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Trading Volume and Information Asymmetries in Index Option Markets: An Empirical Investigation

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Abstract of master's thesis

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Abstract

While the exploitation of the firm-specific private information via equity options is now well documented, relatively little is known about the existence and exploitation of market-wide private information. This thesis investigates the behavior of aggregate trading volume in the S&P 500 index, the S&P 500 ETF, and the VIX options preceding informational announcements and further considers whether these volume series have any predictive power over absolute returns of the S&P 500 index. Interestingly, the trading volume in all series appears to be abnormally high preceding important macroeconomic announcements and trading days associated with high absolute returns. However, predictive regression and Granger causality test results indicate that only the volume of ETF options has statistically significant, although economically modest, predictive power over absolute returns of the S&P 500 index.

Keywords Trading volume, Information, Options

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1. Introduction

Financial economists and policy makers have long puzzled the degree of trading activity in highly competitive securities markets. The last decade in particular has witnessed a large growth in the market for derivatives. This statement is especially true for cash index options and options on exchange traded funds and notes. Indeed, the combined trading activity in these products was more than 12 times larger in 2011 than in 2002 in terms of contracts traded.[1] While financial theory has traditionally considered options as redundant securities which can be replicated in a continuous time by investments in stocks and bonds (e.g., Black and Scholes, 1973), another strand of literature emphasizes the role of options as a preferred vehicle for privately informed investors.

Black (1975) first noted that the higher leverage available in option markets might induce informed traders to transact options rather than stocks. Also Back (1993) suggests that an important motivation for informed traders to use options is to gain additional leverage or to avoid short-sale constraints. Easley, O'Hara, and Srinivas (1998) formally develop an asymmetric information model in which informed traders may trade in option or equity markets. Their model predicts that in a pooling equilibrium buying a call or selling a put (selling a call or buying a put) signals positive (negative) information about future stock prices. More recently, Johnson and So (2012) develop a multimarket asymmetric information model in which equity short-sale costs result in a negative relation between the ratio of total option market volume (aggregated across calls and puts) to total equity market volume and future firm value.

Given the practical and theoretical motivation, it is not surprising that there exist convincing empirical evidence on exploitation of the firm-specific private information via equity options. Easley, O'Hara, and Srinivas (1998), Chakravarty, Gulen, and Mayhew (2004), and Pan and Poteshman (2006) find that order flow in options contains information about the future stock prices. Cao, Chen, and Griffin (2005) find evidence that options volume predicts returns around takeover announcements, indicating the presence of informed investors in option markets prior to these events. Poteshman (2006) in turn indicates that the buying activity of put options was abnormally high on trading days leading up to September 11, 2001. Ni, Pan,

[1] See the Chicago Board Options Exchange (CBOE) Annual Market Statistics 2011, available at http://www.cboe.com/data/AnnualMarketStatistics.aspx.

and Poteshman (2008) find that the non-market maker demand for volatility constructed from option order flow forecasts realized volatility of underlying stocks. Roll, Schwartz, and Subrahmanyam (2010) investigate the behavior of options/stock trading volume ratio (O/S) around the earnings announcements and document that post-announcement absolute returns are positively related to pre-announcement O/S, suggesting that at least part of the pre-announcement options trading is informed.

However, the empirical evidence on the exploitation of private information of a macroeconomic nature by trading multiple individual equities or equity index derivatives is far more inconclusive. Bessembinder and Seguin (1992) find that futures volume has only a limited impact on stock volatility. Chordia, Roll, and Subrahmanyam (2001) document that the aggregate volume of NYSE equities increases prior to rescheduled announcements of Gross Domestic Product (GDP) and Employment situation. Hasbrouck (2003) documents that the index futures dominate exchange-traded funds (ETFs) in price discovery. Pan and Poteshman (2006) find that informed trading is only present in the individual stock option market but not in the index option market. In a recent paper, Roll, Schwartz, and Subrahmanyam (2012) make a significant contribution to this literature by investigating the joint dynamics and the relative informational role of the daily trading volume in the cash S&P 500 index and its derivatives (options, the legacy and E-mini futures contracts and the ETF) during 1997-2009. They find (consistent with the literature on trading activity in options on individual stocks) that the trading volume in index options exhibits strongest relation with the proxies for market-wide information flows and further has the strongest forecasting ability for shifts in macroeconomic variables. Perhaps most importantly, they also find evidence on informed speculation (in the sense of Kyle, 1985 class of models) in index option markets. Firstly, they document that trading volume in index options is abnormally high on five trading days preceding announcement of Consumer Price Index (CPI) and Employment situation. Furthermore, their results also indicate that aggregate volume in index options would have predictive power over absolute returns of the S&P 500 index on trading days associated with announcement of CPI and Employment situation.

The presence of information asymmetries and informed trading in index derivatives markets has important implications to different market participants. From the point of view of speculators, if the process by which the prices adjust to information is not immediate, past trading activity could be informative of the future process of returns. On the other hand, the adverse-selection risk caused by informal trades could also imply extra transaction cost to

uninformed market participants who trade for example for hedging reasons. Given that the modern index option markets are dominated by traders who trade for hedging purposes (e.g., Whaley, 2009), such extra transaction costs are certainly of economic importance. The presence of informed trading is also of a significant interest to policy makers and regulators who monitor market activities.

1.1 Objectives and contribution

In this thesis, I contribute to the literature investigating the existence of information asymmetries and exploitation of private information in equity index derivatives markets by expanding the recent empirical study by Roll, Schwartz, and Subrahmanyam (2012) in a several dimensions. In particular, by using a different research design I aim to provide additional evidence whether the aggregate trading volume in the S&P 500 index derivatives potentially favored by informed investors is abnormally high preceding informational announcements of a macroeconomic nature and whether such volume series have any predictive power over the absolute returns of the S&P 500 index. In addition to S&P 500 cash index options (index options) analyzed in Roll, Schwartz, and Subrahmanyam (2012), I also consider two recent product innovations which have gained enormous popularity recently in terms of contracts traded, namely options on the S&P 500 (SPDR) ETF (ETF options) and options on the widely-cited S&P 500 implied volatility index published by CBOE (VIX options).[2] Finally, this study considers only the very recent time-period from January 2009 to September 2012 in contrast to earlier period from January 1997 to December 2009 analyzed by Roll, Schwartz, and Subrahmanyam (2012).

To the best of my knowledge, this study also represents the first attempt to analyze the trading volume and its informational role (if any) in ETF options and VIX options. Consequently, the present study contributes to longstanding strand of empirical literature investigating the relation between volume and price changes and time-series regularities in trading volume. This literature is fairly abundant, and it has largely ignored the volume in equity derivatives (notable exceptions include e.g., Bessembinder and Seguin, 1992; Bessembinder, Chan, and Seguin, 1996; Roll, Schwartz, and Subrahmanyam, 2012). For instance, number of empirical papers has documented a positive relation between aggregate equity volume and absolute

[2] The CBOE Volatility Index (VIX) is a measure of market expectations of 30-day expected volatility of the S&P 500 Index conveyed by S&P 500 index option prices. See further information from the website of the CBOE: http://www.cboe.com.

market-wide returns (see, e.g., Karpoff, 1987; Jain and Joh, 1988; Gallant, Rossi, and Tauchen, 1992). In another influential strand of research, Campbell, Grossman, and Wang (1993), Hiemstra and Jones (1994), Gervais, Kaniel, and Mingelgrin (2001), Llorente, Michaely, Saar, and Wang (2002), and Statman, Thorley, and Vorkink (2006) analyze the dynamic relation between equity volume and returns. Jain (1988) and Mitchell and Mulherin (1994) in turn study relation between volume and economic news. Another interesting stream of research documents calendar-based regularities in equity volume. Examples of well-documented regularities include day-of-the-week effects (Jain and Joh, 1988; Lakonishok and Maberly, 1990; Foster and Viswanathan, 1993) and holiday effects (Chordia, Roll, and Subrahmanyam, 2001; Frieder and Subrahmanyam, 2004).

1.2 Hypotheses

To state the previously discussed research objectives formally, I test the following hypotheses:

HYPOTHESIS 1: *Aggregate trading volume in index, ETF and VIX options is abnormally high preceding informational announcements of a macroeconomic nature*

According to Hypothesis 1, informed traders should attempt to exploit their private information preceding informational announcement which would lead to an increase in aggregate trading volume preceding announcements. This prediction is consistent with the informed speculation paradigm by Kyle (1985) in which liquidity or uninformed trading is exogenous and inelastic to price. Additionally, for example He and Wang (1995) develop a multiperiod model of trading volume with private and public information and show that informed investors increase their speculative positions just prior to a public announcement and reduce their positions immediately after the announcement. Consequently, abnormal volume is observed around such announcements. This implies that if Hypothesis 1 is true, it would indicate existence of information asymmetries and presence of agents with private information of a macroeconomic nature in these markets.[3]

[3] I note that rejection of Hypothesis 1 is not however direct evidence against existence of information asymmetries and presence of informed traders in these markets. As noted for example by Chae (2005), if liquidity traders have timing discretion, as in Admati and Pfleiderer (1988) or in Foster and Viswanathan (1990), total trading volume can even decrease before announcements in information asymmetry. In these models, when discretionary liquidity traders receive exogenous trade demands prior to announcements, they will postpone trading until the announcement is made and the information asymmetry is resolved.

HYPOTHESIS 2: *Aggregate trading volume in index, ETF and VIX options has predictive power over absolute returns of the S&P 500 index*

Given that the Hypothesis 1 is true; it is reasonable to hypothesize that trading volume in these products could have predictive power over absolute returns of the S&P 500 index. As argued by Roll, Schwartz, and Subrahmanyam (2012), the total volume does not reveal whether the trade is initiated by a buyer or seller, and thus is not directly related to signed returns. However, if volume represents trading on information, then it could predict absolute returns (especially around informational announcements). Additionally, for example Ni, Pan, and Poteshman (2008) note that options are uniquely suited for investors with information about future volatility. As absolute return is a close proxy for realized volatility, this methodology can also detect informed volatility trading in addition to directional trading.[4]

1.3 Methodology and main results

To test the Hypothesis 1, I regress the detrended daily trading volume series in each option to proxies for announcements of important macroeconomic information (lagged by one trading day) and a broad set of control variables. Motivated by the empirical work by Flannery and Protopapadakis (2002), I assume that the rescheduled macroeconomic announcements on International trade in goods and services, CPI, Producer Price Index (PPI), Employment situation and Housing starts contain relevant information for valuing equities. As in practice it is difficult to link large price movements to any particular news event (see, e.g., Roll, 1988; Cutler, Poterba, and Summers, 1989), I also test whether trading activity is abnormally high preceding trading days associated with abnormally high absolute returns (conditional to past absolute returns). The set of control variables includes concurrent price movements, change in VIX index, and indicator variables for day-of-the-week, for holidays, for expiration-day effects and for rescheduled macroeconomic announcements.

This analysis reveals strong evidence that trading activity in these three products is abnormally high preceding informational events. Considering first the rescheduled

[4] Reader might wonder whether it is sensible to investigate whether volume in contingent claims on implied volatility index of equity index could have predictive power over absolute returns of the equity index itself. However, given that daily absolute returns in S&P 500 index and absolute changes in VIX index are strongly correlated contemporaneously (the correlation between these series is approximately 0.73 over the period from January 2009 to September 2012), I consider this approach to be feasible starting point in investigating the relative informational role of these markets in lack of further theoretical guidance.

macroeconomic announcements, the results suggest that trading volume on trading days *preceding* these five announcements is approximately 9-16 percent higher compared to other trading days. In addition, results also suggest that trading volume is also abnormally high preceding trading days associated with unexpectedly high absolute returns. In light of the informed speculation paradigm by Kyle (1985), these results indicate existence of information asymmetries and presence of agents with private information of a macroeconomic nature in each of these markets.

The coefficient estimates for control variables largely confirm the patterns documented in the earlier empirical work, but few results are worth of mentioning. Firstly, the volume in ETF options appears to exhibit exceptional day-of-the-week pattern with gradually increasing volume over the week towards the weekend. In light of Foster and Viswanathan (1990), this suggests that accumulation of private information over a weekend has particularly strong impact to trading activity of ETF options. Additionally, ETF options appear to exhibit strongest relation with absolute returns of the S&P 500 index and daily changes in VIX index, indicating that volume in ETF options is also most sensitive to informational flows (e.g., Andersen, 1996).

To test the Hypothesis 2, I first perform predictive regression in which the whitened daily absolute return of the S&P 500 index is regressed on the sum of lagged detrended volumes up to three days for each of the volume series. This approach is motivated by the work by Roll, Schwartz, and Subrahmanyam (2012). I also consider alternative framework which includes estimating a (reduced form) vector autoregressive (VAR) model in which the three volume series, absolute returns of the S&P 500 index, and VIX index are endogenous variables and calculate the joint coefficient restrictions representing the (linear) Granger causality test.

The results from predictive regression suggest that only the volume in ETF options has predictive power over the absolute returns of the S&P 500 index. Furthermore, the results from Granger causality analysis confirm that only the volume in ETF options predicts shifts in the absolute returns. Interestingly, these results also suggest that only the volume in ETF options predicts shifts in the VIX index. Taken in totality, the picture that emerges from the analysis of the predictive role of the volume series is that ETF options dominate index options and VIX options in price formation.

I note that the total explanatory power of the model employed to predict whitened absolute returns of the S&P 500 index accords with a market that is quite efficient, with adjusted R^{2}'s ranging from 2 percent to 4 percent. However, my findings do not rule out the possibility that for example more detailed transaction level data for these products could be more useful in forecasting absolute returns or volatility of the S&P 500 index; no doubt practitioners will explore these possibilities.

1.4 Structure

The remainder of this thesis is organized as follows. Section 2 presents the data and documents the properties of the continuous time-series utilized in this study. Section 3 presents the regression intended to detect the abnormal trading volume preceding informational announcements. Section 4 describes the role of volume series in predicting absolute returns. Section 5 offers conclusions and suggestions for future research. Finally, Section 6 lists the references.

2. Data

This Section introduces the main data used in this study. The first subsection describes the sample selection procedure and presents the data sources. The second subsection discusses the data adjustments methodologies and reports the properties of the continuous time-series utilized in this study.

2.1 Sample selection and data sources

The continuous time-series data required in this study consist of daily observations of trading volume in S&P 500 cash index options (index options), trading volume in S&P 500 SPDR ETF options (ETF options), trading volume in S&P 500 implied volatility index published by CBOE (VIX options), VIX index and the S&P 500 index.

One challenge in empirical studies of trading volume is that there is exists no theoretically or even empirically agreed-upon measure of trading volume. This statement is particularly true for options and hence the choice of volume measure used in this study is solely guided by the related study of Roll, Schwartz, and Subrahmanyam (2012). As Roll, Schwartz, and Subrahmanyam (2012) point out, using for example dollar volume or delta-weighted volume for options creates a possibility that volume dynamics could be driven by shifts in prices, the measure of trading volume for each three products in this study is simply the total number of contracts traded. Roll, Schwartz, and Subrahmanyam (2012) further note that disaggregating index option data by calls and puts does not lead to any material insights over and above those obtained considering combined call and put volume. Hence the empirical part of this study considers only combined volume in calls and puts. The above defined trading volume series and values of VIX index are collected directly from the website of the CBOE and data on the S&P 500 index is collected from Yahoo Finance. [5]

To test the Hypothesis 1, also proxy for announcement of information relevant for valuing the S&P 500 stocks is needed. Intuitively, most suitable candidates would be the rescheduled macroeconomic announcements. Practical challenge is that the number of different announcements is extensive and theory provides very limited guidance for choosing the most

[5] While index options and VIX options are exclusive products of CBOE, the ETF options are also traded in several other exchanges. For ETF options I anyway consider only volume reported by CBOE to minimize the possibility that the results are influenced by differences in trading protocols.

relevant ones. Arguably, the most comprehensive empirical investigation of the relative informational content of different rescheduled macroeconomic announcements for valuing equities is the study conducted by Flannery and Protopapadakis (2002). These authors test the impact of 17 different macroeconomic announcements to realized returns and conditional variance of NYSE-AMEX-NASDAQ market index over period from 1980 to 1996 and document that only the announcements on International Trade in Goods and Services, CPI, PPI, Employment Situation and New Residential Construction impact either the level of returns or conditional volatility of returns. Consistent with the informational role of these announcements, they also document that only these five announcements are followed by abnormally high volume. Motivated by the empirical work by Flannery and Protopapadakis (2002), I expect that the rescheduled macroeconomic announcements on International Trade in Goods and Services, CPI, PPI, Employment Situation and New Residential Construction contain relevant information for valuing equities. One advantage with this set of announcements is that all the releases are made in the morning before market opening, which allows very straightforward definition of pre-announcement and post-announcement period with daily data. Release dates for these announcements are collected directly from the websites of U.S. Bureau of Economic Analysis, U.S. Bureau of Labor Statistics, and U.S. Census Bureau.

As the VIX options started trading on February 24, 2006, the original sample contained observations for the period February 24, 2006 to September 28, 2012. However, the preliminary descriptive analysis revealed several econometric challenges including strong trend component in the variances of (log-transformed and detrended) trading volume of ETF options and VIX options, especially for the period between 2006 and 2008. In addition, the stock market crash of 2008 was associated with several extreme values in absolute returns of the S&P 500 index. This all can be handled, of course, but rather than getting side-tracked to discussion on how to adjust the series to be able to perform meaningful statistical interference without imposing too much structure to data, I choose to limit the sample to period from January 2009 to September 2012. As will be shown later in this Section, over this time period imposing structure familiar from existing empirical work will be enough to induce stationarity

in the series. Presumably, the most recent empirical evidence is also of a greatest practical importance especially for practitioners.[6]

2.2 Data adjustments and descriptive analysis

Based on existing literature it is expectable that trading volume series are non-stationary due to stochastic trend or seasonal components (Campbell, Grossman, and Wang, 1993; Lo, and Wang, 2000) and daily absolute returns of the S&P 500 index exhibit strong persistency (Ding, Granger, and Engle, 1993; Taylor, 2005). VIX index in turn should contain a unit root by definition. From the purely econometric point of view, it is necessary to have stationary measures of trading volume for the purposes of testing the Hypothesis 1. Intuitively, a measure of abnormal volume should also be a better proxy for informed trading than raw volume. Additionally, given that trading volume and absolute returns are strongly correlated contemporaneously (see, e.g., Karpoff, 1987; Gallant, Rossi, and Tauchen, 1992; Bessembinder, Chan, and Seguin, 1996; Chordia, Roll, and Subrahmanyam, 2001; Roll, Schwartz, and Subrahmanyam, 2012), it is preferable to use a measure of absolute returns which would be difficult to forecast based on its own historical values while testing the Hypothesis 2. Hence, I begin the descriptive analysis by adjusting these series accordingly.

Considering first the volume series, following Mitchell and Mulherin (1994) I detrend each trading volume series by taking natural logarithm and subtracting 20-day trailing average. Although some alternative detrending methods could be proposed,[7] this methodology appears particularly suitable for the purposes of this study. Most importantly, this procedure induces stationarity (as will be illustrated later in this subsection) and uses only past values to identify the trend components. While first-differencing would presumably also yields stationary time-series, my concern is that first-differencing volume series potentially obscures partially the

[6] In unreported tests it was however confirmed that performing tests over the period February 24, 2006 to September 28, 2012 yields qualitatively similar results with the ones reported.

[7] Arguably the most popular detrending methodologies in equity trading volume literature are linear-quadratic detrending and deseasonalization originally proposed and implemented by Gallant, Rossi and Tauchen (1992) or subtracting trailing moving average from the natural logarithm of the series (e.g., Campbell, Grossman, and Wang, 1993; Mitchell and Mulherin (1994); Bessembinder, Chan, and Seguin, 1996; Chen, Hong, and Stein, 2001; Llorente, Michaely, Saar, and Wang, 2002; Chae, 2005; Griffin, Nardari, and Stulz, 2007). Alternatively, for example Chordia, Roll, and Subrahmanyam (2001) study the percentage changes in daily trading volume while Statman, Thorley, and Vorkink (2006) use a detrending method familiar from real business cycle studies and define abnormal trading activity as the stationary component that remains after logged volume series is passed through a Hodrick and Prescott (1997) filter.

cyclical fluctuations possible representing informed trading, which behavior is the primary interest of this study. In addition, the cycle of 20-trading days closely matches the interval of rescheduled macroeconomic announcements and expiration cycle of most options series.

The daily absolute return series of the S&P 500 index is divided to expected and unexpected components. Unexpected component is defined as the residual from whitening regression and expected components as the difference between raw series and unexpected component. The lag length for whitening regression (eight) is chosen based on Hannan and Quinn (1979) criterion. For VIX index, I consider the daily changes (first-difference) in the empirical part of this study.

Fig. 1 - 10 plot the raw and adjusted daily time-series of trading volume in index options, trading volume in ETF options, trading volume in VIX options, absolute returns of the S&P 500 index and VIX index for the period January 2009 to September 2012. As can be seen from the Fig. 1, Fig. 3 and Fig. 5, all the raw volume series appear non-stationary due to slow-moving cyclical components. Volume in VIX options also appears to have trended significantly upward during the sample period. However, the plots of detrended volume series (Fig. 2, Fig. 4 and Fig. 6) do not contain visually observable trend components or seasonal fluctuations, although some persistency is still observable. The unadjusted absolute return series of the S&P 500 index (Fig. 7) exhibits similar cyclical behavior as the raw volume series. This indicates strong persistency and positive correlation with the volume series. Additionally, the well documented property of time-varying variance (heteroscedasticity) is clearly observable from the Fig. 7. The plot of whitened absolute return series (Fig. 8) does not seem to contain notable cyclical fluctuations, although substantial heteroscedasticity is still observable. VIX index (Fig. 9) exhibits unique pattern compared to other series with sudden upward jumps and very slow reversion back to the mean. However, the graph of daily changes in VIX index (Fig. 10) seems very similar with the whitened absolute return series (Fig. 8) with periods associated with several extreme values and high variance on spring 2009, spring 2010 and fall 2011.

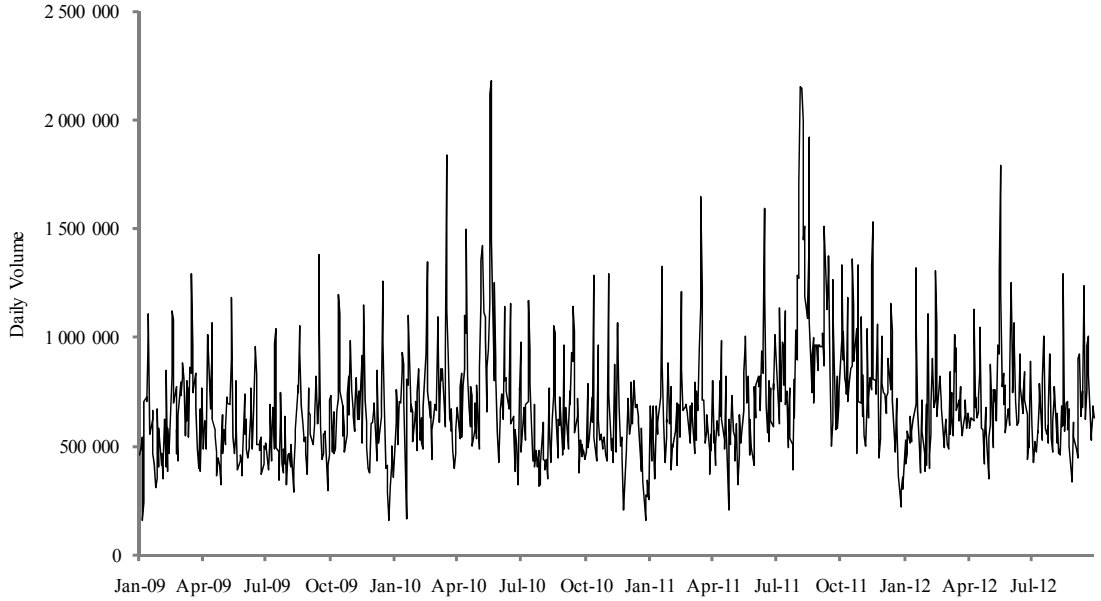

Fig. 1. Volume in S&P 500 index options

This figure plots the daily trading volume in terms of contracts traded for S&P 500 (cash) index options from January 2009 to September 2012.

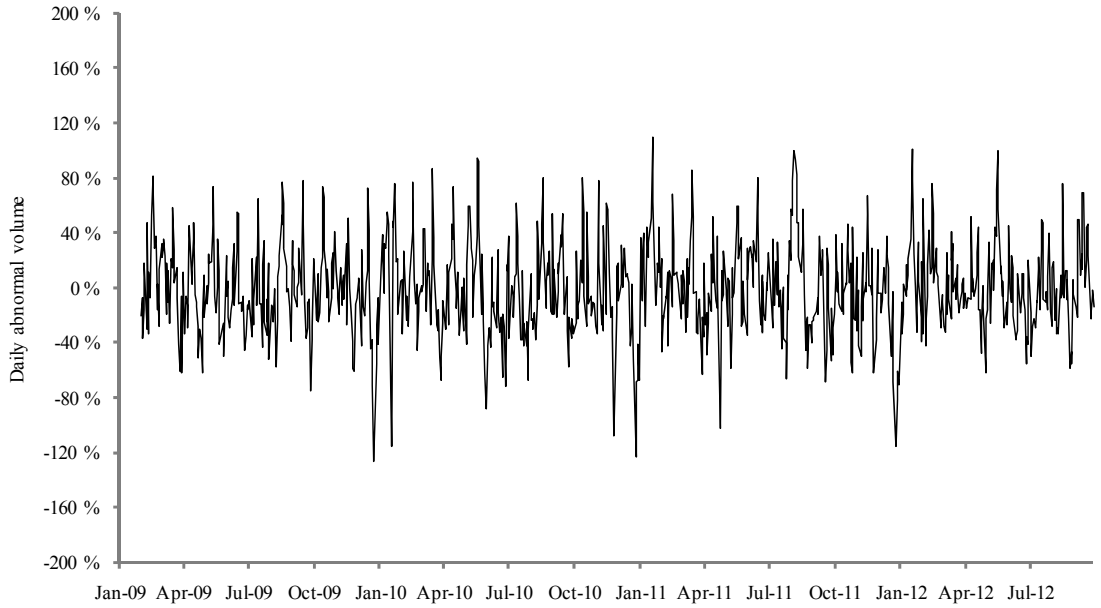

Fig. 2. Detrended volume in S&P 500 index options

This figure plots the daily detrended trading volume in S&P 500 (cash) index options from January 2009 to September 2012. Volume series is detrended by taking natural logarithm and subtracting 20-day trailing average.

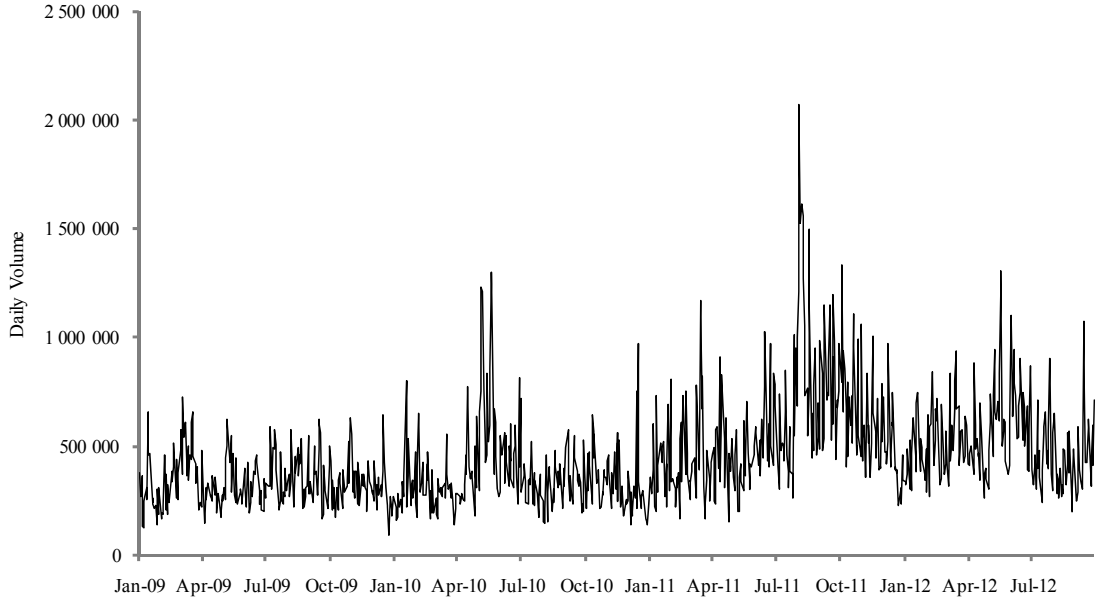

Fig. 3. Volume in S&P 500 ETF options

This figure plots the daily trading volume in terms of contracts traded for S&P 500 (SPDR) ETF options from January 2009 to September 2012.

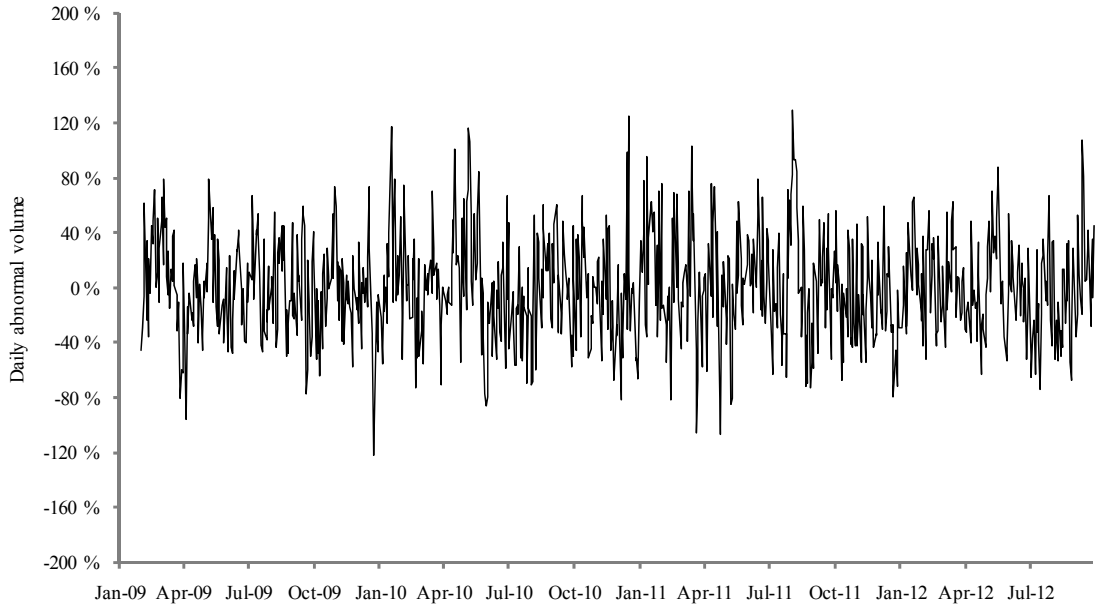

Fig. 4. Detrended volume in S&P 500 ETF options

This figure plots the daily detrended trading volume in S&P 500 (SPDR) ETF options from January 2009 to September 2012. Volume series is detrended by taking natural logarithm and subtracting 20-day trailing average.

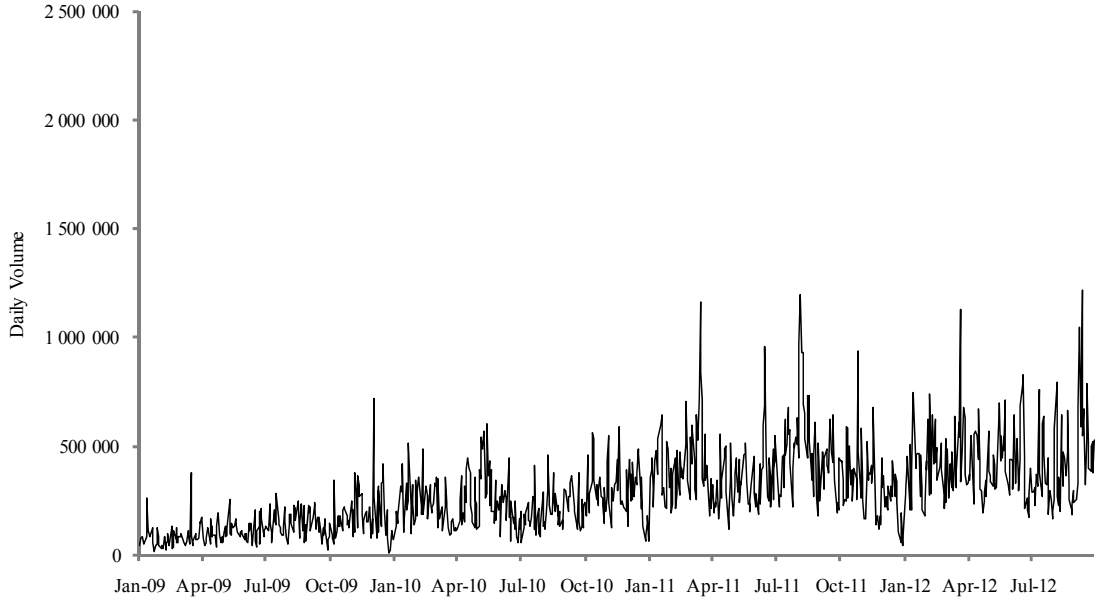

Fig. 5. Volume in VIX options

This figure plots the daily trading volume in terms of contracts traded for VIX options from January 2009 to September 2012.

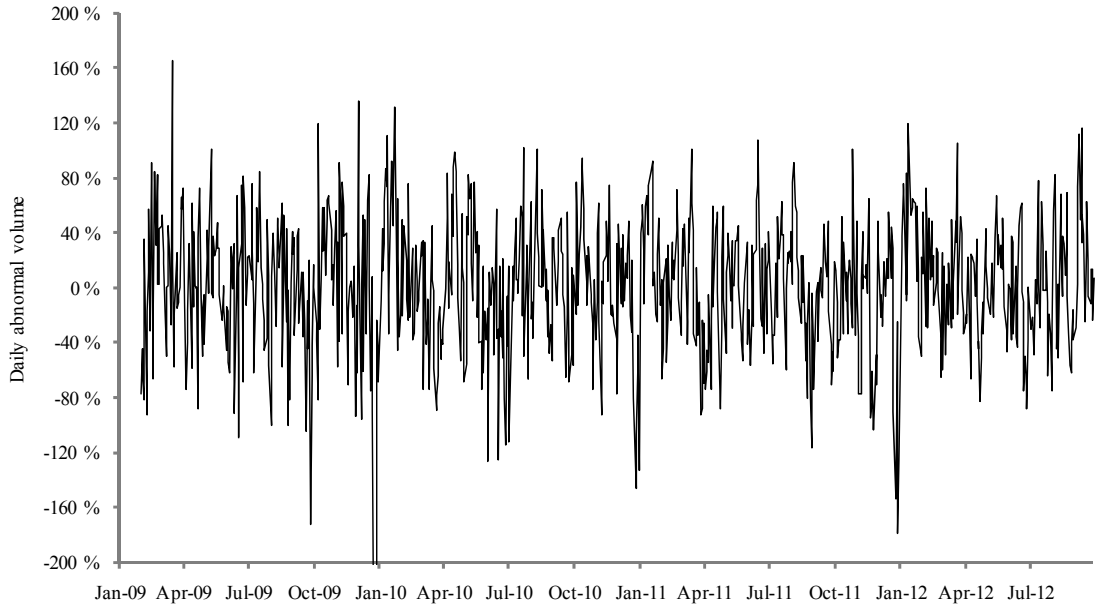

Fig. 6. Detrended volume in VIX options

This figure plots the daily detrended trading volume in VIX options from January 2009 to September 2012. Volume series is detrended by taking natural logarithm and subtracting 20-day trailing average.

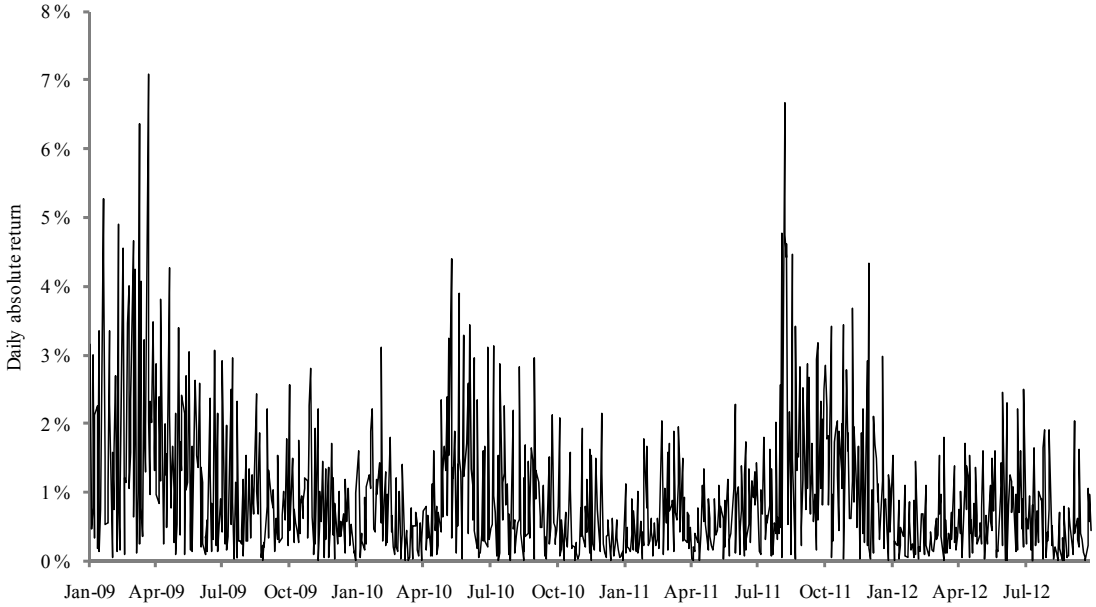

Fig. 7. Absolute return of the S&P 500 index

This figure plots the daily absolute return of the S&P 500 index from January 2009 to September 2012.

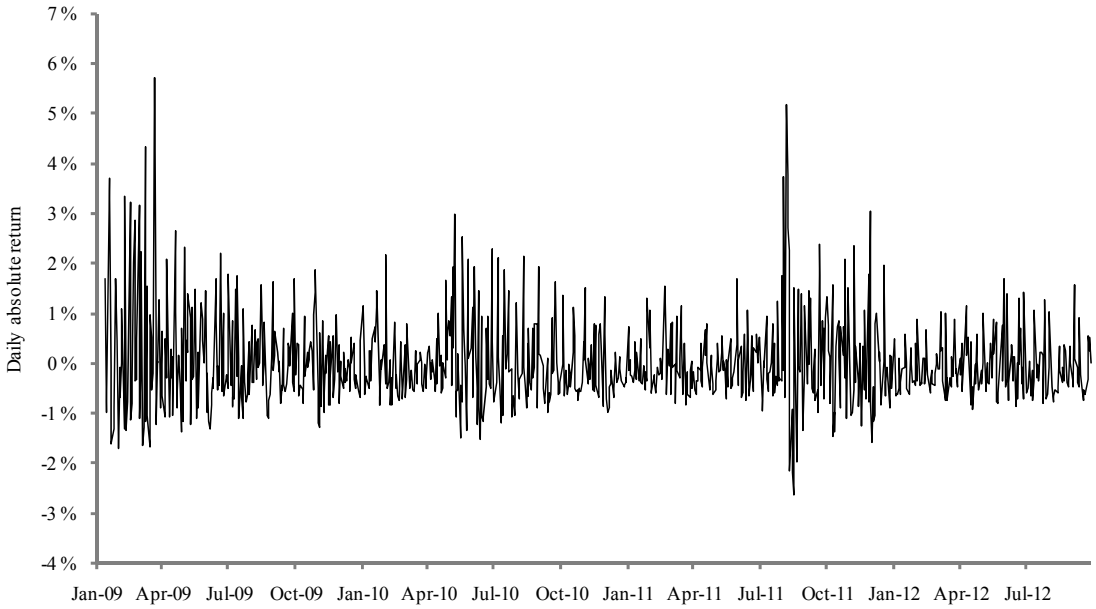

Fig. 8. Whitened absolute return of the S&P 500 index

This figure plots the whitened daily absolute returns of the S&P 500 index from January 2009 to September 2012. The lag length for whitening regression (eight) is chosen based on Hannan and Quinn (1979) criterion.

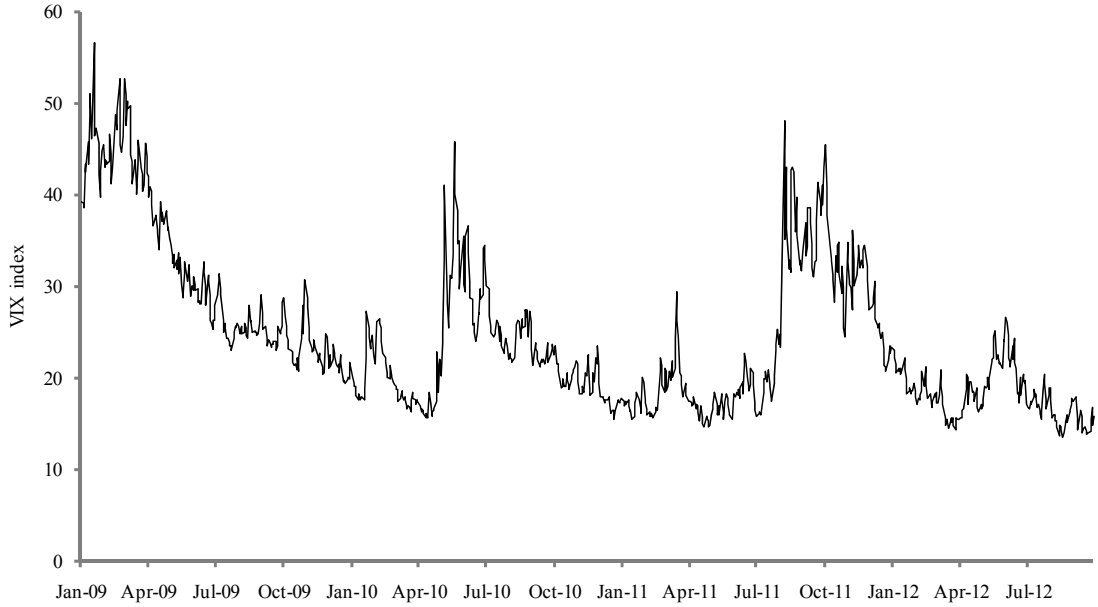

Fig. 9. VIX index

This figure plots the daily values of CBOE Volatility Index (VIX) from January 2009 to September 2012. VIX is quoted in percentage points and measures market expectations of annualized 30-day expected volatility of the S&P 500 index conveyed by S&P 500 index option prices.

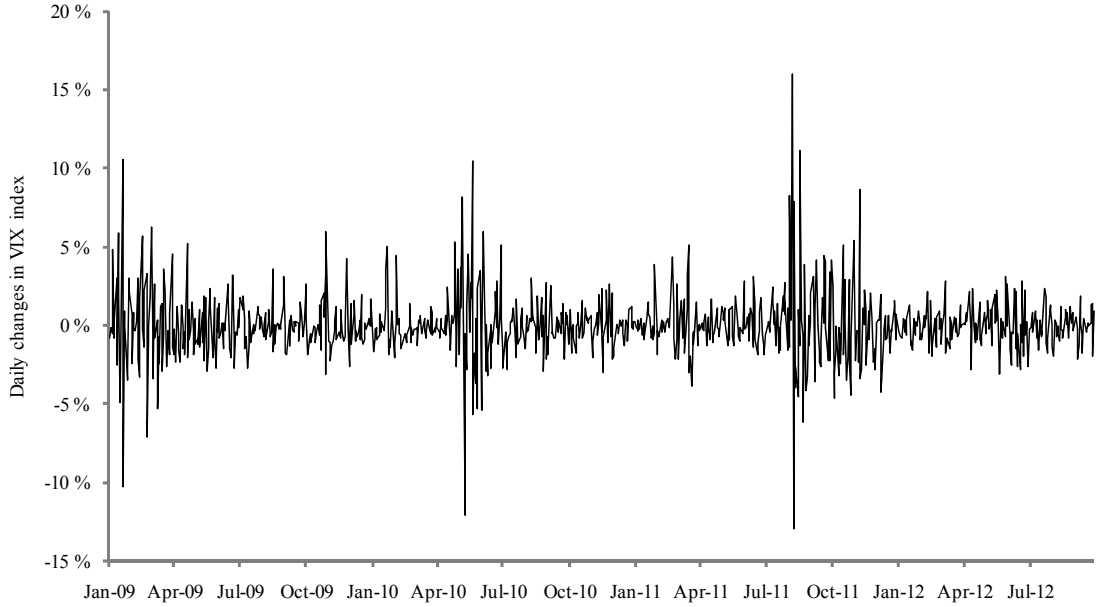

Fig. 10. Daily changes in VIX index

This figure plots the first difference in daily values of VIX index from January 2009 to December 2012.

Table 1 reports selected descriptive statistics for raw and detrended daily contract volumes in index options, ETF options, VIX options, for absolute returns of the S&P 500 and its unexpected component, and for VIX index and the daily change in VIX index. The last two columns of Table 1 also report the test statistics allowing constant in the test equation of augmented Dickey-Fuller (1979) (ADF) test of a unit root null versus stationary and Kwiatkowski, Phillips, Schmidt and Shin (1992) Lagrange Multiplier (KPSS) test of stationary null versus unit root.

Considering first the raw volume series, in terms of contracts traded the index options have the highest average volume (699 634), ETF options have the second highest (448 356), while VIX options have the lowest (291 998). However, while comparing the economic importance of these three products few factors need to be considered. Firstly, the notional contract size of index option is 10 times that of the ETF option. Precisely, the multiplier of index options is $100. Given that the average of the daily closing values of the S&P 500 index in 2011 was 1268, this indicates approximate notional size of $126 800 per contract during 2011. On the other hand, ETF options are traded in several exchanges while this study considers only volume reported by CBOE. According to the website of The Options Clearing Corporation, the total number of cleared ETF options contracts in 2011 was approximately 730 million. CBOE's portion was approximately 146 million contracts, indicating market share of 20 percent for CBOE. The multiplier of VIX options is $100, suggesting notional size of approximately $2 420 per contract during 2011.

As can be seen from Table 1, all the raw volume time-series appear to be plagued by well known econometric problems including substantial departure from normal distribution due to positive skewness and high kurtosis. All the series also appear to be highly persistent with fifth order autocorrelations ranging from 0.48 for VIX options to 0.20 for index options. Although substantial positive serial correlation is an expectable property of trading volume based on existing theoretical work (e.g., Harris and Raviv, 1993; Wang, 1994; Banerjee and Kremer 2010), it is also an indication of nonstationarity. Indeed, while the ADF test results suggest that none of the volume series contains a unit root, the KPSS test rejects the stationary null for all the raw volume series. These properties confirm that for the purposes of this study it is necessary to log transform the raw volume series to address the skewness and further detrend the log transformed series to address the trends and slow moving seasonal components observable from the Fig.1, Fig.3 and Fig. 5.

I will next discuss about the properties of the detrended volume series. As could be expected, the means are very close to zero. The standard deviations appear quite high comparing to figures reported for aggregate equity volume (e.g., Campbell, Grossman, and Wang, 1993; Chordia, Roll, and Subrahmanyam, 2001), possibly due to higher sensitivity of derivatives to informational flows (Roll, Schwartz, and Subrahmanyam, 2012). Skewness and kurtosis figures indicate that detrended volume series exhibit only modest departure from normal distribution with skewness ranging from -0.46 for VIX options to 0.22 for ETF options and kurtosis from 3.16 for ETF options to 4.46 for VIX options. Fortunately, the KPSS test also accepts the stationary null for all three volume series, although positive autocorrelation is still present.

The absolute returns exhibit patterns expectable based on earlier literature, most notably strong persistency. Interestingly, the fifth order autocorrelation (0.25) is even larger than the first order autocorrelation (0.11). As could be perhaps expected, the ADF test rejects the unit root null while the KPSS also test rejects the stationary null. The whitened absolute return series appears to have very low autocorrelation and the ADF and KPSS tests formally confirm that the series is stationary. However, the whitened absolute returns exhibit substantial departure from normal distribution due to positive skewness (1.63) and high kurtosis (8.22), suggesting that standard test statistics for OLS regression with whitened absolute return series as a dependent variable should be interpreted with caution.

Table 1. Descriptive statistics

This table reports the selected descriptive statistics for raw and detrended daily contract volumes in S&P 500 (cash) index options (Index options), S&P 500 ETF (SPDR) options (ETF options), options on the CBOE Volatility Index (VIX options), for absolute returns of the S&P 500 index (|RET|) and its unexpected component (Unexpected |RET|), and for the CBOE Volatility Index (VIX index) and the daily change in VIX index. The volume series are detrended by taking natural logarithm and subtracting 20-day trailing average. The unexpected component of the absolute returns of the S&P 500 index equals the residual from whitening regression with eight lags. The last two columns report the test statistics allowing constant in the test equation of augmented Dickey-Fuller (1979) test of a unit root null versus stationary and Kwiatkowski, Phillips, Schmidt and Shin (1992) Lagrange Multiplier test of stationary null versus unit root. Test statistics indicating nonstationarity at five percent level are indicated by bolding. The time-period is January 2009 through September 2012.

	Statistic							
Series	Mean	St.dev	Skewness	Kurtosis	AC1	AC5	ADF t-stat.	KPSS LM-stat.
Panel A: Index options								
Raw volume	699 634	271 952	1.63	7.62	0.60	0.20	-15.27	**0.55**
Detrended volume	0.00	0.34	0.13	3.69	0.49	0.05	-17.73	0.02
Panel B: ETF options								
Raw volume	448 356	228 660	1.86	8.63	0.57	0.43	-4.23	**1.82**
Detrended volume	0.01	0.38	0.22	3.16	0.30	0.15	-12.53	0.02
Panel C: VIX options								
Raw volume	291 998	183 404	1.21	5.41	0.66	0.48	-6.18	**3.31**
Detrended volume	0.02	0.48	-0.46	4.46	0.35	0.05	-21.21	0.04
Panel D: S&P 500 index								
|RET|	0.01	0.01	2.08	8.94	0.11	0.25	-6.35	**0.68**
Unexpected |RET|	0.00	0.01	1.63	8.22	0.00	-0.03	-30.65	0.34
Panel E: VIX index								
Raw	24.35	8.28	1.23	3.97	0.97	0.90	**-3.03**	**1.13**
First-differenced	0.00	0.02	0.86	14.11	-0.18	-0.05	-21.60	0.06

Table 2 provides the correlation matrix for detrended daily contract volumes in index options, ETF options and VIX options, for daily absolute returns of the S&P 500 index and its unexpected component, and for daily change in VIX index. Confirming our intuition based on the time-series plots of these series, all the series are positively correlated with each other. Volume series are strongly correlated with each other, particularly the index options and ETF options (0.58). Volume series also exhibit substantial correlation with the absolute returns of the S&P 500 index, particularly with its unexpected component. Consistent with Roll,

Schwartz, and Subrahmanyam (2012), the volume series, particularly the one of ETF options, also appear to be positively related to the changes in volatility expectations, i.e. changes in VIX index. Notice also the relatively low correlation between changes in VIX index and absolute returns (0.15). However, it should be noticed that absolute returns proxy the realized volatility over the day while daily changes in VIX represent the change in market expectations of 30-day volatility.

Table 2. Correlation matrix of continuous time-series

This table reports the correlation matrix for detrended daily contract volumes in S&P 500 (cash) index options (Index vol.), S&P 500 ETF (SPDR) options (ETF vol.), options on the CBOE Volatility Index (VIX vol.), for absolute returns of the S&P 500 index (|RET|) and its unexpected component (Unexpected |RET|), and for the daily change in the CBOE Volatility Index (ΔVIX). The volume series are detrended by taking natural logarithm and subtracting 20-day trailing average. The unexpected component of the absolute returns of the S&P 500 index equals the residual from whitening regression with eight lags. The time-period is January 2009 through September 2012.

Variable	Index vol.	ETF vol.	VIX vol.	|RET|	Unexpected |RET|	Δ VIX
Index vol.						
ETF vol.	0.58					
VIX vol.	0.44	0.36				
|RET|	0.23	0.25	0.17			
Unexpected |RET|	0.26	0.31	0.20	0.90		
Δ VIX	0.09	0.16	0.05	0.15	0.18	

3. Abnormal volume preceding informational announcements

In this Section, I test whether the detrended trading volume as defined in the previous Section in index, ETF, or VIX options is abnormally high preceding informational announcements of a macroeconomic nature (Hypothesis 1). As discussed in the introductory part of this thesis, if informed traders attempt to exploit their private information preceding informational announcement this could lead to an increase in aggregate trading volume preceding announcements. Theoretical support for this prediction can be found for example in Kyle (1985) and He and Wang (1995). However, it should be noted that rejection of the Hypothesis 1 is not direct evidence against existence of information asymmetries in these markets. As noted by Chae (2005), if liquidity traders have timing discretion, as in Admati and Pfleiderer (1988) or in Foster and Viswanathan (1990), total trading volume can even decrease before announcements in information asymmetry as discretionary liquidity traders potentially postpone trading until the announcement is made and the information asymmetry is resolved.

The method used to test the Hypothesis 1 involves the OLS regression estimated at the daily frequency where the dependent variable is the detrended trading volume measure and explanatory variables include indicator variables for announcements of relevant macroeconomic information for valuing S&P 500 equities. Although relatively straightforward, the research design must still deal with some obvious estimation problems including the sharp definition of indicator variables for pre-informational announcements and variables to control for the part of trading volume potentially driven by other factors than the level of asymmetric information. I will next discuss each of these issues in turn.

3.1 Definition of explanatory variables

As already discussed in the previous Section, intuitively the most suitable candidates for proxies for announcement of public information relevant for valuing S&P 500 stocks would be the rescheduled macroeconomic announcements. Motivated by the empirical work by Flannery and Protopapadakis (2002), I consider only the rescheduled macroeconomic announcements on International Trade in Goods and Services, CPI, PPI, Employment Situation and New Residential Construction. Obvious advantage with this set of announcements is that all the releases are made in the morning before market opening, which allows very straightforward definition of pre-announcement and post-announcement period

with daily data. Although the relative importance of these announcements and its potential time variation remains poorly understood, and would be interesting empirical question itself, I consider it necessary to stack all of these announcements together for the purposes of this study due to the somewhat small sample size.

To test the existence of abnormal trading volume before these announcements, I include indicator variable in the model which equals one on trading days preceding any of these announcements and zero otherwise. Given that these announcements occasionally occur on consecutive days, and that trading volume on announcements days can also increase due to other reasons than existence of private information (see, e.g., Harris and Raviv, 1993; Kandel and Pearson, 1995; Banerjee and Kremer, 2010), as control I include also a indicator variable that equals one on the announcement dates and zero otherwise. As in practice it is difficult to link large price movements to any particular news event (Roll, 1988; Cutler, Poterba, and Summers, 1989), as a robustness check I also test whether trading activity is abnormally high preceding trading days associated with abnormally high absolute returns. To test this effect, I further include indicator variable that takes value of one preceding trading days when the unexpected component of the absolute returns of the S&P 500 index (as defined in the previous Section) exceeds 0.02, and zero otherwise.

Trading volume is also well known to be driven by factors other than the level of asymmetric information. A contemporaneous price change is intuitively the most important factor, as recent market moves could trigger changes in investor expectations while also prompting changes in optimal asset allocation. This intuition is also supported by strand of theoretical literature (e.g., Harris and Raviv, 1993; Wang, 1994; Andersen, 1996; Suominen, 2001; Banerjee and Kremer 2010) and vast empirical evidence.[8] Additionally, for example in Suominen (2001), unexpected volume and unexpected price variability are positively correlated while correlation between unexpected volume and expected price variability can be either positive or negative, suggesting that disaggregating absolute returns to expected and unexpected components could increase the explanatory power of the model and hence power in testing the Hypothesis 1. To control for these effects, I include the measures of both unexpected and expected components of absolute returns. As trading volume could also be

[8] See for example Jain and Joh, 1988, Bessembinder and Seguin, 1992, Gallant, Rossi, and Tauchen (1992), Bessembinder, Chan, and Seguin (1996), Chordia, Roll, and Subrahmanyam (2001). Summary of the earlier evidence can be found in Karpoff (1987).

correlated with changes in volatility expectations (Kyle, 1985; Roll, Schwartz, and Subrahmanyam, 2012), also the first-difference in VIX index is included.

Trading activity is also known to exhibit predictable day-of-the-week patterns, potentially due to day-of-the-week effect in processing information (Osborne, 1962), accumulation of private information over a weekend (Foster and Viswanathan, 1990), or day-of-the-week pattern in opportunity cost of devoting time to trading decisions (Chordia, Roll, and Subrahmanyam, 2001). Jain and Joh (1988) appear to be the first to provide formal empirical evidence for day-of-the-week seasonal pattern in aggregate equity volume. They document that on the period between 1979 and 1983, Mondays have the lowest volume, and the most active periods are in the middle of the week. Lakonishok and Maberly (1990) further show that volume from individuals is larger but institutional volume is smaller on Mondays. Foster and Viswanathan (1993) and Bessembinder, Chan, and Seguin (1996) provide further evidence by documenting that Monday's trading volume drop seems to be larger for actively traded firms and companies with higher market capitalization which are presumably preferred by institutions and other professional investors. In a recent paper, Roll, Schwartz, and Subrahmanyam (2012) document that also the trading volume in S&P 500 index derivatives (options, the legacy and E-mini futures contracts and the ETF) is abnormally low on Mondays during 1997-2009. Given that for example announcements of Employment situation generally occur on Fridays, it is necessary to control for these day-of-the-week effects in volume. To do this, I include indicator variables for days of the week (with Wednesday omitted) in the model.

Chordia, Roll, and Subrahmanyam (2001) and Frieder and Subrahmanyam (2004) propose that in addition to the weekly cycle the trading activity could also vary around holidays due to the variations in the opportunity cost of devoting time to trading decisions (or executing trades). In their comprehensive study on the time-series determinants of aggregate equity trading activity and liquidity, Chordia, Roll, and Subrahmanyam (2001) document that on the period between 1988 and 1998 the aggregate trading activity of NYSE is approximately 7-11 percent lower on trading days around U.S. national holidays than on regular trading days. To capture such effects, I include an indicator variable on trading days immediately preceding or following a national holiday accompanied by an extra rescheduled closing of CBOE.[9] Furthermore, additional indicator variable is included on those trading days associated with

[9] These include New Year's Day, Martin Luther King, Jr. Day, Washington's Birthday, Good Friday, Memorial Day, Independence Day, Labor Day, Thanksgiving Day, and Christmas Day.

early close of the exchange (Black Fridays 2009-2011 and Christmas Eve 2009). This information is collected from the CBOE trading calendars available in the CBOE website.

The last set of control variables relates to expiration-day effects. Empirical evidence in Stoll and Whaley (1987), Mitchell and Mulherin (1994), and Roll, Schwartz, and Subrahmanyam (2012) strongly suggest that trading volume in index options around contract expiration could be extremely high for non-informational reasons. Given that expirations generally occur on same weekdays, it is preferable to control for such effects to avoid spurious results.[10] To capture these effects I include indicator variables for the last trading day and trading day immediately following last trading day. This information is collected from the CBOE trading calendars available in the CBOE website.

To summarize the above discussion, the explanatory variables in the OLS regression are:

Pre-announcement: 1.0 on trading days preceding rescheduled announcement on International Trade in Goods and Services, CPI, PPI, Employment Situation or New Residential Construction and zero otherwise.

Post-announcement: 1.0 on trading days associated with rescheduled announcement on International Trade in Goods and Services, CPI, PPI, Employment Situation or New Residential Construction and zero otherwise.

Pre-high $|RET|$: 1.0 on trading days preceding trading days when the value of whitened absolute return of the S&P 500 index is larger than 0.02 and zero otherwise.

Expected $|RET|$: the difference between absolute return of the S&P 500 index and the whitened absolute return of the S&P 500 index.

Unexpected $|RET|$: the value of whitened absolute return of the S&P 500 index

Δ *VIX*: the concurrent daily change in VIX index

Monday-Friday: 1.0 if the trading day is a Monday, Tuesday, Thursday, or Friday, and zero otherwise.

[10] The ETF options follow generally the same expiration cycle with standard equity options with last trading day on the third Friday of the expiration month. Last trading day for index options is generally the third Thursday of the expiration month. The last trading day for VIX options in turn is the Tuesday that is thirty days prior to the third Friday of the calendar month immediately following the expiring month.

Pre-holiday: 1.0 on the trading days immediately preceding a national holiday associated with a rescheduled extra market closing and zero otherwise.

Post-holiday: 1.0 on the trading days immediately following a national holiday associated with a rescheduled extra market closing and zero otherwise.

Early close: 1.0 on Black Friday or Christmas Eve (if trading day) and zero otherwise.

Pre-expiration: 1.0 on the last trading day of the particular month and zero otherwise.

Post-expiration: 1.0 on the trading day immediately following the last trading day of the particular month and zero otherwise.

Table 3 reports the correlations of these explanatory variables. Rescheduled announcements of macroeconomic information tend to take place on Fridays, as demonstrated by positive correlation between Friday and Post-announcement (0.21).[11] Pre-high |RET| is positively correlated with Δ VIX, indicating that VIX could have some forecasting power over absolute returns. Interestingly, Δ VIX is also positively correlated with Monday and Post-holiday, suggesting that volatility expectations tend to increase after longer market closings.

[11] To be exact, these figures represent the tendency of announcements of Employment situation to occur on Fridays. During the period from January 2009 to September 2012, 41 out 44 of these announcements took place on Friday.

Table 3. Correlations of explanatory variables in Table 4 regressions

This table reports the correlations of explanatory variables in Table 4 regressions. *Explanatory variables* are: *Pre(Post)-announcement*: a variable that takes on value of 1.0 on a trading days preceding (associated with) rescheduled announcement on International Trade in Goods and Services, CPI, PPI, Employment Situation or New Residential Construction and zero otherwise; *Pre-high |RET|*: a variable that takes on value of 1.0 on trading days preceding trading days when the value of whitened absolute return of the S&P 500 index is larger than 0.02 and zero otherwise; *Expected |RET|*: the difference between absolute return of the S&P 500 index and the whitened absolute return of the S&P 500 index; *Unexpected |RET|*: the value of whitened absolute return of the S&P 500 index; *Δ VIX*: the concurrent daily change in VIX index; *Monday-Friday*: four variables that take on value of 1.0 if the trading day is, respectively, Monday, Tuesday, Thursday or Friday, and zero otherwise; *Pre(Post)-holiday:* a variable that takes on value of 1.0 on trading days immediately preceding (following) a national holiday accompanied by an extra rescheduled market closing and zero otherwise; *Early close*: a variable that takes on a value of 1.0 on Black Friday and on Christmas Eve and zero otherwise; *Pre-expiration:* a variable that takes on value of 1.0 on the last trading day of the particular month for S&P 500 ETF (SPDR) options and zero otherwise; *Post-expiration:* a variable that takes on value of 1.0 on the trading day immediately following the last trading day of the particular month for S&P 500 ETF (SPDR) options and zero otherwise. The time-period is January 2009 through September 2012. # of observation refers to number of observation involved in the regressions.

	Pre-announcement	Post-announcement	Pre-high |RET|	Expected |RET	Unexpected |RET|	Δ VIX	Monday	Tuesday	Thursday	Friday	Pre-holiday	Post-holiday	Early close	Pre-expiration	Post-expiration
Post-announcement	0.06														
Pre-high |RET|	-0.05	-0.02													
Expected |RET|	0.04	0.01	0.19												
Unexpected |RET|	0.02	-0.02	0.05	0.00											
Δ VIX	0.05	-0.04	0.08	-0.02	0.18										
Monday	0.02	-0.23	-0.01	0.01	0.02	0.06									
Tuesday	-0.02	-0.01	0.00	-0.01	0.02	-0.01	-0.24								
Thursday	0.21	0.04	-0.09	0.01	0.05	-0.01	-0.24	-0.26							
Friday	-0.26	0.21	0.06	0.00	-0.07	-0.02	-0.24	-0.25	-0.25						
Pre-holiday	-0.07	0.04	0.03	-0.03	0.01	-0.01	-0.09	-0.08	0.02	0.21					
Post-holiday	0.00	-0.07	0.03	-0.05	0.06	0.12	0.04	0.19	-0.08	-0.05	-0.04				
Early close	-0.03	-0.03	-0.01	-0.02	0.00	0.06	-0.03	-0.03	0.01	0.09	0.08	0.25			
Pre-expiration	-0.12	0.09	0.10	-0.01	-0.06	-0.06	-0.11	-0.11	-0.04	0.38	0.07	-0.04	-0.01		
Post-expiration	0.02	-0.12	0.02	-0.01	0.08	0.04	0.34	-0.07	-0.11	-0.04	-0.04	0.07	-0.01	-0.05	
# of observations	200	200	30	925	925	925	172	191	188	183	32	32	4	44	44

3.2 Regression results

Table 2 presents the results for regressing the detrended contract volumes in index options, ETF options and VIX options on the explanatory variables defined in the previous subsection. The reported t-statistics are heteroscedasticity and autocorrelation-consistent (HAC) t-statistics computed as per Newey and West (1987).[12] The Durbin-Watson statistic and the adjusted R^2 are reported for each three regressions in the last two rows of the Table 2. I will next discuss the effects of each individual explanatory variable.

In light of the Hypothesis 1, it should be first noted that the coefficient estimates for Pre-announcement are positive and statistically significant at the one percent level for all volume series. The coefficients are also economically significant, ranging from 0.091 for ETF options to 0.159 for VIX options, suggesting that trading volume in these products is 9-16 percent higher on trading days immediately preceding the rescheduled announcement on International Trade in Goods and Services, CPI, PPI, Employment Situation and New Residential Construction compared to other days. These results, albeit surprisingly strong, are much in line with the few previous empirical studies which investigate the behavior of trading volume preceding rescheduled macroeconomic announcements.

[12] As suggested by Newey and West (1994), the lag-length is set to equal integer portion of $4(T/100)^{2/9}$, where T refers to the number of observations. This suggests using lag length of seven.

Table 4. Time-series regressions of volume series

Dependent variables are the detrended total contract volumes in S&P 500 (cash) index options (index options), S&P 500 ETF (SPDR) options (ETF options) and options on the CBOE Volatility Index (VIX options). The volume series are detrended by taking natural logarithm and subtracting 20-day trailing average. *Explanatory variables* are: *Pre(Post)-announcement*: a variable that takes on value of 1.0 on a trading days preceding (associated with) rescheduled announcement on International Trade in Goods and Services, CPI, PPI, Employment Situation or New Residential Construction and zero otherwise; *Pre-high |RET|*: a variable that takes on value of 1.0 on trading days preceding trading days when the value of whitened absolute return of the S&P 500 index is larger than 0.02 and zero otherwise; *Expected |RET|*: the difference between absolute return of the S&P 500 index and the whitened absolute return of the S&P 500 index; *Unexpected |RET|*: the value of whitened absolute return of the S&P 500 index; *Δ VIX*: the concurrent daily change in VIX index; *Monday-Friday*: four variables that take on value of 1.0 if the trading day is, respectively, Monday, Tuesday, Thursday or Friday, and zero otherwise; *Pre(Post)-holiday:* a variable that takes on value of 1.0 on trading days immediately preceding (following) a national holiday accompanied by an extra rescheduled market closing and zero otherwise; *Early close*: a variable that takes on a value of 1.0 on Black Friday and on Christmas Eve and zero otherwise; *Pre-expiration:* a variable that takes on value of 1.0 on the last trading day of the particular month and zero otherwise; *Post-expiration:* a variable that takes on value of 1.0 on the trading day immediately following the last trading day of the particular month and zero otherwise. Coefficient estimates significantly different from zero at the one (five) percent level are indicated by ** (*). The time-period is January 2009 through September 2012. The Newey and West (1987) method with seven lags corrects the standard errors for heteroscedasticity and autocorrelation in the OLS residuals.

	Index options		ETF options		VIX options	
Explanatory variables	Coefficient	t.stat.	Coefficient	t.stat.	Coefficient	t.stat.
Pre-announcement	0.105 **	4.51	0.091 **	3.16	0.159 **	4.54
Post-announcement	0.113 **	5.39	0.092 **	3.67	0.095 *	2.54
Pre-high |RET|	0.150 *	2.28	0.186 *	2.39	0.106	1.48
Expected |RET|	-3.363	-1.03	-6.960	-1.55	-6.015	-1.30
Unexpected |RET|	10.755 **	10.77	13.729 **	10.16	12.108 **	7.69
Δ VIX	1.139 **	2.58	2.726 **	5.11	0.889	1.64
Monday	-0.091 **	-3.98	-0.193 **	-6.81	-0.238 **	-4.40
Tuesday	0.004	0.18	-0.027	-0.92	0.002	0.04
Thursday	0.039	1.66	0.086 **	3.06	-0.001	-0.03
Friday	0.022	0.97	0.124 **	4.33	0.021	0.50
Pre-holiday	-0.182 **	-3.25	-0.151 **	-2.73	-0.388 **	-3.73
Post-holiday	-0.178 *	-2.25	-0.081	-1.08	-0.186 **	-3.01
Early close	-0.699 **	-4.42	-0.612 **	-3.19	-0.732	-1.64
Pre-expiration	0.351 **	7.40	0.242 **	5.68	0.394 **	6.47
Post-expiration	0.439 **	8.35	0.165 **	3.74	0.373 **	5.36
Intercept	-0.034	-1.02	0.018	0.42	0.048	0.85
Adjusted R^2	0.380		0.319		0.186	
Durbin-Watson stat	1.247		1.537		1.449	

For example, Chordia, Roll, and Subrahmanyam (2001) test the response of daily percentage change in aggregate volume of NYSE equities over the period from 1998 to 1999 to the announcements about GDP, CPI and the Employment situation. These authors find that trading activity increases approximately 7-13 percent prior to announcements of GDP but find no conclusive evidence that aggregate volume of NYSE equities would increase preceding announcements on CPI and Employment situation. The results of this study appear quite

strong compared to those documented by Chordia, Roll, and Subrahmanyam (2001), consistent with the informational role of options and with the propositions by Subrahmanyam (1991) and Gorton and Pennachi (1993). These authors suggest that agents who possess information relevant for valuing large number of equities (e.g., information of a macroeconomic nature) will prefer to trade equity index derivatives, rather than portfolio of multiple equities, for at least two reasons. Firstly, the relative transaction costs for trading portfolio of index component stocks can be higher than those incurred by trading the index derivative. Secondly, the adverse selection costs are higher when trading individual stocks as there is a greater change that the counterparty has firm-specific private information.

Roll, Schwartz, and Subrahmanyam (2012) test the response of daily trading volume series in the cash S&P 500 index and its derivatives (options, the legacy and E-mini futures contracts and the ETF) to the announcements about Gross Domestic Product (GDP), CPI and the Employment situation during 1997-2009. In line with the results of this study, these authors document that trading activity in index options is 8.6 percent higher than on other trading days during five trading days preceding announcement of Employment situation. They additionally document that trading activity in index options is 20.3 percent higher than on other trading days during five trading days preceding announcement of CPI. They find no evidence for abnormal trading activity in index options markets around GDP announcements. However, it should be noted that these authors define pre-announcement period as five trading days preceding the announcement. As such a long period potentially contains multiple macroeconomic announcements; their results are not directly comparable to the results of this study. In addition, they do not control for contemporaneous market moves, while the results presented in this study are conditional to contemporaneous absolute return of the S&P 500 index and change in VIX index.

Consistent with the Hypothesis 1 and the results already discussed, the coefficient estimate for Pre-high $|RET|$ is positive for all three volume series. The coefficient estimates are economically significant, ranging from 0.106 for VIX options to 0.186 for ETF options. This indicates that high absolute return itself is reasonable proxy for announcement of important market-wide information. However, only the coefficient estimates for index options and ETF options are statistically significant at five percent level, potentially due to the small amount of observations (n=30).

Given the evidence on abnormally high volume preceding rescheduled macroeconomic announcements and preceding trading days being associated with unexpectedly high absolute returns, I conclude that aggregate trading volume in index, ETF and VIX options is abnormally high preceding informational announcements of a macroeconomic nature and hence accept the Hypothesis 1. Intuitively, this is a strong evidence of speculative activity in these option markets preceding informational announcements. From theoretical perspective, these findings also suggest presence of information asymmetries and informed traders in these markets (e.g., Kyle, 1985; He and Wang, 1995).

The coefficient estimates for Pre-high |RET| also represent preliminary evidence for volume series having predictive power over absolute returns of the S&P 500 index, consistent with the arguments by Roll, Schwartz, and Subrahmanyam (2010) and Roll, Schwartz, and Subrahmanyam (2012). This issue (Hypothesis 2) will be investigated in more detail in the next Section of this thesis. However, as this study represents the first attempt to analyze the trading volume and its time-series regularities in ETF options and VIX options, I expect the coefficient estimates of the control variables to also be of an independent interest. Additionally, these results could also shed further light about the relative informational role of these volume series. Hence, I will next discuss these results in detail.

Trading volume could increase *after* the informational announcement simply due to portfolio balancing needs of investors. Apart of this motive there are two schools of thought that develop theories for trading activity following public announcements. In first set of models, trading activity increases following public announcements because traders disagree on the interpretation of public information due to prior information asymmetries (e.g., Grundy and McNichols, 1989; Kim and Verrecchia, 1991; Kim and Verrecchia, 1997). In the second school of thought, traders disagree on the interpretation of public information even in the absence of private information (e.g., Harris and Raviv, 1993; Shalen, 1993; Kandel and Pearson, 1995; Banerjee and Kremer, 2010). On the other hand, for example George, Kaul, and Nimalendran, (1994) argue that trading volume could in increase after the announcement due to the decrease in adverse selection costs.

While the increase in trading volume of individual equities following announcements of firm-specific information such as earnings announcements is well-documented (e.g., Bamber, 1987; Kandel and Pearson, 1995; Chae, 2005), the evidence of the reactions of market-wide volume or volume in index derivatives to announcements of information of macroeconomic nature is

more inconclusive. Jain (1988) investigates the trading volume response to announcements about the money supply, CPI, PPI, industrial production, and the unemployment rate by using hourly NYSE data over the 7-year period from 1978 to 1984, but finds no evidence that surprises in announcements would impact volume. Chordia, Roll, and Subrahmanyam (2001) test the NYSE trading activity response to the macroeconomic announcements about GDP, CPI and the unemployment rate and find some evidence that trading activity would increase following the announcement of unemployment rate. Arguably, the most comprehensive empirical investigation on the reaction of aggregate equity volume to different rescheduled macroeconomic announcements is the study conducted by Flannery and Protopapadakis (2002). These authors test the impact of 17 different macroeconomic announcements to aggregate volume of NYSE-AMEX-NASDAQ equities over period from 1980 to 1996 and find that announcements on International Trade in Goods and Services, CPI, PPI, Employment Situation and New Residential Construction are followed by statistically significant increase in volume. However, in economic terms the increase in volume seems quite modest, ranging from 2-3 percent.

Consistent with the theoretical predictions and empirical evidence discussed above, the coefficient estimates for Post-announcement are positive and statistically significant at the one percent level for all volume series. The coefficients are also economically meaningful, ranging from 0.092 for ETF options to 0.113 for index options, indicating that trading volume in these products is approximately 9-11 percent higher on trading days associated with rescheduled announcement on International Trade in Goods and Services, CPI, PPI, Employment Situation and New Residential Construction compared to other days. These results appear quite strong compared to those reported by Jain (1988), Chordia, Roll, and Subrahmanyam (2001) and Flannery and Protopapadakis (2002) for aggregate volume in individual equities. However, in light of the theoretical work by for example Kim and Verrecchia (1997), (i.e. under assumption that volume increases following public announcement due to pre-announcement or event-period information asymmetries) this result is consistent with notion that agents who possess information relevant for valuing large number of equities prefer to trade equity index derivatives, rather than portfolio of multiple equities.

As already discussed in the previous Sections of this study, the notion that trading volume and absolute price changes or volatility are positively correlated has strong theoretical and empirical support and is generally considered as a consistent fact of financial markets. The

results of this study are consistent with this literature. The coefficient estimates for Unexpected |RET| are significantly positive for all volume series. Consistent with for example Suominen (2001), the coefficient estimates for Expected |RET| are negative, although statistically insignificant. Note that the volume in ETF options appears to exhibit strongest relation with the absolute returns of the S&P 500 index, indicating that volume in ETF options is also most sensitive to informational flows (Andersen 1996).

Trading volume could also be positively related to changes in volatility expectations, i.e. changes in the VIX index. Roll, Schwartz, and Subrahmanyam (2012) argue that in the theoretical framework by Kyle (1985), high expected volatility would increase returns from speculative trading and thus attract more informed volume. These authors also document that the aggregate volume in S&P 500 equities and volume in several S&P 500 index derivatives are positively related to the VIX. Consistent with the intuition an empirical results of these authors, I find that the volume in index options and particularly in ETF options is significantly related to the daily changes in the VIX index. As could be expected based on the correlation coefficient reported in Table 4 in the Section 2 (0.05), the relation between volume in VIX options and the VIX index is insignificant, although positive.

As already discussed in the previous subsection, trading volume is also known to exhibit predictable day-of-the-week patterns, possibly due to day-of-the-week effect in processing information (Osborne, 1962), accumulation of private information over a weekend (Foster and Viswanathan, 1990), or day-of-the-week pattern in opportunity cost of devoting time to trading decisions (Chordia, Roll, and Subrahmanyam, 2001). Jain and Joh (1988) use aggregate volume data for NYSE equities and document that on the period between 1979 and 1983 Mondays and Fridays have the lowest volume, and the most active periods are in the middle of the week. Lakonishok and Maberly (1990) document that for the period between 1962 and 1986 the aggregate NYSE volume is more than 10 percent lower on Mondays compared to the other days of the week. Authors additionally show that volume from individuals is larger but institutional volume is smaller on Mondays. Foster and Viswanathan (1993) and Bessembinder, Chan, and Seguin (1996) provide additional evidence by documenting that the Monday's trading volume drop seems to be larger for actively traded firms and companies with higher market capitalization which are potentially preferred by institutions and other professional investors. More recently, Roll, Schwartz, and Subrahmanyam (2012) document that also the trading volume in S&P 500 index derivatives (options, the legacy and E-mini futures contracts and the ETF) exhibits the day-of-the-week

effects. Their results also suggest that the Monday's trading volume drop would be larger for derivatives compared to aggregate volume of S&P 500 equities.

The results of this study suggest that there are strong day-of-the-week effects in trading volume of index, ETF and VIX options for the period January 2009 to September 2012. Most notably, the coefficient estimates for Monday are significantly negative for all volume series. The magnitude of the coefficient estimate for index options (-0.091) is in line with those reported by for example Jain and Joh, 1988, Lakonishok and Maberly (1990), and Roll, Schwartz, and Subrahmanyam (2012) for aggregate equity volume. However, the coefficient estimates for ETF options (-0.198) and VIX options (-0.238) are surprisingly large, indicating that trading volume in these products is approximately 20 percent lower on Mondays compared to Wednesdays. Assuming that the index options are particularly attractive to large institutional investors with little financial constrains due to their larger contract size and hence lower transaction costs, this finding is surprising in light of the results by Foster and Viswanathan (1993) and Bessembinder, Chan, and Seguin (1996). As noted earlier, these authors document that the trading volume drop on Mondays is particularly high for actively traded firms and companies with higher market capitalization, which are presumably preferred by institutions and other professional investors. Note also that volume in index options and VIX options on Tuesdays, Thursdays, and Fridays does not significantly differ the volume on Wednesdays. However, the volume in ETF appears to exhibit exceptional day-of-the-week pattern with gradually increasing volume over the week towards the weekend. In light of Foster and Viswanathan (1990), this suggests that accumulation of private information over a weekend has particularly strong impact to trading activity of ETF options.

Chordia, Roll, and Subrahmanyam (2001) and Frieder and Subrahmanyam (2004) propose that trading activity could vary around holidays due to the variations in the opportunity cost of devoting time to trading decisions. In their comprehensive study on the time-series determinants of aggregate equity trading activity and liquidity, Chordia, Roll, and Subrahmanyam (2001) document that on the period between 1988 and 1998 the aggregate trading activity of NYSE is approximately 7-11 percent lower on trading days around U.S. national holidays than on regular trading days. Frieder and Subrahmanyam (2004) show that the NYSE dollar volume is significantly lower on trading days associated with Jewish High Holy Days of Rosh Hashanah and Yom Kippur. For the period between 1946 and 1972, the trading volume drops associated with Rosh Hashanah and Yom Kippur are found to be 17 percent and 2 percent, respectively. For the latter subperiod between 1973 and 2000, the

trading volume drops are documented to be 21 percent and 26 percent, respectively. In a somewhat related study Hong and Yu (2009) show that the aggregate market turnover is significantly lower on a summer vacation season (defined as the third quarter for Northern Hemisphere countries and first quarter for Southern Hemisphere countries) compared to the rest of the year. This effect seems to be particularly pronounced for European and North American markets. For the U.S. the market turnover drop associated with summer vacation season (July, August and September) is found to be approximately 9 percent on the period between 1962 and 2005.

The results of this study are in line with the hypothesis of Chordia, Roll, and Subrahmanyam (2001) and suggest that the variation in opportunity cost of trading due to holidays also significantly influences the trading activity of index derivatives. The coefficient estimates for Pre-holiday, Post-holiday, and Early close are all negative for all volume series, although not significantly so in statistical sense in case of Post-holiday for ETF options and Early close for VIX options. Especially the coefficient estimates for Pre-holiday are surprisingly large compared to findings of Chordia, Roll, and Subrahmanyam (2001), ranging from -0.151 for ETF options to -0.388 for VIX options. As most of the holidays considered in this study are celebrated only in the U.S., one could expect the holiday effect to be weakest in trading volume of investment products preferred by foreign investors. Intuitively, one could expect the foreign investors to be more sensitive to firm-specific information asymmetries and hence have relatively larger role in equity index derivatives markets than in equity markets. This finding, together with somewhat surprising day-of-the-week effects discussed earlier, suggests that a more direct investigation into of what types of clientele these different markets attract would be of considerable interest.

The last set of control variables relates to expiration-day effects. As discussed in the previous subsection, the evidence in Stoll and Whaley (1987), Mitchell and Mulherin (1994), and Roll, Schwartz, and Subrahmanyam (2012) suggest that trading volume in index options around contract expiration could be abnormally high. This seems indeed to be the case. The coefficient estimates for both Pre-expiration and Post-expiration are significantly positive for all volume series. The magnitudes of these effects are also very large compared to those of other calendar-based regularities, such as the day-of-the-week effects and holiday effects. These results underscore the importance of controlling for potential expiration-day effects in empirical studies of daily trading volume in options.

4. Predictive role of volume over absolute returns

The time-series regularities documented in the previous Section indicate the presence of information asymmetries and informed traders in index, ETF, and VIX option markets. If these volume series indeed represents trading on information, then they could predict absolute returns (Roll, Schwartz, and Subrahmanyam, 2010; Roll, Schwartz, and Subrahmanyam, 2012). [13] As discussed in the introductory part of this thesis, Roll, Schwartz, and Subrahmanyam (2010) document that options/stock trading volume ratio preceding earnings announcements predicts post-announcement absolute returns while Roll, Schwartz, and Subrahmanyam (2012) find the sum of lagged volume up to three days in S&P 500 index options to predict absolute returns of the S&P 500 index on trading days associated with announcement of CPI and Employment situation. Although Roll, Schwartz, and Subrahmanyam (2012) do not directly propose or test whether trading volume in index derivatives potentially preferred by informed investors could in general be informative for future absolute price changes, I consider this question to be of so direct importance that it should be directly tested based on the existing preliminary evidence. I do realize that the detrended aggregate contract volume series are very crude proxies for informed trades; however, note that this would make any predictive relation using these series even more striking.

In this Section, I test whether the aggregate volume series in index options, ETF options or VIX options have predictive power over absolute returns of the S&P 500 index (Hypothesis 2). I begin with most simple methodology in which the whitened daily absolute return series of the S&P 500 index is regressed on the sums of lagged detrended volumes up to three days for each of the volume series. In the second subsection, I test the robustness of these results by estimating (reduced form) VAR with the three volume series, absolute returns of the S&P 500 index, and VIX index as endogenous variables and calculate the joint coefficient restrictions representing the (linear) Granger causality test.

[13] The proposition that volume could be informative on future volatility is by no means new. For instance Lamoureux and Lastrapes (1990) indicate that volume could contain relevant information for predicting future volatility by documenting that autoregressive conditional heteroscedasticity (ARCH) effects tend to disappear when volume is included in the variance equation. More recent paper by Brooks (1998), finds aggregate NYSE volume to Granger cause squared returns of the Dow Jones Composite Average index.

4.1 Predictive regressions of absolute returns

To test the Hypothesis 2, I first perform predictive OLS regression in which the whitened daily absolute return of the S&P 500 index is regressed on the lagged detrended volume measures of index options, ETF options and VIX options. In line with Roll, Schwartz, and Subrahmanyam (2012), I consider the sum of lagged volumes up to three days for each of the volume series. Given the contemporaneous correlation between the volume series and daily changes in the VIX index evident from Table 2, and the prominence of option implied volatility to predict future realized volatility (Blair, Poon, and Taylor, 2001; Corrado and Miller, 2005), I also investigate the robustness of the results for inclusion of the variable representing past three day change in the VIX index to the model. To further verify that the results are not driven by especially strong lead-lag relation between volume and absolute returns around macroeconomic announcements documented by Roll, Schwartz, and Subrahmanyam (2012),[14] I also consider model which contains indicator variables for trading days preceding and following announcement on International Trade in Goods and Services, CPI, PPI, Employment Situation or New Residential Construction.

The results from predictive regressions are presented in Table 5. As can be seen from first panel, the coefficient estimate for ETF options is significant and positive, while coefficient estimates for index options and VIX options are negative and insignificant. In terms of economic significance, the coefficient of 0.218 for ETF options implies that cumulative abnormal volume of 1.00 (approximately 2.7 standard deviations) for past three days is followed by an extra absolute return of 0.218 percent. The adjusted R^2 for the first regression is quite low (0.020), which is of course expectable result in light of efficient market hypothesis as the data consist of publicly available time series.

[14] As discussed earlier, Flannery and Protopapadakis (2002) find strong evidence that the rescheduled macroeconomic announcements considered in this study potentially impact the level and conditional volatility of equity returns. In addition, the results presented in Section 3 suggest that the trading volume is abnormally high preceding these announcements.

Table 5. Predictive regressions of absolute returns

Dependent variable is the whitened daily absolute return of the S&P 500 index. *Explanatory variables* are: *Index options*: sum of three lags of detrended total contract volume in S&P 500 (cash) index options; *ETF options*: sum of three lags of detrended total contract volume in S&P 500 ETF (SPDR) options; *VIX options*: sum of three lags of detrended total contract volume in options on the CBOE Volatility Index; *Δ VIX*: sum of three lags of daily changes in CBOE Volatility Index; *Pre(Post)-announcement*: a variable that takes on value of 1.0 on a trading days preceding (associated with) rescheduled announcement on International Trade in Goods and Services, CPI, PPI, Employment Situation or New Residential Construction and zero otherwise. The volume series are detrended by taking natural logarithm and subtracting 20-day trailing average. Coefficient estimates significantly different from zero at the one (five) percent level are indicated by ** (*). The time-period is January 2009 through September 2012. Test statistics are calculated by using White's (1980) heteroscedasticity-robust standard errors. The coefficient estimates are multiplied by 100.

	1		2		3	
Explanatory variables	Coefficient	t.stat.	Coefficient	t.stat.	Coefficient	t.stat.
Index options	-0.104	-1.91	-0.088	-1.61	-0.073	-1.30
ETF options	0.218 **	3.80	0.161 **	2.96	0.158 **	2.93
VIX options	-0.044	-1.26	-0.042	-1.21	-0.038	-1.12
Δ VIX			4.448 **	3.31	4.370 **	3.25
Pre-announcement					-0.109	-1.65
Post-announcement					-0.003	-0.05
Adjusted R^2	0.020		0.041		0.042	
Durbin-Watson stat	2.108		2.174		2.176	

The results presented in the second panel demonstrate that controlling for past changes in the VIX index does not alter the results considerably. Most notably, the coefficient estimate for ETF options is still positive (0.161) and significant in all conventional significance levels. Consistent with Blair, Poon, and Taylor (2001) and Corrado and Miller (2005), the coefficient for Δ VIX (4.448) is positive and statistically significant. In terms of economic significance, the coefficient estimate of 4.448 implies that cumulative increase of 0.55 in the value of VIX index (approximately 2.7 standard deviations) for past three days is followed by an extra absolute return of 0.245 percent. Note also that inclusion of past three day change in the VIX index increases significantly the explanatory power of the model, although the adjusted R^2 of the second regression (0.041) is still somewhat uninteresting from practical point of view. In third panel the coefficient estimates for Pre-announcement are Post-announcement are insignificant, and consequently the inclusion of these variables to the model has only marginal impact to other coefficient estimates.

Overall, the results from predictive regression suggest that volume in ETF options has strongest forecasting ability for absolute returns of the S&P 500 index. I consider this result to be surprising, given that from these three markets the relative role of large professional investors should intuitively be smallest in ETF option markets. As discussed in the Section 2

of this thesis, the notional contract size of ETF option is only one tenth of that of the index option, suggesting that ETF options should be more attractive to less-sophisticated retail clientele (Hvidkjaer, 2008; Roll, Schwartz, and Subrahmanyam, 2012). VIX options have actually smaller notional contract size than ETF options, but when considering the actual option prices it should be noted that volatility of the VIX index is significantly higher than the volatility of the S&P 500 index.[15] Additionally, calculating the theoretical value for VIX option can be very complex relative to index or ETF options due to the term structure and mean reverting property of the VIX index. This suggests that unsophisticated investors should have relatively small role in VIX option markets. The next subsection presents alternative test for the relative informational role of these three volume series.

4.2 Granger causality tests

Granger causality test is well-known test for bivariate causality. Granger (1969) called a variable say Y_t causal for variable X_t if Y_t can be better predicted using the histories of both X_t and Y_t than it can by using the history of Y_t alone. This concept is very straightforward to implement in VAR framework. For simplicity, suppose that Y_t and X_t are generated by the following bivariate VAR(p) process:

$$Y_t = a_0 + a_1 Y_{t-1} + ... + a_p Y_{t-p} + b_1 X_{t-1} + ... + b_p X_{t-p} + u_t \quad (1)$$

$$X_t = c_0 + c_1 X_{t-1} + ... + c_p X_{t-p} + d_1 Y_{t-1} + ... + d_p Y_{t-p} + v_t \quad (2)$$

Then, testing H_0: $b_1 = b_2 = ... = b_p = 0$, against alternative is a test that X does not Granger-cause Y. Similarly, testing H_0: $d_1 = d_2 = ... = d_p = 0$, against alternative is a test that Y does not Granger-cause X.

In the VAR to be estimated the endogenous variables are the volume in index options, volume in ETF options, volume in VIX options, absolute returns of the S&P 500 index, and VIX index. For the sake of parsimony, I do not include any exogenous variables in the model. Note that in this VAR, the endogenous variables are in unadjusted form. As evident from Table 1, this implies that the VAR model contains variables integrated of order one, which in turn implies that the Wald test statistic does not follow its usual asymptotic chi-square distribution under the null (Toda and Phillips, 1993). To fix this (at some cost in terms of efficiency), I

[15] According to CBOE, the volatility of VIX as measured by spot VIX values was 115.7 percent in 2010, while volatility of the S&P 500 index was only 18 percent.

follow Toda and Yamamoto (1995) and include one redundant lag to the VAR in estimating the parameters of the process. Note that this redundant lag is not included while calculating the Wald chi-square test statistics.[16]

Table 6. Granger causality tests

This table reports the results from Granger causality tests (chi-square statistics and p-values on the parenthesis below) based on reduced form vector autoregression where the endogenous variables are log transformed daily total contract volumes in S&P 500 (cash) index options (index options), S&P 500 ETF (SPDR) options (ETF options), options on the CBOE Volatility Index (VIX options), daily absolute return of the S&P 500 index (|RET|), and daily values of the CBOE Volatility Index (VIX). The time-period is January 2009 through September 2012.

	Dependent variable				
	Index options	ETF options	VIX options	|RET|	VIX
Index options		52.27	16.55	1.22	2.48
		(0.00)	(0.00)	(0.75)	(0.48)
ETF options	8.41		16.98	9.17	10.58
	(0.04)		(0.00)	(0.03)	(0.01)
VIX options	42.14	29.78		6.31	3.26
	(0.00)	(0.00)		(0.10)	(0.35)
|RET|	11.96	17.36	4.80		5.43
	(0.01)	(0.00)	(0.19)		(0.14)
VIX	23.50	24.99	8.38	62.16	
	(0.00)	(0.00)	(0.04)	(0.00)	

Table 6 reports the results from Granger causality tests (chi-square statistics and p-values on the parenthesis below) based on reduced form VAR where the endogenous variables are log transformed daily total contract volumes in index, ETF, and VIX options, absolute returns of the S&P 500 index, and VIX index. As the Hannan and Quinn (1979) criterion suggested the lag length of three, the lag length of four is used in estimating the parameters of VAR and the lag length of three is used in calculating the Wald test statistics.

Considering first the joint dynamics of the volume series, in line with the results by Roll, Schwartz, and Subrahmanyam (2012) all the volume series seem to be useful in forecasting shifts in each other. Absolute returns also seem to have predictive power over the volume in index options and ETF options, consistent with the notion that recent market moves could trigger changes in optimal portfolio allocation. Shifts in the VIX index appear to have forecasting ability for all volume series. This result supports the notion that increase in

[16] I thank Dave Giles for providing guidance on performing Granger causality test as proposed by Toda and Yamamoto (1995) by using EViews software on his website: http://davegiles.blogspot.ca/2011/04/testing-for-granger-causality.html

expected future volatility is associated with increase in trading activity, consistent with the results of for example Gallant, Rossi, and Tauchen (1992).

Considering finally the predictive power of the volume series over absolute returns, the results for Granger causality analysis suggest that only trading activity in ETF option markets has forecasting ability for absolute returns of the S&P 500 index. Strikingly, the results also suggest that only the volume in ETF options has predictive power for shifts in the VIX index. Taken in totality with the results presented in the previous subsection, the results suggest that ETF option markets dominate other volume series with regard to price formation.

5. Conclusions

The enormous amount of trading volume in financial markets represents one of the great challenges to the field of finance. The public transfers billions of dollars every year to intermediaries in the form of commissions and bid-ask spreads (French, 2008), and many investors tend to lose money even before transaction costs (Odean, 1999). In the most theoretical models of trading, significant part of trading activity is a consequence of information asymmetries and profit motives of privately informed investors.

While the question on how well the models that generate volume using asymmetric information can explain the observed level and patterns of trading volume can be disputed,[17] it is fair to say that understanding the informational content of trading volume is of a direct importance to both academics developing models of market interaction and portfolio managers or traders identifying optimal trading strategies. The presence of informed trading is presumably also of a significant interest to policy makers and regulators who monitor market activities. Given that option markets should appear particularly attractive for informed traders due to enhanced leverage (e.g., Back, 1992) and nonlinear payoffs which allow for example taking positions in volatility (Ni, Pan, and Poteshman, 2008), especially the volume in options and its informational content warrants for a throughout investigation.

While the exploitation of the firm-specific private information via equity options is now well documented (e.g., Easley, O'Hara, and Srinivas, 1998; Chakravarty, Gulen, and Mayhew, 2004; Pan and Poteshman, 2006), relatively little is known about the existence and exploitation of market-wide private information in index option markets. Motivated by the theoretical work by Kyle (1985), He and Wang (1995), and recent empirical study by Roll, Schwartz, and Subrahmanyam (2012), this thesis attempts fill this void by investigating the behavior of aggregate trading volume in S&P 500 index, S&P 500 ETF and VIX options preceding informational announcements and further testing whether these volume series have any predictive power over absolute returns of the S&P 500 index. To the best of my knowledge, this study also contains the first analysis of trading volume and its informational role in ETF options and VIX options.

[17] An important strand of literature models trading as induced by differences of opinion and often de-emphasizes the role of information symmetries. Examples of this literature include Harris and Raviv (1993), Kandel and Pearson (1995), Cao and Ou-Yang (2009), and Banerjee and Kremer (2010).

I find that trading volume in all these products is abnormally high preceding important rescheduled macroeconomic announcements and trading days associated with high absolute returns, indicating existence of informed speculation in these markets. Results also suggest that there exist some notable differences in time-series regularities of these volume series. Firstly, volume in ETF options appears to exhibit strongest relation with absolute returns of the S&P 500 index and daily changes in VIX index, indicating that volume in ETF options is most sensitive to informational flows. Additionally, volume in ETF options appears to exhibit strongest day-of-the-week effects with gradually increasing volume over the week towards the weekend. In light of Foster and Viswanathan (1990), this suggests that accumulation of private information over a weekend has particularly strong impact to trading activity of ETF options. Consistent with these results, I find that only the volume in ETF options has predictive power over the whitened absolute returns of the S&P 500 index. Furthermore, the results from Granger causality analysis indicate that only the volume in ETF options predicts shifts in the VIX index.

Overall, the picture that emerges from my analysis is that ETF options dominate index options and VIX options in price formation. I consider this result puzzling, given that from these three markets the relative role of less-sophisticated retail investors should intuitively be highest in ETF option markets. This underscores that much remains to be done in the empirical side. Firstly, the robustness of the results in this study could be investigated by using more detailed volume data. For instance, investigating whether the order flow for example in ETF options as proposed by Easley, O'Hara, and Srinivas (1998) could predict signed index returns would be of a considerable interest. Additionally, testing whether volume in these products that could have been part of straddle trades is particularly strong predictor of absolute returns or volatility as proposed by Ni, Pan, and Poteshman (2008), would be intriguing. Finally, in light of the somewhat surprising time-series regularities and predictive regression results documented in this study, it would be interesting to investigate more directly what type of clientele these markets attract. These questions form a fertile agenda for forthcoming research.

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