Stock Market Reactions to Macroeconomic Announcements

The Dynamics of the Price Adjustment Process

Martin Nilsson Erleman[a]

Major in Finance

Stockholm School of Economics

Mathias Wallestam[b]

Major in Finance

Stockholm School of Economics

Abstract

The link between information and changes in asset prices is central to financial economics. A fundamental tenet of market efficiency is that investors react to new information as it arrives, resulting in price changes that reflect investors' expectations of risk and return. By shedding light on the process by which security prices adjust to the release of macroeconomic announcements, this paper contributes to the understanding of financial markets' short term reactions to news. It moreover explores the speed at which the market adjusts to these news releases and evaluates algorithmic trading strategies based on market data versus announcement estimations. Extending the existing literature, we analyze the intraday effects of major American macroeconomic announcements on the German DAX Index Future. Our results show that the DAX Index Future reacts quickly and decisively to the macroeconomic news. We also show that the volatility peaks during the 10 to 20 seconds subsequent to the news release but the volatility remains high for at least 600 seconds. With the major price adjustment done as quickly as 20 seconds, it is questionable if there is enough data to create a reliable momentum strategy based on the market reaction, and still earn excess return. A possible solution may be to build an algorithm that takes both the Expectation Error and some initial market data into account to give more strength to the buy or sell signal.

Master's Thesis in Finance
Tutor: Stefan Engström
Presentation date: December 20, 2007, 10:15
Room: C437
Discussants: Marcus Olausson and Pontus von Essen

We would like to thank SEB that have supplied us with vital inputs for our data sample, in particular Mikael Anveden for his enthusiasm, support and expertise. We would also like to thank Stefan Engström for his valuable guidance.

[a] 20279
[b] 20278

TABLE OF CONTENTS

1.	**INTRODUCTION**	**3**
1.1	**Purpose and Contribution**	**4**
2.	**THEORETICAL FRAMEWORK**	**6**
2.1	**Macroeconomic Announcement and Prices**	**6**
2.1.1	The Relation between Public Information and Market Activity	6
2.1.2	The Importance of Macroeconomic Announcements	7
2.1.3	The Impact of Inflation Surprises	8
2.2	**Market Efficiency**	**9**
2.2.1	The Efficient Market Hypothesis	9
2.2.2	Breaking the Hypothesis - A Violation of Efficient Markets	10
2.3	The Intra-Day Price Dynamics	11
3.	**ALGORITHMS AND THE FINANCIAL MARKETS**	**12**
3.1	**Algorithmic Trading**	**12**
4.	**HYPOTHESES**	**14**
4.1	**Volatility hypotheses**	**14**
4.2	**Correlation hypothesis**	**15**
4.3	**Return hypothesis**	**15**
5.	**DATA DESCRIPTION**	**16**
5.1	**Description of the DAX Index Future**	**16**
5.2	**Macroeconomic announcements**	**16**
5.3	**Tick-by-Tick Data**	**17**
5.4	**Prices and Returns**	**18**
6.	**THE REESPONSE OF THE STOCK PRICE: EMPIRICAL RESULTS**	**19**
6.1	**Calculating Volatility**	**19**
6.2	**Volatility Patterns**	**20**
6.3	**More or Larger Price Changes**	**21**
6.4	**Efficiency and leakage**	**23**
6.5	**Correlation between succeeding intervals**	**24**
6.6	**The dynamics of the price adjustment**	**25**
6.7	**Leakage**	**28**
6.8	**Price adjustment**	**28**
6.9	**Preferred Algorithmic Strategy**	**33**

7.	**CONCLUDING REMARKS**	**34**
7.2	**Conclusion**	**34**
7.2	**Critical Evaluation**	**35**
7.3	**Further Research**	**36**
8.	**REFERENCES**	**37**
8.1	**Academic References**	**37**
8.2	**Electronic and Other Sources**	**39**
9.	**APPENDIX**	**40**

1. INTRODUCTION

What happens to stock prices immediately after macroeconomic statistics are released? The process by which security prices adjust to the release of macroeconomic announcements is a continuously developing area of study in finance. Our analysis of the short-term effects of macroeconomic news on the German DAX Index Future is important because it relates to several topics in applied finance. First, the main interest has been whether prices adjust in a rapid and unbiased manner to new information. If prices adjust slowly there are opportunities for traders to earn excess returns, but only if future prices are predictable. Ederinton and Lee (1995) found that the price on Foreign Exchange and Interest Rate Futures markets starts adjusting within 10 seconds and is basically completed within 40 seconds of news. Graham et al. (2003) established that the value of stocks on the S&P 500 index are influenced by scheduled macroeconomic news, however, they did not, investigate any intraday effect. Nofsinger and Prucyk (2003) investigated the intraday volume effect of macroeconomic news on the S&P 100 index option and concluded that it was responsible for most abnormal intraday trading volume. Jain (1988) reported that the response of the S&P 500 Index to unexpected changes in macroeconomic statistics is completed within one hour. In addition to this, the research on market microstructure is important for the understanding of operations and behavior of securities markets as well as the behavior of asset prices on intra-day basis, (O'Hara (1999)). Dufour and Engle (2000) find evidence that when the time duration between transactions decrease, the speed of price adjustment to trade-related information will increase. The implication is that a high presence of informed traders will lead to the most active market. The hypothesis that macroeconomic developments involve important effects on equity returns has a strong intuitive appeal but lack a substantial amount of empirical support.

Second, a fundamental tenet of market efficiency is that investors react to new information as it arrives, resulting in price changes that reflect investors' expectations of risk and return. The technological development in financial markets has drastically changed the environment in which market participants act but the question of efficient markets is still very relevant. In theory, if a news announcement affects the fundamental value of an asset according to the market consensus, then the price of the asset should jump to its new level without requiring any trading activity (French and Roll (1986)). On the other hand, Black (1986) argues that market participants sometimes trade on noise as if it were information. Furthermore, he makes the case that noise trading is necessary for liquid markets because, for two individuals to trade, they need to have different expectations about the good in question. Shleifer and Summers (1990) similarly divide market participants into arbitrageurs on the one side and noise traders on the other side. The noise traders sometimes follow trading strategies based on pseudo-signals, noise and popular models. The authors argue that, while some of these activities cancel each other out, many of them are correlated and lead to aggregate demand shifts. A practical interpretation and in fact the one adopted by a fair part of the academic community is that in an efficient market stock prices reflect all available information to a degree that prevents investors from earning excess returns net of transaction costs.

Third, another interesting aspect is the limitations of the human being. The use of computers enables us to take in more information and trade based on pre programmed variables. It is not unlikely that this will reduce the problems of human inadequacy but it can also lead to increased irrational behavior. With the overwhelming amount of information available in the financial markets, it has almost become impossible for a single person to keep up with all information for a single asset, let alone multiple assets (Oberlechner and Hocking (2004)). Miller (1956) pointed out that the channel capacity for processing information on the part of human brains appears to be limited.

Fourth, as the amount of computer driven trading increases, margins are reduced which increases the need for well-constructed algorithmic models. Algorithmic trading currently stands for approximately one third of the volume traded in America (The Economist, 21 June 2007). Transparence and post trade analysis is developing quickly, making it possible for clients to measure and benchmark brokers' trading performance. A model based on a news feed that reacts within milliseconds has the possibility to reduce transaction costs without inducing further risk. Understanding the behavior of short-term price adjustments can perhaps help investors earn alpha that is independent of the underlying market movements, *see Figure A.15* in the appendix. Grossman and Stiglitz (1980) argue, lacking some scientific evidence that with costly information for a market to come close to efficiency some arbitrageurs must be able to earn excess profits. Understanding the volatility patterns and price dynamics subsequent to news is therefore of the greatest importance in the competition for clients and excess returns.

1.1 Purpose and Contribution

With this study we aim to explore the short-run dynamics of the price adjustment to new information on equity markets. Previous research has been mainly focused on the US markets, our contribution is therefore important since it will enable comparison between results in the US and Europe. Our contribution is that we extend the empirical academic research on short-term market- and price behavior as well as the efficiency of financial markets. By using tick-by-tick data in 10 second intervals we are able to answer some of the questions that are still left unanswered in equity markets. Specifically, we examine the speed of adjustment, explore the number of trades necessary to reach the new equilibrium, examine whether trades occur at non-equilibrium prices, explore the possibility of market overreaction and investigate information leakage before the news release using the framework of Ederington and Lee

(1995) in our analysis. We also investigate volatility and volume patterns as well as the time until the first execution subsequent to macroeconomic announcements. By investigating the short-term reaction to macroeconomic we are able to explain a short term anomaly that to a certain degree deviates from the Efficient Markets Hypothesis, and we argue that the anomaly perhaps can be explained by the cost of developing advanced software systems, such as algorithms. The barriers of entry are high as these systems are difficult and expensive to develop, require experienced people and are at the forefront when it comes to data handling. We are also able to extend previous research by raising questions of how computer trading will change behavior of market participants and if it can reduce human limitations. With the support of our analysis we are able to compare different algorithmic strategies and the possibility of earning excess returns. No earlier published studies have, to the extent of our knowledge, performed a similar analysis.

2. THEORETICAL FRAMEWORK

2.1 Macroeconomic Announcements and Prices

2.1.1 The Relation between Public Information and Market Activity

The issue of information driving market relationships is as old as economics and many papers have tried to show reliable associations between macroeconomic variables and security returns. A widely accepted belief is that asset prices react sensitively to economic news. Daily experience seems to support the view that individual asset prices are influenced by a wide variety of unanticipated events and that some events have a more persistent effect on asset prices than do others. Consistent with the availability for investors to diversify, modern financial theory has focused on systematic influences as the likely source of investment risk (Chen, Roll and Ross (1986)). However, little theory has touched upon which events that are likely to influence all assets. It is indeed a quite embarrassing gap between the theoretically exclusive importance of systematic "state variables" and the complete ignorance of their identity. The correlation of asset prices suggests the presence of underlying exogenous influences.

No satisfactory theory would argue that the relation between financial markets and the macro economy is entirely in one direction. However, stock prices are usually considered as responding to external forces. It is, according to Chen, Roll and Ross (1986), apparent that all economic variables are endogenous in some ultimate sense. Only natural forces are truly exogenous to the world economy. Chen, Roll and Ross (1986) conclude in their paper that stock returns are exposed to systematic economic news and are priced in accordance with their exposure. It is natural to explore the benefits of identifying macro variables that influence aggregate equity returns. First, it may indicate hedging opportunities for investors. Second, if investors as a group are averse to fluctuations in these variables, these variables may constitute priced factors. A macro variable that reliably affects the value-weighted market portfolio's value need not to be a priced factor, but it appears to be an appropriate place to search for such factors (Flannery (2001)).

The relationship between inflation and common stock returns has been studied extensively and there are numerous hypotheses about the distributive effects of unanticipated inflation on stock returns. An important reason to expect a relationship between stock returns and unexpected inflation is that unexpected inflation contains new information about future levels of expected inflation. Schwert (1981) extends the evidence on the relationship between stock returns and inflation by examining the daily returns of the Standard and Poor's composite portfolio around the CPI announcement dated from 1953-1978. Possibly the most interesting finding is that the stock market reacts to unexpected inflation around the time when the CPI is announced, and the stock market does not seem to react to unexpected inflation during the period when the CPI is sampled, several weeks before the announcement date. This suggests that the Bureau of Labor Statistics provides information to the market by collating and assimilating observable prices into a single index number, and the stock market reacts to that information. Nevertheless, he does not find a strong reaction of aggregate stock returns to unexpected inflation.

2.1.2 The Importance of Macroeconomic Announcements

Cutler and Summers (1988) explore whether unexpected macroeconomic realizations can explain a significant fraction of share price movements. In their analysis of stock returns to news about macroeconomic performance, they shed light on the difficulties in explaining more than one third of the return variance from this source. Financial economics has been very successful in explaining the relative prices of different securities. The powerful intuition of arbitrage has facilitated the pricing of a wide range of financial claims. On the other hand, less progress has been recorded in accounting for the absolute level of asset prices. The standard approach holds that fluctuations in asset prices are subject to changes in fundamental value. The extensive event study literature has demonstrated that share prices react to announcements about corporate control, regulatory policy, and macroeconomic condition that plausibly affect fundamentals. However, the stronger idea that only news affects asset values is more difficult to substantiate. The apparent absence of fundamental economic news coincident with dramatic stock market movements of late 1987 is, according to Cutler and Summers (1988), particularly hard to bring together with the standard view.

Macroeconomic announcements may influence the stock market returns if changes in the information set revealed by the news affect either expectations of the pricing operator, future dividends, or both. The expected cash flows change in response to both real and nominal forces (Li and Hu (1998)). The fact that stock markets are sensitive to macroeconomic news is as mentioned an accepted belief in a world where market participants closely follow government releases of economic data and announcements of monetary policy changes. A surprise of macroeconomic character may have dramatic consequences on the global stock exchanges, or at least changes suggested by financial press. Reports of stock prices falling because of disappointing nonfarm payroll employment figures or rising due to encouraging news on the inflation front are common in everyday financial media. Such market behavior is consistent with standard finance theories suggesting that the rate of return on an asset is determined by systematic economic news, while no extra reward can be earned for holding diversifiable or idiosyncratic risk. However, there exists a gap in the empirical identification of the state variables determining asset pricing. Despite the strong association between movements in stock prices and macroeconomic announcements, as suggested by the press, there exist relatively few evidences favoring the belief that stock prices respond to general macroeconomic news, with some exceptions of monetary information.

An underlying source of the failure to capture the impact of macroeconomic news on stock prices is that standard regressions treat the market reaction to the same type of macroeconomic news as being identical at all times. In contrast, depending on the stages of the business cycle or the states of the economy, the market is likely to treat similar macroeconomic information differently. Li and Hu (2002) take the release of data on industrial production as an example. During a recession, a surprising pick-up in industrial production could be interpreted by market participants as a signal for a recovering economy and an improved outlook for corporate earnings and hence result in a rally on the stock market. Conversely, if the same announcement is made after a long period of expansion, it may end up in fears of an overheating economy and possible moves by policy makers to hike interest rates. The same type of macroeconomic unexpected news could have either a good or a bad effect on the stock market, depending on its timing. Most of the empirical research assumes that the response of investors to news is the same over different stages of the business cycle and over different monetary policy regimes. To the extent that actual market behavior deviates from this assumption, the estimated response coefficient on the news variable in these studies would be biased towards zero.

2.1.3 The Impact of Inflation Surprises

The literature has documented that aggregated stock returns are negatively related to inflation and to money growth (Flannery (2001)). If interest rates, and hence stock prices, respond to money supply announcements due to inflationary expectations, they should also be affected by shocks contained in inflation rate announcements. In a study by Fama and Schwert (1977) it is documented that a negative effect should emerge if a positive surprise in announced inflation induces agents to raise their level of expected inflation. Inflation surprises could also affect the financial market through channels other than inflationary expectations (Li Hu (1998)). Unanticipated higher inflation may cause expectation of more restrictive monetary policies, which in turn will lead to the reduced cash flows and lower stock prices. Moreover, a positive inflation surprise could induce agents to adjust their savings, resulting in higher interest rates and lower stock prices. In any event, all these potential links suggest that unexpected news in CPI and PPI announcements could be positively related to interest rates, while negatively related to stock prices.

2.2 Market Efficiency

2.2.1 The Efficient Market Hypothesis

Since Eugene Fama, over 30 years ago, defined the efficient financial market as one where the available information is fully reflected in the security prices, the Efficient Market Hypothesis (EMH) has been an important proposition in finance. The EMH tells us that investors cannot consistently beat the market and all the effort devoted to analyzing, trading and picking securities are all a waste. If this is true, the market is perfectly priced, and it is better to passively hold the market portfolio and skip active money management, (Shleifer (2000)).

There are a vast amount of studies indicating the power of the EMH and it quickly became supported. However, the last twenty years academic researchers have challenged the EMH. New studies have actually found evidence against the EMH, this is mostly regarding the forces making the markets efficient, being weaker and more incomplete than previous research has supposed. Behavioral Finance is an important alternative view of the EMH telling us that there are systematic and significant deviations from efficiency persisting for longer periods (Shleifer (2000)).

The EMH rely on three arguments. The first argument is the assumption of rational investors and that they value securities rationally. Second, the fact that trades are random will make the existence of irrational traders irrelevant and they will not affect prices. The third argument is that the presence of rational arbitrageurs will eliminate the irrational investors influence on prices. Some of the evidence against the EMH is that investors are not fully rational. Investors often trade on noise rather than information implying that they form their demand for securities on irrelevant information (Shleifer (2000)). Behavioral finance also states that arbitrage is risky since securities do not always have perfect substitutes, therefore arbitrage is limited. Many empirical studies have challenged the EMH, showing that volatility in stock market prices are higher than expected and that stock prices overreact which is in line with psychological theory. According to Shleifer (2000), evidence has been found that movements in individual stocks can predict future movements. There are also many studies finding statistical evidence of underreaction and overreaction in security returns following news and earnings announcements. In the next section we will cover previous research in this subject.

2.2.2 Breaking the Hypothesis – A Violation of Efficient Markets

According to Shleifer (2000), Fama take the market efficiency hypothesis to be the simple statement that security prices fully reflect all available information. For this strong version of the market efficiency theory to hold, information and trading costs, as well the costs of getting prices to reflect information, must be equal to zero. An economically more sensible version of the efficiency hypothesis puts forth that prices reflect information to the point where the marginal benefits of acting on information do not exceed the marginal costs. The extreme version of the market efficiency is most likely false, since there are surely positive information and trading costs. On the other hand, its advantage is that it is a clean benchmark that allows taking a step aside from the complex problem of deciding what are reasonable information and trading costs. Instead, we can focus on the more relevant task of laying out the evidence on the adjustment of prices to various kinds of information. Ambiguity about information and trading costs is not the main obstacle to inferences about market efficiency. The joint-hypothesis problem is of a more serious character and, hence, market efficiency per se is not testable. It must, according to Fama, be tested jointly with some model of equilibrium, an asset-pricing model. This gives rise to the question whether the fact that market efficiency must be tested jointly with an equilibrium-pricing model lowers the interest for making empirical research on efficiency? Does the joint-hypothesis problem make empirical work on asset-pricing model uninteresting? Fama's answer to these symmetric questions is an unequivocal no. The cleanest evidence on market-efficiency originates from event studies, especially event studies on daily returns.

Financial markets should not in general be presumed to be efficient (Shleifer (2000)). There is an enormous volume of statistical evidence of underreaction and overreaction in security returns. However, only minor attention is devoted to the behavior of aggregate stock returns because these data often do not provide enough information to reject the hypothesis of efficient markets. Empirical analysis of the aggregate time series of security returns has produced some evidence of underreaction. The stock underreacts to the announcement of news, a mistake which is at least partly corrected in the following period, spreading the impact of the announcement on the price over time. As an effect of the stock underreacting to the actual announcement, there may be profits to collect by trading in the stock after the news is announced. (Shleifer (2000)) This to some extent involves a violation of market efficiency. After a series of announcements of good news, the investor becomes overly optimistic that future news announcements will be of the same good character and therefore overreact, sending the stock price to unduly high levels. Subsequent news most likely contradicts this optimism, creating lower returns. Once more, the idea is that trading on stale information, in this case a series of good or bad news, may earn superior returns.

2.3 The Intra-Day Price Dynamics

The technological development in financial markets has drastically changed the environment in which market participants act and the research within intra-day price reactions to news releases has increased. In theory, if a news announcement affects the fundamental value of an asset according to the market consensus, then the price of the asset should jump to its new level without requiring any trading activity (French and Roll (1986)). If traders disagree on the impact of the new information, there should be an increase in the trading following the news announcement. It could be that the effects of the data release are only capitalized into prices via this trading. With the overwhelming amount of information available in the financial markets, it has almost become impossible for a single person to keep up with all information for a single asset, let alone multiple assets (Oberlechner and Hocking (2004)).

The main interest, in previous research, has been whether prices adjust in a rapid and unbiased manner to new information. Ederington and Lee (1993) found that volatility on Foreign Exchange and Interest Rate Futures markets increases within one minute of a macroeconomic news announcement, and the effect lasts for about 15 minutes. Graham et al. (2003) established that the value of stocks on the S&P 500 index are influenced by scheduled macroeconomic news, however, they did not, investigate any intraday effect. Nofsinger and Prucyk (2003) investigated the intraday volume effect of macroeconomic news on the S&P 100 index option and concluded that it was responsible for most abnormal intraday trading volume.

Lately the availability of large datasets on transaction data and more powerful analytical tools has created a new wave of interest in the market microstructure research which is focusing on the mechanics of price formation (Dufour and Engle (2000)). The research on market microstructure is important for the understanding of operations and behavior of securities markets as well as the behavior of asset prices on intra-day basis, O'Hara (1999). Dufour and Engle (2000) find evidence that when the time duration between transactions decrease, the speed of price adjustment to trade-related information will increase and is related to larger quote revisions and increased positive autocorrelation of signed trades. The implication is that a high presence of informed traders will lead to the most active market. Active markets are said to be illiquid in the sense that trades have greater impact on price and higher informational content (Dufour and Engle (2000)).

3. ALGORITHMS AND THE FINANCIAL MARKETS

3.1 Algorithmic Trading

Trading Algorithms are computer programs that generate buy and sell orders and make lightning quick trades. As the time taken to process computer generated trades falls to thousands of a second, algorithms are being created to react to news headlines faster than the eye can scan them. Trading on news releases is harder than it sounds. Not only is the reported consensus number important but so are the whisper numbers and the revisions. Depending on the current state of economy the relative importance of these releases may also change.

Table I
Glossary

Glossary	
Concept	Explanation
Trading Algorithms	Trading Algorithms are computer programs that electronically generate buy and sell orders allowing quicker trades to take place. As the time taken to process computer generated trades falls to thousands of a second, algorithms are being created to react to news headlines faster than the eye can scan them.
Black-box trading	Use of computer programs for entering trading orders with the computer algorithm deciding on certain aspects of the order such as the timing, price, or even the final quantity of the order.
Statistical arbitrage" trading	Trading based on statistical models, that forecast future events of the behavior of individuals and institutions, and thereby take advantage of arbitrage situations.
White-box trading	Order handling algorithms that brake up large trades. Sell or buy orders are given to brokers by the client with certain instructions, for example to buy 1/3 of the volume, Volume Weighted Average Price or Time Weighted Average Price in the market.
Elementized data	Machine readable information

Quantitative trading strategies, including algorithmic trading and arbitrage or strategy trading, have emerged as the next generation of solutions to facilitate the electronic trading markets. This status is driven more by the changing market structure and movement to electronic trading than by the revolutionary capabilities of the underlying algorithms. The financial markets have gone through quite dramatic changes during the past decades. Floor trading has been substituted by electronic trading. Electronic trading has improved the efficiency of stock markets and hence reduced the cost of providing liquidity and also increased the accuracy of price signals. It has also improved the speed and lowered the cost of trading (Stoll (2006)). Today, algorithmic trading stands for approximately one third of the volume traded in America (The Economist, 21 June 2007).

In 2007 Dow Jones announced that it will provide its customers with an Elementized News Feed, that will allow financial institutions to instantly and continuously analyze, evaluate and respond to complex market events. It allows institutions to build, test and deploy algorithmic trading strategies that analyze and react to news that has an immediate impact on asset prices. The systems can pick up changes in economic data such as CPI and PPI but more qualitative, non number news are still being worked on.

The ability to scan for keywords has existed for some time. The event processing platform that helps algorithmic trading grew out of academic research to harvest events and correlate them. But the machine readable news grabs news events at the same speed as market-data systems read market prices. Investors then put the news stories through an algorithm that feeds a trade execution system. The system bases trade decisions on rules that have been programmed into the system and it can even detect patterns and recognize non-events. As news feed incorporate a growing number of variables, in the same fashion as market-data dependent algorithms, the algorithms that react to the news will improve. What moves markets is often the news. The market might be trending downward and an algorithm produces a sell signal. But at the same time macroeconomic releases might indicate that the market is undervalued. So putting news into the algorithm is an important predictor of market behavior. A normal trader needs about half a second to read a headline and make a trading decision. The new technological improvements can make the same decision in milliseconds.

It is important to minimize the delay between the time of the order and the execution. Every moment is crucial in “black-box”, “white-box” and “statistical arbitrage” trading, where computers prowl through the market for price distortions that may last only for a split second. Order-handling algorithms, which break up large trades, must be extremely fast to ensure they get the best electronic prices. The speed is so important that even the location of servers matters. Having the server closest to the trading venue can cut milliseconds to the timing of a trade and ensure a better price. The low latency can also help investors get a jump on economic news as it flashes across the wires. This news release trading algorithm is still at an early stage and there exists a risk that the algorithm misunderstands keywords in the surrounding. This has caused traders to use the news algorithms in combination with other variables such as price or volume to reinforce the buy or sell signal. Now that news algorithms are reading the news, it will not be surprising if news will come from reading the algorithmic trades, and not the other way around.

4. HYPOTHESES

We derive our hypotheses from the theoretical framework; specifically we follow the framework put forward by Ederington and Lee (1995) in our analysis. We contribute to the research on intra-day effect of macroeconomic news on the German DAX Index Future. We extend the previous research done on equity markets and shed light on the implications for practical applications.

4.1 Volatility hypotheses

In order to start our investigation of the speed at which the DAX Index Future adjusts, we test if the volatility on announcement days is higher than on non-announcement days. If the volatility prior to announcement is higher than normally there could be leakage of information, but the reason can also be non-informed trading. High volatility subsequent to a news release implies that the market adjusts to the new information and if the volatility continues throughout the window, there could be slow reaction and drift in prices.

Hypothesis 1: The short-term volatility is higher on announcement days than on non-announcement days.

High volatility on announcement days could either reflect a quick move to a new equilibrium on only a few trades or more frequent trades on intermediate levels. The distinction is important since the former gives evidence of a more efficient market. To investigate the way in which the price adjust, we calculate the median time between ticks, the percentage of price changes exceeding one tick in size, the average number of ticks per interval and the volume/tick divided into 10 second intervals.

Hypothesis 2: Volatility primarily increases post-announcement through an increased number of executions, rather than larger price movements or larger size of the executions.

Macroeconomic key figures are released instantly to the market but the components of which they are composed are normally released shortly afterwards. Media and information providers' focus on these figures and the whole truth is therefore not captured right away. Investor with different level of information can therefore respond differently to these figures. Significant information leakage would violate the efficient market hypothesis and cause post announcement returns to be independent and insignificantly correlated.

Hypothesis 3: There is no leakage of information prior to macroeconomic announcements.

4.2 Correlation hypothesis

We are interested in whether the return of an interval represents a continued reaction to the initial news release or not. Depending on which intervals we find significant correlation in, we will be able to draw conclusions on leakage, the speed of adjustment and market efficiency.

Hypothesis 4: There exists a significant and continued reaction correlated with the initial news release on announcement days.

4.3 Return hypothesis

In order to fully understand the dynamics of the price adjustments to macroeconomic news we also look at the magnitude of price adjustments, i.e. how much of the adjustment from the old equilibrium price to the new equilibrium price that occurs within the first 10 seconds, 20 seconds etc.

Hypothesis 5: Average Adjusted Returns are significantly different from zero during the major price adjustment shortly after the news release on announcement days.

Table II
Summary of Hypotheses

Hypotheses:
H1: The short-term volatility is higher on announcements days than on non-announcement days
H2: Volatility primarily increases post-announcement through an increased number of executions, rather than larger price movements or larger size of the executions.
H3: There is no leakage of information prior to macroeconomic announcements.
H4: There exists a significant and continued reaction correlated with the initial news release on announcement days.
H5: Average Adjusted Returns are significantly different from zero during the major price adjustment shortly after the news release on announcement days.

5. DATA DESCRIPTION

5.1 Description of the DAX Index Future

We examine the response of the DAX future, the German Stock Index Future, to scheduled macroeconomic announcements. The underlying DAX Index measures the performance of the Prime Standard's 30 largest German companies in terms of order book volume and market capitalization. The index is based on prices generated in the electronic trading system Xetra. The DAX Index Future is traded between 08:00 and 22:00 and is therefore exposed to all the US macroeconomic announcements. The DAX Index Future matures every three months, for example the current DAX Index Future Dec 07 will expire in December 21 and the next contract will be the DAX Index Future Mar 08 with expiry date March 20. Since the contracts mature within 3 months we switch to the second nearby contract when the trading volume exceeds the nearby.

The underlying reasons for choosing the DAX Index Future in our paper are the high liquidity, the easy access, the fact that it is a well known asset to traders and that we believe - it is a good proxy for the European investor's reaction to news. Since it is traded between 08:00 and 22:00 it includes both the European and US open hours. SEB is especially interested in the reaction of the DAX future since they believe that it is the most interesting market for their clients in this area of trading. Furthermore, since all chosen macroeconomic statistics are released at exactly 14:30 CET, one hour before the opening of the US Markets, we believe that the investor reactions should be well captured by the DAX Future. We have not found any existing studies examining the news reaction on the DAX Index Future

5.2 Macroeconomic announcements

The macroeconomic announcements we have taken into consideration are as mentioned; the Consumer Price Index (CPI), Producer Price Index (PPI), Initial Jobless Claims (IJC) and the Non-Farm Payrolls (NFP). All variables except IJC are announced with a one-month lag and represent month to month percentage changes. IJC is quoted in thousands of persons and is announced weekly. All the announcements are announced at 14:30 CET. The release procedures of scheduled macroeconomic announcement follow almost identical procedures. Bureau of Labor Statistics (BLS) releases Principal Federal Economic Indicators at exactly 14:30:00 CET. A clock receiving a signal from the U.S. Naval Observatory is used to count down to 14:30:00 CET (Gary Steinberg, BLS (2007)).

CPI measures changes in prices of all goods and services purchased for consumption by urban households. User fees, sales and excise taxes paid by the consumer are included. Income taxes and investment items are not included. PPI measures price changes for the entire output of domestic goods-producing sectors and lately coverage is extended to many of the non-goods producing sectors of the economy. NFP represents the total number of paid U.S. workers of any business, excluding the following employees: general government employees, private household employees, and employees of nonprofit organizations that provide assistance to individuals and farm employees. The IJC measure the number of filings for state jobless benefits. (Bloomberg Professional).

Table III
Macroeconomic Announcements

Macroeconomic Announcements	
Statistic	Description
PPI	Measures price change for the entire output of domesticgoods-producing sectors.
CPI	Measures changes in prices of all goods and services purchased for consumption by urban households.
IJC	Measures the number of filings for state jobless benefits.
NFP	The total number of paid U.S. workers of any business, excluding general government employees, private household employees, and employees of nonprofit organizations that provide assistance to individuals and

5.3 Tick-by-Tick Data

In the main analysis we examine tick-by-tick data from July 5, 2006 through September 21, 2007. The prices are recorded when they are received by the broker from XETRA, with only a small time lag. The lag is in the size of milliseconds so it will not affect our results. The broker records every tick to the nearest second. Tick-by tick data of this length is very hard to find and many banks and brokers do not save more than 50 days of tick-by-tick data because of the size. Our dataset consists of 5,178,430 data-points and includes time, price and volume for every tick. Our analysis will focus on the 12 minutes around the announcement, two minutes before to 10 minutes after the announcement (14:28:00-14:39:59 CET). We also create a 12 minute non-announcement dataset which contains the tick-by-tick prices for non-announcement days. A non-announcement day is defined as a day without any macroeconomic announcement in accordance with the Economic Releases function in Bloomberg. However, other types of asset specific news releases and unscheduled announcements may exist on these days.

During the time period, July 5, 2006 to September 21, 2007, there are 16 PPI, 16 CPI, 16 NFP and 69 IJC announcements, a total of 117 observations. However, our dataset contains a gap during the summer and there are weekdays where the broker has not recorded the prices. In our final dataset we investigate 62 observations over the time period. The number of non-announcement days in our sample is less than a third of the announcement days, only 20, which should be taken into account when considering the strength of the results.

In 2006, daylight saving time occurred on the second Sunday of October in the US as well as in Europe. But in the spring of 2007 daylight saving time occurred on the second Sunday of March in the US whilst on the last Sunday of March in Europe. The scheduled news are released at 13:30 CET on these days and we have therefore included the 13:28:00 – 13:39:59 CET interval in our tick-by-tick data for the 15th, 16th and 22nd of March.

5.4 Prices and Returns

Previous research has shown that the discreteness of security prices and the bid-ask spreads causes returns, especially for short-term periods, to overestimate equilibrium price variances and exhibit spurious negative serial correlation (Ederington and Lee (1995)). They also suggest that price changes, especially on non-announcement dates, reflect a bid-ask bounce and not changes in the underlying equilibrium price. To adjust for these issues we base the return calculations on pseudo-equilibrium prices. The pseudo equilibrium price is an average of the last two prices observed on or before time t. This removes price fluctuations solely due to bid-ask bounce and gives a better approximation of the equilibrium price. Pseudo-equilibrium prices reduce but do not eliminate bias in return volatility estimates. Two smaller, partially offsetting biases remain.

i) The procedure tends to smooth price changes due to equilibrium price changes leading to a small underestimation of equilibrium prices.
ii) Since prices are still discrete pseudo-prices will slightly overestimate equilibrium price volatility (Ederington and Lee (1995)).

It is important that the equilibrium price returns are serially uncorrelated, because our tests are based on serial correlation measures and bid-ask bounce imparts a strong negative bias to short period correlation coefficients. We calculate returns for each 10-second interval within the twelve minute period around the announcement. For each 10-second interval we calculate log returns as

$$R_t = \ln(P_t / P_{t-1})$$

where P_t, is the pseudo equilibrium price. The 10 second intervals are named as starting times in seconds relative to the announcement, see *Table IV*.

Table IV
Time Intervals

Time(s)	0	10	20	30	40	50
Interval (start(s);end(s))	(0;10)	(10;20)	(20;30)	(30;40)	(40;50)	

The figure provides an explanation of how we name and define the 10 second intervals.

6. THE RESPONSE OF STOCK PRICES: EMPIRICAL RESULTS

Generally, announcement effects on the level of prices have been found to be significant and systematic, but to account for a rather small fraction of total asset price movements, especially for stock returns and exchange returns. The effect of news announcements on the level of prices generally occurs rapidly, within a few minutes or less. News releases have been widely found to raise price volatility, and research has shown that volatility often remains elevated for a relatively long period of time after the announcement. Jain (1988) examines the hourly response of stock prices and trading volume, in the period of 1978 to 1984, to announcements of money supply, the CPI, PPI, unemployment rate, and industrial production. Two of the five announcement surprises had significant impact on stock prices. In particular, money-supply announcement and CPI-announcement surprises tend to have significant negative effects on stock prices.

6.1 Calculating Volatility

The average standard deviations for each 10 second interval from 120 seconds before the announcement through 600 seconds after are calculated for all observations. Calculating normal standard deviation does not fully capture the volatility in the asset price when looking at short term returns. In practice volatility calculations are often based on a volume-weighted mid-price, rather than the last execution price, i.e. looking at the bid-ask spreads rather than the tick prices.

$$Adj.St.Dev = St.Dev\left(\frac{(Bid * AskSize + Ask * BidSize)}{(AskSize + BidSize)}\right)$$

This adjustment captures the bid-ask movements in the absence of executions. A time period without executions can be caused by low activity but also by new information or perception (French and Roll (1986)). If there is no execution and the level and spread of the bid-ask is constant there is obviously low volatility but new information can lead to wider spreads moving up or down; executions will then only occur when buyers and sellers agree on a new equilibrium price. The two examples have both zero executions but the dynamics are very different. Since our data consist of tick prices we cannot calculate volatility based on bid-ask spreads. If we have zero executions in a ten second interval we may underestimate the true activity in the sample. The second issue regarding the tick-by-tick data is that the time between the executions is irregular. If we for example have two ticks in the beginning of a 10 second interval and thereafter no ticks the volatility will be overestimated. One can argue that the prices have to be time-synchronized for the volatility to be correctly calculated. However, we cannot adjust our data for these issues since we do not have access to orderbook data. Furthermore, in our analysis the change in volatility is far more important than the exact size. To partly solve these issues we have adjusted the standard deviation to the average time between the ticks within each ten second interval.

$$Adj.St.Dev = St.Dev \times \sqrt{\frac{IntervalLength(s)}{AverageTimeBetweenTicks}}$$

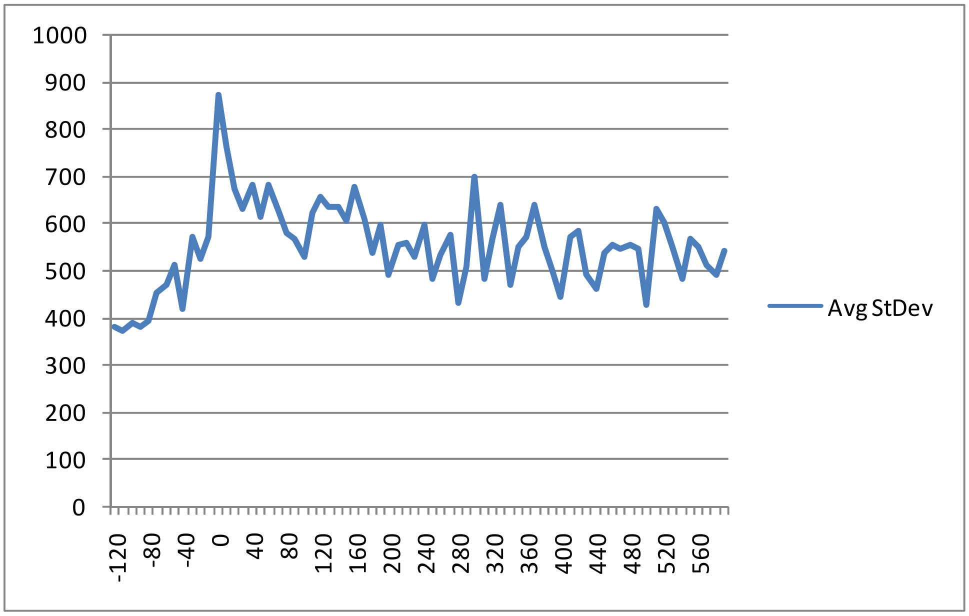
6.2 Volatility Patterns

We display the average standard deviation throughout the twelve minute period for the announcement days in *Figure 1*. From a visual inspection of *Figure 1* there is a pick up in volatility prior to the news release, a sharp increase in the standard deviation during the first 10 seconds of trading followed by a decrease in volatility until t = 190. We test the hypothesis that the volatility on announcement days is higher than on non-announcement days. We observe the highest standard deviation, significant on the 0.01 level, in the first ten second interval subsequent to the announcement. The standard deviation remains significant on the 0.01 level until t = 30. Standard deviation gradually decline following the peak but remain significant at the 0.05 level to t = 190. Between 190 seconds and 600 seconds there are a number of significant peaks in the volatility implying that the price continues to adjust, see appendix *Table A.I*. The implication of this evidence is that the major price adjustment occurs within the first 30 seconds but that the market probably continues to adjust for at least 600 seconds. This is quicker compared to earlier results on the stock markets but is in line with our expectations of shorter response time. Ederington and Lee (1995) find similar volatility patterns when analyzing exchange and interest rates. This gives us some support for the theory that the technological improvements have enabled more traders to evaluate new information more quickly and take action. This would make the response time to new information shorter and more concentrated to the first minutes of trading.

The volatility is significantly higher at the 0.05 level in the (-30,-10) interval which can be seen in *Figure 1*. The significantly higher volatility before t = 0 gives some contrary evidence to the conventional wisdom that traders withdraw from the market just before major announcements due to the high uncertainty. The high volatility on announcement days could reflect either more price changes or larger price changes. The distinction is important since a quick move to a new equilibrium on only a few trades would imply a more efficient market than if many trades are done at intermediate levels (Ederington and Lee (1995)). Ederington and Lee (1995) and Brown, et al. (1992) finds evidence that the increased volatility following macroeconomic announcements is primarily due to more frequent and only secondary to larger price changes.

Figure 1

Adjusted Average Standard Deviation of Ten Second Intervals



The adjusted average standard deviation of log returns for 10 second intervals, from 120 seconds before the news release until 600 seconds after the release, are calculated on all major announcement days. Returns are based on pseudo-prices. The times on the x-axis are intervals' beginning times in seconds relative to the announcement at time 0. We have calculated the adjusted average standard deviation in 10 second intervals adjusted for the time between ticks in each interval. The reported returns are 10^7 time the actual return. The data sample is from 05/07/06 through 21/09/07.

6.3 More or Larger Price Changes

To investigate the way in which the price adjust, we calculate the median time between ticks, the percentage of price changes exceeding one tick in size, the average number of ticks per interval, the average volume per interval and the average volume per tick. The statistics are presented in *Table V*. The statistics are reported in 10 second intervals between -60 and 120 and in one minute intervals outside this window.

The number of ticks per 10 seconds starts to increase approximately 80 seconds before the announcements. Promptly, at the announcement there is a sharp increase that remains relatively stable during the first 30 seconds. After the peak the number of ticks/interval is decreasing until t = 190. At t = 190 the number of ticks has almost adjusted to the level prior to the announcement. However, minor adjustments continue throughout the remaining time period.

The percent of price changes exceeding one unit tick increases sharply in the first 10 seconds after the announcement and falls back to the average level at t = 30. However this kind of movement can be seen throughout the time period and there is no clear pattern in the price changes over time. There are some outliers in the data that distorts our results and we are not able draw any strong conclusions from this data.

The volume starts increasing at t = -60, remains high over the announcement and peaks during interval (30;40). This is followed by a reasonably steady decline to t = 600. We can not say whether the volumes are unusually high or if these types of variations are normal. But looking at the volume/tick in *Table V* and *Figure A.5* in the appendix, we see that the increase in volume is mainly due to more frequent executions rather than larger executions. In fact the volume/tick is well below its average as the news is released. The reason for this can be uncertainty or the fact that more market participants are active at the time of announcement than otherwise.

At the time of the announcement the median time between ticks dips significantly below the average for the period. The median time quickly shift back after the first 10 seconds. Within 30 seconds it has almost adjusted to the levels prior to the announcement. There is a small increase in the time between ticks in intervals between t = 30 and t = 600.

Our results suggest that the increased volatility following macroeconomic announcements is due primarily to more frequent price changes, rather than larger price changes or larger volume/tick. This is in line with what we expect and the results of Brown, et al. (1992) concerning the equity markets' response to earnings announcements and Ederington and Lee (1995) regarding the interest rate markets' and exchange markets' response to macroeconomic announcements.

Table V
Frequency, Volume and Size of Price Changes following Macroeconomic Announcements

The Frequency and Size of Price Changes following Macroeconomic Announcements					
Time Interval (s)	Median Time between Ticks (s)	Number of Ticks	Volume	Average Volume per Tick	Price Changes Exc. One Tick
(-120;-60)	4,3	3,2	16,2	5,0	1,2%
(-60;-50)	5,4	4,1	22,7	5,6	1,6%
(-50;-40)	3,4	4,0	28,8	7,2	1,6%
(-40;-30)	5,2	4,1	26,7	6,5	2,0%
(-30;-20)	3,4	4,3	26,3	6,1	1,9%
(-20;-10)	3,8	4,0	22,4	5,6	0,4%
(-10;0)	3,8	4,5	21,8	4,9	0,7%
(0;10)	2,5	6,6	22,9	3,5	2,7%
(10;20)	3,2	6,0	26,7	4,5	1,9%
(20;30)	3,3	6,4	28,2	4,4	1,3%
(30;40)	3,8	5,3	31,3	5,9	1,5%
(40;50)	3,5	5,3	23,2	4,3	1,8%
(50;60)	2,9	6,0	21,0	3,5	3,0%
(60;70)	3,8	5,2	23,2	4,4	2,2%
(70;80)	3,3	5,1	28,4	5,6	1,3%
(80;90)	3,2	4,6	25,5	5,5	3,8%
(90;100)	4,4	4,9	24,5	5,0	2,3%
(100;110)	4,7	4,6	24,7	5,4	0,4%
(110;120)	3,3	5,1	23,3	4,6	1,9%
(120;180)	3,8	5,2	22,3	4,3	1,6%
(180;240)	4,3	4,8	20,9	4,4	1,1%
(240;300)	4,3	4,7	21,7	4,6	2,0%
(300;360)	4,0	4,8	18,9	3,9	2,0%
(360;420)	4,1	4,6	19,7	4,3	1,1%
(420;480)	4,3	4,4	22,7	5,1	1,5%
(480;540)	4,8	4,5	22,0	4,9	2,4%
(540;600)	4,4	4,3	20,0	4,6	2,0%
(-120;600)	4,1	4,7	22,1	4,7	1,7%

The table display statistics of the median time between ticks, the number of ticks, volume, average volume/tick and the percent of price changes exceeding one unit tick in size for 10 second intervals from 60 seconds before the announcement to 120 seconds after the announcement and one minute intervals outside this window. The average of the whole time period is also calculated. Also see Figures A.1-A.13. The statistics are based on the tick-by-tick data from 07/05/06 to 09/21/07.

6.4 Efficiency and leakage

There are several matters affecting the speed and efficiency of the market's adjustment after macroeconomic announcements. Slow information flow may be caused by the fact that macroeconomic key figures are released instantly but that the components of which they are constructed are released shortly afterwards. Media focuses on these figures and therefore the whole truth is not captured right away. Traders and investors with different level of information may respond differently to the implications of the information in the announcements (Ederington and Lee (1995)). Ederington and Lee put the explanation forward that investors with immediate market access can earn excessive returns trading on the initial price reactions when price adjustment is slow making the returns within the adjustment period positively correlated. If continuing and independent information flow generates the volatility, investors cannot make profits trading on the initial price reaction (Ederington and Lee (1995)).

6.5 Correlation between succeeding intervals

We report the first order serial correlation coefficients between successive 10-second or one-minute returns in *Table VI*. The average correlation coefficients of non-announcement days are close to and insignificantly different from zero. This confirms that, when the spurious correlation caused by the bid-ask bounce is eliminated, there is no significant correlation between returns during no –news periods. The results are expected but we take the limited number of non-announcement days in our sample into account.

Most reported announcement period correlation coefficients in *Table VI* are positive and some are significant. This gives us an indication of a tendency for equilibrium prices to trend in the same direction over successive intervals during announcement periods. But the significant and large coefficients are spread over the intervals subsequent to the news announcement. Coefficients prior to the announcement are small and insignificant. The data indicates that prices tend to trend in the same direction over intervals (0;10) and (10;20), which has a large and significant coefficient. This is followed by an insignificant correction during interval (20;30). Coefficients for intervals between t = 30 and t = 100 are small, have mixed signs and are insignificant, except for correlation between intervals (40;50) and (50;60) that is significantly positive. In the period between t = 100 to t = 600 we observe some succeeding intervals with significant coefficients but mixed signs. There are significant correlations between succeeding intervals during the 10 minutes after t = 0 and we will investigate if these are a result of the initial news announcement or other factors when we continue and look for correlation with the initial interval return in the next section.

Table VI
Market Efficiency and the Speed of Adjustment:
Evidence from Serial Correlation Coefficients

First order Serial Correlation Coefficients	
Return Interval (s)	Correlation
(-120;-60)	NA
(-60;-50)	0.176
(-50;-40)	0.476**
(-40;-30)	-0.107
(-30;-20)	0.091
(-20;-10)	0.058
(-10;0)	-0.058
(0;10)	0.099
(10;20)	0.318**
(20;30)	-0.208
(30;40)	-0.086
(40;50)	-0.126
(50;60)	0.338**
(60;70)	0.247
(70;80)	0.089
(80;90)	-0.011
(90;100)	0.014
(100;110)	0.292*
(110;120)	-0.481**
(120;180)	0.181
(180;240)	-0.087
(240;300)	0.324*
(300;360)	-0.084
(360;420)	-0.294*
(420;480)	0.255*
(480;540)	0.059
(540;600)	0.504**

The table displays Pearson Serial Correlation Coefficients between log returns, based on Pseudo-prices, in 10 second intervals or one minute intervals with the preceding interval. * and ** denote significance at the 0.01 and the 0.05 level. The data sample is from 05/07/06 through 21/09/07.

6.6 The dynamics of the price adjustment

We are more interested in whether the return of an interval represents a continued reaction to the initial news release than if it is correlated with the preceding interval's return. Is there a continued reaction to the initial new release or are the reactions independent?

Since we do not have an independent measure of whether a given announcement is positive or negative for German stocks[1], we base this determination on the sign of an initial interval starting at t = 0 and ending somewhere between (0;10) and (50;60). We want an initial interval that is long enough to capture the initial reaction but short enough not to include most post-adjustments. Looking at *Table VI* again, we can see that there is at least a continued reaction in the same direction during intervals (0;10) and (10;20). They are followed by interval (20;30) with negative but insignificant coefficient. We therefore decide that the return between t = 0 and t = 20 is most appropriate to use to determine if the news announcement was "positive" or "negative" for the DAX Future. We include the initial price adjustment and hopefully leave out most post adjustment intervals.

We continue our analysis by investigating Pearson's correlation coefficient between each interval's return and the (0;20) return. Our results are summarized in *Table VII*, we also report correlation coefficients between each interval's return and intervals (0;10), (0;30), (0;40), (0;50) and (0;60) in *Table A.II* in the appendix. To avoid correlating intervals between for example 0 and +20 with themselves, the reported coefficients for the (0;10), (10;20) are between that interval's return and the difference between the (0;20) return and that interval's return. In the case of (0;20) these will be of equal size by definition. To illustrate initial return window calculations, we present an example for the (0;30) return:

$$R_{\text{initial30}} = R_{(0;10)} + R_{(10;20)} + R_{(20;30)}$$

For intervals included in the initial return (0;10), (10;20) and (20;30) we calculate correlation between that interval's returns and $R_{\text{initial}}\text{-}R_{(0;10)}$, $R_{\text{initial}}\text{-}R_{(10;20)}$, $R_{\text{initial}}\text{-}R_{(20;30)}$ respectively.

Returns in the two first 10-second intervals between 0 and +20 are positively and strongly correlated with the other 10 seconds in the (0;20) interval. The (20;30) return is strongly negatively correlated with the (0;20) return. Between t = 30 and t = 70 coefficients are insignificant and rather small. Quite surprisingly intervals between t = 70 and t = 110 have significant coefficients. The first interval is negatively correlated, whilst the following three intervals are positively correlated. This is followed by approximately four minutes with insignificant and small coefficients

[1] We have forecasts for the key figures from Bloomberg for upcoming events. But there are many issues with using them to determine whether the announcement is positive or negative. The implication of a higher or lower number than expected for the German equity market may not be clear or can be conditional upon other factors. Further, the surveys are performed several days ahead of the news release, and may not incorporate all information available to the market.

Table VII
Market Efficiency and the Speed of Adjustment:
Evidence from Correlation Coefficients with $R_{(0;20)}$ on Announcement Days

Correlations with $R_{(0;20)}$	
Return Interval (s)	Announcement days
(-120;-60)	0.110
(-60;-50)	0.040
(-50;-40)	0.030
(-40;-30)	-0.056
(-30;-20)	-0.037
(-20;-10)	0.088
(-10;0)	0.109
(0;10)	0.318**
(10;20)	0.318**
(20;30)	-0.398**
(30;40)	0.130
(40;50)	-0.190
(50;60)	-0.018
(60;70)	0.034
(70;80)	-0.398**
(80;90)	0.345**
(90;100)	0.437**
(100;110)	0.320*
(110;120)	-0.073
(120;180)	0.040
(180;240)	-0.081
(240;300)	0.070
(300;360)	-0.071
(360;420)	-0.287*
(420;480)	-0.476**
(480;540)	0.204
(540;600)	0.232

All correlations are based on pseudo-equilibrium prices. For all intervals outside the (0;20) determination window, correlations are reported between that interval and the (0;20) return. For Intervals within the (0;20) window, correlations are reported between that interval's returns and the (0;20) return less the interval's return. * and ** denote significance at the 0.01 and 0.05. The data sample is from 05/07/06 through 21/09/07.

Even more surprising is that intervals (360;420) and (420;480) are negatively correlated to the initial price adjustment.[2] The implication of our results in *Table VII* is that the initial price adjustment starts within the first 10 seconds subsequent to the news release and the major price adjustment is done within the first 20

[2] One must consider these results with the fact that we chose to focus on this period after observing the results.

seconds. But we also find that there are further periods with negative and positive later in the event window. These intervals could represent continuations or corrections of the initial news release, and as we investigate returns later on we will be able to say more about their importance.

6.7 Leakage

As we can see in *Table A.2* and Figure 1 there are evidence of higher than normal volatility in the DAX Future ahead of news releases. We also found evidence of serial correlation in the (-50;-40) interval prior to the news announcement in *Table VI*. With the help of *Table VII,* we can continue to investigate this further. Here we find that the correlation coefficients for intervals before the news announcement are small and insignificant, implying that instead of leakage, the higher than normal volatility and serial correlations seem to represent uninformed trading generated by uncertainty ahead of the news announcement. Worth noting is that we have only looked at returns from two minutes ahead of the announcement. The leakage could of course have occurred before this time and may not have occurred for all announcements. With our tests we cannot reject the possibility of that leakage occasionally occurred, but if it did our results suggest that it was not enough to affect prices. We also believe that the probability of leakage is low since the procedures for releasing the news are so strict and controlled. The results are expected and we will not investigate this matter further.

6.8 Price adjustment

So far we have focused on analyzing the length of the price adjustments but it is also very essential to investigate the magnitude of price adjustments. By this we mean how much of the adjustment from the old equilibrium price to the new equilibrium price that occurs within the first 10 seconds, the first 20 seconds, the first 30 seconds etc. As earlier explained we do not have an independent measure of whether a certain news release has positive or negative implications for the DAX Future. We therefore base this determination on the sign of the (0;20) price change. This ex post adjustment creates a couple of problems that we correct for, we explain these corrections below. We define the adjusted returns AR_t in the same way as Ederington and Lee (1995), for each 10-second interval as

$$AR_t = R_t * D_t$$

Where R_t represents returns calculated using pseudo-equilibrium prices. $R_{(0;20)}$ is the return during the first 20 seconds (0;20) after t = 0. For intervals t < 0 and t > 20, we define

$$D_t = 1 \text{ if } R_{(0,20)} > 0$$

$$D_t = -1 \text{ if } R_{(0,20)} < 0$$

$$D_t = 0 \text{ if } R_{(0,20)} = 0$$

As previously mentioned the use of a dummy, to determine if an announcement is negative or positive, creates some problems for intervals within the (0;20) window. Spurious correlation could appear since the (0;20) return is based on these intervals. To avoid this spurious correlation between D_t and R_t, for intervals within the (0;20) window, we define

$$D_t = 1 \text{ if } (R_{(0,20)} - R_t) > 0$$

$$D_t = -1 \text{ if } (R_{(0,20)} - R_t) < 0$$

$$D_t = 0 \text{ if } (R_{(0,20)} - R_t) = 0$$

We calculate AAR_t, the Average Adjusted Returns, for each 10 second interval for announcement- and non-announcement days. We expect the $AAR_t = 0$ on non-announcement days, we test the null hypothesis AAR_t for all 10-second intervals between -120 and +600. We can not reject the null hypothesis for any of the intervals on the 0.01 level. One should take into account that we have a very limited sample of non-announcement days, and the strength of the findings can be questioned but they make economic sense and are in-line with what we expected. The following should be true for AAR_t if there is no information leakage:

$$AAR_t = 0 \text{ for } t < 0$$

$$AAR_t > 0 \text{ for } t > 0 \text{ during the adjustment}$$

$$AAR_t = 0 \text{ when the adjustment is ended}$$

The cumulative average adjusted return, CAR is calculated from -120 to +600 on announcement days

$$CAR_t = \sum_{-120}^{t} AAR_t$$

We have plotted the results for all 10-second announcement day intervals between -120 and +600 in *Figure 2*. We have also summarized the individual AARs and CARs during announcement days in *Table VIII* together with a ratio of CAR_t divided by CAR_{600} to show how much of the total adjustment is done in every single interval.

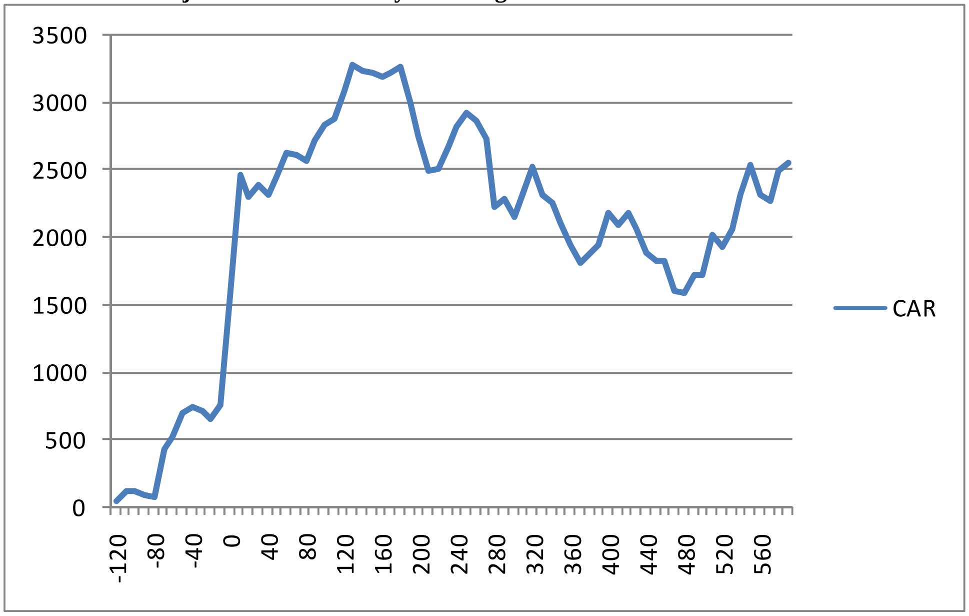
Table VIII
Speed and duration of the Price Adjustment following the News Release

AAR and CAR			
Return Interval (s)	AAR	CAR	Ratio
(-120;-60)	428	428	17%
(-60;-50)	90	518	20%
(-50;-40)	184	702	28%
(-40;-30)	39	741	29%
(-30;-20)	-28	713	28%
(-20;-10)	-57	656	26%
(-10;0)	101	757	30%
(0;10)	846**	1603	63%
(10;20)	853**	2455	97%
(20;30)	-164	2291	90%
(30;40)	93	2384	94%
(40;50)	-81	2303	91%
(50;60)	132	2435	96%
(60;70)	186	2621	103%
(70;80)	-15	2607	103%
(80;90)	-50	2557	101%
(90;100)	144	2701	106%
(100;110)	118	2819	111%
(110;120)	54	2873	113%
(120;180)	343	3215	127%
(180;240)	-558	2658	105%
(240;300)	-373	2285	90%
(300;360)	-180	2105	83%
(360;420)	-25	2080	82%
(420;480)	-473	1606	63%
(480;540)	450	2056	81%
(540;600)	485	2541	100%

The AARs and CARs are reported in the table together with the CAR to that time divided by the (-120;600) CAR, in percent. CAR equals the sum of the AAR from two minutes before the news release to the interval time. $AR_t = R_t{*}D_t$, where R_t is the returns calculated using pseudo equilibrium prices. D_t is a dummy variable with the signs -1,+0,-1. For intervals outside the (0;20) window it depends on the sign of the (0;20) window. For intervals within the (0;20) window it depends on the sign of the other 10 seconds in the window. The reported returns are 10^7 time the actual return. * and ** denote significance at the 0.05 and 0.0001 level. The data sample is from 05/07/06 through 21/09/07.

We have tested each interval on announcement days for the null hypothesis that $AAR_t > 0$. The results are summarized in Table VII and *Figure 2*, all calculations are based on 10-second intervals but we have reported them as minute intervals before t = -60 and after t = 120 to make them more presentable. At t < 0 the 10-second intervals have small and insignificant AARs. We can not reject the null hypothesis that $AAR_t > 0$ for intervals (0;10) and (10;20) at the 0.0001 level. Furthermore, we can not reject the null hypothesis for intervals (-70;-60) and (280;290) on the 0.05 level. During the remaining 10-second intervals, the AARs are small and insignificant.

Figure 2
The Price Adjustment immediately following the Release of Macroeconomic Statistics



The cumulative average adjusted returns, CAR equals the sum of the average adjusted returns from two minutes before the news release to the interval time. $AR_t = R_t*D_t$, where R_t is the returns calculated using pseudo equilibrium prices. D_t is a dummy variable with the signs -1,+0,-1. For intervals outside the (0;20) window it depends on the sign of the (0;20) window. For intervals within the (0;20) window it depends on the sign of the other 10 seconds in the window. The reported returns are 10^7 time the actual return. The data sample is from 05/07/06 through 21/09/07.

Analyzing results in *Table VIII and Figure 2* we can see that the AAR between t = 0 and t = 10 is large, positive and significant at the 0.0001 level and that it remains large and significant until t = 20. The (20;30) AAR is negative but much smaller than the two preceding intervals and insignificant. The implication is that the adjustment is basically complete after 20 seconds. Even though interval (20;30) is significantly correlated with the initial news release, the returns are insignificant which contradicts the idea of an overreaction followed by a correction. The same goes for all intervals at t > 70 that had significant correlation with the news release, see *Table VII*. Since intervals (-70;60) and (280;290) are uncorrelated with the initial news release, the significant returns are probably due to new information or readjustment of portfolio. The absence of significance at t < 0 provides us with some further evidence that there is no information leakage during the two minutes prior to a news announcement. In conclusion, we can not find any strong evidence of drift; instead our results suggest a quick price adjustment to the new equilibrium price. We do not find any strong evidence of an overreaction, and if one exists it is probably because either new information about the news has become available or people are readjusting their portfolios to the overall market view.

The most important conclusion we can draw from this is that the correlation is strong and positive in the first 20 seconds of post news trading, and that the price adjustment is basically complete within 20 seconds. Since volatility remains significantly higher than normal for as long as 190 seconds and remain high during most intervals until t = 600 after a news release. It appears that the price continues to fluctuate as those with different market opinion adjust their portfolios in combination with further details from the news announcement becoming available. Our data suggest that the these continued price adjustments mainly are independent of the initial price change. Earlier studies on the equity markets have found that the average time to the first trade subsequent to an earnings or dividend report is 14 minutes (Woodruff and Senchack (1988) and Brown, et al. (1992)). They have also found evidence that the prices appear to continue to drift up or down for several hours. According to our results the markets react within 1 second. Our tick-by-tick data is only rounded to the nearest second. On announcement days 39% have response times rounded to 14:30:00, i.e. between 0 and 1 second. 43 out of 62 observations have reaction times rounded to between 14:30:00 and 14:30:01, i.e. reacts in less than 1.5 seconds, see *Figure A.14* in the appendix. The results are also interesting because we can see that we have a couple of outliers in our sample, perhaps our evidence would have been stronger if we had removed “non event” announcements days, where investor discard the news release. According to evidence put forward the basic adjustment appears to finish within the first 20 seconds and we have not been able to spot any drift during the subsequent 10 minutes. The rationale behind this is that the dynamics of the financial markets have changed drastically. The access to information is today instantaneous and the modern trading systems, elementized news release data and capacity of computers makes it possible to analyze and react to news releases within milliseconds. The announcements are also widely anticipated. Market participants know down to the second when the information will be released and are prepared to accept and analyze it. This can also explain why response times after news releases in single stocks are much longer. Another possible explanation of the increase in the higher speed of price adjustment is the higher trading frequency in the post announcement period, which is in line with Dufour and Engle (2000).

Table IX
Summary of Empirical Findings

Summary of Empirical Findings		
Hypotheses	Test-result	Findings
H1: The short-term volatility is higher on announcements days than on non-announcement days.	Not Rejected	We find evidence of a significantly higher volatility on announcement days than on non-announcement days subsequent the macroeconomic announcement.
H2: Volatility primarily increases post-announcement through an increased number of executions, rather than larger price movements or larger size of the executions.	Not Rejected	We conclude that the increase in volatility is due to a higher trading frequency rather than larger price changes, in the post announcement period.
H3: There is no leakage of information prior to macroeconomic announcements.	Data supportive but fails to statiscally validate	We cannot reject the possibility of that leakage occasionally occurred, but if it did our results suggest that it was not enough to affect prices.
H4: There exists a significant continued reaction over succeeding interval post macroeconomic announcements.	Not Rejected	We find evidence of a continued reaction and that the major price adjustment is done within the first 20 seconds.
H5: Average Adjusted Returns are significantly different from zero during the major price adjustment shortly after the news release on announcement days.	Not Rejected	We conlcude that the AARs are statistically different from zero in the first 20 seconds subsequent a macroeconomic announcement.

6.9 Preferred Algorithmic Strategy

The birth of elementized data from the major news agencies has enabled investors to analyze and react to information within milliseconds. This development will have important implication on the choice of news release trading strategy. If the basic adjustment is done within the first 20 seconds there is little time to come up with a reliable trade signal based on market data. In theory, such a strategy would have the advantage of making more reliable decisions, in the sense that it provides a buy or signal once the trend is formed, instead of basing it on in-house or market consensus estimations. This strategy will however only be profitable if there is a continued reaction in the same direction. The cost of this strategy is the potential loss of initial price adjustments. The problem with a trading strategy based on the Expectation Error is the risk of the algorithm misunderstanding the news figures or not taking all information into account. The implication of a higher or lower number may be unclear or may be conditional on other factors. A way of reducing this risk can be to look at the distribution of the survey and build trading rules based on the skewness. Strictly looking at the latest macroeconomic statistic may be risky as revisions of prior data can have significant effects on the reception and interpretation of the news release. The surveys are also conducted several days in advance of the announcement and hence might not incorporate all information available to the market at the time of the announcement. Our results suggest that the time to the first execution, initial volatility patterns and noise before the event are other factors that can provide valuable information when constructing an algorithm.

The overall impression of the efficiency of the market in incorporating new information that is released is impressive. Following the announcement, traders with low latency form an opinion about the release's implication for market prices almost immediately and the actual price seems to adjust to this level within 20 seconds. The window for excessive return is obviously short unless further components of the data are released that changes the markets opinion. This causes us to believe that an algorithm based on the estimation of the macroeconomic news would possibly outperform a strategy based on the momentum of market data.

7. CONCLUDING REMARKS

7.1 Conclusion

The primary purpose of this paper is to explore the short term effects of macroeconomic announcements on stock markets and analyze the speed of adjustment following macroeconomic news releases. We also wanted to examine different algorithmic trading strategies in connection with macroeconomic announcements. Below we outline our most important findings.

First, when investigating volatility patterns we find evidence of volatility peaking within the first 30 seconds but continued high volatility suggest that the market continues to adjust for at least 600 seconds. This is quicker compared to earlier results on the stock markets but it is in line with our expectations of shorter response time. Ederington and Lee (1995) find similar volatility patterns when analyzing exchange and interest rates. This gives us some support for the theory that the increased computer trading enables investors to more rapidly evaluate larger amounts of information and take action.

Second, we investigate whether the high volatility on announcement days reflects more price changes or larger price changes. The distinction is important since a quick move to a new equilibrium on only a few trades would imply a more efficient market than if many trades are done at intermediate levels. Our results suggest that the increased volatility following macroeconomic announcements is due primarily to more frequent price changes, rather than larger price changes or larger volume/tick. This is in line with what we expect and the results of Brown, et al. (1992) concerning the equity market response to earnings announcements and Ederington and Lee (1995) regarding the interest rate markets response to macroeconomic announcements.

Third, with our tests we cannot reject the possibility of that leakage occasionally occurred, but if it did our results suggest that it was not enough to affect prices. We also believe that the probability of leakage is low since the procedures for releasing the news are so strict and controlled.

Fourth, we investigate whether there is a continued reaction to the initial new release or if the reactions are independent. We find significant evidence of that the initial price adjustment starts within the first 10 seconds subsequent to the news release and the major price adjustment is done within the first

20 seconds. But we also find weak evidence that there are further periods with negative and positive reactions with the initial news release.

Fifth, we find evidence that the price adjustment subsequent to a macro economic announcement is basically complete after 20 seconds. We can not find significant evidence of any drift; late intervals with significant correlation coefficients do not have significant AARs. Instead our results suggest a quick price adjustment to the new equilibrium price. We do not find any strong evidence of an overreaction, and if one exists it is probably because either new information about the news has become available or people are readjusting their portfolios to the overall market view. Schleifer (2000) argue that financial markets should not be presumed to be efficient since there is an enormous amount of statistical evidence of under- and overreaction in financial markets. Anomalies are one of the most common challenges to the Efficient Market Hypothesis. The supporters of the Efficient Market Hypothesis argue that these anomalies cannot be exploited because of factors such as risk and transaction cost (Lo (2007)). Our results suggest that macroeconomic announcement create short-term anomalies in the returns of the DAX Index future. This is partially contradictory, to the view of Malkiel (2005) who argues that stock market price movements approximate those of a random walk. Even though we are able to describe the individual anomaly well we cannot offer a more general paradigm since we only look in the very short term. The explanation for the continued price reactions can be that there are high costs involved with complex algorithmic and information systems in combination with transaction costs. As in so many other areas of finance, some questions cannot be answered by an unqualified “yes” or “no”. Rather, we believe that our findings can contribute to the research in efficient markets by explaining how efficient they are in the short run.

With the major price adjustment done as quickly as within 20 seconds, it is questionable if there is enough data to create a reliable momentum strategy based on the market reaction, and still earn excess return. Perhaps the solution is to build an algorithm that takes both the Expectation Error and some initial market data into account to give more strength to the buy or sell signal. Answering our questions and other anomalies indeed sharpens the understanding of price adjustments to macroeconomic releases. This is an interesting area of extensive future research potential.

7.2 Critical Evaluation

Investigating tick-by-tick data during extremely short periods is inherently hard. In order to avoid distortions by market noise, it is vital to conduct test on a large data sample. We recognize that our result to some extent may be influenced by sample specific noise. We follow the framework of Ederington and Lee (1995) to be able to properly compare and evaluate our findings. Furthermore, we analyze the price adjustment dynamics from many different angles in our analysis, to ensure the robustness of our results. We also use different significance levels to ensure that the findings are consistent, but the conclusions are not stronger than our data. We have over 5 million data points in our sample and handling, sorting and analyzing this kind of high frequency data is very time consuming.

7.3 Further Research

It would be very interesting to see research done on larger data samples comparing price adjustments to macroeconomic releases between the DAX Future, S&P Future and the Eurostoxx Future and investigate the reasons for deviations in results, if any. The institutional settings are to some extent different and the financial markets are regulated differently. A study comparing short term effects between open-outcry exchanges and electronic exchanges could contribute with valuable insight on the dynamics of price adjustments and computer driven trading. We have not been able to find any recent research on the tick-by-tick price adjustments to asset specific news, such as profit warnings, earnings announcements etc. It could also be of interest to estimate the potential gains of trading strategies based on news-feeds; this would provide a stronger link between previous research on macroeconomics and applied finance. Since events studies are not appropriate, simulations would be an interesting approach to the investigation.

8. REFERENCES

8.1 Academic References

Berry, and Keith M. Howe, 1994, Public Information Arrival, *Journal of Finance* 49, 1331-1346.

Black, Fischer, 1986, Noise, *Journal of Finance 41*, 529-543.

Brown, Glinch, and G. Foster, 1992, Market Microstructure and Capital Market Information Content Research, American Accounting Association.

Cenesizoglu, Tolga, 2006, Asymmetries in the Reaction of Stock Prices to Macroeconomic News, Working paper, HEC Montreal.

Chan, Wesley S, 2001, Stock Price Reaction to News and No-news: Drift and Reversal After Headlines, Working paper, M.I.T.

Chen, Roll, and Stephen A. Ross, 1986, Economic Forces and the Stock Market, *Journal of Business* 59, 383-403.

Cutler, Poterba, and L.H. Summers, 1988, What Moves Stock Prices?, Working paper, National Bureau of Economic Research.

Dufour, A., and R.F. Engle, 2000, Time and the Price Impact of a Trade, *The Journal of Finance 55*, 2467-2498.

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

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

Fama, E. F., and G. W. Schwert, 1977, Asset Returns and Inflation, *Journal of Financial Economics* 5, 115-146.

Fama, E. F., 1991, Efficient Capital Markets: II, *Journal of Finance* 46, 1575-1617.

Flannery, Mark J. and Aris A. Protopapadakis, 2002, Macroeconomic Factors Do Influence Aggregate Stock Returns, *The Review of Financial Studies 15*, 751-782.

French, K. and Richard Roll, 1986, Stock Return Variances: The Arrival of Information and the Reaction of Traders, *Journal of Financial Economics* 17, 5-26.

Graham, M., Nikkinen J., and P. Salstrom, 2003, Relative Importance of Scheduled Macroeconomic News for Stock Market Investors, *Journal of Economics and Finance* 27, 153-165.

Grossman, Sanford J., and E. Stiglitz, 1980, On the Impossibility of Informationally Efficient Markets, *American Economic Review 70*, 393-408.

Hong, Harrison, and Stein Jeremy C, 1999, A unified theory of Underreaction, Momentum Trading, and Overreaction in Asset Markets, *Journal of Finance* 54, 2143-2184.

Jain, Prem C., 1988, Response of Hourly Stock Prices and Trading Volume to Economic News, *Journal of Business* 61, 219-231.

Jennings, Robert, and Laura Starks, 1985, Information Content and the Speed of Stock Price Adjustment, *Journal of Accounting Research* 23, 336-350.

Li, Li, and Zuliu F. Hu, 1998, Responses of the Macroeconomic Announcements across Economic States, Working paper, IMF.

Lo, A., 2007, Efficient Markets Hypothesis, to appear in *The New Palgrave: A Dictionary of Economics*, 2nd edition.

Malkiel, Burton G., 2005, Reflections on the Efficient Market Hypothesis: 30 Years Later, *The Financial Review 40*, 1-9.

Miller, George A., 1956, The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information, *The Psychological Review 63*, 81-97.

Mitchell, Mark L., and Harold Mulherin, 1994, The Impact of Public Information on the Stock Market, *Journal of Finance* 49, 923-950.

Niederhoffer, Victor, 1971, The Analysis of World Events and Stock Prices, *Journal of Business* 44, 193-219.

Nofsinger, J.R and B.Prucyk, 2003, Option volume and volatility response to scheduled economic news releases, *Journal of Futures markets* 23, 315-345.

O'Hara, Maureen, 1999, Making Market Microstructure Matter, *Financial Management 28,* 83-90.

Oberlechner, T. and S.Hocking, 2004, Information sources, News, and Rumours in Financial Markets: Insights into the Foreign Exchange Market, *Journal of Economic Psychology* 254, 407-424.

Robertson, Geva, and Rodney Wolff, 2007, The Intraday Effect of Public Information: Empirical Evidence of Market Reaction to Asset Specific News from the US, UK, and Australia, Working paper, Queensland University of Technology.

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

Shleifer, Andrei, 2000, *Inefficient Markets: An in Introduction to Behavioral Finance,* New York: Oxford University Press Inc., 1-27, 112-153.

Schleifer, Andrei, and Lawrence Summers, 1990, The Noise-Trader Approach to Finance, *Journal of Economic Perspectives* 4, 19-33.

Stoll, Hans R., 2005, Electronic Trading in Stock Markets, Working paper, Vanderbilt University.

Woodruff, and A.J. Senchack, 1988, Intraday Price-Volume Adjustments of NYSE Stocks and Unexpected Earnings, *Journal of Finance* 43, 467-491.

8.2 Electronic and Other Sources

Bloomberg Professional®, "Consumer Price Index", 19 Oct. 2007.

Bloomberg Professional®, "Producer Price Index", 19 Oct. 2007.

Bloomberg Professional®, "Initial Jobless Claims", 19 Oct. 2007.

Bloomberg Professional®, "Non Farm Payrolls", 19 Oct. 2007.

Bloomberg Professional®, "Economic Releases", 19 Oct. 2007.

Duffy, Maureen N., Apr, 2007, Trading on the News, Securities Industry News, 27 Oct. 2007 http://www.securitiesindustry.com/.

The Economist, 21 Jun, 2007, Ahead of the tape, The Economist, 27 Oct. 2007 http://www.economist.com/finance/displaystory.cfm?story_id=9370718.

E-mail correspondence with Gary Steinberg, Press Officer, Bureau of Labor Statistics, 5 Dec. 2007.

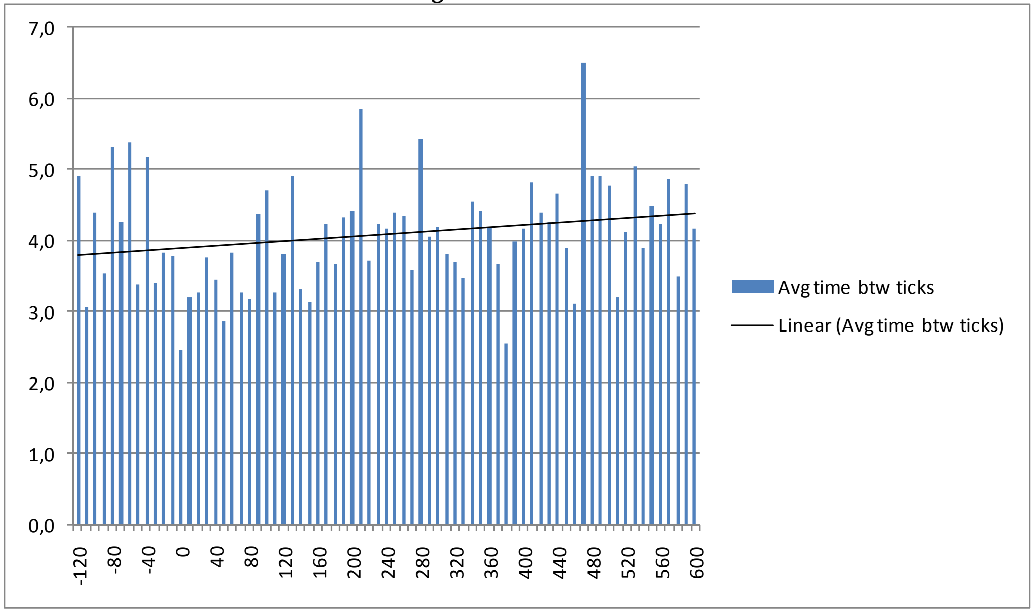
9. APPENDIX

Table A.I
Standard Deviation of Ten Second Intervals

[redacted]

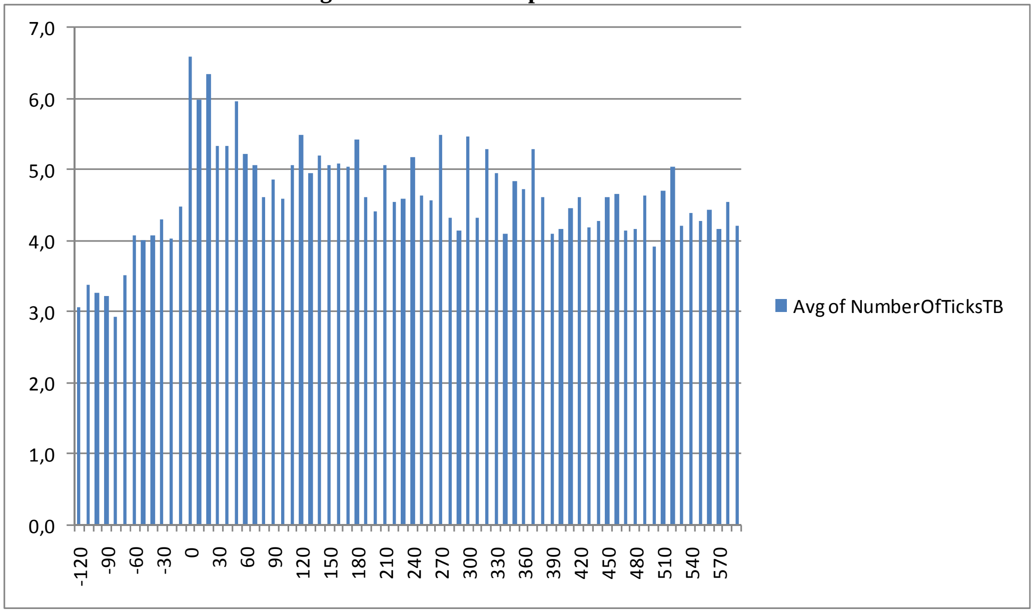
All standard deviations are based on pseudo-equilibrium prices and adjusted for the time between ticks in each ten second interval. * and ** denote significance at the 0.01 and 0.05. The data sample is from 05/07/06 through 21/09/07.

Figure A.1
Average Time between Ticks



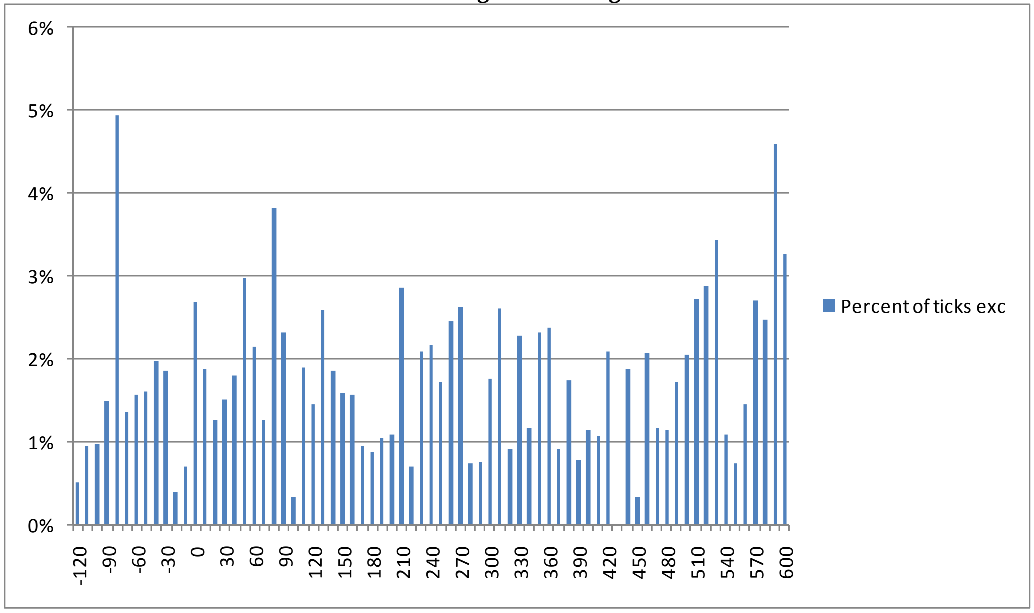
The average time between ticks from 120 seconds prior to 600 seconds after the announcement. The data sample is from 05/07/06 through 21/09/07.

Figure A.2
Average Number of Ticks per Ten Second Interval



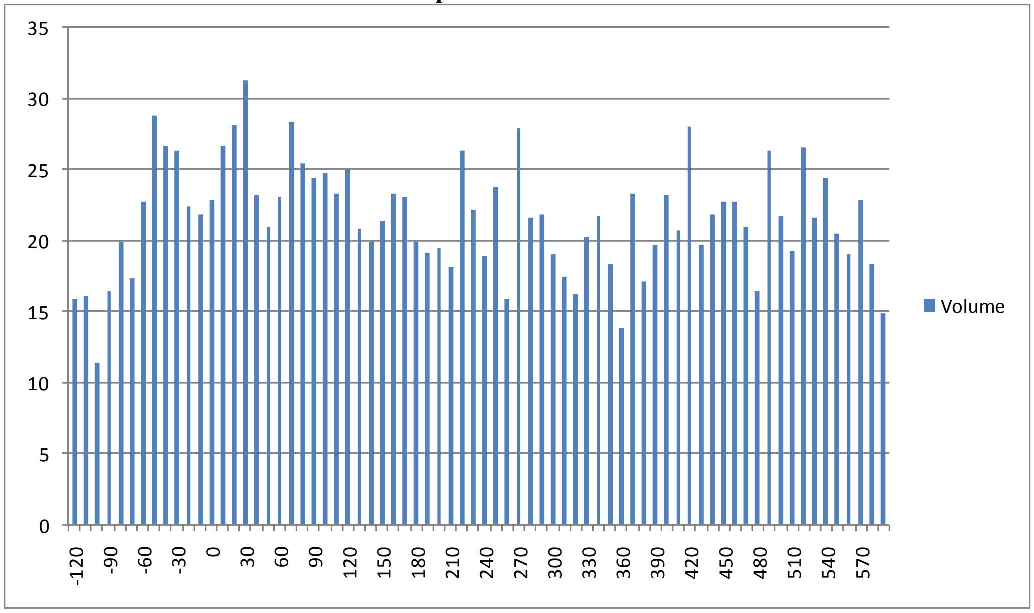
The average number of ticks per ten second interval from 120 seconds prior to 600 seconds subsequent the announcement. The data sample is from 05/07/06 through 21/09/07.

Figure A.3
Percent of Price Changes Exceeding One tick in size



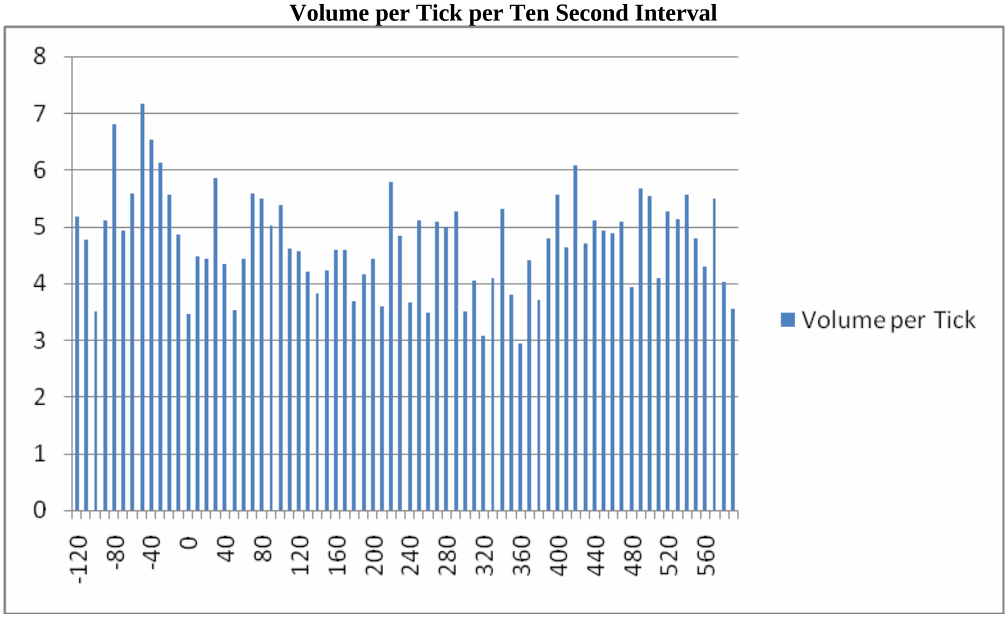
The percent of price changes exceeding one tick in size from 120 seconds prior to 600 seconds subsequent the announcement. The data sample is from 05/07/06 through 21/09/07.

Figure A.4
Volume per Ten Second Interval



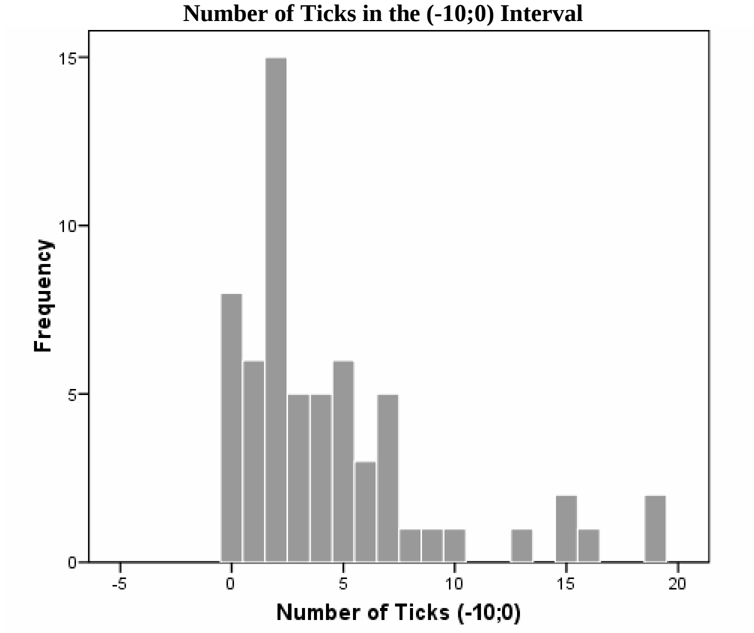
The average volume per ten second interval from 120 seconds prior to 600 seconds subsequent the announcement. The data sample is from 05/07/06 through 21/09/07.

Figure A.5
Volume per Tick per Ten Second Interval



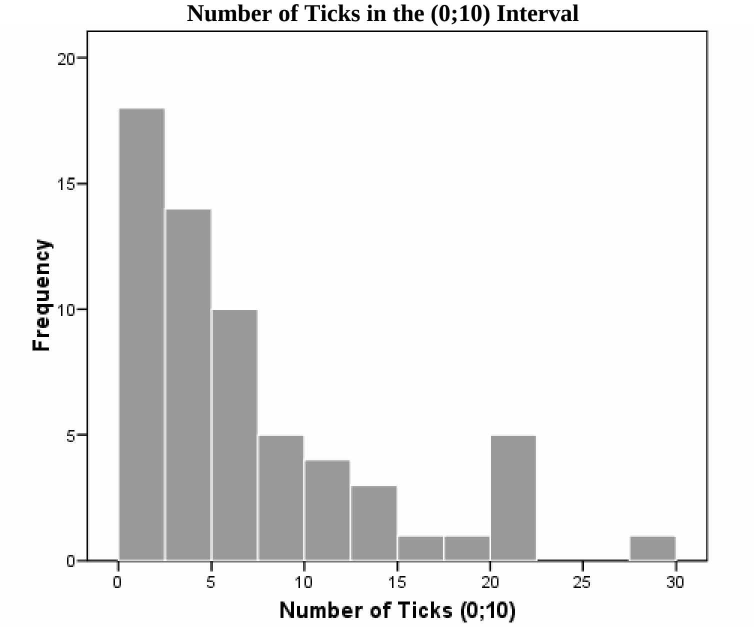
The average volume per tick per ten second interval from 120 seconds prior to 600 seconds subsequent the announcement. The data sample is from 05/07/06 through 21/09/07.

Figure A.6
Number of Ticks in the (-10;0) Interval



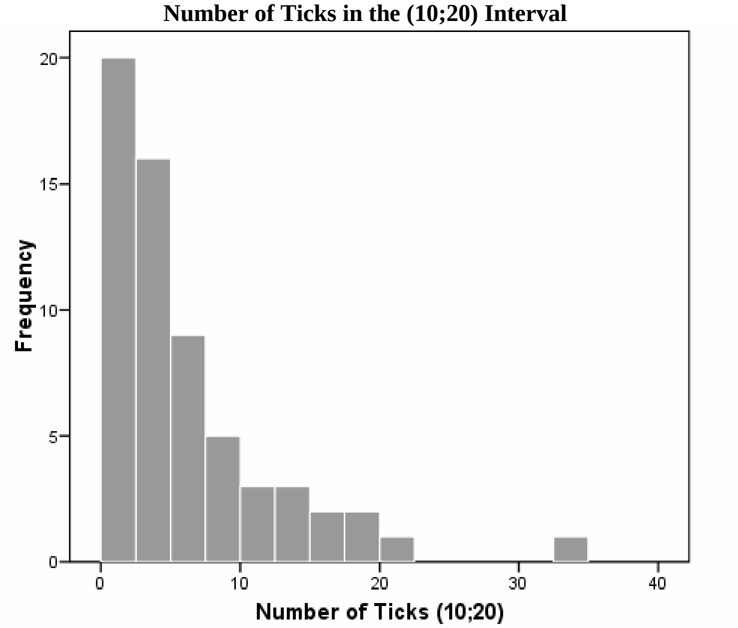
The distribution of the number of ticks in the (-10;0) interval. The data sample is from 05/07/06 through 21/09/07

Figure A.7
Number of Ticks in the (0;10) Interval



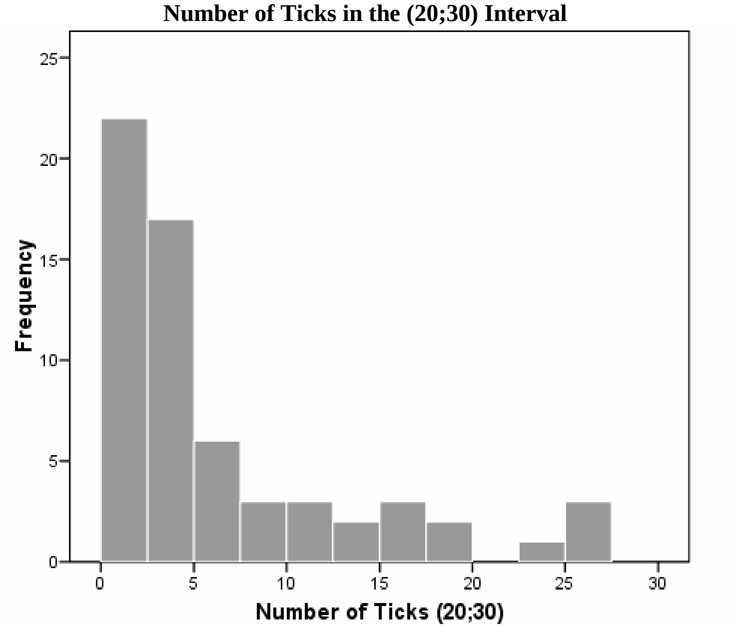
The distribution of the number of ticks in the (0;10) interval. The data sample is from 05/07/06 through 21/09/07

Figure A.8
Number of Ticks in the (10;20) Interval



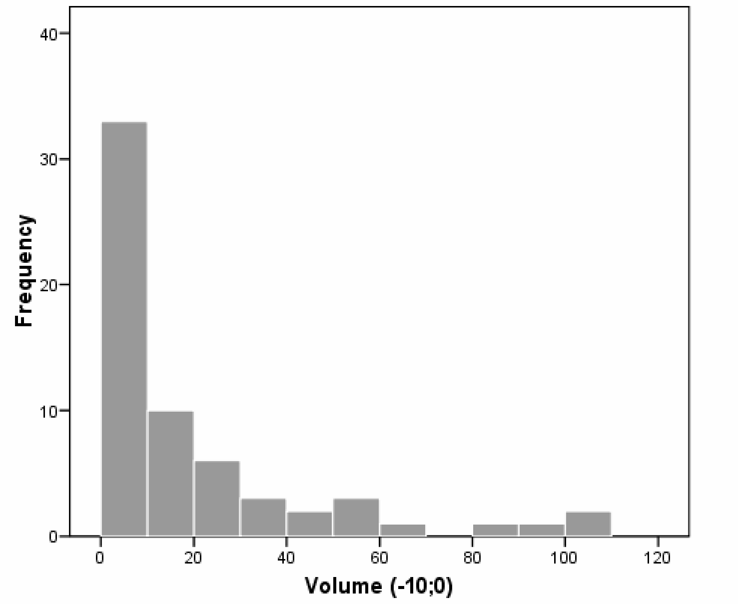
The distribution of the number of ticks in the (10;20) interval. The data sample is from 05/07/06 through 21/09/07

Figure A.9
Number of Ticks in the (20;30) Interval



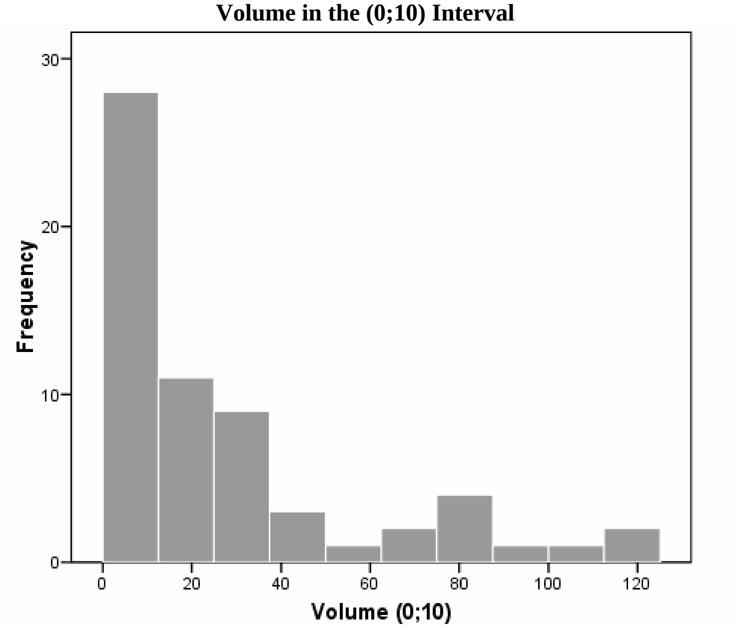
The distribution of the number of ticks in the (20;30) interval. The data sample is from 05/07/06 through 21/09/07

Figure A.10
Volume in the (-10;0) Interval



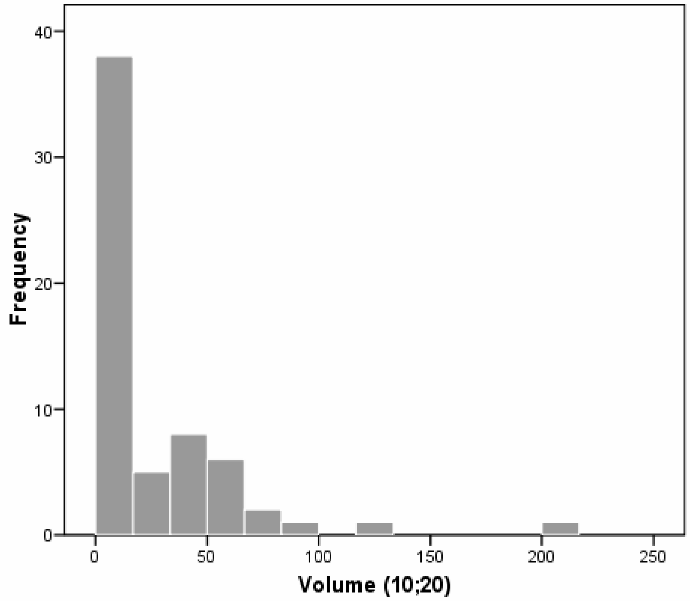
The distribution of the volume in the (-10;0) interval. The data sample is from 05/07/06 through 21/09/07

Figure A.11
Volume in the (0;10) Interval



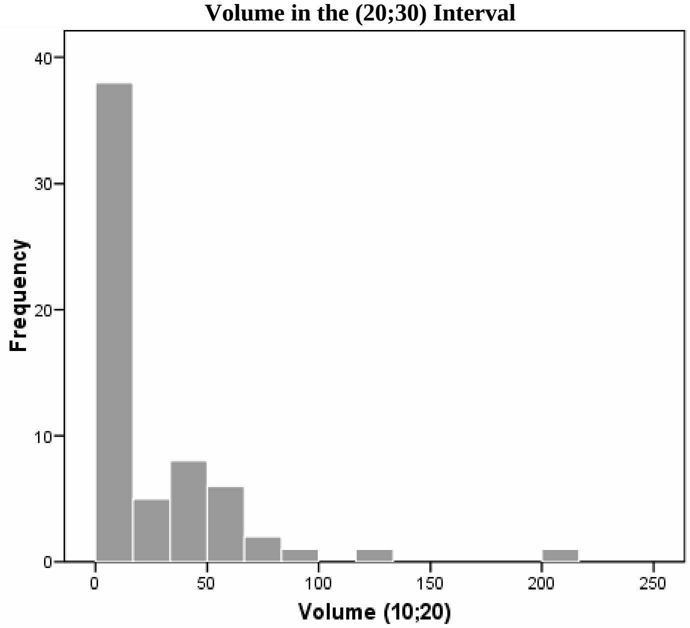
The distribution of the volume in the (0;10) interval. The data sample is from 05/07/06 through 21/09/07

Figure A.12
Volume in the (10;20) Interval



The distribution of the volume in the (10;20) interval. The data sample is from 05/07/06 through 21/09/07

Figure A.13
Volume in the (20;30) Interval



The distribution of the volume in the (20;30) interval. The data sample is from 05/07/06 through 21/09/07

Table A.II

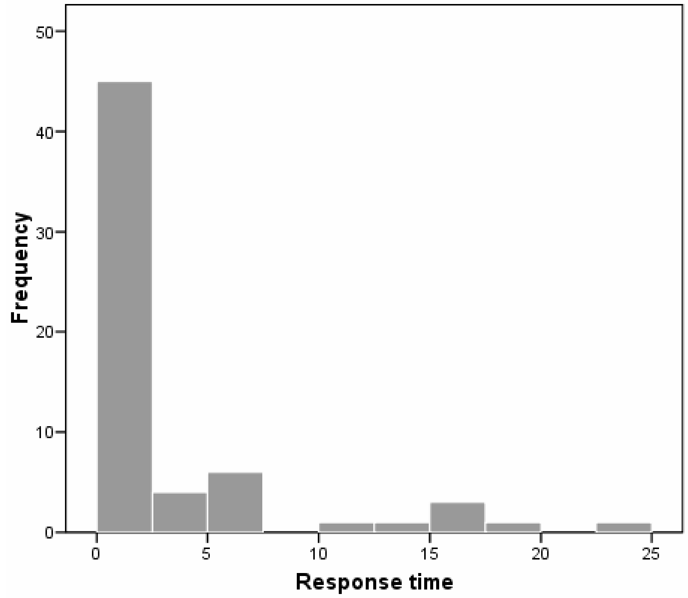
Market Efficiency and the Speed of Adjustment:

Evidence from Correlation Coefficients with Determination Windows on Announcement Days

[redacted]

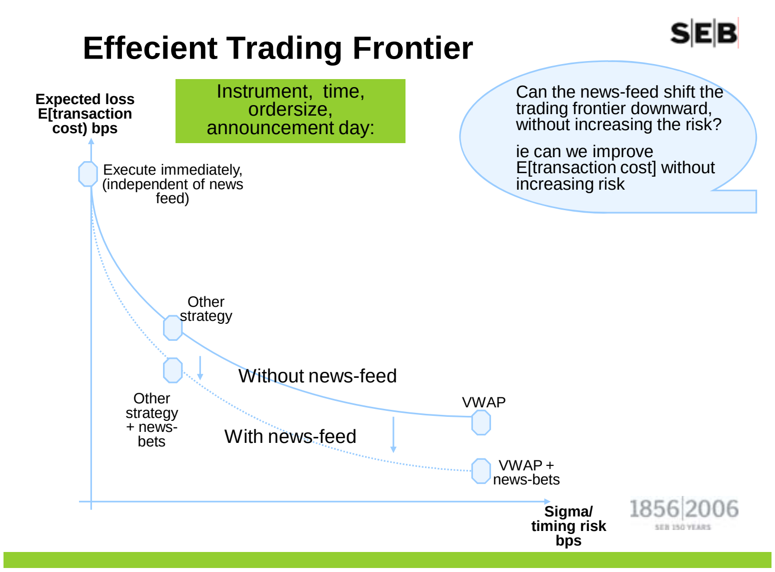
All correlations are based on pseudo-equilibrium prices. For all intervals outside the (0;X) determination window, correlations are reported between that interval and the (0;X) return. For Intervals within the (0;X) window, correlations are reported between that interval's returns and the (0;X) return less the interval's return. * and ** denote significance at the 0.01 and 0.05. The data sample is from 05/07/06 through 21/09/07.

Figure A.14
Time to the First Execution after News Announcements



The distribution of the time until the first tick in the (0;10) interval. The data sample is from 05/07/06 through 21/09/07

Figure A.15
Efficient trading frontier



The figure is provided by SEB to explain key issues concerning algorithmic trading on news feed.