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The High-Frequency Effects of U.S. Macroeconomic Data Releases on Prices and Trading Activity in the Global Interdealer Foreign Exchange Market.

Alain P. Chaboud, Sergey V. Chernenko, Edward Howorka, Raj S. Krishnasami Iyer, David Liu and Jonathan H. Wright*

Abstract: We introduce a new high-frequency foreign exchange dataset from EBS (Electronic Broking Service) that includes trading volume in the global interdealer spot market, data not previously available to researchers. The data also gives live transactable quotes, rather than the indicative quotes that have been used in most previous high frequency foreign exchange analysis. We describe intraday volume and volatility patterns in euro-dollar and dollar-yen trading. We study the effects of scheduled U.S. macroeconomic data releases, first confirming the finding of recent literature that the conditional mean of the exchange rate responds very quickly to the unexpected component of data releases. We next study the effects of data releases on trading volumes. News releases cause volume to rise, and to remain elevated for a longer period. However, in contrast to the result for the level of the exchange rate, even if the data release is entirely in line with expectations, we find that there is still typically a large pickup in trading volume.

Keywords: Trading Volume, Conditional Mean, Conditional Volatility, Foreign Exchange, High Frequency Data, News Announcements.
JEL Classification: F31, G14.

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1. Introduction.

The study of the effects of macroeconomic announcements on financial asset markets at high frequency (daily or intraday) has yielded a number of important papers in recent years. Authors considering the effect of news announcements on asset markets include Cutler, Poterba and Summers (1989) and McQueen and Roley (1993) (for stocks); Ederington and Lee (1993), Fleming and Remolona (1997, 1999) and Balduzzi, Elton and Green (2001) (for bonds); and Edison (1997), Almeida, Goodhart and Payne (1997) and Andersen, Bollerslev, Diebold and Vega (2003) (for exchange rates), among others. Common to all this work is the idea that in a short enough window around the time of a macroeconomic announcement, other information hitting the market should be dominated by the surprise component of the public news release, giving us something of a natural experiment on price discovery in financial markets.

Most of the literature on announcement effects has considered the effects of news releases on the level of asset prices, more specifically on the *conditional mean* of asset returns.¹ The 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 rate returns. The effect of news announcements on the level of prices generally occurs rapidly -- within a few minutes or less. Several papers have also considered the effects of these data releases on volatility, specifically on the *conditional variance* of returns. 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 (see e.g. Jones, Lamont and Lumsdaine

¹ The conditional mean and conditional variance of exchange rate returns refer to the expectation and variance of exchange rate returns given all information up to the time of the announcement, including the announcement itself.

(1998) and Andersen, Bollerslev, Diebold and Vega (2003) which we refer to henceforth as ABDV).

Fewer papers have discussed the high-frequency effects of economic announcements on trading volume in financial markets. The impact of announcements on trading volume is theoretically ambiguous. In theory, if a public data release affects the fundamental value of an asset in a way that everyone agrees on, then the price of that asset should jump to its new level without requiring any trading activity (French and Roll (1986)). On the other hand, if traders disagree about the impact of a given piece of news, then there could be a surge in trading following the news announcement, and it could be that the effects of the data release are capitalized into prices only via this trading. Fleming and Remolona (1999) is one paper that does look at the high-frequency effects of news announcements on the conditional mean and variance of returns and on trading volume, in the Treasury securities market. They find that news releases have a two stage effect on the Treasury market. In the first stage, trading activity is subdued, and prices move very sharply. This movement is effectively a jump. Then volatility and trading volume pick up and remain elevated for several hours.

In the foreign exchange market for major currency pairs, which is over-the-counter, geographically dispersed, and highly competitive, the absence of data on market-wide trading volume has precluded almost all research on the topic. A few researchers have attempted to proxy for actual transaction volume data by using futures exchange volume data (e.g. Chaboud and LeBaron (2001)), or the frequency of indicative quotes on Reuters data screens (e.g. Melvin and Yin (2000)), but these measures have clearly been

poor substitutes. Only a minute fraction of foreign exchange is traded on exchanges, and the frequency of indicative quotes is not necessarily strongly related to trading volume.

In this paper, we introduce a new high-frequency dataset of volume and prices in spot euro-dollar and dollar-yen trading from EBS (Electronic Broking System). Our goal is to describe intraday trading volume and volatility patterns and to study the effect of news announcements on trading volume and prices in exchange rate markets using five years of these high frequency data. As described in section 2, EBS has, in the last few years, become the *de facto* global marketplace for interdealer trading in these two currency pairs. As a result, the data used in this paper represent the vast majority of global spot interdealer trading in the two most-traded currency pairs over the sample period. In addition to the fact that we can observe volume data, another advantage of the dataset used in this study is that the prices consist of live transactable quotes from the EBS system rather than the Reuters indicative quotes assembled by Olsen and Associates, which have been used by many researchers, including ABDV.

Some researchers have recently begun to use data from electronic trading systems to study price discovery in foreign exchange markets. Evans and Lyons (2002) analyzed the relationship between daily net order flow and exchange rate returns using 1996 data from the Reuters bilateral trading platform. Killeen, Lyons and Moore (2001) considered the relationship between daily net order flow and exchange rate returns in French Franc/Deutschemark EBS data from 1998. Love and Payne (2003) studied the high frequency association between net order flow, macroeconomic announcements and exchange rate returns in ten months of Reuters data from 1998 and 1999. None of these papers studied trading volume.

We will first preview our key findings. Firstly, we document the pattern of trading volume throughout the day, and find that there are spikes in trading volume around the time of scheduled macroeconomic data releases and also at some other times of the day, where trading volume tends to be elevated for institutional reasons. Secondly, confirming the findings of recent research, we find that there is a systematic relationship between the surprise component of the news announcement and the level of the exchange rate. The effect of the data surprise on the conditional mean of the exchange rate occurs quickly. Thirdly, we find that macroeconomic announcements are immediately followed by higher trading volume and volatility, and that volume and volatility remain elevated for a period of time. The pattern is not unlike that which Fleming and Remolona (1999) found for the bond market. Fourthly, we relate the extra trading volume following an announcement to the magnitude of the surprise component of the data release and find that there is a relationship, but that it is quite weak. In sharp contrast with the reaction of the level of the exchange rate, most of the extra trading volume occurs even if the data release is right in line with expectations. We also do some additional analysis on the determinants of trading volume in the wake of news announcements.

The plan for the remainder of this paper is as follows. In section 2, we briefly describe the EBS system and introduce the data. In section 3, we describe the intraday patterns in volume and volatility. Section 4 contains analysis of the high-frequency effects of data releases on the conditional mean and conditional variance of exchange rate returns, and on exchange rate trading volume. Section 5 concludes.

2. The EBS System and Data

2.1 Recent Developments in the Interdealer Spot Foreign Exchange Market

Trading technology in the interdealer spot foreign exchange market has undergone a radical change since the early 1990s, when electronic broking systems were introduced (Chaboud and Weinberg (2002)). Prior to their introduction, a dealer could either contact another dealer bilaterally to request a quote, either by telephone or using a “direct dealing” electronic system (e.g. Reuters Dealing 2000-1), or could trade through the intermediation of a number of “voice brokers.” Voice brokers, linked by dedicated telephone lines to a large number of dealers in their regional markets, would collect bid and ask limit orders from the various dealers, announce the best prices by intercom to their community of clients, and arrange the feasible matches between dealers. Electronic broking systems were introduced beginning in 1992 to perform the same matching function at a reduced cost, and voice brokers, with a few exceptions, have since been supplanted. Additionally, for the major currency pairs, the share of interdealer dealing conducted through brokered transactions has, since that time, risen sharply relative to that conducted through direct dealing, with a substantial majority of trading now brokered through electronic systems.

Today, two electronic broking systems are used globally for interdealer spot trading, one offered by EBS, and one offered by Reuters. Most importantly, over time, trading in each major currency pair has become very highly concentrated on only one of the two systems. Of the most-traded currency pairs, the top two, euro-dollar and dollar-yen are, across the globe, traded primarily on EBS, while the third, sterling-dollar is

traded primarily on Reuters.² The process of price discovery for each of these currency pairs now occurs within the computers of the respective electronic brokers -- the modern Walrasian auctioneers. As a result, the reference price at any moment for, say, spot interdealer euro-dollar is the current price on the EBS screen, and all dealers base the prices they quote to their customers on the EBS price.

The interdealer foreign exchange market for each major currency pairs has therefore acquired some of the characteristics of an exchange: a large share of matches between buyers and sellers is conducted through one common facility, and price discovery occurs in that facility. As is the case for traditional exchange-traded assets, such as stocks, reliable high-frequency data representing a very large share of the overall spot market in the most-traded currency pairs now exists.

2.2 The Structure of the EBS System and the Data

The EBS system operates 24 hours a day and is used by dealers in all major financial trading centers. The system allows trading only in multiples of 1 million of the base currency, up to 999 million per single order. In practice, the vast majority of orders are for small amounts, below 10 million. Transactions between dealers are completed very quickly, usually under 1 second.

EBS dealers can only transact on prices submitted by counterparties with whom they have established credit lines. These credit lines are drawn down as dealing is conducted during the day, and are refreshed at 5:00 p.m. New York time, when the value date changes. Therefore not every dealer on the system sees the exact same dealable price at a given moment, or, even if two dealers see the same price, different underlying amounts may be available at that price.

² Many more currency pairs are traded actively on each of the systems.

For each currency pair selected, the EBS system shows four types of prices, updated each second. Dealers see the best overall price in the market (“EBS Best”). They also see the best credit-screened price that they can trade on (“Best Dealable”), as well as a credit-screened price for a “regular” amount of pre-determined size (e.g., 15 million euros for euro-dollar quotes). If the amount available at the Best Dealable price is less than the regular amount, then the available amount is also shown. The last actual dealt prices in the market are also displayed.

The price data provided by EBS for this paper consist, second-by-second, of the highest bid quotes and lowest ask quotes in the EBS system (the “EBS Best” prices) from January 1999 to January 2004 for the dollar-yen and euro-dollar currency pairs. The trading volume data consist of total trading volume per minute for each currency pair, denominated in the base currency. The data present only an aggregate and purely numerical picture of the EBS system, and do not contain any information on the identity or characteristics of any market participants. To preserve data confidentiality, we show trading volume data in index form rather than as actual amounts of base currency. The euro-dollar volume index is normalized such that the average amount traded per minute in that currency pair over the whole sample is set at 100. Likewise, the dollar-yen volume index sets the average per-minute trading volume in dollar-yen to 100.

We exclude all price and volume data collected from Friday 21:00 GMT through Sunday 21:00 GMT from our sample, as activity on the system during these “non-standard” hours is minimal and not encouraged by the foreign exchange community. We also drop certain holidays and days of unusually light volume: December 24-December 26, December 31-January 2, Good Friday, Easter Monday, Memorial Day, Labor Day,

Thanksgiving and the following day, and July 4 (or, if this is on a weekend, the day on which the Independence Day holiday is observed). Similar conventions were adopted by ABDV. Using the midpoint of the best bid and the best ask price at the start of each minute, we then construct a minute-by-minute price series and calculate continuously-compounded one-minute returns. That is, we compute our returns as 10,000 times the one-minute change in the log exchange rate. This means that our returns have the interpretation of (approximately) the percentage change in the exchange rate multiplied by 100, and so the units can be thought of as basis points of exchange rate movements.

3. Intraday Trading Volume and Volatility Profile

Before turning to the effects of news announcements, we first report some general results about intraday volume and price volatility patterns.

3.1 Intraday Volume Pattern

Figure 1 plots trading volume in each minute of the day averaged across all days in our sample in the euro-dollar and dollar-yen currency pairs. Note that all times in this paper are in New York time, except where otherwise stated. Figure 1 is broken into days when New York is on daylight savings (summer) time (Figure 1a) and days when it is on standard (winter) time (Figure 1b), because Tokyo, a major foreign exchange trading center, does not observe daylight savings time.³ Trading in euro-dollar and dollar-yen is particularly high between about 8am and noon New York time, as these are business

³ A display in New York time of global trading volume per minute averaged over the whole year would therefore show, for instance, two peaks at the time of a given data announcement in Japan, where only one truly exists in Tokyo time.

hours in both Europe and North America. There is relatively high trading volume in dollar-yen during the night in New York, clearly due to trading activity in Asian markets.

We see that average one-minute volume spikes at or just after 8:30am, 10am and 11am. The 8:30am spike is caused by news announcements, our main focus in this paper, as most important U.S. macroeconomic data releases come out at 8:30am.

The 10am spike is likely related to the convention that 10am New York time is the expiration time for many foreign currency options (not just those traded in New York). Participants in currency options markets delta-hedge these positions in the spot market, and need to unwind these hedges after the options have expired⁴. Note that some macroeconomic announcements do come out at 10am: consumer confidence, factory orders, the ISM index⁵, and new and existing home sales. However, we computed the average daily one-minute volume dropping days of any of these releases and found that this lowers the trading volume around 10am by only about a tenth -- there is still a substantial spike in trading volume at this time.

The 11am spike is likely related to the WM/Reuters spot foreign exchange fixing, which is at 4pm London time. The WM/Reuters spot fixing is used for expressing international indices in dollars. A fund that is trying to track such an index will want to do currency trading at a rate that is as close as possible to the WM/Reuters spot foreign exchange fixing, so as to minimize tracking errors. A number of banks guarantee to trade with customers at the WM/Reuters fixing rate (WM Company (2004)). Those banks will likely want to trade in the interdealer market right around the 4pm fixing, so as to avoid inventory risk.

⁴ See Rzepkowski (2004) for a discussion of how delta hedging in the FX options market could feed back on the FX spot market

⁵ Formerly known as the NAPM index.

There are smaller spikes in volume at or just after 8:20am and 3pm. These times are the start and close of regular trading hours in currency futures and options on the Chicago Mercantile Exchange (7:20am and 2:00pm Central Time).

For dollar-yen, there is a subsequent spike in the evening corresponding to the times of Japanese data releases, many of which come out at 8:50am Tokyo time. This is either 6:50pm or 7:50pm New York time, depending on whether it is summer time in New York, or not. This is in fact the largest spike in the day, on average.

Many authors have looked at the correlation between trading volume and proxies for the flow of public information “news” (such as the frequency of Dow Jones or Reuters news stories). Berry and Howe (1994) and Mitchell and Mulherin (1994) find a moderately strong positive correlation between equity trading volume and the rate of flow of public information. Likewise, Melvin and Yin (2000) find a positive correlation between the frequency of indicative foreign exchange quotes and the rate of flow of public information. The volume spikes in Figure 1 shed a little light on the question of the high frequency correlation between foreign exchange trading volume and the arrival of news. On the one hand, the spikes in trading volume at the times of macroeconomic announcements indicate that there is some contemporaneous association between foreign exchange trading volume and economic news. On the other hand, the spikes in trading volume at 10am and 11am (and 8:20am and 3pm) indicate that some portion of foreign exchange trading volume is unlikely to be contemporaneously associated with any news, as we find it hard to imagine why there would be a such a surge of public information at these times (recall that the 10am spike is not due to the few data releases that come out at

this time). Instead, these spikes in trading volume appear to reflect institutional features of the foreign exchange market.

3.2 Intraday Volatility Pattern

Figure 2 plots the average absolute returns in each minute of the day, averaged across all days in our sample, in the two currency pairs, again broken into summer time and winter time. This shows the intraday volatility pattern. The plots of minute-by-minute trading volumes and minute-by-minute absolute returns appear, at first glance, to be highly correlated, and surges in volume and volatility generally occur at the same times. Overall, the peaks in absolute returns, in New York morning trading hours, are greater in euro-dollar than in dollar-yen. Notice however that whereas the dollar-yen volume spike is smaller at 8:30am than at 10am or 11am, the dollar-yen volatility spike is larger at 8:30am than at 10am or 11am. For euro-dollar, whereas there is a notable spike in trading volume at 11am, volatility is only very slightly elevated at that time. Thus the institutional factors that generate spikes in trading volume at 10am and 11am (and 8:20am and 3pm) are also associated with spikes in the volatility of returns, but these are generally somewhat smaller in relative terms.

We also see in Figure 2 that there is a rise in dollar-yen volatility (and a small increase in euro-dollar volatility) at around 5pm New York time, although there is little increase in trading volume at that time. This is the time at which the value date rolls. Trades made after 5pm will settle one business day later than trades made before 5pm. Volatility at this time is quite consistent with the work of Chaboud and Wright (2004) who argued that, in the presence of nonzero interest rate differentials, there should be relatively large absolute returns in the spot foreign exchange rate at around the time that

the value date rolls⁶. Notice finally that although dollar-yen trading volume is quite large at the time of Japanese macroeconomic announcements, dollar-yen volatility is not especially elevated at these times.

3.3 Focusing on US Macroeconomic Data Releases

Our key finding in this section is that U.S. macroeconomic data announcements at 8:30am are clearly accompanied by spikes in both trading volume and return volatility. Importantly, relative to days without data announcements, the spikes on announcement days are actually more pronounced than those shown in Figures 1 and 2, as the figures show data averaged across all days, not just days with macroeconomic announcements. As we shall see below, GDP and nonfarm payrolls (employment report)⁷ releases are on average associated with surges in euro-dollar and dollar-yen trading volume indices to about 2000 and 1000 respectively -- 20 or 10 times the average per-minute volume, and way off the scale of Figure 1.

The detailed analysis of the effects of U.S. news announcements is our focus in the remainder of this paper. We shall study patterns in volume and volatility on the days of 6 different types of U.S. macroeconomic data releases: GDP (the advance release), PPI, nonfarm payrolls, the trade balance, retail sales and the Federal Reserve's announcement about the target Fed Funds rate on the day of an FOMC meeting. All of these releases come out at 8:30am sharp (New York time) under tightly controlled conditions, except for the Fed Funds rate announcement which comes out under tightly

⁶The reason for the jump at that time is that, as intraday interest rates are zero, the full overnight interest differential in a carry-trade accrues when the value date rolls, by convention 5:00 p.m. New York time. The larger peak in volatility in dollar-yen reflects the fact that, during much of our sample period, the difference between short-term dollar and yen interest rates was quite large.

⁷ The employment report includes the release of nonfarm payrolls and the unemployment rate. We will henceforth refer to this data release as the release of nonfarm payrolls.

controlled conditions at around 2:15pm. The timing of the release of the FOMC announcement is not as precise, and it can be a few minutes early or late. We use as the FOMC announcement time the timestamp of the first Dow Jones newswire story describing the outcome of each FOMC meeting.⁸

All of these data releases are monthly except for GDP (quarterly) and the Fed Funds rate (eight times a year). The units of each of these releases are listed in Table 1. Standard economic theory tells us that the unexpected component of these releases should be important, rather than the release itself. We measure the unexpected component of these releases as the difference between the actual release and the Money Market Services (MMS) median survey expectation, a widely-used source of market expectations data. For the Fed Funds rate, instead of using survey expectations, we measure the unexpected component of the announcement from the Fed Funds futures market. Table 1 also lists the standard deviation of the unexpected component of each type of data release.

⁸ The FOMC announcement times used here are recorded only to the minute and can come out any time during that minute -- for example an announcement recorded at 2:12pm could have been released by the wire service between 2:12:00 and 2:12:59. This adds imprecision relative to the 8:30am announcements, which are released within a few seconds of 8:30:00. Release times varied from 2:11pm to 2:20pm in our sample.

4. The High Frequency Effects of U.S. Economic News Announcements.

4.1 The Effect of News Announcements on Trading Volume

Figure 3 plots the average euro-dollar trading volume by minute from 8:00am to 9:30am on days of announcements for GDP, nonfarm payrolls, PPI, retail sales and the trade balance. The average trading volume per minute on days when there are no 8:30 announcements is also shown as a benchmark. Figure 3 also shows the average trading volume by minute on days of FOMC announcements, plotted from 30 minutes before the actual release time to 60 minutes after the release (which is approximately from 1:45pm to 3:15pm). In the graph, the actual FOMC release time is marked as t . For the FOMC release, the benchmark shown is volume on non-FOMC days from 1:45pm to 3:15pm instead. Here and henceforth, where we refer to days with “no 8:30 announcements”, we mean days on which there is no release of business inventories, CPI, durable goods orders, GDP (advance, preliminary or final), housing starts, initial claims, personal consumption expenditures, personal income, PPI, nonfarm payrolls⁹, retail sales, or trade balance data. This is meant to be a fairly complete list of all of the market-sensitive data releases that come out at 8:30am. Figure 4 gives the same results for dollar-yen trading volume.

Here are the key findings to notice from Figures 3 and 4:

1. Each of the 8:30am announcements generates an instantaneous surge in trading volume (for both currency pairs) at 8:30 am, which varies by the type of announcement. This surge dissipates only quite slowly. Although the peak volume comes right after the

⁹ This means that days of unemployment rate releases are also dropped, as these are always concurrent with nonfarm payrolls releases.

announcement, the extra volume on announcement days in the few minutes immediately following the data release is actually small relative to the total extra volume on announcement days from 8:30am to 9:30am.

2. Of the five types of 8:30am announcements we study, quarterly GDP and monthly nonfarm payrolls releases are associated with especially large peaks in volume. Euro-dollar trading volume just after 8:30am is about six times higher on the days of either of these releases than on non-announcement days. Dollar-yen trading volume is about five times higher. Retail sales and trade balance releases have smaller effects on volume, and PPI releases have the smallest impact on volume of any of the five 8:30am announcements that we consider.¹⁰

3. The FOMC announcement generates trading volume that is also greatly elevated relative to the non-announcement day benchmark. The peak is not as high as for 8:30am announcements, but the extra volume dissipates slowly, and volume remains elevated for over an hour. Two points should however be borne in mind. Firstly, benchmark non-announcement day trading volume is much lower at this time of day than it is at 8:30am. The volume after the FOMC announcements is lower than it is around any of the 8:30am announcements, but is very high relative to the non-announcement day benchmark. Secondly, as noted earlier, the timing of the fed funds rate announcement is not recorded quite as precisely as it is for the other announcements, which may cause a downward bias in the measured peak trading volume right after the announcement.¹¹

¹⁰ We also studied three other 8:30am announcements: CPI, housing starts and initial jobless claims, and found that they had even smaller impacts on volume.

¹¹ For example, suppose that an FOMC announcement actually came out at 2:14:55. We would record the announcement as having come out at 2:14pm and would take the interval of time from 2:14:00 to 2:14:59 as the first minute after the announcement, but would probably measure little extra volume during this minute. The first minute after the announcement is actually the interval of time from 2:14:55 to 2:15:54.

4. For announcements other than nonfarm payrolls, the volume returns to close to normal after about an hour. We only show the volume for one hour after the announcements in Figures 3 and 4, but the average euro-dollar trading volume on the days of nonfarm payrolls announcements remains above the average on nonannouncement days for about two hours after the data release.

5. There is some tendency for volume to be lower right *before* some news announcements than it is at that same time on nonannouncement days. This is an effect that we could call the calm before the storm.

4.2 The Effects of News Announcements on Volatility

Figure 5 plots the absolute one minute returns in euro-dollar and dollar-yen from 8:00am to 9:30am averaged across all days of announcements of each of the six types that we consider (for the FOMC announcement, from 30 minutes before the announcement to 60 minutes afterwards). The average one-minute absolute returns on days with no 8:30am announcements are also shown as a benchmark (for the FOMC release the benchmark is non-FOMC days from 1:45pm to 3:15pm instead). These patterns are quite similar to those observed for volume. Following an announcement, exchange rate volatility spikes sharply, and then remains elevated for a period of time. GDP, target federal funds rate and nonfarm payrolls data releases have the largest (and longest-lasting) effects on exchange rate volatility.

4.3 Effects of data surprises on the level of exchange rates

We next turn to relating exchange rate changes to what the market has learned about the state of the economy from the economic data releases. For each type of data

But we do not observe the actual times of FOMC announcements to the second, and so cannot do this. The problem does not arise for the other announcements, as they are released within a few seconds of 8:30:00.

release and for both currency pairs, we start by considering the basic regression estimating the price impact of an announcement surprise:

$$r_{t,h} = \beta_h s_t + \varepsilon_t \quad (1)$$

where s_t is the unexpected component of the data release and $r_{t,h}$ is the return from one minute *before* the announcement release time (8:30am or the time of the FOMC release) to h minutes *after* the announcement release time. The regression is run over days on which there is a release of that particular type. The interpretation of the slope coefficient is the effect of a one unit surprise in that data release (measured in the units listed in Table 1) on the exchange rate returns (in basis points).

The OLS estimates of β_h are plotted in Figure 6 against h , along with pointwise 95% heteroskedasticity-robust confidence intervals. Firstly, we find that news indicating stronger-than-expected U.S. activity tends to systematically be followed by dollar appreciation, confirming the finding of ABDV using Reuters indicative quotes. Much work in international economics, going back to the paper of Meese and Rogoff (1983), has argued that exchange rates are very hard to forecast, or even to relate to *ex-post* fundamentals. The fact that it is possible to find a significant association between exchange rates and macroeconomic fundamentals, even at these very short horizons, makes the work of ABDV an important contribution to international economics. Secondly, as found by ABDV and other authors, we find that the effect of the unexpected component of the macroeconomic announcement is capitalized into prices very fast -- the surprise component of the announcement produces a movement in the conditional mean that is generally completed within a few minutes, and that is effectively a jump. That is, the exchange rate returns *subsequent* to the few minutes around the time of the data

release are orthogonal to the unexpected component of the macroeconomic announcement. Put another way, the expectation of the exchange rate a few minutes after the data release, conditional on the announcement, is about the same as the conditional expectation (say) an hour later.

4.4 Effects of data surprises on trading volume

The relationship between the unexpected component of macroeconomic announcements and foreign exchange trading volume in major currency pairs has not been previously studied, and we turn to it next. For each type of data release and for both currency pairs, we consider the regression:

$$V_{t,h} = \alpha_h + \gamma_h |s_t| + \varepsilon_t \quad (2)$$

where s_t is the unexpected component of the data release and $V_{t,h}$ is the transacted volume in the one-minute window h minutes after the announcement time. Again, the regression is run over days on which there is a release of that particular type. The interpretation of the slope coefficient is the effect of a one-unit absolute surprise in that data release on the transactions volume.

The OLS estimates of α_h and γ_h are plotted in Figures 7 and 8, respectively, along with pointwise 95% heteroskedasticity-robust confidence intervals. The plot of α_h against h has the interpretation of the predicted volume on the day of an announcement which actually turned out to be in line with expectations. Meanwhile, the plot of γ_h against h is the predicted *extra* volume that is generated when the actual data release is one unit different from expectations (either above or below).

The estimates of the intercept coefficients α_h account for a large share of the surge in volume after announcements. In contrast, the estimated slope coefficients γ_h are rather small, and are often not significantly different from zero. Both coefficients peak immediately at the announcement time. To get a sense of the relative magnitudes of these coefficients, consider, for example, the effect of nonfarm payrolls announcements on volume in the euro-dollar market. The peak intercept coefficient α_h is about 1,800 whereas the peak slope coefficient γ_h is about 4. This means that the predicted peak effect of an announcement right in line with median market expectations is to immediately raise the trading volume index to 1,800, or to 18 times the average per-minute volume. As shown in Table 1, the payrolls release is measured in thousands of workers. So, if the announcement surprise is plus or minus 100,000 (close to a one standard deviation surprise over our sample), then the volume index is further elevated, but only by about another 400, making a predicted peak volume of 2,200, or 22 times the average per minute volume. Data releases with a large unexpected component (whether positive or negative) may move prices a lot, but do not generate much more trading volume than releases close to market expectations.

It is quite possible that the low response of volume to the surprise component of data releases owes in part to mismeasurement of the surprise, biasing the coefficient on the surprise in the estimation of equation (2) towards zero. *Ex-ante* expectations of the 8:30am macroeconomic news releases, measured from surveys, are noisy and somewhat stale. This same measurement error concern arises equally in the estimation of equation

(1) and is a very hard obstacle to overcome in this literature.¹² It is however less of an issue for the FOMC release of the target federal funds rate, because the expected component of that release is instead measured directly from federal funds futures.

4.5 Effect of heterogeneity of market expectations on trading volume

Even if a data release perfectly matches the survey expectation number published by MMS, that number is itself the median of a large number of point estimates. Unless all market participants have identical *ex-ante* beliefs, some market participants will be surprised by the data release, and they might trade among themselves. Greater dispersion of *ex-ante* market expectations might then be associated with a higher trading volume. A proxy for the dispersion of *ex-ante* market expectations is the standard deviation of MMS survey responses, and this might be associated with trading volume. To investigate this possibility, we computed the total trading volume in euro-dollar and dollar-yen from 8:30am to 8:45am on days of PPI, nonfarm payrolls, GDP and retail sales releases, and the total trading volume from 2:10pm to 2:25pm on days of FOMC releases of the target federal funds rate.¹³ Then, on days of each of these announcement types, we regressed the total volume over this 15 minute window in each currency pair on the absolute value of the surprise component of the announcement (as before), but augmented this regression with the standard deviation of MMS survey responses.

The results are shown in Table 2. Somewhat surprisingly, the coefficient on the standard deviation of survey responses is in most cases negative, but often not

¹² Recently Goldman Sachs and Deutsche Bank have introduced economic derivatives based on macro data releases. These include “digital options” which are simply Arrow-Debreu securities that pay \$1 if the data release exceeds a “strike price”, and nothing otherwise (there are also “vanilla options” with the conventional options payout profile). These trade in Dutch auctions 3 days and 1 day prior to certain important macro data releases (including nonfarm payrolls and retail sales). They do not suffer from the same staleness problem as survey expectations, and may turn out to be very useful in future work, but we do not yet have a long enough time series on the prices of these derivatives to use them in this paper.

¹³ We did not have data on the standard deviation of survey expectations for the trade balance release.

significantly different from zero. It appears that, in our sample, the *ex-ante* disagreement among analysts does have a weak (and if anything negative) relationship to trading volume. However, a major caveat concerning these results is that the standard deviation of survey responses is a very imperfect measure of the true heterogeneity of beliefs ahead of news announcements.

4.6 Trading Volume and the Digestion of News Announcements

The effect of the difference between the median of analysts' *ex-ante* expectations and the headline data release on the conditional mean of the exchange rate gets incorporated quickly, and without requiring much trading volume. The surprise component of the news announcement is only weakly related to total trading volume. This leaves open the question of what generates the long period of elevated trading volume after a news announcement.

One important factor is likely the fact that macroeconomic news announcements are often complex, consisting of much more than a single headline number. Much of the information content of a data release can be in the wording of a statement, or in the subaggregate statistics included with the release. This is perhaps especially true for FOMC announcements. Many FOMC announcements in our sample period involved decisions about the target federal funds rate that were almost perfectly anticipated by the market, but the markets inferred a lot of information from the text of the accompanying statements. Investors may be more likely to have different interpretations of the information content of the text of a statement than of a simple headline number. Recall that the pattern of elevated trading volume following FOMC announcements had a small peak and a long period of elevated trading volume, relative to the other announcements

that we considered. Our results are consistent with the view that the relatively long period of trading volume after a macroeconomic data release is the result of the aggregation of investors' heterogeneous interpretations of the information content of the details of the news announcement. Unfortunately, the extent to which agents disagree about the information content of a particular data release is very difficult to quantify.

We did one final exercise that gives some further tentative support to the idea that foreign exchange trading volume in the wake of a news announcement is being driven by some aspect of how the market interprets the news announcement, over and above the surprise in the headline release. The change in two-year Treasury yields from a minute before an announcement to 15 minutes after the announcement can be thought of as a measure of how much the market has learned from the data release about the state of the economy and the likely course of monetary policy. For example, as mentioned above, although many recent FOMC announcements contained little surprise in the decision about the target federal funds rate (the headline release), market participants may nevertheless have learned about the path of future monetary policy from the text of the accompanying statement. The change in the two-year yield is a simple measure of the total information content of the FOMC release for current and near-term future monetary policy.

On days of each type of macroeconomic announcement, we regressed the total volume over the 15 minutes following the announcement on the absolute value of the headline surprise component of the announcement, but augmented this regression with the absolute change in two-year Treasury yields. The exercise aims to answer the following question: if one knew how much information the market learned about

monetary policy and the state of the economy from a data release, would this information help predict the volume following that data release, even after controlling for the size of the headline surprise? The answer to this question is a tentative yes. The results, shown in Table 3, show that the coefficient on the change in Treasury yields is often positive and statistically significant, though not for all types of releases. It is highly significant for the FOMC announcement. This gives support to the idea that there exists some dimension of the data release, other than the measured headline surprise, that is associated with elevated trading volume. That could be simply that we have mismeasured the headline surprise. Alternatively, and we think more likely, it could reflect the interpretation of some more subtle aspect of the data release than the headline number as, for example, the market aggregates the information content of the statement following an FOMC meeting.

There are other factors possibly explaining part of the surge in volume that follows a data release in line with expectations. Even if a release perfectly matches market expectations in all respects, the risk profile associated with holding a foreign exchange position will change discretely at the moment of the data release, as a risk event will have passed. This, in and of itself, may well be sufficient to induce trading. Market participants may have placed hedges ahead of the data release, which might be viewed as unnecessary or suboptimal after the release, leading to additional trading activity as they are unwound even in the complete absence of any surprise or any price reaction.

The almost-instantaneous spike in price that follows a data release likely reflects almost purely the dealing community's immediate assessment of the likely impact of the data release. In the following minutes, as the dealers execute trades required by their

limit order books, receive orders from other desks in their firms, and observe their customers' reactions to both the data release and the initial price adjustment, additional interdealer trading volume will also likely be generated.

5. Conclusion and Directions for Future Work

We have studied the impact on foreign exchange trading of U.S. macroeconomic data announcements and have described the intraday patterns in volume and volatility, using spot interdealer trading data in the two most-traded currency pairs, euro-dollar and dollar-yen from January 1999 through January 2004. The high-frequency dataset used in this paper, from EBS, marks a major advance over the data used in previous exchange rate studies. First, the data represents the vast majority of global spot interdealer trading in these two currency pairs over the sample period. Secondly, the EBS prices that we use are live transactable prices, not the indicative quotes used in most previous studies of high frequency exchange rate data. Third, and most importantly, we are able to observe, at very high frequency, foreign exchange trading volume. Our four key findings are as follows:

1. We find that there are sharp spikes in trading volume around the time of scheduled macroeconomic data releases and also at some other times of the day, where trading volume tends to be elevated for institutional reasons.
2. We find that there is a systematic relationship between the surprise component of the news announcement and the level of the exchange rate. The effect of the data

surprise on the conditional mean of the exchange rate occurs quickly and can be effectively thought of as a jump, confirming other recent studies that however used indicative quotes.

3. We find that announcements are followed immediately by higher trading volume and volatility, and that volume and volatility remain elevated for a period of time. However, much of the extra trading volume and volatility associated with a news announcement takes place after the systematic part of the price change has occurred. The pattern is not unlike that which Fleming and Remolona (1999) found for the Treasury market.

4. We relate the extra trading volume following an announcement to the magnitude of the surprise component of the data release and find that there is a relationship, but that it is quite weak. Most of the extra trading volume occurs even if the data release is right in line with expectations. An interpretation of these findings is that trading volume following a news announcement is not driven primarily by the headline surprise (that gets priced in without much trading), but rather by the process whereby investors aggregate their heterogeneous interpretations of the information content of the detailed news announcement.

Recent research (Evans and Lyons (2002, 2003)) has argued that information (including the interpretation of macroeconomic announcements) is likely transmitted to the exchange rate via order flow, the net of buyer-initiated trades minus seller-initiated

trades, and that much of the variability of exchange rates is accounted for by information that is effectively aggregated in this way. This view contrasts with the idea that all price-sensitive information is public common knowledge that gets incorporated into prices directly.¹⁴ Our analysis in this paper of the effect of news announcements on volume does not give a direct test of whether macroeconomic news is transmitted to the exchange rate via order flow, as unsigned volume is not the same thing as order flow (which is signed volume). The study of the association between order flow, macroeconomic data releases, and exchange rate returns using EBS data is an important unanswered question that is the subject of ongoing research by the authors of this paper.

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¹⁴ Love and Payne (2003) studied the high frequency association between order flow, macroeconomic announcements and exchange rate returns in ten months of data from the Reuters electronic dealing system.

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Table 1
Macroeconomic Announcements

Data Release	Source ¹	Frequency	Release Time	Units	Surprise Standard Deviation
Fed Funds Rate (Target)	Fed	8 per year	2:15pm	Change in basis points	4.9
GDP (Advance Release)	BEA	Quarterly	8:30am	% change qoq ²	0.91
Nonfarm Payrolls	BLS	Monthly	8:30am	Change in thousands	107.0
PPI	BLS	Monthly	8:30am	% change mom	0.42
Retail Sales	Census	Monthly	8:30am	% change mom	0.52
Trade Balance	BEA	Monthly	8:30am	\$ billion	2.3

¹ Acronyms for the sources are as follows: BEA (Bureau of Economic Analysis), BLS (Bureau of Labor Statistics), Census (Bureau of the Census), Fed (Federal Reserve Board of Governors).

² Expressed at an annualized rate.

Table 2: Regression of Total Trading Volume in 15 mins Around Data Releases on the absolute value of the headline surprise & on the survey standard deviation

Announcement	Coefficient on Absolute Surprise	Coefficient on Survey St. Dev. (Standard Error)	R ²
Euro-Dollar			
GDP	1107.8* (2275.6)	-10650.1** (4388.7)	0.20
Payrolls	7.6 (7.9)	-92.2* (41.6)	0.08
PPI	2923.3* (1517.9)	-12162.0* (6957.5)	0.05
Retail Sales	3797.1*** (1325.5)	202.1 (1648.9)	0.11
FOMC	194.9* (103.5)	7102.3 (8550.4)	0.26
Dollar-Yen			
GDP	1549.2 (1529.5)	-9575.8** (4086.8)	0.27
Payrolls	7.9 (7.6)	-47.2* (28.3)	0.05
PPI	3358.4** (1224.6)	-7759.2*** (3917.9)	0.08
Retail Sales	2675.7** (1147.9)	-385.8 (1273.7)	0.11
FOMC	347.6*** (101.5)	-10402.2 (9132.7)	0.36

* denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level. The total trading volume is measured in index terms where the average per-minute trading volume is normalized to 100. The headline surprise and standard deviation of the survey expectations are both measured in the units listed in Table 1.

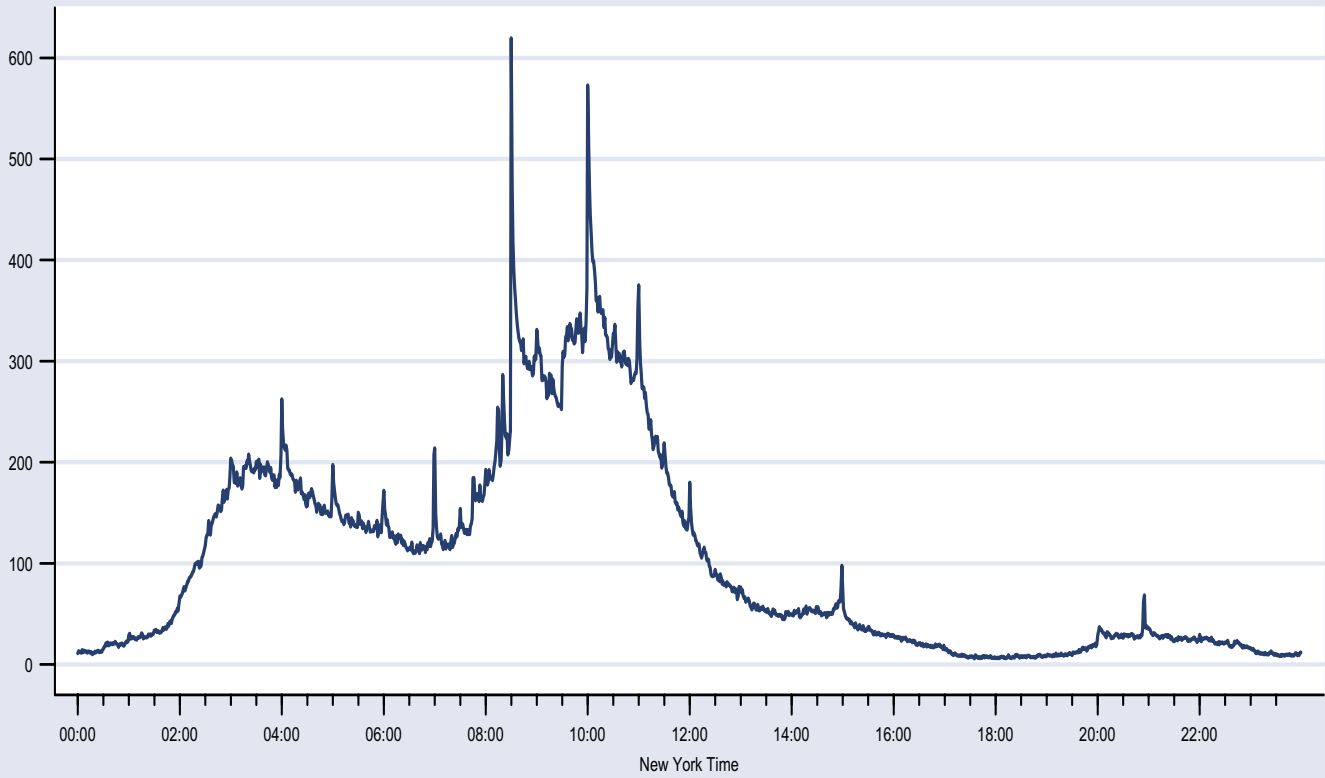
Table 3: Regression of Total Trading Volume in 15 mins around Data Releases on the absolute value of the headline surprise & on the absolute change in 2-year yield

Announcement	Coefficient on Absolute Surprise (Standard Error)	Coefficient on Absolute Change in 2-year yield (Standard Error)	R ²
Euro-Dollar			
GDP	685.6 (1927.3)	389.1*** (137.8)	0.22
Payrolls	8.1 (7.5)	347.6 (213.0)	0.12
PPI	898.3 (1726.6)	476.1 (322.7)	0.06
Retail Sales	3091.3** (1364.9)	404.6* (245.7)	0.15
Trade Balance	807.8* (476.0)	-640.1* (367.8)	0.10
FOMC	168.8* (90.1)	302.5*** (83.7)	0.46
Dollar-Yen			
GDP	2077.3 (2417.2)	11.7 (235.3)	0.09
Payrolls	7.3 (7.1)	272.9** (106.5)	0.15
PPI	2479.8** (1153.4)	221.5 (246.5)	0.08
Retail Sales	1916.7* (1169.2)	440.3*** (128.0)	0.24
Trade Balance	565.8* (313.2)	-605.2** (270.7)	0.11
FOMC	179.1** (81.1)	222.0*** (59.3)	0.50

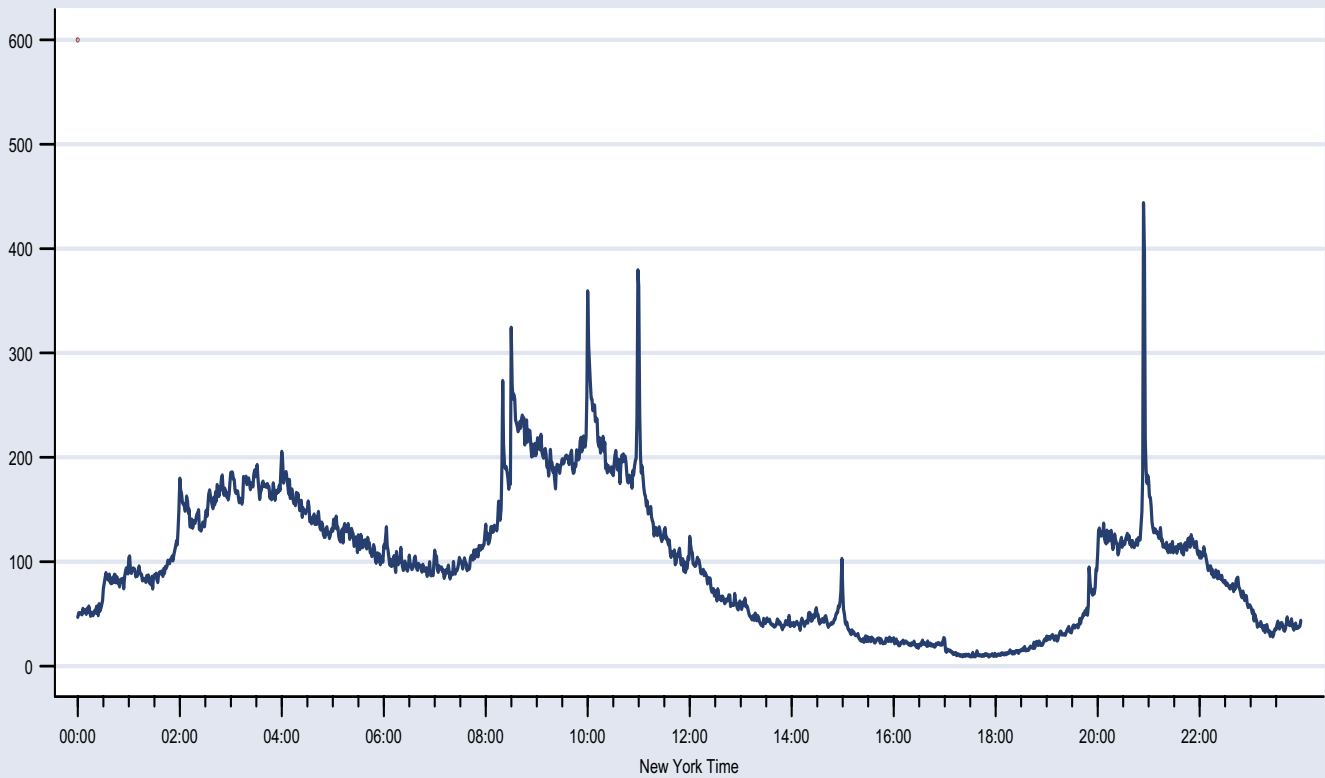
* denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level. The total trading volume is measured in index terms where the average per-minute trading volume is normalized to 100. The headline surprise is measured in the units listed in Table 1. The absolute change in two-year yields is measured in basis points.

Figure 1a: Average One-Minute Volume During U.S. Daylight Savings Time

Euro/Dollar



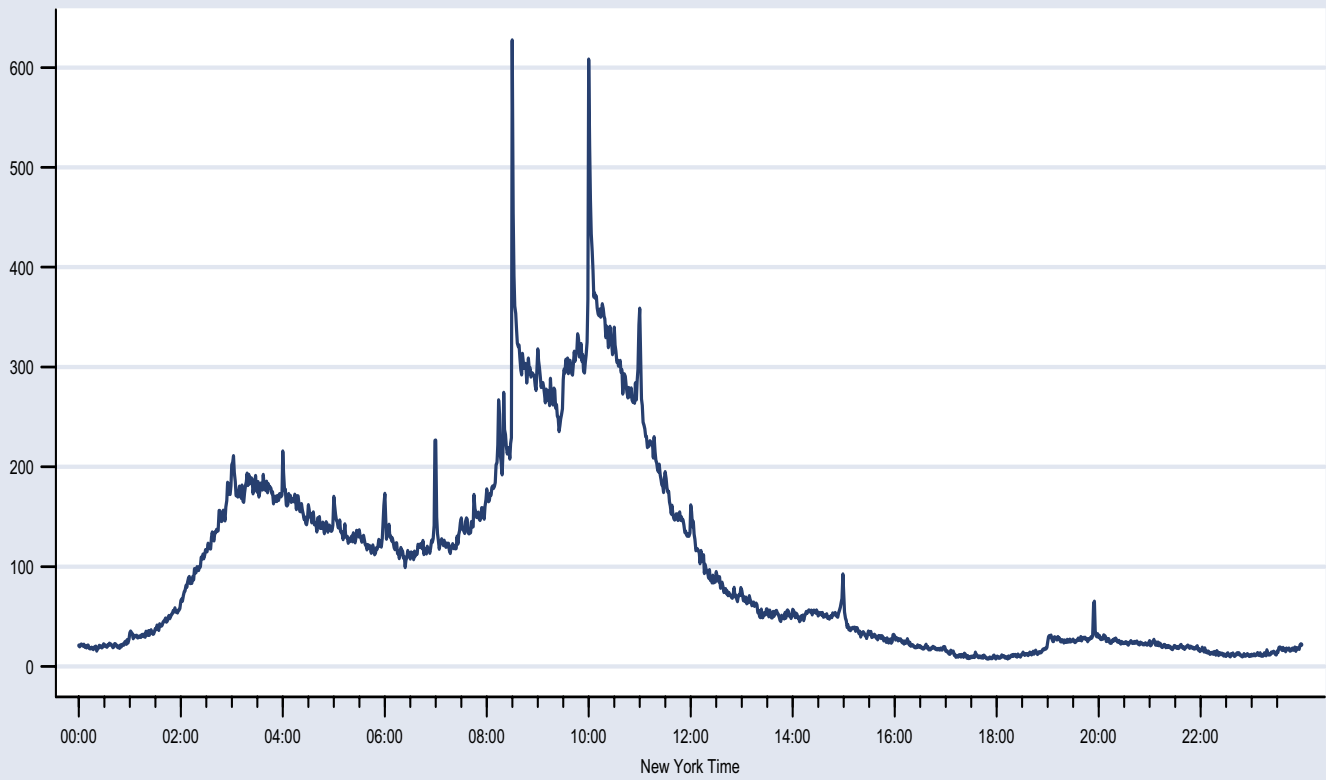
Dollar/Yen



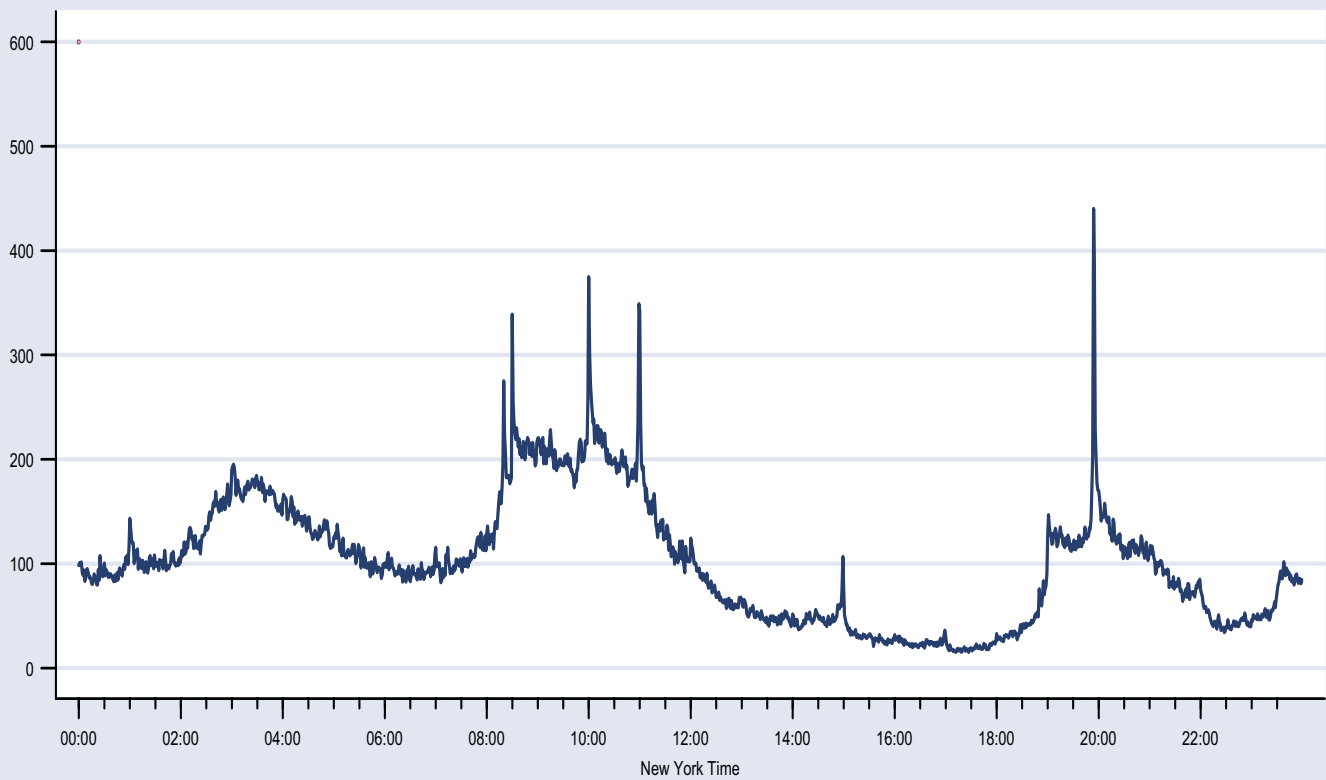
Index: 100 = Average volume per one-minute period over the whole sample (separate index for each currency pair)

Figure 1b: Average One-Minute Volume During U.S. Standard Time

Euro/Dollar



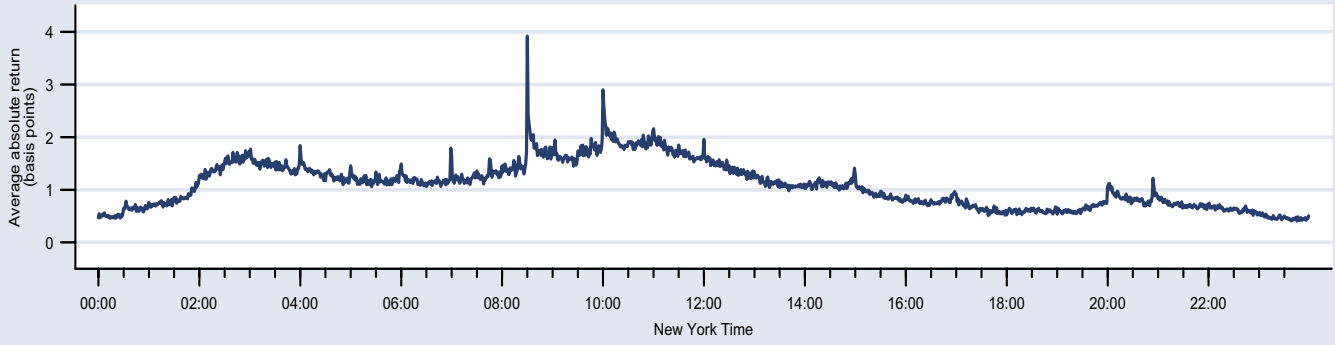
Dollar/Yen



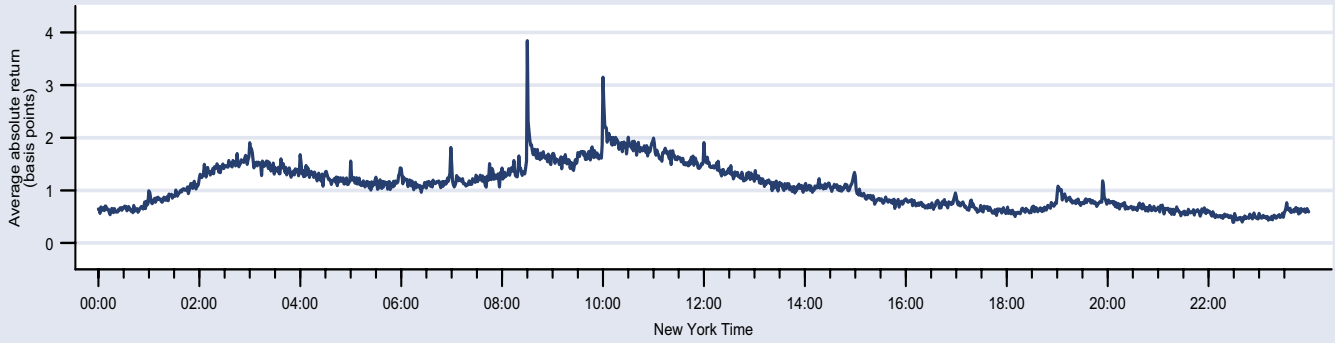
Index: 100 = Average volume per one-minute period over the whole sample (separate index for each currency pair)

Figure 2: Intradaily volatility
Average absolute return in each minute of the day

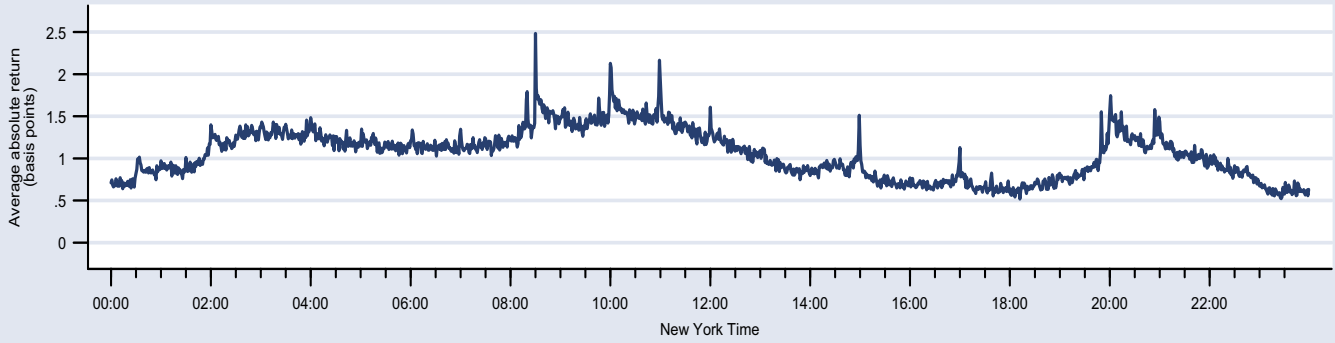
Euro/Dollar
(Summer)



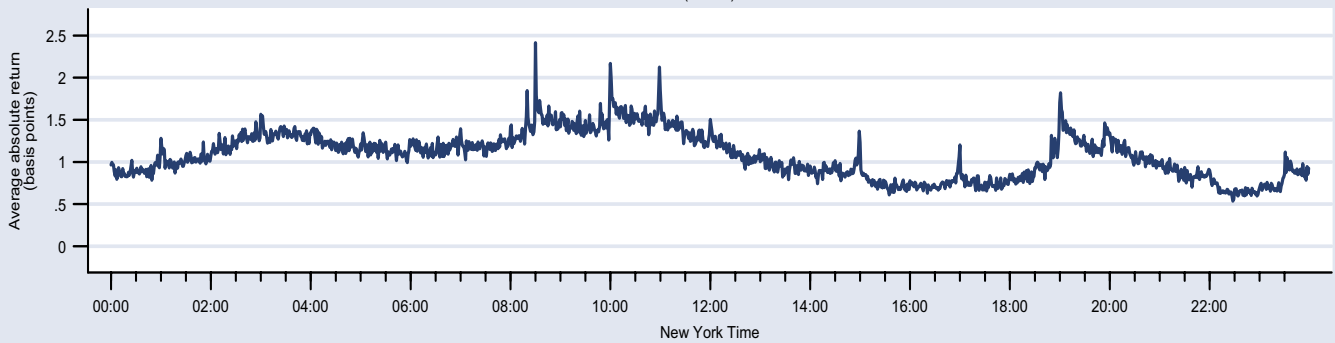
Euro/Dollar
(Winter)



Dollar/Yen
(Summer)

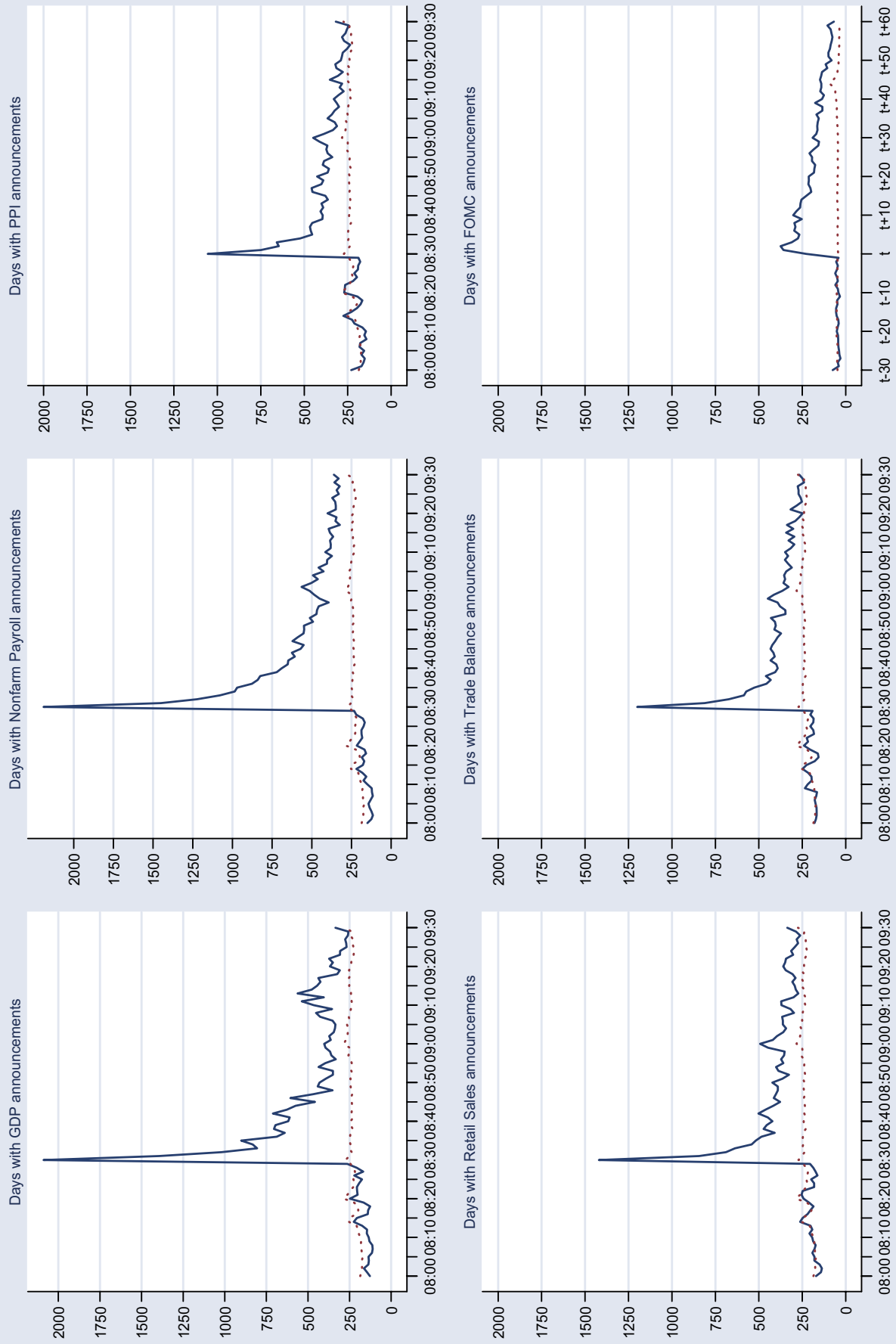


Dollar/Yen
(Winter)



Summer means during US daylight savings time

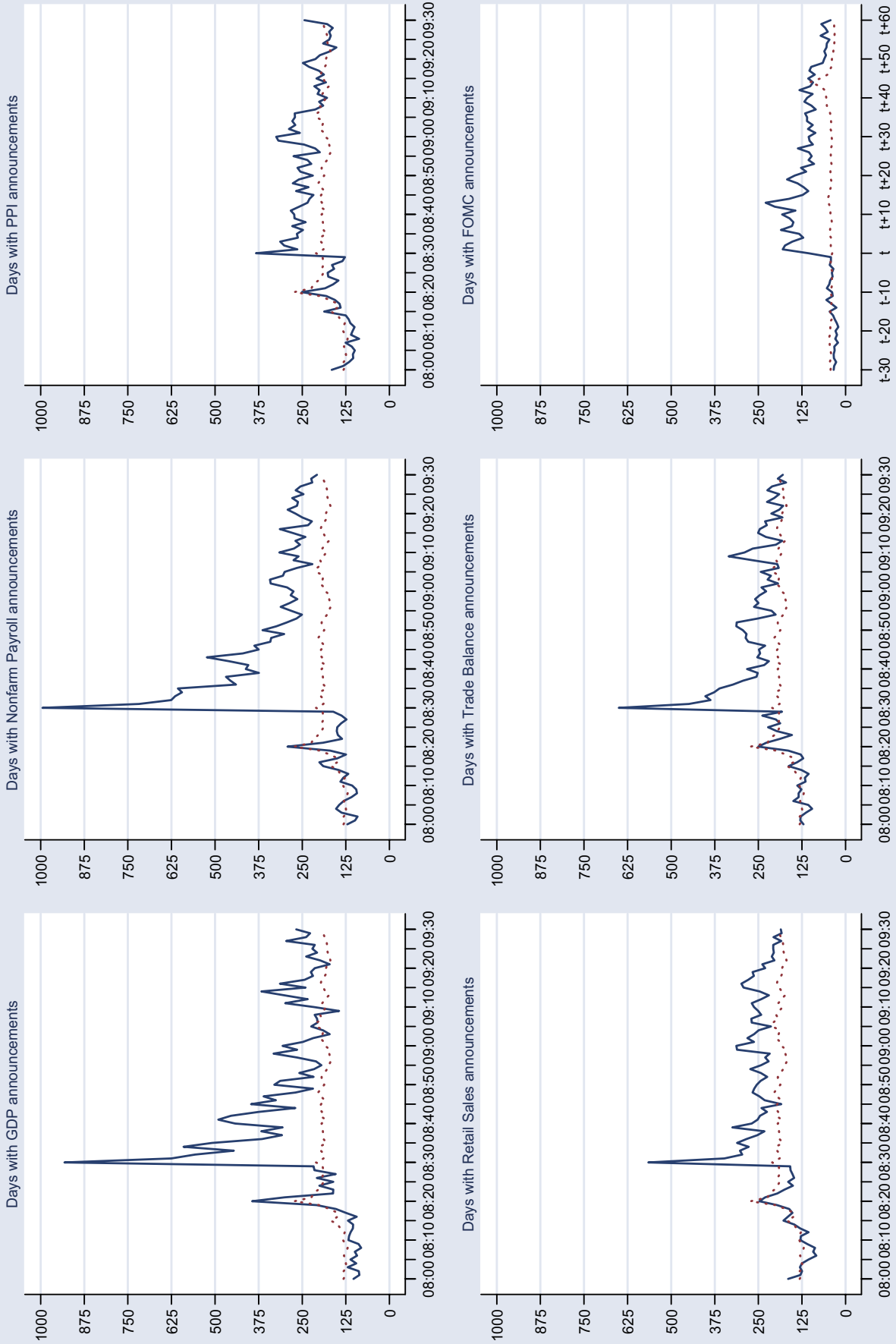
Figure 3: Average One-Minute Euro/Dollar Volume on Announcement Days
(Index: 100 = average volume per minute)



Average volume on announcement days versus the benchmark

t denotes the time of an FOMC announcement

Figure 4: Average One-Minute Dollar/Yen Volume on Announcement Days
(Index: 100 = average volume per minute)

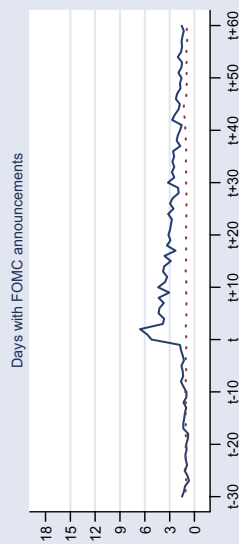
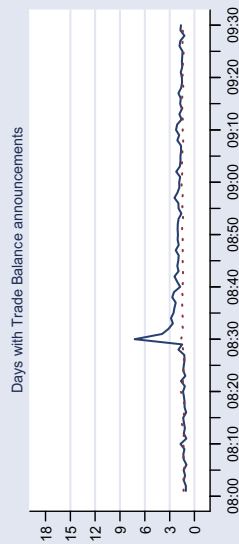
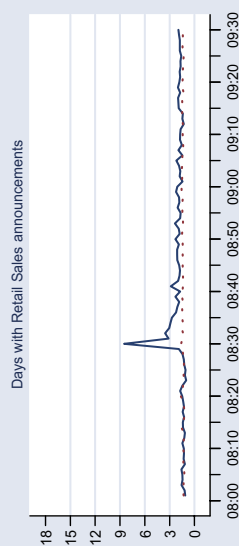
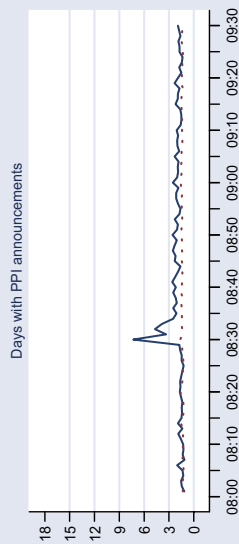
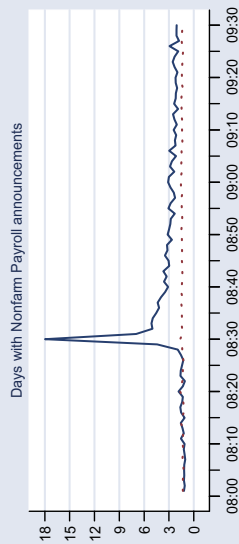
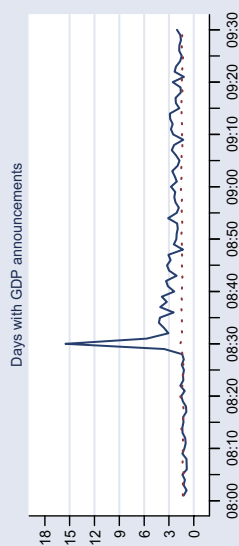


Average volume on announcement days versus the benchmark

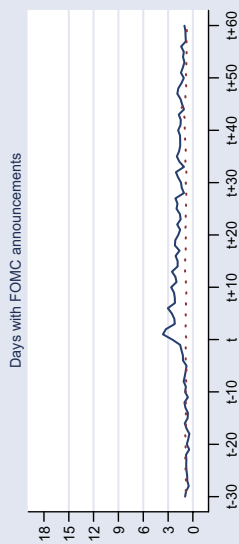
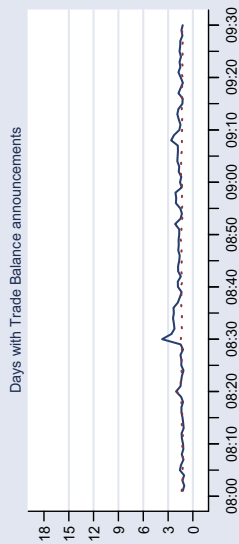
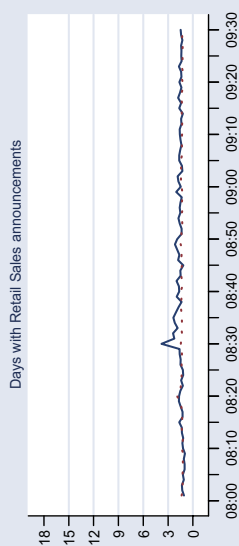
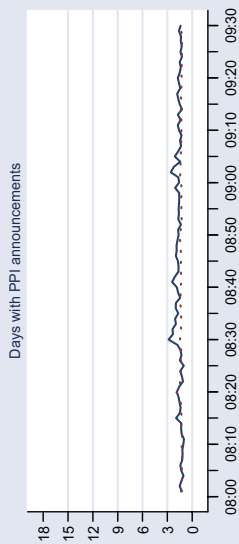
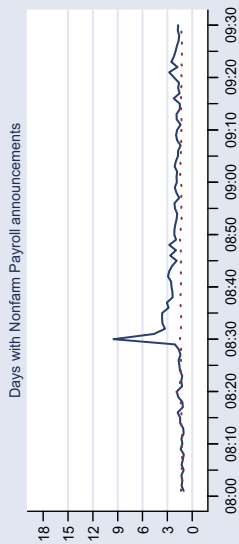
t denotes the time of an FOMC announcement

Figure 5: Volatility (Average Absolute One-Minute Returns on Announcement Days)
(basis points)

Euro/Dollar



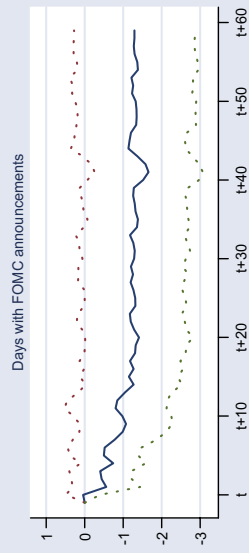
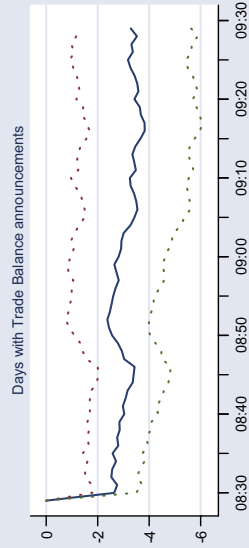
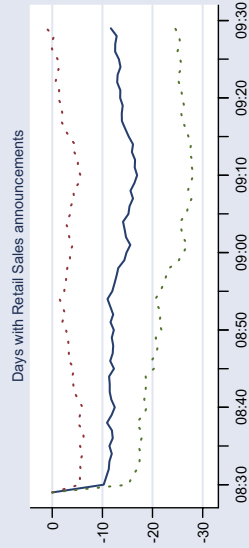
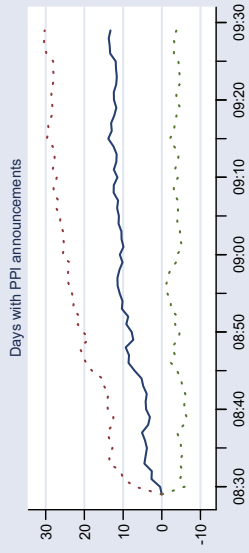
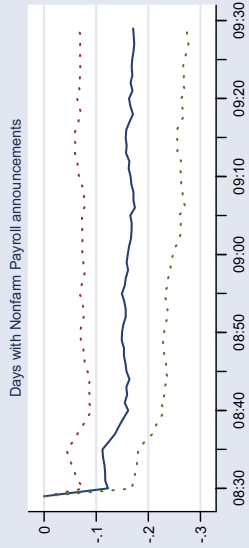
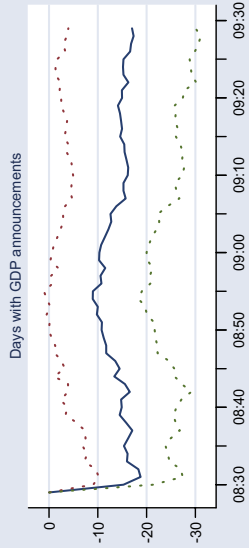
Dollar/Yen



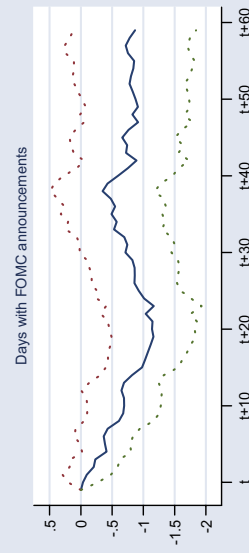
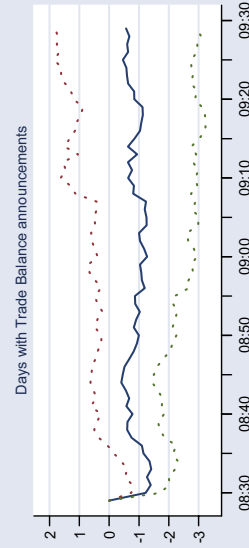
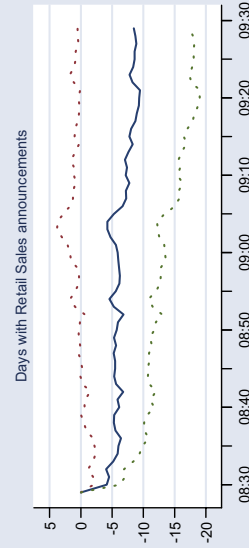
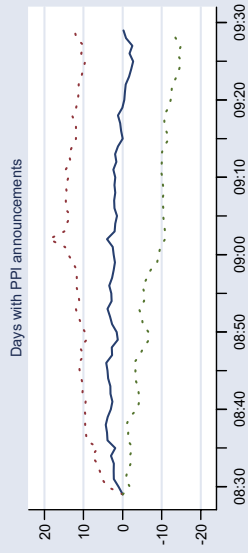
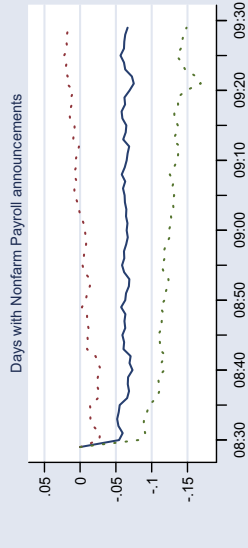
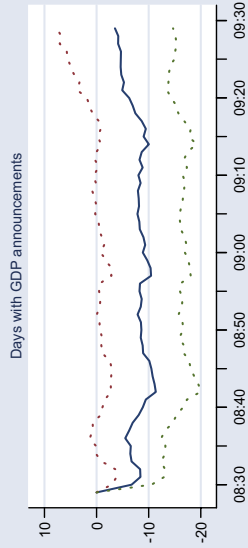
Average absolute one-minute returns versus the benchmark (days with no announcements)
t denotes the times of an FOMC announcement

Figure 6: Slope coefficients in the regression of cumulative returns since announcement on the size of an announcement surprise

Euro/Dollar



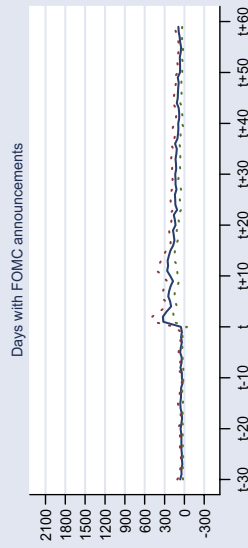
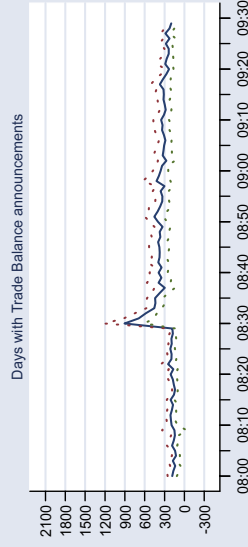
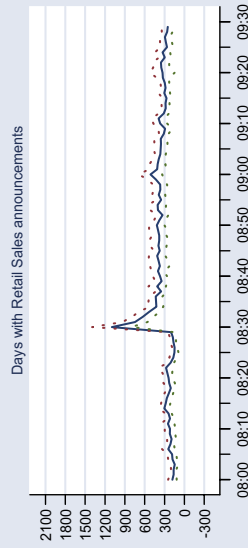
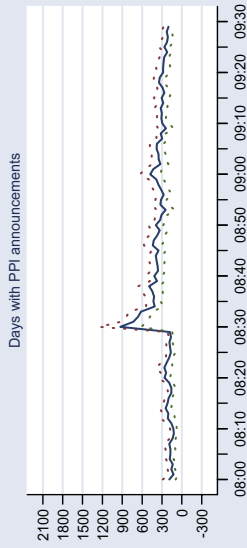
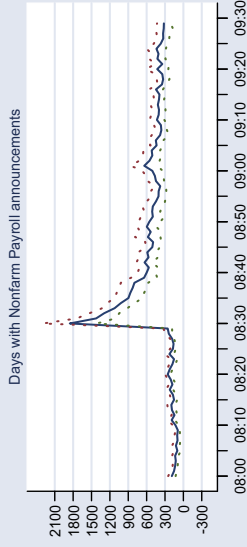
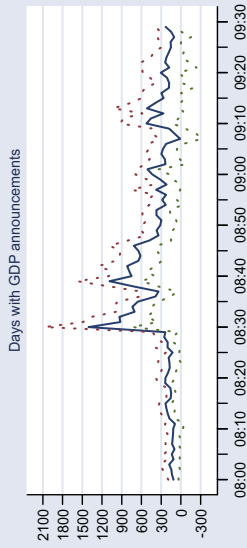
Dollar/Yen



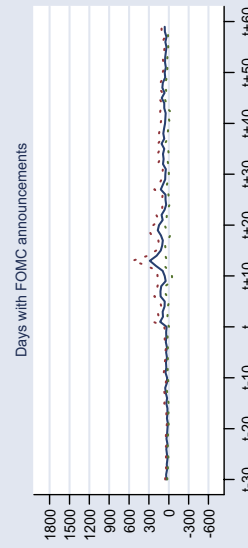
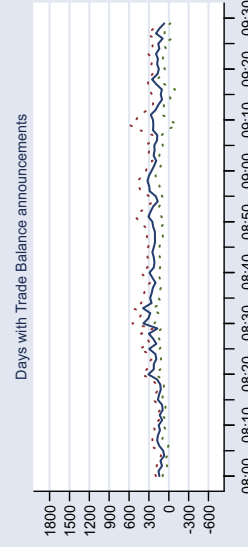
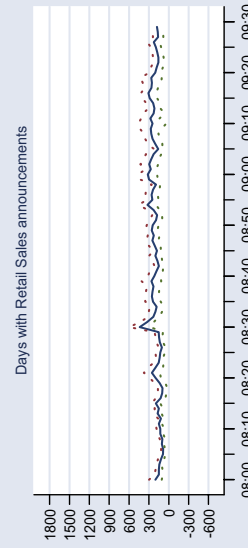
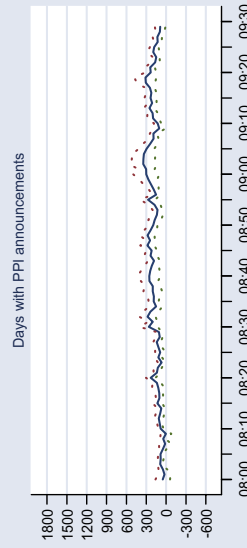
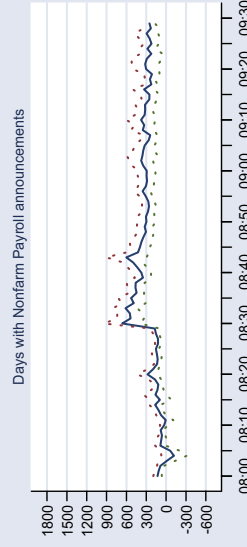
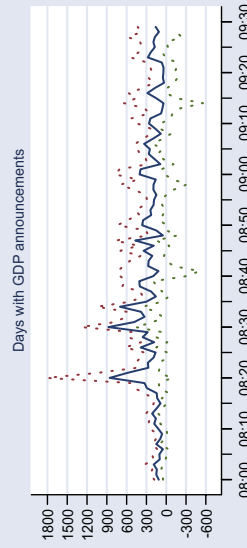
Estimates of the price impact of an announcement surprise along with pointwise 95% confidence intervals
 t denotes the time of an FOMC announcement

Figure 7: Intercept coefficients in the regression of one-minute volume on the absolute size of an announcement surprise
(Index:100 = average volume per minute)

Euro/Dollar



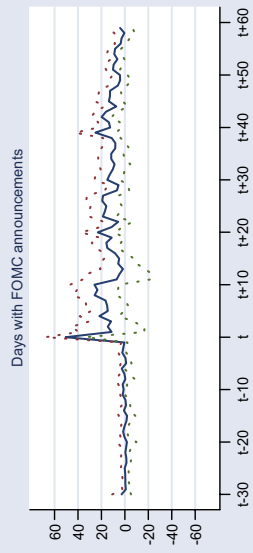
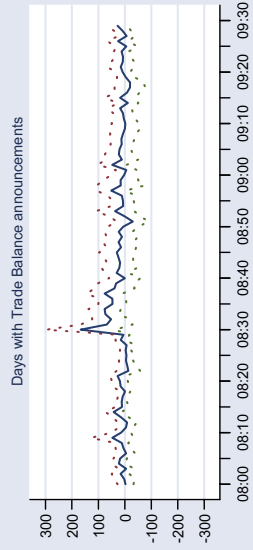
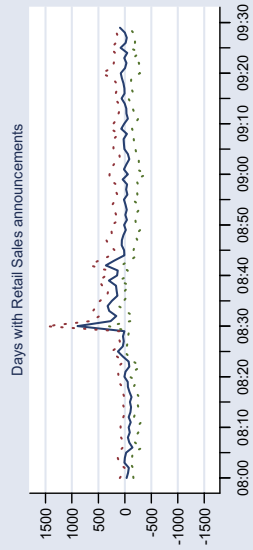
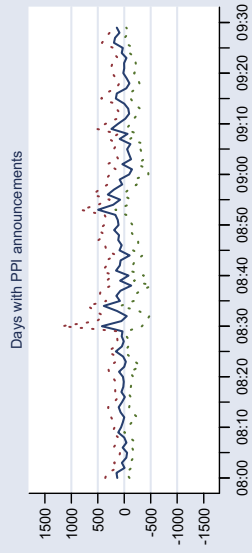
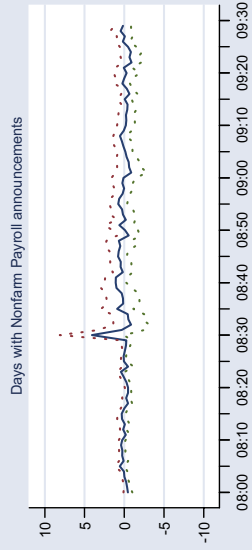
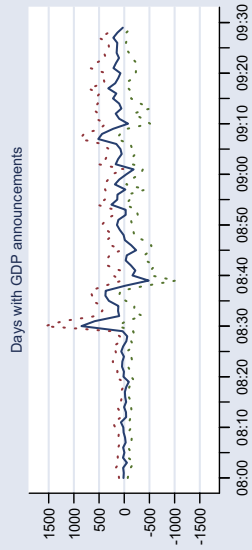
Dollar/Yen



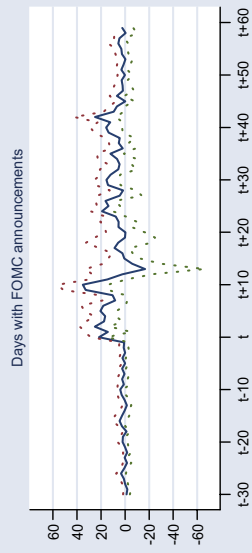
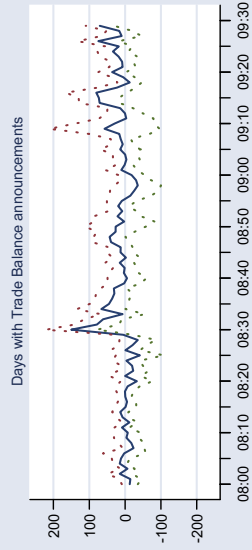
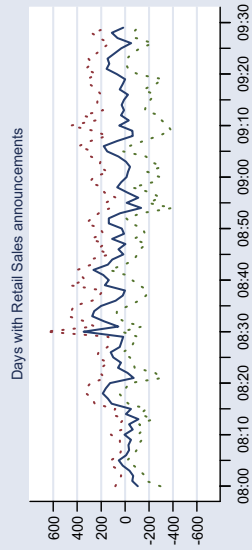
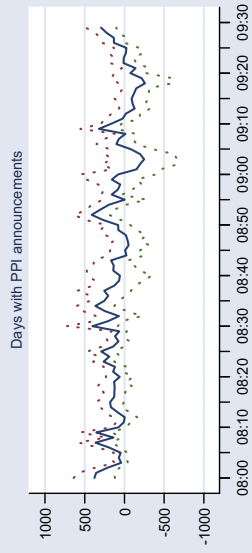
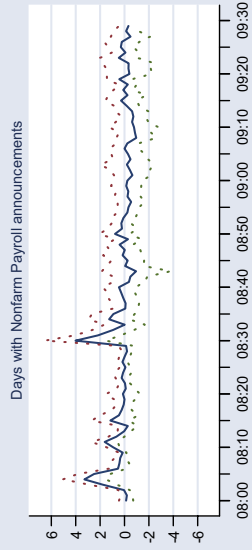
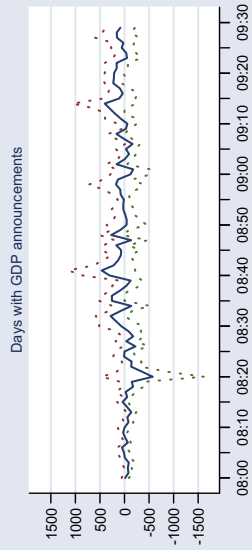
t denotes the time of an FOMC announcement

Figure 8: Slope coefficients in the regression of one-minute volume on the absolute size of an announcement surprise
(Index: 100 = average volume per minute)

Euro/Dollar



Dollar/Yen



t denotes the time of an FOMC announcement