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Volatility Risk Premium and European Equity Index Returns

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***Abstract*—For most of the time, equity index option implied volatilities exceed the corresponding realized volatilities. The resulting volatility risk premium seems to be directly linked with the equity risk premium, which motivates to study whether this investor risk aversion-related premium has explanatory power on the future stock index returns. Based on several linear regression models, this study shows that volatility risk premiums can explain a non-trivial fraction of the aggregate stock returns in Europe. Furthermore, both local and global risks are found to be systematically priced. Our findings confirm the consistency and deterministic power of volatility risk premium in the European equity markets. Additionally, the evidence supports the hypothesis that the global volatility risk and equity market premium are inter-linked.**

I. Introduction

VOLATILITY risk premium (VRP) represents the compensation for investing in risky securities instead of risk-free assets. It is essential to understand how investors deal with the uncertainty and variance of future returns not only in risk management, asset allocation, and pricing purposes, but also in attempts to understand the behavior of financial assets in general [11]. This study aims to explore the components that drive the equity risk premium, and the expected equity index returns, and to identify the risks that are ultimately being compensated for investors.

There is broad evidence of volatility risk premium and its significant explanatory power over expected stock returns in the U.S. market. [3] examined volatility risk premium using statistical properties of delta hedged option portfolios constructed from S&P 500 index options and concluded that negative volatility risk premium and mean delta-hedged gains share the same sign. [11] presented the existence of a systematic variance risk factor in the U.S. stock market as evidenced by highly negative risk premium. [8] found similar results derived from the squared VIX index and realized variance measures calculated using intraday data. They provided empirical evidence that stock market returns are predictable from the difference between model-free implied variance and realized variance and concluded that a strong positive relationship exists between the variance risk premium and following equity index returns in the U.S.

[12] studied higher moments estimated from the S&P 500 index option data and found highly negative and economically significant market skewness risk premium related to the cross-section of stock returns. Focusing on the higher moments of the probability distribution, [20] introduced a concept of a synthetically built skew swap to explore the relationship between the option implied skew and realized skew. They showed that skew risk premium (SRP) can explain almost half of the implied skew in index option prices, implying that common risk factors drive both variance and SRP.

Comprehensive study of volatility risk premiums in the European stock market has not been implemented at broad aggregate level. [16] studied moment risk premia in Europe using portfolio sorting techniques to obtain volatility risk from Euro Stoxx 50 index options and reflected it to a cross-section of STOXX Europe 600 index constituent returns. Evidence of negative variance risk premium and positive skewness premium was found amongst the individual stocks. Their findings were robust to the inclusion of other risk factors such as size, book-to-market, and momentum.

In contrast to the majority of existing studies on the U.S. stock market returns, this study focuses solely on European stock markets. Although [16] provide valuable insights of individual European stocks, there is a lack of evidence on aggregate stock market returns. A comprehensive study of a broad set of European indexes is needed to distinguish whether investors require compensation for the volatility risk, whether these premiums show predictive power on expected returns in the short term, and in addition, whether global variance risk premium exhibits significant predictive power on future European equity index returns.

The primary contribution of this study is to provide new empirical evidence on the predictive power of option-implied information on subsequent aggregate equity returns. The aim is to provide new evidence from understudied European stock markets and gain a better understanding of the risks and their pricing in expected stock returns. Since the information content of option prices seems to be superior to the historical measures, especially for short-term horizons, this paper focuses on one-month (21 business days) and three-month (63 business days) equity index excess returns. The examined equity indexes are Euro Stoxx 50 (European-wide), DAX index (Germany), FTSE 100 index (United Kingdom), SMI index (Switzerland), and STOXX Europe 600 (European-wide). Model-free volatility indexes are used to capture information in option prices. Option-implicit information is then used to explain the subsequent returns of these stock indexes. The studied period spans from the beginning of 2007 until the end of October 2017. This period

· This work was carried out during the postgraduate studies of Antti Ihalainen at LUT University. Finland.

is selected in order to include the regimes of high and low stock market returns and volatility during the most recent times. The 2007-2009 financial crisis, EU sovereign debt crisis 2009-2012, and the period of growth from 2012 to 2017 are all included in the sample period. Special attention is paid to *ex-ante* volatility premiums (forward-looking) in explaining the future equity index returns. The distinction between *ex-ante* and *ex-post* premiums (future and historical, respectively) is important because the expected returns of the financial assets and option prices are determined on the basis of past, present, and future information of the underlying assets' volatility at any given point of time according to the notion of strong-form market efficiency.

Potential existence of global volatility risks is examined by using the information in VIX index. All the implied volatility indexes being examined are calculated in a similar model-free manner and they utilize a broad set of out-of-the-money (OTM) call and put options expiring in 30 days, providing risk-neutral and model-free expectations of second and third moments of risk-neutral probability distributions (RNPDs).

According to the results, volatility risk premiums explain a non-trivial fraction of the equity index return in Europe and both local and global volatility risk are systematically priced into the European equity index returns. The findings of the explanatory power of volatility risk premiums on aggregate stock market returns are consistent with the previous evidence reported on the U.S. market.

This remainder of the paper is structured as follows: previous literature on volatility risk premium and option-implied information is summarized in section II. Section III describes in detail the data and methodology. Section IV presents empirical results of the univariate and multivariate regression analyses. Finally, section V concludes and discusses the limitations and suggestions for future research.

II. Literature Review

A. Volatility and risk aversion

As stock market volatility seems to be harmful to most investors, they demand compensation. It is well-established that market volatility of equity returns varies over time. While time-varying volatility changes the expectations of future returns or risk-return tradeoff, rational investors whose utility increases as a function of wealth require compensation for being exposed to the changes in market volatility. Yet the relationship between market volatility and stock returns has proven to be ambiguous.

[1] studied the pricing of aggregate volatility risk in the cross-section of equity returns and found that stocks with high sensitivities to innovations in market volatility have low average returns. They used changes in implied volatility index VIX as a proxy of changes in market volatility and made a reservation regarding the use of the VIX, noting that it incorporates both stochastic volatility and the stochastic volatility risk premium. According to their research, aggregate volatility may be a priced factor, partly because assets with high sensitivities to volatility risk hedge against the risk of substantial market declines.

In lieu of risk aversion, [4] noted that out-of-the-money options became remarkably expensive during the year prior to the market crash of October 1987. His interpretation was that conditional expectations in jumps in asset prices revealed significant time variation. According to the [5], the volatility smile should be a flat line, because only one volatility parameter rules the underlying stochastic process based on which all options are priced. [18] showed that the observed RNPDs describing investor expectations for equity indexes across the globe are mostly left-skewed and leptokurtic. The corresponding distributions of realized returns are somewhat lognormally distributed, implying that investors are pricing some non-occurring risks in asset prices. These downward sloping volatility smirks and negatively skewed risk-neutral densities representing the "crash-o-phobia" phenomenon, meaning that investors, who consider a market crash as a risk, buy OTM put options to cover their positions and to put a floor on their maximum losses.

Building on the notion of investor risk aversion and fears of a crash, [24] studied the perceived *ex-ante* risks by using S&P 500 index options. They made a distinction between diffusion risk and jump risk, the former referring to the quadratic variation of the realized price process, and the latter to the anticipated risk of large price movements. Their findings showed that the premium embedded in option prices is, on average, 40% higher than the premium required to compensate for the realized stock returns and support the risk aversion-explanation for the equity premium puzzle. [13] studied volatility and jump risk. Their result showed strong evidence of a priced jump risk, and stocks with high sensitivities to jump and volatility risk had low expected returns. Investors' risk aversion was revealed through the jump and volatility premiums. Implied volatilities can be high due to high volatility expectations, high risk aversion, or a combination of these, therefore using the implied volatilities as an indicator of general risk aversion is somewhat fallacious. Nevertheless, implied volatilities provide a valuable tool for revealing the risk-neutral expectations of investors when combined with corresponding realized volatility information. This leads us to the use of the volatility risk premiums instead of pure volatility estimates in predicting expected returns.

B. Options-implied information

Option prices reflect the market's common assessment of the probability distribution of the underlying asset prices on the date of expiry, and this assessment is adjusted to include the degree of investors' risk tolerance. As the option-implicit factors provide the market's forward-looking risk-neutral approximation of the expected prices of an underlying, they provide RNPDs that cannot be derived from historical prices.

The superiority of option implied volatilities over the backward-looking volatility estimates is widely documented by [6], [14], [19], and [22], among many others. Traditionally, some specific option pricing models have been used to extract option implied information from option prices, but this kind of approach have some shortcomings: Probably the most important of these is that the implementation of a certain model for the purposes of implied volatility estimation is always a combined test of the option-implicit information content and the option model itself.

By using a continuous set of options with strike prices from zero to infinity, [9] showed that it is possible to form the entire risk-neutral probability distribution. [10] extended the work of [9] by deriving implied volatility from a set of current option prices without the use of any specific option model. The suggested model-free approach does not assume a constant volatility or suffer from the inconsistencies of traditional models. [19] showed that the calculation of VIX, which is the most well-known model-free implied volatility (MFIVI) index, is essentially consistent with the theoretical framework of [10].

Following [26], VIX is calculated on the basis of near- and next-term put and call options with more than 23 days but less than 37 days to expiry. Once each week, the index options used to calculate the VIX are rolled to new maturities, making the previous next-term options (more than 30 days until expiry) now near-term options (30 or fewer days until expiry). Both standard monthly options expiring on the 3rd Friday of each months and weekly options expiring every Friday are employed in the calculations. In order to make the time-to-expiry calculations more straightforward, monthly options are deemed to expire at the open of trading on the S&P 500 settlement day (i.e., on the 3rd Friday of the month), whereas for the weekly options, the expiry is assumed to at the close of trading (i.e., 4:00 p.m. ET).

The risk-free interest rates used in the calculations are yields of the U.S. Treasury bills maturing closest to the corresponding S&P 500 index option, implying that the used risk-free rates may vary between near- and next-term options. The options included in the VIX index calculation of are out-of-the-money put and calls and centered around an at-the-money strike price. Only the options quoted with non-zero bid prices are used in the calculations. Finally, the put and call prices for the same strike price are averaged to produce a single value. After the options included in the VIX calculation are identified, the variance is first calculated as follows:

$$\sigma^2 = \frac{2}{T}\sum_i \frac{\Delta K_i}{K_i^2} e^{rT} Q(K_i) - \frac{1}{T}\left[\frac{F}{K_0}\right]^2 \quad (1)$$

where $\sigma = VIX/100$, T is time to expiration, K_0 is the first strike price below the forward index level F, K_i is the strike price of the i^{th} OTM option (call if $K_i>K_0$, put if $K_i<K_0$, and both if $K_i=K_0$), r is the risk-free interest rate, and $Q(K_i)$ is the average of bid-ask spread for each option with strike K_i. ΔK is defined by halving the difference between the strikes on both sides of K_i:

$$\Delta K_i = \frac{K_{i+1} - K_{i-1}}{2} \quad (2)$$

The formula presented in Equation 2 is then applied for both near- and next-term options by using times to expirations T_1 and T_2, respectively. The resulting If_1^2 (for T_1 near-term options) and If_2^2 (for T_2 next-term options) are then averaged over 30 days. The VIX index value is obtained by taking the square root of the 30-day weighted average of σ_1^2 and $\sigma_2^2\sigma_2^2$, and multiplying it by 100:

$$VIX = 100 \times \sqrt{\left\{T_1\sigma_1^2\left[\frac{N_{T_2} - N_{30}}{N_{T_2} - N_{T_1}}\right] + T_2\sigma_2^2\left[\frac{N_{30} - N_{T_1}}{N_{T_2} - N_{T_1}}\right]\right\} \times \frac{N_{365}}{N_{30}}} \quad (3)$$

[25] conducted a comprehensive global review of all available implied volatility indexes, concluding that the European MFIVIs, namely VSTOXX, V1X-NEW, VSMI, and VFTSE index calculation methodologies follow closely the one introduced by CBOE VIX. The methodology for the calculation of the VIX's European equivalents involves a summation over a band of OTM option prices. The intuition behind the use of option implied information is relatively simple: a cross-section of option prices (and implied volatilities) for the same underlying asset and the same maturity reveals the RNPD, which then reveals an estimate of the future state and its pricing at the maturity of the options' cross-section. Specific to Eurex-based indexes VSTOXX, V1X-NEW, and VSMI is that they are calculated based on eight expiry months and a sub-index is calculated for each option expiry. Linear interpolation is then used to calculate the main indexes from the sub-indexes (E.g., [27] describes the calculation and interpolation scheme of VSTOXX in detail).

C. *Volatility risk premium*

The academic literature has documented a consistently positive spread between implied and realized volatilities. Figure I shows one-month volatility spread of Euro Stoxx 50 index over the studied period. On average, volatility selling over the Euro Stoxx 50 index has been profitable over the ten-year period.

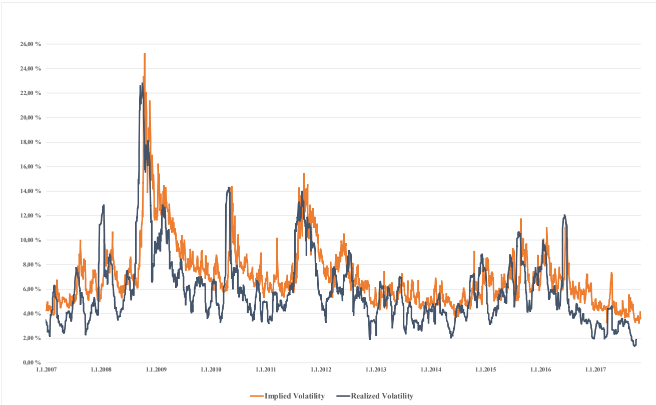

Figure I: Daily volatility spread of Euro Stoxx 50 index from Jan 2007 to Oct 2017

This difference between risk-neutral and realized volatility is proven to have predictive power for equity returns on both individual and aggregate level. The second moment of a return distribution, quantified by variance or volatility, seems to exhibit significant explanatory power on following equity returns. Using the S&P 500 and S&P 100 index options, [3] present the VRP in a non-parametric way by analyzing delta hedged option positions. They show that the implication of the volatility risk premium is that the profits on delta-neutral option strategy are non-zero and are determined mutually by the volatility risk premium and option vega. Moreover, the volatility risk premium and delta hedged gains seem to have the same negative sign. Negative VRP implies an equilibrium, where equity-index options act as a hedge to the market portfolio. Investors are willing to pay a premium to hold options in their portfolio for hedging purposes, which makes options' price higher than it would be when volatility is not priced.

The intuition behind the existence of VRP is again relatively simple: if investors do not want to be exposed to the variation in prices and therefore in expected returns, they require being compensated for it. [2] showed that implied return distribution of the S&P 100 index was much more volatile than its physical equivalent. They concluded that "rational risk-averse investors are sensitive to extreme loss states and willing to counteract these exposures by buying protection." Investors need to hedge against extreme losses drives up the option implied probability of occurrence relative to the actual probability of occurrence, causing the volatility spread to widen.

The risk-neutral expectation of variance can also be interpreted as variance swap rate, following the methodology introduced by [11]. The fixed leg of the swap is the option implied variance, and the floating leg represents the realized variance. The spread between the risk-neutral and physical values unveils the variance risk premium. Variance swap rate represents the market's risk-neutral expected value of the realized variance and is synthesized by a linear combination of option prices. Their findings prove the existence of the common and stochastic risk factor, that the Fama-French factors cannot explain. This negative premium indicates that investors regard rises in market volatility as an unfavorable shock and are willing to pay a large premium against market volatility increases. Writing variance swaps is therefore on average profitable, since the fixed swap rate is prone to exceed the floating rate.

The evidence of the existence of return impacts of variance risk premium has been established both on an aggregate market level and an individual stock level. [17] focused on the cross-section of large-cap stock returns and found that an individual stock's expected return increases with its variance risk premium. They used a model-free approach and found that the top VRP quintile stock returns outperform the stocks in the lowest. Low VRP stocks seem to be serving as useful hedges against systematic and therefore also have lower expected returns. Investors seem to have preferences about equity volatility at both individual and aggregate levels.

[8] proved the existence of a significant risk-return relationship and found that the variance risk premium is most effective in forecasting equity index returns in quarterly to six-month horizons, even though the results hold for shorter one-month and longer annual periods as well. Their results hold when other, more common equity index return predictor variables are included in multiple regressions. The predictive power of P/E ratios becomes more effective and significant when combined with the variance risk premium.

[15] argued that the variance risk premium is closely linked to the uncertainty of economic fundamentals. They found a strong statistically significant relationship between the variance risk premium and aggregate stock market returns, and their findings support the superior short-term predictive power of VRPs. They concluded that the variance risk premium is an extremely useful tool in measuring the market's perceptions of uncertainty and the risks of influential shocks to the economy. Not only does the VRP provide a measure for uncertainty perceptions, but it is also a useful tool in understanding what preferences are able to map the risk onto asset prices. VRP can be seen to provide a vehicle to capture investor risk aversion and its pricing in equity markets.

In this paper, the volatility risk premium is defined to be the difference between the model-free implied volatility (*IV*) and the corresponding realized volatility (*RV*) estimated as standard deviation of each equity index. The formula of *RV* is presented in Equation 4.

$$RV = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}, \tag{4}$$

where x refers to daily logarithmic returns and $\overline{xx}$ is the corresponding average return calculated over n trading days.

III. Data and methodology

The European equity indexes employed in the empirical tests are Euro Stoxx 50, DAX, FTSE 100, SMI, STOXX Europe 600, and S&P 500. Descriptive statistics of all the used equity indexes are presented in Table I. These equity indexes also have dedicated model-free one-month implied volatility indexes. The option-implied volatility is derived from the corresponding options underlying the volatility index of the respective stock index. The risk premiums (implied minus realized volatilities) are used to test their prediction power on future returns of the underlying indexes.

TABLE I
DESCRIPTIVE STATISTICS OF MONTHLY EXCESS RETURNS OF THE EQUITY INDEXES.

	Euro Stoxx 50	*DAX*	*FTSE 100*	*SMI*	*STOXX Europe 600*	*S&P 500*
Mean	-0.001837	0.004397	0.000475	-0.000566	-0.00035	0.003647
Median	0.005037	0.012246	0.006023	0.005383	0.008328	0.008333
Maximum	0.135916	0.153838	0.080398	0.095632	0.125243	0.101949
Minimum	-0.162803	-0.214371	-0.143831	-0.121759	-0.146255	-0.188121
Standard Deviation	0.052744	0.055848	0.040235	0.037745	0.044108	0.043425
Skewness	-0.599381	-0.830805	-0.659834	-0.525199	-0.690271	-0.987473
Kurtosis	3.63626	4.978845	3.855028	3.468004	4.325541	5.511011
N	130	130	130	130	130	130

The table shows one-month logarithmic excess returns of the risk-free rates for all equity indexes. The risk-free rates used in excess return calculations are three-month Euribor for Euro Stoxx 50, DAX, FTSE 100, SMI, and STOXX Europe 600 and three-month Libor for S&P 500.

The existence of the global risks is analyzed by using volatility and skew risk premiums (SRP) embedded in the U.S markets explaining the European stock market returns with S&P 500 equity index (SPX) and CBOE's model-free volatility index. The US market volatilities are used to test the relationship between global sources of risk and local European stock index returns. This is an important step to see the extent of global risk premiums affecting the aggregate European stock returns.

Each index prices are downloaded from Refinitiv Eikon in their base currency, and the returns are reported in percentages. The risk-free rate used in the calculation of the excess returns of European (US) indexes is three-month EURIBOR (LIBOR). Risk-free rates are modified considering the day count convention and conversion into continuously compounded rates. All the employed variables and their abbreviations are presented in Appendix I.

The calculation methodology of VRP and SRP closely follows the approach of [7] and [8]. Annualized implied volatilities obtained from MFIVIs are translated to monthly (quarterly) volatilities simply by dividing the index levels by $\sqrt{12}$ ($\sqrt{4}$). This approach has a clear advantage from the viewpoint of forecasting. One-month VRP at time t is obtained by using the implied volatility observed at t for the time period $t + 21$ and subtracting the realized volatility that is calculated using the returns of the preceding month. One-month ex-post volatility and skew risk premiums (EPVRPs and EPSRPs, respectively) for each time interval (t) are obtained by subtracting the *ex-post* observed realized volatility of time period $t + 21$ from the implied volatility observed at time t. Autoregressive conditional heteroscedasticity effects and autocorrelation effects are tested in post estimation purposes by conducting ARCH and the Breusch-Godfrey tests. As evidence of both heteroscedasticity and autocorrelation is found in OLS standard errors, the regressions are run by adjusting the standard errors by the Newey-West [21] procedure, which simultaneously controls for the biases stemming from heteroscedasticity and autocorrelation, therefore providing a better estimation accuracy.

The forecasts are based on linear regressions of the excess returns of European equity indexes. Both univariate and multivariate regression models are used to determine the relationship between risk premium and returns. All the conducted regressions with volatility and skew risk premium variables, as well as control variables, can be formally expressed in the general form of regression equation presented in Equation 5.

$$ER = \beta_0 + \beta_1\alpha_1 + \beta_2\alpha_2 + \cdots + \beta_k\alpha_k + \varepsilon, \quad (5)$$

where ER = daily excess return (over and above the risk-free rate), β_0 = intercept term, $\beta_{1...k}$ = regression slopes of risk premiums or control variables represented by $\alpha_{1...k}$, respectively.

The observed period for implied volatilities, realized volatilities, and closing prices of the stock indexes spanned from 28.11.2006 to 31.10.2017. This analysis directly employs the model-free implied volatilities provided by Refinitiv Eikon. The Term spread (TERM) is the difference between 10-year and 3-month government liability yields, explicitly 10-year Bund yield and 3-month German government liability BD deposit. Default spread (DEFT) is defined as the Difference between Moody's Baa Corporate bond yield and 10-year Treasury yield. The main explanatory variables are *ex-ante* volatility risk premiums (VRP) and *ex-post* volatility risk premiums (EPVRP) of the Euro Stoxx 50, DAX, FTSE 100, SMI index, and S&P 500 index.

IV. Results

The results show that the European volatility risk premium is able to explain the subsequent equity index returns for next one month. Table II shows that the *ex-post* observable volatility risk premium is significantly and substantially related to the European equity index returns. On average, one percentage point increase in observed volatility risk premium leads to 0.81%–1.64% increase in monthly returns, highly significant t-statistics of the volatility risk premium coefficients altering correspondingly from 4.05 all the way to 9.88. An increase in the volatility risk premium can potentially result from an increase in implied volatility, decrease in realized volatility, or as a result of occurrence of both.

Table II

Monthly regression results for VRP variables

One-month returns				
	Euro Stoxx 50	*DAX*	*FTSE 100*	*SMI*
VRP coefficient	0.0195	0.0392	0.0894	0.0095
	(-0.06)	(0.11)	(0.39)	(0.04)
Constant	-0.0021	0.0032	-0.0004	-0.0007
	(-0.29)	(0.44)	(-0.09)	(-0.13)
Adj. R Squared (%)	-0.77	-0.77	-0.66	-0.77
EPVRP coefficient	1.4576	1.6483	1.2434	0.8169
	(9.88)***	(7.45)***	(6.95)***	(4.05)***
Constant	-0.0195	-0.0121	-0.0184	-0.0085
	(-5.27)***	(-2.86)***	(-4.01)***	(-2.74)***
Adj. R Squared (%)	40.56	37.82	35.85	21.26
N	129	130	129	130

*p < 0.1; **p < 0.05; ***p < 0.01

The table shows univariate OLS-regression results with the Newey-West standard errors for one-month (21 business days) excess returns of the European equity indexes. These excess returns are explained by the volatility risk premium variables of each index. Corresponding NW-based t-statistics are presented in parentheses.

The largest return-impact is for the DAX index. One percentage point increase in *ex-post* volatility risk premium increasing the one-month excess returns by 1.65%. The results for all of the examined indexes are significant at the 1% level. Volatility risk is clearly priced in the aggregate equity markets, and the volatility risk premium provides consistent explanatory power on subsequent equity index returns.

The strong explanatory power might be due to the EPVRP's relationship to the equity risk premium, or it can result from the observation that realized volatilities are prone to be higher in the downward markets, and lower in upward markets. It is likely that both of these explanations are right and that the substantial return impact of *ex-post* observed volatility risk premium is a joint result of the connection of the volatility risk premium to the equity risk premium and volatility's connections to market trends.

Since the *ex-post* measure does not provide forecasting value in a real decision-making context, special interest lies on *ex-ante* volatility risk premium. VRP does not deliver statistically significant forecasting results for European equity index returns in one-month periods, but for Euro Stoxx 50, DAX, and SMI index, the VRP slopes become significant in quarterly periods (see Table III). One percentage increase in three-month VRP leads on average to a 1.35% increase in quarterly returns of Euro Stoxx 50 index, a 1.28% increase of quarterly SMI index returns, and 1.14% increase in quarterly returns of the DAX index. Local VRP seems to exhibit significant predictive power over following equity index returns when tested in isolation.

Table III
QUARTERLY REGRESSION RESULTS FOR VRP VARIABLES

Three-month returns				
	Euro Stoxx 50	*DAX*	*FTSE 100*	*SMI*
VRP coefficient	1.3472	1.1390	0.6153	1.2781
	(2.41)**	(1.77)*	(1.59)	(2.47)**
Constant	-0.0262	-0.0004	-0.0061	-0.0166
	(-1.73)*	(-0.02)	(-0.55)	(-1.11)
Adj. R Squared (%)	8.06	4.10	1.23	12.95
EPVRP coefficient	0.1263	0.0212	0.2108	-0.3446
	(0.46)	(0.05)	(0.49)	(-1.14)
Constant	-0.0079	0.0124	-0.0014	0.0021
	(-0.48)	(0.70)***	(0.09)	(0.14)
Adj. R Squared (%)	-2.27	0.24	-1.81	-0.37
N	43	43	43	43

*p < 0.1; **p < 0.05; ***p < 0.01

The table shows univariate OLS-regression results with the Newey-West standard errors for three-month excess (63 business days) returns of the European equity indexes. These excess returns are explained by volatility risk premium variables of each index. Corresponding NW-based t-statistics are presented in parentheses.

The findings support the hypothesis that the volatility risk premium would have explanatory power over short-term European equity index returns. The hypothesis of the return-forecasting nature of the European volatility risk premiums is also supported. Own-country-based volatility risk premiums explain a significant fraction of the European equity index returns and provide predictive power for return forecasting purposes.

Univariate models with pure S&P 500 volatility premiums are similar to the local evidence. Table IV shows that S&P 500-based *ex-post* volatility risk premium explains a substantial fraction of the broader European equity index (STOXX Europe 600) returns on one-month periods. The corresponding coefficients of other local market indexes are also significant at the 1% level. One percentage point increase in the global *ex-post* volatility risk premium increases the STOXX Europe 600 index one-month logarithmic excess returns at 1.36%, on average.

Table IV
MONTHLY REGRESSION RESULTS FOR SPX VARIABLES.

One-month returns					
	STOXX Europe 600	*Euro Stoxx 50*	*DAX*	*FTSE 100*	*SMI*
SPX VRP coefficient	0.4611	0.4416	0.3946	0.2802	0.3793
	(1.46)*	(1.41)*	(1.09)	(1.22)	(1.94)**
Constant	-0.0060	-0.0072	-0.0004	-0.0030	-0.0052
	(-0.85)	(-0.99)	(-0.06)	(-0.59)	(-1.06)
Adj. R Squared (%)	2.30	1.12	0.63	0.59	2.06
SPX EPVRP coefficient	1.3763	1.5901	1.6996	1.1391	0.8377
	(11.41)***	(10.12)***	(7.61)***	(11.17)***	(7.56)***
Constant	-0.0162	-0.0201	-0.0152	-0.0126	-0.0102
	(-5.39)***	(-5.52)***	(-3.45)***	(-4.75)***	(-3.35)***
Adj. R Squared (%)	39.62	36.93	37.65	32.47	19.66
N	129	130	129	129	130

*p < 0,1; **p < 0,05; ***p < 0,01

The table shows univariate OLS-regression results with the Newey-West standard errors for one-month (21 business days) excess returns of the European equity indexes. These excess returns are explained by the *ex-ante* (SPXVRP) and ex-post (SPXEPVRP) volatility risk premiums of S&P 500 index. Corresponding NW-based t-statistics are presented in parentheses.

By contrast, the results of the forecasting power of S&P 500-based *ex-ante* volatility risk premium are ambiguous. These results were confirmed by cutting the observed period in shorter sub-periods, calculating quarterly returns with monthly data, as well as by using the actual three-month implied volatilities without any major improvement in significance. Although the evidence for the predictive power of SPX VRP over European equity indexes is weak, the *ex-post* measure of volatility risk premium implies the existence of positive cross-market relation between innovations in S&P 500 volatility risk premium and European equity index returns. The results show that the ex-post S&P 500 volatility risk premium is consistently positively related to the corresponding European equity index returns, explaining significantly the short-term future return variability of the FTSE100 and SMI indices.

Table V
QUARTERLY REGRESSION RESULTS FOR SPX VARIABLES.

Three-month returns					
	STOXX Europe 600	*Euro Stoxx 50*	*DAX*	*FTSE 100*	*SMI*
SPX VRP coefficient	-0.1590	-0.4095	-0.4011	-0.3788	0.0596
	(-0.23)	(-0.55)	(-0.50)	(-0.71)	(0.11)
Constant	0.0016	0.0017	0.0202	0.0082	-0.0030
	(0.06)	(0.06)	(0.73)	(0.42)	(-0.14)
Adj. R Squared (%)	-2.29	-1.60	-1.77	-1.14	-2.40
SPX EPVRP coefficient	0.4031	0.3379	0.3615	0.6031	0.0970
	(1.06)	(1.06)	(0.78)	(2.28)**	(0.35)**
Constant	-0.0097	-0.0130	0.0052	-0.0113	-0.0039
	(-0.63)	(-0.78)	(-0.30)	(-1.06)	(-0.30)
Adj. R Squared (%)	0.17	-1.14	-1.17	5.32	-2.24
N	43	43	43	43	43

*p < 0,1; **p < 0,05; ***p < 0,01

The table shows univariate OLS-regression results with the Newey-West standard errors for three-month (63 business days) excess returns of the European equity indexes. These excess returns are explained by the *ex-ante* (SPXVRP) and ex-post (SPXEPVRP) volatility risk premiums of S&P 500 index. Corresponding NW-based t-statistics are presented in parentheses.

Local and global sources of volatility risk premiums consistently explain a non-trivial part of the European excess returns. The predictive power of the local VRP is stronger at quarterly return periods than monthly returns, whereas the global SPX VRP does not show any sign of *ex-ante* predictability of European returns (see Table V). This means that on quarterly basis, the local VRP seems to be more consistently predicting the subsequent European equity index returns than the global SPX VRP.

The main empirical results from the local part of the study are robust to the inclusion of traditional explanatory variables. Results from the multivariate controlled regressions shown in Table VI indicate that the monthly impact of local *ex-post* volatility risk premium (*EPVRP*) remain highly similar to the univariate results in all four indices. The local *ex-ante* volatility risk premium displayed significant forecasting power over subsequent equity index returns for Euro Stoxx 50 and DAX but not for FTSE100 and SMI on monthly basis. While corresponding univariate monthly regressions results (see table 2) showed no significant relationships between expected returns and *ex-ante* volatility risk premium (*VRP*) in all cases.

The local sources of volatility risk premium displayed significant forecasting power over subsequent equity index returns on quarterly horizons in isolation and remained relatively robust to the inclusion of control variables. The obtained coefficients from the controlled regressions de-

TABLE VI
MONTHLY MULTIVARIATE REGRESSION FOR VRP AND CONTROL VARIABLES

One-month returns

	Euro Stoxx 50	*DAX*	*FTSE 100*	*SMI*
VRP	-0.5113	-0.6245	-0.1296	-0.3579
	(-2.46)**	(-2.09)**	(-0.64)	(-1.97)
IV	-1.5688	-1.6693	-1.1587	-1.6951
	(-4.91)***	(-5.74)***	(-4.12)***	(-4.50)***
ln(DIV)	0.0396	-0.0090	-0.1173	-0.0379
	(1.23)	(-0.20)	(-1.72)*	(-1.78)*
ln(PE)	0.0279	0.0391	0.01500	0.0059
	(1.30)	(2.81)***	(1.66)*	(0.48)*
DEFT	0.0181	0.0203	0.0312	0.0241
	(1.42)	(1.30)	(2.85)***	(2.31)**
TERM	0.0117	0.0056	0.0079	0.0062
	(2.11)	(1.02)	(1.39)	(1.36)
Constant	-0.0683	-0.0433	0.0816	0.0440
	(-0.83)	(-0.93)	(1.29)	(1.33)
Prob (F-statistic)	0.00	0.00	0.00	0.00
Adj. R Squared (%)	25.72	29.13	23.34	32.58
EPVRP	1.2543	1.2969	0.9983	0.5195
	(7.06)***	(5.08)***	(4.85)***	(2.90)***
IV	-0.4932	-0.6979	-0.6606	-1.1235
	(-1.56)	(-2.05)**	(-2.70)***	(-2.77)***
ln(DIV)	0.0079	-0.0540	-0.0959	-0.0254
	(0.32)	(-1.56)	(-1.89)*	(-1.37)
ln(PE)	0.0379	0.0209	0.0199	-0.0050
	(2.39)**	(1.99)**	(2.97)***	(-0.40)
DEFT	0.0041	0.0153	0.0215	0.0139
	(0.40)	(1.44)	(2.41)**	(1.48)
TERM	0.0007	0.0034	0.0012	0.0029
	(0.17)	(1.00)	(0.33)	(0.71)
Constant	-0.1067	-0.0068	0.0360	0.0563
	(-1.89)*	(-0.18)	(0.77)	(1.44)
Prob (F-statistic)	0.00	0.00	0.00	0.00
Adj. R Squared (%)	47.36	44.17	42.94	36.88
N	130	129	129	130

*p < 0.1; **p < 0.05; ***p < 0.01

The table presents multivariate OLS linear regression results with the Newey-West standard errors explaining one-month logarithmic excess returns of the European equity indexes. The independent variables are *ex-ante* volatility risk premium (VRP), *ex-post* volatility risk premium (EPVRP), monthly implied volatility (IV), log-dividend yield (ln(DIV)), log-price-to-earning-ratio (ln(PE)), default spread (DEFT), and term spread (TERM). Corresponding NW-based t-statistics are presented in parentheses.

TABLE VII
QUARTERLY MULTIVARIATE REGRESSION FOR VRP AND CONTROL VARIABLES

Three-month returns

	Euro Stoxx 50	*DAX*	*FTSE 100*	*SMI*
VRP	0.7329	0.6525	0.3490	0.9170
	(1,97)**	(1.53)*	(0.88)	(2.18)**
IV	-1.6820	-1.6469	-1.4174	-1.8906
	(-4.73)***	(-3.53)***	(-2.87)***	(-4.05)***
ln(DIV)	0.0696	0.0208	-0.1977	-0.0429
	(0.92)	(0.16)	(-1.48)	(-1.18)
ln(PE)	0.0971	0.1118	0.0369	0.0492
	(1.66)	(3.02)***	(1.75)*	(1.65)
DEFT	0.0277	-0.0046	0.0486	0.0169
	(-1.59)	(-0.15)	(1.58)	(0.97)
TERM	0.0229	0.0071	0.0147	0.0177
	(2.14)**	(0.56)	(0.82)	(1.49)
Constant	-0.2541	-0.1409	0.1388	-0.0055
	(-1.10)	(-1.36)	(1.12)	(-0.08)
Prob (F-statistic)	0.00	0.00	0.00	0.00
Adj. R Squared (%)	48.55	46.92	39.46	58.18
EPVRP	0.1834	-0.1816	0.2067	-0.2138
	(0.40)	(-0.44)	(0.92)	(-0.53)
IV	-1.7017	-1.5196	-1.3851	-1.8538
	(-4.03)***	(-3.08)***	(-2.91)***	(-4.36)***
ln(DIV)	0.0663	0.0165	-0.1937	-0.0401
	(0.83)	(0.12)	(-1.56)	(-1.26)
ln(PE)	0.0953	0.1095	0.0341	0.0451
	(-1.56)	(2.75)***	(1.91)*	(1.35)
DEFT	0.0237	-0.0140	0.0439	0.0170
	(-1.22)	(-0.38)	(1.63)	(1.35)
TERM	0.0259	0.0120	0.0157	0.0255
	(2.09)**	(0.83)	(0.91)	(1.55)
Constant	-0.2261	-0.1119	0.1520	0.0063
	(-0.95)	(-0.98)	(1.20)	(0.07)
Prob (F-statistic)	0.00	0.00	0.00	0.00
Adj. R Squared (%)	45.83	45.12	39.06	51.59
N	43	43	43	43

*p < 0,1; **p < 0,05; ***p < 0,01

The table presents multivariate OLS linear regression results with the Newey-West standard errors explaining three-month logarithmic excess returns of the European equity indexes. The independent variables are *ex-ante* volatility risk premium (VRP), *ex-post* volatility risk premium (EPVRP), quarterly implied volatility (IV), log-dividend yield (ln(DIV)), log-price-to-earning-ratio (ln(PE)), default spread (DEFT), and term spread (TERM). Corresponding NW-based t-statistics are presented in parentheses.

creased, but the results remained consistent and statistically significant (see Table VII). Decrease in predictive return-impact of VRP might be subject to minor fading when other return-predictors are added into the same model. Similarly, Appendix II & III demonstrates that return-impacts of S&P 500 *ex-post* measure remained sufficiently unaffected when tested along with other controlling variables. The empirical findings of volatility risk premiums remain robust to the controlled effects for both, local and global measures.

V. CONCLUSIONS

The results show that volatility risk premiums are able to explain a non-trivial fraction of the equity index return and that volatility risk is systematically priced into the European equity index returns locally and globally. Our findings of the explanatory power of volatility risk premiums on aggregate stock market returns are in line with the results from the U.S. markets, for example, by [3] and [11].

The negative sign of variance premium means that variance buyers are willing to accept negative returns to hedge against the volatility risk. As the volatility risk premium, on average, is positive for all the examined indexes, volatility selling over European equity indexes has been consistently profitable over the sample period. By contrast, buying volatility would have been unprofitable. Our results show that this negative premium is related to the equity risk premium and explains a relatively large portion of European equity index excess returns.

All European equity index monthly returns are positively related to the *ex-post* volatility risk premium so that one percentage point increase in EPVRP has on average resulted in increase of 1.28% *p.m.* for equity index excess returns. For quarterly return predictions, ex-ante risk premiums are better than ex-post volatility risk premiums. On average, one percentage point increase in quarterly volatility risk premium leads to 1.25% *per quarter* increase in subsequent quarterly European equity index excess returns.

The S&P 500-based quarterly *ex-ante* and *ex-post* volatility risk premiums did not show a significant forecast ability of subsequent European equity index excess returns. However, the corresponding monthly volatility risk premiums are found to be significantly related to all the European equity index returns. On average, one percentage point increase in the S&P 500 volatility risk premium leads to 1.36% *p.m.* increase in excess returns of European stock indexes in univariate settings. The S&P 500-based monthly measure of the *ex-post* volatility risk premium provides slightly stronger (by 8 basis points) predictive power for European equity index returns than the corresponding local measures. These findings are consistent with [23], who showed an increasing inter-market linkage between US and developed European markets during post-financial crisis period. Overall, ex-post volatility risk premiums show better explanatory power (Adj. R Squared) than ex-ante variants.

This study contributes to the existing literature in two ways. Firstly, the finding of the positive relationship between the volatility risk premium and European equity index excess returns is significant, since this is the first time the phenomenon is addressed at a market-wide level in the European stock markets. Our results are in line with the previous findings from the U.S. markets and complement the existing literature in this respect. Investors demand compensation for bearing volatility risk, and a part of equity risk premium can be explained by this risk-aversion-related information implicit in option prices. The local European forward-looking volatility risk premium provides forecasting power on subsequent quarterly equity index excess returns.

Secondly, the finding of globally priced volatility and skewness preferences is important in understanding risks that are priced in equity index returns. The risks in aggregate stock market volatility and skewness of the S&P 500 index seem to be important in Europe as well. Particularly, the risk-neutral implied volatility that is captured by the S&P 500 index options and further by the VIX index, provides a useful tool when assessing the risks embedded globally in the equity markets. Risk aversion captured by the S&P 500-based volatility risk premium exhibits a substantial return-explanatory power across markets and displays as a useful measure for understanding the risks that are relevant in the aggregate European equity market.

To better understand driving forces of the positive relation between the volatility risk premium and expected equity index returns, it might be worthwhile to extend this study to analyze European equity market's exposure to jump risks. Forming a specific measure of tail risk would enrich the knowledge of risk-return tradeoffs in the European equity markets.

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Appendices

Appendix I

Variables and Abbreviations Used in the Empirical Section

Class	*Variable*	*Abbreviation*
	Euro Stoxx 50 index	*ESTOXX*
	DAX index	*DAX*
Equity indexes	*FTSE 100 index*	*FTSE*
	SMI index	*SMI*
	STOXX Europe 600 index	*STOXX*
	S&P 500 index	*SPX*
	Euro Stoxx 50 implied volatility index	*VSTOXX*
	DAX implied volatility index	*VIX-NEW*
Volatility- and skew indexes	*FTSE 100 implied volatility index*	*VFTSE*
	SMI implied volatility index	*VSMI*
	S&P 500 implied volatility index	*VIX*
	S&P 500 implied skew index	*SKEW*
	Ex ante volatility risk premium	*VRP*
	Ex post volatility risk premium	*EPVRP*
Moment risk premiums	*Ex ante S&P 500 volatility risk premium*	*SPX VRP*
	Ex post S&P 500 volatility risk premium	*SPX EPVRP*
	Ex ante skew risk premium	*SRP*
	Ex post skewrisk premium	*EPSRP*
	Implied volatility	*IV*
	S&P 500 implied volatility	*SPX IV*
	S&P 500 implied skewness	*IS*
Control variables	*Dividend yield*	*DIV*
	Price-to-earnings-ratio	*PE*
	Default spread	*DEFT*
	Term spread	*TERM*

Appendix II

monthly Multivariate Regression for S&P 500 Volatility Risk Premiums and Control Variables

	One-month returns				
	STOXX Europe 600	*Euro Stoxx 50*	*DAX*	*FTSE 100*	*SMI*
SPX VRP	-0.1362	-0.1061	-0.2200	-0.1900	-0.1198
	(-0.54)	(-0.39)	(-0.69)	(-0.76)	(-0.66)
SPX IV	-0.8509	-1.0112	-1.0721	-0.9379	-1.0149
	(-3.44)***	(-3.05)***	(-4.04)***	(-3.63)***	(-2.86)***
ln(DIV)	-0.0255	0.0277	0.0001	-0.1132	-0.0287
	(-0.54)	(0.86)	(0.00)	(-1.73)*	(-1.12)
ln(PE)	0.0194	0.0236	0.0232	0.0144	0.0008
	(1.39)	(1.08)	(1.67)*	(1.76)*	(0.07)
DEFT	0.0117	0.0090	0.0090	0.0296	0.0166
	(0.92)	(0.81)	(0.59)	(2.81)***	(1.26)
TERM	0.0116	0.0089	0.0080	0.0099	0.0122
	(2.47)	(1.57)	(1.25)	(1.80)*	(2.64)***
Constant	-0.0174	-0.0711	0.0293	0.0704	0.0304
	(-0.34)	(-0.87)	(-0.61)	(1.17)	(0.98)
Prob (F-statistic)	0.00	0.00	0.00	0.00	0.00
Adj. R Squared (%)	25.15	17.55	17.02	19.98	23.00
SPX EPVRP	1.1141	1.4370	1.5498	0.9412	0.5195
	(5.32)***	(6.44)***	(5.07)***	(7.06)***	(1.44)***
SPX IV	-0.5132	-0.4132	-0.5165	-0.5628	-1.1235
	(-2.45)**	(1.59)	(2.15)**	(2.81)***	(2.77)***
ln(DIV)	-0.0437	0.0077	-0.0526	-0.0850	-0.0254
	(-1.28)	(0.28)	(-1.48)	(-1.62)	(-1.37)
ln(PE)	0.0159	0.0349	0.0131	0.0155	-0.0050
	(1.40)	(2.07)**	(1.25)	(2.12)**	(-0.39)
DEFT	0.0111	0.0049	0.0145	0.0215	0.0139
	(1.30)	(0.61)	(1.37)	(2.50)**	(1.48)
TERM	0.0027	-0.0034	-0.0006	0.0014	0.0029
	(0.89)	(-1.00)	(-0.16)	(0.40)	(0.71)
Constant	-0.0083	-0.1088	-0.0009	0.0273	0.0563
	(-0.20)	(-1.73)*	(-0.02)	(0.61)	(1.44)
Prob (F-statistic)	0.00	0.00	0.00	0.00	0.00
Adj. R Squared (%)	46.49	42.20	41.88	37.85	36.88
N	130	129	130	129	130

*p < 0.1; **p < 0.05; ***p < 0.01

Appendix III
quarterly Multivariate Regression for S&P 500 Volatility Risk Premiums and Control Variables

Three-month returns

	STOXX Europe 600	*Euro Stoxx 50*	*DAX*	*FTSE 100*	*SMI*
SPX VRP	-1.1846	-1.2448	-1.2704	-1.3778	-0.7284
	(-3.16)***	(-2.49)**	(-2.42)**	(-4.33)***	(1.27)***
SPX IV	-0.6786	-1.0593	-1.1081	-0.9183	-0.9267
	(-1.49)	(-1.42)	(-1.44)	(-2.89)***	(-3.48)***
ln(DIV)	-0.1551	0.0530	0.0753	-0.2306	-0.0457
	(-1.46)	(0.56)	(-0.87)	(-2.85)***	(-1.55)
ln(PE)	0.0788	0.0588	0.0690	0.0360	0.0202
	(1.68)	(0.85)	(-0.96)	(2.04)	(0.51)
DEFT	0.0098	-0.0019	0.0107	0.0400	0.0045
	(0.45)	(-0.06)	(-0.40)	(2.21)**	(0.22)
TERM	0.0446	0.0408	0.0305	0.0384	0.0429
	(4.60)***	(3.19)***	(2.66)**	(3.42)***	(3.60)
Constant	-0.0106	-0.1264	-0.2004	0.1717	0.0421
	(-0.08)	(-0.47)	(-0.73)	(1.77)*	(0.41)
Prob (F-statistic)	0.00	0.00	0.00	0.00	0.00
Adj. R Squared (%)	58.94	44.73	46.85	53.26	44.36
SPX EPVRP	-0.1985	-0.0920	-0.1937	0.2447	-0.3977
	(-0.71)	(-0.25)	(-0.54)	(1.48)	(-1.88)*
SPX IV	-0.7897	-1.1786	-1.3094	-1.0735	-1.0164
	(-2.03)*	(-1.79)***	(-2.09)**	(-3.04)***	(-3.27)***
ln(DIV)	-0.1044	0.0783	-0.0273	-0.1418	-0.0281
	(0.90)	(0.89)	(-0.23)	(-1.29)	(-0.87)
ln(PE)	0.0956	0.0813	0.0960	0.0270	0.0380
	(1.97)*	(1.17)	(2.26)**	(1.70)*	(1.09)
DEFT	0.0053	0.0023	0.0008	0.0326	0.0012
	(0.25)	(0.09)	(0.02)	(1.45)	(0.07)
TERM	0.0332	0.0283	0.0248	0.0220	0.0430
	(3.23)***	(2.23)*	(1.86)*	(1.72)*	(2.56)**
Constant	-0.1098	-0.2274	-0.1169	0.1009	-0.0202
	(-0.77)	(-0.87)	(-0.95)	(0.95)	(-0.23)
Prob (F-statistic)	0.00	0.00	0.00	0.00	0.00
Adj. R Squared (%)	52.77	38.70	41.94	40.46	43.72
N	43	43	43	43	43

*p < 0,1; **p < 0,05; ***p < 0,01