International Volatility Arbitrage *

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JOB MARKET PAPER

October 18, 2018

Abstract

Are options on exchange-traded products (ETPs) and indexes consistently priced internationally? The cross-section of international option returns exhibits a mispricing by sorting on ex-ante volatility returns. In addition, selling international ETP options and buying their corresponding index options commands a positive risk premium. Both empirical findings are economically large and pervasive internationally, whereas they are comparably small domestically. While volatility hedge funds are exposed towards domestic option products, they neglect the possibility of engaging in foreign volatility arbitrage. These findings entail that alpha seekers may expand their horizon towards international derivatives which at first glance are similar, but institutionally are not.

Keywords: systematic volatility arbitrage, cross-section of option returns, dispersion trading

JEL Classification: G11, G12, G13, G14

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1 Introduction

Most empirical option pricing research focuses on US option markets.[1] Nevertheless, little is known about option returns internationally. The increasing range of newly issued exchange-traded product (ETP) and index options worldwide raises two empirical questions. Are options consistently priced internationally? Do analogous US options exhibit similar pricing behavior?

This paper studies option returns in international and domestic-US markets. International options refer to equity options on country ETPs and indexes. For instance, I ask whether Korean ETP and index options are consistently priced with Brazilian derivatives. Domestic options refer to equity options on US ETPs and indexes. For example, I ask if ETP and index options on NASDAQ and S&P500 are consistently priced. This study shows two main empirical results among international derivative products. The first result is a cross-sectional mispricing. The second result is a dispersion trading risk premium. Both results are comparably small in the domestic derivative space. The sample period is 2006-2015.

First, I consider an analysis *across* financial instruments by pooling together all the country ETP and index options. Specifically, the cross-section of international option returns on ETPs and indexes exhibits a mispricing by sorting on the relative valuation of implied and realized volatility (henceforth, ex-ante volatility returns). I construct ex-ante volatility returns as one minus the ratio of previous year realized volatility to time t implied volatility. Substantial volatility deviations across ETP and index options reveal an inconsistency in pricing of derivatives at the international level.

Second, I consider an analysis *between* financial instruments by taking the difference between ETP and index option returns on the same country. Explicitly, selling international ETP options and buying their corresponding country index options commands a positive risk premium. This dispersion premium is especially pronounced among options with high ex-ante volatility return difference. The pricing gap between ETP and index options depicts the presence of a premium which is not hedgeable by means of index options.

Both stylized facts are economically sizable internationally, with annualized risk-adjusted returns reaching 20%. The main determinants of the different pricing behavior of international options reside in volatility and institutional differences. These options have substantial heterogeneity in volatility and some contract specification discrepancies. The latter feature refers to option contracts, which may differ in expiration day, underlying asset, exercise-settlement and venue. In addition, international ETP products are recently issued. In this paper, I show that combining assets in different ways leads to capture diverse risk / return profiles. Specifically,

[1] For instance, seminal papers of Coval and Shumway (2001), Goyal and Saretto (2009) and Driessen et al. (2009).

these asset combinations tilt a strategy exposure towards either a mispricing (cross-section) or a risk premium (dispersion trading). To the best of my knowledge, this is the first paper that presents these findings. I report a literature review in Section 2.

The methodology adopted to study the systematic behavior of international option returns in the cross-section is a simple univariate sort. Each month, international at-the-money (ATM) straddles are sorted by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. Then, a long-short portfolio sells the expensive tercile, buys the cheap tercile and holds options to maturity. Domestic long-short portfolios are constructed similarly. After that, I analyze return and risk characteristics of these option strategies.[2]

International long-short option portfolios outperform the equivalent domestic option strategies, as shown in Figure 1. This figure shows cumulative returns of international and domestic option portfolios sorted by volatility returns. International long-short option strategies yield annualized average return (Sharpe ratio) ranging between 16.38% and 18.52% (1.83 and 2.29). These returns are neither spanned by equity nor volatility factor models, yielding risk-adjusted returns of similar magnitude as the raw returns. Despite their sizable abnormal returns, international long-short option returns are positively skewed and have a neutral exposure to the equity market. In contrast, domestic long-short option portfolios exhibit a weaker pattern in the data yielding annualized average return (Sharpe ratio) between 3.64% and 5.04% (0.56 and 0.67), as Table 1 shows.

By means of cross-sectional regressions, I show that volatility returns are an important determinant of the cross-sectional variation of option returns. Their significance is both statistically and economically more pronounced internationally than domestically. This predominance holds with and without controls. In line with this evidence, the paper analyzes the over-reaction of implied over realized volatility, by means of ex-post volatility returns.[3] The results show an unjustified cross-sectional variation of ex-post volatility returns across international options. Specifically, international long-short portfolios have average ex-post volatility returns ranging between 14.39% and 29.11% on a yearly basis. A smaller cross-sectional variation is present among domestic ex-post volatility returns, which range only between 7.25% and 19.33%.

I then investigate pricing differences between ETP and index options by selling country ETP straddles and buying the corresponding country index straddles. Each month, international ETP and index dispersion pairs are ranked by previous day volatility returns difference. Then, these pairs are assigned to one of three equally weighted tercile portfolios and held to maturity. The high dispersion trading portfolio is the tercile among the ETP and index pairs with the largest

[2]Throughout the paper, all option returns are excess returns, denominated in US dollars and computed at mid-price, unless it is stated differently.

[3]I construct ex-post volatility returns as one minus the ratio of ex-post realized volatility to time t implied volatility. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t + \tau$.

ex-ante volatility return dispersion. Domestic high dispersion trading portfolios are constructed similarly, by pairing domestic ETP and index straddles. Then, I examine the distribution characteristics of these ETP-index spread portfolio returns.

The dispersion risk premium is concentrated among international option products rather than in the domestic derivative space, as shown in Figure 2. This figure depicts cumulative returns of international and domestic high dispersion trading portfolios in which the former are considerably higher than the latter. Concretely, international high dispersion trading portfolios generate annualized average returns between 24.97% and 26.23%. Consistently, their annualized Sharpe ratio is substantial, ranging from 2.03 to 2.25. Not surprisingly, standard equity and volatility factor models cannot explain these returns. Different results are shown by the domestic high dispersion trading portfolios which yield a lower annualized average return ranging between 1.48% and 1.98%. To such a degree, the domestic Sharpe ratio is minimal, varying between 0.14 and 0.19, as Table 1 reports. Even though international high dispersion trading portfolios have low market exposure, they are exposed to higher moment risks. Specifically, international high dispersion trading standard deviation is larger than the domestic equivalent volatility risk, with a relative difference up to 90%. Similarly, international high dispersion trading returns are negatively skewed, implying the possibility of steep drawdowns.

The discrepancy in pricing between ETP and index options internationally is further supported by the gap in volatility returns between these two instruments. In particular, a one-standard-deviation increase in the wedge between ETP and index volatility returns implies an increase of 136 basis points in next month dispersion trading option returns. In contrast, domestic derivatives do not show such a pronounced elasticity. Consistent with this finding, the same country options on different underlying assets can exhibit remarkably different ex-post volatility returns. Their difference can be up to 34.70% on an annual basis. With smaller dispersion, the equivalent domestic ex-post volatility returns vary only between 2.96% and 10.98%. The presence of a risk premium between international derivatives is further corroborated by the low correlation of their underlying assets. This attenuated comovement can be attributed to institutional differences, e.g. diverse market capitalization. Therefore, international ETP and index options may react differently to exogenous shocks. As a result, a premium should be priced between these contingent claims to compensate for heterogeneous product specifications.

To further inspect the main source of these substantial option returns, I analyze the cross-sections of ETP and index options separately, both in international and domestic markets. The key finding is that the volatility mispricing is concentrated in international ETP options.

While the exposure of hedge funds towards volatility products is a known fact, I document that volatility hedge funds are not exploiting volatility deviations among international option products. By means of univariate regressions of hedge funds indexes on international and domestic option strategies, I find a statistical significant exposure of these funds only towards domestic option portfolios. These simple regressions may imply the possibility of finding some opportunities in foreign volatility arbitrage.

The main implications of this study are the following. First, good returns may reside between securities that at first glance are similar, but institutionally are not. Second, exploring newly-issued exotic contingent claims may be an interesting path for unknown returns. Third, hedge funds seeking for alpha may expand their horizon towards international derivative products.

The paper is organized as follows: Section 2 provides a literature review, Section 3 describes the data, Section 4 explains the methodology, Section 5 presents the empirical results and Section 6 concludes.

2 Literature Review

This paper contributes to four different strands of literature. The first one is the growing literature on international options, the second studies domestic-US index options, the third investigates the cross-section of option returns, and the fourth analyzes dispersion trading strategies.

This study is related to the literature exploring the systematic behavior of international options. In particular, Hodges et al. (2003) find that out-of-the-money (OTM) call and put options on S&P 500 and FTSE 100 index futures yield large negative returns for the period 1985-2002. Driessen and Maenhout (2013) study international index option returns on S&P 500, FTSE 100 and Nikkei 225 for the period 1992-2001. They show that volatility and jump risk factors are priced in foreign option products. In addition, they find that UK and US derivatives are increasingly interdependent. Kelly et al. (2016) study the price of political uncertainty across 20 countries for the period 2002-2012. They find that options' implied volatility and variance risk premium are higher for those countries facing political elections, implying that options provide protection for tail risk. Andersen et al. (2017) find a priced left tail risk factor in equity index options among six European indexes. They show a differential risk factor among countries during the European sovereign debt crises. Israelov et al. (2017) document the profitability of covered call writing across eleven global indexes, for the period 2002-2015.

My paper complements this literature by studying the return and risk characteristics of option strategies across 28 countries and 46 different international option products. I show that there is a large cross-sectional variation in straddle returns across international ETP and index options by sorting on ex-ante volatility returns. Furthermore, this international long-short option portfolios cannot be explained by standard risk factors and hedge funds strategies.

This paper is linked to the research investigating domestic-US index option returns. The literature finds that straddles and OTM put options yield large and puzzling returns. In particular, S&P 100 and S&P 500 straddles have been documented to yield weekly returns of -3% (Coval and

Shumway (2001)). Similarly, S&P 500 options generate monthly returns of -50% (Santa-Clara and Saretto (2009)) and they are unexplained by common risk factors (Jackwerth (2000)). Consistent negative variance risk premium is shared by S&P 500 futures options (Bakshi and Kapadia (2003), Broadie et al. (2009), Bondarenko (2014) and Ziegler and Ziemba (2015)). Other studies show that index option returns are larger in non-trading periods (Jones and Shemesh (2018) and Muravyev and Ni (2017)). These enormous index option returns have been rationalized by potential mispricing explanations (Constantinides et al. (2009) and Faias and Santa-Clara (2017)) and consistency or inconsistency of these returns with option pricing models (Broadie et al. (2009) and Jones (2006)). Others explain the index options' expensiveness by the demand of market participants (Bollen and Whaley (2004) and Garleanu et al. (2009)). Closely related to this paper, Ammann and Herriger (2002) investigate volatility arbitrage strategies across S&P 500, S&P 100 and NYSE composite index options for the period 1995-2000. They find that there are some volatility deviations which can be profitably exploited. Koijen et al. (2017) extend the concept of FX carry trade to six different asset classes, among which ten US index options for the period 1996-2011. They find that index option carry-trade portfolios yield substantial risk-adjusted returns, but with negative skewness, by sorting on the option term structure slope. Lastly, Agarwal and Naik (2004) and Agarwal et al. (2017) show the exposure of hedge funds towards S&P 500 index OTM put options, straddles and VIX related strategies.

The paper contributes to this literature by analyzing the return and risk characteristics of 52 different derivative products among ETP and index options in the domestic US market. I document a moderate profitability of domestic long-short option portfolios sorted by ex-ante volatility returns. Finally, I document that volatility hedge funds are exposed towards domestic ETP and index options, while neglecting the possibility of using international volatility spread strategies.

The paper is associated to the literature on the cross-section of US equity stock option returns which finds an extensive set of potentially profitable sorts. Specifically, sorts on historical-implied volatility difference (Goyal and Saretto (2009)), call-put implied volatility difference (Doran et al. (2013)), idiosyncratic volatility (Cao and Han (2013)) underlying volatility (Hu and Jacobs (2017)), ex-ante skewness (Boyer and Vorkink (2014)), term-structure slope (Jones and Wang (2012), Vasquez (2017), Campasano and Linn (2016)) and moneyness (Ni (2008)). Schürhoff and Ziegler (2011) rationalize some of the volatility findings by showing that common idiosyncratic variance risk is an essential determinant of the cross-section of stock option returns. Additionally, Goodman et al. (2018) document how accounting information adds predicting power with respect to future option returns beyond implied and realized volatility. Cao et al. (2017) forecast the cross-section of option returns by means of past stock returns, firm profitability, cash holding, new share issuance and analyst's dispersion.

Consistent with the previous literature, this paper finds that the relative valuation of implied to realized volatility is a strong predictor of future option returns. I complement this literature by showing that the international cross-section of ETP and index option returns is mispriced by sorting on ex-ante volatility returns. Furthermore, I show that this mispricing is especially pronounced across international ETP options.

My paper is closely related to the literature studying dispersion trading strategies. The existing literature document the different behavior between US index options and US equity stock options. Specifically, Carr and Wu (2009) find a negative variance risk premium in index options and approximately zero among 35 equity stock options. Driessen et al. (2009) explain dispersion trading strategies between S&P 100 index options and constituent equity stock options with a correlation risk argument. Schürhoff and Ziegler (2011) show that the correlation risk premium is a combination of systematic and idiosyncratic volatility risk premia. Successively, Driessen et al. (2013) show a large gap between implied and realized correlation on S&P 500 and Dow Jones 30 indexes and constituent options, confirming the presence of a pervasive risk premium. Buraschi et al. (2014) find that analyst's forecast dispersion is positively associated with the difference of index and single stock options volatility risk premia. By means of correlation swap products on S&P500 stocks, Buraschi et al. (2013) document that the cross-section of hedge funds returns is exposed towards dispersion trading strategies. A recent paper investigates the volatility gap between index and single stock options at the international level. Faria et al. (2018) analyze the correlation premium between CAC40, DAX, EuroStoxx50, FTSE100, SMI and SPX index options and constituent single stock options for the period 2002-2012. They find a statistically significant and economically positive correlation premium in international markets.

So far, the literature has studied the volatility gap between index and single stock options. My research differs from the previous one by studying the relative valuation between ETP and index options. I complement the literature by showing that international ETP options command a positive dispersion trading risk premium with respect to the corresponding index options. The pricing gap between international ETP and index options is determined by large volatility deviations, contract specifications heterogeneity and newer issuance of the former instruments over the latter ones. This effect is only marginally shared by domestic ETP-index option products.

3 Data

This section presents the data used in the empirical analysis. The sample period is from January 2006 until the end of December 2015. Subsection 3.1 introduces international option data. Subsection 3.2 presents domestic option data. Subsection 3.3 considers institutional data. Subsection 3.4 lists factor models.

3.1 International Option Data

International option data has daily frequency and comes from OptionMetrics IvyDB database. Within the MSCI world universe, I select one ETP and one index option product for each country available in the database. The data is collected as of August 2017. Table A.1 shows international

ETP and index option specific market, financial product, start and end year of the sample. A list of option variables is reported in Appendix A.1. The international sample covers 28 countries. This data comprises 46 different equity option products among ETP options and index options.[4]

The international index option data covers 17 distinct countries. The international ETP option data consists of 27 countries and two instruments on world regions. The two world regions are on developed and emerging markets. These two instruments are among the first international ETP options issued in 2006. While there is a clear motivation for including these two instruments, their exclusion does not alter the result of this paper.

Over the entire sample period, there are 16 dispersion pairs of international ETP and index options. The countries for which I could merge ETP and index option products are all those among the international index option sample except Finland, which does not have ETP options traded. Panel (A) of Table A.3 shows the paired financial products.

The international option sample spans over the 2006-2015 period due to data availability. International ETP options data is available since 2006. International index options recording data quality improved remarkably since mid 2000, both for pricing and contractual data. Appendix A.3 outlines information about international index options data limitations before 2006.

3.2 Domestic Option Data

The domestic option sample is used as a comparison group. The option data has daily frequency and comes from OptionMetrics IvyDB database for the period 2006-2015. This sample is restricted as the international one for comparison on an uniform time range. Domestic ETP and index option products are selected as follows. First, I look for the universe of US equity cash indexes among three major exchanges widely used in the literature: NYSE, Nasdaq and NYSE American. Second, I then find ETP and index options available in the database which correspond to US equity cash index space. Table A.2 shows domestic ETP and index option products, start and end year of the sample. The sample consists of 52 different domestic equity option products on ETP and index underlying assets.

The domestic index option sample consists of 16 products. The domestic ETP option sample covers 36 different instruments, among which 27 ETP options are on corresponding US equity cash indexes and nine on sector ETPs. The nine sector ETP options correspond to S&P 500 (SPX) sector space.[5] The sector ETP options inclusion aims to enlarge the number of pairs in the domestic dispersion trading analysis. Without the sector ETP options, the domestic dispersion trading number of ETP-index pairs would be approximately half of the corresponding international sample. While there is a clear motivation for including these sector products, their exclusion does not alter the conclusions of this paper.

[4]Option product specification rules are written for general ETP products as of 2017-08-31. The general definition of ETP products includes exchange-traded funds (ETFs), exchange-traded vehicles (ETVs) and exchange-traded notes (ETNs).

[5]The only sector that does not have ETP traded options is real estate, which accounts for a mere 3% of SPX market capitalization.

Throughout the entire sample, I establish 19 pairs of domestic ETP and index options. ETP and index options referring to the same underlying broad cash index are matched, e.g. SPY with SPX options. While each sector ETP option is paired with SPX options. Panel (B) of Table A.3 shows the paired derivative products at the domestic level. To conclude, Table A.4 provides a summary overview of the entire option sample.

3.3 Institutional Data

Contractual and institutional data are from exchanges' websites, clearing houses and market makers worldwide.[6] These contract specifications cover expiration month / date, exercise-settlement value, AM / PM settlement, option multiplier and exercise style. A list of the exchanges' websites is in Appendix A.2. Whenever possible, the first source of institutional information is the one provided by the exchanges. If needed, I complement this contractual information with the one provided by OptionMetrics database information files and Bloomberg data. In addition, changes in option contract specifications are taken into account over the 2006-2015 period. To mention a few examples: KOSPI 200 index options undertook a change in contract multiplier in March 2012, S&P 500-Mini options contract specifications changed from AM to PM settlement in November 2013 and London Stock Exchange LIFFE option contracts migrated to ICE Futures Europe in September 2014.

This paper considers only monthly options with the shortest maturity. Monthly options have a longer history, higher liquidity and are the most studied in the literature on SPX options. However, option products may have, at least, two near-term months and one month from a January, February or March quarterly cycle. Depending on the popularity of the derivative, options can have: long term equity anticipation security (LEAPS), quarterly, monthly, weekly or even daily options. For instance, Dutch index options have also daily expiration cycle. In addition, options with non-standard settlement for which additional securities or cash may be required at expiration are excluded.

To compute option returns, I take into account the heterogeneity in expiration day across different option products worldwide. All option instruments considered in this paper have expiration date on the third Friday of the month, with the exception of five international index options. Specifically, Korean and Japanese index options usually expire on the second Thursday and Friday of the month, respectively. Similarly, Taiwanese and Australian index options usually expire on the third Wednesday and Thursday of the month, respectively. Finally, Hong Kong index options usually expire on the day preceding the last business day of the month.

All ETP options have PM settlement, whereas index options have either AM or PM settlement. Differences in AM and PM settlement among option products are taken into account while

[6] I would like to especially thank the following institutions for clarifications on option products specifications and for providing institutional data: Korean Exchange (KRX), KRX clearing house, Taiwan Futures Exchange, MEFF Exchange's market makers and services, BME Market Data, Borsa Italiana, ICE Exchange, London Stock Exchange and OptionMetrics.

computing option returns.

In this study, all ETP options have physical delivery, whereas all index options are cash settled. At expiration, most of index options are settled with a special exercise-settlement value calculated by the exchange or the clearing house. Interestingly, calculations of the special exercise-settlement value can differ substantially across exchanges. For instance, some of the exchanges compute the special exercise-settlement value by employing the opening price of each constituent security in the index on the expiration date, e.g. SPX options. Others compute it as an average of the cash index over a predefined time interval before expiration, e.g. Taiwanese index options.

In this paper, ETP options have ETPs as underlying, while index options have as underlying security a cash index with only one exception. The exception is the Spanish IBEX-35 index options which are on front-month futures. I collect underlying prices and returns in local currency from OptionMetrics database, security and futures price files, and Bloomberg. Underlying asset returns are dividend and split adjusted. Option contracts multipliers denominated in local currency are collected from the exchanges websites.

ETP options have American exercise style. All international index options are European. Domestic index options can be either European or American depending on the particular contract specification. In this study, I neglect the early exercise of American options to facilitate computations.[7] Even though the early exercise assumption is widely used in the literature, I tested that this is not a concern for the option strategies presented in this paper. In particular, I find that the monthly option returns are of similar magnitude both in dividend and non-dividend months. In fact, American options are more likely to be exercised in presence of dividend payments. About 65% of the ETP products have dividend payments on March quarterly cycle and the remaining 35% on a semiannual and annual frequency in June and December. When excluding March, June, September and December from the entire analysis, I find that the remaining monthly returns have similar economic magnitude and statistical significance to those presented below.

3.4 Factor Return Data

I consider two equity and two volatility factor models to compute risk-adjusted returns and factors exposure of the option strategies considered throughout the paper. These factor models are widely used in the literature and among practitioners to evaluate hedge fund strategies. All

[7]This early exercise assumption of American options is previously used in other academic studies in option strategies, e.g. Goyal and Saretto (2009), Driessen et al. (2009), Doran et al. (2013), Buraschi et al. (2014), Boyer and Vorkink (2014) and Cao et al. (2017). Furthermore, Santa-Clara and Saretto (2009) show that the economic magnitude of S&P500 European and American option returns is similar. Consistently, Driessen et al. (2009) show that the early exercise premium of American index options is negligible for short-term options with days to maturity between 14 and 60. Evidence regarding the early exercise of American options in the academic literature is not conclusive. Researchers found that American options are both exercised more and less frequently than expected. For instance, Barraclough and Whaley (2012) find that a fraction of put equity stock options that should have been exercised early remain unexercised for the period 1996-2008. In contrast, Poteshman and Serbin (2003) find an irrational early exercise of American options among retail investors for the period 1996-1999 and Jensen and Pedersen (2016) show the possibility of an optimal early exercise due to funding costs.

the factors are excess returns expressed in US dollars.

The first equity factor model is a six-factor model comprised of Fama and French (2015) five-factor model in addition to Carhart (1997) momentum factor (henceforth domestic equity factor model). These factors comprise market (MKT), size (SMB), value (HML), profitability (RMW), investment (CMA) and momentum (MOM). The second equity factor model is a six-factor model comprised of Fama-French global five-factor and global momentum factor (henceforth international equity factor model). These global factors are constructed using stocks data from 23 countries worldwide and built with the same methodology as the domestic equity factor model. I take both the equity factor models monthly and daily data and US risk-free rate from Kenneth French's website for the period 2006-2015.[8]

The first volatility factor is a hedge fund short volatility (SV) index comprised of 16 hedge funds which take net short positions in volatility related products (henceforth SV factor). The second volatility factor is a hedge fund relative volatility value (RV) index comprised of 40 hedge funds which take long-short positions in volatility related products (henceforth RV factor). Both of the monthly volatility factors come from Bloomberg for the period 2006-2015.[9]

I run univariate capital-asset-pricing-model (CAPM) regressions to investigate the systematic market-risk exposure of international and domestic option strategies. CRSP value-weighted index and MSCI world index monthly and daily data come from Kenneth French's website and Bloomberg, respectively, for the period 2006-2015.

In this paper, I run monthly time series regressions by matching the holding period of the equity factors as the one of the option portfolios. International options do not expire all at the same time. Hence, there is no unique holing period. I choose to approximate the holding period from the moment of portfolio formation to the third Friday of the month. The majority of international and domestic options expire on the third Friday of the month. Hence, this approximation is reasonable. However, my results are robust to different holding period of the equity factors. Section 5.7 reports robustness of the different possible regression specifications.

Lastly, spot foreign exchange rates (FX) data is from WRDS, Federal Reserve Bank monthly and daily FX spot files for the period 2006-2015. The obtained FX rates are in currency units per US dollar and used to convert foreign currency returns in US dollars.

4 Methodology

This section presents the volatility measures used in the relative valuation of securities, how option portfolios are built and option returns computed. The paper focuses on cross-sectional long-short and dispersion trading option strategies. The former type of option strategies exploits volatility deviations across straddles. The latter type of strategy exploits volatility deviations between ETP and index options pairs. Accordingly, I form two types of volatility measures to

[8] `http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html`

[9] For further information on SV and RV factors see, CBOE website `http://www.cboe.com/products/strategy-benchmark-indexes`.

analyze securities across and between option instruments.

4.1 Volatility Measures

To asses the relative expensiveness of option products in the cross-section, I use ex-ante volatility returns, IV_t^r. They are estimated as one minus the ratio of previous year realized volatility to time t implied volatility, that is,

$$IV_t^r = 1 - \frac{RV_{t-12,t}}{IV_t}, \tag{1}$$

where $RV_{t-12,t}$ is the realized volatility estimated from the underlying returns daily data over the last 12 months. IV_t is the average implied volatility of ATM call and ATM put options at time t. The implied volatility is estimated using either Black and Scholes (1973), Cox et al. (1979) or Black (1976) model depending on whether the option contract is European, American or an option on futures, respectively. However, my results are robust to heuristically computing IV by Black and Scholes (1973) for all option types.

In addition, I use a model-free version of equation (1). Volatility returns are estimated by means of model-free volatility swap rate (VSR). VSR is computed by VIX index methodology for short term options.[10] In case of an insufficient number of strikes (lower than three) VSR is estimated by using the volatility approximation of Brenner and Subrahmanyan (1988). The VSR returns, VSR_t^r, are obtained by substituting IV_t with VSR_t in equation (1).

To assess the subsequent valuation of option portfolios in volatility terms, I estimate ex-post volatility returns. This volatility return is computed as one minus the ratio of ex-post realized volatility to time t implied volatility. I calculate the underlying ex-post realized volatility from time t to the option expiration day $t+\tau$ with daily returns data, $RV_{t,t+\tau}$. Then, the ex-post volatility returns are obtained by substituting $RV_{t-12,t}$ with $RV_{t,t+\tau}$ in equation (1). Its model free version uses VSR in place of IV.

I employ dispersion trading ex-ante volatility return to assess the relative expensiveness between ETP and index option pairs. I compute dispersion trading volatility return as the difference between ETP and index volatility return, formally given by

$$IV^r_{t,\text{ Dispersion}} = IV^r_{t,\text{ETP}} - IV^r_{t,\text{Index}}, \tag{2}$$

where $IV^r_{t,\text{ETP}}$ is the volatility return of an ETP option product and $IV^r_{t,\text{Index}}$ is the volatility return of the corresponding index product. Model-free versions as well as ex-post volatility returns follow accordingly by substituting the corresponding quantities in equation (2).

[10] https://www.cboe.com/micro/vix/vixwhite.pdf

4.2 Option Portfolios

Portfolios are built without any look-ahead bias. To avoid any non-synchronous trading concern across time zones, I lag the entire information set used to construct portfolios by one day. In addition, cash flows are synchronized across products. This synchronization ensures that all instruments held in the portfolios have expired by the time the new option baskets are established. I choose to execute trades on the fourth Friday of each month. This day ensures to have Taiwanese and Australian cash flows always available, independently of the first day of the current and subsequent month. Results are robust to the choice of a different calendar time.

First, volatility measures and option returns are computed using the mid-price calculated from closing bid and ask prices. For international options, whenever the bid and ask prices are not available, I use the closing trade price or the settlement price published by the exchange. Second, I utilize only strike prices available at the moment of portfolio construction. Additional strike prices are usually issued when market participants make a specific request or the underlying passes the highest or lowest listed strike. Third, I ensure that option prices fulfill no-arbitrage conditions across strikes within each instrument, both at portfolio construction and at trade execution. Specifically for any strike $K_{i+1} > K_i$, I ensure that call prices satisfy $C(K_{i+1}) \leq C(K_i)$ and put prices satisfy $P(K_{i+1}) \geq P(K_i)$. In case of a no-arbitrage violation that specific option is excluded from the computations.[11] Fourth, options are selected with the level of the underlying. ATM options are those with the first strike price OTM. In order to build a straddle position, I require to have at least an ATM call and an ATM put. At the moment of trade execution, I select the previous day ATM call and put options.

The following portfolio construction is adopted for international and domestic options cross-sections, as well as at the micro level for ETP and index derivative cross-sections. Each month, straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). After that, options are held to maturity. I use both types of volatility returns for sorting, IV or VSR returns. The unconditional (U) portfolio return is the equally weighted average of all the straddles available at the moment of portfolio formation.

International and domestic dispersion trading portfolios are constructed in the following way. Each month, ETP and index dispersion pairs are ranked in descending order by previous day volatility returns difference, equation (2). Then, they are assigned to one of three equally weighted tercile portfolios. After that, I sell ETP straddles and buy the corresponding index straddles. Options are held to maturity. The high (low) dispersion trading portfolio is the tercile among the ETP and index pairs with the largest (smallest) ex-ante volatility return dispersion. The

[11] Results are robust to the easing of the no-arbitrage screen. The largest violations of no-arbitrage, which is a recording error, belongs to CAC 40 index options for date 2010-04-20 and expiration contract 2010-05-21. The violation of no-arbitrage is confirmed by the data provider as of 2017-11-06.

long-short dispersion trading portfolio is the difference between 50% of the high and 50% of the low dispersion tercile. The unconditional (U) dispersion trading portfolio is the equally weighted average of the ETP minus index straddles pairs. A list of variables and measures aggregated in each portfolio is reported in Appendix A.1.

I generalize the cross-sectional and dispersion trading analysis for international and domestic option portfolios by studying their time series properties. The portfolio construction is kept as previously described. However, I change the moment in which is executed. Specifically, option portfolios are constructed and trades are executed on the $n^{th}-1$ and n^{th} day since the last third Friday of the month. Cash flows are synchronized for each independent n^{th} day. The aim of this analysis is to show the pervasiveness and robustness of the pattern in the data documented in this paper. In addition, such an analysis shows heterogeneity in return and risk characteristics of different option strategies over time.

4.3 Option Returns

This subsection reports straddles and dispersion returns calculation. The long straddle return denominated in US dollar (USD) from time t to expiration date $t+\tau$ is given by

$$r_{t+\tau}^{\text{Long,USD}} = \left(1 + r_{t+\tau}^{\text{Long,Local}}\right) \frac{S_t}{S_{t+\tau}} - (1 + r_{f,t+\tau}), \tag{3}$$

where $r_{t+\tau}^{\text{Long,Local}}$ is a long option straddle return in local currency, S_t is the foreign exchange rate in currency units per US dollar and $r_{f,t+\tau}$ is the US risk-free rate. The short straddle return is minus the long straddle return, $r_{t+\tau}^{\text{Short,USD}} = -r_{t+\tau}^{\text{Long,USD}}$. The straddle return in local currency is given by

$$r_{t+\tau}^{\text{Long,Local}} = \frac{(X_{t+\tau} - K_C)^+ + (K_P - X_{t+\tau})^+}{C_t + P_t} - 1, \tag{4}$$

where $X_{t+\tau}$ is the exercise-settlement value of the option product at expiration, whereas K_C and K_P are the call and put strike prices, respectively. C_t and P_t are the call and put option prices at the time the position is opened. For each option product, I take into account anticipated settlements due to non-trading days. In case of missing special exercise-settlement value, I use the underlying cash index level by following the option contract specification rules for this exception. All the option straddles returns are adjusted for splits by following the rules of the exchanges, which imply adjusting the strike prices by the amount by which the index is split.

For each pair of ETP-index option products, the dispersion trading return is given by

$$r_{t+\tau}^{\text{Dispersion}} = r_{t+\tau,\text{ETP}}^{\text{Short,USD}} - r_{t+\tau,\text{Index}}^{\text{Short,USD}}, \tag{5}$$

where $r_{t+\tau,\text{ETP}}^{\text{Short,USD}}$ is the short straddle return of an ETP option product and $r_{t+\tau,\text{Index}}^{\text{Short,USD}}$ is the short straddle return of the corresponding index option product. The dispersion trading return is a long-short portfolio.

All option and volatility returns are multiplied by 7%. This scaling approximately ensures to fulfill margin requirements and margin calls over the option holding period. This deleveraging is consistent with the literature. Santa-Clara and Saretto (2009) and Doran et al. (2013) use 7% to 10% of portfolio value in writing ATM options. By scaling the option returns, I implicitly assume a prefect FX hedge on the margin account.[12]

5 Results

This section presents the main empirical findings of this paper. To start with, Subsection 5.1 analyzes the cross-sectional pricing of international and domestic option portfolios. Subsection 5.2 quantifies the dispersion trading risk premium of international and domestic option returns. Subsection 5.3 then considers the cross-section of ETP and index options separately, both in international and in domestic markets. Subsection 5.4 investigates the relation between option and volatility returns by means of Fama-MacBeth regressions. Then, Subsection 5.5 analyzes ex-ante and ex-post volatility returns overreaction of the considered option portfolios. Subsection 5.6 reports the impact of liquidity and transaction costs on cross-sectional and dispersion trading option strategies. Lastly, Subsection 5.7 considers robustness and extensions.

5.1 Cross-Section

This section investigates the pricing in the cross-section. I use two different universes: international and domestic. Within each of them, ETP and index options are considered. The following sorting analysis shows that the cross-section of international option returns is systematically mispriced. This effect is only marginally shared by the cross-section of domestic option returns.

Figure 3 and Table 2 analyze the cross-sections of international and domestic option returns by reporting unconditional, high tercile, low tercile and high minus low (long-short) option portfolios. Unconditional, high and low portfolio returns are presented as short positions. All conditional portfolios are sorted by previous day IV or VSR volatility returns. The first three panels of Figure 3 show annualized average return in percent, alpha t-statistic with respect to the domestic equity six factors model and annualized Sharpe ratio. The last three panels report annualized standard deviation in percent, skewness and CAPM-β t-statistic with respect to CRSP value weighted index (henceforth CAPM-β).[13] [14]

[12]Nonetheless, market-makers, hedge funds and proprietary trading firms may achieve greater leverage by means of the new portfolio margining rules of the CBOE and risk-based margining rules of European and Asian exchanges. See `http://www.cboe.com/aboutcboe/cboe-cbsx-amp-cfe-press-releases?DIR=ACNews&FILE=20061213.doc`. Further procedures regarding data and methodology are discussed in Appendix A.1

[13]Newey and West (1987) standard errors computed with three lags are used throughout the entire paper to account for heteroskedasticity and autocorrelation.

[14]CAPM-β t-statistic with respect to MSCI world index is similar to the one reported for CRSP.

International long-short option portfolios depicted in blue in the figure yield economically large average returns. This effect is only modestly present among equivalent domestic long-short option portfolios, drawn in green. Specifically, international long-short option portfolios deliver annualized average returns between 16.38% and 18.52%, with t-statistics of 5.82 and 6.87. The risk-adjusted returns confirm the pattern in the data ranging between 17.92% and 19.65%, with t-statistics varying from 6.49 to 7.29. Consistently, international Sharpe ratios are remarkable, varying between 1.83 and 2.29. By contrast, the returns from applying the same long-short strategy to domestic assets are much lower. The average returns range between 3.64% and 5.04%. Similarly, the mean t-statistic is weaker and approximately 2. Along these lines, the Sharpe ratio is considerably smaller varying between 0.56 and 0.67. Taken together, these results show that international long-short option portfolio returns are both statistically and economically significant. In contrast, domestic long-shot portfolios have comparably small returns and share only weakly the international volatility spread.

The results for the international sample show that volatility returns are very effective at selecting options with low and high expected returns. In international long-short option portfolios, the largest fraction of average return profitability comes from the short leg (high-basket), whereas the long leg (low-basket) plays a hedging role. Specifically, the short lag accounts for at least 85% of the long-short average return. Accordingly, these sorts yield larger returns and Sharpe ratios than a mere short position in an unconditional option basket. The unconditional international (domestic) option portfolio has an annualized average return of 5.39% (6.76%), a mean t-statistic of 1.17 (1.05) and Sharpe ratio of 0.32.[15] It is known that shorting volatility generates good returns. Yet, international long-short option portfolios yield greater average and risk-adjusted returns than unconditional short option strategies.

Despite their substantial average returns, international long-short option portfolios have low volatility, positively skewed returns and no exposure to market returns. The low risk characteristics of these portfolios are even more puzzling when compared to unconditional, high and low tercile portfolios. These unhedged portfolios exhibit standard deviations that are twice as high and negatively skewed returns. The risk characteristics of international option returns are presented in the last three panels of Figure 3 and Panels (B) and (C) of Table 2. Specifically, international long-short option portfolios have annualized standard deviations between 8.10% and 8.93%, skewness between 0.37 and 0.60 and maximum monthly drawdown between -5.96% and -3.67%. By contrast, the international unconditional option portfolio has a standard deviation of 16.97%, a strongly negative unconditional skewness of -3.03 and a maximum monthly drawdown of -25.47%. High and low baskets have risk characteristics similar to the unconditional portfolio, but they differ in average return. International long-short portfolios have low excess kurtosis between 0 and 1.56, which is approximately normal. On the other hand, the international unconditional, high and low portfolios exhibit an excess kurtosis between 8.16 and

[15]CRSP and MSCI mean t-statistics are about 1 as well over the same time period.

12.73. These stylized facts between international long-short and (un)conditional portfolios show a cross-sectional mispricing among international options.

To gauge whether these attractive returns represent a compensation for risk, I compute the portfolio market exposure. I show the absence of CAPM-β risk for long-short international portfolios. Their betas range between -0.16 and -0.01, with t-statistics of -3.41 and -0.19. On the other hand, CAPM-β risk is present in unconditional, high and low international baskets, betas (t-statistics) ranging between 0.46 and 0.66 (3.63 and 4.62). The market neutrality of international long-short portfolios is not surprising on the basis of the delta and gamma values at the moment of portfolio formation. International long-short option portfolios delta (gamma) ranges between -0.06 and -0.03 (0.03 and 0.12). Whereas the (un)conditional high and low portfolios have delta (gamma) ranging between 0.37 and 0.42 (0.09 and 0.21). In short, international long-short option returns are remarkable for being zero-beta portfolios.

5.1.1 Is the Anomaly Spanned by Common Risk Factors?

To investigate the potential sources of these international option returns, I run factor model regressions. In these time-series regressions, the dependent variable is the return on an international or domestic long-short option portfolio sorted either by IV returns or VSR returns. The independent variables span over the following factor models. (i) Domestic equity factors model, (ii) international equity factors model, (iii) the corresponding unconditional (U) short option portfolio returns, (iv) a hedge fund short volatility (SV) factor and (v) a hedge fund relative volatility value (RV) factor. While running regressions with volatility factors, I control for equity exposure either internationally or domestically depending if the dependent variable is an international or domestic long-short option portfolio. Whenever a volatility regressor is included, the market factor is excluded from the control variables due to collinearity between volatility and market factors. Table 3 presents risk-adjusted returns and factor exposures from this analysis.

International long-short option portfolios deliver substantial risk-adjusted returns with respect to all equity and volatility factor models. In contrast, the risk-adjusted returns of the domestic long-short portfolios are considerably smaller.

Specifically, annualized abnormal returns (t-statistics) on international long-short portfolios range between 16.36% and 19.86% (5.12 and 7.45), whereas the annualized alphas (t-statistic) on domestic long-short portfolios range between 2.59% and 7.28% (1.01 and 3.12). Thus, international abnormal returns are two to three times larger than domestic ones.

Table 3 reveals that the returns on international and domestic long-short portfolios are mainly exposed to few factors. International long-short option portfolios have a negative exposure to the Fama-French robust minus weak (RMW) factor and a positive exposure towards the momentum factor, which are both statistically significant at the 5% level. The factor exposures imply that a one standard deviation increase in RMW (momentum) factor decreases (increases) the international long-short option portfolio return by about 55 (50) basis points per month. This factor exposures imply that international long-short option portfolios suffer (benefit) from increasing operating profitability (momentum) among international stocks.

Domestic long-short option portfolios have negative exposure to the hedge fund short volatility (SV) factor, which is not the case for the international long-short option portfolios. The SV factor exposure implies that a one standard deviation increase in SV factor decreases the domestic long-short option portfolio return by about 37 to 56 basis points per month, with a statistical significance between 10% and 5% level. This SV factor exposure among domestic long-short option portfolios implies that hedge funds take net short volatility exposure among domestic derivatives but neglect the possibility of doing so internationally.

5.1.2 Is the Mispricing Pervasive?

To investigate the extensiveness of the international mispricing, I analyze its time series properties. To do so, international and domestic long-short option portfolios are studied together with their unconditional option strategy as a function of when portfolios are constructed. These option strategies are constructed on the n^{th}-1 day and trades are executed on the n^{th} day, after the last third Friday of the month. Figure 4 presents the generality of the cross-sectional mispricing. In this Figure the x-axis represents the first 15 business days following the last third Friday of the month. The y-axes report: annualized average return in percent, the abnormal return t-statistic with respect to Fama and French (2015) plus Carhart (1997) factor model, annualized Sharpe ratio, annualized standard deviation in percent, skewness and CAPM-β t-statistic.

First, the international cross-sectional mispricing is present at each point in time. The domestic mispricing is systematically weaker than the international one. Specifically, throughout different points in time international long-short option portfolios have average returns ranging between 15% and 25%. Risk-adjusted return t-statistics range between 4 and 10 and Sharpe ratios vary between 1.5 and 3. On the other hand, domestic long-short option portfolios exhibit weaker pattern in the data, yielding an average return between 2% and 10%. Along the same line, the risk-adjusted return t-statistics vary between 2 and 4 and the Sharpe ratios between 0.5 and 1.5. Both international and domestic long-short option portfolios have larger returns and Sharpe ratios closer to the option contract expiration date. These stylized facts show that the difference between high and low straddle terciles is systematically larger internationally than domestically. This conclusion holds independently of which time the sorting is done.

Second, international long-short option portfolios are systematically less risky than unconditional option portfolios at each point in time. This low risk is puzzling, in light of the larger returns exhibited by the former portfolios over the latter ones. In particular, the standard deviation of international long-short option portfolios is below 12%, their skewness is systematically positive and CAPM-β t-statistics range between -4 and 0. Different risk characteristics are shown by unconditional option strategies, which have a standard deviation steadily above 15%. Consistently, the unconditional option returns are negative skewed and the CAPM-β t-statistics ranges between 0 and 5. The discrepancy between higher moment risks among international long-short and unconditional portfolios confirms the hypothesis of an international anomaly.

To summarize, the cross-section of international option returns is systematically mispriced. The international long-short option returns are an anomaly and not a compensation for risk.

5.2 Dispersion Trading

Are international ETP options more expensive than their corresponding index options? This section documents a positive risk premium between ETP and index options internationally. The dispersion premium increases in ex-ante volatility return gap between these two instruments. These findings are not always shared by equivalent domestic derivatives.

Figure 5 and Table 4 document the dispersion trading risk premium of international and domestic option returns by reporting statistical performance metrics for unconditional, high, low and long-short dispersion trading portfolios. Conditional portfolios are sorted by previous day ETP-index volatility returns difference, equation (2). Figure 5 displays annualized average return in percent, alpha t-statistic with respect to the domestic equity factors model, annualized Sharpe ratio, annualized standard deviation in percent, skewness and CAPM-β t-statistic.

International (domestic) high dispersion trading portfolios yield large (small) annualized average returns, as depicted in the top panel of Figure 5.

First, international high dispersion trading annualized average returns range from 24.97% to 26.23%. Risk-adjusted returns are as large and exhibit t-statistics between 7.00 and 7.19. Along the same line, annualized Sharpe ratios range between 2.03 and 2.25. This empirical evidence outlines a stunning difference between ETP and index option returns behavior. A completely different picture emerges for domestic high dispersion trading option portfolios, which annual returns span between 1.48% and 1.98%. Domestic Sharpe ratios are tiny, ranging between 0.14 and 0.19.

Second, I test if international high dispersion trading portfolios generate economically large returns in excess of the low dispersion trading tercile. On average, the international long-short dispersion trading option portfolios yield annualized average returns (mean t-statistic) ranging between 11.48% and 14.73% (4.54 and 5.92).[16] In line with this evidence, risk-adjusted returns and their t-statistics are of the same economic and statistical magnitude, alpha (t-statistic) ranging between 11.51% and 15.62% (4.06 and 6.08). This substantial difference between international high and low dispersion trading terciles implies that sorting ETP-index pairs by ex-ante volatility returns adds value to the unconditional dispersion trading strategies.

Third, international high dispersion trading portfolios outperform the unconditional dispersion portfolios, as illustrated in Figure 5. The international high dispersion trading average return is approximately twice the international unconditional one; $\frac{26.00\%}{12.60\%} \approx 2$. Similarly, the international high tercile Sharpe ratio is approximately 57% higher than the Sharpe ratio shown

[16] A dispersion trading return is a self-financing portfolio. Thus, only w and $1 - w$ fraction of the high and low dispersion terciles can be combined.

by the international unconditional basket; $\frac{2.25}{1.43} \approx 1.57$. It is worth noticing that the international unconditional dispersion trading Sharpe ratio is 1.43, whereas the domestic case has a Sharpe ratio merely of 0.43. Accordingly, this different behavior between international and domestic baskets, even at the unconditional level, outlines the presence of a risk premium among ETP and index options internationally and none or weaker in the domestic derivative space.

International high dispersion trading returns are exposed to volatility and skewness risks, but have low market risk. Accordingly, international high dispersion trading portfolios command a positive risk premium for their systematic exposure towards high moment risks. The last three panels of Figure 5 and Panels (B) and (C) of Table 4 report the risk pattern in the data.

First, international high dispersion trading option portfolios are exposed to large volatility risk. Specifically, their standard deviation is 40% higher than what is exhibited by the unconditional dispersion trading strategy; $\frac{12.32\%}{8.78\%} \approx 1.40$. Consistently, the international unconditional dispersion trading standard deviation is 28% higher than what is shown by the unconditional domestic basket; $\frac{8.78\%}{6.83\%} \approx 1.28$. Hence, there is a decreasing volatility risk from high dispersion to unconditional dispersion and from international to domestic dispersion.

Second, dispersion trading portfolios are exposed to skewness risk. The international high (unconditional) dispersion trading skewness is negative and ranges between -0.92 and -0.48 (-0.56). Similarly the minimum monthly return for international high dispersion trading portfolios is twice as large as the unconditional dispersion minimum monthly return; $\frac{-14.22\%}{-7.14\%} \approx 2$. This implies that dispersion trades are exposed to steep drawdowns.

Third, high dispersion trading portfolios have low exposure to market risk. This approximate neutrality is consistent with the feature of being short ETP contingent claims and long index derivatives, which offset the market exposure. Specifically, high dispersion trading portfolios have a CAPM-β ranging between 0.07 and 0.10 with t-statistic of 0.99 and 1.89.

To sum up, high moment risks are priced beyond market risk. Heterogeneity between international ETP and index options regarding exercise-settlement value and AM / PM settlement lead to an increase in hedging risk. These non-linear risks are present between assets that at first glance are similar but institutionally are not.

5.2.1 Underlying Pairs Comovement

International ETP and index options differ in their product specifications. First, their underlying assets are not the same. Second, these instruments are quoted in different currency and venue. These differences are smaller among domestic pairs.

The market capitalization of the international underlying assets might differ to some degree. For instance, MSCI Korea ETP covers approximately 85% of the Korean equity universe. While KOSPI 200 index covers approximately 93% of the total stocks market value of the Korea exchange.[17] This is not the case at the domestic level in which the underlying market capitalization

[17] The market capitalization sources are: MSCI website and KRX exchange.

is similar for ETP and index options, e.g. S&P100 ETP iShares and S&P100 index.

International index underlying assets and options are exchanged in local currency and in their country's exchange. By contrast, international ETP underlying assets and options are traded in USD through the CBOE. The different currency and venue between international ETPs and indexes lead to an increasing hedging risk between the corresponding derivative instruments. In contrast, domestic ETP and index underlying assets and options are both exchanged in USD and on the CBOE.

To highlight the difference in systematic behavior between international ETP and index underlying assets, I analyze the cross-sectional distribution of their correlations. Panel (A) of Figure 6 shows the cross-sectional distribution of underlying return correlations for international and domestic ETP and index pairs. Panel (B) shows the distribution of the difference between the upper and lower bound of these estimated correlations at the 95% confidence level. These correlations are estimated by full-sample daily returns in USD between ETP and index pairs underlying assets for the period 2006-2015.

The international underlying assets comove less than the domestic ones, as depicted in Panel (A) of Figure 6. Precisely, the median (mean) correlation between international pairs is 0.73 (0.69), whereas is 0.94 (0.92) for the domestic ones. Along the same line, Panel (B) shows grater estimation uncertainty in realized correlation among international underlying assets than among the domestic ones. Internationally, the median (mean) difference between upper and lower bound is 0.035 (0.038), while domestically is 0.01 (0.009). Thus, the uncertainty in estimated correlations is about three times larger internationally than domestically.

Institutional differences between international ETP and index underlying assets increase the hedging uncertainty. ETP and index options may move distinctively in turbulent environments. Intuitively, a correlation premium should be priced between contingent claims that exhibit heterogeneous comovement.

5.2.2 Are the Returns Abnormal?

To understand the sources of these return differences, I further investigate risk-adjusted returns and factor exposures of international and domestic high dispersion trading option portfolios. I run time series regressions in which the dependent variable is a return on an international or domestic high dispersion trading portfolio. These portfolios are formed by sorting either by IV returns or VSR returns. The factor models used as independent variables are: (i) domestic equity factor model, (ii) international equity factor model, (iii) the corresponding unconditional dispersion trading portfolio of the dependent variable, (iv) hedge fund short volatility (SV) index and (v) hedge fund relative volatility value (RV) index. Table 5 shows the results of this analysis.

International high dispersion trading option portfolios have substantial risk-adjusted returns with respect to any considered model. Furthermore, they have positive exposure to the unconditional dispersion trading factor and the market factor. By contrast, domestic high dispersion trading portfolios have statistically insignificant risk-adjusted returns with respect to any considered factors model.

Specifically, the findings are the following. First, international high dispersion trading option portfolios exhibit annualized alphas ranging between 12.00% and 25.00%. These abnormal returns are all statistically significant at the 1% level. In contrast, domestic high dispersion trading option portfolios show risk-adjusted returns varying between -2.00% and 2.70%, which are all statistically insignificant at the 10% level.

Second, international high dispersion trading option portfolios have a remarkable exposure to the corresponding unconditional dispersion trading factor. These beta estimates are statistically significant at the 1% level. This factor exposure implies that a one-standard-deviation increase in the unconditional dispersion trading factor increases the international high dispersion trading portfolio return by about 200 to 240 basis points per month. In contrast, international high dispersion trading option portfolios have relatively low exposure to the market factor. Only the dispersion portfolio sorted by VSR returns exhibits a statistically significant exposure at 5% level. This factor exposure implies that a one-standard-deviation increase in the market factor increases the international high dispersion trading portfolio return by 69 basis points per month.

Third, domestic high dispersion trading portfolio sorted by VSR returns has positive factor exposure to the short volatility hedge fund index. The factor exposure is statistically significant at the 5% level. Contrary, there is no such factor exposure to any international high dispersion trading portfolio. This means that hedge funds taking short volatility bets are more prone to use domestic derivatives, while ignoring the international derivative space.

5.2.3 The Generality of Dispersion Trading Risk Premium

After identifying which dispersion pairs are systematically more expensive, I investigate how their return and risk characteristics change over time. Figure 7 documents the time series properties of international and domestic dispersion trading option returns, both for high and unconditional baskets. These option strategies are constructed on the n^{th}-1 day and trades are executed on the n^{th} day, after the last third Friday of the month. The x-axis of Figure 7 represents the first 15 business days following the last third Friday of the month. The y-axes report annualized average returns in percent, abnormal return t-statistic with respect to the domestic equity factor model, annualized Sharpe ratio, annualized standard deviation in percent, skewness and CAPM-β t-statistic.

International high dispersion trading risk premium is pervasive at each point in time and is a compensation for systematic volatility risk, as shown in Figure 7.

First, international high dispersion trading portfolios have large returns, for all portfolio formation dates considered. Specifically, annualized average returns range between 20% and 30%, abnormal returns t-statistics between 3 and 7, and annualized Sharpe ratios between 1 and 2.5. On the other hand, the domestic option returns are systematically smaller.

Second, international high dispersion trading portfolios are exposed to systematic volatility and skewness risks, but only marginally to market risk. International high (unconditional) dispersion trading standard deviations range between 10% and 20% (5% and 11%). In the same manner, international high dispersion trading standard deviation is larger than the domestic equivalent volatility risk, which relative difference can vary from 5% to 90%. Additionally, international high dispersion trading portfolios have negative skewness risk ranging between -1 and 0. In contrast, international high dispersion portfolios rarely reject the null hypothesis of a zero CAPM-β, which t-statistics varying between 0 and 2.

Third, the volatility of international high dispersion trading portfolios depends on the time of portfolio formation. Their standard deviations are higher between the first and the second Friday of the expiration month (corresponding approximately between days 10 and 15 in Figure 7). This variability is driven by heterogeneity in expiration days between Asian ETP and index options. While ETP options expire on the third Friday of the month, Asian index options generally do not. For instance, Korean and Japanese index options expire earlier, on the second Thursday and Friday of the month, than the corresponding ETP options. This structural divergence implies that the portfolios short ETP positions are unhedged for about a week's time. To show how these institutional differences affect the risk of these portfolios, I run the analysis excluding the following Asian indexes: Korean, Japanese, Taiwanese, Australian and the Hong Kong ones. The results in Figure A.1 show that the dispersion trading pattern is robust to the exclusion of these indexes. However, the standard deviation of high dispersion trading portfolios between the first and second Friday of the month is much lower. Specifically, without Asian indexes the standard deviation of international high dispersion trading portfolios barely exceed 15% at its peak.[18] In contrast, in the case of a comprehensive use of all the indexes the volatility risk ranges strongly between 15% and 20% at its peak.

To sum up, international high dispersion trading risk premium is large, pervasive and a compensation for systematic volatility. This volatility risk is related to heterogeneity in contract specifications across instruments. Generally, the dispersion premium is greater internationally than domestically.

5.3 ETP v.s. Index Options

This section considers ETP and index option returns separately, both for international and domestic markets. Subsection 5.3.1 analyzes the cross-sections of ETP and index option returns internationally. Subsection 5.3.2 investigates the cross-sections of ETP and index option returns domestically.

5.3.1 International ETP and Index Option Returns

Figure 8 and Table 6 present statistical performance metrics for the cross-sections of international ETP and index option returns separately. The cross-sections are analyzed by reporting

[18] Figure A.2 shows the consistency and robustness of the cross-sectional mispricing without Asian indexes.

unconditional, high, low and long-short option portfolios. The following sorting analysis shows that the long-short returns are substantially larger for ETP options than for index options. In addition, the absence of volatility, skewness and market risks among long-short portfolios confirm a cross-sectional mispricing explanation. Interestingly, this larger profitability of ETP options is not driven by market segmentation. All international ETP options are exchanged through the CBOE and in USD.

First, annualized average returns of international ETP long-short option portfolios range between 19.83% and 20.30%. Their risk-adjusted returns with respect to the domestic factor model vary between 19.69% and 21.15%, with t-statistics of 4.86 and 5.69. Their annualized Sharpe ratios range between 1.66 and 1.72. Even if international index options show analogues pattern in the data, their returns are much smaller. Specifically, the annualized average returns of index option high minus low portfolios range between 6.36% and 8.01%. Their Sharpe ratios only lie between 0.47 and 0.71. This empirical evidence underlines a larger systematic spread among ETP options returns than among index options returns.

Second, international ETP long-short (unconditional) option portfolios have low (high) risk, as Figure 8 indicates in the last three panels. Specifically, ETP long-short option portfolios annualized standard deviations vary between 11% and 12% (18.22%), while skewness ranges between 0.51 and 0.57 (-2.84). Similarly, their excess kurtosis fluctuates between 0.55 and 2.21 (10.13) and CAPM-β t-statistics range between -1.63 and 0.37 (4.07).

Third, the difference in unconditional ETP and index option returns support the hypothesis of an international dispersion premium. Concretely, the unconditional ETP options basket annualized average return is 10.93% with a mean t-statistic of 2.29. Opposed to the unconditional index options basket annualized average return which is -2.15% with a mean t-statistic of -0.45.

Details of the risk-adjusted returns and factor exposures of cross-sectional long-short ETP and index option portfolios are presented in Table 7. These time series regressions use as dependent variable the return on an ETP or index long-short option portfolio sorted either by IV returns or by VSR returns. These regressions use as independent variables one of the following factor models: (i) domestic equity factors model, (ii) international equity factors model, (iii) the corresponding unconditional options portfolio return, (iv) hedge fund short volatility (SV) index and (v) hedge fund relative value volatility (RV) index.

The main result in Table 7 is that international ETP long-short option portfolios have abnormal returns with respect to all factor models. On the other hand, international index options have sporadic abnormal returns. Specifically, the annualized abnormal returns of international ETP (index) options range between 17.00% and 22.00% (3.60% and 9.30%), with t-statistics between 3.40 and 5.70 (0.80 and 2.90).

Lastly, international index long-short option portfolios have three statistically significant factor exposures, namely to the domestic market, momentum and value factors. The market factor exposure is negative and statistically significant at the 1% level. In contrast, momentum and value beta estimates are positive and statistically significant at the 5% level. These factor exposures imply that a one-standard-deviation increase in the momentum (value) factor increases the international index long-short option portfolio return by 88 (72) basis points per month. This effect means that international index options are indeed affected by momentum (value) in the US equity stock market. In contrast, neither ETP nor index long-short option portfolios have exposure to any hedge fund factors.

5.3.2 Domestic ETP and Index Option Returns

This subsection presents results from performing a similar analysis as in subsection 5.3.1, but now for domestic ETP and index options. Figure 9 and Table 8 report return and risk characteristics for the cross-sections of ETP and index option returns, separately. The results differ remarkably from those in the international sample in three main respects: domestic ETP or index long-short option portfolios yield moderate returns, their statistical significance is relatively weak and hedge funds have exposure toward domestic derivative products.

First, there is no clear systematic pattern across portfolio average returns in Figure 9. Specifically, the annualized average returns of ETP (index) long-short option portfolios vary between 3.29% and 5.59% (0.92% and 3.42%), have t-statistic of merely 1.44 and 1.99 (0.37 and 1.33), and Sharpe ratios between 0.43 and 0.60 (0.09 and 0.37).

Second, further analysis on risk-adjusted returns and factor exposures reveal similar return pattern but additional insights on hedge funds' derivative use, as Table 9 shows. Both ETP and index long-short option portfolios deliver sporadic statistically significant risk-adjusted returns when benchmarked against most models. Concretely, ETP long-short annualized abnormal returns (t-statistics) range between 0.30% and 6.92% (0.12 and 2.34). Index long-short annualized risk-adjusted returns (t-statistics) range between 1.61% and 6.93% (0.63 and 3.19).

Third, both domestic ETP and index long-short option portfolios have an exposure to the SV and RV hedge fund factors, statistically significant at the 10% to 1% level. Index long-short option portfolios are negatively exposed to the hedge fund short volatility (SV) factor. The SV factor exposure implies that a one-standard-deviation increase in SV factor decreases the domestic index long-short option portfolio return by about 100 to 116 basis points per month. Even more interesting is the positive (negative) exposure of long-short ETP (index) option portfolios to the RV hedge fund index. The RV factor exposure of the ETP (index) portfolios implies that a one-standard-deviation increase in RV factor increases (decreases) the domestic ETP (index) long-short option portfolio return by about 40 (50) basis points per month. These factor exposures imply that relative volatility funds arbitrage ETP and index options. Surprisingly, it seems that these funds are not exploiting international differences in option richness.

To further test the hypothesis that volatility hedge funds have exposure towards domestic derivative products, but not among the international ones, I do the following. For both of the volatility indexes SV and RV, I run univariate time-series regression on all the cross-sectional long-short and high dispersion trading strategies considered so far in the paper. Then, the estimated factor loadings are plotted as a function of their t-statistics in Figure 10. This figure shows that volatility funds do have an exposure towards domestic option strategies. Nonetheless, none of the factor loadings of international option portfolios are statistically significant at the 10% level.

To summarize the results up to this point, I document that the cross-sectional mispricing is mainly concentrated among international ETP options, moderately among international index options and only sporadically among domestic derivative products. Additionally, I show a discrepancy between international ETP and index option returns, at the unconditional level, supporting the presence of an international dispersion premium. Lastly, I document that volatility hedge funds, among the two considered indexes, are exposed towards domestic derivative products, while neglecting the possibility of engaging in international volatility arbitrage.

5.4 Options and Volatility Returns: Fama-MacBeth Regressions

The results until now have shown a strong predictability of ex-ante volatility returns for international option returns, by means of univariate sorts. Nevertheless, further specific option product characteristics may be important determinants of the cross-sectional variation in international option returns. Accordingly, volatility returns may be subsumed by other variables. To further explore the predictive power of volatility returns for future option returns, while controlling for specific option characteristics, I estimate Fama and MacBeth (1973) regressions. This section shows that volatility returns are an important determinant of the cross-sectional variation of option returns. This predominance holds with and without controls. Furthermore, the cross-sectional predictability of volatility returns is statistically and economically more pronounced internationally than domestically, hence confirming the results so far.

Specifically, each month I run cross-sectional regressions of monthly option returns on portfolio construction volatility returns plus a set of control variables.

$$r_{i,t+\tau}^{\text{Short,USD}} = \lambda_{1,t} \cdot \text{Volatility Return}_{i,t} + \Lambda_t' \mathbf{Z}_{i,t} + \varepsilon_{i,t+\tau} \tag{6}$$

where $r_{i,t+\tau}^{\text{Short,USD}}$ is the option straddle return on product i at expiration day $t+\tau$. Volatility Return$_{i,t}$ is the product i ex-ante volatility return at portfolio construction. The volatility returns can be either model dependent (IV) or model-free (VSR) return. $\lambda_{1,t}$ is the volatility return coefficient. Λ_t is a column vector of controls coefficients. $\mathbf{Z}_{i,t}$ is a vector of control characteristics for product i at time t. The controls considered are the following. The underlying asset's skewness and kurtosis estimated from daily data over the previous year. The underlying asset's momentum estimated as the cumulative return over the last twelve months skipping the most recent month. Market beta and coskewness beta estimated from an univariate regression of the underlying asset's returns on previous year market index daily returns and squared returns, respectively.

The market index is either MSCI or CRSP index depending if the option underlying asset is an international or domestic security. Additional control variables include: absolute delta, dollar volume, dollar open interest and bid-ask spread average between call and put options used to construct the straddle.[19] [20] Lastly, I report the time-series average of the estimated coefficients together with their Newey and West (1987) t-statistics computed with three lags. Alternative regression specifications are discussed in the robustness section.

Table 10 reports the regression results for the cross-sections of international and domestic option returns. For the international sample the volatility coefficients are positive and highly statistically significant, both with and without controls. Regarding economic significance, a one standard deviation increase in volatility return implies an increase in option returns of 76 to 78 basis points per month, with t-statistic ranging between 6 and 8. Domestic volatility return coefficients are positive and statistically significant. Yet, they have lower economic and statistical magnitude than the international ones. Specifically, the domestic volatility return coefficients range between 23 and 38 basis points per month with t-statistics between 3 and 4. The predictability of international volatility returns is larger than the domestic equivalent, as illustrated in Panel (A.1) of Figure 11. This plot shows Fama-MacBeth volatility return coefficients as a function of their t-statistics, with and without control variables. In addition, international volatility returns have the largest economic magnitude and statistical significance with respect to any of the control variables considered in multivariate regressions. The control coefficients are plotted as a function of their t-statistics in Panel (A.2) of Figure 11. These facts imply that volatility returns are one of the main determinants in explaining the cross-sectional variation of option returns, especially at the international level.

Table 11 reports Fama-MacBeth regression results for international and domestic dispersion trading pairs. In these regressions the left hand side variable is a dispersion trading option return, equation (5). For each international or domestic cross-section of dispersion pairs, the main variable of interest is the IV or VSR dispersion return, equation (2). Consistently, all the control variables are the difference between the ETP and index variables.

The key finding is that dispersion trading volatility return coefficients are economically large and statistically significant internationally, whereas they are not domestically. Specifically, a one standard deviation increase in dispersion trading volatility return implies an increase of 136 basis points in next month international dispersion trading option returns. When including control variables the volatility returns coefficients range between 80 and 140 basis points, with t-statistics between 3 and 7. By contrast, domestic dispersion trading volatility returns do not have any predictive power for domestic dispersion option returns. None of these coefficients is statistically significant at the 10% level. The striking difference in return predictability between international

[19]The bid-ask spread is assumed to be zero in case of missing value. Results are robust to the exclusion of those securities for which the bid-ask spread is missing.

[20]Monthly cross-sectional regressions have both the dependent and independent variables demeaned. The independent variables are standardized to unit variance.

and domestic dispersion trading volatility returns is shown in Panel (B.1) of Figure 11, in which coefficients are plotted as a function of their t-statistics. The different systematic behavior of ETP and index options internationally is driven by volatility deviations, while this is not the case among domestic derivative products.

To further inspect the main source of volatility return predictability, I run Fama-MacBeth regressions on ETP and index straddle return cross-sections, at the international level. Volatility return coefficients are economically larger for ETP options, while they are smaller for index options, as Panel (A.1) of Figure 12 shows. While the volatility return coefficients range between 70 to 100 basis points per month for ETP options with and without controls, index options coefficients barely reach 30 to 50 basis point per month and statistical significance when controls are included, as Table 12 reports. This implies that volatility returns have greater cross-sectional predictability among international ETP derivatives, t-statistic about 6.5, than among international index options, t-statistic about 2.6.

Along the same line, I run Fama-MacBeth regressions for domestic ETP and index option cross-sections. Also at the domestic level the largest cross-sectional predictability of volatility returns is concentrated among ETP options rather than among index options as shown in Panel (B.1) of Figure 12 and Table 13. Nevertheless, the volatility return coefficients of ETP options domestically are substantially smaller than the ones for the international ETP options. Specifically, a one standard deviation increase in volatility returns domestically implies 20 to 40 basis points higher domestic ETP option returns next month. In contrast, for international ETP options their coefficients are about 100 basis points per month. These facts underline a difference in option products behavior among international and domestic derivatives with respect to volatility deviations across securities. Thus, exploiting volatility return deviations in the international cross-section is more successful than doing so in the domestic one.

In short, Fama-MacBeth regressions confirm the pattern in the data characterized by the sorting analysis. Volatility returns are strong predictors of future option returns internationally, with and without controls. While domestic volatility return predictability is weaker.

5.5 Volatility Returns Overreaction: From Ex-Ante To Ex-Post

So far, the data have shown that ex-ante volatility returns have a stunning predictability for future straddle returns, both across and between options. Having said that, a natural question arises. What is the excess implied price of options over their holding period? This section analyzes the economic magnitude of ex-ante and ex-post volatility returns. The key findings are the following. First, there is a pronounced cross-sectional variation of ex-post volatility returns across and between international options. Second, this ex-post variability is less pronounced among domestic volatility returns. Third, international ETP options exhibit the largest variation. These findings of implied volatility overreaction are consistent with previous empirical evidence in the academic literature. For example, Poteshman (2001) finds that SPX options overreact to changes in the underlying instantaneous variance. Comparably, Goyal and Saretto (2009) find overreaction of implied volatility in the cross-section of US equity stock options.

International long-short option portfolios have large ex-ante and ex-post volatility return deviations, as shown in Panels (A.1) and (A.2) of Figure 13 respectively. The volatility return deviations at portfolio construction range between 29.74% and 41.70% on a yearly basis. On the other hand, the ex-post volatility returns vary between 14.39% and 29.11%. Even if there is volatility mean reversion between ex-ante and ex-post volatility returns, this reversion is too slow, making international options inconsistently priced. This volatility spread between high and low option portfolios implies that the top tercile of most expensive options has an excess price that is 14 to 29 percentage points higher than what is shown by the cheapest options. To put things into perspective, the domestic ex-post volatility return spread is considerably smaller ranging between 7.25% and 19.33%, as Table 14 shows. Ex-post volatility returns are 50% to 100% larger internationally than domestically. Accordingly, domestic options are more aligned with their future realization than the international ones, showing once more how the mispricing is concentrated internationally.

High dispersion trading portfolios show substantial volatility deviations between ETP and index options, internationally, as Figure 13 depicts in Panels (B.1) and (B.2). Specifically, high dispersion trading ex-ante volatility returns have deviations as large as 22.89% and 40.70% on an annual basis. Implying that country options on different underlying assets can exhibit remarkable different excess implicit prices. This ex-post volatility return difference can be up to 16.55% and 34.70%, among the top tercile of most heterogeneous derivative pairs. With smaller dispersion, domestic high dispersion trading ex-post volatility returns vary between 2.96% and 10.98%, as Panel (B) of Table 14 reports. Therefore, this ETP-index volatility return discrepancy makes the international high dispersion trading option portfolios likely to command a risk premium.

Among all the considered option products, international ETP options exhibit the largest cross-sectional variation in their ex-ante and ex-post volatility returns, as depicted in Figure 14. This fact shows how newly issued derivatives may be less understood and display lower speed of volatility arbitrage. Specifically, international ETP long-short portfolios have ex-ante (ex-post) volatility returns varying between 33.65% and 47.56% (19.98% and 37.42%) on an annual basis. Implying that the most expensive international ETP options are overpriced between 20 to 40 percentage points more than the cheapest ones. With smaller cross-sectional variation, all the other ETP and index options have their long-short ex-post volatility returns varying between 2% to 20%. In addition, international ETP options exhibit extraordinary elevated ATM implied volatility of 28. While all the other derivatives show an ATM implied volatility of about 20, as Table 15 reports. Comparing ETP and index volatility return deviations between international and domestic markets shows that the main pricing discrepancy is concentrated internationally and in ETP options.

5.6 Liquidity and Transaction Costs

The paper has shown that international option strategies yield larger returns than the domestic ones. Nonetheless, liquidity and transaction costs can decrease the profitability of option schemes substantially. How much of these returns are actually achievable? This section investigates the performance of cross-sectional and dispersion trading option strategies under market frictions. The key finding is that market participants able to execute trades at most at 25% of the effective to quoted spread may profitably exploit the pattern in the data. Specifically, with such a trade execution, international option strategies yield annualized average return ranging from 7% to 12% with a Sharpe ratio of about 1. In contrast, domestic strategies do not deliver positive returns, as Table 16 shows.

In the academic literature, the evidence regarding the impact of liquidity and transaction costs on option strategies is not conclusive. Researchers find both that option strategies may be driven by limit to arbitrage or that these strategies may be achievable only by a subset of professional investors. The academic literature reports the limit of contingent claim models under the constraints of real financial markets (Green and Figlewski (1999) and Figlewski (2017)). Similarly, most of the option strategies and irregularities documented appear restricted by liquidity and transaction costs (Figlewski (1989), Gould and Galai (1974), Ho and Macris (1984), Swidler and Diltz (1992), George and Longstaff (1993), Ofek et al. (2004), Goyal and Saretto (2009), Driessen et al. (2009), Cao and Han (2013) and Koijen et al. (2017)), among which the bid-ask spread plays a prominent role. Yet, non-synchronous trading between derivative and underlying markets leads to a widening on the quoted spread at market close. Studies in the US equity stock option market show that the effective to quoted spread ranges from 50% to 100% (Mayhew (2002), De Fontnouvelle et al. (2003) and Battalio et al. (2004)). A recent paper in market microstructure shows narrower effective spreads for option execution timers (Muravyev and Pearson (2017)). High frequency traders may be able to execute trades close to 10% of the effective to quoted spread, if not lower. Other market players, such as discretionary traders, on average can execute trades below 20% of effective to quoted spread. In addition, the liquidity of options and associated transaction costs have been improving in US index options and equity stock option markets, since mid 2000 (Muravyev and Ni (2017) and Christoffersen et al. (2017)).[21] Lastly, the annualized Sharpe ratio of volatility hedge fund indexes range between 0.86 and 2.41 over the sample period. This realized performance shows that professionals can exploit volatility deviations. Nonetheless, it seems that they neglect the possibility of engaging in foreign volatility arbitrage. In this section, I show that exploiting volatility deviations inter-

[21] Changes in regulation such as the option penny pilot program have improved liquidity in the US option market, since 2007-2008, see `https://www.nyse.com/publicdocs/nyse/markets/arca-options/Penny_Pilot_Report_IV_VI.pdf`

nationally may be better than doing so domestically even after moderate levels of market frictions.

As a result of data constraints, the sample does not have actual measures of effective spread. Accordingly, I study the profitability of option strategies by assuming the effective to quoted spread to be 0% (mid-price), 10%, 25%, 50%, 75% and 100% (as in Goyal and Saretto (2009), Koijen et al. (2017) and Cao et al. (2017)). For those options which bid and ask prices are not available, the closing trade price is used. For derivatives with physical delivery, the underlying is assumed to have negligible transaction costs. To alleviate liquidity concerns, the options selected at trade execution have either positive volume or positive lagged open interest. Whenever possible, the selected option is required to have positive bid price. Then, the closest strike to the ATM is selected. If none of the OTM options have such characteristics, the first ITM option is appointed with same methodology. The rest of the portfolio construction is as previously delineated.

Panel (A) of Figure 15 shows annualized Sharpe ratio of international and domestic cross-sectional strategies as a function of the effective to quoted spread. These strategies are long-short portfolios. The results under market frictions confirm the findings presented in the paper so far. International long-short option strategies yield larger Sharpe ratio than domestic equivalent scheme. Nonetheless, Sharpe ratio declines steadily with the widening of the effective to quoted spread. Specifically, when trades are executed at mid-price the Sharpe ratio ranges between 1.31 and 1.67 for international portfolios, while it varies between 0.33 and 0.62 for domestic option strategies. When trades are executed at 25% of the effective to quoted spread the Sharpe ratio ranges between 0.81 and 1.16 internationally, whereas it ranges between -0.04 and -0.25 domestically. Yet, any trade executed with an effective to quoted spread beyond 50% makes the strategy unprofitable, both internationally and domestically.

High dispersion trading option strategies deliver grater performance internationally than domestically, even with market frictions. Returns computed at mid-price deliver Sharpe ratio ranging between 1.50 and 1.64 for international portfolios, while it varies between 0.03 and -0.02 for domestic strategies, as Panel (B) of Figure 15 reports. When trades are executed at 25% of the effective to quoted spread the Sharpe ratio is reduced between 0.95 and 1.11 for international strategies, while it ranges between -0.18 and -0.26 for the domestic ones. However, any trade executed beyond 50% of effective to quoted spread makes the dispersion trading strategies unprofitable.

A consistent picture emerges from the liquidity and transaction costs analysis. International option strategies may lead to better performance than domestic ones. Yet, there is no limit to arbitrage only for those alternative investment funds which can execute their trades at most at 25% of the effective to quoted spread.

5.7 Robustness

To better understand the stability of the empirical findings, I present robustness checks regarding the results presented in the paper.

Sorting volatility measures: The portfolio strategies are robust to different sorting measures. Relative and absolute valuation measures between implied and realized volatility yield similar results, e.g. implied to realized volatility ratio and implied minus realized volatility. In addition, I test the estimation window of the realized volatility at the moment of portfolio formation. Any long term estimate of realized volatility performs equally good as the ones presented in the main body of the paper, e.g. between 6 months and 5 years back. Results become weaker whenever the realized volatility estimate is done on a too short sample, e.g. a month. Furthermore, sorting straddles or dispersion pairs by the volatility return average rank over the past one to ten days leads to similar results as the ones in the main body of the paper. Additionally, by increasing the number of baskets in portfolios sorting shows that option returns are larger among extreme basket portfolios.

Dispersion trading: I sort dispersion pairs by absolute dispersion trading volatility returns and swap ETP and index long / short straddle position on the sign of the deviation. There are few swaps and results are robust to this change.

Exchange rate and interest rate: I run all the tests of this paper by assuming an exchange rate equal to one for all the currencies and zero risk free rate while computing option returns. The economic magnitude of returns and their statistical significance are similar to the ones presented.

Time series regressions, holding period: I run time series regressions by using different holding periods of the equity factors. This allows to match approximately the holding period of the option portfolios. I consider the following holding periods: from the moment of portfolio entry to (i) the third Friday, (ii) the fourth Friday and (iii) the end of the expiration month. In addition, I consider running monthly time series regressions in (iv) calendar time. Realized option returns in a calendar month are matched with same calendar month factor return. Across all these alternatives, the abnormal returns and factor exposures keep same sign, similar economic magnitude and similar statistical significance as the ones presented in the paper. Annualized risk-adjusted returns may increase or decrease at most by $\pm$ 2%. Factor exposures may increase or decrease of at most by $\pm$ 20 basis points per month, and t-statistics may change at most by $\pm$ 1. My results are robust to this changes and the qualitative conclusion of the paper remains the same.

Fama-MacBeth regressions: I run Fama-MacBeth regressions by using as explanatory variables their cross-sectional rank as in Asness et al. (2017). Rank regressions ameliorate noisy estimates and outliers. The regression results are robust to this change.

6 Conclusion

In this paper, I present two new patterns in international option returns: a cross-sectional mispricing and a dispersion trading risk premium.

First, international option returns on ETPs and indexes reveal an asset pricing anomaly by sorting on ex-ante volatility returns. An international long-short option portfolio yields annualized risk-adjusted returns (Sharpe ratios) ranging between 16% and 20% (1.8 and 2). These returns have low volatility, positive skewness and absence of market risk. Consistently, I find large cross-sectional variation in ex-post volatility returns among international portfolios.

Second, international ETP options command a positive risk premium with respect to their corresponding index options. A high volatility spread portfolio between ETP and index option straddles produces substantial annualized risk-adjusted returns (Sharpe ratio) of 25% (2). This volatility spread between international ETP and index options is a compensation for systematic volatility risk, skewness risk and heterogeneity in option product specifications. Accordingly, I show sizable ex-post volatility returns deviations and contract specification discrepancies, e.g. expiration day and underlying asset comovement. These latter two features, among others, induce the presence of a risk premium which is not hedgeable.

Both of the systematic patterns in the data are widespread internationally, while they are modest domestically. Finally, I present evidence that volatility hedge funds are predominantly exposed towards domestic derivative products, while they neglect the possibility of engaging in foreign volatility arbitrage.

The main implications of this study are the following. To begin with, good returns may reside between securities that at first glance are similar, but institutionally are not. Exploring newly-issued derivatives may be an interesting path for unexplored returns. Lastly, alternative investment funds looking for abnormal returns may enlarge their interest towards international contingent claims. Decades of research has focused mainly on domestic option products. Future paths for research might explore institutional differences between equity stock options and contingent convertible bonds at the international level.

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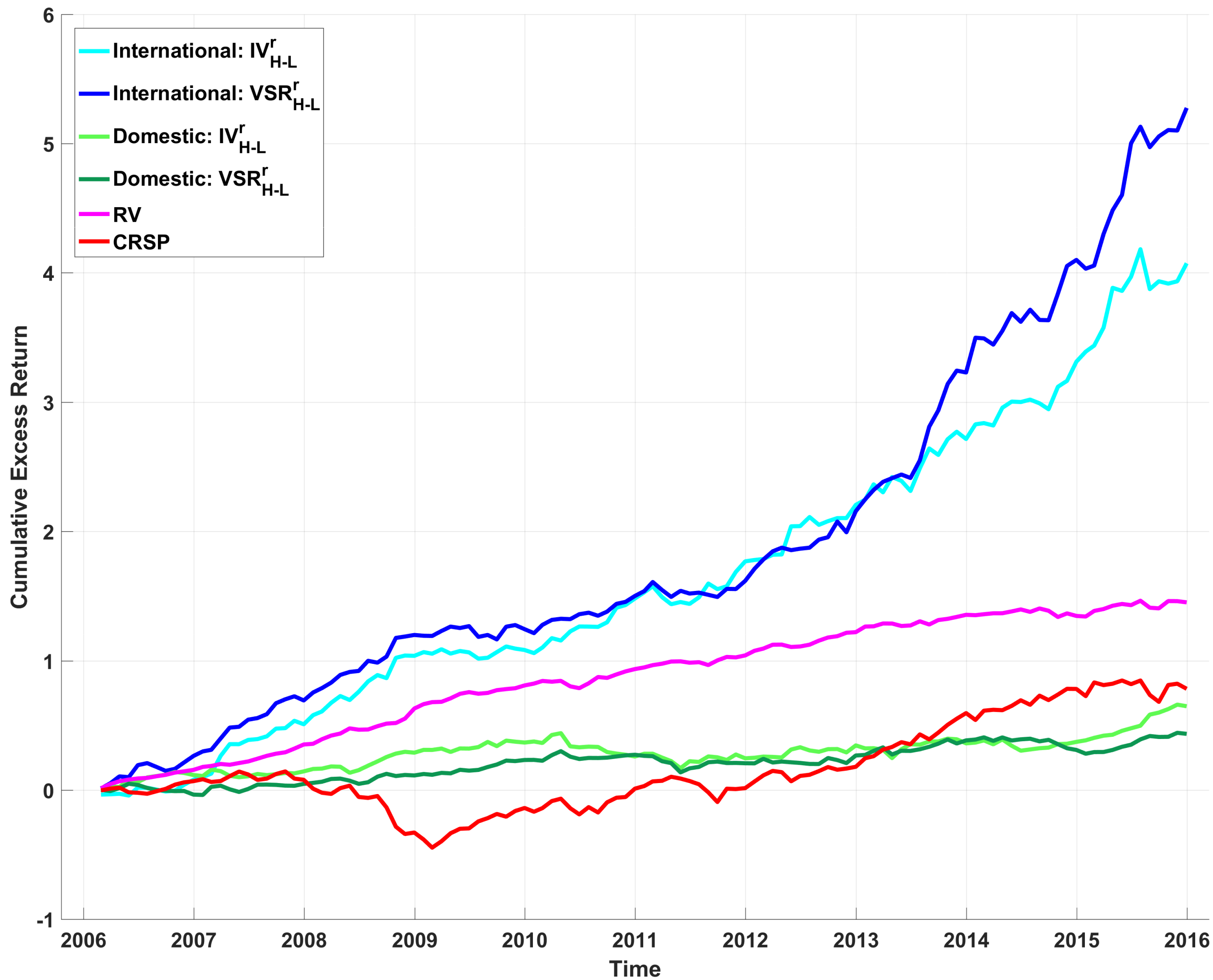

Figure 1

Cumulative Excess Returns of Cross-Sectional Long-Short International and Domestic Option Portfolios.

This figure shows cumulative excess returns of international and domestic cross-sectional long-short option strategies. Each month, international at-the-money (ATM) straddles are sorted by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. Then, the long-short (H-L) portfolio sells the expensive tercile and buys the cheap tercile. Domestic long-short portfolios are constructed similarly. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Volatility returns are either model dependent, implied volatility returns (IV^r), or model-free, volatility swap rates returns (VSR^r). Straddle returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. In addition, the figure reports cumulative excess returns for a hedge fund relative volatility (RV) value index and CRSP value weighted index as benchmarks. The sample period is January 2006 - December 2015.

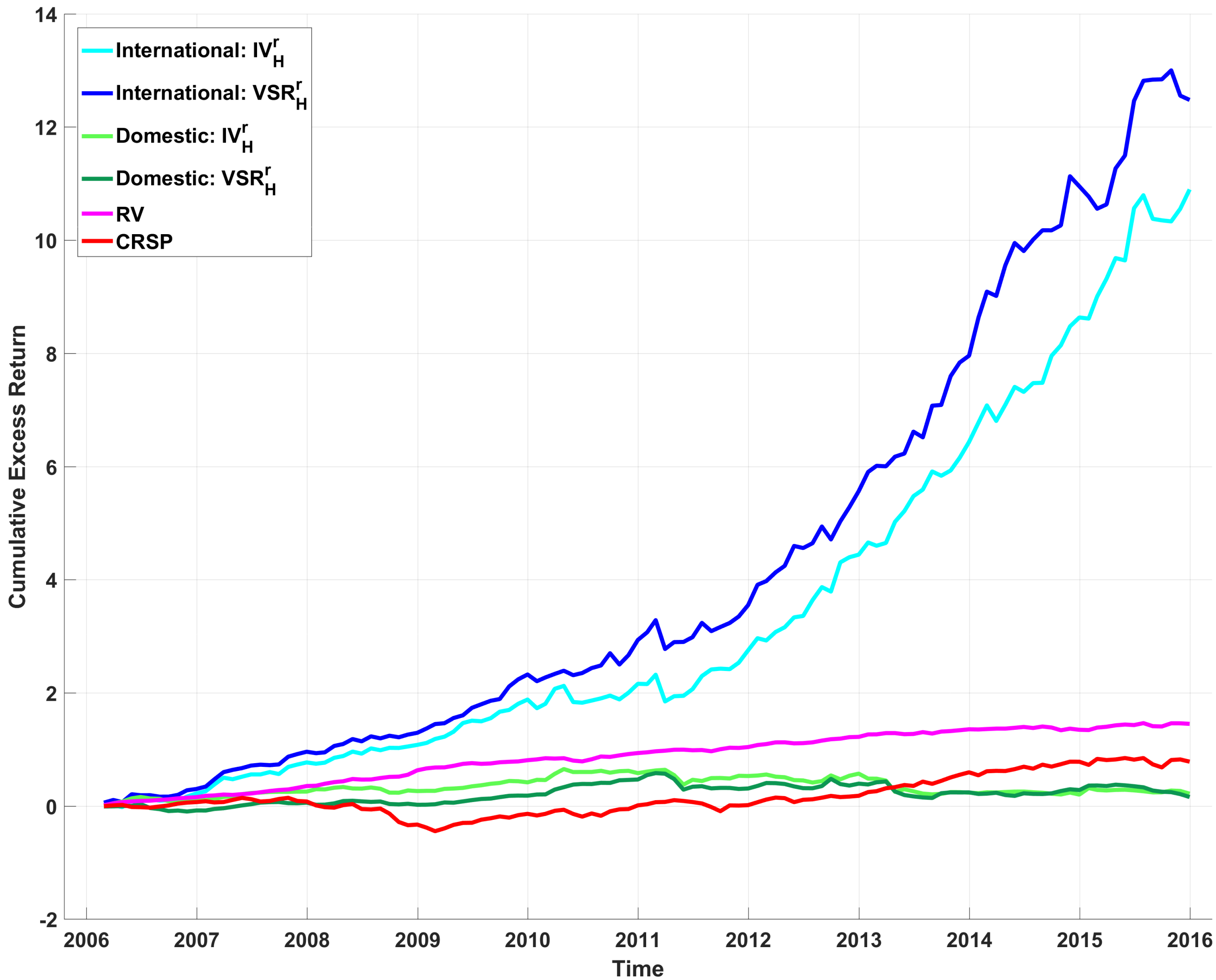

Figure 2

Cumulative Excess Returns of High Dispersion Trading International and Domestic Option Portfolios.

This figure shows cumulative excess returns of international and domestic high dispersion trading option strategies. Each month, international ETP and index dispersion pairs are ranked by previous day volatility returns difference and assigned to one of three equally weighted tercile portfolios. Then, ETP ATM straddles are sold and index ATM straddles are bought. The high (H) dispersion trading portfolio is the tercile among the ETP and index pairs with the largest ex-ante volatility return dispersion. Domestic high dispersion trading portfolios are constructed similarly, by pairing domestic ETP and index straddles. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Volatility returns are either model dependent, implied volatility returns (IV^r), or model-free, volatility swap rates returns (VSR^r). Straddle returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. In addition, the figure reports cumulative excess returns for a hedge fund relative volatility (RV) value index and CRSP value weighted index as benchmarks. The sample period is January 2006 - December 2015.

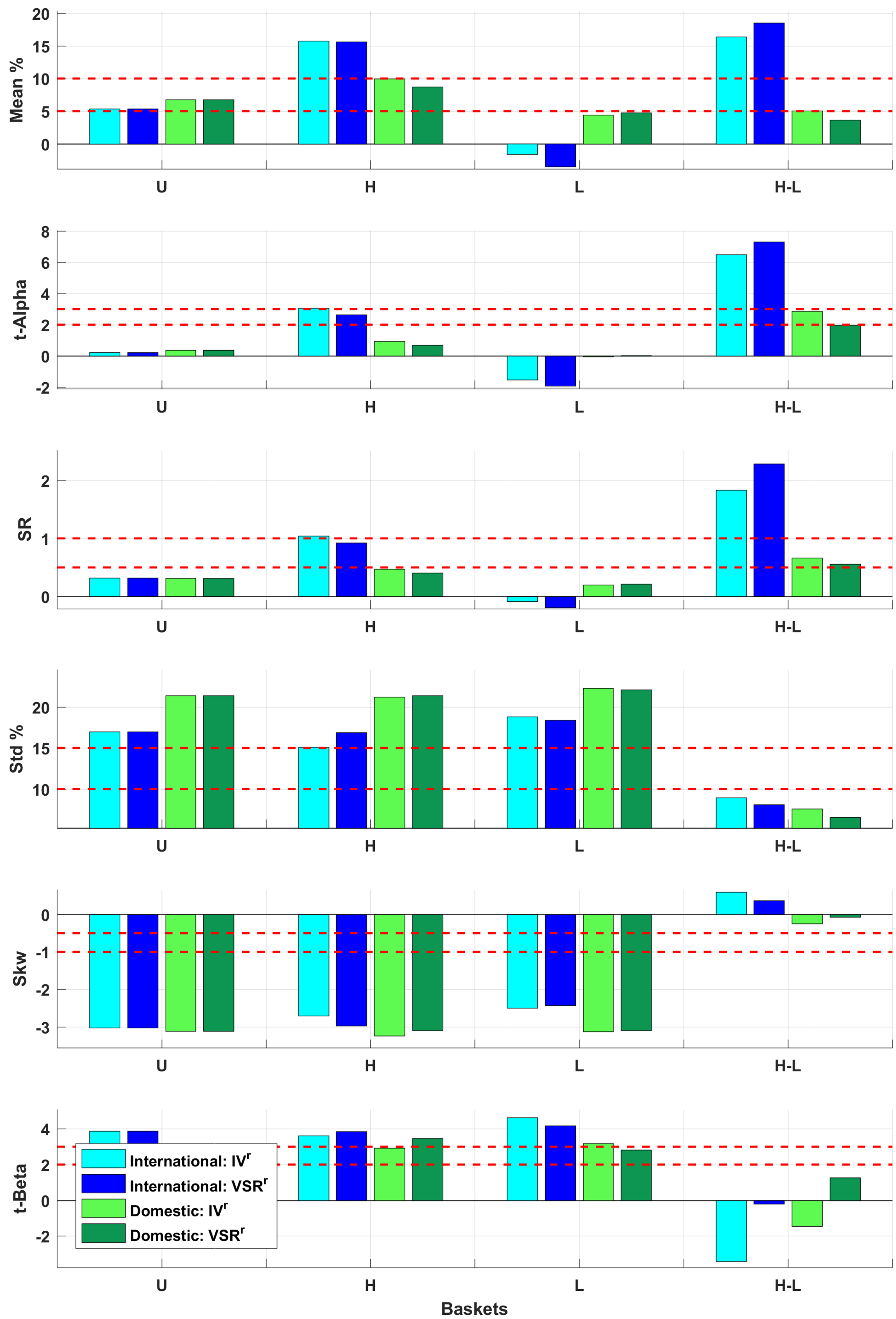

Figure 3

Cross-Section of International and Domestic Option Returns.

This figure shows statistical performance metrics for the cross-sections of international and domestic option returns. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) straddle portfolios. U, H and L straddle returns are presented as short positions. The conditional portfolios are sorted by previous day volatility returns. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

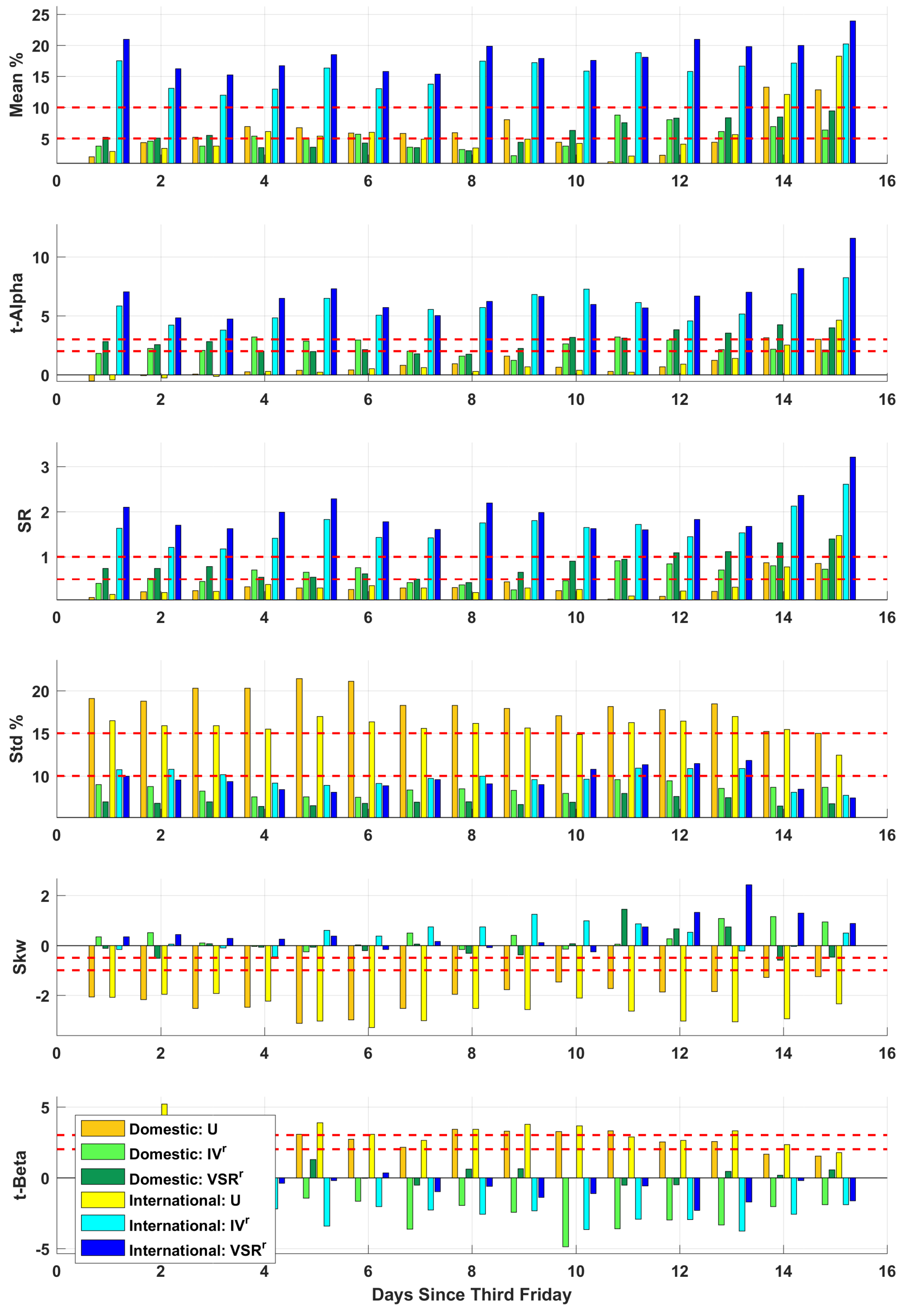

Figure 4

Cross-Section International and Domestic: Time Series Properties.

This figure investigates the time series properties of international and domestic option return cross-sections. The x-axes represents the day in which portfolios are executed, which is the number of days since the last third Friday of the month. The figure reports short unconditional (U) and long-short straddle portfolios sorted either by ex-ante implied volatility returns (IV^r) or ex-ante volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

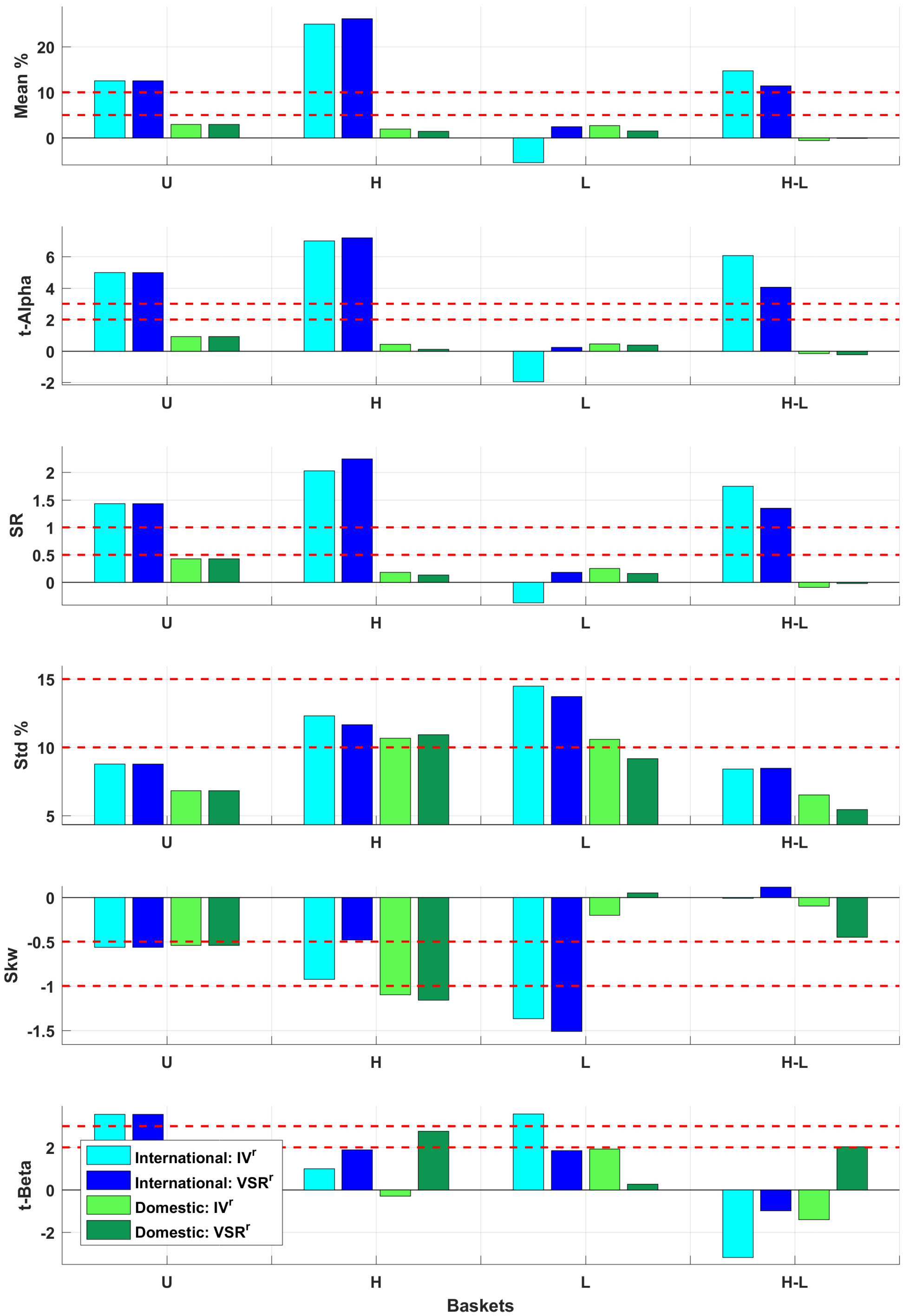

Figure 5

Dispersion Trading of International and Domestic Option Returns.

This figure shows statistical performance metrics for dispersion trading strategies of international and domestic option returns. Dispersion trading pairs are formed by selling ETP straddles and buying their corresponding index straddles. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) dispersion portfolios. The conditional pairs portfolios are sorted by previous day volatility returns ETP-index difference. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

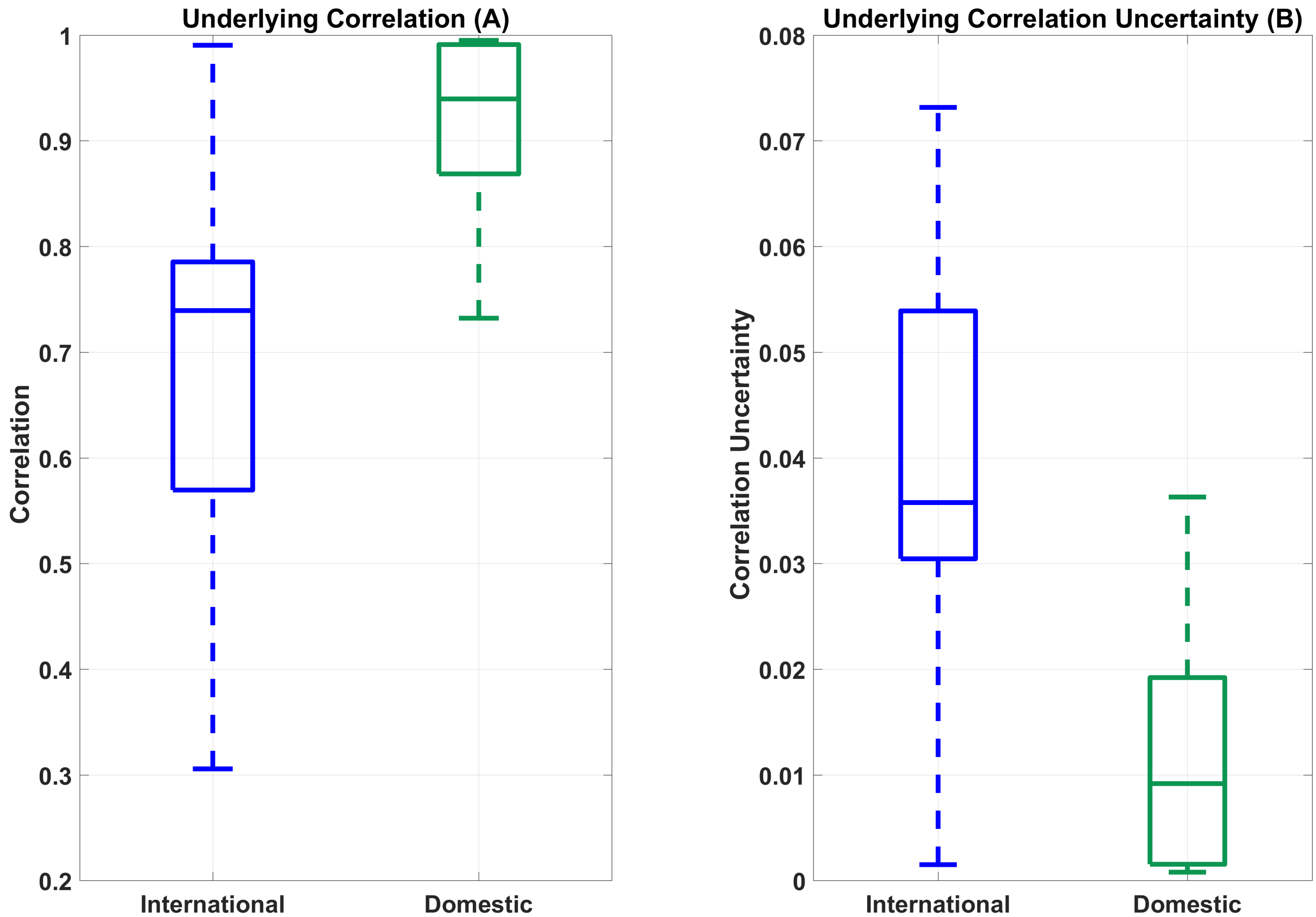

Figure 6

Underlying Correlation in International and Domestic Dispersion Pairs.

This figure shows the cross-sectional distribution of underlying correlations in international and domestic dispersion pairs. Panel (A) shows the distribution of correlations between ETP and index underlying assets. Panel (B) shows the distribution of the difference between the upper and lower bound of these estimated correlations at the 95% confidence level. The correlations are estimated by full-sample daily returns in USD between ETP and index underlying assets, for the period January 2006 - December 2015. In the plot, the central line indicates the median, while the bottom and top edges display the 25th and 75th percentiles. The dashed lines reach the most extreme data points.

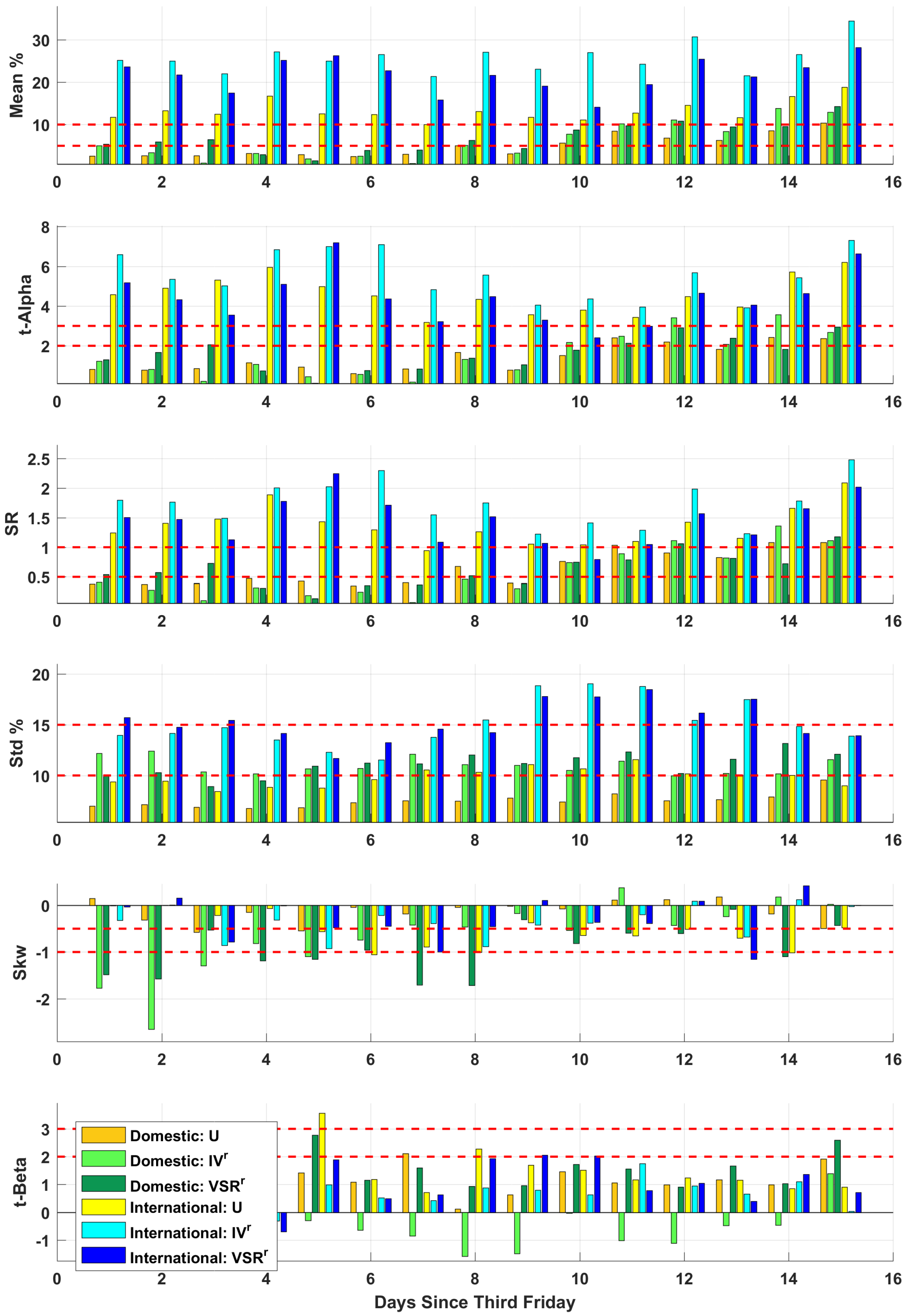

Figure 7

Dispersion Trading International and Domestic: Time Series Properties.

This figure investigates the time series properties of international and domestic dispersion trading option strategies. The x-axes represents the day in which portfolios are executed, which is the number of days since the last third Friday of the month. The figure reports unconditional (U) and high dispersion trading portfolios sorted either by ex-ante implied volatility returns (IV^r) or ex-ante volatility swap rate returns (VSR^r) ETP-index difference. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

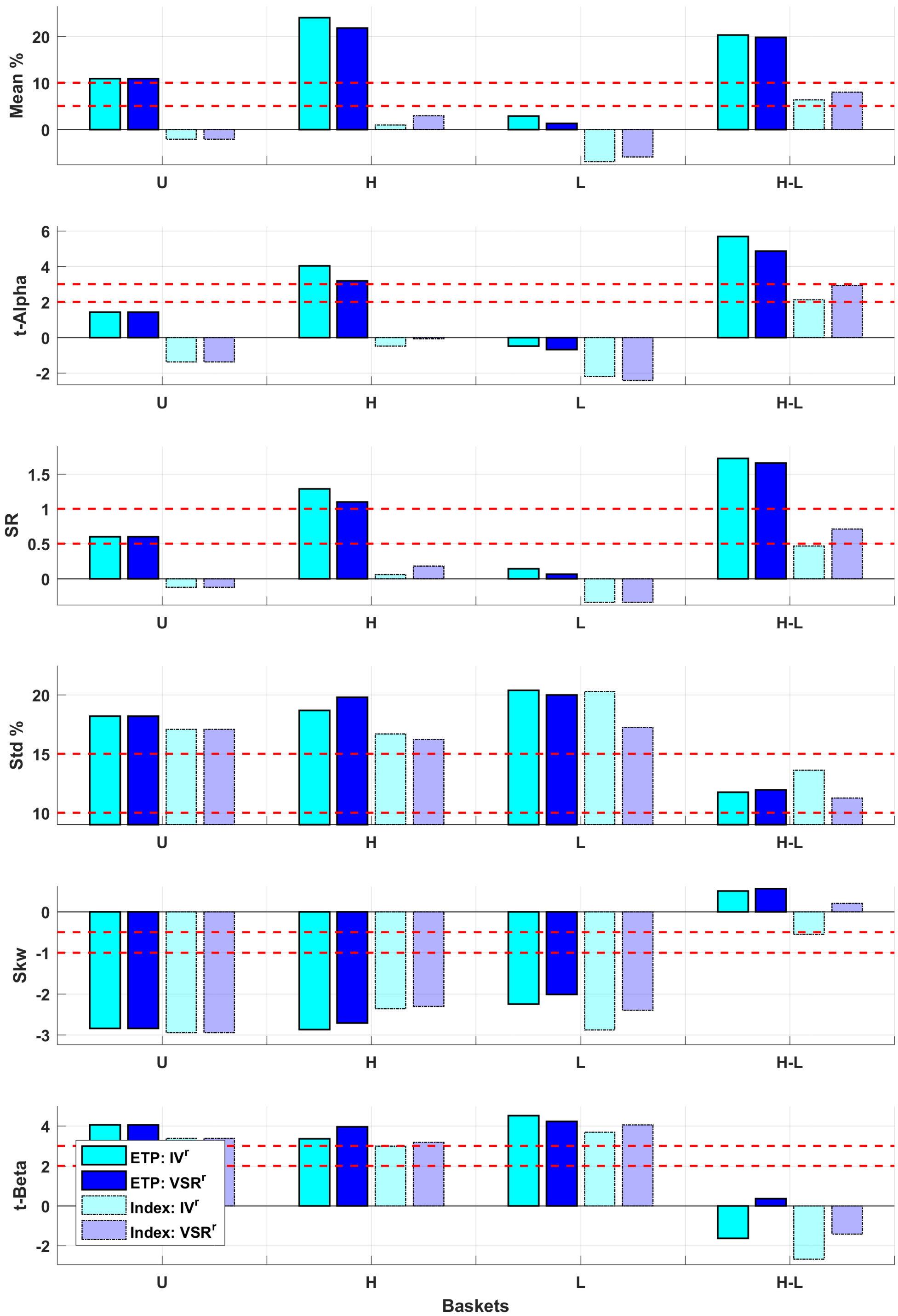

Figure 8

Cross-Section of International ETP and Index Option Returns.

This figure shows statistical performance metrics for the cross-sections of ETP and index option returns internationally. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) straddles portfolios. U, H and L straddle returns are presented as short positions. The conditional portfolios are sorted by previous day volatility returns. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

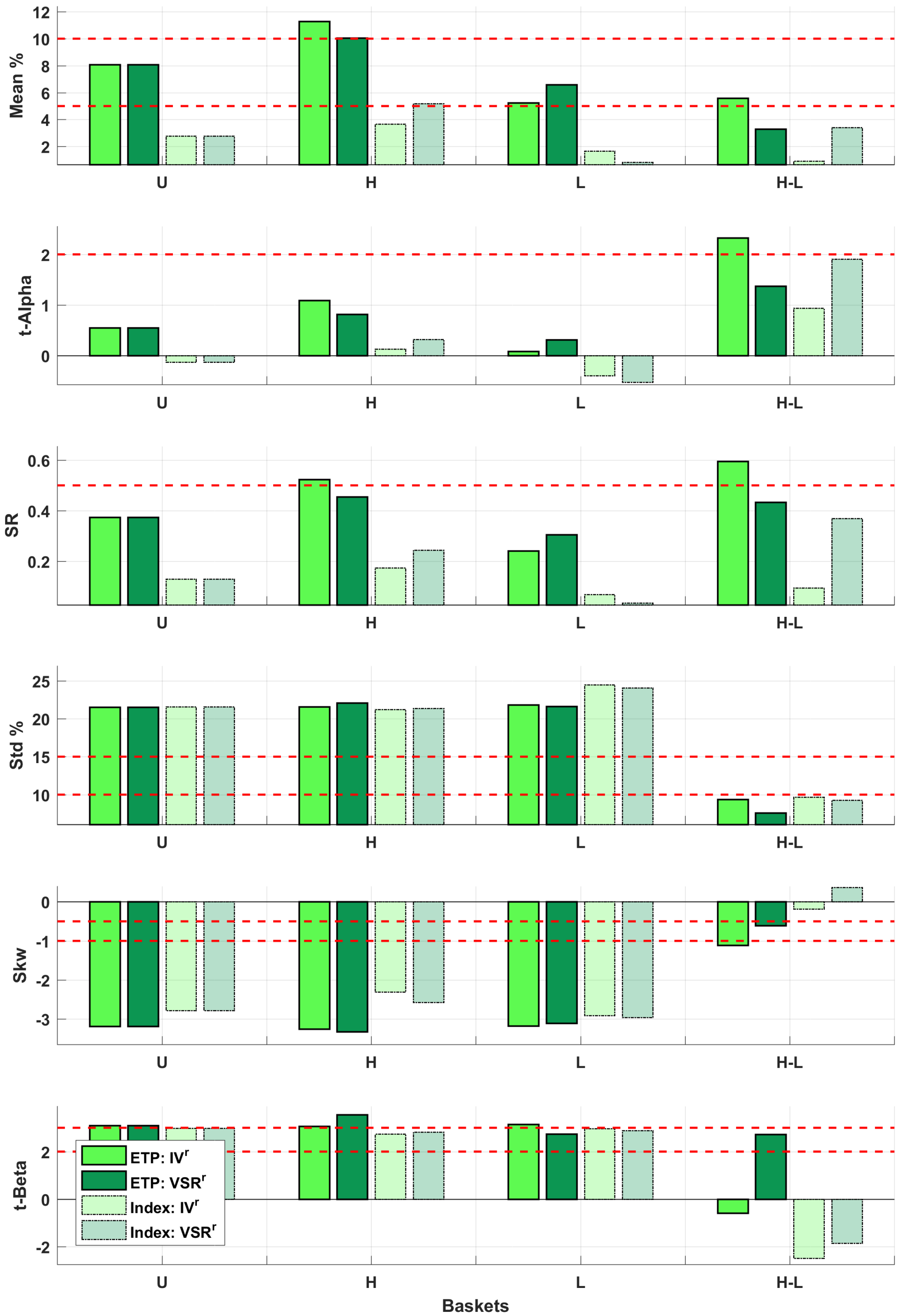

Figure 9

Cross-Section of Domestic ETP and Index Option Returns.

This figure shows statistical performance metrics for the cross-sections of ETP and index option returns domestically. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) straddles portfolios. U, H and L straddle returns are presented as short positions. The conditional portfolios are sorted by previous day volatility returns. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

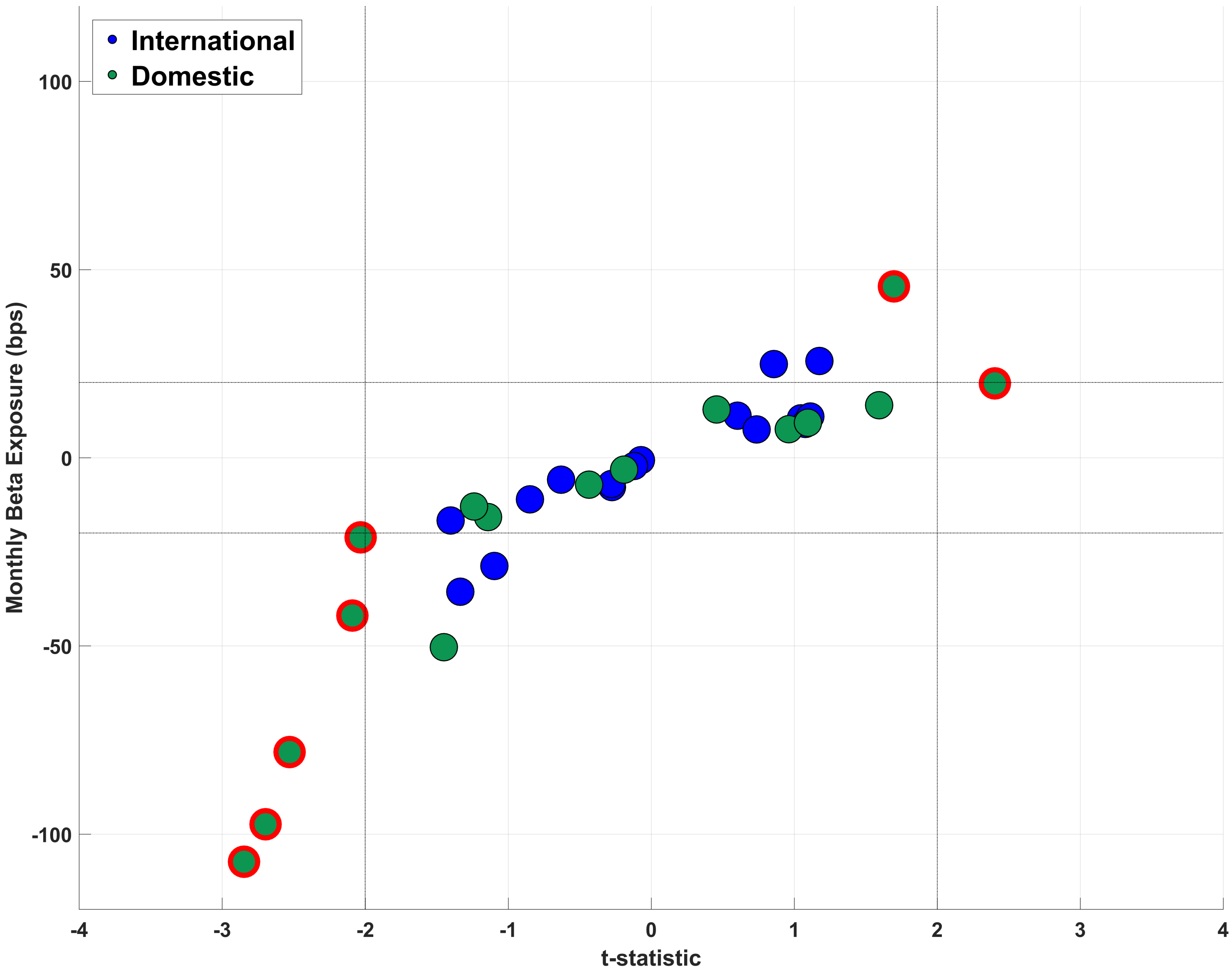

Figure 10

Volatility Hedge Funds' Exposures: International and Domestic.

This figure shows factor loadings of volatility hedge funds on international and domestic option strategies. The factor loadings are estimated by univariate time-series regressions of short volatility (SV) or relative value volatility (RV) funds index returns on a set of option strategies. The strategies considered are cross-sectional long-short option strategies among international and domestic derivatives, high dispersion trading strategies at the international and domestic level and cross-sectional long-short option strategies among ETP and index options in international and domestic markets. The x-axes represent the t-statistic of the estimation loading. The y-axes represent the monthly exposure in basis points for a one-standard-deviation increase in the explanatory variable. Red edges represent statistical significance at the 10% level with Newey and West (1987) standard errors (three lags). The sample period is January 2006 - December 2015.

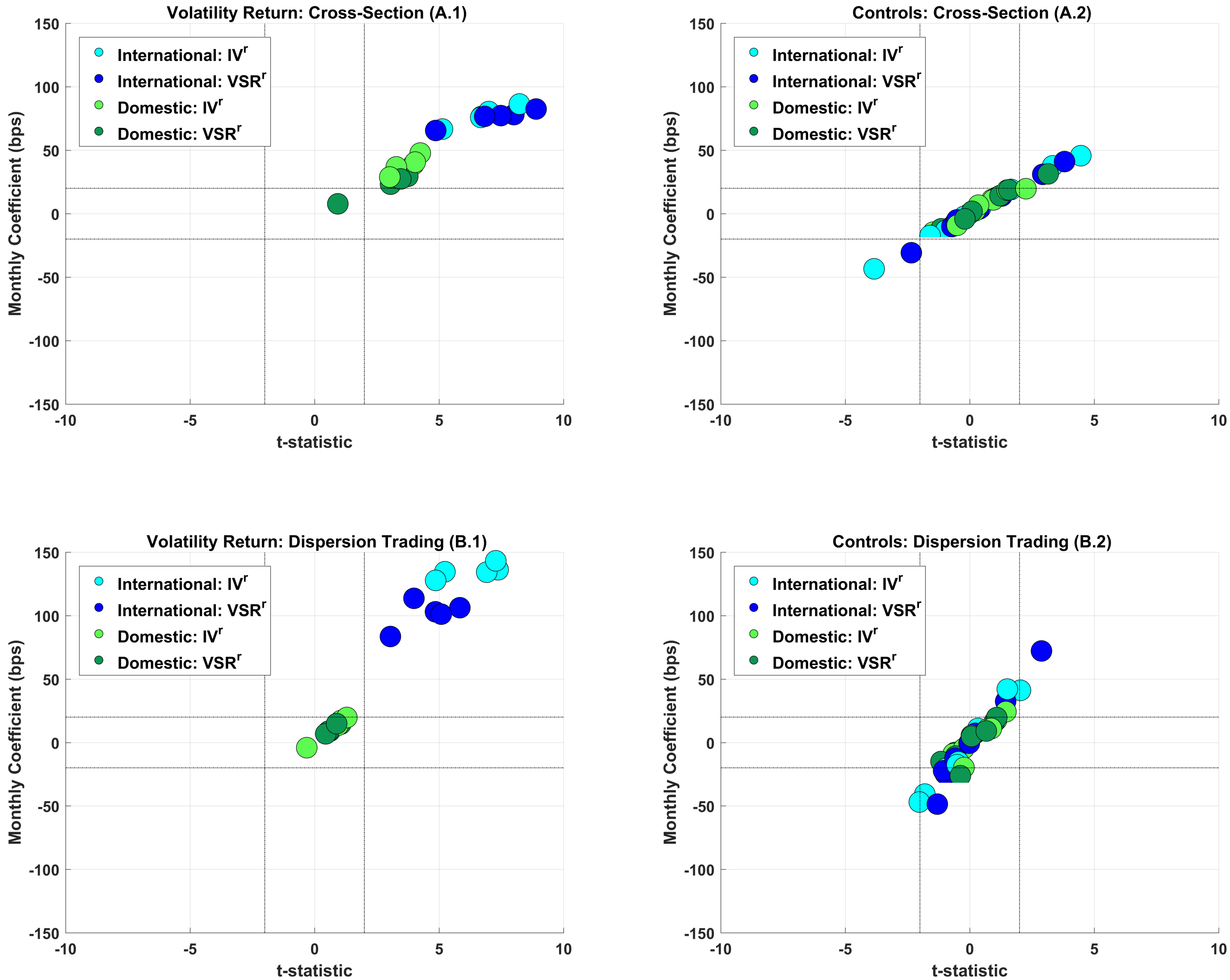

Figure 11

Fama-MacBeth Regressions of International and Domestic Option Returns.

This figure shows Fama and MacBeth (1973) regressions of international and domestic option returns. Each month, cross-sectional regressions of monthly option returns on portfolio formation volatility returns plus a set of control variables are estimated. The volatility return can be either model dependent (IV^r) or model-free (VSR^r) return. Panel (A.1) and (A.2) presents regression coefficients of international and domestic option returns cross-sections, for a detailed explanation see Table 10. While Panel (B.1) and (B.2) presents regression coefficients of dispersion trading option returns in international and domestic markets, for a detailed explanation see Table 11. Panel (A.1) and (B.1) shows the average coefficient of volatility returns as a function of their Newey and West (1987) t-statistic computed with three lags. While Panel (A.2) and (B.2) present the coefficients of the control variables as a function of their t-statistics. The color of control variables corresponds to the color of the corresponding main variable of interest. The sample period is January 2006 - December 2015.

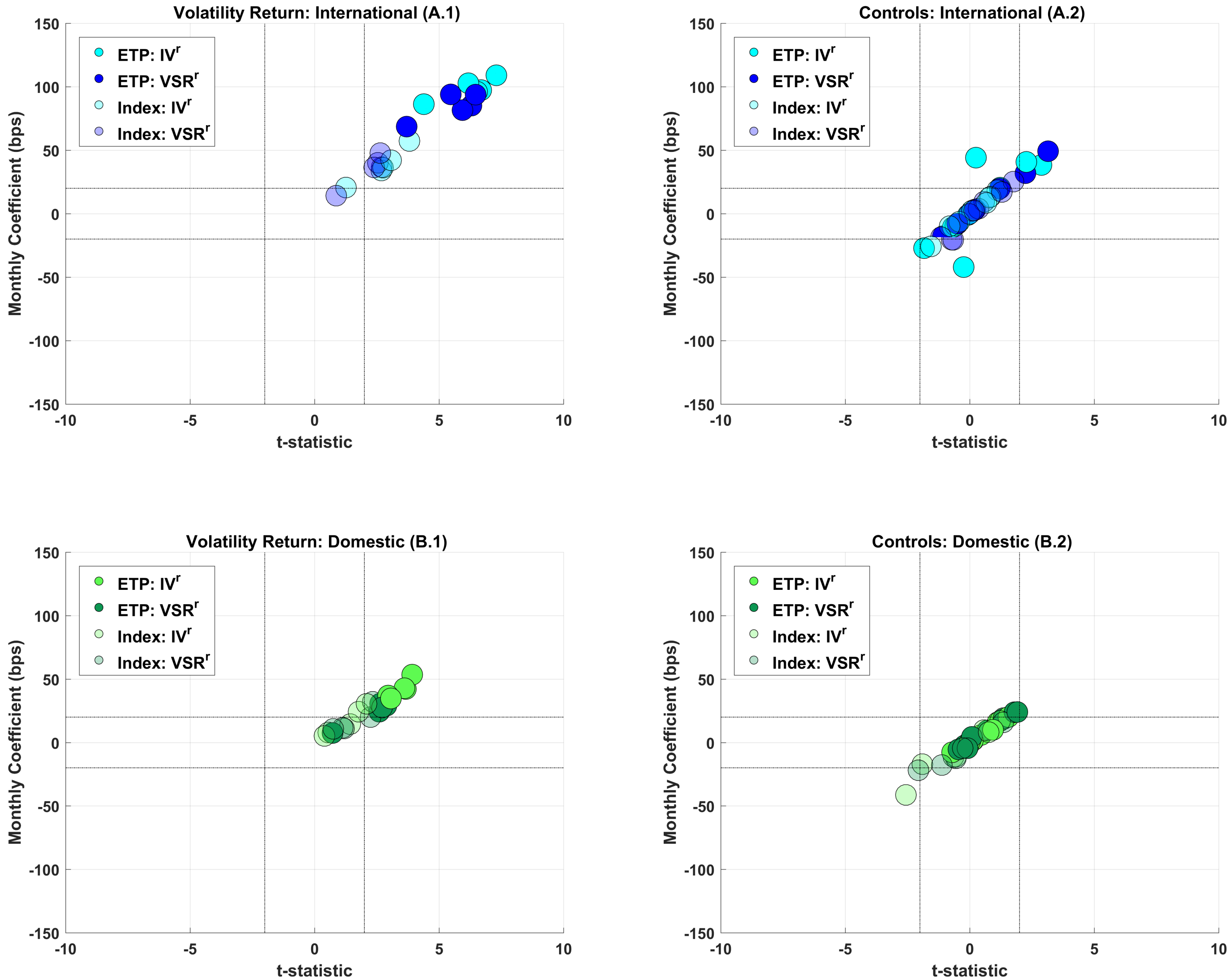

Figure 12

Fama-MacBeth Regressions of ETP and Index Option Returns.

This figure shows Fama and MacBeth (1973) regressions of ETP and index option returns cross-sections in international and domestic markets. Each month, cross-sectional regressions of monthly option returns on portfolio formation volatility returns plus a set of control variables are estimated. The volatility return can be either model dependent (IV^r) or model-free (VSR^r) return. Panel (A.1) and (A.2) presents regression coefficients of ETP and index option returns cross-sections at the international level, for a detailed explanation see Table 12. While Panel (B.1) and (B.2) presents regression coefficients of ETP and index option returns cross-sections at the domestic level, for a detailed explanation see Table 13. Panel (A.1) and (B.1) shows the coefficient of volatility returns as a function of their Newey and West (1987) t-statistic with three lags. While Panel (A.2) and (B.2) present the coefficients of the control variables as a function of their t-statistics. The color of control variables corresponds to the color of the corresponding main variable of interest. The sample period is January 2006 - December 2015.

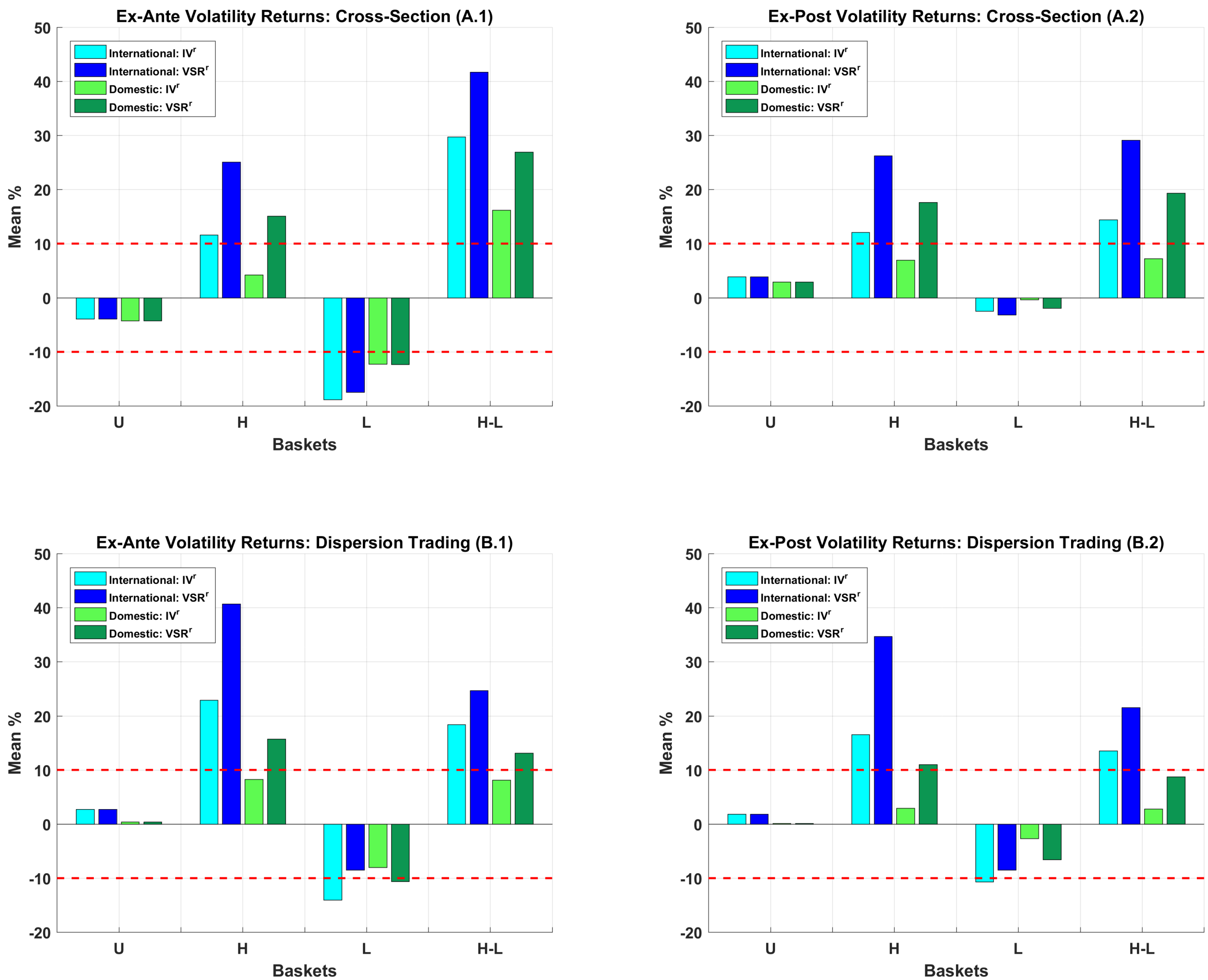

Figure 13

Ex-Ante and Ex-Post Volatility Returns of International and Domestic Portfolios.

This figure shows annualized average ex-ante and ex-post volatility returns for international and domestic option portfolios. Ex-ante (ex-post) volatility returns are constructed as one minus the ratio of previous year (ex-post) realized volatility to time t implied volatility or volatility swap rate. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t+\tau$. Panel A.1 (A.2) shows ex-ante (ex-post) volatility returns for international and domestic cross-sections. Panel B.1 (B.2) reports ex-ante (ex-post) volatility returns for international and domestic dispersion trading strategies. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) volatility return portfolios. The conditional portfolios are sorted by previous day volatility returns. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). The sample period is January 2006 - December 2015.

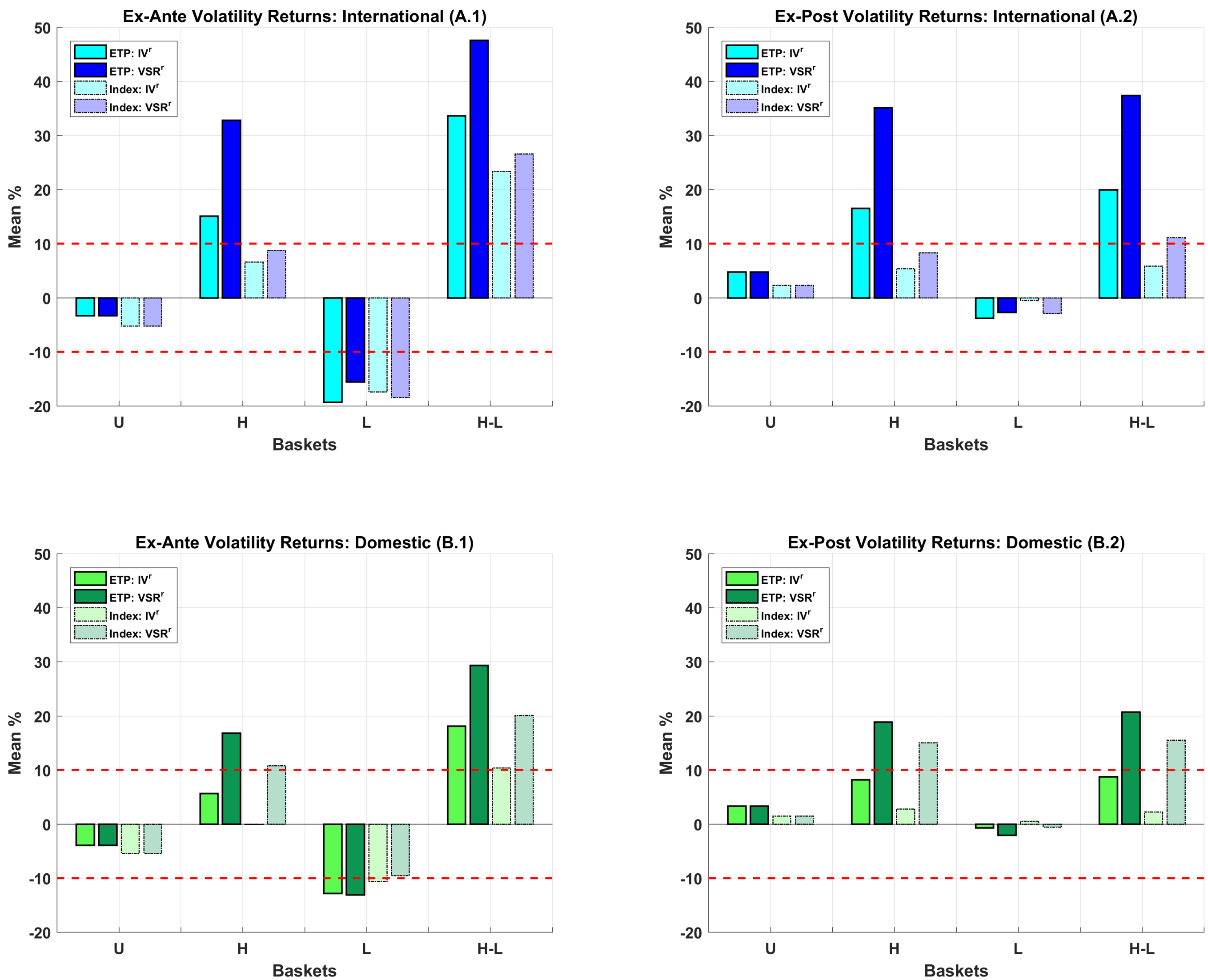

Figure 14

Ex-Ante and Ex-Post Volatility Returns of ETP and Index Portfolios.

This figure shows annualized average ex-ante and ex-post volatility returns for ETP and index option portfolios. Ex-ante (ex-post) volatility returns are constructed as one minus the ratio of previous year (ex-post) realized volatility to time t implied volatility or volatility swap rate. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t+\tau$. Panel A.1 (A.2) shows ex-ante (ex-post) volatility returns for ETP and index cross-sections, internationally. Panel B.1 (B.2) reports ex-ante (ex-post) volatility returns for ETP and index cross-sections, domestically. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) volatility returns portfolios. The conditional portfolios are sorted by previous day volatility returns. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). The sample period is January 2006 - December 2015.

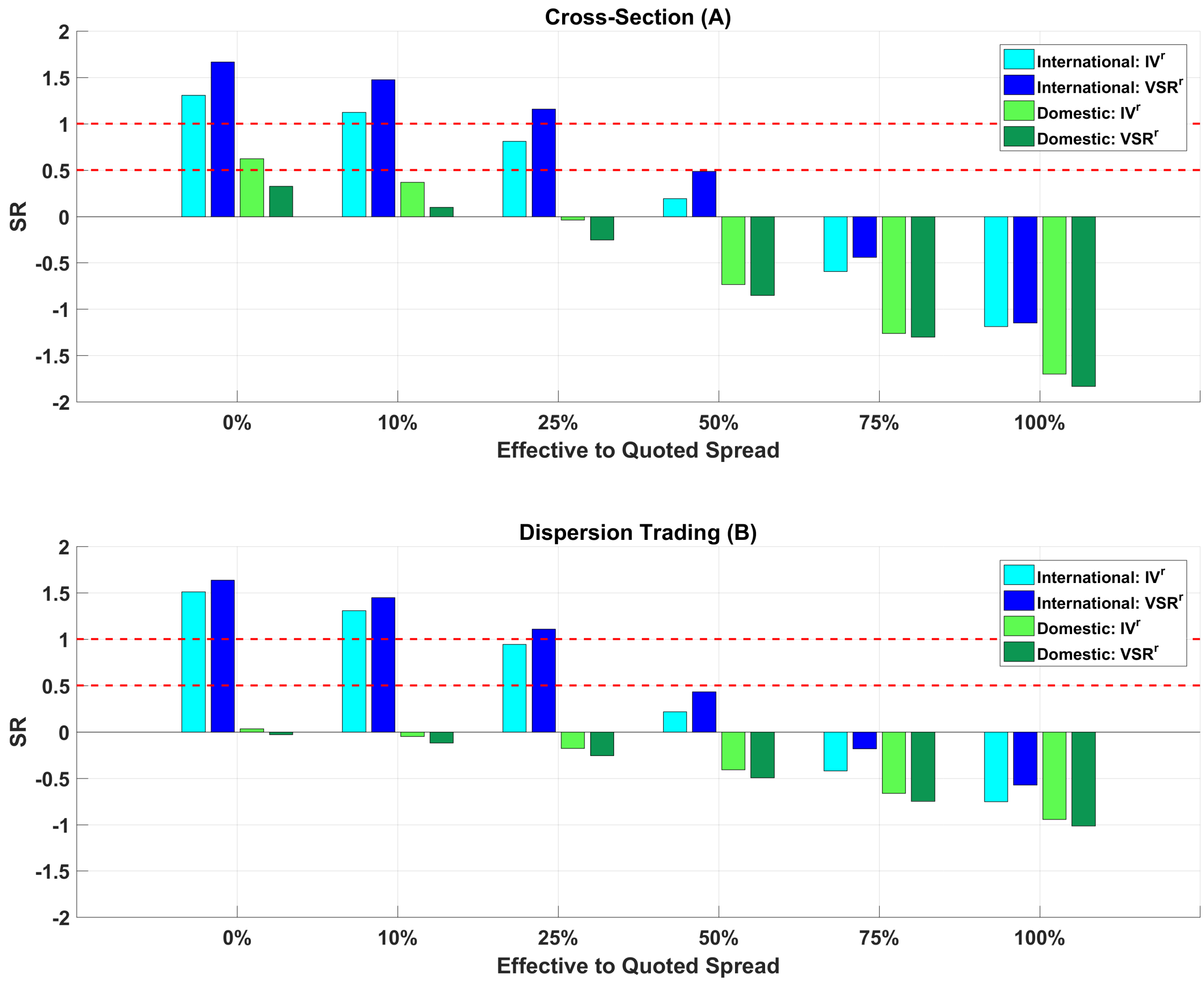

Figure 15

International and Domestic Option Strategies with Market Frictions.

This figure shows annualized Sharpe ratio (SR) of international and domestic option strategies. Option returns are computed by executing trades at x% of the effective to quoted bid-ask spread. Trades are executed on options with either positive volume or positive previous day open interest. The figure presents two types of option schemes, cross-sectional and dispersion trading strategies. Panel (A) shows international and domestic long-short option strategies in the cross-section. While Panel (B) shows international and domestic high dispersion trading option schemes. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). The sample period is January 2006 - December 2015.

Table 1

International and Domestic Option Strategies.

This table reports portfolio performance metrics for international and domestic option strategies. The sample period is January 2006 to December 2015. The table presents two types of option schemes, cross-sectional and dispersion trading strategies, and a set of benchmark indexes. Option returns are computed at mid-prices, denominated in US dollars, expressed in excess of US risk-free rate and held to maturity. The cross-sectional option schemes show portfolio performance metrics for the cross-sections of international and domestic option returns. The international (domestic) cross-section includes all ETP and index option products displayed in Table A.1 (A.2). Ex-ante volatility returns are the sorting variable. There are two types of sorts: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante (ex-post) volatility returns are constructed as one minus the ratio of previous year (ex-post) realized volatility to time t implied volatility or volatility swap rate. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t + \tau$. Each fourth Friday of the month, ATM straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). The unconditional (U) portfolio return is the equally weighted average of all the ATM straddles available at the moment of portfolio formation. The table includes high minus low (H-L) and unconditional (U) option portfolios. Unconditional portfolio is presented as short position. The dispersion trading option schemes show portfolio performance metrics for international and domestic dispersion trading option strategies. The international (domestic) dispersion trading pairs include ETP and index options displayed in Table A.3 Panel (A) ((B)). Each fourth Friday of the month, ETP and index dispersion pairs are ranked in descending order by previous day volatility returns difference. Then, they are assigned to one of three equally weighted tercile portfolios. Successively, ETP ATM straddles are sold and the corresponding index ATM straddles are bought. The high dispersion trading portfolio is the tercile among the ETP and index pairs with the largest ex-ante volatility return dispersion. The unconditional (U) dispersion trading portfolio is the equally weighted average of the ETP minus index straddles pairs available at the moment of portfolio formation. The table includes high (H) and unconditional (U) dispersion trading portfolios. Panel (A) presents annualized average return (μ), annualized Sharpe ratio (SR), annualized risk-adjusted return (α) and its t-statistic (t-α). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), skewness (Skw), CAPM-β with respect to CRSP value weighted index (β) and its t-statistic (t-β). Panel (C) presents option portfolio volatility returns: ex-ante volatility return (ex-ante Vol. Ret.), its t-statistic, ex-post volatility return (ex-post Vol. Ret.) and its t-statistic. Both of the volatility returns are annualized averages in percentage terms. Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation. Lastly, the benchmark indexes include: CRSP value weighted index, MSCI world index, a hedge fund short volatility (SV) index and a hedge fund relative volatility value (RV) index.

	Cross-Section						**Dispersion Trading**						**Benchmarks**			
	International			**Domestic**			**International**			**Domestic**						
Returns (A)	IV^r_{H-L}	VSR^r_{H-L}	U	IV^r_{H-L}	VSR^r_{H-L}	U	IV^r_H	VSR^r_H	U	IV^r_H	VSR^r_H	U	CRSP	MSCI	SV	RV
μ	16.38	18.52	5.39	5.04	3.64	6.76	24.97	26.23	12.59	1.98	1.48	2.94	5.83	3.93	7.79	9.04
SR	1.83	2.29	0.32	0.67	0.56	0.32	2.03	2.25	1.43	0.19	0.14	0.43	0.37	0.24	0.86	2.41
α	17.92	19.65	0.98	5.88	3.79	2.52	24.74	25.07	11.71	1.47	0.45	2.17	0.00	-2.07	5.46	8.47
t-α	6.49	7.29	0.23	2.86	1.98	0.39	7.00	7.19	4.99	0.45	0.12	0.94	0.76	-1.60	1.97	5.36
Risk (B)																
Std	8.93	8.10	16.97	7.56	6.54	21.41	12.32	11.68	8.78	10.67	10.93	6.83	15.69	16.70	9.07	3.76
Skw	0.60	0.37	-3.03	-0.25	-0.07	-3.12	-0.92	-0.48	-0.56	-1.10	-1.16	-0.54	-0.89	-1.00	-3.04	0.06
β	-0.16	-0.01	0.59	-0.08	0.05	0.65	0.07	0.10	0.18	-0.02	0.14	0.05	1.00	1.03	0.31	0.05
t-β	-3.41	-0.19	3.89	-1.45	1.28	3.07	0.99	1.89	3.57	-0.30	2.77	1.42		44.48	3.37	1.71
Volatility (C)																
ex-ante Vol. Ret.	29.74	41.70	-3.93	16.19	26.94	-4.27	22.89	40.70	2.74	8.25	15.70	0.38				
t-statistic	21.09	17.00	-1.08	15.02	16.84	-1.00	12.93	16.33	1.99	9.34	9.56	0.87				
ex-post Vol. Ret.	14.39	29.11	3.88	7.25	19.33	2.94	16.55	34.70	1.82	2.96	10.98	0.13				
t-statistic	13.88	13.84	1.63	9.37	19.08	1.02	8.03	13.26	1.21	3.32	10.59	0.27				

Table 2

Cross-Section of International and Domestic Option Returns.

This table reports portfolio performance metrics for the cross-sections of international and domestic option returns. The international (domestic) cross-section includes all ETP and index option products displayed in Table A.1 (A.2). The sample period is January 2006 to December 2015. Each fourth Friday of the month, ATM straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). Options are held to maturity. The volatility returns used for sorting are: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. The unconditional (U) portfolio return is the equally weighted average of all the ATM straddles available at the moment of portfolio formation. Option returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The table includes unconditional (U), high (H), low (L) and high minus low (H-L) option portfolios. Unconditional, high and low portfolio returns are presented as short positions. Panel (A) presents annualized average return (μ), its t-statistic (t-μ), annualized risk-adjusted return (α), its t-statistic (t-α) and annualized Sharpe ratios (SR). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), excess-kurtosis (Kur), maximum (Max) and minimum (Min) monthly returns in percentage and skewness (Skw). Panel (C) presents option portfolios market exposures: delta (Δ) and gamma (Γ) Greeks at the moment of portfolio formation, ex-post CAPM-β with respect to CRSP value weighted index (β), its t-statistic (t-β), and first order auto-correlation coefficient in percentage (ρ). Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation.

	International							**Domestic**						
		IV^r			VSR^r				IV^r			VSR^r		
Returns (A)	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
μ	5.39	15.76	-1.60	16.38	15.64	-3.50	18.52	6.76	9.95	4.43	5.04	8.75	4.78	3.64
t-μ	1.17	3.83	-0.31	5.82	3.54	-0.70	6.87	1.05	1.56	0.65	2.27	1.36	0.71	1.91
α	0.98	12.31	-6.89	17.92	11.71	-8.75	19.65	2.52	6.22	-0.21	5.88	4.41	0.29	3.79
t-α	0.23	3.07	-1.52	6.49	2.64	-1.91	7.29	0.39	0.94	-0.03	2.86	0.70	0.04	1.98
SR	0.32	1.04	-0.09	1.83	0.93	-0.19	2.29	0.32	0.47	0.20	0.67	0.41	0.22	0.56
Risk (B)														
Std	16.97	15.12	18.84	8.93	16.88	18.40	8.10	21.41	21.21	22.30	7.56	21.42	22.10	6.54
Kur	12.73	9.49	8.38	1.56	11.76	8.16	-0.00	12.96	13.48	13.39	0.99	12.37	13.65	0.89
Max	5.73	6.33	6.40	12.20	6.62	5.73	8.47	6.50	6.50	6.84	5.73	6.53	6.84	6.49
Min	-25.47	-20.43	-24.71	-5.96	-24.34	-23.67	-3.67	-30.89	-29.16	-32.67	-7.07	-29.71	-32.76	-5.94
Skw	-3.03	-2.71	-2.50	0.60	-2.98	-2.43	0.37	-3.12	-3.24	-3.13	-0.25	-3.10	-3.10	-0.07
Exposure (C)														
Δ	0.41	0.39	0.42	-0.03	0.37	0.42	-0.06	0.43	0.42	0.43	-0.00	0.41	0.44	-0.03
Γ	0.13	0.15	0.13	0.03	0.21	0.09	0.12	0.12	0.12	0.13	-0.01	0.15	0.11	0.05
β	0.59	0.46	0.66	-0.16	0.58	0.61	-0.01	0.65	0.61	0.70	-0.08	0.69	0.64	0.05
t-β	3.89	3.63	4.62	-3.41	3.86	4.18	-0.19	3.07	2.94	3.19	-1.45	3.47	2.83	1.28
ρ	-13.39	-11.86	-12.89	-3.40	-14.24	-11.17	7.80	-5.72	-5.06	-6.32	-10.33	-6.95	-3.86	0.62

Table 3

Alpha and Factor Exposures of Cross-Sectional Long-Short International and Domestic Option Portfolios.

This table reports time series regressions for international and domestic cross-sectional long-short option strategies. The dependent variable is an international or domestic long-short option portfolio sorted either by IV returns or VSR returns. The long-short option returns correspond to those in in Table 2 for the period 2006-2015. The independent variables span over the following factors models. Domestic (D) and international (I) equity factors models comprised of Fama and French (2015) five factors model in addition to Carhart (1997) momentum factor. These factors comprise market (MKT), size (SMB), value (HML), profitability (RMW), investment (CMA) and momentum (MOM). Both domestic and international equity factors models are from Kenneth French's website. Additional models comprise the following volatility factors. The corresponding unconditional (U) option portfolio return of the dependent variable. A hedge fund short volatility (SV) index comprised of 16 hedge funds which take net short positions in volatility related products. A hedge fund relative volatility value (RV) index comprised of 40 hedge funds which take long-short positions in volatility related products. Both of the volatility factors are from Bloomberg. While running regressions with volatility factors, domestic or international equity exposures are controlled, besides the market factor due to collinearity with the volatility factor. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the option portfolio return by β percentage points monthly. Alphas are expressed in percentage terms and annualized. Newey and West (1987) t-statistics computed with three lags are used to account for heteroskedasticity and autocorrelation. Adjusted R^2 is in percentage terms. N is the number of observations. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	International									
	IV^r_{H-L}					VSR^r_{H-L}				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
α	17.919***	17.105***	17.337***	16.362***	18.702***	19.646***	19.465***	19.860***	19.321***	19.594***
	(6.493)	(6.196)	(6.234)	(5.767)	(5.126)	(7.293)	(7.188)	(7.457)	(7.301)	(6.058)
MKT_D	-0.854***					-0.120				
	(-3.486)					(-0.455)				
SMB_D	-0.072					-0.335*				
	(-0.348)					(-1.676)				
HML_D	0.046					0.486**				
	(0.189)					(2.260)				
RMW_D	-0.547**					-0.423*				
	(-2.381)					(-1.768)				
CMA_D	0.103					-0.173				
	(0.443)					(-0.837)				
MOM_D	0.461***					0.512**				
	(2.667)					(2.472)				
MKT_I		-0.699**					-0.144			
		(-2.455)					(-0.617)			
SMB_I		-0.016	-0.084	0.025	0.020		-0.263	-0.306	-0.255	-0.254
		(-0.071)	(-0.403)	(0.115)	(0.088)		(-1.211)	(-1.446)	(-1.200)	(-1.200)
HML_I		0.160	-0.128	-0.160	-0.168		0.361	0.307	0.294	0.294
		(0.525)	(-0.538)	(-0.662)	(-0.738)		(1.486)	(1.359)	(1.311)	(1.308)
RMW_I		-0.266	-0.274	-0.133	-0.153		-0.559**	-0.596**	-0.532**	-0.533**
		(-1.021)	(-1.163)	(-0.486)	(-0.564)		(-2.257)	(-2.469)	(-2.241)	(-2.243)
CMA_I		-0.022	0.170	0.423*	0.491**		-0.151	-0.182	-0.060	-0.046
		(-0.065)	(0.714)	(1.680)	(2.026)		(-0.589)	(-0.842)	(-0.282)	(-0.207)
MOM_I		0.497**	0.526***	0.421**	0.378*		0.523**	0.551**	0.507**	0.501**
		(2.429)	(2.719)	(2.113)	(1.745)		(2.238)	(2.492)	(2.263)	(2.187)
U			-0.829***					-0.355*		
			(-3.175)					(-1.771)		
SV				-0.156					-0.035	
				(-0.544)					(-0.240)	
RV					-0.341					-0.047
					(-1.295)					(-0.264)
$\bar{R}^2$	7.655	6.015	11.791	2.664	4.116	1.340	3.732	5.648	3.560	3.582
N	119	119	119	119	119	119	119	119	119	119

	Domestic									
	IV^r_{H-L}					VSR^r_{H-L}				
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
α	5.878***	5.451**	5.493**	6.886***	7.280**	3.787**	3.944**	4.154**	4.984**	2.592
	(2.859)	(2.391)	(2.491)	(3.124)	(1.985)	(1.984)	(2.301)	(2.207)	(2.452)	(1.007)
MKT_D	-0.494*					0.052				
	(-1.770)					(0.259)				
SMB_D	0.044		-0.053	-0.004	-0.075	0.221		0.282	0.300	0.222
	(0.192)		(-0.227)	(-0.016)	(-0.332)	(1.042)		(1.291)	(1.429)	(1.030)
HML_D	0.691**		0.650**	0.476	0.600*	0.250		0.240	0.129	0.291
	(2.439)		(2.101)	(1.562)	(1.892)	(1.208)		(1.119)	(0.560)	(1.429)
RMW_D	0.113		0.234	0.169	0.244	0.026		-0.012	-0.048	0.018
	(0.570)		(1.080)	(0.833)	(1.067)	(0.110)		(-0.051)	(-0.226)	(0.082)
CMA_D	-0.045		-0.053	-0.067	-0.017	-0.111		-0.121	-0.128	-0.127
	(-0.212)		(-0.240)	(-0.345)	(-0.081)	(-0.576)		(-0.622)	(-0.709)	(-0.684)
MOM_D	0.225		0.273	0.173	0.200	0.039		0.036	-0.031	0.077
	(0.957)		(1.223)	(0.740)	(0.771)	(0.214)		(0.201)	(-0.160)	(0.413)
MKT_I		-0.690**					0.081			
		(-2.147)					(0.327)			
SMB_I		0.161					0.361**			
		(1.141)					(2.412)			
HML_I		1.101***					0.453*			
		(3.681)					(1.853)			
RMW_I		0.173					-0.033			
		(0.789)					(-0.165)			
CMA_I		-0.466					-0.087			
		(-1.429)					(-0.265)			
MOM_I		0.280					0.074			
		(1.153)					(0.340)			
U			-0.249					-0.246		
			(-0.802)					(-1.127)		
SV				-0.568**					-0.377*	
				(-2.228)					(-1.820)	
RV					-0.257					0.156
					(-0.906)					(1.016)
$\bar{R}^2$	3.769	10.063	1.471	6.475	1.549	-1.164	4.721	0.469	2.500	-0.541
N	119	119	119	119	119	119	119	119	119	119

Table 4

Dispersion Trading of International and Domestic Option Returns.

This table reports portfolio performance metrics for international and domestic dispersion trading option strategies. The international (domestic) dispersion trading pairs include ETP and index options displayed in Table A.3 Panel (A) ((B)). The sample period is January 2006 to December 2015. Each fourth Friday of the month, ETP and index dispersion pairs are ranked in descending order by previous day volatility returns difference, equation (2). Then, they are assigned to one of three equally weighted tercile portfolios. Successively, ETP ATM straddles are sold and the corresponding index ATM straddles are bought. Options are held to maturity. The high (low) dispersion trading portfolio is the tercile among the ETP and index pairs with the largest (smallest) ex-ante volatility return dispersion. The long-short dispersion trading portfolio is the difference between 50% of the high and 50% of the low dispersion tercile. The dispersion trading volatility returns used for sorting are: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. The unconditional (U) dispersion trading portfolio is the equally weighted average of the ETP minus index straddles pairs. Option returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The table includes unconditional (U), high (H), low (L) and high minus low (H-L) dispersion portfolios. Panel (A) presents annualized average return (μ), its t-statistic (t-μ), annualized risk-adjusted return (α), its t-statistic (t-α) and annualized Sharpe ratios (SR). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), excess-kurtosis (Kur), maximum (Max) and minimum (Min) monthly returns in percentage and skewness (Skw). Panel (C) presents option portfolios market exposures: delta (Δ) and gamma (Γ) Greeks at the moment of portfolio formation, ex-post CAPM-β with respect to CRSP value weighted index (β), its t-statistic (t-β), and first order auto-correlation coefficient in percentage (ρ). Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation.

	International							**Domestic**						
		IV^r			VSR^r				IV^r			VSR^r		
Returns (A)	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
μ	12.59	24.97	-5.39	14.73	26.23	2.50	11.48	2.94	1.98	2.72	-0.58	1.48	1.52	-0.08
t-μ	5.15	7.61	-1.32	5.92	7.97	0.61	4.54	1.23	0.59	0.79	-0.30	0.38	0.53	-0.05
α	11.71	24.74	-7.57	15.62	25.07	1.07	11.51	2.17	1.47	1.55	-0.27	0.45	1.09	-0.38
t-α	4.99	7.00	-1.95	6.08	7.19	0.25	4.06	0.94	0.45	0.47	-0.15	0.12	0.38	-0.23
SR	1.43	2.03	-0.37	1.75	2.25	0.18	1.35	0.43	0.19	0.26	-0.09	0.14	0.17	-0.01
Risk (B)														
Std	8.78	12.32	14.50	8.42	11.68	13.72	8.49	6.83	10.67	10.61	6.54	10.93	9.18	5.44
Kur	1.24	4.81	3.63	2.55	2.44	5.13	1.17	1.59	5.38	0.58	0.72	4.76	1.25	0.71
Max	8.26	12.86	9.16	9.48	12.86	9.16	8.44	5.37	9.56	8.46	5.10	9.41	9.46	3.38
Min	-7.14	-14.22	-17.26	-8.21	-11.89	-17.73	-7.05	-7.22	-13.69	-9.51	-5.83	-12.72	-7.93	-5.47
Skw	-0.56	-0.92	-1.37	-0.01	-0.48	-1.51	0.11	-0.54	-1.10	-0.20	-0.10	-1.16	0.05	-0.45
Exposure (C)														
Δ	-0.10	-0.12	-0.08	-0.02	-0.13	-0.07	-0.03	-0.06	-0.07	-0.07	-0.00	-0.08	-0.05	-0.01
Γ	0.25	0.27	0.24	0.02	0.31	0.20	0.05	0.18	0.20	0.20	-0.00	0.22	0.17	0.02
β	0.18	0.07	0.36	-0.14	0.10	0.27	-0.07	0.05	-0.02	0.13	-0.07	0.14	0.01	0.06
t-β	3.57	0.99	3.59	-3.19	1.89	1.86	-0.98	1.42	-0.30	1.94	-1.41	2.77	0.27	2.04
ρ	-13.73	-11.50	-5.80	-1.93	-14.77	-8.19	-7.73	10.24	-7.02	-2.29	-11.25	18.33	-5.23	2.00

Table 5

Alpha and Factor Exposures of Dispersion Trading International and Domestic Option Portfolios.

This table reports time series regressions for international and domestic high dispersion trading option strategies. The dependent variable is an international or domestic high dispersion trading option portfolio sorted either by IV returns or VSR returns. The high dispersion trading option returns correspond to those in Table 4 for the period 2006-2015. The independent variables span over the following factors models. Domestic (D) and international (I) equity factors models comprised of Fama and French (2015) five factors model in addition to Carhart (1997) momentum factor. These factors comprise market (MKT), size (SMB), value (HML), profitability (RMW), investment (CMA) and momentum (MOM). Both domestic and international equity factors models are from Kenneth French's website. Additional models comprise the following volatility factors. The corresponding unconditional (U) option portfolio return of the dependent variable. A hedge fund short volatility (SV) index comprised of 16 hedge funds which take net short positions in volatility related products. A hedge fund relative volatility value (RV) index comprised of 40 hedge funds which take long-short positions in volatility related products. Both of the volatility factors are from Bloomberg. While running regressions with volatility factors, domestic or international equity exposures are controlled, besides the market factor due to collinearity with the volatility factor. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the option portfolio return by β percentage points monthly. Alphas are expressed in percentage terms and annualized. Newey and West (1987) t-statistics computed with three lags are used to account for heteroskedasticity and autocorrelation. Adjusted R^2 is in percentage terms. N is the number of observations. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	International										Domestic									
	IV^r_H					VSR^r_H					IV^r_H					VSR^r_H				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
α	24.740***	24.725***	12.111***	25.070***	23.647***	25.072***	25.553***	15.184***	25.423***	24.767***	1.473	2.423	-1.281	0.707	-0.362	0.447	2.760	-1.960	0.038	-1.368
	(7.000)	(6.706)	(3.412)	(6.791)	(4.697)	(7.193)	(7.264)	(4.330)	(7.264)	(5.970)	(0.446)	(0.962)	(-0.551)	(0.211)	(-0.097)	(0.122)	(0.803)	(-0.978)	(0.010)	(-0.250)
MKT_D	0.406					0.692**					-0.019					0.577**				
	(1.047)					(2.162)					(-0.057)					(2.160)				
SMB_D	-0.671**					-0.424					0.204		-0.088	0.156	0.177	0.496		0.327*	0.595	0.633*
	(-2.044)					(-1.192)					(0.573)		(-0.446)	(0.424)	(0.515)	(1.297)		(1.723)	(1.642)	(1.771)
HML_D	-0.111					-0.238					0.255		0.619*	0.336	0.309	-0.419		0.042	-0.253	-0.308
	(-0.323)					(-0.711)					(0.572)		(1.889)	(0.981)	(0.682)	(-1.332)		(0.199)	(-0.802)	(-0.800)
RMW_D	-0.437					-0.070					0.610		0.618**	0.654	0.627	0.163		-0.004	0.057	0.010
	(-1.359)					(-0.184)					(1.472)		(2.319)	(1.635)	(1.532)	(0.356)		(-0.017)	(0.122)	(0.023)
CMA_D	0.170					0.333					-0.049		-0.295	-0.038	-0.071	-0.017		-0.309*	-0.002	-0.052
	(0.582)					(1.084)					(-0.152)		(-1.297)	(-0.115)	(-0.223)	(-0.058)		(-1.668)	(-0.008)	(-0.173)
MOM_D	-0.174					-0.154					-0.194		0.092	-0.149	-0.130	-0.167		0.113	-0.151	-0.132
	(-0.448)					(-0.507)					(-0.660)		(0.366)	(-0.503)	(-0.445)	(-0.599)		(0.602)	(-0.541)	(-0.459)
MKT_I		0.283					0.589					-0.459					0.384			
		(0.641)					(1.494)					(-1.083)					(1.088)			
SMB_I		-0.272	-0.310	-0.290	-0.283		-0.024	-0.087	-0.033	-0.059		0.163					0.250			
		(-0.917)	(-1.580)	(-0.970)	(-0.902)		(-0.083)	(-0.470)	(-0.110)	(-0.194)		(0.840)					(1.257)			
HML_I		0.073	-0.103	0.202	0.208		0.027	0.027	0.303	0.300		1.183**					-0.070			
		(0.150)	(-0.325)	(0.353)	(0.365)		(0.067)	(0.083)	(0.874)	(0.887)		(2.429)					(-0.174)			
RMW_I		0.007	0.147	-0.048	-0.033		-0.009	0.037	-0.094	-0.112		0.404					-0.411			
		(0.020)	(0.510)	(-0.132)	(-0.088)		(-0.028)	(0.133)	(-0.263)	(-0.301)		(1.014)					(-1.046)			
CMA_I		-0.070	0.421*	-0.255	-0.278		0.273	0.453	-0.018	-0.158		-0.890					-0.251			
		(-0.197)	(1.915)	(-0.809)	(-0.802)		(0.713)	(1.556)	(-0.060)	(-0.539)		(-1.601)					(-0.564)			
MOM_I		-0.190	-0.223	-0.159	-0.135		-0.180	-0.173	-0.114	-0.088		0.151					0.024			
		(-0.453)	(-0.776)	(-0.363)	(-0.291)		(-0.515)	(-0.552)	(-0.323)	(-0.242)		(0.527)					(0.074)			
U			2.374***					2.074***					2.171***					2.552***		
			(8.252)					(6.861)					(6.677)					(9.145)		
SV				0.052					0.330					0.248					0.406**	
				(0.190)					(1.447)					(0.773)					(2.137)	
RV					0.188					0.222					0.223					0.323
					(0.531)					(0.975)					(1.059)					(1.067)
$\bar{R}^2$	-1.394	-3.319	39.285	-3.617	-3.351	-0.983	-2.039	32.867	-2.726	-3.121	-2.679	3.329	48.017	-2.077	-2.164	1.817	2.050	66.289	1.004	0.498
N	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119

Table 6

Cross-Section of International ETP and Index Option Returns.

This table reports portfolio performance metrics for the cross-sections of ETP and index option returns internationally. The ETP (index) cross-section includes all ETP (index) option products displayed in Table A.1 Panel (A) ((B)). The sample period is January 2006 to December 2015. Each fourth Friday of the month, ATM straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). Options are held to maturity. The volatility returns used for sorting are: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. The unconditional (U) portfolio return is the equally weighted average of all the ATM straddles available at the moment of portfolio formation. Option returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The table includes unconditional (U), high (H), low (L) and high minus low (H-L) option portfolios. Unconditional, high and low portfolio returns are presented as short positions. Panel (A) presents annualized average return (μ), its t-statistic (t-μ), annualized risk-adjusted return (α), its t-statistic (t-α) and annualized Sharpe ratios (SR). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), excess-kurtosis (Kur), maximum (Max) and minimum (Min) monthly returns in percentage and skewness (Skw). Panel (C) presents option portfolios market exposures: delta (Δ) and gamma (Γ) Greeks at the moment of portfolio formation, ex-post CAPM-β with respect to CRSP value weighted index (β), its t-statistic (t-β), and first order auto-correlation coefficient in percentage (ρ). Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation.

	ETP							**Index**						
		IV^r			VSR^r				IV^r			VSR^r		
Returns (A)	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
μ	10.93	24.09	2.85	20.30	21.80	1.25	19.83	-2.15	1.00	-6.92	6.36	2.91	-5.91	8.01
t-μ	2.29	5.15	0.52	5.69	4.28	0.23	5.42	-0.45	0.22	-1.20	1.71	0.68	-1.21	2.44
α	6.34	19.98	-2.33	21.15	16.99	-3.53	19.69	-6.44	-2.15	-12.25	8.17	-0.24	-10.56	9.29
t-α	1.43	4.05	-0.48	5.69	3.20	-0.67	4.86	-1.37	-0.48	-2.20	2.14	-0.06	-2.42	2.93
SR	0.60	1.29	0.14	1.72	1.10	0.06	1.66	-0.13	0.06	-0.34	0.47	0.18	-0.34	0.71
Risk (B)														
Std	18.22	18.70	20.41	11.77	19.83	20.01	11.97	17.08	16.71	20.32	13.63	16.24	17.25	11.26
Kur	10.13	9.74	6.20	2.21	8.62	5.14	0.55	13.11	8.21	12.27	3.67	8.06	8.49	2.09
Max	6.19	7.03	6.90	15.84	7.02	7.03	12.53	5.63	6.17	6.24	15.51	6.39	5.80	14.67
Min	-24.39	-22.80	-22.94	-8.36	-24.39	-23.50	-5.06	-26.82	-22.59	-30.58	-15.55	-22.70	-23.47	-8.43
Skw	-2.84	-2.86	-2.24	0.51	-2.70	-2.01	0.57	-2.94	-2.36	-2.88	-0.54	-2.31	-2.40	0.21
Exposure (C)														
Δ	0.37	0.34	0.39	-0.05	0.32	0.41	-0.09	0.45	0.45	0.45	0.01	0.46	0.44	0.02
Γ	0.22	0.25	0.21	0.04	0.30	0.18	0.12	0.01	0.01	0.01	-0.00	0.01	0.01	-0.00
β	0.61	0.51	0.65	-0.11	0.61	0.59	0.03	0.56	0.44	0.69	-0.20	0.46	0.57	-0.09
t-β	4.07	3.36	4.54	-1.63	3.97	4.25	0.37	3.38	3.01	3.69	-2.66	3.19	4.06	-1.42
ρ	-15.64	-18.93	-11.38	-5.29	-16.46	-8.21	2.34	-10.95	-8.71	-10.88	-11.79	-13.60	-9.80	-8.81

Table 7
Alpha and Factor Exposures of Cross-Sectional Long-Short International ETP and Index Portfolios.

This table reports time series regressions for ETP and index cross-sectional long-short option strategies internationally. The dependent variable is an ETP or index long-short option portfolio sorted either by IV returns or VSR returns. The long-short option returns correspond to those in in Table 6 for the period 2006-2015. The independent variables span over the following factors models. Domestic (D) and international (I) equity factors models comprised of Fama and French (2015) five factors model in addition to Carhart (1997) momentum factor. These factors comprise market (MKT), size (SMB), value (HML), profitability (RMW), investment (CMA) and momentum (MOM). Both domestic and international equity factors models are from Kenneth French's website. Additional models comprise the following volatility factors. The corresponding unconditional (U) option portfolio return of the dependent variable. A hedge fund short volatility (SV) index comprised of 16 hedge funds which take net short positions in volatility related products. A hedge fund relative volatility value (RV) index comprised of 40 hedge funds which take long-short positions in volatility related products. Both of the volatility factors are from Bloomberg. While running regressions with volatility factors, domestic or international equity exposures are controlled, besides the market factor due to collinearity with the volatility factor. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the option portfolio return by β percentage points monthly. Alphas are expressed in percentage terms and annualized. Newey and West (1987) t-statistics computed with three lags are used to account for heteroskedasticity and autocorrelation. Adjusted R^2 is in percentage terms. N is the number of observations. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	ETP										Index									
	IV^r_{H-L}					VSR^r_{H-L}					IV^r_{H-L}					VSR^r_{H-L}				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
α	21.154***	20.176***	20.748***	18.856***	22.212***	19.690***	19.026***	19.718***	17.828***	17.159***	8.167**	7.866**	5.625	6.738*	7.122	9.292***	8.071**	7.068**	6.375*	3.604
	(5.691)	(5.271)	(4.886)	(4.887)	(3.667)	(4.861)	(4.632)	(4.778)	(4.298)	(3.409)	(2.141)	(2.084)	(1.642)	(1.692)	(1.542)	(2.933)	(2.341)	(2.178)	(1.852)	(0.789)
MKT_D	-0.549					0.292					-1.046**					-0.410				
	(-1.340)					(0.605)					(-2.473)					(-1.087)				
SMB_D	-0.239					-0.675*					-0.070					0.032				
	(-0.781)					(-1.946)					(-0.167)					(0.080)				
HML_D	0.121					0.377					0.111					0.725**				
	(0.411)					(1.067)					(0.287)					(2.114)				
RMW_D	-0.311					-0.058					-0.277					0.047				
	(-1.021)					(-0.155)					(-0.732)					(0.137)				
CMA_D	0.185					0.065					-0.247					-0.310				
	(0.560)					(0.188)					(-0.882)					(-0.984)				
MOM_D	0.210					-0.062					0.249					0.889**				
	(0.675)					(-0.167)					(0.543)					(2.035)				
MKT_I		-0.366					0.314					-1.255***					-0.531			
		(-0.815)					(0.620)					(-2.755)					(-1.311)			
SMB_I		-0.047	-0.087	0.006	-0.038		-0.305	-0.338	-0.272	-0.312		-0.318	-0.311	-0.252	-0.223		-0.203	-0.164	-0.134	-0.128
		(-0.176)	(-0.342)	(0.023)	(-0.140)		(-1.034)	(-1.173)	(-0.953)	(-1.087)		(-0.965)	(-0.942)	(-0.756)	(-0.662)		(-0.698)	(-0.565)	(-0.468)	(-0.446)
HML_I		0.065	-0.094	-0.095	-0.113		0.175	0.317	0.332	0.328		0.294	-0.229	-0.282	-0.279		0.703*	0.466	0.469	0.479
		(0.177)	(-0.241)	(-0.230)	(-0.291)		(0.446)	(0.899)	(0.903)	(0.920)		(0.716)	(-0.571)	(-0.698)	(-0.692)		(1.655)	(1.046)	(1.059)	(1.123)
RMW_I		-0.109	-0.121	-0.007	-0.067		-0.078	-0.154	-0.083	-0.113		-0.226	-0.058	0.005	0.027		0.002	0.111	0.143	0.167
		(-0.290)	(-0.343)	(-0.018)	(-0.186)		(-0.192)	(-0.405)	(-0.221)	(-0.295)		(-0.494)	(-0.141)	(0.012)	(0.059)		(0.005)	(0.361)	(0.472)	(0.547)
CMA_I		0.270	0.379	0.605*	0.540		0.353	0.113	0.322	0.122		-0.472	0.176	0.303	0.444		-0.321	0.047	0.141	0.063
		(0.675)	(1.008)	(1.879)	(1.549)		(0.766)	(0.287)	(0.787)	(0.343)		(-1.190)	(0.539)	(0.673)	(1.116)		(-0.724)	(0.120)	(0.334)	(0.154)
MOM_I		0.248	0.244	0.211	0.168		-0.112	-0.076	-0.074	-0.041		0.168	0.147	0.031	0.009		0.686	0.638	0.631	0.681
		(0.717)	(0.658)	(0.584)	(0.457)		(-0.244)	(-0.167)	(-0.163)	(-0.092)		(0.365)	(0.343)	(0.066)	(0.019)		(1.406)	(1.326)	(1.300)	(1.375)
U			-0.441					-0.032					-0.738					-0.053		
			(-0.895)					(-0.082)					(-1.457)					(-0.182)		
SV				0.164					0.474					-0.334					0.180	
				(0.602)					(1.205)					(-0.621)					(0.728)	
RV					-0.318					0.287					-0.192					0.401
					(-0.777)					(0.909)					(-0.589)					(1.233)
$\bar{R}^2$	-1.519	-1.377	-0.415	-1.755	-1.069	-1.290	-1.642	-2.046	-0.421	-1.356	1.950	1.832	0.082	-2.616	-3.000	1.824	0.996	-0.311	-0.071	1.210
N	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119

Table 8

Cross-Section of Domestic ETP and Index Option Returns.

This table reports portfolio performance metrics for the cross-sections of ETP and index option returns domestically. The ETP (index) cross-section includes all ETP (index) option products displayed in Table A.2 Panel (A) ((B)). The sample period is January 2006 to December 2015. Each fourth Friday of the month, ATM straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). Options are held to maturity. The volatility returns used for sorting are: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. The unconditional (U) portfolio return is the equally weighted average of all the ATM straddles available at the moment of portfolio formation. Option returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The table includes unconditional (U), high (H), low (L) and high minus low (H-L) option portfolios. Unconditional, high and low portfolio returns are presented as short positions. Panel (A) presents annualized average return (μ), its t-statistic (t-μ), annualized risk-adjusted return (α), its t-statistic (t-α) and annualized Sharpe ratios (SR). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), excess-kurtosis (Kur), maximum (Max) and minimum (Min) monthly returns in percentage and skewness (Skw). Panel (C) presents option portfolios market exposures: delta (Δ) and gamma (Γ) Greeks at the moment of portfolio formation, ex-post CAPM-β with respect to CRSP value weighted index (β), its t-statistic (t-β), and first order auto-correlation coefficient in percentage (ρ). Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation.

	ETP							**Index**						
		IV^r			VSR^r				IV^r			VSR^r		
Returns (A)	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
μ	8.07	11.29	5.25	5.59	10.05	6.58	3.29	2.79	3.68	1.65	0.92	5.20	0.82	3.42
t-μ	1.23	1.74	0.78	1.99	1.50	0.98	1.44	0.44	0.59	0.23	0.37	0.81	0.12	1.33
α	3.62	7.34	0.53	6.29	5.38	2.15	3.12	-0.85	0.84	-2.81	2.31	2.16	-3.63	4.62
t-α	0.55	1.09	0.08	2.32	0.81	0.31	1.37	-0.13	0.13	-0.40	0.94	0.32	-0.52	1.90
SR	0.37	0.52	0.24	0.60	0.45	0.30	0.43	0.13	0.17	0.07	0.09	0.24	0.03	0.37
Risk (B)														
Std	21.55	21.59	21.85	9.39	22.09	21.61	7.59	21.57	21.24	24.49	9.69	21.36	24.07	9.26
Kur	13.45	13.32	14.13	5.28	14.04	14.06	1.26	10.62	7.57	11.78	1.12	9.22	12.51	1.64
Max	6.61	6.60	6.78	6.47	6.58	6.78	5.51	6.22	7.00	6.99	8.47	7.00	6.99	9.53
Min	-31.30	-28.56	-32.45	-12.69	-31.43	-32.39	-7.71	-29.68	-26.70	-34.39	-8.63	-26.69	-34.54	-7.65
Skw	-3.19	-3.25	-3.18	-1.11	-3.32	-3.10	-0.61	-2.78	-2.30	-2.91	-0.19	-2.57	-2.96	0.36
Exposure (C)														
Δ	0.42	0.41	0.42	-0.01	0.40	0.43	-0.03	0.45	0.45	0.45	0.00	0.45	0.45	0.00
Γ	0.15	0.15	0.16	-0.01	0.18	0.13	0.05	0.03	0.03	0.03	0.00	0.04	0.02	0.01
β	0.66	0.63	0.69	-0.05	0.73	0.62	0.11	0.61	0.53	0.71	-0.14	0.55	0.69	-0.11
t-β	3.10	3.06	3.15	-0.58	3.55	2.74	2.72	2.99	2.74	2.97	-2.48	2.82	2.88	-1.84
ρ	-5.36	-4.51	-5.47	-8.62	-6.55	-3.30	-0.11	-6.12	-6.63	-9.42	-4.64	-6.04	-7.17	2.30

Table 9

Alpha and Factor Exposures of Cross-Sectional Long-Short Domestic ETP and Index Portfolios.

This table reports time series regressions for ETP and index cross-sectional long-short option strategies domestically. The dependent variable is an ETP or index long-short option portfolio sorted either by IV returns or VSR returns. The long-short option returns correspond to those in in Table 8 for the period 2006-2015. The independent variables span over the following factors models. Domestic (D) and international (I) equity factors models comprised of Fama and French (2015) five factors model in addition to Carhart (1997) momentum factor. These factors comprise market (MKT), size (SMB), value (HML), profitability (RMW), investment (CMA) and momentum (MOM). Both domestic and international equity factors models are from Kenneth French's website. Additional models comprise the following volatility factors. The corresponding unconditional (U) option portfolio return of the dependent variable. A hedge fund short volatility (SV) index comprised of 16 hedge funds which take net short positions in volatility related products. A hedge fund relative volatility value (RV) index comprised of 40 hedge funds which take long-short positions in volatility related products. Both of the volatility factors are from Bloomberg. While running regressions with volatility factors, domestic or international equity exposures are controlled, besides the market factor due to collinearity with the volatility factor. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the option portfolio return by β percentage points monthly. Alphas are expressed in percentage terms and annualized. Newey and West (1987) t-statistics computed with three lags are used to account for heteroskedasticity and autocorrelation. Adjusted R^2 is in percentage terms. N is the number of observations. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	ETP										**Index**									
	IV^r_{H-L}					VSR^r_{H-L}					IV^r_{H-L}					VSR^r_{H-L}				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
α	6.290**	5.449*	5.826**	6.927**	6.444	3.117	3.249	3.721	3.923*	0.345	2.310	2.118	1.618	4.346**	5.419	4.615*	3.978*	3.824	6.932***	6.075*
	(2.323)	(1.735)	(2.030)	(2.340)	(1.254)	(1.374)	(1.566)	(1.625)	(1.688)	(0.122)	(0.935)	(0.925)	(0.635)	(2.068)	(1.558)	(1.904)	(1.750)	(1.490)	(3.196)	(1.714)
MKT_D	-0.342					0.398*					-0.771**					-0.838***				
	(-0.828)					(1.784)					(-2.573)					(-2.669)				
SMB_D	0.138		0.041	0.102	0.047	0.150		0.272	0.279	0.227	-0.418		-0.533	-0.466	-0.593*	0.185		0.049	0.139	-0.027
	(0.547)		(0.166)	(0.448)	(0.206)	(0.584)		(1.000)	(1.048)	(0.883)	(-1.236)		(-1.644)	(-1.435)	(-1.730)	(0.564)		(0.161)	(0.451)	(-0.080)
HML_D	0.999**		0.979**	0.857*	0.961**	0.262		0.282	0.256	0.384	0.199		0.133	-0.187	0.031	0.263		0.193	-0.169	0.137
	(2.392)		(2.270)	(1.860)	(2.106)	(0.958)		(1.011)	(0.889)	(1.440)	(0.515)		(0.297)	(-0.557)	(0.067)	(0.793)		(0.537)	(-0.464)	(0.356)
RMW_D	0.305		0.404	0.347	0.400	0.021		-0.098	-0.108	-0.074	-0.503		-0.343	-0.439	-0.304	-0.337		-0.156	-0.272	-0.108
	(1.222)		(1.407)	(1.237)	(1.338)	(0.076)		(-0.354)	(-0.394)	(-0.289)	(-1.580)		(-1.088)	(-1.520)	(-0.943)	(-1.390)		(-0.596)	(-1.317)	(-0.397)
CMA_D	-0.087		-0.085	-0.101	-0.077	-0.133		-0.136	-0.138	-0.176	0.091		0.062	0.050	0.147	0.184		0.155	0.137	0.220
	(-0.315)		(-0.300)	(-0.378)	(-0.293)	(-0.569)		(-0.571)	(-0.589)	(-0.792)	(0.369)		(0.251)	(0.202)	(0.588)	(0.817)		(0.672)	(0.629)	(0.957)
MOM_D	0.422		0.454	0.390	0.432	0.135		0.098	0.083	0.211	0.056		0.152	-0.051	-0.015	0.046		0.147	-0.076	0.034
	(1.274)		(1.508)	(1.160)	(1.144)	(0.627)		(0.415)	(0.349)	(0.947)	(0.195)		(0.501)	(-0.174)	(-0.048)	(0.160)		(0.568)	(-0.269)	(0.112)
MKT_I		-0.526					0.485*					-0.998***					-0.661*			
		(-1.141)					(1.684)					(-2.784)					(-1.739)			
SMB_I		0.209					0.417**					0.032					0.249			
		(1.273)					(2.464)					(0.171)					(1.495)			
HML_I		1.545***					0.430					0.545					0.337			
		(3.880)					(1.449)					(1.422)					(0.875)			
RMW_I		0.348					-0.003					-0.149					-0.166			
		(1.127)					(-0.012)					(-0.543)					(-0.611)			
CMA_I		-0.561					-0.056					-0.321					0.218			
		(-1.369)					(-0.149)					(-1.038)					(0.704)			
MOM_I		0.520*					0.162					0.151					0.004			
		(1.787)					(0.633)					(0.535)					(0.017)			
U			-0.006					-0.038					-0.629***					-0.619*		
			(-0.013)					(-0.151)					(-2.830)					(-1.884)		
SV				-0.372					-0.085					-1.042***					-1.167***	
				(-1.094)					(-0.468)					(-5.151)					(-4.654)	
RV					-0.077					0.410**					-0.516*					-0.323
					(-0.186)					(2.564)					(-1.826)					(-1.161)
$\bar{R}^2$	3.350	12.249	2.234	3.993	2.314	1.823	9.404	-0.466	-0.354	2.966	4.451	3.523	4.143	12.046	2.474	2.928	4.564	1.358	13.783	-2.521
N	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119

Table 10

Fama-MacBeth Regressions: Cross-Section of International and Domestic Option Returns.

This table reports Fama and MacBeth (1973) regressions on international and domestic option returns cross-sections. International products are reported in Table A.1, while domestic products are reported in Table A.2. Each month cross-sectional regressions of monthly option returns on portfolio construction volatility returns plus a set of control variables are estimated.

$$r_{i,t+\tau}^{\text{Short,USD}} = \lambda_{1,t} \cdot \text{Volatility Return}_{i,t} + \Lambda_t' \mathbf{Z}_{i,t} + \varepsilon_{i,t+\tau} \qquad (7)$$

where $r_{i,t+\tau}^{\text{Short,USD}}$ is the option straddle return on the product i at expiration day $t+\tau$. Volatility $\text{Return}_{i,t}$ is the product i ex-ante volatility return at portfolio construction. The volatility returns can be either model dependent (IV) or model-free (VSR) return. $\lambda_{1,t}$ is the volatility return coefficient. $\mathbf{Z}_{i,t}$ is a vector of control characteristics for product i at time t. The controls considered are the following. Underlying asset's skewness (Skw) and kurtosis (Kur) estimated from previous year daily data. Underlying asset's momentum (MOM) estimated as the cumulative return over the last twelve months by skipping the most recent month. Market beta (Beta) and coskewness beta (CoSkw) which are estimated by an univariate regression of the underlying returns on previous year market index daily returns and squared returns, respectively. The market index is either MSCI or CRSP index depending if the option underlying is an international or domestic security. Additional control variables include: absolute delta (Delta), dollar volume (Dollar Volume), dollar open interest (Dollar OI) and bid-ask spread (BAS) average between call and put options used to construct the straddle. Λ_t is a column vector of control coefficients. Monthly cross-sectional regressions have both the dependent and independent variables demeaned. The independent variables are also standardized to unit variance. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the next month option returns by β percentage points. The time-series average of the estimated coefficients are reported in percentage. Newey and West (1987) t-statistics with three lags are reported in brackets. Adjusted R^2 is in percentage terms and it is the average over time of the adjusted R^2 in each cross-sectional regression. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	International										Domestic									
	IV^r					VSR^r					IV^r					VSR^r				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Volatility Return	0.765***	0.804***	0.759***	0.864***	0.666***	0.780***	0.772***	0.766***	0.824***	0.655***	0.388***	0.477***	0.406***	0.368***	0.288***	0.232***	0.294***	0.283***	0.274***	0.077
	(6.697)	(6.999)	(6.675)	(8.229)	(5.136)	(8.005)	(7.483)	(6.831)	(8.897)	(4.866)	(3.977)	(4.246)	(4.041)	(3.283)	(3.020)	(3.053)	(3.742)	(3.142)	(3.462)	(0.934)
Skw		0.044					0.037					0.111					0.126			
		(0.433)					(0.378)					(0.892)					(1.054)			
Kur		0.191*					0.139					0.023					-0.005			
		(1.662)					(1.291)					(0.215)					(-0.047)			
Delta			-0.434***					-0.308**					-0.146					-0.119		
			(-3.840)					(-2.346)					(-1.464)					(-1.144)		
Beta			0.376***					0.310***					0.109					0.142		
			(3.331)					(2.932)					(0.946)					(1.218)		
CoSkw				-0.133					-0.101					0.186					0.188	
				(-0.959)					(-0.721)					(1.507)					(1.564)	
MOM				-0.045					-0.016					-0.003					-0.033	
				(-0.363)					(-0.137)					(-0.031)					(-0.301)	
Dollar Volume					-0.172					-0.063					-0.092					0.018
					(-1.593)					(-0.554)					(-0.507)					(0.092)
Dollar OI					-0.022					-0.049					0.067					-0.041
					(-0.226)					(-0.517)					(0.351)					(-0.194)
BAS					0.457***					0.410***					0.197**					0.314***
					(4.461)					(3.808)					(2.258)					(3.150)
$\bar{R}^2$	6.033	8.446	13.286	11.035	11.138	6.733	9.016	13.038	11.879	10.658	7.933	18.765	18.639	20.379	7.640	5.285	15.108	15.660	17.933	5.717
N	4301	4301	4301	4301	4301	4301	4301	4301	4301	4301	5099	5099	5099	5099	5099	5099	5099	5099	5099	5099

Table 11

Fama-MacBeth Regressions: Dispersion Trading of International and Domestic Option Returns.

This table reports Fama and MacBeth (1973) regressions on international and domestic dispersion trading option returns. Dispersion pairs are reported in Table A.3. Each month cross-sectional regressions of monthly dispersion trading option returns on portfolio construction dispersion trading volatility returns plus a set of control variables are estimated.

$$r_{i,t+\tau}^{\text{Dispersion,USD}} = \lambda_{1,t} \cdot \text{Volatility Return}_{i,t}^{\text{Dispersion}} + \Lambda_t' \mathbf{Z}_{i,t} + \varepsilon_{i,t+\tau}$$

where $r_{i,t+\tau}^{\text{Dispersion,USD}}$ is the dispersion trading option returns on the i ETP product minus the corresponding index option return at expiration day $t+\tau$. Volatility Return$_{i,t}^{\text{Dispersion}}$ is the dispersion trading volatility return at portfolio formation which can be either model dependent (IV) or model-free (VSR) return. $\lambda_{1,t}$ is the volatility return coefficient. $\mathbf{Z}_{i,t}$ is a vector of control characteristics for product i at time t. All the control variables are the difference between ETP and index variable values. The controls considered are the following. Underlying asset's skewness (Skw) and kurtosis (Kur) estimated from previous year daily data. Underlying asset's momentum (MOM) estimated as the cumulative return over the last twelve months by skipping the most recent month. Market beta (Beta) and coskewness beta (CoSkw) which are estimated by an univariate regression of the underlying returns on previous year market index daily returns and squared returns, respectively. The market index is either MSCI or CRSP index depending if the option underlying is an international or domestic security. Additional control variables include: absolute delta (Delta), dollar volume (Dollar Volume), dollar open interest (Dollar OI) and bid-ask spread (BAS) average between call and put options used to construct the straddle. Λ_t is a column vector of control coefficients. Monthly cross-sectional regressions have both the dependent and independent variables demeaned. The independent variables are also standardized to unit variance. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the next month option returns by β percentage points. The time-series average of the estimated coefficients are reported in percentage. Newey and West (1987) t-statistics with three lags are reported in brackets. Adjusted R^2 is in percentage terms and it is the average over time of the adjusted R^2 in each cross-sectional regression. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	International										**Domestic**									
	IV^r					VSR^r					IV^r					VSR^r				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Volatility Return	1.361***	1.342***	1.432***	1.345***	1.277***	1.062***	1.030***	1.136***	1.011***	0.835***	0.143	0.172	0.136	-0.041	0.197	0.144	0.090	0.089	0.068	0.148
	(7.372)	(6.915)	(7.280)	(5.235)	(4.863)	(5.836)	(4.855)	(3.991)	(5.090)	(3.046)	(1.017)	(1.061)	(0.942)	(-0.314)	(1.296)	(1.051)	(0.623)	(0.564)	(0.449)	(0.887)
Skw		0.110					0.072					0.177					0.161			
		(0.327)					(0.223)					(1.078)					(0.984)			
Kur		-0.172					-0.287					0.121					-0.079			
		(-0.503)					(-0.829)					(0.882)					(-0.590)			
Delta			-0.407*					-0.246					-0.089					-0.151		
			(-1.804)					(-0.984)					(-0.659)					(-1.155)		
Beta			0.411**					0.324					-0.047					-0.108		
			(2.036)					(1.442)					(-0.235)					(-0.562)		
CoSkw				-0.469**					-0.223					0.242					0.196	
				(-2.025)					(-1.051)					(1.454)					(1.082)	
MOM				-0.204					-0.124					0.104					-0.004	
				(-0.940)					(-0.594)					(0.712)					(-0.026)	
Dollar Volume					-0.153					-0.006					0.055					0.048
					(-0.451)					(-0.015)					(0.067)					(0.070)
Dollar OI					-0.176					-0.486					-0.198					-0.262
					(-0.511)					(-1.302)					(-0.232)					(-0.377)
BAS					0.420					0.721***					0.110					0.090
					(1.508)					(2.881)					(0.868)					(0.664)
$\bar{R}^2$	14.810	21.907	24.929	20.415	21.266	13.610	21.596	24.475	18.442	21.051	12.964	23.530	26.665	25.577	10.762	11.427	21.360	24.168	25.958	9.499
N	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871

Table 12

Fama-MacBeth Regressions: Cross-Section of International ETP and Index Option Returns.

This table reports Fama and MacBeth (1973) regressions on international ETP and index option returns cross-sections. International ETP and index products are reported in Table A.1. Each month cross-sectional regressions of monthly option returns on portfolio construction volatility returns plus a set of control variables are estimated.

$$r^{\text{Short,USD}}_{i,t+\tau} = \lambda_{1,t} \cdot \text{Volatility Return}_{i,t} + \Lambda'_t \mathbf{Z}_{i,t} + \varepsilon_{i,t+\tau} \tag{8}$$

where $r^{\text{Short,USD}}_{i,t+\tau}$ is the option straddle return on the product i at expiration day $t+\tau$. Volatility $\text{Return}_{i,t}$ is the product i ex-ante volatility return at portfolio construction. The volatility returns can be either model dependent (IV) or model-free (VSR) return. $\lambda_{1,t}$ is the volatility return coefficient. $\mathbf{Z}_{i,t}$ is a vector of control characteristics for product i at time t. The controls considered are the following. Underlying asset's skewness (Skw) and kurtosis (Kur) estimated from previous year daily data. Underlying asset's momentum (MOM) estimated as the cumulative return over the last twelve months by skipping the most recent month. Market beta (Beta) and coskewness beta (CoSkw) which are estimated by an univariate regression of the underlying returns on previous year MSCI market index daily returns and squared returns, respectively. Additional control variables include: absolute delta (Delta), dollar volume (Dollar Volume), dollar open interest (Dollar OI) and bid-ask spread (BAS) average between call and put options used to construct the straddle. Λ_t is a column vector of control coefficients. Monthly cross-sectional regressions have both the dependent and independent variables demeaned. The independent variables are also standardized to unit variance. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the next month option returns by β percentage points. The time-series average of the estimated coefficients are reported in percentage. Newey and West (1987) t-statistics with three lags are reported in brackets. Adjusted R^2 is in percentage terms and it is the average over time of the adjusted R^2 in each cross-sectional regression. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	ETP										**Index**									
	IV^r					VSR^r					IV^r					VSR^r				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Volatility Return	0.973***	0.960***	1.027***	1.090***	0.863***	0.851***	0.816***	0.940***	0.938***	0.686***	0.340***	0.572***	0.206	0.363***	0.421***	0.366***	0.401**	0.142	0.364**	0.477***
	(6.692)	(6.527)	(6.177)	(7.302)	(4.389)	(6.300)	(5.941)	(5.471)	(6.469)	(3.699)	(2.683)	(3.810)	(1.261)	(2.748)	(3.074)	(2.695)	(2.543)	(0.870)	(2.393)	(2.640)
Skw		-0.010					0.033					0.026					-0.205			
		(-0.068)					(0.223)					(0.110)					(-0.723)			
Kur		0.384***					0.319**					0.022					-0.206			
		(2.880)					(2.237)					(0.078)					(-0.664)			
Delta			-0.271*					-0.177					0.185					0.252*		
			(-1.834)					(-1.075)					(1.109)					(1.758)		
Beta			0.205					0.197					0.134					0.095		
			(1.220)					(1.204)					(0.838)					(0.582)		
CoSkw				-0.106					-0.080					-0.063					-0.185	
				(-0.679)					(-0.491)					(-0.416)					(-1.153)	
MOM				-0.094					-0.079					-0.098					0.040	
				(-0.574)					(-0.504)					(-0.807)					(0.352)	
Dollar Volume					-0.421					-2.239					-0.258					-0.002
					(-0.243)					(-0.979)					(-1.559)					(-0.013)
Dollar OI					0.441					2.242					0.127					0.026
					(0.250)					(0.960)					(0.791)					(0.173)
BAS					0.408**					0.492***					0.085					0.171
					(2.274)					(3.147)					(0.667)					(1.290)
$\bar{R}^2$	9.388	12.451	16.272	14.057	7.230	10.110	12.610	15.684	14.236	6.786	10.551	13.867	18.240	16.529	18.567	9.832	13.801	16.260	17.183	19.017
N	2448	2448	2448	2448	2448	2448	2448	2448	2448	2448	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845

Table 13

Fama-MacBeth Regressions: Cross-Section of Domestic ETP and Index Option Returns.

This table reports Fama and MacBeth (1973) regressions on domestic ETP and index option returns cross-sections. Domestic ETP and index products are reported in Table A.2. Each month cross-sectional regressions of monthly option returns on portfolio construction volatility returns plus a set of control variables are estimated.

$$r_{i,t+\tau}^{\text{Short,USD}} = \lambda_{1,t} \cdot \text{Volatility Return}_{i,t} + \Lambda_t' \mathbf{Z}_{i,t} + \varepsilon_{i,t+\tau} \qquad (9)$$

where $r_{i,t+\tau}^{\text{Short,USD}}$ is the option straddle return on the product i at expiration day $t+\tau$. Volatility $\text{Return}_{i,t}$ is the product i ex-ante volatility return at portfolio construction. The volatility returns can be either model dependent (IV) or model-free (VSR) return. $\lambda_{1,t}$ is the volatility return coefficient. $\mathbf{Z}_{i,t}$ is a vector of control characteristics for product i at time t. The controls considered are the following. Underlying asset's skewness (Skw) and kurtosis (Kur) estimated from previous year daily data. Underlying asset's momentum (MOM) estimated as the cumulative return over the last twelve months by skipping the most recent month. Market beta (Beta) and coskewness beta (CoSkw) which are estimated by an univariate regression of the underlying returns on previous year CRSP market index daily returns and squared returns, respectively. Additional control variables include: absolute delta (Delta), dollar volume (Dollar Volume), dollar open interest (Dollar OI) and bid-ask spread (BAS) average between call and put options used to construct the straddle. Λ_t is a column vector of control coefficients. Monthly cross-sectional regressions have both the dependent and independent variables demeaned. The independent variables are also standardized to unit variance. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the next month option returns by β percentage points. The time-series average of the estimated coefficients are reported in percentage. Newey and West (1987) t-statistics with three lags are reported in brackets. Adjusted R^2 is in percentage terms and it is the average over time of the adjusted R^2 in each cross-sectional regression. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	ETP										**Index**									
	IV^r					VSR^r					IV^r					VSR^r				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Volatility Return	0.422***	0.534***	0.427***	0.369***	0.347***	0.243***	0.289***	0.306***	0.276***	0.075	0.145	0.078	0.242*	0.305**	0.052	0.110	0.200**	0.321**	0.116	0.107
	(3.666)	(3.922)	(3.608)	(2.955)	(3.067)	(2.598)	(2.884)	(2.633)	(2.711)	(0.722)	(1.433)	(0.550)	(1.766)	(2.086)	(0.397)	(1.182)	(2.250)	(2.337)	(1.132)	(0.751)
Skw		0.159					0.186					-0.114					-0.125			
		(1.121)					(1.361)					(-0.653)					(-0.557)			
Kur		0.016					-0.009					-0.112					0.001			
		(0.145)					(-0.090)					(-0.555)					(0.006)			
Delta			-0.077					-0.024					-0.171*					-0.219**		
			(-0.708)					(-0.209)					(-1.903)					(-2.060)		
Beta			0.059					0.095					0.097					0.192		
			(0.461)					(0.706)					(0.565)					(1.351)		
CoSkw				0.201					0.238*					0.170					0.158	
				(1.559)					(1.797)					(1.218)					(1.346)	
MOM				0.014					-0.054					-0.414**					-0.178	
				(0.122)					(-0.454)					(-2.562)					(-1.120)	
Dollar Volume					-0.033					0.044					3.407					1.952
					(-0.064)					(0.086)					(1.052)					(0.775)
Dollar OI					0.014					-0.045					-3.419					-2.009
					(0.027)					(-0.089)					(-1.055)					(-0.796)
BAS					0.099					0.240*					0.081					-0.044
					(0.935)					(1.912)					(0.761)					(-0.282)
$\bar{R}^2$	8.796	19.537	18.875	20.280	9.285	6.165	15.986	15.530	18.312	7.902	21.649	46.037	39.466	50.034	30.081	15.770	38.910	33.534	44.273	25.474
N	3819	3819	3819	3819	3819	3819	3819	3819	3819	3819	1280	1280	1280	1280	1280	1280	1280	1280	1280	1280

Table 14

Ex-Ante and Ex-Post Volatility Returns of International and Domestic Portfolios.

This table reports ex-ante and ex-post volatility returns for international and domestic option portfolios. Ex-ante (ex-post) volatility returns are constructed as one minus the ratio of previous year (ex-post) realized volatility to time t implied volatility. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t+\tau$. Volatility returns can be either implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). The sample period is January 2006 to December 2015. Panel (A) reports volatility returns for the cross-sections of international and domestic option returns. The international (domestic) cross-section includes all ETP and index option products displayed in Table A.1 (A.2). Each fourth Friday of the month, volatility returns are sorted in descending order by previous day ex-ante volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). The unconditional (U) portfolio is the equally weighted average of all the volatility returns available at the moment of portfolio formation. Panel (B) reports dispersion trading volatility returns for international and domestic dispersion trading portfolios. The international (domestic) dispersion trading pairs include ETP and index options displayed in Table A.3 Panel (A) ((B)). Each fourth Friday of the month, ETP and index dispersion pairs are ranked in descending order by previous day ex-ante volatility returns difference, equation (2). Then, they are assigned to one of three equally weighted tercile portfolios. Successively, ETP volatility returns are sold and the corresponding index volatility returns are bought. The high (low) dispersion trading portfolio is the tercile among the ETP and index pairs with the largest (smallest) ex-ante volatility return dispersion. The long-short dispersion trading portfolio is the difference between 50% of the high and 50% of the low dispersion tercile. The unconditional (U) dispersion trading portfolio is the equally weighted average of ETP minus index volatility returns pairs. The table includes unconditional (U), high (H), low (L) and high minus low (H-L) portfolios. Both of the Panels report the following measures. Ex-ante implied volatility or volatility swap rate level at the moment of portfolio construction (ex-ante Vol). Ex-ante underlying assets' realized volatility over the previous 12 months at the moment of portfolio construction (ex-ante Std). Ex-ante volatility return (ex-ante Vol. Ret.) and its t-statistic. Ex-post volatility return (ex-post Vol. Ret.) and its t-statistic. Both of the volatility returns are annualized averages in percentage terms. Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation. The unconditional basket is always expressed in implied volatility terms.

	International							**Domestic**						
		IV^r			VSR^r				IV^r			VSR^r		
	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
Cross-Section (A)														
ex-ante Vol	24.91	28.85	22.87	5.97	38.86	22.94	15.92	20.13	21.96	18.97	3.00	24.36	19.14	5.22
ex-ante Std	24.43	22.43	27.18	-4.75	22.72	27.00	-4.28	20.13	19.70	20.88	-1.18	18.92	21.41	-2.49
ex-ante Vol. Ret.	-3.93	11.58	-18.80	29.74	25.07	-17.43	41.70	-4.27	4.25	-12.23	16.19	15.10	-12.33	26.94
t-statistic	-1.08	3.88	-4.35	21.09	7.63	-4.18	17.00	-1.00	1.11	-2.58	15.02	4.71	-2.63	16.84
ex-post Vol. Ret.	3.88	12.11	-2.48	14.39	26.22	-3.14	29.11	2.94	6.95	-0.38	7.25	17.64	-1.90	19.33
t-statistic	1.63	5.74	-0.91	13.88	8.64	-1.09	13.84	1.02	2.58	-0.12	9.37	6.18	-0.56	19.08
Dispersion Trading (B)														
ex-ante Vol	7.11	14.74	3.04	5.85	28.93	3.85	12.54	1.24	1.96	1.21	0.37	4.21	1.07	1.57
ex-ante Std	5.24	3.13	7.63	-2.25	3.10	6.98	-1.94	1.23	0.00	3.34	-1.67	-0.45	3.63	-2.04
ex-ante Vol. Ret.	2.74	22.89	-14.05	18.38	40.70	-8.50	24.66	0.38	8.25	-8.01	8.10	15.70	-10.60	13.11
t-statistic	1.99	12.93	-6.90	16.44	16.33	-3.44	17.64	0.87	9.34	-13.23	14.34	9.56	-12.12	15.02
ex-post Vol. Ret.	1.82	16.55	-10.70	13.53	34.70	-8.50	21.55	0.13	2.96	-2.64	2.79	10.98	-6.57	8.76
t-statistic	1.21	8.03	-4.78	10.80	13.26	-2.94	14.61	0.27	3.32	-3.66	5.30	10.59	-12.27	16.52

Table 15
Ex-Ante and Ex-Post Volatility Returns of ETP and Index Portfolios.

This table reports ex-ante and ex-post volatility returns for ETP and Index portfolios. Ex-ante (ex-post) volatility returns are constructed as one minus the ratio of previous year (ex-post) realized volatility to time t implied volatility. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t+\tau$. Volatility returns can be either implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). The sample period is January 2006 to December 2015. Each fourth Friday of the month, volatility returns are sorted in descending order by previous day ex-ante volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). The unconditional (U) portfolio is the equally weighted average of all the volatility returns available at the moment of portfolio formation. Panel (A) reports volatility returns for the cross-sections of ETP and index option returns internationally. The ETP (index) cross-section includes all ETP (index) option products displayed in Table A.1 Panel (A) ((B)). In this table, Panel (B) reports volatility returns for the cross-sections of ETP and index option returns domestically. The ETP (index) cross-section includes all ETP (index) option products displayed in Table A.2 Panel (A) ((B)). This table includes unconditional (U), high (H), low (L) and high minus low (H-L) portfolios. Both of the Panels report the following measures. Ex-ante implied volatility or volatility swap rate level at the moment of portfolio construction (ex-ante Vol). Ex-ante underlying assets' realized volatility over the previous 12 months at the moment of portfolio construction (ex-ante Std). Ex-ante volatility return (ex-ante Vol. Ret.) and its t-statistic. Ex-post volatility return (ex-post Vol. Ret.) and its t-statistic. Both of the volatility returns are annualized averages in percentage terms. Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation. The unconditional basket is always expressed in implied volatility terms.

	ETP							**Index**						
		IV^r			VSR^r				IV^r			VSR^r		
	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
International (A)														
ex-ante Vol	28.68	34.41	25.59	8.82	48.20	26.61	21.59	20.21	22.15	18.67	3.48	21.71	18.75	2.95
ex-ante Std	27.72	24.94	30.66	-5.71	24.23	30.91	-6.68	20.39	19.46	21.46	-2.01	18.69	21.99	-3.29
ex-ante Vol. Ret.	-3.30	15.07	-19.27	33.65	32.82	-15.55	47.56	-5.20	6.59	-17.35	23.41	8.77	-18.37	26.57
t-statistic	-0.83	4.28	-4.38	22.93	9.04	-3.51	18.78	-1.54	2.39	-4.20	13.93	3.21	-4.67	17.03
ex-post Vol. Ret.	4.76	16.53	-3.79	19.98	35.14	-2.69	37.42	2.29	5.41	-0.52	5.85	8.34	-2.87	11.11
t-statistic	1.81	7.29	-1.15	12.07	10.75	-0.77	16.22	0.98	2.18	-0.22	5.50	3.36	-1.17	9.29
Domestic (B)														
ex-ante Vol	20.43	22.49	19.11	3.38	24.94	19.21	5.74	19.24	20.43	18.68	1.75	23.37	19.47	3.90
ex-ante Std	20.29	19.64	21.22	-1.58	18.84	21.68	-2.83	19.65	19.87	20.02	-0.14	18.90	20.89	-1.99
ex-ante Vol. Ret.	-3.87	5.66	-12.77	18.09	16.81	-13.07	29.32	-5.40	-0.04	-10.58	10.37	10.84	-9.49	20.07
t-statistic	-0.91	1.50	-2.68	14.33	5.65	-2.77	15.67	-1.22	-0.01	-2.28	14.94	2.49	-2.07	12.08
ex-post Vol. Ret.	3.38	8.18	-0.66	8.75	18.90	-2.03	20.71	1.52	2.83	0.52	2.26	15.03	-0.58	15.49
t-statistic	1.20	3.07	-0.22	10.35	6.72	-0.59	18.91	0.50	0.96	0.17	2.53	4.18	-0.17	9.44

Table 16

International and Domestic Option Strategies: Returns Computed at 25% of Effective to Quoted Spread.

This table reports portfolio performance metrics for international and domestic option strategies. The sample period is January 2006 to December 2015. The table presents two types of option schemes, cross-sectional and dispersion trading strategies, and a set of benchmark indexes. Option returns are computed by executing trades at 25% of the effective to quoted bid-ask spread. Returns are denominated in US dollars, expressed in excess of US risk-free rate and options are held to maturity. In addition, trades are executed on options with either positive volume or positive previous day open interest. The cross-sectional option schemes show portfolio performance metrics for the cross-sections of international and domestic option returns. The international (domestic) cross-section includes all ETP and index option products displayed in Table A.1 (A.2). Ex-ante volatility returns are the sorting variable. There are two types of sorts: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Each fourth Friday of the month, ATM straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). The table includes high minus low (H-L) option portfolios. The dispersion trading option schemes show portfolio performance metrics for international and domestic dispersion trading option strategies. The international (domestic) dispersion trading pairs include ETP and index options displayed in Table A.3 Panel (A) ((B)). Each fourth Friday of the month, ETP and index dispersion pairs are ranked in descending order by previous day volatility returns difference. Then, they are assigned to one of three equally weighted tercile portfolios. Successively, ETP ATM straddles are sold and the corresponding index ATM straddles are bought. The high dispersion trading portfolio is the tercile among the ETP and index pairs with the largest ex-ante volatility return dispersion. The table includes high (H) dispersion trading portfolios. Panel (A) presents annualized average return (μ), annualized Sharpe ratio (SR). annualized risk-adjusted return (α) and its t-statistic (t-α). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), skewness (Skw), CAPM-β with respect to CRSP value weighted index (β) and its t-statistic (t-β). Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation. Lastly, the benchmark indexes include: CRSP value weighted index, MSCI world index, a hedge fund short volatility (SV) index and a hedge fund relative volatility value (RV) index.

	Cross-Section				**Dispersion Trading**				**Benchmarks**			
	International		**Domestic**		**International**		**Domestic**					
Returns (A)	IV^r_{H-L}	VSR^r_{H-L}	IV^r_{H-L}	VSR^r_{H-L}	IV^r_H	VSR^r_H	IV^r_H	VSR^r_H	CRSP	MSCI	SV	RV
μ	7.11	9.46	-0.27	-2.12	11.64	12.78	-1.90	-2.98	5.83	3.93	7.79	9.04
SR	0.81	1.16	-0.04	-0.25	0.95	1.11	-0.18	-0.26	0.37	0.24	0.86	2.41
α	8.71	11.20	-0.12	-2.07	13.11	13.34	-2.37	-3.76	0.00	-2.07	5.46	8.47
t-α	3.17	4.25	-0.06	-0.77	3.51	4.01	-0.71	-0.97	0.76	-1.60	1.97	5.36
Risk (B)												
Std	8.75	8.17	7.26	8.37	12.32	11.51	10.64	11.59	15.69	16.70	9.07	3.76
Skw	0.62	0.69	-0.33	0.55	-0.17	-0.38	-0.99	-0.88	-0.89	-1.00	-3.04	0.06
β	-0.19	-0.14	0.01	0.06	-0.13	-0.10	-0.06	0.10	1.00	1.03	0.31	0.05
t-β	-3.51	-2.88	0.16	0.60	-1.94	-1.11	-1.18	1.53		44.48	3.37	1.71

A Appendix

A.1 Further Data Information and Procedures

- *Option data variables.* I obtain option pricing data containing: the date of the option price record, strike price, call-put flag, closing bid and ask option prices, the closing trade price or the settlement price published by the exchange of the option (if available), volume, open interest, implied volatility, option sensitivities (Greeks) and adjustment factor for splits.

- *Cross-sectional option portfolios, variables aggregation.* For each type of basket-portfolio unconditional, high tercile and low tercile, I compute the equally weighted cross-sectional average of the following variables: option straddle returns, ex-ante volatility returns, ex-post volatility returns, implied volatility level, volatility swap rate level, ex-ante realized volatility level, call and put average absolute delta and gamma. The long-short portfolio is the high tericle portfolio minus the low tercile portfolio variable value.

- *Dispersion trading option portfolios, variables aggregation.* For each of the following variables I take the difference between the ETP and index option variable value: option straddle returns, ex-ante volatility returns, ex-post volatility returns, implied volatility level, volatility swap rate level, ex-ante realized volatility level, call and put average absolute delta and gamma. Then, I compute the equally weighted average across ETP-index pairs for each basket portfolio and for each variable. I do this procedure for the following baskets: unconditional, high tercile and low tercile. The long-short dispersion portfolio is 50% of the high minus 50% of the low tercile portfolio variable value.

- *Cash flows synchronization.* I synchronize cash flows as follows, if the expected entry day is before the fourth Friday of the month Taiwan and Australia index options are not included in the portfolio formation. This ensures full cash flows availability for next month portfolio construction independently from the first calendar day of the month. While if the expected entry day is before the end of the month Hong Kong index options are not included in the portfolio formation.

- *Taiwan index options.* I find inconsistency in monthly expiration dates among Taiwanese index options. Taiwanese index options are supposed to expire on the third Wednesday of the month.[22] Nonetheless, recording errors in the option data have swapped them with third Fridays expiration, which is an expiration cycle that does not exist in monthly Taiwanese options. This issue is confirmed by the data provider and the exchange as of 2017-08-31. I created an algorithm that identifies monthly Wednesday expiring options, with 100% precision for the period 2006-2015. In addition, this data has an institutional recording error in exercise option style. Taiwan index options are European, while the data swaps between European and American style flags.

[22] `http://www.taifex.com.tw/eng/eng2/TXO.asp`

- *Merging options by ID and strike price.* I identify option securities by their unique option ID. In case there is a disappearance of options IDs from one day to another for no institutional reason, I identify options from day $t-1$ to t by strike price for each term-structure point and for each call / put option type. I cross check the merge by no violation of arbitrage across-strikes and check the evolution of securities from time $t-1$ to t. This issue can occur sporadically for Taiwan index options. Exclusion of these few IDs exceptions does not effect the result of this paper.

- *Missing option prices for international index options.* in case an international index option product has a missing price for a specific strike price, -99.99, I exclude that strike from the computations. Depending on when this issue occur, I exclude that strike either at the moment of portfolio formation or at the moment of trade execution (moving to its closest OTM strike available).

- *Software unit tests:* I reproduce Israelov et al. (2017) empirical study and obtain similar results under their research design. Furthermore, I use as inputs module one of the following return values: (i) zero returns for all assets, (ii) a constant, (iii) S&P 500 cash (or general) index returns and (iv) the negative of S&P 500 cash (or general) index returns. I obtain the following outputs module for unconditional, high, low and long-short portfolios: (i) zero everywhere, (ii) a constant for unconditional, high and low baskets and zero for long-short, (iii) S&P 500 cash (or general) index returns for unconditional, high and low baskets returns and zero returns for long-short baskets, (iv) as in case (iii) but reversed. Regarding dispersion trading portfolios, I obtain zero returns everywhere. Lastly, to grantee a correct merging of option contracts and specifications, I tested odd and even contract months by assigning to the latter a value of -1000. The output results in a -1000 value for even months and the option returns value for odd months.

A.2 Contractual Information

Websites, as of 2017-08-31:[23]

- **Australia:** (S&P/ASX 200) `http://www.asx.com.au/products/equity-options/options-contract htm`

- **Belgium:** (BEL-20) `https://derivatives.euronext.com/en/products/index-options/BEL-DBRU/contract-specification`

- **Canada:** (S&P/TSX 60) `https://www.m-x.ca/produits_indices_sxo_en.php`

- **Finland:** (OMXH25) `http://www.eurexchange.com/exchange-en/products/idx/hex/OMXH25-Options/17082`

[23]Further institutional data sources are option clearing corporation and options industry council: `https://www.theocc.com/` and `https://www.optionseducation.org/about_oic.html`, respectively

- **France:** (CAC 40) https://derivatives.euronext.com/en/products/stock-options/PXA-DPAR/contract-specification
- **Germany:** (DAX) http://www.eurexchange.com/exchange-en/products/idx/dax/DAX--Options/17252
- **Hong Kong:** (Hang Seng) https://www.hkex.com.hk/eng/prod/drprod/hkifo/options.htm
- **Italy:** (FTSE MIB) http://www.borsaitaliana.it/derivati/specifichecontrattuali/ftsemiboptions.en.htm
- **Japan:** (Nikkei 225) http://www.jpx.co.jp/english/derivatives/products/domestic/225options/01.html
- **Korea:** (KOSPI 200) http://global.krx.co.kr/contents/GLB/02/0201/0201040202/GLB0201040202.jsp
- **The Netherlands:** (Aex-Index) https://derivatives.euronext.com/en/products/index-options/AEX-DAMS/contract-specification
- **Spain:** (IBEX 35) http://www.meff.com/ing/Financial-Derivatives/Options-on-IBEX-35
- **Sweden:** (OMXS 30) http://www.nasdaqomx.com/transactions/markets/optionsfutures/europe/product-information/index-options
- **Switzerland:** (SMI) http://www.eurexchange.com/exchange-en/products/idx/smi/SMI--Options/19508
- **Taiwan:** (TXO) http://www.taifex.com.tw/eng/eng2/TXO.asp
- **UK:** (FTSE-100) https://www.theice.com/products/38716770/FTSE-100-Index-Option
- **USA:** (SPX) http://www.cboe.com/products/stock-index-options-spx-rut-msci-ftse/s-p-500-index-options
- **ETP options and domestic index options:** http://www.cboe.com/

A.3 International Index Option Data Before January 2006

I choose to study option returns from January 2006 onward for the following reasons: (i) availability of international ETP option data from January 2006 and (ii) international index option higher pricing and contractual data quality since January 2006. In this Appendix, I outline the main data concerns regarding international index options for the period between 2002-01-01 and 2005-12-31. The OptionMetrics IvyDB-Global Indexes database is received as of 2017-June-30.

- *Australia:* I could not collect exercise settlement values and contractual data before 2006. In addition, I find that Australian index options have missing pricing data for the period between 2005-01-01 and 2005-12-31. This issue is confirmed by the data provider as of 2017-08-31.

- *Belgium:* the Belgium index options have several expiration months missing in 2003, this is also confirmed by the data provider as of 2017-08-31.

- *France:* the France index options have missing expiration months between 2005-09-16 and 2005-12-16. The data provider confirmed this hole in the database and the exchange doesn't have the data itself as of 2017-08-31.

- *Japan:* the Japanese index options have several missing expiration months during 2004. The data provider confirms this issue as of 2017-08-31.

- *Netherlands:* The Dutch index options have missing expiration contracts in mid 2002 and between 2004-12-17 and 2005-06-17. The data provider confirms this data problem as of 2017-08-31. The Netherlands index options have missing contractual information over the sample period.

- *Taiwan:* I find inconsistency in monthly expiration dates among Taiwanese index options. Taiwanese index options are supposed to expire on the third Wednesday of the month.[24] Nonetheless, recording errors in the option data have swapped them with third Fridays expiration, which is an expiration cycle that does not exist in monthly Taiwanese options. This issue is confirmed by the data provider and the exchange as of 2017-08-31. In addition, this data has an institutional recording error in exercise option style. Taiwan index options are European, while the data swaps between European and American style flags.

- Generally, there is a lack of contractual information, e.g. exercise settlement values, for most of the international index options before 2006.

A.4 Appendix: Figures & Tables

[24] `http://www.taifex.com.tw/eng/eng2/TXO.asp`

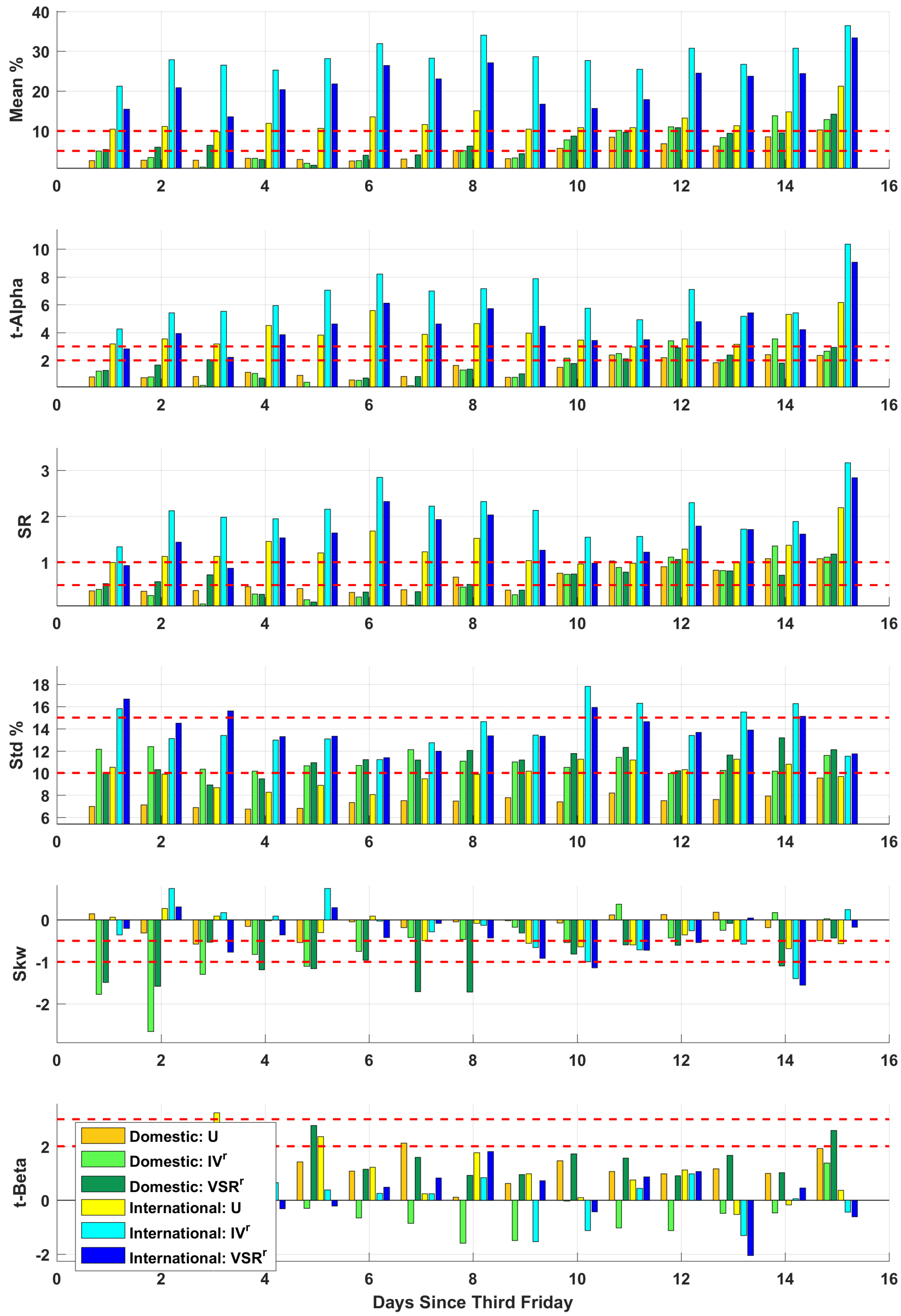

Figure A.1

Dispersion Trading International and Domestic: Without Asian Indexes.

This figure investigates the time series properties of international and domestic dispersion trading option strategies without Asian indexes: Korean, Japanese, Taiwanese, Australian and the Hong Kong index options. The x-axes represents the day in which portfolios are executed, which is the number of days since the last third Friday of the month. The figure reports unconditional (U) and high dispersion trading portfolios sorted either by ex-ante implied volatility returns (IV^r) or ex-ante volatility swap rate returns (VSR^r) ETP-index difference. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

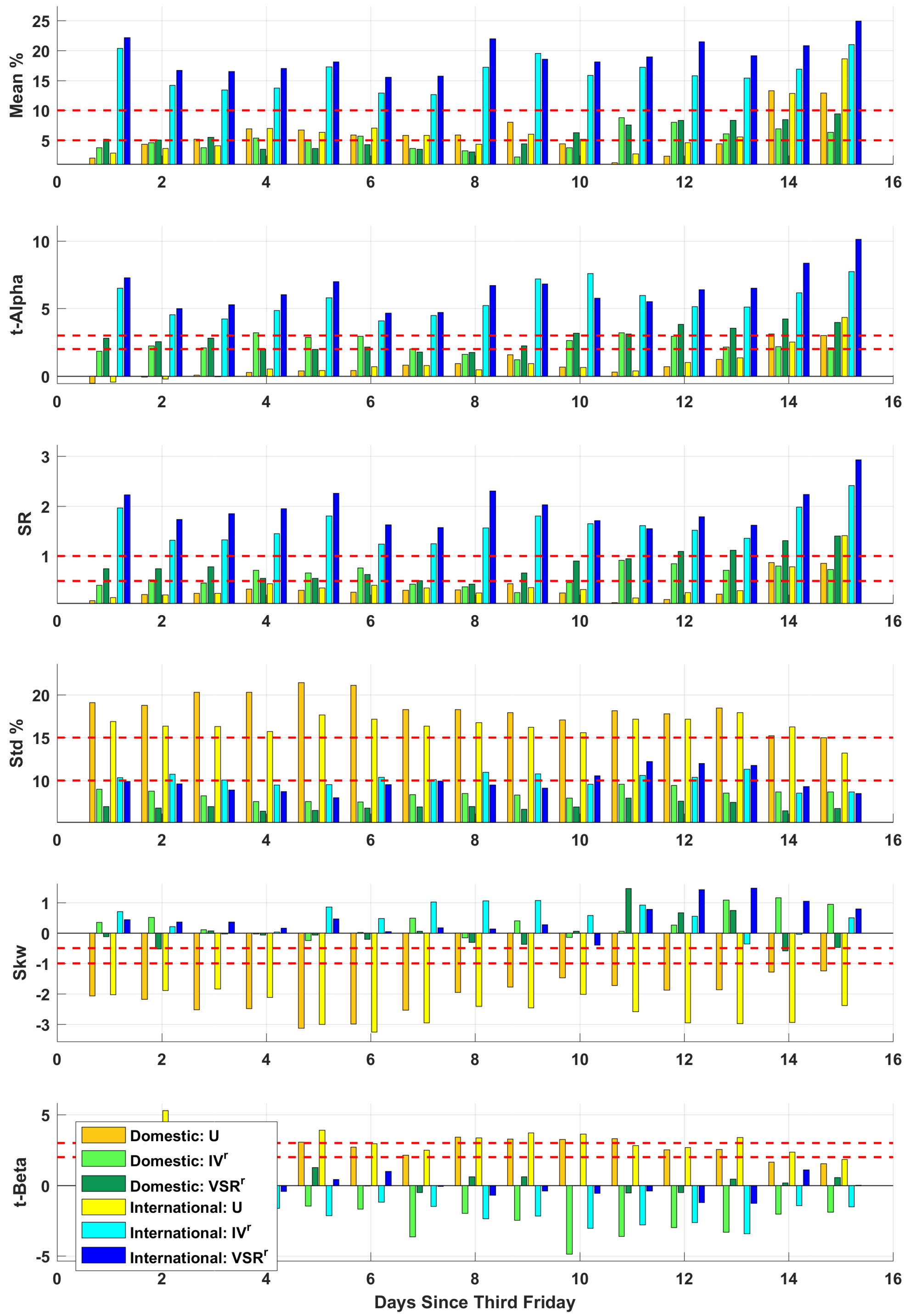

Figure A.2

Cross-Section International and Domestic: Without Asian Indexes.

This figure investigates the time series properties of international and domestic option return cross-sections without Asian indexes: Korean, Japanese, Taiwanese, Australian and the Hong Kong index options. The x-axes represents the day in which portfolios are executed, which is the number of days since the last third Friday of the month. The figure reports unconditional (U) and long-short option portfolios sorted either by ex-ante implied volatility returns (IV^r) or ex-ante volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

Table A.1

International Option Products.

This table reports all the international option products considered in the sample. Panel (A) displays ETP options, while panel (B) shows index options. The four columns display the foreign market, product name, start and end year of the sample. The sample period is January 2006 to December 2015.

	Market	Product	Start Year	End Year
ETP (A)				
	Australia	MSCI Australia	2007	2015
	Belgium	MSCI Belgium	2013	2015
	Brazil	MSCI Brazil	2006	2015
	Canada	MSCI Canada	2006	2015
	China	FTSA China 25	2006	2015
	EAFE	MSCI EAFE	2006	2015
	Emerging Markets	MSCI Emerging Markets	2006	2015
	France	MSCI France	2011	2015
	Germany	MSCI Germany	2006	2015
	Greece	FTSE Greece	2013	2015
	Hong Kong	MSCI Hong Kong	2006	2015
	India	MSCI India	2013	2015
	Italy	MSCI Italy	2010	2015
	Japan	MSCI Japan	2006	2015
	Korea	MSCI South Korea	2007	2015
	Malaysia	MSCI Malaysia	2007	2015
	Mexico	MSCI Mexico	2007	2015
	Netherlands	MSCI Netherlands	2013	2015
	Russia	Vectors Russia	2007	2015
	Singapore	MSCI Singapore	2009	2015
	South Africa	MSCI South Africa	2007	2015
	Spain	MSCI Spain	2007	2015
	Sweden	MSCI Sweden	2007	2015
	Switzerland	MSCI Switzerland	2008	2015
	Taiwan	MSCI Taiwan	2006	2015
	Thailand	MSCI Thailand	2014	2015
	Turkey	MSCI Turkey	2013	2015
	United Kingdom	MSCI United Kingdom	2006	2015
	United States	SPDR SP 500	2006	2015
Index (B)				
	Australia	SP ASX 200	2006	2015
	Belgium	BEL 20	2006	2015
	Canada	SP TSX 60	2007	2015
	Finland	OMXH Helsinki 25	2006	2015
	France	CAC 40	2006	2015
	Germany	DAX	2006	2015
	Hong Kong	Hang Seng	2006	2015
	Italy	FTSE MIB	2006	2015
	Japan	NIKKEI 225	2006	2015
	Korea	KOSPI 200	2006	2015
	Netherlands	AEX	2006	2015
	Spain	IBEX 35	2006	2015
	Sweden	OMXS30	2006	2015
	Switzerland	SMI	2006	2015
	Taiwan	TAIEX	2006	2015
	United Kingdom	FTSE 100	2006	2015
	United States	SP 500 - AM	2006	2015

Table A.2

Domestic Option Products.

This table reports all the domestic option products considered in the sample. Panel (A) displays ETP options, while panel (B) shows index options. The three columns display product name, start and end year of the sample. The sample period is January 2006 to December 2015.

	Product	Start Year	End Year
ETP (A)			
	Barrons 400	2013	2015
	Consumer Discretionary (XLY)	2006	2015
	Consumer Staples (XLP)	2006	2015
	Dow Jones	2006	2015
	Energy (XLE)	2006	2015
	Financials (XLF)	2006	2015
	Health Care (XLV)	2006	2015
	Industrials (XLI)	2006	2015
	Materials (XLB)	2006	2015
	NASDAQ 100	2006	2015
	NYSE Composite NYA	2006	2008
	NYSE U.S. 100 NYID	2006	2008
	Russell 1000	2006	2015
	Russell 1000 Growth	2006	2015
	Russell 1000 Value	2006	2015
	Russell 2000	2006	2015
	Russell 2000 Growth	2006	2015
	Russell 2000 Value	2006	2015
	Russell 3000	2006	2015
	Russell MidCap	2006	2015
	Russell MidCap Growth	2006	2015
	Russell MidCap Value	2006	2015
	Russell Small Cap	2006	2015
	SP 100 A (OEF)	2006	2015
	SPDR SP 500	2006	2015
	SP 500 Growth	2007	2015
	SP 500 Index Fund	2006	2015
	SP 500 Value	2006	2015
	SP Midcap 400	2006	2015
	SP Midcap 400 Growth	2006	2015
	SP Midcap 400 Value	2006	2015
	SP SmallCap 600	2006	2015
	SP SmallCap 600 Growth	2006	2015
	SP SmallCap 600 Value	2006	2015
	Technology (XLK)	2006	2015
	Utilities (XLU)	2006	2015
Index (B)			
	AMEX Major Market Index - XMI	2006	2008
	Dow Jones (DJX)	2006	2015
	NASDAQ - Mini	2006	2015
	NASDAQ 100	2006	2015
	Russell 1000	2006	2015
	Russell 1000 Growth	2006	2015
	Russell 1000 Value	2006	2015
	Russell 2000	2006	2015
	Russell 2000 - Mini	2006	2012
	SP 100 A (OEX)	2006	2015
	SP 100 E (XEO)	2006	2015
	SP 500 - AM	2006	2015
	SP 500 - Mini	2006	2014
	SP 500 - Mini (New)	2013	2015
	SP Midcap 400	2006	2012
	SP SmallCap 600	2006	2012

Table A.3
Dispersion Trading Pairs.

This table reports all the dispersion trading pairs considered in the sample. Panel (A) shows international pairs, while panel (B) displays domestic pairs. Column one reports ETP option product, whereas column two reports the corresponding index option associated with the ETP option product. The sample period is January 2006 to December 2015.

	ETP Option Product	Index Option Product
International Pairs (A)		
	MSCI Australia	SP ASX 200
	MSCI Belgium	BEL 20
	MSCI Canada	SP TSX 60
	MSCI France	CAC 40
	MSCI Germany	DAX
	MSCI Hong Kong	Hang Seng
	MSCI Italy	FTSE MIB
	MSCI Japan	NIKKEI 225
	MSCI South Korea	KOSPI 200
	MSCI Netherlands	AEX
	MSCI Spain	IBEX 35
	MSCI Sweden	OMXS30
	MSCI Switzerland	SMI
	MSCI Taiwan	TAIEX
	MSCI United Kingdom	FTSE 100
	SPDR SP 500	SP 500 - AM
Domestic Pairs (B)		
	Consumer Discretionary (XLY)	SP 500 - AM
	Consumer Staples (XLP)	SP 500 - AM
	Dow Jones	Dow Jones (DJX)
	Energy (XLE)	SP 500 - AM
	Financials (XLF)	SP 500 - AM
	Health Care (XLV)	SP 500 - AM
	Industrials (XLI)	SP 500 - AM
	Materials (XLB)	SP 500 - AM
	NASDAQ 100	NASDAQ-100
	Russell 1000	Russell 1000
	Russell 1000 Growth	Russell 1000 Growth
	Russell 1000 Value	Russell 1000 Value
	Russell 2000	Russell 2000
	SP 100 A (OEF)	SP 100 - A (OEX)
	SPDR SP 500	SP 500 - AM
	SP Midcap 400	SP Midcap 400
	SP SmallCap 600	SP SmallCap 600
	Technology (XLK)	SP 500 - AM
	Utilities (XLU)	SP 500 - AM

Table A.4

Sample Overview: Option Products.

This table reports an overview of the option products included in the sample. Column one reports the type of option product and column two reports the number of option products in the corresponding category. Panel (A) considers the total number of international options and its subgroups of ETP and index options. Panel (B) reports the same type of information as panel (A) but for the domestic sample. Lastly, Panel (C) shows the number of dispersion trading pairs for international and domestic options separately. The sample period is January 2006 to December 2015.

	Type of Option Products	Number of Option Products
International Sample (A)		
	International Options	46
	ETP	29
	Index	17
Domestic Sample (B)		
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