Stock Prices and Liquidity in the U.S. Stock Market: The Response to Economic News across the Business Cycle

Wenlong Lai *

Abstract

The arrival of scheduled macroeconomic announcements in the U.S. stock market leads to a two-stage adjustment process for prices and trading transactions. In a brief first stage, the release of a news announcement induces a sharp and nearly instantaneous price change along with a rise in the number of trading transactions. In a prolonged second stage, the release causes significant and persistent increases in price volatility and trading transactions within approximately an hour. After allowing for different stages of the business cycle, we demonstrate that the release of a news announcement induces larger immediate price changes per interval in an expansion period but more immediate price changes per interval in a contraction period as prices shift from the old equilibrium to the approximate new equilibrium. The announcement causes smaller subsequent adjustments of stock prices along with a lower number of trading transactions across a shorter time during a contraction period as the information contained in the news announcement is incorporated fully in stock prices. These findings imply that there is a more efficient market in a contraction period. We use a static analysis to investigate the immediate effects of news announcements, as measured by the level of surprise in the news, on prices and adopt a wavelet analysis to examine their eventual effects on prices. The evidence shows that only 6 out of 17 announcements have a significant immediate impact, but all announcements have an eventual impact over different time periods. The combination of the results of both analyses provides us with a time-profile for each type of news announcement's impact on stock prices and shows that the impact is significant within approximately an hour but is exhausted after a day.

Keywords: announcement effects, market expectation, business cycle, wavelets.

JEL: C32, E32, G14.

*Department of Economics, University of Leicester, University Road, Leicester LE1 7RH, e-mail: wl69@le.ac.uk

1. Introduction

Many economic indicators that reflect economic fundamentals have a major impact on financial markets. Therefore, scheduled macroeconomic news announcements, such as the employment report, CPI (consumer price index), and PPI (producer price index), are a natural focus for market participants. How do market participants respond to news announcements? Is public information about the economy immediately reflected in asset prices, or does its effect on volatility persist over the course of several days? How does the impact on financial markets from announcements persist? Market participants' responses to news announcements are interpreted by the way information spreads in the market, which is viewed as information processing. Information processing is an important topic in financial economics. Consequently, much attention has been devoted to its study.

In the early stage, economists found mixed and relatively weak empirical evidence using monthly or daily data. Cornell (1983), Pearce and Roley (1983, 1985), and Hardouvelis (1987) find a negative effect of monetary announcement surprises on stock prices. However, limited evidence supports the view that stock prices significantly react to nonmonetary announcement surprises. Schwert (1981) finds that daily stock prices significantly but weakly react to the announcement of unexpected information in the CPI. A limited impact of inflation (PPI) surprises and no impact of industrial production and unemployment rate surprises on stock prices are found by Pearce and Roley (1985), and only the unemployment rate, trade deficit, and personal income of eleven announcements are found to be significant in Hardouvelis (1987). Edison (1997) only finds a statistically significant response for daily exchange rates and short-term and long-term interest rates for nonfarm payroll information in six U.S. news announcements.

Over time, the sampling frequency of data in the literature has been questioned. Low frequency data, consisting of monthly or daily data, are believed to be unable to capture the impact on financial markets of news announcements. Oberlechner and Hocking (2004) find that the speed of information is the primary characteristic of important foreign exchange market news, the importance of which is actually rated higher than the accuracy and content of news by a questionnaire survey of 321 traders and 63 financial journalists from leading banks and financial news providers in the European foreign exchange market. Market participants' responses to news announcements are so fast that they cause immediate changes in asset prices. The daily or monthly data are unable to reflect these behaviours. Furthermore, several announcements and other news may be released on the same day but at different times. The price behaviour is difficult to attribute to any specific announcement using daily or monthly data. Consequently, higher frequency data have been preferred in the past two decades. A growing number of works in the literature study the impact of macroeconomic news announcements on financial markets using intraday data, such as one-minute or five-minute data. Ederington and Lee (1993) find that most price adjustments to announcements are within one minute of the monthly economic information releases; volatility remains considerably higher than normal for another fifteen minutes or so and slightly higher for several hours. Following this study, Ederington and Lee (1995) study the price changes in interest rate and foreign exchange futures markets to monthly announcements in the short run. They conclude that asset prices adjust to the scheduled announcements within the first 10 seconds. The adjustments are small but rapid, which implies that some trades occur at nonequilibrium prices. Furthermore, it takes 40-50 seconds to complete the major adjustments to the initial releases.

These empirical studies focus on scheduled macroeconomic news announcements and examine their impact on futures markets, including Treasury bond and foreign exchange futures markets, which are highly related to spot markets. However, according to challenges to the efficient market hypothesis, asset prices not only reflect all information in the market but also include market participants' expectations. Market participants constantly discount expectations of the future in their present buying and selling decisions. As a result, the importance of news announcements in financial markets declines. This observation is consistent with the findings of Oberlechner and Hocking (2004): foreign exchange traders regard news that is unanticipated by the foreign exchange market and that contradicts an expectation of the foreign exchange market as more important than the reliability of the news source and the perceived accuracy of the news. This view is also implicitly identified by Ederington and Lee (1993). For a total of 19 monthly announcements, they find that the employment report, PPI, CPI and durable goods orders are most important for the Treasury bond and Eurodollar futures prices. In addition, the monthly announcements with the greatest impact on the dollar-deutsche mark exchange rate are the employment report, merchandise trade deficit, PPI, durable goods orders, GNP, and retail sales: note that they are listed in order of decreasing impact. The employment report that imposes the greatest impact on financial markets is normally the first government release concerning economic activity in a given month. Furthermore, the PPI is released before the CPI. Ederington and Lee (1993) infer that later releases are less important because they are partially predictable based on earlier releases.

Consequently, announcements are worth less as expectations conform more closely to them. The unanticipated components of announcements, but not the announcements themselves, affect asset prices. As a result, the credibility of the findings of previous studies is challenged. Moreover, they allow us to assess the different impacts of several announcements that are released simultaneously. Ederington and Lee (1993) and Fleming and Remolona (1997) study the impact of macroeconomic news announcements on financial markets by using dummy variables to represent announcements as regressors in the model. However, it is impossible to individually evaluate the effects of several announcements that are released at the same time. To study information processing, it is important to estimate expectations. On the one hand, expectations can be produced from extrapolative benchmarks such as ARMA models, a strategy that is adopted by Schwert (1981). On the other hand, expectations can be collected from financial companies, such as the International Money Market Services (MMS) and the Bloomberg Terminal.[1] Compared to the expectations generated by econometric models, the MMS survey data are unbiased and less variable (Andersen *et al.*, 2003). Accordingly, these data are proposed to represent the expectations of market participants on scheduled macroeconomic news. Cornell (1983), Pearce and Roley (1983, 1985), Hardouvelis (1987), Harvey and Huang (1993), McQueen and Roley (1993), Edison (1997), Balduzzi *et al.* (2001), and Andersen *et al.* (2003) use data from the MMS survey and announced macroeconomic news to generate announcement surprises and then study the response of asset prices to them.

We extend the literature in four directions. First, how does the stock market respond to scheduled news announcements? Previous papers (Ederington and Lee (1993, 1995), Edison (1997), Fleming and Remolona (1997, 1999), Balduzzi *et al.* (2001), and Andersen *et al* (2003)) primarily focus on the Treasury bond and foreign exchange markets using low frequency and high frequency data. Although some papers (Schwert (1981), Cornell (1983), Pearce and Roley (1983, 1985), Hardouvelis (1987), and McQueen and Roley (1993)) have studied the impact of news announcements on the stock market using low frequency data−(daily data), to the best of our knowledge, no previous studies have used high frequency data to examine this impact.

Second, do news announcements immediately or eventually affect the stock market in the form of price volatility and trading volume? Ederington and Lee (1993, 1995), Fleming and Remolona (1997, 1999), Balduzzi *et al.* (2001), and Andersen *et al.* (2003) propose that the information contained in news announcements is incorporated in asset prices so immediately that a sharp and instantaneous price change occurs at the news release time.

[1] Every week since 1977, MMS has conducted a Friday telephone survey of approximately forty money managers, collected forecasts for all figures from news announcements to be released during the next week, and reported the median forecasts from the survey.

However, the implicit information from a news announcement is not fully learned when it is released. Market participants' responses to the information are based on their initial analyses. They need to adjust their investment decisions to reconcile their different views about the news after the release. The subsequent adjustment of prices induces significant and persistent increases in price volatility and trading volume. Accordingly, the impact of news announcements on the stock market comprises an immediate impact and an eventual impact. Price volatility and trading volume by one-minute intervals and by five-minute intervals, respectively, are used to study these impacts.

Naturally, two questions are raised regarding which announcements immediately or eventually affect the stock price. Based on a questionnaire survey with traders and financial journalists, news that contradicts market expectations is considered far more important than news that confirms these expectations (Oberlechner and Hocking, 2004). To address the first question, we thus regress one-minute price changes on announcement surprises. Regarding the second question, the traditional literature fixes the time before the announcement and shifts the examined time after the announcement. The largest time interval in which the price changes significantly in reaction to the news announcement indicates the time during which the news announcement's impact on the market remains significant. However, the analysis based on these static changes in prices cannot explain why increases in price volatility persist over a longer time, as has been found by Ederington and Lee (1993), Balduzzi *et al.* (2001), and Andersen *et al.* (2003). This issue stems from static changes in prices, which cannot fully reflect the eventual impact of a news announcement on the market. To manage the disadvantages of these static changes, we use wavelets to construct wavelet-scale price changes. These data are then regressed on announcement surprises to answer the second question. Moreover, because wavelets produce an orthogonal decomposition of a data sequence by time scale, wavelet-scale price changes on different time scales are mutually orthogonal, which implies that they are linearly independent. The combination of estimation results from the OLS regression model of static price changes and from wavelet-scale price changes gives us the time-profile for the news announcement's impact on stock prices.

Third, we study the different responses of the stock market to news announcements over various stages of the business cycle. The same type of news is considered a positive signal regarding the economy in some states of the business cycle and a negative signal of the economy in others. Consequently, the market's responses are different. For example, on the one hand, a negative surprise in the announcement of the unemployment rate during a boom reduces asset prices because the market fears that the economy is overheating and policy makers will increase the interest rate to cool it down. On the other hand, the same negative surprise in the unemployment rate during a gloom raises asset prices because the market considers it a signal of economic recovery. Even when the market has the same interpretation of news announcements over different stages of the economy, the response of the market to news announcements is unlikely to be consistent considering the divergent behaviours of market participants conditional on the state of the economy. It is interesting to examine the stability of the market's response over various stages of the business cycle. Due to the significant impact of only monetary announcement surprises on daily stock prices, McQueen and Roley (1993) classify economic states into high, medium, and low based on the industrial production index. They find different responses for daily stock prices from a variety of news announcements conditional on the state of the economy. The low frequency data in this paper motivate us to investigate the market's response to news announcements over different stages of the business cycle using high frequency data.[2]

The fourth direction is to examine a so-called "calm before the storm" effect on the stock market. As the weather is particularly calm before a storm, this effect may also observed in financial markets. Market participants withdraw from the market and stabilise asset prices prior to the arrival of a scheduled news announcement, which is taken as a shock to the market, because they do not want to undergo the news release with heavily held stocks. This strategy implies high uncertainty.

This paper is organised as follows. In section 2, we introduce the tick-by-tick data, news announcements, and corresponding forecast data used in the analysis. In section 3, we document price volatility and trading volume. According to the results, we divide the market's response to news announcements into two stages: the immediate response in the first stage and the subsequent adjustment in the second stage. We infer market participants' behaviours conditional on the stages of the economy. In section 4, we propose a simple "news" model and use the data on news announcements and market surveys to generate announcement surprises. Then, we introduce the wavelet analysis and estimate wavelet-scale price changes. We regress static price changes and wavelet-scale price changes on announcement surprises using an ordinary-least squares (OLS) regression model to identify which announcements immediately and which eventually move the stock market. In section

[2]We follow the method of McQueen and Roley (1993) and examine the response of daily closing prices of the S&P 500 index to news announcements conditional on the economic states in the sample, which runs from February 3, 1997 to January 30, 2009. Unlike these authors, our results are quite weak. In our opinion, this difference is due to the emergence of the Internet and other advanced communication technologies that facilitate the spread of information during our sample period. In McQueen and Roley (1993), the sample period covers September 1977 to May 1988. Consequently, low frequency data are not appropriate for examining the impact of news announcements on financial markets.

5, we summarise our findings.

2. Data

This section provides a detailed description of the data set used in the empirical analysis: S&P 500 index futures data and data on news announcement release values and the corresponding forecast survey values.

2.1. S&P 500 Index Futures

The sample data collected are tick-by-tick S&P 500 index futures from February 3, 1997 to January 30, 2009. Due to the need for high-frequency data but the lack of high-frequency S&P 500 index data, it is only possible to use tick-by-tick S&P 500 index futures, which are highly related to the spot assets, to study the news announcements' impact on the stock market. The S&P 500 index futures have been listed on the Chicago Mercantile Exchange (CME) since the spring of 1982 and comprise the largest 500 listed stocks. They are traded from 09 : 30 to 16 : 15 Eastern Time (ET) on working days except holidays.[3] The price of the tick-by-tick S&P 500 index futures is recorded when a trading transaction occurs. Therefore, we know the trading prices and the number of ticks in a one-minute interval, but not the second when a trading transaction occurs. The one-minute price change is defined as the difference in the price from the last trade in the previous minute interval to the last trade in the current minute interval by percentage. The two-minute price change is the price of the last trade in the current minute interval subtracted from the price of the last trade in the minute interval two minutes previously in percentage terms, and so on. In addition, the total number of trading transactions in a time period is the proxy of the corresponding trading volume. Following this definition, the one-minute trading volume is the total number of ticks in a one-minute interval, and so on.

2.2. News Announcements and Market Survey Data

The data on news announcements and the corresponding market expectations are from the Bloomberg Terminal, which is a global financial market database providing data, business news, and analytics. The forecasts of news announcements' release values are collected from a number of economists in different companies on a variety of days before the news

[3] In this paper, the time is based on American Eastern Standard Time.

announcement. The last forecast of an news announcement in each month is usually conducted only one day before the announcement. The standard deviation of all forecasts of the same news announcement in each month is small, approximately 0.1% to 0.2%. This standard deviation suggests that the survey data, which reflect the market's expectations on news announcements 'release values, include all publicly available information one day before the announcements.[4] The median of the survey data for a news announcement represents the market's expectation for it.

The 17 monthly news announcements that we consider are reported in Table 1. Seven of the announcements are released at 8:30, two at 9:15, six at 10:00, one at 14:00, and one at 15:00.[5] The precise release times of these announcements stem from the Bloomberg Terminal. For the nonfarm payrolls, trade balance, consumer confidence, new single-family home sales, PMI (purchasing managers index), federal budget, and consumer credit, we convert the announcement release values into percentage changes from the previous month's announced level.

3. Price Volatility and Trading Volume

To examine intraday volatility, the standard deviations of the one-minute price changes at the same time interval across all 3003 trading days are shown in Figure 1A.[6] The means of the corresponding trading volumes at the same time interval across all trading days are shown in Figure 1B as well. In these and other figures, the time on the horizontal axis denotes the end of the interval in Eastern Time (e.g., 10:00 for 9:59 to 10:00 price changes). An apparent spike emerges over the 16:15 to 9:30 period in Figure 1A. It is not surprising to find high volatility in price changes at this time interval because of overnight information. Indeed, this price change does not belong to the one-minute price change. The price change over the 9:59 to 10:00 period is also very volatile. The corresponding trading volumes over the 16:15 to 9:30 period and over the 9:59 to 10:00 period are unusually high.

[4]One could conjecture that the survey data miss some information and cannot precisely reflect the market's expectations because the market updates its expectations on the later released announcement in accordance with the earlier released one. However, the survey data from the Bloomberg Terminal are collected on a variety of days before the announcement. The last forecast is usually conducted one day before the announcement, and the standard deviation of all forecasts of the same news announcement in each month is small, approximately 0.1% to 0.2%, which implies that the survey data do not miss the information before the announcement.

[5]The release times of these announcements change in some months. Here, we classify the times in terms of when they are usually released.

[6]Given the small magnitude of intraday price changes, they are all multiplied by 100.

The difference between them is that trading volume declines substantially after 9:30 but falls slowly after 10:00. It is observed that 9 of our news announcements occur before 9:30, which is the opening time of the CME; 6 of the news announcements occur at 10:00; 1 news announcement occurs at 14:00; and 1 news announcement occurs at 15:00. To investigate whether the price volatility and trading volume patterns observed in Figures 1A and 1B are attributed to news announcements, we divide the sample into those days that contain at least one of our seventeen news announcements (1541 days) and those with none (1462 days). As shown in Figure 2A, the 9:59 to 10:00 spike in price volatility disappears on nonannouncement days. Figure 2B also indicates that the 9:59 to 10:00 trading volume on announcement days is significantly higher than on nonannouncement days. Moreover, price volatility and trading volume remain considerably higher than normal for a time after the news announcements, particularly for those released at 10:00.

Consequently, the price volatility and trading volume patterns observed in the above figures are due to news releases. Given the price volatility and trading volume over the 16:15 to 9:30 period, it is very difficult to clarify whether news announcements before 9:30 affect the stock market because overnight information dominates. However, the persistent increases in price volatility and trading volume after 9:30 on announcement days are shown in Figures 2A and 2B, respectively. It is believed that these patterns are related to news announcements before 9:30.

The above study in price volatility and trading volume only concentrates on the sample period. The findings imply that market participants' response to news is the same in different stages of the economy. However, market participants' behaviours may vary for different macroeconomic environments: there is no reason to believe in a consistent response to news announcements over different stages of the business cycle. An economic expansion denotes an increase in the level of economic activity, whereas an economic contraction represents a decline in the economy and more volatile financial markets. Market participants chase returns in an expansion period, whereas they prefer to decrease their exposure to aggregate risk factors in a contraction period (Cederburg, 2008). McQueen and Roley (1993) utilise an example to show that market participants' behaviours are related to divergent levels of economic activity. A negative surprise in the unemployment rate, which was released on February 4, 1983 after 16 months of recession, increased the Dow Jones Industrial Average because it was viewed as an signal of economic recovery ("The Chairmen of the Council of Economic Advisers, Martin Feldstein, commented that a recovery was either beginning or already here in the *Wall Street Journal*, February 7, 1983"). However, a similar surprise, which was announced on November 4, 1998 after six years of expansion, reduced stock prices because it was considered a signal of tighter Fed Policies that would increase the interest rate, which is called the "policy anticipation effect" by Urich and Wachtel (1981) ("Bond market investors reacted with gloom, sending interest rates higher on fears of tighter Fed Policy. The stock market also fell. They were reported by *Wall Street Journal*, November 7, 1988"). Consequently, market participants adapt their behaviours to different macroeconomic environments. This observation infers that their response to news announcements will vary for different stages of the business cycle, as McQueen and Roley (1993) argue.

Accordingly, it would be interesting to explore the patterns in price volatility and trading volume over different stages of economic activity. It is necessary to first classify the divergent levels of the economy. Due to the lack of a widely accepted definition, we quote the NBER business cycle as the classification. Regarding the definition of the NBER business cycle, the time periods from February 1997 to March 2001 and from December 2001 to December 2007 are the expansion periods, and the rest of the sample is in the contraction periods. As a result, the announcement days and nonannouncement days are divided into two groups: the expansion period and the contraction period. There are 1314 announcement trading days in the expansion period and 227 announcement trading days in the contraction period, and there are 1252 nonannouncement trading days in the expansion period and 210 nonannouncement trading days in the contraction period.

On both announcement days and nonannouncement days, Figures 5A and 6A show that price volatility during the contraction periods is apparently greater than during the expansion periods. As introduced earlier, the spike over the 16:15 to 9:30 period emerges on both announcement days and nonannouncement days, whereas the spike over the 9:59 to 10:00 period only appears on announcement days. Conditional on the business cycle, aside from the greater volatility over the 9:59 to 10:00 period, price volatility remains higher than normal within the minutes following 9:30 or 10:00 in both the expansion periods and the contraction periods, as shown in Figures 3A and 4A. Moreover, the increases in price volatility persist over a longer period of time in the expansion periods compared with the contraction periods, especially for 10:00 announcements.

Figures 5B and 6B show that trading volume in the contraction periods is generally lower than in the expansion periods on both announcement days and nonannouncement days. One of the few time intervals contradicting this finding is from 9:59 to 10:00, when trading volume in the contraction periods is higher than in the expansion periods on announcement days. As shown in Figures 3B and 4B, for the same stage of the business cycle, trading volume over the 9:59 to 10:00 period on announcement trading days is higher than on nonannouncement trading days. Subsequently, trading volume falls less after 10:00 in the expansion periods compared with the contraction periods. Furthermore, it is found that trading volume remains higher than normal within nearly an hour after 10:00 in the expansion periods. However, this persistence in the contraction periods is not as obvious, and the time is shorter. In addition, trading volume in the expansion periods remains higher than normal within the minutes following the market opening at 9:30, whereas this phenomenon is not observed in the contraction periods. It is concluded that persistent increases in price volatility and trading volume emerge after news announcements but vary with different stages of economic activity.

3.1. The First Stage: The Immediate Impact of Public Information

In the above section, we briefly introduce the impact of news announcements on price volatility and trading volume. Based on the findings that price volatility and trading volume surge in the news release minute and show persistent increases afterwards, we divide the news announcements' impact on the stock market into two categories: the immediate impact and the eventual impact. To examine the impact of news announcements on the stock market in detail, we form 4 groups of announcements based on their release times: 8:30 9:15 announcements, 10:00 announcements, the 14:00 announcement, and the 15:00 announcement.[7] Consequently, the announcement days only include the trading days when a specific-time announcement is released, whereas the nonannouncement days are trading days excluding all days when an announcement is released. Table 2 reports price volatility and trading volume by one-minute intervals as well as a comparison between announcement and nonannouncement days using the ratio of price volatility and the difference in trading volume mean. The Brown-Forsythe-modified Levene F-statistic comparing variances for announcement and nonannouncement days and the t-statistic comparing means for announcement and nonannouncement days assuming unequal variances are also included in this table. All one-minute intervals between 9:30 and 9:41 and the time period over 16:15 to 9:30 are examined for the 8:30 & 9:15 announcements. For other announcements, we examine all one-minute intervals from 5 minutes before the announcement to 7 minutes after the announcement.

[7] Because the market is open from 9:30 to 16:15, 8:30 and 9:15 announcements, which are released before the opening time, are put into one group. The 8:30 & 9:15 announcements are CPI, PPI, civilian unemployment, nonfarm payrolls, personal consumption, personal income, the trade balance, capacity utilisation, and IP (industrial production); 10:00 announcements are consumer confidence, durable goods orders, the leading index, manufacturers' new orders, new single-family home sales, and PMI; the 14:00 announcement is the federal budget; and the 15:00 announcement is consumer credit.

Panel A of Table 2 shows that the ratio of price volatility on announcement days to that on nonannouncement days increases in the news release minute and/or the next minute, reflecting the market's initial reaction to the announcement. The ratio increases in the next minute for the 8:30 & 9:15 announcements and the 14:00 announcement and increases in both the news release minute and the next minute for the 10:00 announcements. In particular, price volatility surges at these time intervals. This surge denotes that price volatility on announcement days is greater than on nonannouncement days. Moreover, the results of the B-F-L test indicate that price volatility between these two different types of days is significantly distinguished in the corresponding time intervals. Meanwhile, trading volume significantly increases for the same time intervals along with an increase in price volatility, particularly for the 10:00 announcements, as shown in Panel B. For the 14:00 announcement, the increase in price volatility is not accompanied by a higher trading volume.

Some important macroeconomic news consisting of civilian unemployment, CPI, and IP fall into the category of 8:30 & 9:15 announcements. Ederington and Lee (1993, 1995), Fleming and Remolona (1997, 1999), Balduzzi *et al.* (2001), and Andersen *et al.* (2003) find a fierce initial response to these types of announcements on other markets including the Treasury bond and foreign exchange markets. However, the market's initial response to 8:30 & 9:15 announcements in terms of stock prices is not as intense as it is for other markets' asset prices and is not as the same as it is for 10:00 announcements. Stock prices significantly change only over the next minute when the market opens because the market participants already know the contents of these news announcements, and the market responds to them based on the performance of other 24-hour markets after these announcements. The stock prices are changed by more homogeneous analyses, whereas other markets' asset prices are affected by more heterogeneous analyses, similar to the change in stock prices from 10:00 announcements.

Tables 3 and 4 compare announcement with nonannouncement days by one-minute price volatility and trading volume during the expansion and contraction periods, respectively. As shown in Table 2 for the entire sample period, price volatility and trading volume rise in the news release minute or the next minute. The difference is that the significant increase in price volatility in the expansion periods is larger than in the contraction periods, whereas the significant increase in trading volume in the expansion periods is smaller than in the contraction periods. Accordingly, news announcements induce larger price changes per interval in the expansion periods and more price changes in the contraction periods. These tables also demonstrate the divergent market's behaviours at different stages of economic activity. In the expansion periods, market participants who are relatively calm on normal days are more sensitive to news announcements and prefer to use a lower number of trading transactions to achieve a greater price change. However, in the contraction periods, market participants who are relatively susceptible on normal days are less sensitive to news announcements. Their response to announcements is more prudent; they prefer to change stock price on a smaller scale through a higher number of trading transactions.

It is noted that these comparisons are based on the same stage of economic activity. As shown in Figures 5A, 5B, 6A, and 6B, Tables 3 and 4 report higher price volatility and lower trading volume in the contraction periods in comparison with the expansion periods on both announcement days and nonannouncement days. These figures illustrate that the market is more susceptible and less active during the contraction periods compared with the expansion periods. It is not surprising to find that the magnitude of price volatility in the news release minute or the next minute over the contraction periods is greater than that at the same time intervals over the expansion periods, whereas the magnitude of the corresponding trading volume over the contraction periods is generally lower than that over the expansion periods, with an exception for the trading volume over the 9:59 to 10:00 period.

It is interesting to note that price volatility and trading volume significantly decline 2 or 3 minutes before the 10:00 announcements, as shown in Tables 2, 3, and 4, because market participants reduce trading transactions and stabilise the stock price at those times to prepare for the arrival of announcements. This pattern is called the "calm before the storm" effect by Jones *et al.* (1998), although these authors use daily data to investigate this effect. This effect is consistent with the claim of the financial press that financial markets are particularly quiet prior to scheduled news announcements. However, the effect of news announcements on financial markets lasts only a few hours. Thus, it is doubtful that markets remain silent for the days. We find that the effects only last a few minutes.

In conclusion, the market's initial response to news announcements is strong and induces a sharp and nearly instantaneous price change along with a rise in trading volume. The information contained in news announcements is incorporated into stock prices immediately. There are different market behaviours conditional on the business cycle: a larger initial price change is driven by a lower trading volume in the expansion periods, whereas a smaller initial price change is accompanied by a higher trading volume in the contraction periods. Moreover, the "calm before the storm" effect arises 2 or 3 minutes before an announcement because market participants withdraw from the market just prior to lower their risk.

3.2. The Second Stage: The Eventual Impact of Public Information

After an announcement, market participants need to adjust their initial reactions in accordance with others' behaviour. To obtain profits or avoid losses when an news announcement is released, market participants immediately react based on their initial analyses. After the announcements, they learn others' decisions from changes in stock prices and trading volume. The participants may then realise that their initial behaviours were an over- or underreaction and may then further adjust their response. Consequently, stock prices are still volatile and are still accompanied by high trading volume for a long time before equilibrium is reached.

We characterise the subsequent adjustment to news announcements measured through price volatility and trading volume by five-minute intervals from 9:30 to 10:25, adding the measurements over the closing (16:15) to opening (9:30) time period for 8:30 & 9:15 announcements, and from 5 minutes before to 55 minutes after for other announcements, including the 10:00; 14:00, and 15:00 announcements. Tables 5, 6, and 7 present the comparisons between announcement days and nonannouncement days over the entire sample period, over the expansion periods, and over the contraction periods, respectively, following the same format as in Tables 2, 3, and 4. Standard deviations of five-minute price changes across the trading days for the specific economic period are presented in Panel A, and five-minute trading volume means are shown in Panel B.

The sharp initial price change is followed by a significantly prolonged increase in trading volume along with high price volatility for the 8:30 & 9:15 announcements and the 10:00 announcements. This pattern indicates the persistent increases in price volatility and trading volume. Panel A of Table 5 and Figure 2A show that price volatility remains significantly higher than normal from 9:45 to 10:20 for 8:30 & 9:15 announcements and from 10:00 to 10:40 for 10:00 announcements, respectively. Panel B of Table 5 and Figure 2B indicate significantly higher trading volume across the announcement days from 9:35 to 10:10 for 8:30 & 9:15 announcements and from 10:00 to 10:40 for 10:00 announcements, respectively. We do not find persistent increases in either price volatility or trading volume for the 14:00 or the 15:00 announcement. Because there is only one announcement at these times, the subsequent adjustment is too small to significantly change the stock price or increase the trading volume.

The higher price volatility and trading volume following 8:30 & 9:15 announcements indicate that market participants still need to adjust their initial decisions for more than an hour after the announcements. This length of time implies that market participants cannot accurately absorb the implicit information from news announcements until that time, although they already know the response to these announcements for other markets. Ederington and Lee (1993), Fleming and Remolona (1999), Balduzzi *et al.* (2001), and Andersen *et al.* (2003) find that price volatility remains considerably higher than normal for approximately one hour and up to several hours on the Treasury bond and foreign exchange markets. The persistent increases in price volatility and trading volume on the stock market from 8:30 & 9:15 announcements are accompanied by these continued adjustments in asset prices for other markets.

The above results for the entire sample period vary over the two different stages of the economy. In the expansion periods, the eventual effects of announcements on price volatility and trading volume persist over time for as long as they do for the entire sample period. Both price volatility and trading volume remain significantly higher than normal from 9:35 to 10:20. The 10:00 announcements induce higher price volatility and higher trading volume from 10:00 to 10:40. However, in the contraction periods, the time encompassing persistent increases in price volatility and trading volume is shorter. For 8:30 & 9:15 announcements, price volatility remains significantly higher than normal only from 10:00 to 10:20, whereas trading volume is significantly higher only over the 10:00 to 10:05 period. For 10:00 announcements, price volatility and trading volume are significantly higher than normal only from 10:00 to 10:05. These results provide evidence for our earlier arguments: in the expansion periods, news-sensitive market participants overreact or underreact to news announcements and thus need to spend more time adjusting their initial behaviours. In the contraction periods, news-insensitive market participants react to news announcements moderately based on prudent decisions; thus, they spend less time adjusting their initial behaviours.

In conclusion, market participants reconcile the differential views over a prolonged second stage that induces an increase in price volatility and trading volume after the announcements. Because market participants initially overreact or underreact to news announcements, they need to adjust their initial responses according to others' behaviour as seen in the market's performance. This process causes persistent increases in price volatility and trading volume within an hour and over even a longer time. In the expansion periods, the patterns in price volatility and trading volume are similar to those for the entire sample period. However, the increases in price volatility and trading volume persist over a shorter time in the contraction periods. Compared to nonannouncement days at the same stage of economic activity, news-sensitive market participants make larger subsequent adjustments in stock prices through a higher number of trading transactions across a longer time in the expansion periods, whereas news-insensitive market participants are so cautious that they make smaller subsequent adjustments in stock prices through a lower number of trading transactions across a shorter time in the contraction periods. These findings imply that there is a more efficient market in the contraction periods. Accordingly, news announcements induce substantial and long-term repercussions in the stock market over expansion periods, whereas they have small and short-term repercussions on the stock market over contraction periods.

4. Economic News and Stock Prices

The results shown in the above figures and tables demonstrate that scheduled macroeconomic news announcements significantly affect stock prices. Naturally, the next question involves identifying which announcements move the stock market. In this section, we propose a simple "news" model for stock prices to explain why announcement surprises affect them. Then, we study the impact of different news announcements on stock prices, including the immediate impact and the eventual impact.

4.1. The Theoretical Framework of the "News" Model

The underlying principle of investment in the stock market is that stock prices are identical to the present discounted values of rationally expected future dividends through infinity, which is called the dividend discount model. This model is expressed as follows:

$$P_t = \sum_{\tau=1}^{\infty} \frac{E_t D_{t+\tau}}{1 + E_t r_{t+\tau}}, \tag{1}$$

where P_t is the stock price at time t, $D_{t+\tau}$ is the dividend at time $t+\tau$, $r_{t+\tau}$ is the stochastic discount rate of cash flows at time $t+\tau$, and $E_t[\cdot]$ denotes the mathematical expectation conditional on available information Ω_t at time t. Correspondingly, the stock price at time $t-1$ is P_{t-1}, which is equal to

$$P_{t-1} = \sum_{\tau=1}^{\infty} \frac{E_{t-1} D_{t-1+\tau}}{1 + E_{t-1} r_{t-1+\tau}}. \tag{2}$$

Consequently, the stock price change from time $t-1$ to t is

$$
\begin{aligned}
P_t - P_{t-1} &= \sum_{\tau=1}^{\infty} \frac{E_t D_{t+\tau}}{1+E_t r_{t+\tau}} - \sum_{\tau=1}^{\infty} \frac{E_{t-1} D_{t-1+\tau}}{1+E_{t-1} r_{t-1+\tau}} \\
&= -\frac{E_{t-1} D_t}{1+E_{t-1} r_t} + \sum_{\tau=1}^{\infty} (\frac{E_t D_{t+\tau}}{1+E_t r_{t+\tau}} - \frac{E_{t-1} D_{t+\tau}}{1+E_{t-1} r_{t+\tau}}) \\
&= \frac{D_t}{1+r_t} - \frac{E_{t-1} D_t}{1+E_{t-1} r_t} + \sum_{\tau=1}^{\infty} (\frac{E_t D_{t+\tau}}{1+E_t r_{t+\tau}} - \frac{E_{t-1} D_{t+\tau}}{1+E_{t-1} r_{t+\tau}}) - \frac{D_t}{1+r_t}. \qquad (3)
\end{aligned}
$$

Suppose that the dividend and the discount factor are only determined by the economic fundamentals; we then have

$$\frac{D_t}{1+r_t} = f(z_t), \qquad (4)$$

where z_t is the vector of fundamental variables, and $f[\cdot]$ is the linear function with the variable z_t. Market participants rationally expect the next period's dividend using Equation (4).[8] Specifically, the participants use all publicly available information at time $t-1$ to form their expectation of the dividend at time t:

$$\frac{E_{t-1} D_t}{1+E_{t-1} r_t} = f(E_{t-1} z_t). \qquad (5)$$

Subtracting Equation (5) from Equation (4), we have

$$\frac{D_t}{1+r_t} - \frac{E_{t-1} D_t}{1+E_{t-1} r_t} = f(z_t - E_{t-1} z_t), \qquad (6)$$

where $f(z_t) - f(E_{t-1} z_t) = f(z_t - E_{t-1} z_t)$ because $f[\cdot]$ is the linear function with the variable z_t. $z_t - E_{t-1} z_t$ is the unexpected component of the fundamentals in z_t, which is defined as "news". This component is interpreted as the announcement surprise and shows the deviation of the actual value of the figure on an news announcement from its mathematical expected value. This deviation should be random in the sense that it has an average value of zero and displays no systematic pattern over time. Otherwise, market participants could obtain the potentially predictable element from it to upgrade their expectation at the time. Although the news releases the previous month's data about fundamentals, these data involve the latest reliable information about economic fundamentals. Market participants use these announcements to update their knowledge about fundamentals. The efficient market hypothesis implies that market participants immediately respond to information when it becomes available. As a result, stock prices should react when market participants perceive information about fundamentals, which is at the same time that the institution collects the

[8] Here, it is assumed that market participants know the underlying structural model between the endogenous variables, D_t and r_t, and the fundamental variable, z_t. This assumption allows us to infer that the same structural model links the expectations of those variables.

relative data. However, Schwert (1981) finds the contrary result that the stock market does not respond to unexpected inflation during the period in which CPI data is collected, which is before the release date, but the market significantly reacts to unexpected inflation around the time that it is released. Therefore, $z_t - E_{t-1}z_t$ is viewed as the unexpected component of a news announcement that occurs at time t.

Similarly, the relationship between the expected dividend and the expected fundamentals at time $t+1$ conditional on the information at time t is

$$\frac{E_t D_{t+1}}{1 + E_t r_{t+1}} = f(E_t z_{t+1}). \tag{7}$$

The expected dividend and the expected discount factor at time $t+1$ are determined by the expected fundamentals at time $t+1$ based on all available information at time $t-1$:

$$\frac{E_{t-1} D_{t+1}}{1 + E_{t-1} r_{t+1}} = f(E_{t-1} z_{t+1}). \tag{8}$$

Consequently, the first term in the bracket on the right-hand side of Equation (3) is generated by subtracting Equation (8) from Equation (7):

$$\frac{E_t D_{t+1}}{1 + E_t r_{t+1}} - \frac{E_{t-1} D_{t+1}}{1 + E_{t-1} r_{t+1}} = f(E_t z_{t+1} - E_{t-1} z_{t+1}). \tag{9}$$

The expected fundamentals z_t are generated by using the past information about fundamentals, which is assumed to be

$$E_{t-1} z_t = \sum\nolimits_i \lambda_i z_{t-i}, \tag{10}$$

where λ_i is the decreasing weight. At time $t-1$, market participants anticipate the future fundamentals at time $t+1$ using the past fundamentals and the expected future fundamentals at time t based on the information set Ω_{t-1}. Following the same format as Equation (10), we have the expected fundamentals at time $t+1$, which are

$$E_{t-1} z_{t+1} = \lambda_1 E_{t-1} z_t + \sum\nolimits_i \lambda_{i+1} z_{t-i}. \tag{11}$$

According to Equation (10), the expected fundamentals at time $t+1$ conditional on the information set Ω_t, are identical to

$$E_t z_{t+1} = \sum\nolimits_i \lambda_i z_{t+1-i}. \tag{12}$$

Subtracting Equation (11) from Equation (12), we have

$$\begin{aligned} E_t z_{t+1} - E_{t-1} z_{t+1} &= \sum\nolimits_i \lambda_i z_{t+1-i} - (\lambda_1 E_{t-1} z_t + \sum\nolimits_i \lambda_{i+1} z_{t-i}) \\ &= \lambda_1 (z_t - E_{t-1} z_t). \end{aligned} \tag{13}$$

Therefore, the first term in the bracket on the right-hand side of Equation (3) can also be expressed by

$$\frac{E_t D_{t+1}}{1+E_t r_{t+1}} - \frac{E_{t-1} D_{t+1}}{1+E_{t-1} r_{t+1}} = f[\lambda_1(z_t - E_{t-1} z_t)]. \tag{14}$$

Based on the same method, it is not difficult to determine that every term in the bracket on the right-hand side of Equation (3) can be represented by the function $f[\cdot]$ with the variable $z_t - E_{t-1}z_t$. Consequently, Equation (3) is identical to

$$P_t - P_{t-1} = -\frac{D_t}{1+r_t} + \sum_{i=1}^{\infty} f[\mu_i(z_t - E_{t-1} z_t)]. \tag{15}$$

The left-hand side of this equation is the stock price change from time $t-1$ to t. The unexpected component of the fundamentals in z_t, which is revealed by the announcement surprise, is the variable in the function $f[\cdot]$ on the right. It is the simple "news" model about stock prices, and it tells us that the announcement surprise affects the stock price change.

4.2. "News"

"News" is defined as the difference between the expected and real values for an announcement. The unanticipated component of announcement j is

$$S_{j,t} = \frac{A_{j,t} - E_{j,t}}{\hat{\sigma}_j}, \tag{16}$$

where $A_{j,t}$ is the real value for announcement j at time t, $E_{j,t}$ is the median of the market-based survey forecast for announcement j, which is collected from the Bloomberg Terminal, and $\hat{\sigma}_j$ is the sample standard deviation of surprise $A_{j,t} - E_{j,t}$, which is used to facilitate the comparison between stock market responses to different news announcements. Therefore, $S_{j,t}$ is interpreted as the standardised surprise of announcement j. The regression coefficient shows how much a one standard deviation change in the surprise affects the price change when regressing price changes on announcement surprises. Due to the constant standard deviation $\hat{\sigma}_j$ across all observations for announcement j, the standardisation affects neither the significance of the estimates nor the fit of the regression.

Table 1 reports the sample standard deviations of announcement surprises and the descriptive statistics for the data on standardised announcement surprises, including the number of observations, the number of zero values for standardised announcement surprises, the means, and the t-statistics testing the zero mean for the entire sample period, for the expansion periods, and for the contraction periods. The highest ratio for the number of zero values over the number of observations occurs for the leading index (36.17%), with the CPI (32.64%) and civilian unemployment (31.69%) following for the entire sample period. Regarding the different stages of the economy, the highest ratio is for civilian unemployment (35.53%), following the leading index (35%) and CPI (34.96%) during the expansion periods. The leading index (42.86%) with the PPI (40%) following for the contraction period. Moreover, the mean of every standardised announcement surprise is close to zero. However, only the standardised surprise of personal income is significantly different from zero for the entire sample period. Regarding the different stages of the business cycle, the means of the standardised surprises are significantly different from zero for civilian unemployment, personal income, and the trade balance for the expansion periods and PPI and the federal budget for the contraction periods. These results are consistent with our inference in the "news" model that the average of the deviations for the actual value of an news announcement from its mathematical expectation should be zero.[9] This result is attributed to random deviation; otherwise market participants would be able to improve their expectation according to the potentially predictable information from the deviation. Consequently, this result provides indirect evidence that the survey data from the Bloomberg Terminal are rational forecasts.

4.3. Which News Announcements Immediately Affect Stock Prices?

To investigate which news announcements immediately affect stock prices, we regress one-minute price changes on the surprises for the 17 economic variables:

$$(P_t - P_{t-1})/P_{t-1} * 100 = C + \sum_{k=1}^{17} \beta_k S'_{k,t} + e_t, \tag{17}$$

where

i) P_t is the price of the last trade in the current minute interval;

ii) P_{t-1} is the price of the last trade in the previous minute interval. Because the magnitude of the one-minute price change is small, we multiply it by 100 and interpret it as a change in percentage;

iii) β_k is the response coefficient of the price to the kth announcement;

iv) $S'_{k,t}$ is the kth economic variable. It is equal to the standardised surprise of the kth announcement $S_{k,t}$ when the kth announcement occurs at time t; otherwise, it is identical

[9] The mean of the announcement surprises equals the production of the mean of the standardised surprises and the standard deviation of surprises. Because the standard deviation of surprises is smaller than 1, the mean of announcement surprises is more likely to approximate zero. The t-statistic for the mean of the announcement surprises is identical to that of the standardised surprises.

to zero.

The model takes concurrent news announcements into account. For example, the civilian unemployment and the nonfarm payroll figures are always announced in the same report. The different values for the standardised surprises of concurrent news announcements distinguish them, but the dummy variables that have been used to represent news announcements in previous papers cannot separate them. This difference is one advantage of adopting announcement surprises as regressors. Another advantage is the ability to study whether asset prices increase when news announcements are better than expected by assessing the response coefficients. However, this ability is not available when dummy variables represent news announcements. In the literature, to reduce the computational burden, only data around the news release time are analysed. The results of these two methods are similar, except for the higher adjusted R^2 in the latter method. Because the market is open from 09:30 to 16:15, we take the 8:30 and 9:15 announcements as the 9:30 announcements in the model.

Table 8 presents the estimation results of the model, including the response coefficients and the t-statistics.[10] Intercept terms are not listed because they are rarely significant. The results show the significant response of the stock price to 6 announcement surprises regarding PPI, consumer confidence, durable goods orders, the leading index, PMI, and the federal budget. Of these announcements, PPI is released at 8:30, the federal budget is released at 14:00, and the other 4 announcements are released at 10:00. The positive signs for the response coefficients on the 10:00 announcement surprises indicate that the stock price rises when these announcements are better than expected, implying that the the economy has outperformed market expectation, and drops when these announcements are worse than expected, implying that the economy has underperformed market expectation. Moreover, the negative signs of the response coefficients for the the PPI surprise and the federal budget surprise show a reverse movement in the stock price. An unexpectedly high PPI reduces the stock price, whereas an unexpectedly low PPI increases the stock price. A positive surprise in the federal budget reduces the stock price, whereas a negative surprise increases the stock price. The market's response to news announcements is ambiguous. Our results indicate the overall market reaction to these surprises in the sample period.

It would be interesting to examine the stability of the response coefficients over different stages of the business cycle. Seven announcements consisting of CPI, PPI, consumer

[10] To address the heteroskedasticity issue, standard errors and test statistics use the HAC coefficient covariance matrix. We use the slash line instead of the data if the response coefficient on the announcement surprise is not significant in every time period.

confidence, the leading index, PMI, the federal budget and consumer credit significantly affect stock price in the expansion periods, whereas seven different announcements comprising nonfarm payrolls, consumer confidence, durable goods orders, new single-family home sales, PMI, the federal budget, and consumer credit significantly affect the stock price in the contraction periods. Compared to the results for the entire sample period, more news announcements have a significant impact on stock prices when examining different stages of the economy. This finding implies that the market is only responsive to surprises in some news announcements over a particular economic period but not over the entire sample period. In addition, stock prices react to some announcement surprises over both economic periods, including PMI, consumer confidence, the federal budget, and consumer credit. In particular, the signs of the response coefficients for these announcement surprises are quite stable in both stages of the business cycle. The one exceptional announcement is consumer credit, which is negatively related to stock prices in the expansion periods and positively related to stock prices in the contraction periods. We do not find that the market significantly reacts to consumer credit over the entire sample period because the signs of its response coefficients vary based on the stage of economic activity.

The overall response of the stock market to these news announcements is described as follows: unexpected high figures in the leading index in the expansion periods and durable goods orders and new single-family home sales in the contraction periods increase the stock price, whereas unexpected low figures in these announcements for the corresponding periods reduce the stock price. Moreover, unexpected CPI and PPI in the expansion periods negatively affect the stock price. In both economic periods as well as in the entire sample period, surprises in consumer confidence and PMI have a positive impact on the stock price, whereas in the federal budget have a negative impact on the stock price.

In terms of the size of the impact of news announcements on stock prices in the entire sample period, PPI is the most significant. It is noted that the standard deviation of the daily price change for the S&P 500 index futures is 1.37%. A one standard deviation surprise in the PPI, which is related to a 0.27% monthly variation in the index, causes a price change of approximately 11.41% in the normal daily volatility of price changes.[11] Consumer confidence (8.58%), durable goods orders (6.38%), PMI (2.66%), the leading index (2.65%),and the federal budget (0.33%) lead to price changes between 0.33% and 8.58% of daily volatil-

[11] The seventh column of Table 1 reports the sample standard deviations of announcement surprises. The response coefficients in the regression model combined with these standard deviations provide the economic interpretations of the estimation results.

ity, and their importance decreases by the listing order.[12] According to the effect of news announcements on stock prices in the expansion period, PPI is also the most important announcement with an effect of approximately 11.03% of daily volatility on the price change. In terms of the decreasing size of the news announcements' impact on stock prices, PPI is followed by consumer confidence (8.70%), CPI (7.82%), PMI (2.32%), the federal budget (0.30%), and consumer credit (0.30%), where the federal budget and consumer credit are of identical importance. In the contraction periods, new single-family home sales have the greatest impact on the market with an effect of approximately 171.25% of daily volatility on the price change. Next are nonfarm payrolls with an effect of approximately 65.23% of daily volatility, followed by consumer credit (28.62%), durable goods orders (15.11%), consumer confidence (8.39%), and PMI (3.57%). The federal budget (2.05%) has the smallest effect on stock prices. In conclusion, the magnitudes of the response coefficients on news announcement surprises in the contraction periods are generally greater than those in the expansion periods. This result suggests that the impact of news announcements on stock prices is more considerable in contraction periods. This finding is consistent with Figure 5A and Tables 2 and 3, which show that price volatility in the contraction periods is higher than in the expansion periods when news announcements are released.

4.4. Which News Announcements Eventually Affect Stock Prices?

The results of the regression model of one-minute price changes on announcement surprises identify which announcements move the stock market and confirm the immediate impact of those announcements on the stock price. As discussed earlier, the news announcements' impact on the stock market comprises the immediate and the eventual impact. The eventual impact induces persistent increases in price volatility and trading volume. Regressing price changes from the time before the announcement to the time after the announcement on the surprises in the economic variables or on the dummy variables that represent news announcements is a commonly used method, and this paper also adopts this method to study the immediate impact of announcements on the stock price. To investigate how long news announcements affect asset prices, the time before the announcement is often fixed, and the time after the announcement is moved to obtain the price change for different time intervals. The largest time interval over which the price change is significantly affected by a news announcement tells us the market's response until that time. Because this type of price change is static, the method used to study the impact of news announcements on the price change is defined as static analysis. Ederington and Lee (1993, 1995), Balduzzi

[12] The value in the brackets shows how much the stock price changes given a one standard deviation surprise of an announcement in terms of the normal daily volatility of price changes.

et al. (2001), and Andersen *et al.* (2003) find that asset prices significantly react to news announcements from between one minute to five minutes after the announcements based on this type of static analysis or price volatility over the short time interval. However, Ederington and Lee (1993), Fleming and Remolona (1999), Balduzzi *et al.* (2001), and Andersen *et al.* (2003) find that price volatility and trading volume remain considerably higher than normal over approximately an hour and up to even several hours.

Consequently, the static analysis cannot explain why increases in price volatility persist over longer than the maximum time discovered by economists. The difference in time between them is caused by temporal aggregation. A simple example illustrates why this question arises. Suppose the asset price is P_1 one minute before an announcement at time t, and it increases considerably to P_2 when the news is released. The price then drops to P_3 one minute after the announcement and rises to P_4 two minutes after the announcement. The relationships between these prices are $P_2 > P_4 > P_1 > P_3$ and $P_1P_4 > P_2P_3$, as illustrated in Figure 7A. By the regression model, the asset price significantly reacts to the news announcement through the one-minute price change $(P_2 - P_1)/P_1$, but it does not react through the two-minute price change $(P_3 - P_1)/P_1$ or the three-minute price change $(P_4 - P_1)/P_1$ because those magnitudes are smaller than that of one-minute price change $(P_2 - P_1)/P_1$. Thus, the static analysis claims that the effect of the news announcement on the financial market is within one minute. However, the price change $(P_4 - P_3)/P_3$, whose magnitude is greater than that of $(P_2 - P_1)/P_1$, shows that price volatility remains significantly higher than normal within three minutes after the announcement. Consequently, we find that the effects of announcements on price volatility persist longer than the maximum time declared by the static analysis. Because the asset price changes from P_1 to P_2, P_3 and P_4 are attributed to the news announcement, and the static analysis cannot properly examine the eventual impact of news announcements on the financial market.

Furthermore, in terms of static price change, two scenarios are indistinguishable. In the first scenario, the asset price is assumed to be P_1 one minute before an announcement. When the announcement is released, the asset price surges to the threshold price P_2, which reflects the significant response of the market to the announcement and remains constant for four minutes. According to the static analysis, we fix the time before the announcement. As a result, the one-minute price change $(P_2 - P_1)/P_1$ is identical to the two-minute price change, and so on. The static analysis shows the impact of the news announcement on the financial market within five minutes, although it occurs within one minute. In the second scenario, the asset price is still assumed to be P_1 one minute before an announcement. The announcement induces a linear increase in the price to P_2 in the fourth minute. As a result, the price changes by different time intervals are distinct. The impact of the news announcement on the financial market is within five minutes. These two different scenarios are shown in Figure 7B. They are deemed to be the same when we regress the five-minute price changes on announcement surprises.

Consequently, these examples motivate us to better aggregate the data to capture the eventual impact of news announcements on stock prices. Consider the first example again. If a mathematical operation called first difference is applied to the one-minute price change, the price change from the first one minute to the second one minute is $(P_3 - P_2)/P_2 - (P_2 - P_1)/P_1$. Its magnitude is smaller than that of the first one minute $((P_2 - P_1)/P_1)$. However, the price change from the second one minute to the third one minute is $(P_4 - P_3)/P_3 - (P_3 - P_2)/P_2$, which has a magnitude greater than that of the first one minute. Thus, we conclude that it is within three minutes by using the first-difference to investigate the speed of the eventual impact, which is consistent with reality. Moreover, when this type of temporal aggregation is applied to the second example, the two scenarios are easily distinguished.

4.4.1. Why Do We Use Wavelets?

The first-difference is a type of filter that performs mathematical operations to rearrange a data structure. In empirical works in economics and finance, the required frequency of observations is commonly not available because it is very expensive or not possible to collect data in the required frequency for particular variables. However, there is no reason to believe that data collected in the required frequency would be able to fully capture the movement of economy. Nevertheless, to solve this issue, a mathematical method referred to as temporal aggregation is required. The implicit assumption of this method is that the underlying stochastic process in continuous time is observed in discrete intervals. When the required frequency of observations is not available, the temporal aggregation is applied to obtain the ideal frequency of data.

Consider a case in which monthly observations of an economic variable are collected from the market. However, quarterly data for this variable are actually required to study an empirical issue. A simple and frequently used way of converting the observations would be to take the sums or the averages of successive sets of three months. This process is equivalent to subjecting the data to a three-point moving sum or average and then subsampling the resulting sequence by picking one in every three points. However, a problem called "aliasing" arises with this procedure. Aliasing refers to an effect that leads to different data sequences that are indistinguishable when sampled. For instance, in the second example, the five-minute price changes in the two scenarios are the same. We cannot use them to distinguish the groups to which they belong.

To avoid the aliasing problem, it is appropriate to use a filter that can better aggregate data without creating this problem in the process. Although several filters fulfil this condition, they cannot make the filtered data linearly independent on different time scales. Linear independence means that when price changes on different time scales are applied in an OLS regression model that studies a linear relationship between price changes and announcement surprises, the results do not affect each other. Otherwise, they are ambiguous. As a result, the time profile for a news announcement's impact on the stock price is revealed. Furthermore, news announcements cause jumps in asset prices (Andersen *et al.*, 2003), which requires the filter to maintain this feature when processing data. Fortunately, the wavelet theory provides this type of filter. Wavelets literally mean small waves because they have finite length and are oscillatory. Wavelets on a finite support begin at a point in time and then die out at a later point in time. Their localised nature enables them to be used to analyse episodic variations in the frequency composition of data; thus, they are referred to as a "mathematical microscope". Consequently, wavelets have the ability to isolate jumps at different time scales. The filters, which are based on a Fourier Transform, are not appropriate here because they smooth jumps.

There are two different filters in wavelet theory: the wavelet filter ($\{h_k\}$) and the scaling filter ($\{g_k\}$). Generally, there is a relationship between these filters

$$g_k = (-1)^{k+1} h_{L-k-1} \tag{18}$$

and an inverse relationship

$$h_k = (-1)^k g_{L-k-1}, \tag{19}$$

where L, the width of filter, must be even. $\{g_k\}$ is referred to as the "quadrature mirror filter" (QMF), corresponding to $\{h_k\}$. The scaling filter g_k is a lowpass filter that preserves the contents of the signal at a low frequency and discards the contents at a high frequency, whereas the wavelet filter h_k is a highpass filter that retains only the high-frequency components. The wavelet filter and the scaling filter should fulfil three conditions, respectively:

$$\begin{gathered} \sum h_k = 0,\ \sum h_k^2 = 1,\ \sum h_k h_{k+2m} = 0 \quad (m \neq 0) \\ \sum g_k = \sqrt{2},\ \sum g_k^2 = 1,\ \sum g_k g_{k+2m} = 0 \quad (m \neq 0). \end{gathered} \tag{20}$$

Furthermore, two more conditions are imposed on the wavelet and scaling filters:

$$\begin{aligned} \sum_k g_k h_{k+2m} = 0 \ \ (m \neq 0) \\ \sum_k g_k h_k = 0. \end{aligned} \tag{21}$$

These conditions guarantee that a data sequence can be decomposed orthogonally into components by time scales via discrete wavelet transform (DWT). Correspondingly, a pyramid algorithm is proposed to implement this transform. Specifically, scaling coefficients from the previous level are used as inputs and processed by wavelet and scaling filters to estimate the current level wavelet and scaling coefficients, respectively. The only exception is at the first level, in which the wavelet and scaling filters are applied to the original data sequence. It is noted that jth level is associated with frequency interval $\left(\pi/2^j, \pi/2^{j-1}\right]$. Because frequency ω is related to time horizon T: $\omega = 2\pi/T$, the jth level indicates that the relative data sequence contains information inside the time interval $[2^j, 2^{j+1})$. Wavelet and scaling coefficients can be used to recover the original data sequence or to construct subseries in specific frequency intervals. Here, we use two channel-filter banks to demonstrate wavelet decomposition and synthesis.

4.4.2. The Analysis of Two Channel Filter Banks

A sequence $\{y_t, t = 0, 1, \cdots, T-1\}$, where the tth element of a column vector Y is y_t, goes through a highpass filter H_1 that is constructed by wavelet filters via a downsampling process ($\downarrow 2$) in which the odd-numbered elements of the filtered signal are discarded and the even-numbered elements are preserved. Then, the filtered and downsampled signal, which holds half the information of y_t, is stored and transmitted. Later, this signal goes through an anti-imaging highpass filter C_1, which is constructed by wavelet filters. Prior to this procedure, upsampling ($\uparrow 2$) is performed by inserting zeros between each element of the filtered and downsampled signal. Finally, $\mathbf{w_1}$, involving a half component of the signal y_t in the specific frequency band, is achieved. This process is applied for scaling filters as well, and $\mathbf{v_1}$, which contains the other half part of y_t, is derived. Therefore, the graphic of this flow path is

$$Y \longrightarrow H_1 \longrightarrow \downarrow 2 \longrightarrow \simeq \longrightarrow \uparrow 2 \longrightarrow C_1 \longrightarrow \mathbf{w}_1$$

$$Y \longrightarrow G_1 \longrightarrow \downarrow 2 \longrightarrow \simeq \longrightarrow \uparrow 2 \longrightarrow D_1 \longrightarrow \mathbf{v}_1 \ ,$$

where the structures of matrices G_1 and D_1 are the same as matrices H_1 and C_1, respectively. Both the lowpass filter G_1 and the anti-imaging lowpass filter D_1 are constructed by scaling filters. Here, filters H_1 and G_1 are called analysis filters, and filters C_1 and D_1 are called synthesis filters. The symbol $\simeq$ represents the storage and transmission of the signal.

The output signals formed by the two channel-filter banks are $\mathbf{w}_1$ and $\mathbf{v}_1$, respectively, and their combination is the original signal: $\mathbf{w}_1 + \mathbf{v}_1 = Y$.

Normally, compared to temporal notation, frequency notation is preferred to express this flow path because it can show some properties of these filters. Therefore, the highpass and lowpass flow paths are expressed, respectively, as

$$y(z) \longrightarrow H_1(z) \longrightarrow \downarrow 2 \longrightarrow \simeq \longrightarrow \uparrow 2 \longrightarrow C_1(z) \longrightarrow \mathbf{w}_1(z)$$

$$y(z) \longrightarrow G_1(z) \longrightarrow \downarrow 2 \longrightarrow \simeq \longrightarrow \uparrow 2 \longrightarrow D_1(z) \longrightarrow \mathbf{v}_1(z) \ ,$$

where z could be ω or $e^{-\mathrm{i}\omega}$, and this expression has more generality. It has been proven that the Fourier transforms of $(\downarrow 2)y_t$ and $(\uparrow 2)y_t$ are $[\varepsilon(\omega/2) + \varepsilon(\omega/2 + \pi)]/2$ and $\varepsilon(2\omega)$, respectively.[13] Because $e^{-\mathrm{i}\omega/2} = z^{1/2}$ and $e^{-\mathrm{i}(\omega/2+\pi)} = -z^{1/2}$ where $z = e^{-\mathrm{i}\omega}$, in terms of the z-transform, they can be written as

$$(\downarrow 2)y_t \longleftrightarrow [\varepsilon(z^{1/2}) + \varepsilon(-z^{1/2})]/2 \qquad \text{and} \qquad (\uparrow 2)[(\downarrow 2)y_t] \longleftrightarrow [\varepsilon(z) + \varepsilon(-z)]/2 \ ,$$

where "$\longleftrightarrow$" denotes the Fourier transform, and the right term is the Fourier transform coefficient.

In conclusion, in terms of the z-transform, the highpass and lowpass flow paths are expressed by two equations, respectively:

$$\begin{aligned} \mathbf{w}_1(z) &= \frac{1}{2}C_1(z)[H_1(z)y(z) + H_1(-z)y(-z)] \\ \mathbf{v}_1(z) &= \frac{1}{2}D_1(z)[G_1(z)y(z) + G_1(-z)y(-z)]. \end{aligned} \tag{22}$$

It is presumed that the synthesis of $\mathbf{w}_1(z)$ and $\mathbf{v}_1(z)$ is $x(z)$; thus,

$$\begin{aligned} x(z) = &\frac{1}{2}[C_1(z)H_1(z) + D_1(z)G_1(z)]y(z) \\ &+ \frac{1}{2}[C_1(z)H_1(-z) + D_1(z)G_1(-z)]y(-z). \end{aligned} \tag{23}$$

[13] The details are provided in the appendix: downsampling doubles frequency and upsampling halves frequency.

As $y(-z)$ is caused by aliasing from the downsampling process, it must be eliminated.[14] Here, we set $C_1(z) = -z^{-d}G_1(-z)$, and $D_1(z) = z^{-d}H_1(-z)$, where d is identical to $L-1$, and L is the width of filter. Thus, Equation (23) becomes

$$x(z) = \frac{z^{-d}}{2}[H_1(-z)G_1(z) - H_1(z)G_1(-z)]y(z). \tag{24}$$

It is noted that the aliasing term $y(-z)$ can be cancelled by any choice of $H_1(z)$ and $G_1(z)$ when the anti-imaging filters $C_1(z)$ and $D_1(z)$ are identical to $-z^{-d}G_1(-z)$ and $z^{-d}H_1(-z)$, respectively. However, a restriction on the choice of $H_1(z)$ and $G_1(z)$ is imposed so that the coefficients of the wavelet and scaling filters are mutually orthogonal, including sequential orthogonal and lateral orthogonal. To demonstrate this, we assume that the width of the filter is four. Thus,

$$\begin{aligned} G_1(z) &= g_0 + g_1 z + g_2 z^2 + g_3 z^3 \\ H_1(z) &= h_0 + h_1 z + h_2 z^2 + h_3 z^3. \end{aligned} \tag{25}$$

Because $\{g_k\}$ is referred to as the "quadrature mirror filter" (QMF) corresponding to $\{h_k\}$, $h_k = (-1)^k g_{L-k-1}$ indicates that Equation (25) could be written as

$$\begin{aligned} G_1(z) &= g_0 + g_1 z + g_2 z^2 + g_3 z^3 = z^3 H_1(-z^{-1}) = D_1(z^{-1}) \\ H_1(z) &= g_3 - g_2 z + g_1 z^2 - g_0 z^3 = -z^3 G_1(-z^{-1}) = C_1(z^{-1}), \end{aligned} \tag{26}$$

where

$$\begin{aligned} D_1(z) &= g_0 + g_1 z^{-1} + g_2 z^{-2} + g_3 z^{-3} = z^{-3} H_1(-z) = G_1(z^{-1}) \\ C_1(z) &= g_3 - g_2 z^{-1} + g_1 z^{-2} - g_0 z^{-3} = -z^{-3} G_1(-z) = H_1(z^{-1}). \end{aligned} \tag{27}$$

$C_1(z) = H_1(z^{-1})$ and $D_1(z) = G_1(z^{-1})$ indicate that the synthesis filters are simply the reversed-sequence anti-causal versions of analysis filters. Equations (26) and (27) tell us that Equation (24) can be rendered as

$$\begin{aligned} x(z) &= \frac{1}{2}[H_1(z)H_1(z^{-1}) + G_1(z)G_1(z^{-1})]y(z) \\ &= \frac{1}{2}[D_1(-z)G_1(-z) + D_1(z)G_1(z)]y(z) \\ &= \frac{1}{2}[P(-z) + P(z)]y(z), \end{aligned} \tag{28}$$

[14] Aliasing may occur when a temporal sequence is Fourier transformed in terms of its frequency. This occurs because the basis of the Fourier analysis is the cosine and sine functions. Suppose the angular velocity ω exceeds the Nyquist value (π), $\omega \in (\pi, 2\pi]$, and define $\omega_* = 2\pi - \omega$, $\omega_* \in [0, \pi)$. Thus, for all values of $t = 0, \ldots, T-1$, $\cos(\omega t) = \cos(2\pi t - \omega_* t) = \cos(2\pi t)\cos(\omega_* t) + \sin(2\pi t)\sin(\omega_* t) = \cos(\omega_* t)$. Thus, the cosine functions at the frequency ω and ω_* are identical; this problem is called "aliasing". It is not possible to distinguish the angular frequency ω from the value of the cosine (or sine function). To avoid aliasing, the positive frequencies in the spectral analysis of a discrete time process are limited to the interval $[0, \pi]$. Whether an aliasing problem exists depends on the structure of the particular time series. For many econometric time series, the problem does not arise because their positive frequencies are limited to the average $[0, \pi]$.

where

$$\begin{aligned} P(-z) = D_1(-z)G_1(-z) = H_1(z)H_1(z^{-1}) \\ P(z) = D_1(z)G_1(z) = G_1(z)G_1(z^{-1}). \end{aligned} \tag{29}$$

To achieve the perfect reconstruction in which $x(z)$ is equal to $y(z)$, a condition is imposed:

$$H_1(z)H_1(z^{-1}) + G_1(z)G_1(z^{-1}) = 2. \tag{30}$$

This condition guarantees the perfect reconstruction of the original sequence $y(t)$ from outputs by two-channel filtering. The terms in $H_1(z)H_1(z^{-1})$ and $G_1(z)G_1(z^{-1})$ with an odd power of z are cancelled because of the relationship between the wavelet filter $\{h_l\}$ and the scaling filter $\{g_l\}$ (Equation (21)). The orthogonality conditions of $\{h_l\}$ and $\{g_l\}$ (Equation (20)) make the terms with an even power of z equal to zero and the terms associated with a zero power of z identical to 2. Consequently, Equation (30) is always valid in the wavelet theory. This result is applied to the further decomposition and reconstruction in DWT as well. Thus, the sum of component signals is the original signal: $\sum_{j=1}^{J} \mathbf{w}_j + \mathbf{v}_J = Y$. In conclusion, we briefly introduce the deconstruction and the perfect reconstruction of a time series by two channel filter banks. These two channel filter banks offer us the entire architecture for the dyadic wavelet analysis and help us to interpret this analysis more easily.

The above introduction of dyadic wavelet analysis concentrates on frequency notation. Returning to temporal notation, we use the circulant matrix K_T to replace z in Equation (25), where $K_T = [e_1, e_2, \cdots, e_{T-1}, e_0]$, which is established by shifting the first column of an identity matrix ($I = [e_0, e_1, \cdots, e_{T-1}]$) to the last column, and T is the length of the original time series. The results are the filter matrices H_1 and G_1. Because $K_T^{-1} = K_T'$, the filter matrices H_1' and G_1' are associated with $H_1(z^{-1})$ and $G_1(z^{-1})$, respectively. Because $C_1(z) = H_1(z^{-1})$ and $D_1(z) = G_1(z^{-1})$ in Equation (27), the anti-imaging highpass filter matrix C_1 and lowpass filter matrix D_1 are equal to the transpose of the highpass filter matrix H_1 and the lowpass filter matrix G_1, respectively. The operation "downsampling" can be represented by a matrix V, where $V = \Lambda' = [e_0, e_2, \cdots, e_{T-2}]'$. This comes from the identity matrix ($I = [e_0, e_1, \cdots, e_{T-1}]$), in which the alternate rows are deleted. As introduced earlier by frequency notation, a sequence goes through a highpass filter matrix H_1 or a lowpass filter matrix G_1 and then is downsampled (V). The outputs are wavelet coefficients associated with the highpass filter or scaling coefficients associated with the lowpass filter. The wavelet and scaling coefficients at the first level are referred to as $\alpha_{(1)}$ and $\beta_{(1)}$, respectively, and are identical to

$$\begin{aligned} \alpha_{(1)} &= VH_1Y \\ \beta_{(1)} &= VG_1Y. \end{aligned} \tag{31}$$

To construct the component signals $\mathbf{w}_1$ and $\mathbf{v}_1$, they are first upsampled. Matrix Λ can be used to represent this operation. Second, the upsampled coefficients go through the anti-imaging highpass filter matrix C_1 or the lowpass filter matrix D_1, in which $C_1 = H_1'$ and $D_1 = G_1'$. The results are the component signal $\mathbf{w}_1$ or $\mathbf{v}_1$, which is equal to

$$\begin{aligned} \mathbf{w}_1 &= H_1'\Lambda\alpha_{(1)} = H_1'\Lambda V H_1 Y \\ \mathbf{v}_1 &= G_1'\Lambda\beta_{(1)} = G_1'\Lambda V G_1 Y. \end{aligned} \tag{32}$$

Because the synthesis of the component signals $\mathbf{w}_1$ and $\mathbf{v}_1$ is the original time series, we have

$$Y = \mathbf{w}_1 + \mathbf{v}_1 = H_1'\Lambda V H_1 Y + G_1'\Lambda V G_1 Y. \tag{33}$$

This entire process is also applied on the further decomposition and reconstruction. The only difference is that scaling coefficients from the previous level are used as inputs instead. Consequently, the wavelet coefficients associated with the jth-level wavelet filter are

$$\alpha_{(j)} = V_j H_j V_{j-1} G_{j-1} \cdots V_1 G_1 Y, \tag{34}$$

and the scaling coefficients associated with the jth-level scaling filter are

$$\beta_{(j)} = V_j G_j V_{j-1} G_{j-1} \cdots V_1 G_1 Y, \tag{35}$$

where $V_j = \Lambda_j' = [e_0, e_2, \cdots, e_{T/2^{j-1}-2}]'$, which is established by deleting the alternate rows of an identity matrix ($I_{T/2^{j-1}} = [e_0, e_1, \cdots, e_{T/2^{j-1}-1}]$). The matrices H_j and G_j, in terms of polynomial expression, can be written as

$$H_j = H(K_{T/2^{j-1}}) = h_0 K^0_{T/2^{j-1}} + h_1 K^1_{T/2^{j-1}} + \cdots + h_{L-1} K^{L-1}_{T/2^{j-1}} \tag{36}$$

and

$$G_j = G(K_{T/2^{j-1}}) = g_0 K^0_{T/2^{j-1}} + g_1 K^1_{T/2^{j-1}} + \cdots + g_{L-1} K^{L-1}_{T/2^{j-1}}, \tag{37}$$

where L is the width of the filter and T is the length of original time series. It is not difficult to find that

$$\begin{aligned} V_j H_j V_{j-1} G_{j-1} \cdots V_1 G_1 &= V_j V_{j-1} \cdots V_1 H(K_T^{2j-2}) G(K_T^{2j-4}) \cdots G(K_T) \\ V_j G_j V_{j-1} G_{j-1} \cdots V_1 G_1 &= V_j V_{j-1} \cdots V_1 G(K_T^{2j-2}) G(K_T^{2j-4}) \cdots G(K_T), \end{aligned} \tag{38}$$

where the jth-level wavelet filter $\{h_{j,k}\}$ forms the matrix:[15]

$$H(K_T^{2j-2}) G(K_T^{2j-4}) \cdots G(K_T), \tag{39}$$

[15] To unify the matrix expression, the matrix V and Λ in the first decomposed level are rewritten as V_1 and Λ_1, respectively. $\{h_{1,k}\}$ is referred to as the first-level wavelet filter $\{h_k\}$; it is applied on the first-level scaling filter $\{g_k\}$ as well.

and the jth-level scaling filter $\{g_{j,k}\}$ matrix is

$$G(K_T^{2j-2})G(K_T^{2j-4})\cdots G(K_T). \tag{40}$$

Accordingly, the wavelet and scaling amplitudes can also be expressed by

$$\begin{aligned}\alpha_{(j)} &= V_jV_{j-1}\cdots V_1H(K_T^{2j-2})G(K_T^{2j-4})\cdots G(K_T)Y\\ \beta_{(j)} &= V_jV_{j-1}\cdots V_1G(K_T^{2j-2})G(K_T^{2j-4})\cdots G(K_T)Y.\end{aligned} \tag{41}$$

Observing the component signal $\mathbf{w}_1$, we find that it is estimated by multiplying the transpose of the production of matrices V and H_1 by wavelet coefficients $\alpha_{(1)}$, which are the results of multiplying the production itself by the original time series Y. This mathematical operation also works on another component signal $\mathbf{v}_1$ with the scaling filter matrix G_1. Generally, we find that it is always valid for the component signals $\mathbf{w}_j$ and $\mathbf{v}_j$ at the jth level. Consequently, the component signal $\mathbf{w}_j$ is

$$\begin{aligned}\mathbf{w}_j &= [V_jH_jV_{j-1}G_{j-1}\cdots V_1G_1]'\alpha_{(j)} \qquad (42)\\ &= [V_jV_{j-1}\cdots V_1H(K_T^{2j-2})G(K_T^{2j-4})\cdots G(K_T)]'\alpha_{(j)},\end{aligned}$$

and the component signal $\mathbf{v}_j$ is

$$\begin{aligned}\mathbf{v}_j &= [V_jG_jV_{j-1}G_{j-1}\cdots V_1G_1]'\beta_{(j)} \qquad (43)\\ &= [V_jV_{j-1}\cdots V_1G(K_T^{2j-2})G(K_T^{2j-4})\cdots G(K_T)]'\beta_{(j)}.\end{aligned}$$

According to the orthogonality conditions of wavelet and scaling filters on Equations (20) and (21), we have

$$\begin{bmatrix} V_jH_j \\ V_jG_j \end{bmatrix}\begin{bmatrix} (V_jH_j)' & (V_jG_j)' \end{bmatrix} = \begin{bmatrix} V_jH_jH_j'\Lambda_j & V_jH_jG_j'\Lambda_j \\ V_jG_jH_j'\Lambda_j & V_jG_jG_j'\Lambda_j \end{bmatrix} = \begin{bmatrix} I_{T/2^j} & 0 \\ 0 & I_{T/2^j} \end{bmatrix} \tag{44}$$

and

$$\begin{bmatrix} (V_jH_j)' & (V_jG_j)' \end{bmatrix}\begin{bmatrix} V_jH_j \\ V_jG_j \end{bmatrix} = H_j'\Lambda_jV_jH_j + G_j'\Lambda_jV_jG_j = I_{T/2^{j-1}}. \tag{45}$$

As a result, we infer that

$$\begin{aligned}&\mathbf{v}_j'\mathbf{w}_j = 0\\ &\mathbf{w}_j'\mathbf{w}_k = 0 \;\; (j \neq k)\\ &\sum_{j=1}^{J}\mathbf{w}_j + \mathbf{v}_J = Y,\end{aligned} \tag{46}$$

which illustrate the lateral orthogonality ($\mathbf{w}_j \perp \mathbf{v}_j$) and sequential orthogonality ($\mathbf{w}_j \perp \mathbf{w}_k$), respectively. A data sequence can be decomposed orthogonally into components by time scales using wavelets. Because orthogonality is a special case of linear independence, the components at different time scales are linearly independent. The component signal $\mathbf{w}_j$ is associated with the frequency interval $\left(\pi/2^j, \pi/2^{j-1}\right]$, which implies that it contains information inside the time interval $[2^j, 2^{j+1})$.

In this paper, we use the Daubechies least asymmetric (LA) wavelet filter of width 8 to orthogonally decompose one-minute price changes by ten scales.[16] The tenth scale, which indicates that the time interval of the data sequence is $[2^{10}, 2^{11})$ minutes (approximately one day change), shows the maximum change in time during the ten scales. Because the increases in price volatility persist over approximately an hour in the paper, which is longer than an hour but shorter than the one day suggested by a number of papers, price changes on this scale and smaller scales are sufficient to examine the eventual impact of news announcements on the stock market. Price changes on each scale that are estimated using wavelets are called "wavelet-scale price changes".

4.4.3. The Findings of News Announcements' Eventual Impact on Stock Prices

We regress the wavelet-scale price changes on the surprises in the 17 economic variables, as in the static analysis. Table 9 reports the estimation results of the model of the wavelet-scale price changes using different time intervals, including response coefficients and t-statistics, following the same format as Table 8. The results show the subsequent adjustment of the stock market to more news announcements. In the entire sample period, there are six announcements that significantly affect the price change at the first scale. In these six announcements, this price change is positively related to unexpected components of consumer confidence, the leading index and PMI, and it is negatively related to unexpected components of PPI, new single-family home sales and consumer credit. Similarly, three announcements significantly affect the price change at the second scale. In particular, the unexpected announcements of PPI and consumer credit have a positive impact on this price change, whereas the unexpected announcement of new single-family home sales has a negative impact on this price change.

In addition, the price change at the third scale positively reacts to unanticipated changes in capacity utilisation, new single-family home sales and PMI and negatively reacts to unanticipated changes in PPI and nonfarm payrolls. The price change at the fourth scale positively reacts to IP, consumer confidence, and new single-family home sales and negatively reacts

[16] This filter with this width is recommended by Percival and Walden (2000) and is widely used in the literature on wavelet analysis (Kim and In (2003), Gallegati (2008)).

to personal consumption. The price change at the fifth scale positively reacts to civilian unemployment and consumer credit and negatively reacts to personal consumption, the trade balance, and the federal budget. The price change at the sixth scale positively reacts to personal consumption and negatively reacts to capacity utilisation and the trade balance. The price change at the seventh scale positively reacts to personal consumption and durable goods orders and negatively reacts to IP and personal income. Finally, the price change at the eighth scale negatively reacts to CPI, personal income, durable goods orders, and consumer credit; the price change at the ninth scale negatively reacts to PPI; and the price change at the tenth scale negatively reacts to consumer confidence.

As shown in the static analysis, the wavelet analysis finds that more announcements affect the stock market conditional on the business cycle, and some have an eventual impact only for a particular type of economic period. To explore this observation further, consumer confidence, the leading index, and the federal budget positively affect price change at the first scale, whereas PPI, new single-family home sales, and consumer credit negatively affect this price change in the expansion periods. PMI and durable goods orders positively affect the price change and nonfarm payrolls negatively affect the price change by the same time interval in the contraction periods. Consumer credit has a positive impact, whereas new single-family home sales have a negative impact on the price change at the second scale in the expansion periods. Manufacturers' new orders are positively related, whereas civilian unemployment and personal consumption are negatively related to the price change at the same scale in the contraction periods.

Moreover, the price change at the third scale positively reacts to new single-family home sales in the expansion period and capacity utilisation and PMI in the contraction periods, and it negatively reacts to CPI, PPI, and personal consumption in the expansion period and civilian unemployment and nonfarm payrolls in the contraction period. The price change at the fourth scale positively reacts to new single-family home sales in the expansion period and PPI, IP, and PMI in the contraction period, and it negatively reacts to the federal budget in the contraction period and personal consumption in both economic periods. The price change at the fifth scale positively reacts to consumer credit in the expansion periods and civilian unemployment in both economic periods, and it negatively reacts to personal consumption and the federal budget in the expansion period, capacity utilisation and new single-family home sales in the contraction period, and the trade balance in both economic periods. The price change at the sixth scale positively reacts to the federal budget in the expansion period, new single-family home sales in the contraction period, and personal consumption in both economic periods, and it negatively reacts to capacity utilisation in the expansion period and PMI and the federal budget in the contraction period. The price change at the seventh scale positively reacts to PPI and manufacturers' new orders in the expansion period, nonfarm payrolls, capacity utilisation, the trade balance, consumer confidence, durable goods orders, and consumer credit in the contraction period, and the federal budget in both economic periods. It negatively reacts to personal income in the expansion period and IP and the leading index in the contraction period. The price change at the eighth scale positively reacts to new single-family home sales in the contraction period, and it negatively reacts to CPI, personal income, durable goods orders, and consumer credit in the expansion period and the trade balance and the federal budget in the contraction period. The price change at the ninth scale positively reacts to PPI and negatively reacts to PMI in the contraction period; and the price change at the tenth scale negatively reacts to consumer confidence in the contraction period.

In sum, more news announcements cause the subsequent adjustments of the stock market when examining different stages of the economy. The eventual impact of news announcements on the stock market is quite stable conditional on the business cycle. Furthermore, the signs of the response coefficients on the same announcement surprise vary over wavelet-scale price changes by different time intervals. This finding is attributed to the market participants' subsequent adjustments to news announcements. Only some announcements significantly affect the stock price based on the static analysis. In comparison, all of the news announcements found by the wavelet analysis impose an eventual impact on the stock market over different time periods, regardless of the size of the impact. The stock market significantly reacts to more announcements through price changes at smaller time scales and reacts to fewer announcements through price changes at bigger time scales.

Kimmel (2004), and Oberlechner and Hocking (2004) find that market participants are concerned about rumours in financial markets. The financial press report these rumours, including the *Wall Street Journal*'s "Heard on the Street" and "Abreast of the Market" columns, *Business Week*'s "Inside Wall Street" column, and *SmartMoney*'s Web site. This reporting indicates the importance of rumours and implies that rumours can sometimes affect financial markets as much as scheduled news announcements. Thus, we believe that all reliable news announcements can have a significant impact on the market unless market participants perfectly expect them. This belief contradicts the results of previous papers, which claim that the market responds to only some announcements. As mentioned earlier, previous papers examine the market's response to news announcements based on static changes in prices, which ignores the impact of announcements on the price changes by different time scales, denoting that price change information occurs in different time intervals.

Regarding the size of the eventual impact of news announcements on stock prices, the most important announcements during the entire sample period, the expansion period, and the contraction period are shown as follows, respectively: consumer confidence, PPI, and nonfarm payrolls at the first scale; PPI, new single-family home sales, and nonfarm payrolls at the second scale; capacity utilisation, PPI, and capacity utilisation at the third scale; IP, personal consumption, and the federal budget at the fourth scale; civilian unemployment, personal consumption, and new single-family home sales at the fifth scale; capacity utilisation, capacity utilisation, and new single-family home sales at the sixth scale; IP, personal income, and consumer credit at the seventh scale; and personal income, personal income, and new single-family home sales at the eighth scale. In the entire sample period and the contraction periods, PPI has a larger eventual impact on the stock price change at the ninth scale, and consumer confidence is the only announcement that still significantly affects the stock price change at the tenth scale.

It is noted that the magnitudes of the response coefficients are considerably reduced over the larger time scales. In particular, the magnitudes for the price change at the sixth scale and the larger scales are smaller than 10^{-6}, whereas almost all magnitudes for the price change at the smaller scales are notably larger than 10^{-6}. These findings imply that the eventual impact of news announcements is very small over longer than an hour after the announcements because the sixth scale indicates a time interval for the data sequence of approximately an hour. Consequently, this finding provides evidence of why price volatility remains considerably higher than normal over approximately an hour but less than a day.

According to the results of the wavelet analysis over the entire sample period, the expansion period and the contraction period, most announcements that impose a significant eventual impact on the stock market are released at 8:30 or 9:15. These announcements belong to the 8:30 & 9:15 announcements category. This result is consistent with the findings in Tables 5, 6, and 7 showing that the increases in price volatility persist over approximately an hour for 8:30 & 9:15 announcements, whereas they persist over a shorter time for other announcements.

5. Conclusion

This paper examines the impact of monthly news announcements on the price, trading volume, and price volatility of S&P 500 index futures. The market participants' responses to scheduled news announcements are viewed as information processing in financial markets. In accordance with the participants' initial analyses, they immediately react when a news announcement is released. Then, market participants adjust their investing decisions by observing the market's subsequent performance. Accordingly, the way information spreads in the market is understood by examining market participants' responses to news announcements in two distinct stages.

In sum, the effect of news announcements includes immediate and eventual effects, which are identified by price volatility and trading volume by one-minute and five-minute intervals, respectively. The immediate effect is a sharp and nearly instantaneous price change along with a rise in trading volume, and the eventual effect causes a persistent increase in price volatility and trading volume. Furthermore, the static analysis indicates which announcements immediately affect the stock price, whereas the wavelet analysis shows which announcements eventually affect the stock price. The combination of these results provides us with the time-profile for each type of news announcement's impact on the stock price and demonstrates that the impact is short lived to within a day. Although many announcements do not have an immediate impact on stock price, all announcements impose an eventual impact on stock price over different time periods.

It is important to note that price is more volatile and trading volume is lower over contraction period in comparison with expansion period on both announcement days and nonannouncement days, as shown in Figures 5A, 5B, 6A, and 6B, because market participants are more susceptible and less active in contraction periods. This result explains why the magnitudes of response coefficients in the contraction period are always greater than those in the expansion period. On the one hand, market participants react to news announcements more moderately during contraction periods. They are news insensitive and change stock prices by a smaller scale through a higher number of trading transactions. They then make smaller subsequent adjustments to stock prices along with a lower number of trading transactions across a shorter time to reconcile their different views on news announcements. On the other hand, market participants are news sensitive in expansion periods and change stock prices by a larger scale through a lower number of trading transactions. They then make larger subsequent adjustments of stock prices accompanied by a higher number of trading transactions across a longer time to reconcile their different views of news announcements.

Consequently, news announcements create larger immediate price changes per interval in the expansion periods and more immediate price changes per interval in the contraction periods from the old equilibrium to the approximate new equilibrium. It takes smaller subsequent adjustments of stock prices along with a lower number of trading transactions across a shorter time in the contraction period for the information contained in news announcements to be incorporated fully in stock prices. This finding implies a more efficient market in the contraction periods and shows that the market participants' behaviour is conditional on the economic state. The market's response to news announcements varies over different stages of the business cycle, although the signs of the response coefficients are quite consistent. The combination of the results from the examination of the two different stages of the business cycle shows that the market significantly reacts to more announcements in comparison with the results from the entire sample period because some news announcements impose a significant impact only in a particular type of economic period.

Because the arrival of scheduled news announcements brings high uncertainty into the market, market participants generally withdraw from the market prior to announcements to avoid the high risk. Price volatility and trading volume thus significantly decline prior to announcements. The "calm before the storm" effect arises 2 or 3 minutes before announcements. The financial press usually claims that this effect is observed over the days prior to the announcements, as supported by Jones *et al.* (1998). However, this finding is questioned because the effect of new announcements on financial markets does not last over a day, a result that has been found by a number of previous papers and this paper. Accordingly, we believe that the "calm before the storm" effect is only observed some minutes prior to the announcements, as found in this paper.

References

Andersen, T.G., Bollerslev, T., Diebold, F.X., and Vega, C. (2003). Micro Effects of Macro Announcements: Real-Time Price Discovery in Foreign Exchange. *American Economic Review,* 93(1), 38-62.

Balduzzi, P., Elton, E.J., and Green, T.C. (2001). Economic News and Bond Prices: Evidence from the U.S. Treasury Market. *Journal of Financial and Quantitative Analysis,* 36(4), 523-543.

Cederburg, S. (2008). Mutual Fund Investor Behavior across the Business Cycle. *Working Paper, University of Iowa.*

Cornell, B. (1983). The Money Supply Announcements Puzzle: Review and Interpretation. *American Economic Review,* 73(4), 644-657.

Ederington, L.H., and Lee, J.H. (1993). How Markets Process Information: News Releases and Volatility. *Journal of Finance,* 48(4), 1161-1191.

Ederington, L.H., and Lee, J.H. (1995). The Short-Run Dynamics of the Price Adjustment to New Information. *Journal of Financial and Quantitative Analysis,* 30(1), 117-134.

Edison, H.J. (1997). The Reaction of Exchange Rates and Interest Rates to News Releases. *International Journal of Finance and Economics,* 2(2), 87-100.

Fleming, M.J., and Remolona, E.M. (1997). What Moves the Bond Market? *Federal Reserve Bank of New York Economic Policy Review,* 3(4), 31-50.

Fleming, M.J., and Remolona, E.M. (1999). Price Formation and Liquidity in the U.S. Treasury Market: The Response to Public Information. *Journal of Finance,* 54(5), 1901-1915.

Gallegati, M. (2008). Wavelet Analysis of Stock Returns and Aggregate Economic Activity. *Computational Statistics & Data Analysis,* 52(6), 3061-3074.

Hardouvelis, G.A. (1987). Macroeconomic Information and Stock Prices. *Journal of Economics and Business,* 39(2), 131-140.

Harvey, C.R., and Huang, R.D. (1993) Public Information and Fixed Income Volatility. Unpublished paper, Duke University.

Jones, C.M., Lamont, O., and Lumsdaine, R.L. (1998). Macroeconomic news and bond market volatility. *Journal of Financial Economics,* 47(3), 315-337.

Kim, S., and In, F.H. (2003). The Relationship between Financial Variables and Real Economic Activity: Evidence from Spectral and Wavelet Analysis. *Studies in Nonlinear Dynamics & Econometrics,* 7(4), article 4.

Kimmel, A.J. (2004). Rumors and the Financial Marketplace. *Journal of Behavioral Finance,* 5(3), 134-141.

McQueen, G., and Roley, V.V. (1993). Stock Prices, News, and Business Conditions. *Review of Financial Studies,* 6(3), 683-707.

Oberlechner, T., and Hocking, S. (2004). Information Sources, News, and Rumors in Financial Markets: Insights into the Foreign Exchange Market. *Journal of Economic Psychology,* 25(3), 407-424.

Pearce, D.K., and Roley, V.V. (1983). The Reaction of Stock Prices to Unanticipated Changes in Money: A Note. *Journal of Finance,* 38(1), 1323-1333.

Pearce, D.K., and Roley, V.V. (1985). Stock Prices and Economic News. *Journal of Business,* 58(1), 49-67.

Percival, D.B., and Walden, A.T. (2000). Wavelet Methods for Time Series Analysis. *Cambridge University Press,* Cambridge, UK.

Schwert, G. (1981). The Adjustment of Stock Prices to Information About Inflation. *Journal of Finance,* 36(1), 15-29.

Urich, T., and Wachtel, P. (1981). Market Response to the Weekly Money Supply Announcements in the 1970s. *Journal of Finance,* 36(5), 1063-1072.

Figure 1A

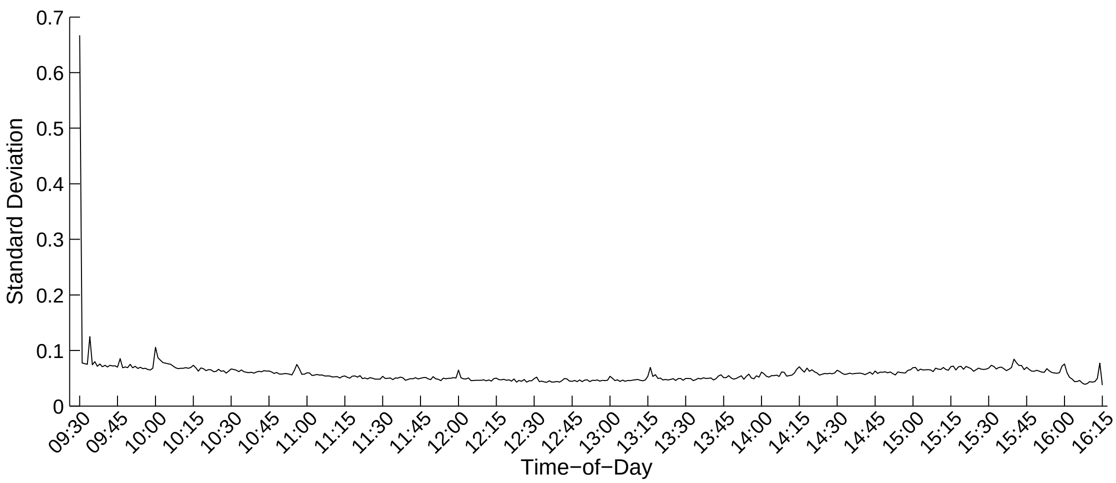

Figure 1B

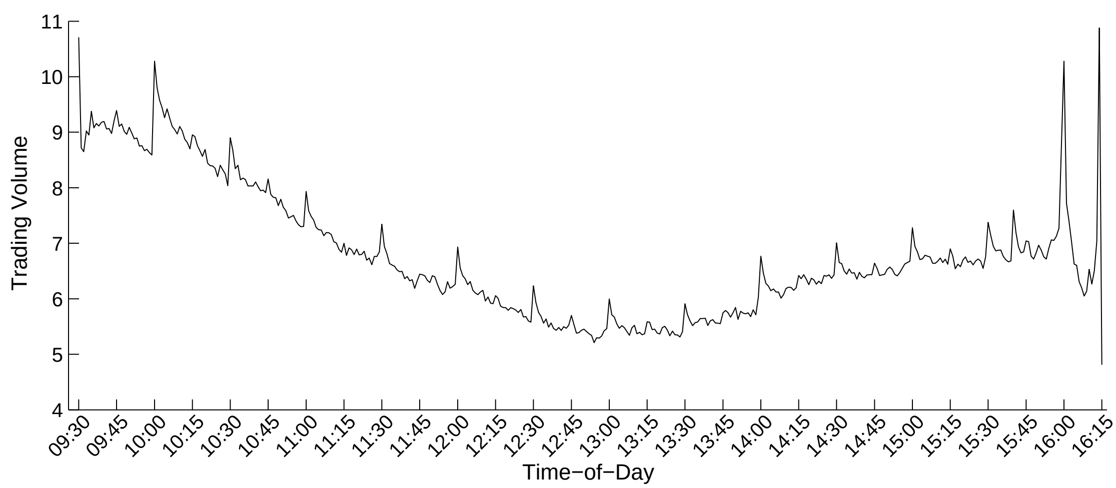

Figure 1. Price volatility and trading volume. The standard deviations of one-minute price changes and the means of one-minute trading volumes, which are proxied by the number of ticks in one minute intervals, at the same time interval across all 3003 trading days from February 3, 1997 to January 30, 2009 are shown in Figure 1A and Figure 1B, respectively. The one-minute price changes are the calculated values times 10^2, and the times shown on the horizontal line are the interval ending times.

Figure 2A

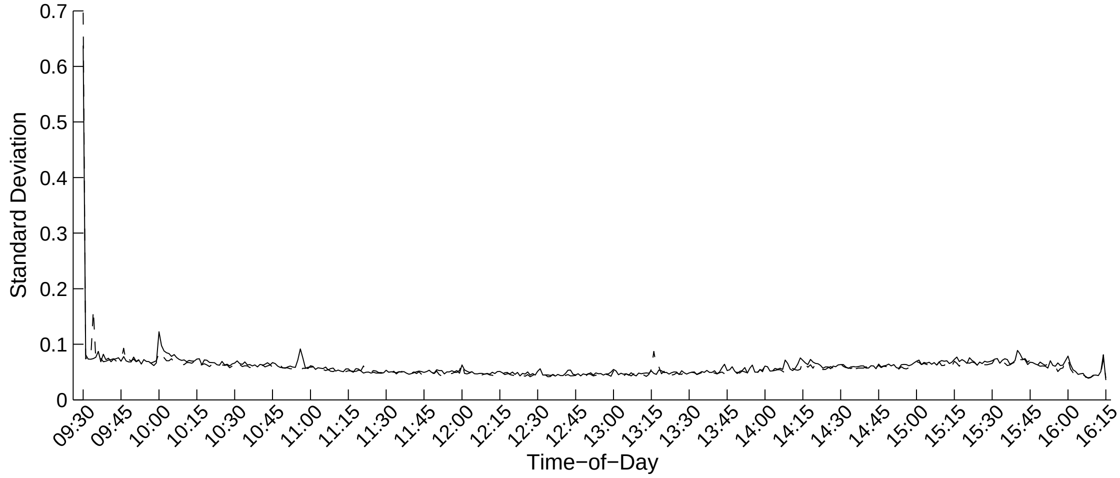

Figure 2B

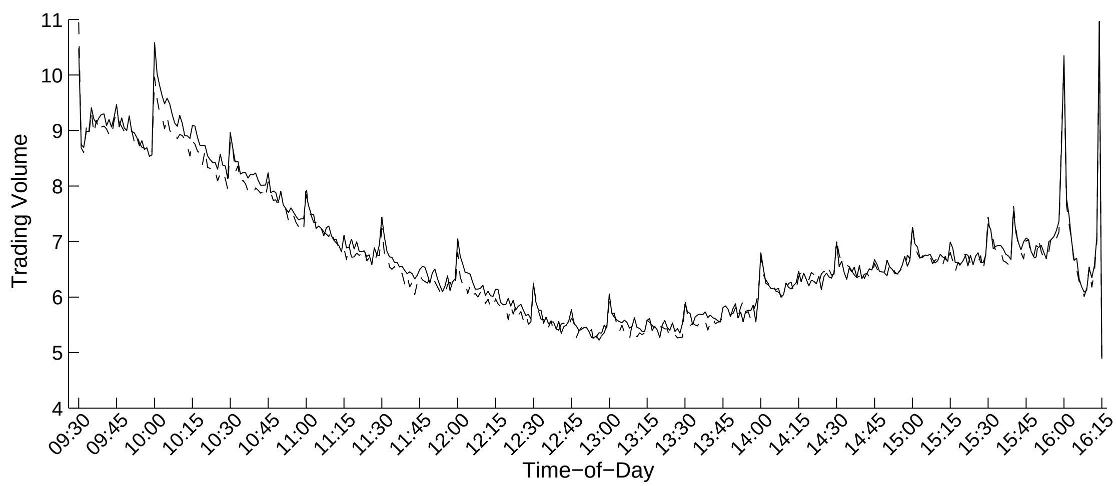

Figure 2. Price volatility and trading volume on announcement and nonannouncement days. The standard deviations of one-minute price changes and the means of one-minute trading volumes, which are proxied by the number of ticks in one minute intervals, are reported for days with at least one of the seventeen announcements (solid line) and days with none of these announcements (dashed line) in Figure 2A and Figure 2B, respectively. The one-minute price changes are the calculated values times 10^2, and the times shown on the horizontal line are the interval ending times.

Figure 3A

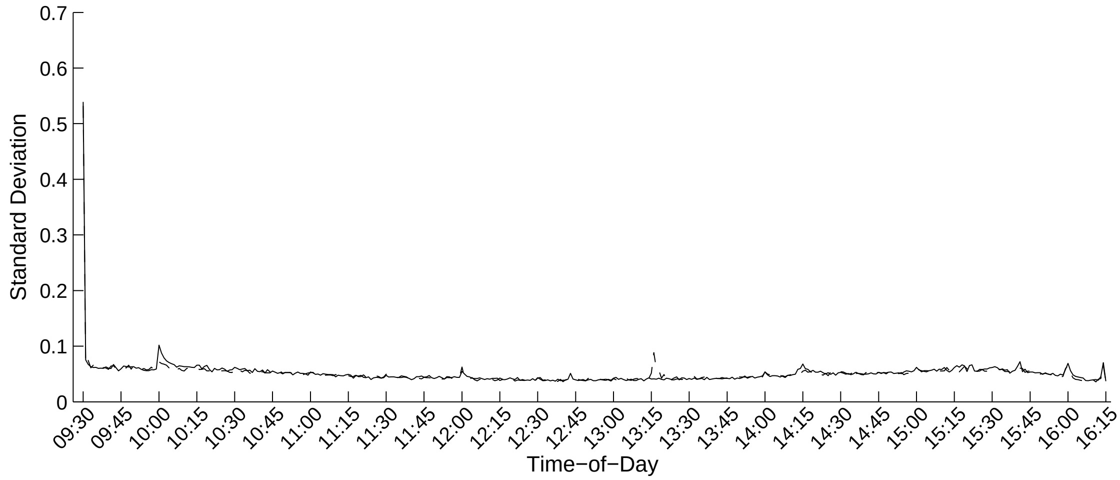

Figure 3B

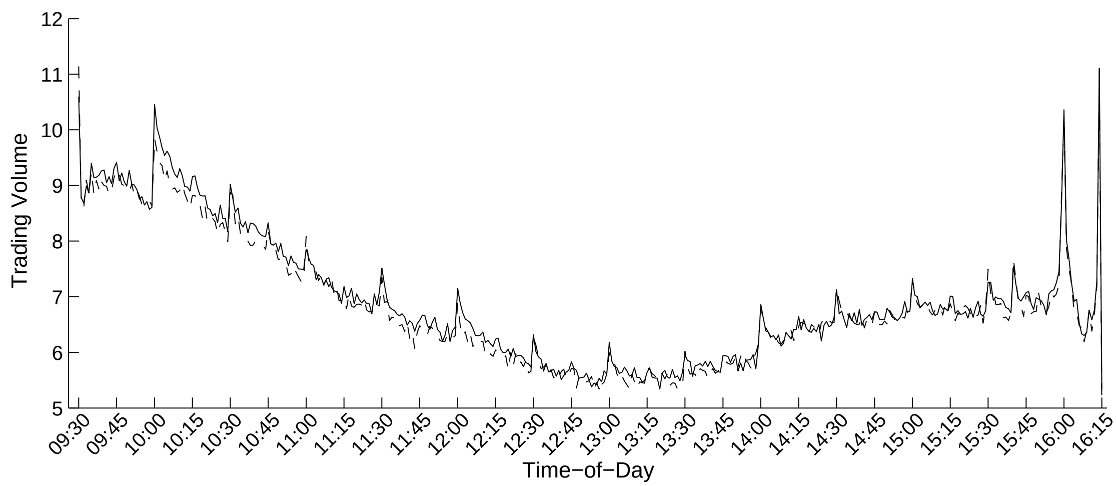

Figure 3. Price volatility and trading volume on announcement and nonannouncement days in the expansion periods. According to the NBER business cycle, trading days from February 3, 1997 to March 30, 2001 and from December 3, 2001 to December 31, 2007 are the expansion periods. The standard deviations of one-minute price changes and the means of one-minute trading volumes, which are proxied by the number of ticks in one minute intervals, are reported for days in the expansion periods with at least one of the seventeen announcements (solid line) and days in the expansion periods with none of these announcements (dashed line) in Figure 3A and Figure 3B, respectively. The one-minute price changes are the calculated values times 10^2, and the times shown on the horizontal line are the interval ending times.

Figure 4A

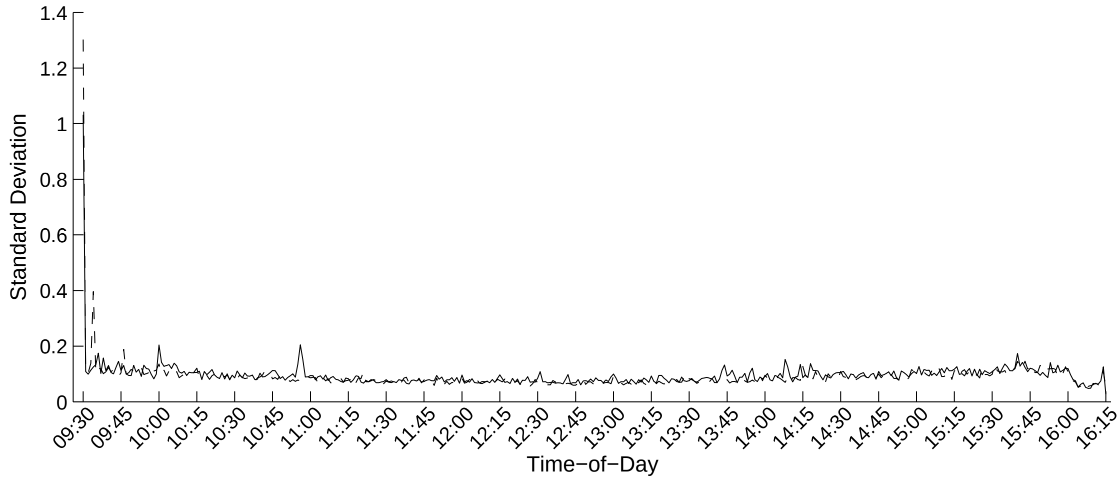

Figure 4B

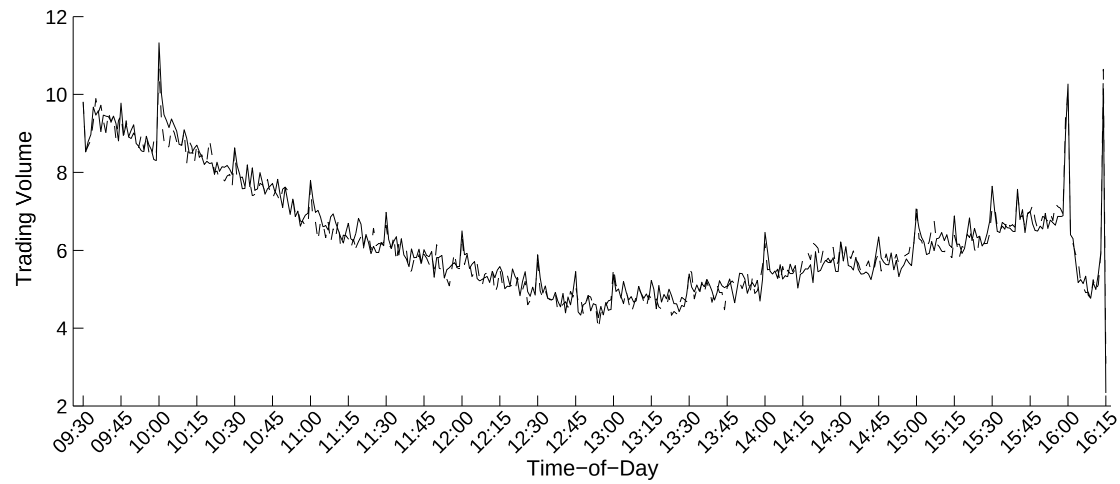

Figure 4. Price volatility and trading volume on announcement and nonannouncement days in the contraction periods. According to the NBER business cycle, trading days from April 2, 2001 to November 30, 2001 and from January 2, 2008 to January 30, 2009 are the contraction periods. The standard deviations of one-minute price changes and the means of one-minute trading volumes, which are proxied by the number of ticks in one minute intervals, are reported for days in the contraction periods with at least one of the seventeen announcements (solid line) and days in the contraction periods with none of these announcements (dashed line) in Figure 4A and Figure 4B, respectively. The one-minute price changes are the calculated values times 10^2, and the times shown on the horizontal line are the interval ending times.

Figure 5A

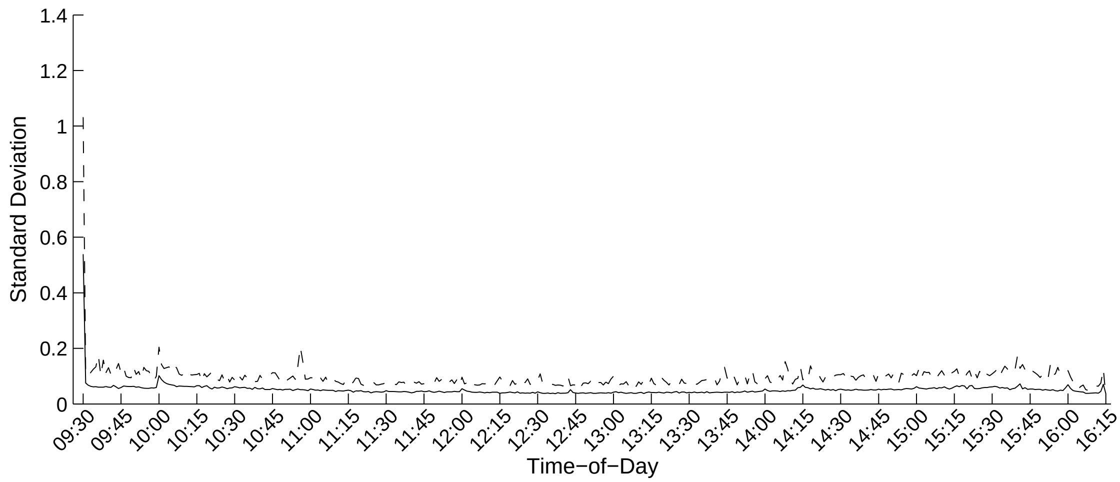

Figure 5B

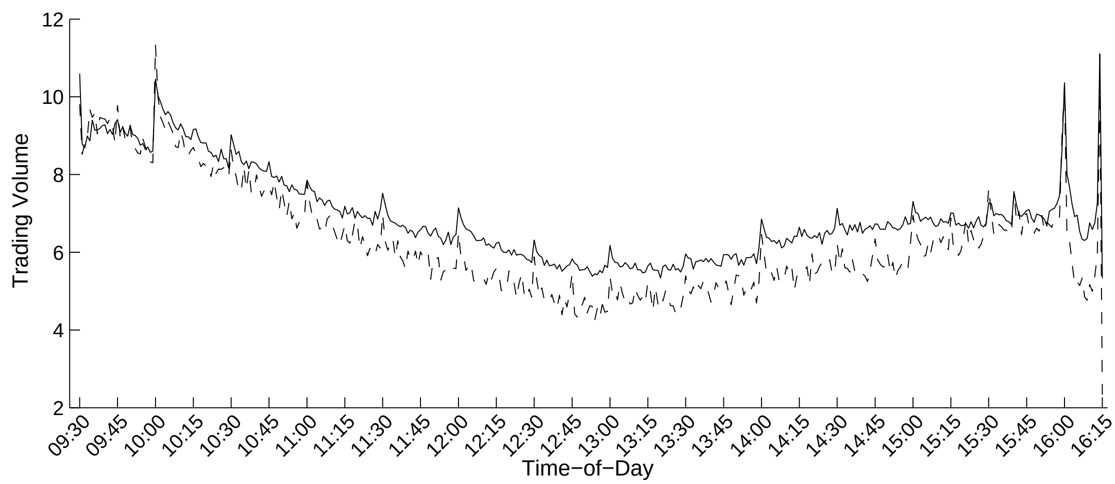

Figure 5. Price volatility and trading volume on announcement days in the expansion periods and in the contraction periods. According to the NBER business cycle, trading days from February 3, 1997, to March 30, 2001, and from December 03, 2001, to December 31, 2007, are the expansion periods, and trading days from April 2, 2001, to November 30, 2001, and from January 2, 2008, to January 30, 2009, are the contraction periods. The standard deviations of one-minute price changes and the means of one-minute trading volumes, which are proxied by the number of ticks in one minute intervals, are reported for days in the expansion periods with at least one of the seventeen announcements (solid line) and days in the contraction periods with at least one of the seventeen announcements (dashed line) in Figure 5A and Figure 5B, respectively. The one-minute price changes are the calculated values times 10^2, and the times shown on the horizontal line are the interval ending times.

Figure 6A

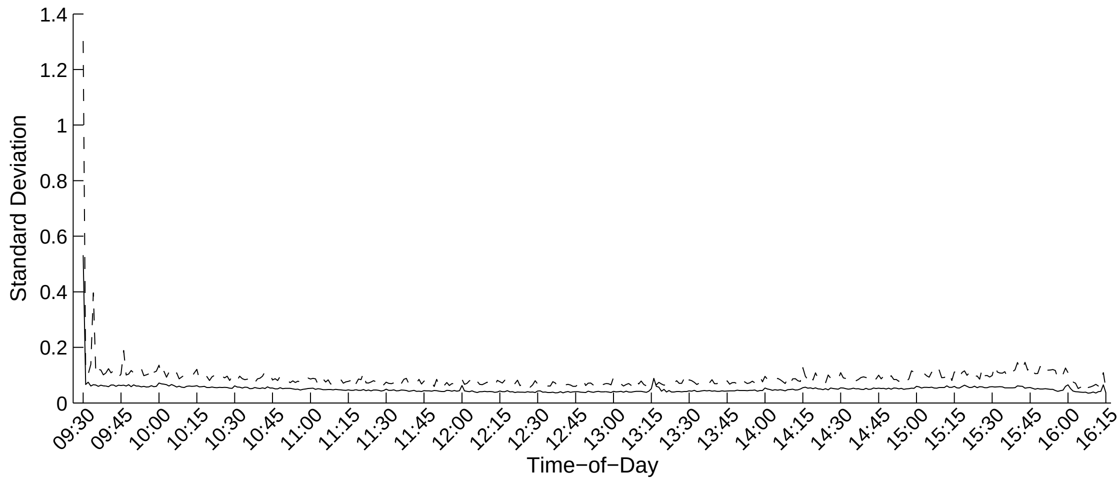

Figure 6B

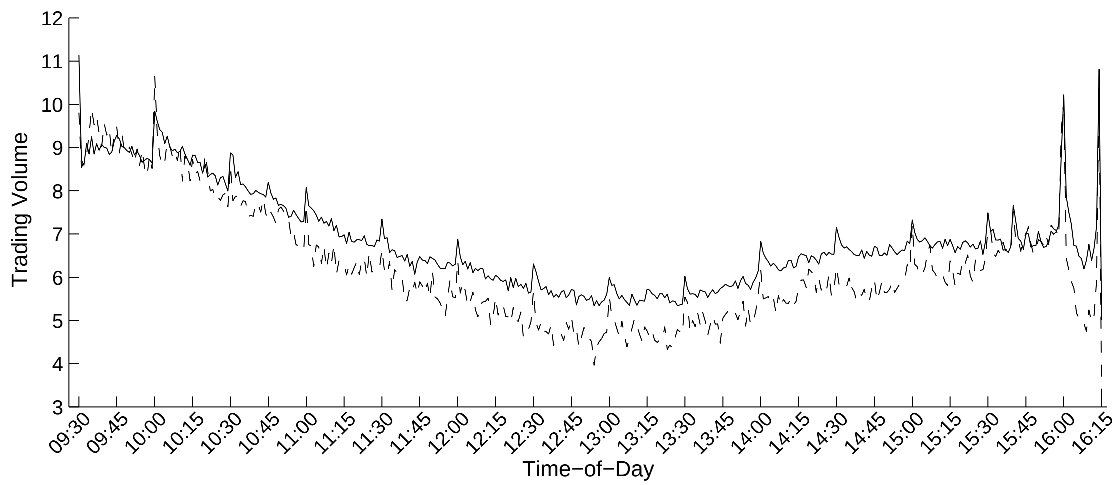

Figure 6. Price volatility and trading volume on nonannouncement days in the expansion periods and in the contraction periods. According to the NBER business cycle, trading days from February 3, 1997 to March 30, 2001 and from December 3, 2001 to December 31, 2007 are the expansion periods, and trading days from April 2, 2001 to November 30, 2001 and from January 2, 2008 to January 30, 2009 are the contraction periods. The standard deviations of the one-minute price changes and the means of the one-minute trading volumes, which are proxied by the number of ticks in one minute intervals, are reported for days in the expansion periods with none of seventeen announcements (solid line) and days in the contraction periods with none of seventeen announcements (dashed line) in Figure 6A and Figure 6B, respectively. The one-minute price changes are the calculated values times 10^2, and the times shown on the horizontal line are the interval ending times.

Figure 7A

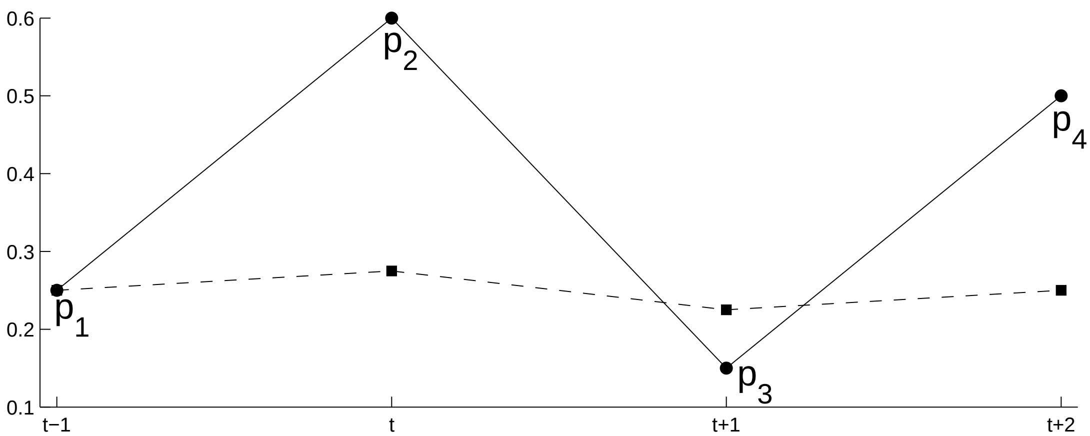

Figure 7B

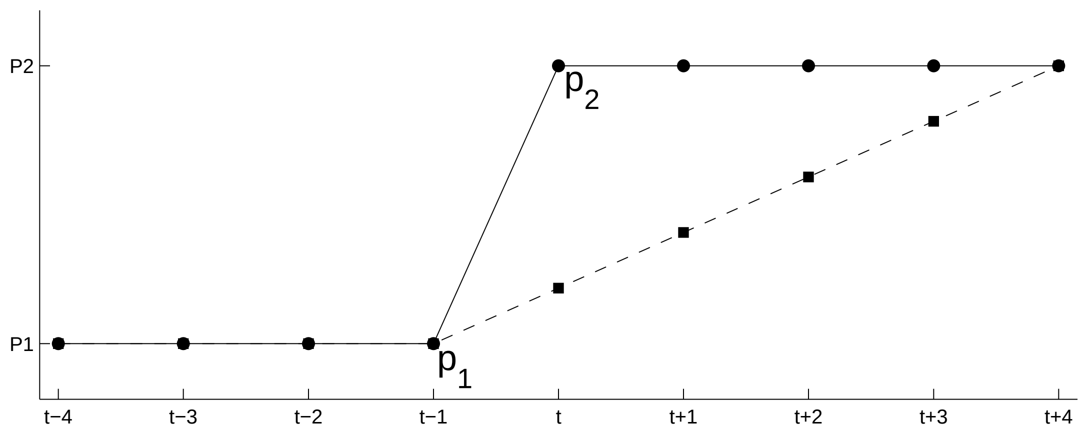

Figure 7. The difference between static price changes. The times shown on the horizontal line are the interval ending times. A news announcement is released at time t. Price changes with and without the effect of a news announcement are shown by the solid and dashed lines, respectively, in Figure 7A. Under the impact of a news announcement at time t on the market, price changes in the first scenario and in the second scenario are drawn with a solid line and a dashed line, respectively, in Figure 7B.

Table 1:

News Announcements and Descriptive Statistics of Data on Standardised Announcement Surprises

News Announcements[1]	Number of Observations[2]			Number of Zeros[3]			$\hat{\sigma}_j^4$	Means[5]			T-statistics		
8:30 Announcements	W[6]	E[6]	C[6]	W[6]	E[6]	C[6]	W[6]	W[6]	E[6]	C[6]	W[6]	E[6]	C[6]
1. CPI (Consumer Price Index)	144	123	21	47	43	4	0.0014	-0.0689	-0.0634	-0.1013	-0.8269	-0.7906	-0.3043
2. PPI (Producer Price Index)	142	122	20	37	29	8	0.0027	-0.0079	-0.0643	0.3361*	-0.0940	-0.6875	2.1628
3. Nonfarm Payrolls	142	121	21	2	2	0	5.0445	-0.0606	-0.0832	0.0701	-0.7217	-0.8540	0.8865
4. Civilian Unemployment	142	121	21	45	43	2	0.0014	-0.1222	-0.2150**	0.4130	-1.4556	-2.6338	1.3884
5. Personal Consumption	139	123	16	38	36	2	0.0017	0.0292	0.0283	0.0362	0.3442	0.3271	0.1104
6. Personal Income	140	123	17	36	33	3	0.0023	0.2073*	0.1874*	0.3515	2.4530	2.2720	0.9593
7. Trade Balance	144	123	21	7	6	1	0.0843	0.1056	0.1764*	-0.3092	1.2667	1.9808	-1.4235
9:15 Announcements													
8. Capacity Utilisation	141	121	20	13	13	0	0.0034	-0.0597	-0.0216	-0.2905	-0.7095	-0.2724	-0.8223
9. IP (Industrial Production)	141	121	20	22	21	1	0.0035	-0.0807	-0.0306	-0.3842	-0.9587	-0.4153	-0.9736
10:00 Announcements													
10. Consumer Confidence	141	120	21	0	0	0	0.0555	0.0076	0.0976	-0.5065	0.0900	1.2891	-1.4438
11. Durable Goods Orders	134	113	21	2	1	1	0.0277	-0.0032	-0.0227	0.1015	-0.0374	-0.2526	0.3762
12. Leading Index	141	120	21	51	42	9	0.0015	-0.0327	-0.0659	0.1568	-0.3883	-0.7638	0.5604
13. Manufacturers' New Orders	143	122	21	10	9	1	0.0104	-0.0603	-0.0526	-0.1050	-0.7213	-0.5753	-0.5019
14. New Single-Family Home Sales	142	121	21	2	1	1	1.1187	-0.0485	-0.0552	-0.0101	-0.5779	-0.5600	-0.8609
15. PMI (Purchasing Managers Index)	142	121	21	4	3	1	0.0392	0.0056	0.0253	-0.1083	0.0662	0.3011	-0.3596
14:00 Announcement													
16. Federal Budget	143	122	21	5	5	0	1.6684	0.1261	0.1225	0.1468*	1.5080	1.2586	2.1046
15:00 Announcement													
17. Consumer Credit	143	122	21	2	2	0	9.8418	0.1022	0.1131	0.0387	1.2219	1.1552	1.2814

1. Sample period: February 1997-January 2009. The release times of news announcements change in some months. Here, we classify the times in terms of when they are usually released.

2. A total of 144 months are in the entire sample period, 123 months are in the expansion period, and 21 months are in the contraction period. For almost all types of news announcements, some observations are missed.

3. A zero value for the announcement surprise indicates that survey participants accurately forecast the announced value of news in the month.

4. $\hat{\sigma}_j$ represents the sample standard deviation of the surprise of announcement j, which is used in Equation (16).

5. $*$ and $**$ denote statistical significance at the 5% and 1% levels, respectively.

6. The entire sample period is abbreviated as "W", the expansion period as "E", and the contraction period as "C".

Table 2:
Price Volatility and Trading Volume by One-Minute Intervals in the Whole Sample Period

One-minute price change standard deviations and trading volume means are reported and compared for announcement (at a specific time) and nonannouncement days for the U.S. S&P 500 index futures for the entire sample period. Announcement days are defined as those with announcements released at the specific time, including 8:30 & 9:30, 10:00, 14:00 or 15:00 announcements. Nonannouncement days are those with no 8:30 & 9:30, 10:00, 14:00 and 15:00 announcements. We list the Brown-Forsythe-modified Levene F-statistic comparing variances for announcement and nonannouncement days and the t-statistic comparing means for announcement and nonannouncement days assuming unequal variances. All one-minute intervals between 9:30 and 9:41 and the time period over 16:15 to 9:30 are examined for 8:30 & 9:15 announcements. All one-minute intervals from 9:55 to 10:07 are examined for 10:00 announcements. All one-minute intervals from 13:55 to 14:07 are examined for the 14:00 announcement. All one-minute intervals from 14:55 to 15:07 are examined for the 15:00 announcement. The data period is February 03, 1997, to January 30, 2009.

					Panel A: Price Volatility							
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:31	9:31-9:32	9:32-9:33	9:33-9:34	9:34-9:35	9:35-9:36	9:36-9:37	9:37-9:38	9:38-9:39	9:39-9:40	9:40-9:41
Announcement day	0.644	0.075	0.071	0.078	0.075	0.077	0.100	0.070	0.094	0.074	0.077	0.069
Nonannouncement day	0.697	0.074	0.079	0.077	0.162	0.071	0.072	0.074	0.069	0.069	0.071	0.072
Standard deviation ratio	0.925	1.014	0.895	1.014	0.462	1.072	1.396	0.938	1.364	1.070	1.078	0.959
F-ratio	1.070	2.746*	0.103	1.574	0.468	0.147	2.436	0.658	2.824*	2.127	1.886	0.498
10 : 00 announcements	9:55-9:56	9:56-9:57	9:57-9:58	9:58-9:59	9:59-10:00	10:00-10:01	10:01-10:02	10:02-10:03	10:03-10:04	10:04-10:05	10:05-10:06	10:06-10:07
Announcement day	0.068	0.059	0.058	0.056	0.142	0.113	0.100	0.095	0.083	0.083	0.073	0.071
Nonannouncement day	0.067	0.066	0.068	0.070	0.084	0.074	0.076	0.070	0.070	0.074	0.067	0.067
Standard deviation ratio	1.011	0.885	0.857	0.803	1.684	1.521	1.318	1.341	1.184	1.120	1.088	1.066
F-ratio	0.111	5.312**	3.031*	8.334***	109.734***	98.197***	25.730***	38.533***	24.231***	5.955**	7.190***	6.933***
14 : 00 announcement	13:55-13:56	13:56-13:57	13:57-13:58	13:58-13:59	13:59-14:00	14:00-14:01	14:01-14:02	14:02-14:03	14:03-14:04	14:04-14:05	14:05-14:06	14:06-14:07
Announcement day	0.061	0.044	0.058	0.050	0.063	0.069	0.056	0.064	0.050	0.048	0.055	0.066
Nonannouncement day	0.051	0.048	0.055	0.050	0.062	0.056	0.055	0.052	0.053	0.054	0.054	0.051
Standard deviation ratio	1.198	0.913	1.058	0.982	1.013	1.223	1.013	1.236	0.938	0.888	1.026	1.283
F-ratio	4.602**	0.361	0.006	0.133	0.319	4.024**	0.429	5.668**	0.297	0.525	0.003	2.991*
15 : 00 announcement	14:55-14:56	14:56-14:57	14:57-14:58	14:58-14:59	14:59-15:00	15:00-15:01	15:01-15:02	15:02-15:03	15:03-15:04	15:04-15:05	15:05-15:06	15:06-15:07
Announcement day	0.073	0.065	0.071	0.069	0.096	0.072	0.066	0.069	0.072	0.062	0.064	0.058
Nonannouncement day	0.055	0.058	0.066	0.064	0.069	0.067	0.063	0.066	0.064	0.062	0.067	0.063
Standard deviation ratio	1.323	1.127	1.089	1.068	1.392	1.064	1.038	1.054	1.131	0.992	0.947	0.930
F-ratio	4.297**	0.089	0.976	0.318	10.297*	0.406	2.407	0.127	1.209	0.001	0.016	0.056
					Panel B: Trading Volume							
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:31	9:31-9:32	9:32-9:33	9:33-9:34	9:34-9:35	9:35-9:36	9:36-9:37	9:37-9:38	9:38-9:39	9:39-9:40	9:40-9:41
Announcement day	10.600	8.786	8.624	9.040	9.023	9.596	9.226	9.172	9.370	9.421	9.354	8.983
Nonannouncement day	10.951	8.687	8.604	9.057	8.913	9.341	8.947	9.180	8.995	9.062	9.079	9.028
Difference in means	-0.351	0.099	0.020	-0.017	0.110	0.255	0.279	-0.008	0.376	0.359	0.275	-0.045
t-statistic value	-0.693	0.667	0.131	-0.108	0.657	1.523	1.704 *	-0.047	2.218**	2.121**	1.633	-0.261
10 : 00 announcements	9:55-9:56	9:56-9:57	9:57-9:58	9:58-9:59	9:59-10:00	10:00-10:01	10:01-10:02	10:02-10:03	10:03-10:04	10:04-10:05	10:05-10:06	10:06-10:07
Announcement day	8.316	8.254	8.056	8.054	11.322	10.597	10.248	9.911	9.791	9.886	9.692	9.394
Nonannouncement day	8.681	8.692	8.733	8.622	9.960	9.564	9.327	9.244	9.030	9.249	9.006	8.910
Difference in means	-0.365	-0.438	-0.678	-0.568	1.362	1.033	0.921	0.668	0.761	0.637	0.686	0.484
t-statistic value	-1.998**	-2.410**	-3.588***	-3.192***	6.702***	5.263***	4.917***	3.591***	4.060***	3.328***	3.839***	2.598***
14 : 00 announcement	13:55-13:56	13:56-13:57	13:57-13:58	13:58-13:59	13:59-14:00	14:00-14:01	14:01-14:02	14:02-14:03	14:03-14:04	14:04-14:05	14:05-14:06	14:06-14:07
Announcement day	6.322	5.909	5.441	6.182	6.958	6.818	6.517	6.189	5.979	6.287	6.399	6.140
Nonannouncement day	5.600	5.747	5.876	6.068	6.735	6.404	6.308	6.243	6.133	6.207	6.105	6.088
Difference in means	0.722	0.162	-0.436	0.113	0.223	0.414	0.210	-0.054	-0.154	0.080	0.294	0.052
t-statistic value	2.194**	0.502	-1.424	0.345	0.741	1.303	0.639	-0.174	-0.542	0.254	0.892	0.157
15 : 00 announcement	14:55-14:56	14:56-14:57	14:57-14:58	14:58-14:59	14:59-15:00	15:00-15:01	15:01-15:02	15:02-15:03	15:03-15:04	15:04-15:05	15:05-15:06	15:06-15:07
Announcement day	6.741	6.958	6.294	6.748	7.699	7.832	7.259	6.748	7.469	6.790	7.084	6.874
Nonannouncement day	6.525	6.516	6.755	6.687	7.311	6.930	6.782	6.702	6.731	6.811	6.788	6.731
Difference in means	0.217	0.442	-0.461	0.061	0.389	0.902	0.477	0.046	0.737	-0.021	0.296	0.144
t-statistic value	0.655	1.291	-1.388	0.162	1.134	2.570**	1.353	0.138	2.082**	-0.067	0.874	0.454

1. *, ** and *** represent statistical significance at the 10%, 5% and 1% levels, respectively.
2. Please note that the price change over the 16:15 to 9:30 period is not the one-minute price change.

Table 3:
Price Volatility and Trading Volume by One-Minute Intervals in the Expansion Period

One-minute price change standard deviations and trading volume means are reported and compared for announcement (at a specific time) and nonannouncement days for the U.S. S&P 500 index future in the expansion period. Announcement days are defined as those with announcements released at the specific time, including 8:30 & 9:30, 10:00, 14:00 or 15:00 announcements. Nonannouncement days are those with no 8:30 & 9:30, 10:00, 14:00 and 15:00 announcements. We list the Brown-Forsythe-modified Levene F-statistic comparing variances for announcement and nonannouncement days and the t-statistic comparing means for announcement and nonannouncement days assuming unequal variances. All one-minute intervals between 9:30 and 9:41 and the time period over 16:15 to 9:30 are examined for 8:30 & 9:15 announcements. All one-minute intervals from 9:55 to 10:07 are examined for 10:00 announcements. All one-minute intervals from 13:55 to 14:07 are examined for the 14:00 announcement. All one-minute intervals from 14:55 to 15:07 are examined for the 15:00 announcement. The data period is February 03, 1997, to January 30, 2009.

Panel A: Price Volatility												
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:31	9:31-9:32	9:32-9:33	9:33-9:34	9:34-9:35	9:35-9:36	9:36-9:37	9:37-9:38	9:38-9:39	9:39-9:40	9:40-9:41
Announcement day	0.569	0.064	0.064	0.066	0.063	0.061	0.061	0.062	0.063	0.066	0.059	0.059
Nonannouncement day	0.532	0.066	0.074	0.061	0.066	0.065	0.060	0.064	0.061	0.061	0.058	0.064
Standard deviation ratio	1.070	0.970	0.854	1.085	0.952	0.951	1.022	0.960	1.027	1.079	1.016	0.922
F-ratio	4.707**	1.268	0.094	3.491*	0.204	0.631	0.881	0.568	0.881	2.488	0.944	0.346
10 : 00 announcements	9:55-9:56	9:56-9:57	9:57-9:58	9:58-9:59	9:59-10:00	10:00-10:01	10:01-10:02	10:02-10:03	10:03-10:04	10:04-10:05	10:05-10:06	10:06-10:07
Announcement day	0.055	0.052	0.055	0.052	0.125	0.105	0.092	0.083	0.079	0.076	0.070	0.066
Nonannouncement day	0.058	0.062	0.058	0.060	0.072	0.069	0.068	0.066	0.061	0.066	0.062	0.057
Standard deviation ratio	0.945	0.836	0.939	0.870	1.736	1.532	1.358	1.263	1.299	1.147	1.125	1.154
F-ratio	0.142	7.519* * *	0.746	4.259**	99.709* * *	83.357* * *	22.471* * *	26.940* * *	35.891* * *	11.366* * *	10.108* * *	11.893* * *
14 : 00 announcement	13:55-13:56	13:56-13:57	13:57-13:58	13:58-13:59	13:59-14:00	14:00-14:01	14:01-14:02	14:02-14:03	14:03-14:04	14:04-14:05	14:05-14:06	14:06-14:07
Announcement day	0.047	0.041	0.045	0.044	0.061	0.059	0.049	0.060	0.040	0.040	0.042	0.048
Nonannouncement day	0.046	0.042	0.045	0.045	0.054	0.050	0.048	0.045	0.047	0.046	0.047	0.046
Standard deviation ratio	1.011	0.967	1.014	0.973	1.132	1.184	1.007	1.325	0.849	0.866	0.890	1.049
F-ratio	0.557	0.000	0.010	0.703	1.415	3.225**	0.005	6.036* * *	0.469	0.717	0.584	0.799
15 : 00 announcement	14:55-14:56	14:56-14:57	14:57-14:58	14:58-14:59	14:59-15:00	15:00-15:01	15:01-15:02	15:02-15:03	15:03-15:04	15:04-15:05	15:05-15:06	15:06-15:07
Announcement day	0.070	0.064	0.059	0.050	0.073	0.061	0.058	0.056	0.056	0.051	0.053	0.051
Nonannouncement day	0.051	0.052	0.053	0.053	0.060	0.058	0.054	0.056	0.056	0.056	0.056	0.053
Standard deviation ratio	1.374	1.247	1.119	0.943	1.225	1.060	1.080	0.996	0.994	0.910	0.942	0.961
F-ratio	4.907**	0.335	0.828	0.799	3.367*	0.087	2.507	0.160	0.008	0.013	0.003	0.045
Panel B: Trading Volume												
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:31	9:31-9:32	9:32-9:33	9:33-9:34	9:34-9:35	9:35-9:36	9:36-9:37	9:37-9:38	9:38-9:39	9:39-9:40	9:40-9:41
Announcement day	10.727	8.791	8.590	9.005	8.882	9.564	9.162	9.195	9.323	9.396	9.287	8.911
Nonannouncement day	11.142	8.712	8.591	9.096	8.847	9.248	8.849	9.089	8.938	9.069	9.001	8.985
Difference in means	-0.415	0.079	-0.002	-0.090	0.035	0.316	0.312	0.106	0.385	0.326	0.286	-0.074
t-statistic value	-0.704	0.488	-0.009	-0.515	0.192	1.709*	1.756*	0.581	2.073**	1.748*	1.546	-0.384
10 : 00 announcements	9:55-9:56	9:56-9:57	9:57-9:58	9:58-9:59	9:59-10:00	10:00-10:01	10:01-10:02	10:02-10:03	10:03-10:04	10:04-10:05	10:05-10:06	10:06-10:07
Announcement day	8.327	8.295	8.085	8.243	11.124	10.636	10.291	10.092	9.915	9.989	9.787	9.520
Nonannouncement day	8.707	8.749	8.720	8.640	9.843	9.606	9.413	9.355	9.090	9.264	9.003	8.931
Difference in means	-0.380	-0.454	-0.635	-0.396	1.281	1.030	0.878	0.738	0.824	0.725	0.784	0.590
t-statistic value	-1.904*	-2.262**	-3.063* * *	-2.036**	5.792* * *	4.751* * *	4.268* * *	3.594* * *	3.982* * *	3.484* * *	3.984* * *	2.872* * *
14 : 00 announcement	13:55-13:56	13:56-13:57	13:57-13:58	13:58-13:59	13:59-14:00	14:00-14:01	14:01-14:02	14:02-14:03	14:03-14:04	14:04-14:05	14:05-14:06	14:06-14:07
Announcement day	6.434	6.016	5.492	6.270	7.123	7.098	6.615	6.303	6.033	6.361	6.516	6.123
Nonannouncement day	5.719	5.879	5.987	6.147	6.830	6.557	6.440	6.359	6.256	6.323	6.261	6.173
Difference in means	0.716	0.137	-0.495	0.124	0.293	0.542	0.175	-0.055	-0.223	0.038	0.255	-0.050
t-statistic value	2.012**	0.380	-1.474	0.337	0.893	1.550	0.474	-0.159	-0.696	0.107	0.709	-0.133
15 : 00 announcement	14:55-14:56	14:56-14:57	14:57-14:58	14:58-14:59	14:59-15:00	15:00-15:01	15:01-15:02	15:02-15:03	15:03-15:04	15:04-15:05	15:05-15:06	15:06-15:07
Announcement day	6.705	7.066	6.213	6.377	7.549	7.787	7.180	6.713	7.525	6.869	6.934	6.836
Nonannouncement day	6.632	6.616	6.833	6.773	7.326	7.036	6.872	6.813	6.843	6.911	6.827	6.728
Difference in means	0.073	0.450	-0.620	-0.396	0.223	0.751	0.308	-0.100	0.682	-0.042	0.108	0.108
t-statistic value	0.203	1.182	-1.684*	-1.091	0.588	1.989**	0.837	-0.270	1.738*	-0.123	0.298	0.306

1. *, **, and * * * represent statistical significance at the 10%, 5%, and 1% levels, respectively.
2. Please note that the price change over the 16:15 to 9:30 period is not the one-minute price change.

Table 4:
Price Volatility and Trading Volume by One-Minute Intervals in the Contraction Period

One-minute price change standard deviations and trading volume means are reported and compared for announcement (at a specific time) and nonannouncement days for the U.S. S&P 500 index future in the contraction period. Announcement days are defined as those with announcements released at the specific time, including 8:30 & 9:30, 10:00, 14:00 or 15:00 announcements. Nonannouncement days are those with no 8:30 & 9:30, 10:00, 14:00 and 15:00 announcements. We list the Brown-Forsythe-modified Levene F-statistic comparing variances for announcement and nonannouncement days and the t-statistic comparing means for announcement and nonannouncement days assuming unequal variances. All one-minute intervals between 9:30 and 9:41 and the time period over 16:15 to 9:30 are examined for 8:30 & 9:15 announcements. All one-minute intervals from 9:55 to 10:07 are examined for 10:00 announcements. All one-minute intervals from 13:55 to 14:07 are examined for the 14:00 announcement. All one-minute intervals from 14:55 to 15:07 are examined for the 15:00 announcement. The data period is February 03, 1997, to January 30, 2009.

Panel A: Price Volatility												
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:31	9:31-9:32	9:32-9:33	9:33-9:34	9:34-9:35	9:35-9:36	9:36-9:37	9:37-9:38	9:38-9:39	9:39-9:40	9:40-9:41
Announcement day	0.910	0.119	0.103	0.127	0.124	0.134	0.216	0.106	0.191	0.112	0.141	0.111
Nonannouncement day	1.303	0.109	0.104	0.139	0.396	0.104	0.121	0.119	0.101	0.108	0.123	0.108
Standard deviation ratio	0.699	1.097	0.992	0.916	0.313	1.293	1.786	0.892	1.892	1.044	1.145	1.022
F-ratio	1.950	1.562	0.001	0.014	0.373	2.282	1.467	0.220	1.673	0.086	0.858	0.272
10 : 00 announcements	9:55-9:56	9:56-9:57	9:57-9:58	9:58-9:59	9:59-10:00	10:00-10:01	10:01-10:02	10:02-10:03	10:03-10:04	10:04-10:05	10:05-10:06	10:06-10:07
Announcement day	0.114	0.087	0.076	0.076	0.213	0.146	0.137	0.140	0.103	0.115	0.092	0.096
Nonannouncement day	0.105	0.088	0.110	0.114	0.136	0.099	0.113	0.093	0.111	0.110	0.094	0.108
Standard deviation ratio	1.084	0.992	0.688	0.669	1.563	1.473	1.210	1.504	0.927	1.044	0.970	0.889
F-ratio	0.612	0.027	4.094**	5.206**	14.132* * *	15.335* * *	3.852**	11.347* * *	0.002	0.546	0.044	0.091
14 : 00 announcement	13:55-13:56	13:56-13:57	13:57-13:58	13:58-13:59	13:59-14:00	14:00-14:01	14:01-14:02	14:02-14:03	14:03-14:04	14:04-14:05	14:05-14:06	14:06-14:07
Announcement day	0.110	0.060	0.104	0.077	0.068	0.111	0.089	0.088	0.082	0.082	0.105	0.129
Nonannouncement day	0.072	0.074	0.095	0.076	0.096	0.085	0.086	0.082	0.078	0.089	0.084	0.077
Standard deviation ratio	1.522	0.804	1.103	1.014	0.706	1.305	1.037	1.069	1.063	0.930	1.257	1.673
F-ratio	7.278*	1.067	0.025	0.103	0.399	0.918	0.759	0.555	0.001	0.042	0.974	2.869* * *
15 : 00 announcement	14:55-14:56	14:56-14:57	14:57-14:58	14:58-14:59	14:59-15:00	15:00-15:01	15:01-15:02	15:02-15:03	15:03-15:04	15:04-15:05	15:05-15:06	15:06-15:07
Announcement day	0.094	0.071	0.121	0.136	0.179	0.111	0.100	0.121	0.133	0.107	0.107	0.090
Nonannouncement day	0.078	0.086	0.115	0.111	0.108	0.107	0.104	0.106	0.098	0.093	0.111	0.101
Standard deviation ratio	1.204	0.823	1.048	1.229	1.666	1.033	0.960	1.139	1.352	1.157	0.969	0.887
F-ratio	0.059	0.111	0.190	2.705	8.247* * *	0.111	0.182	0.942	2.513	0.027	0.052	0.025
Panel B: Trading Volume												
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:31	9:31-9:32	9:32-9:33	9:33-9:34	9:34-9:35	9:35-9:36	9:36-9:37	9:37-9:38	9:38-9:39	9:39-9:40	9:40-9:41
Announcement day	9.868	8.752	8.822	9.240	9.837	9.783	9.597	9.039	9.643	9.566	9.744	9.395
Nonannouncement day	9.810	8.533	8.681	8.829	9.310	9.895	9.529	9.724	9.333	9.014	9.548	9.286
Difference in means	0.059	0.219	0.141	0.412	0.528	-0.112	0.068	-0.685	0.310	0.552	0.197	0.110
t-statistic value	0.176	0.593	0.389	1.032	1.271	-0.291	0.164	-1.688*	0.764	1.397	0.490	0.281
10 : 00 announcements	9:55-9:56	9:56-9:57	9:57-9:58	9:58-9:59	9:59-10:00	10:00-10:01	10:01-10:02	10:02-10:03	10:03-10:04	10:04-10:05	10:05-10:06	10:06-10:07
Announcement day	8.255	8.029	7.892	7.010	12.412	10.382	10.010	8.912	9.108	9.314	9.167	8.696
Nonannouncement day	8.529	8.352	8.810	8.514	10.652	9.314	8.814	8.581	8.671	9.157	9.024	8.790
Difference in means	-0.274	-0.323	-0.917	-1.504	1.759	1.068	1.196	0.331	0.436	0.157	0.143	-0.094
t-statistic value	-0.598	-0.771	-2.018**	-3.573* * *	3.497* * *	2.358**	2.673* * *	0.799	1.026	0.324	0.342	-0.221
14 : 00 announcement	13:55-13:56	13:56-13:57	13:57-13:58	13:58-13:59	13:59-14:00	14:00-14:01	14:01-14:02	14:02-14:03	14:03-14:04	14:04-14:05	14:05-14:06	14:06-14:07
Announcement day	5.667	5.286	5.143	5.667	6.000	5.190	5.952	5.524	5.667	5.857	5.714	6.238
Nonannouncement day	4.890	4.957	5.214	5.600	6.167	5.495	5.519	5.552	5.405	5.514	5.171	5.581
Difference in means	0.776	0.329	-0.071	0.067	-0.167	-0.305	0.433	-0.029	0.262	0.343	0.543	0.657
t-statistic value	0.893	0.487	-0.097	0.095	-0.226	-0.469	0.674	-0.046	0.478	0.543	0.671	0.904
15 : 00 announcement	14:55-14:56	14:56-14:57	14:57-14:58	14:58-14:59	14:59-15:00	15:00-15:01	15:01-15:02	15:02-15:03	15:03-15:04	15:04-15:05	15:05-15:06	15:06-15:07
Announcement day	6.952	6.333	6.762	8.905	8.571	8.095	7.714	6.952	7.143	6.333	7.952	7.095
Nonannouncement day	5.886	5.924	6.290	6.176	7.219	6.300	6.243	6.038	6.067	6.214	6.557	6.748
Difference in means	1.067	0.410	0.471	2.729	1.352	1.795	1.471	0.914	1.076	0.119	1.395	0.348
t-statistic value	1.241	0.556	0.628	1.979*	1.802*	1.856*	1.330	1.121	1.343	0.153	1.483	0.538

1. *, **, and * * * represent statistical significance at the 10%, 5%, and 1% levels, respectively.
2. Please note that the price change over the 16:15 to 9:30 period is not the one-minute price change.

Table 5:
Price Volatility and Trading Volume by Five-Minute Intervals in the Entire Sample Period

Five-minute price change standard deviations and trading volume means are reported and compared for announcement (at a specific time) and nonannouncement days for the U.S. S&P 500 index future in the entire sample period. Announcement days are defined as those with announcements released at the specific time, including 8:30 & 9:30, 10:00, 14:00 or 15:00 announcements. Nonannouncement days are those with no 8:30 & 9:30, 10:00, 14:00 and 15:00 announcements. We list the Brown-Forsythe-modified Levene F-statistic comparing variances for announcement and nonannouncement days and the t-statistic comparing means for announcement and nonannouncement days assuming unequal variances. All five-minute intervals between 9:30 and 10:25 and the time period over 16:15 to 9:30 are examined for 8:30 & 9:15 announcements. All five-minute intervals from 9:55 to 10:55 are examined for 10:00 announcements. All five-minute intervals from 13:55 to 14:55 are examined for the 14:00 announcement. All five-minute intervals from 14:55 to 15:55 are examined for the 15:00 announcement. The data period is February 03, 1997, to January 30, 2009.

Panel A: Price Volatility												
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:35	9:35-9:40	9:40-9:45	9:45-9:50	9:50-9:55	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25
Announcement day	0.644	0.185	0.174	0.183	0.171	0.169	0.184	0.182	0.166	0.153	0.153	0.134
Nonannouncement day	0.697	0.210	0.156	0.161	0.166	0.147	0.162	0.160	0.139	0.147	0.137	0.134
Standard deviation ratio	0.925	0.879	1.114	1.138	1.031	1.149	1.141	1.137	1.197	1.038	1.121	0.996
F-ratio	1.070	0.058	1.206	1.849	2.942*	5.309**	4.620**	6.101**	16.401***	0.764	7.185***	1.357
10 : 00 announcements	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25	10:25-10:30	10:30-10:35	10:35-10:40	10:40-10:45	10:45-10:50	10:50-10:55
Announcement day	0.193	0.219	0.165	0.155	0.155	0.142	0.147	0.137	0.133	0.162	0.137	0.149
Nonannouncement day	0.162	0.160	0.139	0.147	0.137	0.134	0.142	0.132	0.120	0.140	0.129	0.115
Standard deviation ratio	1.197	1.369	1.189	1.052	1.129	1.056	1.041	1.045	1.106	1.160	1.069	1.291
F-ratio	12.736***	50.564***	26.126***	1.540	4.241**	2.734*	1.119	1.433	4.353**	0.478	0.930	2.399
14 : 00 announcement	13:55-14:00	14:00-14:05	14:05-14:10	14:10-14:15	14:15-14:20	14:20-14:25	14:25-14:30	14:30-14:35	14:35-14:40	14:40-14:45	14:45-14:50	14:50-14:55
Announcement day	0.128	0.117	0.145	0.145	0.153	0.124	0.172	0.129	0.160	0.134	0.149	0.144
Nonannouncement day	0.119	0.123	0.112	0.122	0.141	0.125	0.130	0.124	0.130	0.130	0.123	0.126
Standard deviation ratio	1.078	0.955	1.292	1.184	1.086	0.990	1.321	1.035	1.232	1.032	1.214	1.137
F-ratio	0.789	0.569	2.130	0.250	0.094	0.001	4.326**	0.226	0.462	0.240	1.797	1.159
15 : 00 announcement	14:55-15:00	15:00-15:05	15:05-15:10	15:10-15:15	15:15-15:20	15:20-15:25	15:25-15:30	15:30-15:35	15:35-15:40	15:40-15:45	15:45-15:50	15:50-15:55
Announcement day	0.172	0.154	0.148	0.135	0.141	0.134	0.127	0.163	0.139	0.131	0.127	0.121
Nonannouncement day	0.141	0.145	0.140	0.148	0.148	0.142	0.148	0.162	0.160	0.168	0.140	0.148
Standard deviation ratio	1.219	1.059	1.059	0.912	0.949	0.949	0.862	1.003	0.868	0.780	0.905	0.821
F-ratio	2.636	0.003	0.648	0.001	0.055	0.044	1.158	0.000	0.713	0.518	0.398	0.036
Panel B: Trading Volume												
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:35	9:35-9:40	9:40-9:45	9:45-9:50	9:50-9:55	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25
Announcement day	10.600	45.069	46.544	46.132	46.085	44.913	45.315	47.734	45.942	44.596	43.857	42.202
Nonannouncement day	10.951	44.603	45.262	45.326	45.021	44.198	44.688	46.414	44.648	43.813	43.016	41.369
Difference in means	-0.351	0.466	1.282	0.806	1.064	0.715	0.627	1.320	1.294	0.783	0.840	0.832
t-statistic value	-0.693	0.902	2.336**	1.457	1.932*	1.320	1.173	2.334**	2.318**	1.388	1.500	1.504
10 : 00 announcements	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25	10:25-10:30	10:30-10:35	10:35-10:40	10:40-10:45	10:45-10:50	10:50-10:55
Announcement day	44.002	50.433	47.090	45.418	44.066	42.244	42.720	42.221	41.036	40.447	39.027	37.349
Nonannouncement day	44.688	46.414	44.648	43.813	43.016	41.369	41.397	41.456	39.622	39.568	38.700	37.410
Difference in means	-0.687	4.019	2.442	1.605	1.050	0.874	1.324	0.765	1.414	0.878	0.327	-0.061
t-statistic value	-1.144	6.386***	4.041***	2.605***	1.699*	1.431	2.218**	1.255	2.246**	1.417	0.517	-0.096
14 : 00 announcement	13:55-14:00	14:00-14:05	14:05-14:10	14:10-14:15	14:15-14:20	14:20-14:25	14:25-14:30	14:30-14:35	14:35-14:40	14:40-14:45	14:45-14:50	14:50-14:55
Announcement day	30.811	31.790	31.392	30.937	32.014	32.028	32.979	33.385	32.545	32.874	33.392	33.021
Nonannouncement day	30.026	31.295	30.438	31.108	32.036	31.834	32.716	33.062	32.081	32.108	32.111	32.504
Difference in means	0.785	0.495	0.953	-0.171	-0.022	0.194	0.263	0.322	0.464	0.766	1.281	0.517
t-statistic value	0.692	0.441	0.754	-0.140	-0.017	0.163	0.228	0.248	0.367	0.623	1.044	0.439
15 : 00 announcement	14:55-15:00	15:00-15:05	15:05-15:10	15:10-15:15	15:15-15:20	15:20-15:25	15:25-15:30	15:30-15:35	15:35-15:40	15:40-15:45	15:45-15:50	15:50-15:55
Announcement day	34.441	36.098	34.350	34.371	34.420	34.378	35.538	36.385	35.301	35.196	35.853	36.818
Nonannouncement day	33.794	33.956	33.475	33.415	33.042	33.375	34.044	34.553	34.205	34.634	34.192	34.156
Difference in means	0.646	2.142	0.875	0.955	1.377	1.003	1.494	1.832	1.096	0.562	1.662	2.662
t-statistic value	0.525	1.790*	0.688	0.750	1.051	0.811	1.145	1.364	0.875	0.431	1.351	2.204**

1. *, **, and *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.
2. Please note that the price change over the 16:15 to 9:30 period is not the five-minute price change.

Table 6:
Price Volatility and Trading Volume by Five-Minute Intervals in the Expansion Periods

Five-minute price change standard deviations and trading volume means are reported and compared for announcement (at a specific time) and nonannouncement days for the U.S. S&P 500 index future in the expansion periods. Announcement days are defined as those with announcements released at the specific time, including 8:30 & 9:30, 10:00, 14:00, or 15:00 announcements. Nonannouncement days are those with no 8:30 & 9:30, 10:00, 14:00, and 15:00 announcements. We list the Brown-Forsythe-modified Levene F-statistic comparing variances for announcement and nonannouncement days and the t-statistic comparing means for announcement and nonannouncement days assuming unequal variances. All five-minute intervals between 9:30 and 10:25 and the time period over 16:15 to 9:30 are examined for 8:30 & 9:15 announcements. All five-minute intervals from 9:55 to 10:55 are examined for 10:00 announcements. All five-minute intervals from 13:55 to 14:55 are examined for the 14:00 announcement. All five-minute intervals from 14:55 to 15:55 are examined for the 15:00 announcement. The data period is February 03, 1997, to January 30, 2009.

Panel A: Price Volatility												
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:35	9:35-9:40	9:40-9:45	9:45-9:50	9:50-9:55	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25
Announcement day	0.569	0.140	0.145	0.138	0.146	0.146	0.157	0.164	0.150	0.138	0.133	0.128
Nonannouncement day	0.532	0.141	0.134	0.141	0.138	0.131	0.142	0.150	0.124	0.135	0.124	0.122
Standard deviation ratio	1.070	0.988	1.088	0.978	1.062	1.119	1.110	1.096	1.213	1.021	1.072	1.045
F-ratio	4.707**	0.056	2.942*	0.660	4.204**	3.213*	4.094**	2.920*	13.990***	0.271	3.986**	1.488
10 : 00 announcements	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25	10:25-10:30	10:30-10:35	10:35-10:40	10:40-10:45	10:45-10:50	10:50-10:55
Announcement day	0.166	0.206	0.153	0.149	0.151	0.136	0.142	0.131	0.123	0.126	0.130	0.118
Nonannouncement day	0.142	0.150	0.124	0.135	0.124	0.122	0.129	0.120	0.108	0.119	0.119	0.108
Standard deviation ratio	1.173	1.376	1.239	1.097	1.222	1.107	1.099	1.086	1.137	1.058	1.088	1.091
F-ratio	6.657***	47.126***	29.799***	2.800*	6.094**	3.119*	2.516	2.081	4.205**	0.804	1.879	0.285
14 : 00 announcement	13:55-14:00	14:00-14:05	14:05-14:10	14:10-14:15	14:15-14:20	14:20-14:25	14:25-14:30	14:30-14:35	14:35-14:40	14:40-14:45	14:45-14:50	14:50-14:55
Announcement day	0.107	0.114	0.123	0.147	0.128	0.094	0.144	0.098	0.122	0.101	0.113	0.129
Nonannouncement day	0.103	0.104	0.104	0.109	0.118	0.112	0.117	0.111	0.112	0.119	0.105	0.112
Standard deviation ratio	1.037	1.097	1.189	1.352	1.080	0.839	1.229	0.882	1.090	0.844	1.078	1.151
F-ratio	1.593	1.753	1.878	1.644	0.002	0.549	3.611*	0.097	0.379	0.586	0.844	1.952
15 : 00 announcement	14:55-15:00	15:00-15:05	15:05-15:10	15:10-15:15	15:15-15:20	15:20-15:25	15:25-15:30	15:30-15:35	15:35-15:40	15:40-15:45	15:45-15:50	15:50-15:55
Announcement day	0.145	0.111	0.131	0.110	0.121	0.121	0.129	0.137	0.129	0.121	0.126	0.117
Nonannouncement day	0.121	0.124	0.125	0.128	0.130	0.126	0.136	0.140	0.136	0.137	0.115	0.113
Standard deviation ratio	1.203	0.897	1.047	0.856	0.930	0.963	0.946	0.980	0.950	0.886	1.102	1.035
F-ratio	0.529	0.493	0.048	0.323	0.077	0.005	0.378	0.357	0.207	0.547	3.912**	1.773
Panel B: Trading Volume												
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:35	9:35-9:40	9:40-9:45	9:45-9:50	9:50-9:55	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25
Announcement day	10.727	44.832	46.362	45.871	45.926	45.030	45.139	47.830	46.102	44.716	44.110	42.269
Nonannouncement day	11.142	44.494	44.946	45.151	45.027	44.234	44.660	46.728	44.678	44.011	43.154	41.575
Difference in means	-0.415	0.337	1.416	0.720	0.899	0.796	0.479	1.102	1.424	0.705	0.956	0.694
t-statistic value	-0.704	0.594	2.348**	1.196	1.497	1.348	0.824	1.785*	2.346**	1.141	1.564	1.137
10 : 00 announcements	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25	10:25-10:30	10:30-10:35	10:35-10:40	10:40-10:45	10:45-10:50	10:50-10:55
Announcement day	44.075	50.924	47.544	45.977	44.776	42.826	43.185	42.783	41.417	40.941	39.208	37.801
Nonannouncement day	44.660	46.728	44.678	44.011	43.154	41.575	41.659	41.880	39.942	39.866	38.931	37.593
Difference in means	-0.585	4.195	2.865	1.966	1.622	1.251	1.526	0.903	1.475	1.076	0.277	0.208
t-statistic value	-0.886	6.041***	4.315***	2.908***	2.401**	1.873*	2.347**	1.363	2.146**	1.578	0.394	0.297
14 : 00 announcement	13:55-14:00	14:00-14:05	14:05-14:10	14:10-14:15	14:15-14:20	14:20-14:25	14:25-14:30	14:30-14:35	14:35-14:40	14:40-14:45	14:45-14:50	14:50-14:55
Announcement day	31.336	32.410	31.951	32.049	32.951	32.738	33.451	33.943	33.459	33.770	33.779	33.762
Nonannouncement day	30.562	31.934	31.020	31.716	32.387	32.280	33.296	33.683	32.755	32.746	32.748	33.120
Difference in means	0.774	0.476	0.931	0.334	0.563	0.458	0.154	0.260	0.704	1.024	1.030	0.642
t-statistic value	0.626	0.379	0.663	0.246	0.391	0.343	0.118	0.179	0.504	0.755	0.752	0.492
15 : 00 announcement	14:55-15:00	15:00-15:05	15:05-15:10	15:10-15:15	15:15-15:20	15:20-15:25	15:25-15:30	15:30-15:35	15:35-15:40	15:40-15:45	15:45-15:50	15:50-15:55
Announcement day	33.910	36.074	33.877	33.926	34.254	34.057	35.352	35.992	35.246	35.148	35.516	36.770
Nonannouncement day	34.180	34.475	33.799	33.974	33.463	33.749	34.341	34.761	34.207	34.699	34.223	34.100
Difference in means	-0.270	1.599	0.078	-0.048	0.791	0.308	1.011	1.231	1.039	0.449	1.294	2.671
t-statistic value	-0.203	1.210	0.056	-0.035	0.550	0.233	0.728	0.843	0.749	0.310	0.960	2.030**

1. *, **, and *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.
2. Please note that the price change over the 16:15 to 9:30 period is not the five-minute price change.

Table 7:
Price Volatility and Trading Volume by Five-Minute Intervals in the Contraction Periods

Five-minute price change standard deviations and trading volume means are reported and compared for announcement (at a specific time) and nonannouncement days for the U.S. S&P 500 index future in the contraction periods. Announcement days are defined as those with announcements released at the specific time, including 8:30 & 9:30, 10:00, 14:00, or 15:00 announcements. Nonannouncement days are those with no 8:30 & 9:30, 10:00, 14:00, and 15:00 announcements. We list the Brown-Forsythe-modified Levene F-statistic comparing variances for announcement and nonannouncement days and the t-statistic comparing means for announcement and nonannouncement days assuming unequal variances. All five-minute intervals between 9:30 and 10:25, and the time period over 16:15 to 9:30, are examined for 8:30 & 9:15 announcements. All five-minute intervals from 9:55 to 10:55 are examined for 10:00 announcements. All five-minute intervals from 13:55 to 14:55 are examined for the 14:00 announcement. All five-minute intervals from 14:55 to 15:55 are examined for the 15:00 announcement. The data period is February 03, 1997, to January 30, 2009.

Panel A: Price Volatility												
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:35	9:35-9:40	9:40-9:45	9:45-9:50	9:50-9:55	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25
Announcement day	0.910	0.345	0.288	0.343	0.270	0.267	0.296	0.262	0.240	0.219	0.241	0.163
Nonannouncement day	1.303	0.435	0.251	0.248	0.280	0.222	0.249	0.211	0.207	0.203	0.198	0.190
Standard deviation ratio	0.699	0.792	1.146	1.379	0.963	1.202	1.189	1.241	1.158	1.076	1.215	0.861
F-ratio	1.950	0.002	0.112	1.144	0.055	2.060	0.700	3.842**	2.858*	0.550	3.077*	0.019
10 : 00 announcements	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25	10:25-10:30	10:30-10:35	10:35-10:40	10:40-10:45	10:45-10:50	10:50-10:55
Announcement day	0.300	0.281	0.220	0.185	0.171	0.171	0.174	0.172	0.180	0.291	0.175	0.260
Nonannouncement day	0.249	0.211	0.207	0.203	0.198	0.190	0.200	0.185	0.177	0.228	0.175	0.152
Standard deviation ratio	1.208	1.332	1.063	0.912	0.862	0.905	0.871	0.925	1.017	1.278	0.998	1.716
F-ratio	5.245**	4.745**	0.837	0.344	0.217	0.027	0.638	0.057	0.335	0.089	0.438	2.867*
14 : 00 announcement	13:55-14:00	14:00-14:05	14:05-14:10	14:10-14:15	14:15-14:20	14:20-14:25	14:25-14:30	14:30-14:35	14:35-14:40	14:40-14:45	14:45-14:50	14:50-14:55
Announcement day	0.200	0.134	0.235	0.127	0.252	0.233	0.279	0.244	0.288	0.255	0.280	0.210
Nonannouncement day	0.187	0.200	0.152	0.183	0.233	0.185	0.189	0.185	0.206	0.181	0.199	0.190
Standard deviation ratio	1.068	0.669	1.545	0.694	1.083	1.259	1.473	1.319	1.399	1.408	1.407	1.105
F-ratio	0.052	0.279	0.207	1.291	0.115	0.913	0.867	1.222	0.053	0.036	0.589	0.012
15 : 00 announcement	14:55-15:00	15:00-15:05	15:05-15:10	15:10-15:15	15:15-15:20	15:20-15:25	15:25-15:30	15:30-15:35	15:35-15:40	15:40-15:45	15:45-15:50	15:50-15:55
Announcement day	0.287	0.283	0.228	0.231	0.223	0.197	0.112	0.270	0.191	0.184	0.128	0.144
Nonannouncement day	0.228	0.234	0.206	0.234	0.229	0.212	0.202	0.257	0.262	0.294	0.242	0.275
Standard deviation ratio	1.261	1.211	1.107	0.986	0.973	0.930	0.553	1.049	0.727	0.625	0.528	0.526
F-ratio	2.724*	0.591	1.601	0.518	0.004	0.213	1.386	0.433	0.791	0.166	1.553	0.953
Panel B: Trading Volume												
8 : 30 & 9 : 15 announcements	16:15-9:30	9:30-9:35	9:35-9:40	9:40-9:45	9:45-9:50	9:50-9:55	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25
Announcement day	9.868	46.434	47.589	47.636	47.000	44.240	46.333	47.178	45.016	43.907	42.395	41.814
Nonannouncement day	9.810	45.248	47.148	46.371	44.986	43.981	44.857	44.538	44.467	42.633	42.195	40.143
Difference in means	0.059	1.186	0.442	1.264	2.014	0.259	1.476	2.640	0.549	1.274	0.200	1.671
t-statistic value	0.176	0.968	0.343	0.908	1.460	0.189	1.078	1.884*	0.387	0.930	0.145	1.311
10 : 00 announcements	9:55-10:00	10:00-10:05	10:05-10:10	10:10-10:15	10:15-10:20	10:20-10:25	10:25-10:30	10:30-10:35	10:35-10:40	10:40-10:45	10:45-10:50	10:50-10:55
Announcement day	43.598	47.725	44.588	42.333	40.147	39.029	40.157	39.118	38.931	37.716	38.029	34.853
Nonannouncement day	44.857	44.538	44.467	42.633	42.195	40.143	39.833	38.929	37.710	37.795	37.324	36.319
Difference in means	-1.259	3.187	0.122	-0.300	-2.048	-1.113	0.324	0.189	1.222	-0.080	0.706	-1.466
t-statistic value	-0.887	2.220**	0.085	-0.207	-1.403	-0.756	0.218	0.125	0.785	-0.055	0.499	-1.032
14 : 00 announcement	13:55-14:00	14:00-14:05	14:05-14:10	14:10-14:15	14:15-14:20	14:20-14:25	14:25-14:30	14:30-14:35	14:35-14:40	14:40-14:45	14:45-14:50	14:50-14:55
Announcement day	27.762	28.190	28.143	24.476	26.571	27.905	30.238	30.143	27.238	27.667	31.143	28.714
Nonannouncement day	26.829	27.486	26.971	27.486	29.943	29.176	29.257	29.362	28.067	28.305	28.310	28.833
Difference in means	0.933	0.705	1.171	-3.010	-3.371	-1.271	0.981	0.781	-0.829	-0.638	2.833	-0.119
t-statistic value	0.331	0.330	0.436	-1.343	-1.260	-0.580	0.496	0.308	-0.311	-0.249	1.127	-0.049
15 : 00 announcement	14:55-15:00	15:00-15:05	15:05-15:10	15:10-15:15	15:15-15:20	15:20-15:25	15:25-15:30	15:30-15:35	15:35-15:40	15:40-15:45	15:45-15:50	15:50-15:55
Announcement day	37.524	36.238	37.095	36.952	35.381	36.238	36.619	38.667	35.619	35.476	37.810	37.095
Nonannouncement day	31.495	30.862	31.543	30.081	30.533	31.143	32.276	33.310	34.195	34.248	34.005	34.490
Difference in means	6.029	5.376	5.552	6.871	4.848	5.095	4.343	5.357	1.424	1.229	3.805	2.605
t-statistic value	1.848*	1.930*	1.811*	2.092**	1.511	1.466	1.141	1.556	0.501	0.429	1.268	0.839

1. *, **, and * * * represent statistical significance at the 10%, 5%, and 1% levels, respectively.
2. Please note that the price change over the 16:15 to 9:30 period is not the five-minute price change.

Table 8:
The Immediate Effect of Announcement Surprises on the Stock Price

News Announcements	Response Coefficients		
	W[1]	E[1]	C[1]
1. CPI	-0.0868	-0.1072*	-0.0446
	(-1.6079)	(-1.6783)	(-0.4511)
2. PPI	-0.1563* * *	-0.1511* * *	-0.2152
	(-2.9859)	(-2.9489)	(-0.7837)
3. Nonfarm Payrolls	-0.0674	-0.0511	-0.8937* * *
	(-1.4417)	(-1.3553)	(-2.7471)
4. Civilian Unemployment	/	/	/
	/	/	/
5. Personal Consumption	/	/	/
	/	/	/
6. Personal Income	/	/	/
	/	/	/
7. Trade Balance	/	/	/
	/	/	/
8. Capacity Utilisation	/	/	/
	/	/	/
9. IP	/	/	/
	/	/	/
10. Consumer Confidence	0.1175* * *	0.1192* * *	0.1150* * *
	(7.5844)	(5.6781)	(5.1795)
11. Durable Goods Orders	0.0874 **	0.0514	0.2070*
	(2.2164)	(1.3484)	(1.8437)
12. Leading Index	0.0363**	0.0205	0.0856
	(2.0183)	(2.4443)	(1.4310)
13. Manufacturers' New Orders	/	/	/
	/	/	/
14. New Single-Family Home Sales	0.0048	0.0021	2.3461* * *
	(1.5368)	(1.0949)	(4.4629)
15. PMI	0.0364 * * *	0.0318* * *	0.0489*
	(3.0906)	(2.6721)	(1.7067)
16. Federal Budget	-0.0045* * *	-0.0041* * *	-0.0281*
	(-6.7236)	(-5.2428)	(-1.6455)
17. Consumer Credit	-0.0029	-0.0041* * *	0.3921*
	(-1.1115)	(-2.7033)	(1.7694)

1. The entire sample period is abbreviated as "W", the expansion periods as "E", and the contraction period as "C".
2. *, ** and * * * represent statistical significance at the 10%, 5% and 1% levels, respectively.
3. If the response coefficient on the announcement surprise is not significant in every time period, we use the slash line instead of the data.

Table 9:
The Eventual Effect of Announcement Surprises on the Stock Price

News Announcements	Response Coefficients								
	First Scale			Second Scale			Third Scale		
	W^1	E^1	C^1	W^1	E^1	C^1	W^1	E^1	C^1
1. CPI	/	/	/	/	/	/	-2.13E-05	-2.38E-04**	3.21E-04
	/	/	/	/	/	/	(-0.1706)	(-1.9765)	(1.0393)
2. PPI	-0.0035***	-0.0037***	-0.0005	9.71E-05*	6.90E-05	4.17E-04	-2.78E-04*	-3.34E-04**	1.17E-04
	(-2.8321)	(-3.0170)	(-0.0836)	(1.7625)	(1.4349)	(1.0463)	(-1.7375)	(-2.1421)	(0.1222)
3. Nonfarm Payrolls	-0.0010	-0.0005	-0.0261**	-7.71E-05*	-4.48E-05	-2.55E-03***	/	/	/
	(-0.7519)	(-0.4844)	(-2.0152)	(-1.6464)	(-1.4465)	(-4.7115)	/	/	/
4. Civilian Unemployment	/	/	/	-7.86E-05	-2.01E-05	-2.28E-04*	2.32E-05	1.65E-04	-3.45E-04**
	/	/	/	(-1.1208)	(-0.2487)	(-1.7210)	(0.1747)	(1.0068)	(-2.0940)
5. Personal Consumption	/	/	/	9.48E-07	5.74E-05	-2.46E-04**	-2.02E-04	-2.85E-04**	1.48E-04
	/	/	/	(0.0199)	(1.1643)	(-2.2992)	(-1.5803)	(-2.4728)	(0.5529)
6. Personal Income	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/
7. Trade Balance	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/
8. Capacity Utilisation	/	/	/	/	/	/	4.97E-04*	4.66E-05	1.28E-03**
	/	/	/	/	/	/	(1.8400)	(0.3278)	(2.3492)
9. IP	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/
10. Consumer Confidence	0.0036*	0.0019*	0.0062	/	/	/	/	/	/
	(1.8504)	(1.7060)	(1.3550)	/	/	/	/	/	/
11. Durable Goods Orders	0.0016	0.0008	0.0043*	/	/	/	/	/	/
	(1.4797)	(0.6485)	(1.6820)	/	/	/	/	/	/
12. Leading Index	0.0019*	0.0013*	0.0035	/	/	/	/	/	/
	(1.8513)	(1.8383)	(1.0311)	/	/	/	/	/	/
13. Manufacturers' New Orders	/	/	/	-6.92E-06	-2.79E-05	1.33E-04*	/	/	/
	/	/	/	(-0.0998)	(-0.4218)	(1.6886)	/	/	/
14. New Single-Family Home Sales	-0.0006***	-0.0007***	0.0744	-6.05E-05***	-5.96E-05***	-2.16E-03	6.94E-05***	6.55E-05***	9.21E-03
	(-2.7675)	(-3.1606)	(1.5670)	(-4.5690)	(-4.5522)	(-1.2550)	(3.7691)	(4.2221)	(1.1585)
15. PMI	0.0017*	0.0011	0.0033*	/	/	/	2.46E-04**	3.84E-05	8.02E-04***
	(1.7601)	(0.9435)	(1.7532)	/	/	/	(2.2355)	(0.4689)	(3.0410)
16. Federal Budget	3.10E-05	0.0002***	-0.0095	/	/	/	/	/	/
	(0.0980)	(3.4465)	(-0.6311)	/	/	/	/	/	/
17. Consumer Credit	-0.0003**	-0.0002***	-0.0154	3.22E-05**	3.04E-05***	6.63E-04	/	/	/
	(-2.2970)	(-2.8307)	(-1.2351)	(2.3562)	(2.6450)	(0.3655)	/	/	/

Table 9 (Continued)

News Announcements	Response Coefficients								
	Fourth Scale			Fifth Scale			Sixth Scale		
	W^1	E^1	C^1	W^1	E^1	C^1	W^1	E^1	C^1
1. CPI	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/
2. PPI	1.42E-05	3.32E-07	1.31E-04**	/	/	/	/	/	/
	(1.3125)	(0.0348)	(2.4386)	/	/	/	/	/	/
3. Nonfarm Payrolls	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/
4. Civilian Unemployment	/	/	/	1.49E-05**	1.06E-05*	2.56E-05*	/	/	/
	/	/	/	(2.3062)	(1.6667)	(1.6817)	/	/	/
5. Personal Consumption	-2.47E-05***	-2.60E-05***	-1.94E-05*	-9.10E-06**	-1.08E-05**	-1.74E-06	3.91E-07***	2.76E-07***	8.92E-07***
	(-3.1118)	(-2.7142)	(-1.9039)	(-2.3012)	(-2.2658)	(-0.3965)	(3.7518)	(2.9917)	(3.2181)
6. Personal Income	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/
7. Trade Balance	/	/	/	-1.26E-05***	-9.38E-06**	-2.93E-05*	-2.94E-07**	-1.89E-07	-8.80E-07**
	/	/	/	(-2.7034)	(-2.4570)	(-1.6930)	(-2.1868)	(-1.4934)	(-2.1712)
8. Capacity Utilisation	/	/	/	-6.86E-06	9.20E-06	-3.66E-05*	-4.19E-07**	-3.53E-07***	-5.39E-07
	/	/	/	(-0.5744)	(1.2301)	(-1.7568)	(-2.0145)	(-2.8625)	(-1.0471)
9. IP	4.98E-05**	-6.96E-07	1.12E-04**	/	/	/	/	/	/
	(2.4836)	(-0.0592)	(2.5344)	/	/	/	/	/	/
10. Consumer Confidence	2.49E-05*	1.35E-05	4.15E-05	/	/	/	/	/	/
	(1.7098)	(1.0472)	(1.5597)	/	/	/	/	/	/
11. Durable Goods Orders	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/
12. Leading Index	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/
13. Manufacturers' New Orders	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/
14. New Single-Family Home Sales	1.29E-06*	1.21E-06*	2.83E-04	-1.92E-07	-1.49E-09	-4.52E-04*	2.42E-08	1.96E-08	1.11E-05**
	(1.7447)	(1.7907)	(1.0516)	(-0.1549)	(-0.0011)	(-1.8276)	(1.5366)	(1.6056)	(2.3982)
15. PMI	1.41E-05	-1.23E-06	5.50E-05*	/	/	/	-1.08E-07	1.08E-07	-6.89E-07*
	(0.9024)	(-0.0777)	(1.7134)	/	/	/	(-0.7670)	(0.9190)	(-1.9203)
16. Federal Budget	-4.16E-06	-1.06E-06	-1.81E-04***	-1.11E-06**	-1.04E-06***	-4.95E-06	2.43E-08	2.27E-08***	1.18E-07
	(-1.1029)	(-1.3262)	(-4.3519)	(-2.1580)	(-6.1818)	(-0.1744)	(1.5582)	(2.9715)	(0.1478)
17. Consumer Credit	/	/	/	3.05E-06***	2.90E-06***	5.40E-05	/	/	/
	/	/	/	(6.4837)	(5.3754)	(0.7267)	/	/	/

Table 9 (Continued)

News Announcements	Response Coefficients											
	Seventh Scale			Eighth Scale			Ninth Scale			Tenth Scale		
	W[1]	E[1]	C[1]	W[1]	E[1]	C[1]	W[1]	E[1]	C[1]	W[1]	E[1]	C[1]
1. CPI	/	/	/	-2.26E-09*	-1.79E-09**	-3.33E-09	/	/	/	/	/	/
	/	/	/	(-1.8123)	(-2.0844)	(-0.9861)	/	/	/	/	/	/
2. PPI	1.47E-08	2.16E-08**	-2.27E-08	/	/	/	5.65E-10*	4.22E-10	2.26E-09**	/	/	/
	(1.4587)	(2.1539)	(-0.4325)	/	/	/	(1.7615)	(1.2619)	(2.0040)	/	/	/
3. Nonfarm Payrolls	-8.00E-10	-5.96E-09	2.61E-07*	/	/	/	/	/	/	/	/	/
	(-0.1754)	(-1.5083)	(1.6775)	/	/	/	/	/	/	/	/	/
4. Civilian Unemployment	/	/	/	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/	/	/	/
5. Personal Consumption	1.53E-08*	6.83E-09	5.17E-08	/	/	/	/	/	/	/	/	/
	(1.7034)	(0.8390)	(1.2338)	/	/	/	/	/	/	/	/	/
6. Personal Income	-2.80E-08**	-3.00E-08***	-2.58E-08	-3.10E-09**	-3.87E-09***	-8.61E-10	/	/	/	/	/	/
	(-2.5264)	(-3.2505)	(-0.8625)	(-2.3840)	(-2.9365)	(-0.3601)	/	/	/	/	/	/
7. Trade Balance	8.44E-09	-2.45E-09	6.81E-08**	-1.20E-09	-2.44E-10	-6.72E-09**	/	/	/	/	/	/
	(0.6228)	(-0.1771)	(2.3270)	(-1.2210)	(-0.3066)	(-2.1092)	/	/	/	/	/	/
8. Capacity Utilisation	3.48E-08	3.79E-09	6.14E-08**	/	/	/	/	/	/	/	/	/
	(1.4677)	(0.2000)	(2.3572)	/	/	/	/	/	/	/	/	/
9. IP	-6.20E-08**	3.40E-09	-1.29E-07***	/	/	/	/	/	/	/	/	/
	(-2.1579)	(0.1445)	(-4.7581)	/	/	/	/	/	/	/	/	/
10. Consumer Confidence	5.80E-10	-3.19E-08	4.77E-08**	/	/	/	/	/	/	-1.01E-10***	-9.26E-12	-2.18E-10***
	(0.0296)	(-1.2505)	(2.5741)	/	/	/	/	/	/	(-4.3198)	(-0.2302)	(-4.4954)
11. Durable Goods Orders	2.60E-08**	1.76E-08	5.31E-08**	-2.22E-09**	-3.69E-09***	2.80E-09	/	/	/	/	/	/
	(2.2885)	(1.3758)	(2.3293)	(-2.0459)	(-3.4538)	(0.9799)	/	/	/	/	/	/
12. Leading Index	-1.63E-08	5.06E-09	-8.46E-08***	/	/	/	/	/	/	/	/	/
	(-1.5589)	(0.5426)	(-2.9798)	/	/	/	/	/	/	/	/	/
13. Manufacturers' New Orders	1.27E-08	1.30E-08**	1.10E-08	/	/	/	/	/	/	/	/	/
	(1.2738)	(2.0472)	(0.1719)	/	/	/	/	/	/	/	/	/
14. New Single-Family Home Sales	/	/	/	2.60E-11	-5.55E-11	1.94E-07**	/	/	/	/	/	/
	/	/	/	(0.0812)	(-0.1830)	(2.2287)	/	/	/	/	/	/
15. PMI	/	/	/	/	/	/	-2.22E-11	3.81E-10	-1.12E-09 *	/	/	/
	/	/	/	/	/	/	(-0.0693)	(1.0145)	(-1.8274)	/	/	/
16. Federal Budget	1.64E-08	1.14E-08**	3.01E-07 ***	-1.26E-09	-1.40E-10	-6.59E-08**	/	/	/	/	/	/
	(1.5394)	(2.0258)	(3.0614)	(-0.9309)	(-1.2599)	(-2.0534)	/	/	/	/	/	/
17. Consumer Credit	7.41E-10	-1.61E-09	8.13E-07***	-1.12E-09***	-1.16E-09***	1.15E-08	/	/	/	/	/	/
	(0.1531)	(-0.5544)	(2.6083)	(-2.7872)	(-3.3079)	(0.2289)	/	/	/	/	/	/

1. The whole sample period is abbreviated as "W", the expansion period as "E", and the contraction period as "C".
2. *, ** and *** represent statistical significance at the 10%, 5% and 1% levels, respectively.
3. If the response coefficient on the announcement surprise is not significant in every time period, we use the slash line instead of the data.