C: $EU\text{-}RAX_{30}$			Panel D: $EU\text{-}RAX_{60}$		
AEX	0.01340	-0.08526	-0.26590**	0.05368	-0.05131	-0.32627***
ATX	-0.00470	-0.15556	-0.32226**	0.08298	-0.05598	-0.30492
BEL	-0.01302	-0.14211	-0.35005**	0.03049	-0.08353	-0.31953**
CAC	-0.03620	-0.12779**	-0.28840***	-0.00437	-0.07831	-0.23926**
DAX	-0.04706	-0.13213*	-0.27049***	-0.01026	-0.07419	-0.27870**
FTSE	-0.01200	-0.08942	-0.31838***	0.02698	-0.03791	-0.22454**
HEX	-0.05681	-0.18405**	-0.42096**	-0.01622	-0.14541	-0.37720**
IBEX	-0.05955	-0.15832**	-0.20350**	-0.04961	-0.17598*	-0.25948*
MIB	-0.07876	-0.22956**	-0.41831***	-0.02330	-0.14744	-0.27624
OMX	-0.02695	-0.12307	-0.29071***	0.01016	-0.05178	-0.21203**
PSI	-0.01377	-0.11553	-0.26615***	-0.00848	-0.09654	-0.15012
SMI	-0.03687	-0.08242	-0.19031**	-0.00396	-0.04759	-0.14859
	Panel E: $EU\text{-}VOL_{30}$			Panel F: $EU\text{-}VOL_{60}$		
AEX	-0.01451	-0.03142	-0.03181	0.01939	-0.02483	-0.01265
ATX	-0.05999	-0.06292	-0.10678**	-0.03242	-0.05055	-0.12381***
BEL	-0.04174	-0.05097*	-0.06894***	-0.02628	-0.04911	-0.08734***
CAC	-0.01682	-0.02317	-0.02399	-0.00617	-0.03955	-0.05349***
DAX	-0.00136	-0.0054	-0.00691	0.03408	0.00277	-0.01019
FTSE	0.01164	0.00994	0.03584**	0.03969	0.01528	0.06473***
HEX	-0.02501	-0.04475	-0.07982***	-0.01963	-0.05607	-0.12362***
IBEX	-0.00372	-0.00867	0.00128	0.02911	-0.01048	0.02132
MIB	-0.02695	-0.04582	-0.05629***	-0.02648	-0.07259	-0.10768***
OMX	0.03383	0.04415**	0.03603	0.10432***	0.10076***	0.06583***
PSI	-0.01421	-0.01191	-0.02686	0.00229	0.01010	-0.00991
SMI	-0.01150	-0.02589	-0.03405*	-0.00940	-0.06274**	-0.06513***

Note: All the series are tested for significance by using the Newey-West (1994) heteroscedasticity and autocorrelation consistent (HAC) covariance matrix. Significance at the 1% level is denoted by ***, at the 5% level by **, and at the 10% level by *.

Figure 1 - Market capitalizations (in Euro) and relative market capitalization (in percent) for the 12 markets in our dataset.



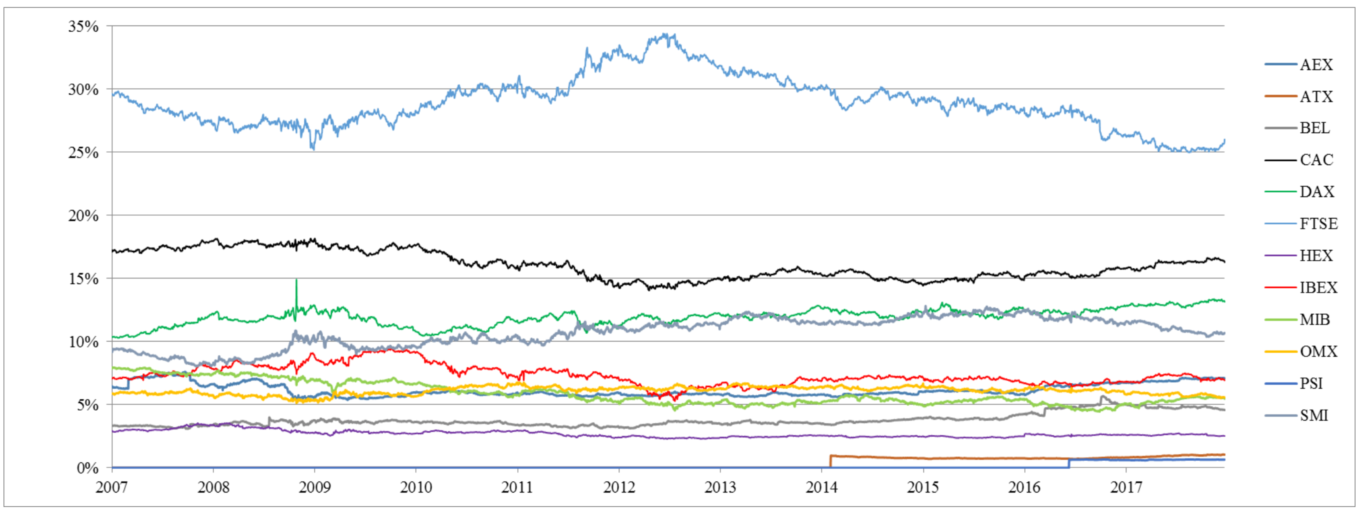


Figure 2 – Aggregate asymmetry indices based on the SKEW (EU-SKEW$_{30}$, EUSKEW$_{60}$) and the RAX (EU-RAX$_{30}$, EU-RAX$_{60}$) methodologies.