Foreign Exchange Market Reactions to News: A Microstructure Analysis of Returns, Volatility, and Order Flow from the Reuters D2000-2 Electronic Trading System

by

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Abstract

The research in this thesis examines the effect of different kinds of news on high frequency order flow, exchange rate returns and volatility.

The first chapter studies the impact of different aspects of central bank interventions (direction, size, frequency, timing), and news about these interventions, on exchange rate volatility. Briefly, we find that interventions decrease volatility contemporaneously but the effect is reversed in two hours. This effect is symmetric with respect to the direction of the intervention. The size and frequency of interventions are usually positively correlated with volatility. 9am and 2pm interventions have different effects on volatility, confirming that when the central bank chooses to intervene is important.

The second chapter examines the intra-daily influence of a broad set of news reports, including variables which are not typically considered "fundamentals" in the context of standard models of exchange rate determination, and asks whether they too help predict exchange rate behavior. We also examine whether "news" not only impacts exchange rates directly, but also influences exchange rates via order flow (signed trade volume). We find that along with the standard fundamentals, both non-fundamental news and order flow matter.

The last chapter examines intra-day foreign exchange market reactions to various types of intervention news (reported actual interventions, falsely reported interventions, oral interventions and unrequited interventions). Research has found that these operations can, under certain circumstances, effectively influence the level and volatility of exchange rates. Using Reuters' time-stamped newswire reports we are able to match the timing of intervention news to movements in intra-day exchange rates. Overall, the results indicate that along with actual interventions, other kinds of intervention news (including denials of intervention

and unrequited interventions) and order flow matter.

The results from these studies suggest that future models of exchange rate determination ought to include a broader concept of price relevant "news".

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[1] This chapter is based on joint work with Prof. Kathryn M.E. Dominguez.

[2] This chapter is based on joint work with Prof. Kathryn M.E. Dominguez.

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Chapter 1

Introduction

1.1 News, Order Flow, Exchange Rate Returns and Volatility

1.1.1 Standard Exchange Rate Models

The asset approach to exchange rate determination treats exchange rates as forward looking asset prices which react to changes in the markets expectation of future fundamentals. This approach assumes that all information is public, that the mapping from information to price is common knowledge and that information is absorbed into prices instantaneously, leaving no role for the trading process in price determination.

Empirical tests of the asset approach examine whether changes in macroeconomic variables (fundamentals) explain exchange rate movements[1]. These tests, especially those that use low frequency data, generally find that macroeconomic variables can explain little of the variation in exchange rate movements. This line

[1]Examples of "fundamentals" include: income (or output) differentials, money differentials, interest rate differentials, inflation differentials and the trade balance.

of research is best summarized by a series of papers, Meese and Rogoff (1983a,b), which find that forecasts of exchange rates based on a random walk model of exchange rate determination do better than forecasts that are based on macroeconomic models. The random walk model out-performs structural macro models even for conditional out-of-sample forecasts using realized values of the fundamentals. One branch of empirical research (exemplified by Andersen, Bollerslev, Diebold, and Vega (2003)) has focused on the possibility that this result is more a function of estimation imprecision than an indictment of the asset approach. If the window of time around the shock to fundamentals is too wide, other news hitting the market will confound the econometrician's ability to precisely estimate the effects of the change in fundamentals on exchange rates. One solution is to use intra-daily exchange rate data that will allow a narrow enough window around the time of macro announcements to be able to set up a natural experiment[2].

1.1.2 Microstructure Approach and Order Flow

There are a number of caveats to the asset approach to exchange rate determination. Not all information is public. In fact, information is often privately held by widely dispersed market participants, making them heterogeneously informed. Further, even if information across market participants was homogeneous, traders may not have the same pricing function linking information and prices, and hence may interpret the same information differently. And finally, information may not be absorbed into prices instantaneously, suggesting that the mechanics of the trading process may be relevant for exchange rate determination.

Microstructure models of asset pricing aim to take these factors into account. In Kyle (1985), the seminal paper in the field, informed traders act strategically,

[2]This research is discussed further in section 1.1.3.

choosing to trade in periods of high liquidity to hide, and hence maximize the value of, their private information. The process of information revelation takes place gradually via order flow, and this private information will eventually become known and be reflected in price. Within the Glosten and Milgrom (1985) framework, in each round of trading the market maker updates his prior on the asset value based on the order flow he observes. Good news results in an excess of buy orders and bad news in an excess of sell orders. Thus the trading process facilitates the incorporation of information into prices. There are a number of papers in the microstructure literature that underscore the importance of order flow and the trading process in price discovery[3]. This is contrary to standard models of exchange rate determination in which there is no role for order flow, since trading occurs only at the equilibrium price which already incorporates all information. Order flow (signed trading volume) is defined as the net of buyer-initiated and seller-initiated orders. In standard models there is no reason for order flow to rise in reaction to news because price is assumed to instantaneously adjust. Trading volume may rise in reaction to news, but as long as the new price is efficient, there is no reason for trades to be biased in favor of purchases or sales.

Evans and Lyons (2002) is one of the first empirical studies that found a link between order flow and exchange rate movements, thus providing evidence in favor of a different modeling strategy for exchange rate determination[4]. It is now an established fact that order flow has a significant impact on exchange rate returns, explaining between 40% to 60% of the variation in returns.

[3]Admati and Pfleiderer (1988), Easley and O'Hara (1987).

[4]Other papers that find similar results include Rime (2000), Danielsson, Payne, and Luo (2002), Payne and Vitale (2003), Payne (2003).

1.1.3 What Drives Order Flow and Returns?

We know that empirically order flow explains exchange rate returns and that theoretically order flow reflects information. The interesting question now facing researchers, on which there is no consensus, is - what drives order flow? Does order flow reflect public information? Does it reflect private information? And even more fundamentally, what is this information that underlies order flow, which in turn drives returns?

One source of information in foreign exchange markets comes from central bank intervention operations. Within the signalling model of central bank intervention popularised by Mussa (1981), agents interpret interventions as signals of future monetary policy which, in turn, influence expected exchange rate movement. For the signalling channel of intervention to work, transparency of interventions and the credibility of the central bank are crucial. Access to disaggregated and time-stamped data on central bank interventions has made it possible to test the signalling hypothesis within the market microstructure approach. In this framework central banks are viewed as informed players with private information on the asset value and interventions are expected to affect the price (exchange rate) since they reveal this information to the market[5].

Addressing another aspect of the information, order flow, exchange rate returns and volatility relationship, researchers have used high frequency exchange rate data and timed "macro surprises" to test the impact of public information about macroeconomic variables on exchange rate returns. This approach is best exemplified by Andersen, Bollerslev, Diebold, and Vega (2003), who find that

[5]Goodhart and Hesse (1993), Chang and Taylor (1998), Fischer and Zurlinden (1999), Dominguez (2003b,a), Payne and Vitale (2003) generally find evidence that interventions are associated with volatility increases in the short run but that they do not affect long run volatility as much.

when a narrow window is used for estimation, they are able to find a strong relationship between certain macro-surprises and exchange rate returns[6]. While these studies provide evidence that macro news influences both returns and volatility, because these announcements occur very infrequently (typically once a month or quarter) they cannot go far in explaining the bulk of foreign exchange rate movements.

Beyond central bank interventions and "macro surprises" do other sorts of news influence exchange rate movements? In practice, dealers in the foreign exchange market receive information from numerous different sources, including their own customers, electronic brokerage systems, squawk boxes, and newswire services. Newswire services report the macro announcements along with various other sorts of news including intervention news. One of the major distinctions that can be made between macro announcements and other news is that the announcements are typically made on a schedule, so that market participants can plan their reactions in advance (depending on realizations). Non-scheduled news is by its nature less likely to be anticipated by the market, and therefore, may have a different influence on exchange rates.

1.2 Thesis Outline and Contribution

This thesis contributes to and extends this literature by analysing the effect of different types of information on order flow, exchange rate returns, and volatility. The first chapter studies the influence of Swiss National Bank interventions, and

[6]There is an enormous literature measuring the effects of macro news on intra-daily exchange rates including Hakkio and Pearce (1985), Ito and Roley (1987), Ederington and Lee (1995), de Gennaro and Shrieves (1997), Almeida, Goodhart, and Payne (1998), Andersen and Bollerslev (1998), Melvin and Yin (2000), Evans and Lyons (2003), Faust, Rogers, Wang, and Wright (2003), Love and Payne (2003), Love (2004), Chaboud, Chernenko, Howorka, Iyer, Liu, and Wright (2004), Bauwens, Omrane, and Giot (2005).

news about these interventions, on the intraday volatility of the Swiss franc-U.S. dollar exchange rate. It characterises the impact of central bank interventions on exchange rate volatility based on different aspects of interventions including direction, size, frequency and time of intervention. Summarizing the findings briefly, I find that the effect of intervention on volatility varies depending on whether volatility is defined as the squared return, the absolute return, or as realised volatility. In general, interventions tend to decrease volatility contemporaneously but this effect is reversed in the two hours afterward and this relationship is symmetric with respect to the direction of the intervention. Larger interventions usually increase volatility more than small interventions while the frequency of interventions has a small but positive impact. The effect of the timing of the intervention is mixed and varies with the type of volatility measure. Reuters news reports of sell interventions have a significant lagged negative effect on volatility.

The second chapter examines intra-day foreign exchange market reactions to a wide array of "news" reported in the press. We measure news broadly, using a unique data set of Reuters' time-stamped newswire reports created by the authors. These data include all Reuters news stories that provide information relevant to foreign exchange markets and classify them by information source (policymaker or market participant), geographic region (Euro zone, Japan, U.S. or U.K.) and substance (both actual events and rumours involving fundamentals and non-fundamentals). Our results do not suggest that our broader definition of news provides a vast improvement over the macro surprises. However, we find that non-scheduled news, and intriguingly, non-scheduled non-fundamentals-related news has a statistically significant influence on both intra-day exchange rate returns and volatility. Further, we find that news has its largest impact dur-

ing periods of higher than normal news arrival and higher market uncertainty. We find that order flow explains a large fraction of the variation in both USD-EUR and USD-GBP exchange rate returns, suggesting that prices are, at the very least, slow to adjust. At the same time, we find that our measure of "news" explains a relatively small fraction of the total variation in order flow. Overall, our results indicate that along with the standard fundamentals, both, non-fundamental news and order flow matter, suggesting that future models of exchange rate determination ought to include all three types of explanatory variables.

The last chapter examines intra-day foreign exchange market reactions to news of various types of intervention (reported actual interventions, falsely reported interventions, oral interventions and unrequited interventions) reported in the financial press. For this study we created a unique data set of time-stamped Reuters' newswire reports of intervention news. Our search criteria retrieved newswire articles under the joint subject area of "foreign exchange" and "intervention". We then coded and grouped news articles according to geographic region (Euro-zone, U.K., U.S. or Japan) and type of intervention (threat, rumour, oral, unrequited, actual and joint). Briefly, the results indicate that unrequited intervention news (and even news of "no intervention") has a statistically significant influence on both exchange rate returns and volatility, suggesting that the expectation of intervention, even when governments do not intervene, can affect currency values. These results provide strong evidence in favor of the hypothesis that interventions influence exchange rates via the information or signalling channel. We find evidence that order flow has some explanatory power for prices, however our various categories of intervention news explain a very small fraction of the variation in order flow. Overall, our results indicate that along with actual interventions, other kinds of intervention news (including denials of intervention

and unrequited interventions) and order flow matter. These results suggest that future models of exchange rate determination ought to include a broader definition of price relevant "news".

To sum up, this thesis extends the existing literature on, and increases our understanding of, the relationship between news, order flow, exchange rate returns and volatility.

1.3 Exchange Rate Volatility and Central Bank Intervention

Chapter 2 studies the impact of Swiss National Bank (SNB) interventions, and news about these interventions, on the intraday volatility of the Swiss franc - U.S. dollar (CHF-USD) exchange rate. It describes the impact of central bank interventions on exchange rate volatility by analysing various characteristics of intervention including direction, size, frequency and time of intervention. Additionally, it considers how markets react to news about these interventions.

1.3.1 Issues, Methodology and Data

While the effectiveness of interventions is important to policy makers, the consensus on the effectiveness has changed several times over the years (see review by Sarno and Taylor (2001)). In the recent past, interventions have been frequent for some currencies, like the euro and especially the yen, but infrequent for other major currencies. Theoretically there are two standard models describing the effect of sterilised central bank interventions on exchange rates, the portfolio balance model and the signalling model. The portfolio balance approach is

based on the idea that a sterilised intervention causes market players to change the composition of their portfolios by buying or selling foreign assets, which in turn leads to a change in the relative price of domestic assets and foreign assets i.e. the exchange rate. If domestic and foreign assets are perfect substitutes, then sterilised intervention cannot work via the portfolio balance channel. The signalling model takes the view that agents interpret interventions as signals of future monetary policy, and therefore the exchange rate is affected by changes in the expectations of future variables. For the signalling channel of intervention to work, transparency of interventions and credibility of the central bank are crucial. Thus theoretically both models, portfolio balance and signalling, predict that sterilised intervention can affect the exchange rate.[7]

The empirical literature on the portfolio balance model is both, scarce and weak (exceptions to this are Dominguez and Frankel (1993a), Evans and Lyons (2001)). This literature provides little support for significant imperfect substitution of domestic and foreign assets for the major OECD country currencies. Empirical evidence on the signalling model, based on low frequency data, is mixed.[8]

Recent access to disaggregated and time-stamped data on interventions has made it possible to test the signalling hypothesis within the market microstructure approach to exchange rates[9]. Within this framework central banks are

[7]A number of papers have considered the influence of central bank interventions and official policy statements on exchange rates. These papers include: Dominguez (1998, 2003b, forthcoming), Cai, Cheung, Lee, and Melvin (2001), Evans and Lyons (2003), Fatum and Hutchinson (2003), Fratzscher (2004), Sager and Taylor (2004), Ehrmann and Fratzscher (2005), Jansen and de Haan (1987).

[8]Edison (1993) provides a review of the empirical literature on the effectiveness of central bank interventions. For references to high frequency work on the effectiveness of interventions see Chang and Taylor (1998). Dominguez (1992a), Dominguez and Frankel (1993a,b), Kaminsky and Lewis (1996) provide evidence in favour of the signalling hypothesis. Vitale (1999) lists papers which suggest that central bank interventions are informative about future monetary policy.

[9]Daily intervention data are available (with a lag) for the US and Japan, but most other countries do not provide this data to researchers. Interventions can also be inferred from

viewed as informed players with private information on the asset value and their trades (interventions) are expected to affect the price (exchange rate) since they reveal this information to the market. Chang and Taylor (1998) examine the effect of Bank of Japan interventions on the Japanese yen - U.S. dollar (JPY-USD) exchange rate. They find that interventions have a significant positive impact on volatility, with the largest impact 30-45 minutes prior to the Reuters news report about the intervention (Reuters reports are used as a proxy for actual intervention)[10]. In addition to observing significant intervention effects on the level of the CHF-USD exchange rate, Fischer and Zurlinden (1999) find that the timing of the intervention may play an important role in the effectiveness of the intervention.

Studying the effect of dollar interventions by G3 governments on exchange rate volatility, Dominguez (2003b) finds that interventions are associated with increases in intraday and daily volatility, but there is not much evidence that intervention affects long term volatility. Expanding on results from Fischer and Zurlinden (1999), Payne and Vitale (2003) find that intervention has significant short run effects on the level of the exchange rate. Additionally, they find that in anticipation of the intervention (and at the time of the intervention) volatility increases but starts decreasing approximately 15 minutes after the operation and the effect is completely reversed over the next 90 minutes.

This chapter extends the existing literature by characterising the impact of central bank interventions on exchange rate volatility based on different aspects of interventions including direction, size, frequency and time of intervention.

changes in international reserves. This is, however, an inaccurate proxy given that reserves are affected by interest receipts and valuations changes.

[10]Using SNB intervention data and Reuters reports Fischer (2003) finds that the latter are not a good proxy for the former and therefore should be used with caution.

1. I examine the following questions: Do interventions have an impact on exchange rate volatility? Do buy and sell interventions have different effects on volatility (direction)? Do larger interventions mean lower volatility (size)[11]? If there is a size effect, is it linear or non-linear? Is there a difference in impact if interventions are one shot or repeated (frequency)? Does one large intervention have a different effect than a set of smaller more frequent interventions? In other words, is there any interaction between size and frequency? Do interventions affect volatility differently when they are carried out during periods of high trading volume, for example, market opening and closing times (time of intervention)?

2. The second aspect this chapter considers is how markets react to news about interventions: Does news about interventions calm markets or make them volatile? Is this news important relative to the actual intervention (if the timing of the two is distinct)? If the news report appears before the intervention, does the actual intervention have any effect? On the other hand, if the news report appears after the intervention (or is missed), does the actual intervention have a larger and/or more persistent impact?

To analyse these questions I use an event study methodology and data on the CHF-USD exchange rate, interventions by the SNB and Reuters news reports of these interventions. I use four different measures of volatility in the analysis - squared returns, absolute returns and two measures of realised volatility, sum of the squared returns for the past hour and the sum of the absolute returns for the

[11]It would not be surprising if there is no size effect given the large daily turnover in foreign exchange markets. In 2001 turnover was $1.2 billion in traditional foreign exchange instruments and $67 billion in OTC foreign exchange derivatives. Source: Pasquariello (forthcoming) and the BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity (1999).

past hour[12]. These data allow more reliable analysis by using

- Actual interventions (not proxies based on international reserves or Reuters reports).
- Indicative quotes of the exchange rate (not proxies based on intervention transaction price).
- Reuters news reports that make it possible to separate the effect of the intervention on volatility from the effect of the news.

1.3.2 Main Results and Contribution

The effect of the different intervention characteristics varies depending on how volatility is defined, but some general conclusions can be drawn.

- Interventions decrease volatility contemporaneously but this effect is reversed in the two hours afterwards. This relationship is symmetric with respect to the direction of the intervention, whether they be buy and sell interventions or with-the-wind and against-the-wind interventions.
- Analysis of the volatility and intervention size relationship finds that larger interventions tend to increase volatility relative to small interventions.
- The frequency of interventions has a small but positive impact on volatility, further underscored when the analysis is done by splitting the sample into low, average and high frequency interventions. The interaction between intervention size and intervention frequency results in a small positive effect on volatility for the squared return and the absolute return volatility measures and a negative effect for both the realised volatility measures.

[12]These are standard ways of measuring volatility used in Payne and Vitale (2003), Dominguez (forthcoming), Andersen and Bollerslev (1997b).

- The effect of the timing of the intervention varies with the volatility measure. 9am interventions reduce volatility when measured as realised volatility while for the other two measures the overall effect is positive. 2pm interventions decrease volatility for both the squared return measures but increase volatility for both the absolute return measures.

- Reuters reports of sell interventions have a significant lagged negative effect on volatility for the squared return measure and both the absolute return measures.

1.4 What Defines "News" in Foreign Exchange Markets?

Chapter 3 examines intra-day foreign exchange market reactions to a wide array of "news" reported in the financial press. A number of previous studies have shown that in order to find significant reactions in the foreign exchange market to the macroeconomic variables that theory suggests should matter, one needs to measure the precise impact of macro surprises at the intra-day level. In this chapter, we ask whether a much broader definition of "news" influences currency values and ought to be included in our models of exchange rate determination.

1.4.1 Issues, Methodology and Data

The asset approach to exchange rate determination suggests that exchange rates are forward looking asset prices that react to changes in the market's expectation of future fundamentals. Empirical tests of the asset approach examine in various ways whether changes in the macroeconomic variables that are considered fun-

damentals explain exchange rate movements[13]. These tests generally find that macroeconomic variables, which tend to have fairly stable time series properties, can explain little of the (sometimes dramatic) variation in exchange rate movements. This line of research is best summarized by a series of papers by Meese and Rogoff (1983a,b) which find that forecasts of exchange rates based on a random walk model of exchange rate determination do better than forecasts that are based on macroeconomic models.

If the window of time around the shock to fundamentals is too wide, other news hitting the market will confound the econometrician's ability to precisely estimate the effects of the change in fundamentals on exchange rates. One solution is to use intra-daily exchange rate data that will allow a narrow enough window around the time of macro announcements to be able to set up a natural experiment. A number of papers, including Andersen, Bollerslev, Diebold, and Vega (2003), find that when a narrow window is used, they are able to find a strong relationship between certain macro-surprises and exchange rate returns[14].

This chapter takes the results in Andersen, Bollerslev, Diebold, and Vega (2003) as a benchmark, and examines the intra-daily influence of a broad set of news reports, including variables which are not typically considered "fundamentals" in the context of standard models of exchange rate determination, and asks whether they too help explain exchange rate movements.

The intra-day foreign exchange data used in this study are transactions prices and quote spreads in the USD-EUR and USD-GBP market from the Reuters

[13]Examples of "fundamentals" include: income (or output) differentials, money differentials, interest rate differentials, inflation differentials and the trade balance.

[14]There is an enormous literature measuring the effects of macro news on intra-daily exchange rates including Hakkio and Pearce (1985), Ito and Roley (1987), Ederington and Lee (1995), de Gennaro and Shrieves (1997), Almeida, Goodhart, and Payne (1998), Andersen and Bollerslev (1998), Melvin and Yin (2000), Evans and Lyons (2003), Faust, Rogers, Wang, and Wright (2003), Love and Payne (2003), Love (2004), Chaboud, Chernenko, Howorka, Iyer, Liu, and Wright (2004), Bauwens, Omrane, and Giot (2005).

D2000-2 electronic trading system. The data do not include information on traded quantities, but they do indicate whether trades were initiated by a buyer or seller, allowing us to measure order flow as well as returns and volatility. We use a 20 minute sampling frequency for each exchange rate and we measure order flow as the cumulative number of buyer initiated trades minus the cumulative number of seller initiated trades over the same 20 minutes.

This study uses a unique data set of Reuters' time-stamped newswire reports created by the authors. We include all news stories that provide information relevant to foreign exchange markets. The stories are then classified by information source (policymaker or market participant), geographic region (Euro zone, Japan, U.S. or U.K.) and substance (both actual events and rumours involving fundamentals and non-fundamentals). Our "news" data include the scheduled macro announcements that have been used in previous studies to allow us to compare the effects of our broader definition of news against these more "traditional" variables. These data allow us to test a number of interesting hypotheses.

1. First, we test whether non-scheduled "news" of different sorts has similar impact effects on returns and volatility as compared to (the already heavily studied) scheduled macro announcements. Theory suggests that ambiguous information may lead to stronger differences of opinion about the implications of the information (and, in turn, larger increases in volatility). In our application, we can distinguish between scheduled (and presumably better-understood) macro announcements and more ambiguous news (for example, market rumours of impending interest rate changes).

2. Second, we test whether news that is typically not considered "fundamental" in the context of standard models of exchange rate determination (for

example, news related to technical analysis), helps to explain exchange rate movements.

3. Third, we examine whether any of the price discovery process in reaction to news occurs via order flow. Previous studies have found evidence that a substantial proportion of the market reaction to macro-announcements occurs via order flow. By examining how a broader set of news events influences order flow, we can begin to better understand how this measure relates to price and volatility movements in the foreign exchange markets.

1.4.2 Main Results and Contribution

In this chapter we examine the role of news in exchange rate determination. We measure news much more broadly, and include both fundamentals-related and non-fundamentals-related news reports.

- Overall, our results do not suggest that our broader definition of news provides a vast improvement over the macro surprises in explaining exchange rate. We do, however, find that non-scheduled news, and intriguingly, non-scheduled non-fundamentals-related news has a statistically significant influence on both intra-day exchange rate returns and volatility.

- Further, we find that news has its largest impact during periods of higher than normal news arrival and higher market uncertainty.

- We find that order flow explains a large fraction of the variation in both USD-EUR and USD-GBP exchange rate returns, suggesting that prices are, at the very least, slow to adjust. At the same time, we find that our measure of "news" explains a relatively small fraction of the total variation in order

flow.

- Overall, our results indicate that along with the standard fundamentals, both non-fundamentals-related news and order flow matter, suggesting that future models of exchange rate determination ought to include all three types of explanatory variables.

1.5 Unrequited Interventions

Chapter 4 examines intra-day foreign exchange market reactions to news of actual and unrequited interventions reported in the financial press. Intervention operations are used by many governments to manage their exchange rates. Previous research has found that these operations can, under certain circumstances, effectively influence the level and volatility of exchange rates[15]. One of the more puzzling aspects of intervention policy is the fact that some governments keep their intervention operations secret, even ex post[16].

[15]A number of recent papers have examined the influence of intervention operations on daily exchange rate returns and volatility and generally find evidence that interventions influence returns and increase volatility. Bonser-Neal and Tanner (1996), Dominguez (1998), Humpage (1999), Chaboud and LeBaron (1999), Beine, Benassy-Quere, and Lecourt (2002), Beine and Laurent (2003), Beine, Laurent, and Lecourt (2003), Beine, Laurent, and Palm (2003), Dominguez (2003b,a, forthcoming), Fatum and Hutchinson (2003), Frenkel, Pierdzioch, and Stadtmann (2005), de Grauwe and Grimaldi (2003), Ito (2003), Taylor (2004), Galati, Melick, and Micu (forthcoming), Fatum and Hutchinson (2006)

[16]Dominguez and Frankel (1993b) discuss the possible reasons that central banks might want to keep their intervention operations secret. Neely (2000) notes that central banks are moving increasingly toward electronic trading methods, which suggests that they are less interested in keeping operations secret. On this topic also see: Vitale (1999), Bhattacharya and Weller (1997), Chiu (2003), Beine, Janssen, and Lecourt (2004), Beine and Bernal (forthcoming). Although the Japanese government does not provide contemporaneous information about their intervention operations, the Ministry of Finance publishes lagged daily intervention data (lagged one month) on their web site http://www.mof.go.jp/english/e1c021.htm.

1.5.1 Issues, Methodology and Data

The financial press often reports over the wire services when a central bank is intervening, though governments rarely officially confirm their presence in the market. Because there is often uncertainty in the market about whether a given government is intervening, there are inevitably circumstances when the financial press reports interventions that have not occurred. There are also frequently reports of what we term, unrequited interventions, interventions that the market expects but do not occur. This chapter examines the effects of various types of intervention news (reported actual interventions, falsely reported interventions, oral interventions and unrequited interventions) on exchange rate behaviour.

The empirical approach we take in this study is based on the assumption that exchange rates are forward looking asset prices that react to changes in the market's expectation of future fundamentals. We further assume that "future fundamentals" may include both standard variables from international macro models (for example, money and income differentials) as well as variables such as actual and unrequited interventions that may provide information about future fundamentals. We use intra-daily exchange rate data to allow a narrow enough window around the times of news announcements to be able to precisely estimate the exchange rate reactions in the spirit of Andersen, Bollerslev, Diebold, and Vega (2003)[17].

For this study we created a unique data set of time-stamped Reuters' newswire reports created to measure intervention news. Our search criteria retrieved

[17]The enormous literature measuring the effects of macro news on intra-daily exchange rates includes Hakkio and Pearce (1985), Ito and Roley (1987), Ederington and Lee (1995), de Gennaro and Shrieves (1997), Almeida, Goodhart, and Payne (1998), Andersen and Bollerslev (1998), Melvin and Yin (2000), Faust, Rogers, Wang, and Wright (2003), Love and Payne (2003), Love (2004), Chaboud, Chernenko, Howorka, Iyer, Liu, and Wright (2004), Bauwens, Omrane, and Giot (2005), Ehrmann and Fratzscher (2005).

newswire articles under the joint subject area of "foreign exchange" and "intervention". We then coded and grouped[18] news articles according to geographic region (Euro-zone, U.K., U.S. or Japan) and type of intervention (threat, rumour, oral, unrequited, actual and joint). Using these time-stamped Reuters' newswire reports we are able to match the timing of intervention news to movements in intra-day exchange rates. We also include scheduled macro announcement news reports which have been used in previous studies to allow us to compare the effects of intervention news against these more "traditional" variables.

The intra-day foreign exchange data used in this study are transactions prices and quote spreads in the USD-EUR, USD-GBP and JPY-USD markets from the Reuters D2000-2 electronic trading system over the period from December 1999 through July 2000. The data do not include information on traded quantities, but they do indicate whether trades were initiated by a buyer or seller, allowing us to measure order flow as well as returns and volatility. We use a 20 minute sampling frequency and measure order flow as the cumulative number of buyer initiated trades minus the cumulative number of seller initiated trades over the same 20 minutes. The intra-day intervention news and exchange rate data allow us to test a number of interesting hypotheses.

1. We test whether intervention news has similar impact effects on returns and volatility as compared to (the already heavily studied) scheduled macro announcements. Theory suggests that ambiguous information may lead to stronger differences of opinion about the implications of the information (and, in turn, larger increases in volatility). In our application, we can distinguish between scheduled (and presumably better-understood) macro

[18] In theory each "news" report may have a different one-time influence on exchange rates. We group similar news items together in order to examine whether certain "types" of intervention news have a systematic influence on exchange rate behaviour.

announcements and more ambiguous intervention news.

2. We also measure what proportion of the price discovery process in reaction to intervention news occurs via order flow. Previous studies have found evidence that a substantial proportion of the market reaction to macro-announcements occurs via order flow. By examining how intervention news events influences order flow - we can begin to better understand how this measure relates to price and volatility movements in the foreign exchange markets.

1.5.2 Main Results and Contribution

This chapter examined whether actual and unrequited intervention news influences exchange rates. Previous studies have found that scheduled macro announcements and official interventions by governments in the foreign exchange market help to explain intra-daily exchange rate behaviour, both returns and volatility.

- Results in this chapter indicate that unrequited intervention news (and even news of "no intervention") has a statistically significant influence on both exchange rate returns and volatility, suggesting that the expectation of intervention, even when governments do not intervene, can affect currency values. These results provide strong evidence in favor of the hypothesis that interventions influence exchange rates via the information or signalling channel.

- We find evidence that order flow has some explanatory power suggesting that prices are, at the very least, slow to adjust. At the same time, we find that actual interventions and our various categories of intervention news

explain a very small fraction of the variation in order flow. Overall, the results indicate that along with actual interventions, other kinds of intervention news (including denials of intervention and unrequited interventions) and order flow matter.

- We do not find evidence that macro surprises have much influence on returns, volatility or order flow over our sample period.

These results suggest that future models of exchange rate determination ought include a broader conception of price relevant "news".

Chapter 2

Exchange Rate Volatility and Central Bank Interventions

2.1 Introduction

This chapter studies the impact of Swiss National Bank (SNB) interventions, and news about these interventions, on the intraday volatility of the Swiss franc - U.S. dollar (CHF-USD) exchange rate.

While the effectiveness of interventions is important to policy makers, the consensus on the effectiveness has changed several times over the years. In the early 1970s and early 1980s it was believed that authorities could not affect the exchange rate while in the late 1970s, late 1980s and the early 1990s the view was that the authorities should intervene (see review by Sarno and Taylor (2001)). Recently, interventions have been frequent for some currencies, like the euro and especially the yen, but infrequent for other major currencies.

Theoretically there are two standard models describing the effect of sterilised central bank interventions on exchange rates, the portfolio balance model and

the signalling model. The portfolio balance approach is based on the idea that a sterilised intervention causes market players to change the composition of their portfolios by buying or selling foreign assets, which in turn leads to a change in the relative price of domestic assets and foreign assets i.e. the exchange rate. If domestic and foreign assets are perfect substitutes, then sterilised intervention cannot work via the portfolio balance channel. The signalling model, popularised by Mussa (1981), takes the view that agents interpret interventions as signals of future monetary policy, making the exchange rate sensitive to changes in the expectations of future variables. For the signalling channel of intervention to work, transparency of interventions and credibility of the central bank are crucial[1]. Thus theoretically both models, portfolio balance and signalling, predict that sterilised intervention can be effective.

The empirical literature on the portfolio balance model is not only scarce, but also finds very little evidence in favour of the model (exceptions to this are Dominguez and Frankel (1993a), Evans and Lyons (2001)). This literature provides little support for significant imperfect substitution of domestic and foreign assets. Empirical evidence on the signalling model is mixed with some evidence for (Dominguez and Frankel (1993a,b), Vitale (1999) lists papers which suggest that central bank interventions are informative about future monetary policy) and some evidence against (Dominguez (1992a), Kaminsky and Lewis (1996))[2].

[1]Related to the effectiveness of interventions via the signalling channel is the secrecy puzzle. The signalling channel should work better under transparency but until very recently interventions have been secret. This has prompted researchers to suggest that central banks might intervene secretly if their objectives conflict with the fundamental value of the exchange rate (Bhattacharya and Weller (1997) and Vitale (1999)). However, the two papers differ on the concealment of interventions with Vitale (1999) claiming that the goals of the intervention should never be revealed while Bhattacharya and Weller (1997) conclude that under certain conditions central banks may prefer to reveal their objectives.

[2]Edison (1993) provides a review of the empirical literature on the effectiveness of central bank interventions. For references to recent low frequency work on the effectiveness of interventions see Chang and Taylor (1998).

Most of this evidence is based on low frequency data. Using daily data Chaboud and LeBaron (1999) study the impact of interventions by the Federal Reserve on trading volume for dollar-yen and dollar-mark futures markets and find a positive correlation between them. This positive relationship survives even after conditioning for daily volatility. The effect is stronger for secret interventions but weaker for Reuters reports about the interventions. Recently, access to disaggregated data on interventions has made it possible to test the signalling hypothesis within the market microstructure approach to exchange rates[3]. In this framework central banks are viewed as informed players in the market and their trades (interventions) are expected to affect the price (exchange rate) since they reveal this information to the market. Assessing effectiveness based on central bank profits from intervention, Goodhart and Hesse (1993) find that interventions are profitable in the long run but not in the short run. Chang and Taylor (1998) examine the effect of Bank of Japan interventions on the Japanese yen - U.S. dollar (JPY-USD) exchange rate. They find that interventions have a significant positive impact on volatility, with the largest impact thirty to forty five minutes prior to the Reuters news report about the intervention (Reuters reports are used as a proxy for actual intervention)[4]. The data set used in the current chapter is an improvement on that in Chang and Taylor (1998) since it consists of actual intervention data from the SNB and Reuters news reports about these interventions, allowing me to separate the effect of the intervention on volatility from the effect of the news. In addition to observing significant intervention effects on the level of the CHF-USD exchange rate Fischer and Zurlinden (1999) find that the

[3]Prior to this interventions were inferred from changes in international reserves. This is an inaccurate proxy given that reserves are affected by interest receipts, valuations changes and sometimes do not include intervention transactions at all

[4]Using SNB intervention data and Reuters reports Fischer (2003) finds that the latter are not good proxy for the former and hence Reuters reports need to be used with caution.

time of the intervention may play an important role in the effectiveness of the intervention. While they use actual foreign exchange transactions data from the SNB which include information on the transacted amount, price and time of day, they do not have exchange rate data to match. So they proxy the change in the exchange rate by the difference between the exchange rates of two consecutive interventions.

Faust, Rogers, Wang, and Wright (2003) study the effect of macroeconomic announcements on high frequency exchange rates (US dollar-Deutsche mark, US dollar-Euro and US dollar-British pound) and interest rates. They find that "stronger-than-expected" announcements lead to significant dollar appreciation. Using data on interest rates and interpreting results in the context of uncovered interest parity, they infer that "such releases either lower the risk premium for holding foreign currency or imply future expected dollar depreciation". Dominguez (2003b) studies intraday and daily effects of dollar interventions by G3 governments on exchange rate volatility. The underlying premise in the paper is that heterogeneity in trader's information can cause exchange rates to move away from fundamentals in the short run and if these heterogeneous traders interpret interventions differently, then interventions might actually increase volatility in the short run. She finds that interventions are associated with increases in intraday and daily volatility, but there is not much evidence that intervention affects long term volatility. Payne and Vitale (2003) expand on the results from Fischer and Zurlinden (1999) by including intraday indicative exchange rate quotes. They find that intervention has significant short run effects on the level of the exchange rate. Additionally, using the absolute value of the of exchange rate return as a measure of volatility, they find that in anticipation of the intervention and at the time of the intervention volatility increases but starts decreasing from

15 minutes after and the effect is completely reversed over the next 90 minutes.

This chapter extends the existing literature by characterising the impact of central bank interventions on exchange rate volatility based on different aspects of interventions including direction, quantity, frequency and time of intervention. It asks the questions: Do interventions have an impact on exchange rate volatility? Do buy and sell interventions have different effects on volatility (direction)? Do larger interventions mean lower volatility (quantity)[5] If there is a size effect, is it linear or non-linear? If central banks do want to intervene, should they do so in one shot or via repeated interventions (frequency)? Does one large intervention have a different effect than a set of smaller more frequent interventions i.e. is there any interaction between quantity and frequency? Do interventions affect volatility more or less when they are carried out during periods of high trading volume, for example, market opening and closing times (timing of intervention)?

The second aspect this chapter considers is how markets react to news about interventions: Does news about interventions calm markets or make them volatile? Is this news important relative to the actual intervention? If the news report appears before the intervention, does the actual intervention have any effect? On the other hand, if the news report appears after the intervention (or is missed), does the actual intervention have a larger and/or more persistent impact?

To analyse these questions I use an event study methodology and high frequency data on the CHF-USD exchange rate, interventions by the SNB and

[5]It would not be surprising if there is no size effect given the large daily turnover in foreign exchange markets. In April 1998 the daily turnover in traditional foreign exchange instruments (spot, forwards and swaps) was $1.5 billion and in OTC foreign exchange derivatives it was $97 billion. Even though the turnover declined between 1998 and 2001, it was $1.2 billion in traditional foreign exchange instruments and $67 billion in OTC foreign exchange derivatives. Approximately 5% of the global transactions in the forex market are accounted for by trading in CHF-USD. This makes it the fourth most traded currency pair. Source: Pasquariello (forthcoming) and the BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity (1999).

Reuters reports of these interventions. As mentioned above this data allows more reliable analysis since I use actual interventions (and not proxies based on international reserves or Reuters reports), volatility measures based on changes in indicative quotes of the exchange rate (and not proxies based on intervention transaction price) and Reuters news reports that allow me to separate the effect of the intervention on volatility from the effect of the news.

Briefly, the chapter finds that the effect of intervention on volatility varies depending on how volatility is defined. Interventions decrease volatility contemporaneously but this effect is reversed in the two hours afterward. This relationship is symmetric with respect to the direction of the intervention, whether they be buy and sell interventions or with-the-wind and against-the-wind interventions. Analysis of the volatility and intervention quantity relationship finds that as we move from small to large interventions, the larger interventions tend to increase volatility more than small interventions. The frequency of interventions has a small but positive impact on volatility, and this is underscored when the analysis is done by splitting the sample into low, average and high frequency interventions. The interaction between intervention quantity and intervention frequency results in a small positive effect on volatility for the squared return measure and the absolute return measure and a negative effect for both the realised volatility measures this effect is negative. As before the effect of the timing of the intervention varies with the volatility measure. The relationship is different for interventions at different times of the day. For the two realised volatility measures 9am interventions reduce volatility while for the other two measures the significant coefficients have an overall positive effect increasing volatility. 2pm interventions decrease volatility for both the squared return measures but increase volatility for both the absolute return measures. Reuters reports of sell

interventions have a significant and lagged negative effect on volatility for the squared return measure and both the absolute return measures.

The data are described in Section 2.2 along with some descriptive statistics on the exchange rate and the intervention series. Section 2.3 describes the methodology briefly, Section 2.4 presents the results and Section 2.5 concludes.

2.2 Data

The data covers the time period 07 Oct 1986 to 15 Aug 1995 and comprises of three components. The first component of the data consists of intraday indicative quotes of the CHF-USD exchange rate at a 15 minute frequency and are provided by Olsen & Associates (Zurich). The second component of the data is the SNB interventions. These interventions were conducted in the CHF-USD market and are time stamped to the exact time of the intervention. Also included is information on the size and direction of the intervention (whether the SNB was buying US dollars or selling US dollars)[6]. The final component of the data is news reports of central bank interventions based on Reuters headlines[7]. The interventions and news reports data are aggregated to 15 minute frequency to match the exchange rate data.

A plot of the exchange rate along with the interventions is in Figure 2.1. Eye-balling the figure it appears that the SNB is following an against-the-wind intervention policy for the majority of the time. Eye-balling the plot of the four volatility measures for an average non-intervention day in figure 2.2, it is clear that there is a distinct intraday pattern in volatility. This is motivation for

[6]An example of a typical data point would be 'SNB bought US dollars 5 million on 05 June 1990 at 10:49 a.m.'.

[7]This data is from Kathryn Dominguez and covers headlines on all days when the Federal Reserve was in the market.

deseasonalising the exchange rate volatility series before analysing it, an issue that is discussed in Section 2.3.

The SNB's intervention strategy consisted of conducting a number of small interventions in a short period of time and the majority of these were in conjunction with the Federal Reserve (Fed) and/or the Bundesbank (Buba). Based on quotes gathered from commercial banks, SNB interventions were conducted in the dealer market. And while the SNB informed the counter-party on completion of the transaction that it was an intervention, it did not publicly announce that it had intervened[8]. It is worth pointing out that in any given intervention episode, the SNB either bought dollars or sold dollars, but never did both. From Table 2.1 we see that the SNB intervened 171 times over 97 days. They bought US dollars on 70 occasions (over 33 different days) and sold US dollars on 101 occasions (over 64 days). figure 2.3 provides further description of the interventions. The SNB intervened more frequently in the early years of the sample but these interventions seem equally spread out during the week (figures 2.3a and 2.3b). figures 2.3c and 2.3d reiterate the point that the SNB intervened frequently and in small quantities rather than intervening a large amount in a single trade. figure 2.3e is very interesting since it shows a bimodal distribution of interventions by time of day. Interventions are most often at 9am and 2pm GMT (Greenwich Mean Time) and can be interpreted as being timed to coincide with the opening of the London and New York markets respectively. These are typically times when trading volumes are high, indicating a possibility that the SNB might be trying to hide its trades from the market[9]. At this point it is worth noting that these data contains no information on whether the interven-

[8]For a more detailed description of the SNB's intervention strategy look at Fischer (2003).

[9]Admati and Pfleiderer (1988), Easley and O'Hara (1987) provide theoretical underpinnings for informed traders' incentives to trade when volumes are high.

tion was conducted jointly with another central bank or singly. Any information on joint interventions was retrieved from Reuters reports. Reuters news reports have been used in numerous microstructure papers analysing interventions and are now a standard way of inferring when the market received information about interventions[10]. Most of this research assumes that the reports are released just after the intervention and typically, the time stamp on the report is taken to be the time the market learned about the intervention. Fischer (2003) carries out tests of the accuracy of these reports for SNB interventions. He finds that there are large prediction errors between Reuters reports and the actual interventions, stemming in part from the fact that it is possible for reports to be released before the intervention in some cases and after the actual intervention in others. So clearly, any results based on these reports must be viewed with caution. Since the Reuters news reports data start in Sept 1989, only a sub-sample (Sept 1989 to Aug 1995) of the interventions data is used to match the Reuters news data. Table 2.3 provides a description of the Reuters reports data[11]. The Reuters reports indicate that the SNB bought US dollars on 16 occasions (of which 11 were joint interventions) and sold US dollars on 19 occasions (of which 15 were joint interventions). Comparing this with the information from the SNB it appears that Reuters falsely reports the SNB buying US dollars on 5 occasions and misses 28 occasions when the SNB sold US dollars[12].

[10]Goodhart and Hesse (1993), Chang and Taylor (1998), Fischer and Zurlinden (1999), Dominguez (2003b,a), Payne and Vitale (2003) are some other papers that have used Reuters news reports on interventions.

[11]An example of a Reuters report - 'Swiss National Bank buys dollars for francs in concerted intervention with Fed'.

[12]It is worth noting here that if there is a report corresponding to the first intervention of an episode it might be possible that the other interventions in the same episode are anticipated by the market, given the SNB's intervention implementation technique of small frequent interventions. So these interventions should be considered as reported even if there are no additional Reuters reports.

2.3 Measuring Exchange Rate Volatility

I use an event study approach to analyse the impact of various intervention characteristics on exchange rate volatility[13]. Four different measures of volatility are used in the analysis. Squared returns, absolute returns and two measures of realised volatility, sum of the squared returns for the past hour and the sum of the absolute returns for the past hour[14]. Returns are calculated as the log difference of the exchange rate series. There are two points I would like to raise at this stage. First, given that the realised volatility variable has a lag structure, the independent variables will have lagged effects on the dependent variable by definition. Secondly, it is widely recognised that seasonal patterns exist in high frequency exchange rate volatility and there is evidence of this in the data used in this chapter as well (see figure 2.2). While the simplest method to control for seasonality would be to include a dummy variable for every 15-minute interval in the day[15], I use Flexible Fourier Forms (FFF) to adjust for seasonality[16]. Intuitively, this method captures seasonality in a non-linear way by taking combinations of periodic components (sine and cosine curves) at different frequencies. For each 15-minute interval indexed by 'j' the volatility seasonal is calculated by

[13]Time series methods are not built to capture the effects of unequally spaced events like interventions. Fatum and Hutchinson (2003) argue that the event study methodology is more appropriate in such cases, where an event is defined as one episode of interventions. Other papers conducting event studies in this context are Chang and Taylor (1998), Fischer and Zurlinden (1999), Payne and Vitale (2003), Dominguez (2003b,a).

[14]These are standard ways of measuring volatility (also used in Payne and Vitale (2003), Dominguez (forthcoming), Andersen and Bollerslev (1997b)).

[15]However this would mean an additional 96 right-hand side variables.

[16]Other papers using FFF in this context are Andersen and Bollerslev (1997b), Payne (1996), Dominguez (forthcoming). For a text book description of the method refer to chapter 6 (Spectral Analysis) in Hamilton (1994).

estimating the following equation over all non-intervention days[17],

$$s_j = c + \sum_{k=1}^{P} \left[\lambda_{2k-1,j} \cos k(\frac{2\pi j}{N}) + \lambda_{2k,j} \sin k(\frac{2\pi j}{N}) \right] \tag{2.1}$$

where j = 1,...,96 and N is the number of return intervals per day (96 in this data).

The parameter 'P' controls the number of periodic components used[18]. figure 2.2 graphs the average realised volatility pattern on non-intervention days along with the fitted FFF.

The dependent variable for all further analysis is the deseasonalised volatility, which is the residual from regressing the volatility variable on the estimated seasonal components. The independent variables are leads and lags of dummy variables corresponding to the different intervention characteristics.

2.4 Results

All regressions are run on a sample of 18621 observations spaced at 15-minute frequency. The data include all 171 interventions over 97 days in the period Oct 1986 to Aug 1995 and are combined with a control sample of non-intervention days to make up the final data set. The control sample was constructed by randomly choosing a non-intervention day that matched the day of week and the year of a given intervention day. The regressions were run for four different

[17]Volatility on intervention days may differ from that on non-intervention days. Using only non-intervention days to capture the seasonal pattern avoids explaining away any intervention day effects by imputing them in the seasonal. Different seasonal components are computed for each of the four different definitions of volatility.

[18]These results are based on P = 8. Varying P to take different values (4, 6, 8, 10) did not affect the fit of the FFF to the data. Dominguez (forthcoming) uses P = 8 for DEM-USD and YEN-USD data for the period Aug 89 - Aug 1995 while Andersen and Bollerslev (1997b) use P = 6 for DEM-USD data for the period 1992-93.

definitions of volatility - squared returns, absolute returns, realised volatility based on squared returns and realised volatility based on absolute returns.[19].

2.4.1 SNB Interventions

To confirm that interventions have an impact on exchange rate volatility the deseasonalised volatility series is regressed on 8 leads and lags of an intervention indicator which takes value 1 when there is an intervention (buy or sell) and is 0 otherwise. The results in Table 2.4 show that there is an intervention effect but it depends on how volatility is defined. There is a significant contemporaneous decline in volatility but only when it is defined as realised volatility. However, in the two hours after the intervention we observe that the majority of the significant coefficients are positive indicating that the effect is reversed[20].

2.4.2 Direction

Having established that depending on how you define it, volatility reduces contemporaneously with an intervention but increases afterward, the next step is to ascertain the relationship between the direction of the intervention and volatility. Do buy interventions have a different impact than sell interventions? In this chapter a buy (sell) intervention refers to the SNB buying (selling) U.S. dollars which would lead to a depreciation (appreciation) in the Swiss franc.

[19]In all the regressions I include two lags of the dependent variable. Newey-West corrected standard errors are used to account for heteroskedasticity and serial correlation usually found in high frequency financial data.

[20]This is in line with previous empirical work in the area. Chang and Taylor (1998), Dominguez (forthcoming) find a positive relationship between intervention and volatility; Chaboud and LeBaron (1999) find a positive relationship between intervention and trading volume.

This hypothesis is tested explicitly based on the following regression[21].

$$\begin{aligned} vol_t = & \quad \alpha + \sum_{j=-8}^{8} \beta_j \ (B_{t+j} + S_{t+j}) + \sum_{k=-8}^{8} \gamma_k \ S_{t+k} + \theta_1 \ vol_{t-1} + \theta_2 \ vol_{t-2} + \varepsilon_t \\ = & \quad \alpha + \sum_{j=-8}^{8} \beta_j \ B_{t+j} + \sum_{k=-8}^{8} (\beta_k + \gamma_k) \ S_{t+k} + \theta_1 \ vol_{t-1} + \theta_2 \ vol_{t-2} + \varepsilon_t \end{aligned} \tag{2.2}$$

where B_t and S_t are dummy variables for buy and sell interventions respectively.

Crucially, this regression tests whether $\gamma_k \neq 0$. A non-zero γ_k coefficient implies that buy and sell interventions have different relationships with volatility. Regression results in Table 2.5 show that almost all the γ_k are insignificant, implying that buy and sell interventions have similar effects on volatility. The few significant γ_k coefficients are positive, indicating that at these lags sell interventions reduce volatility by less than buy interventions.

Another interesting directional aspect is whether against-the-wind and with-the-wind interventions have different effects on volatility. Eye-balling figure 2.1 and Table 2.2, it appears that the SNB intervenes against-the-wind more often than with-the-wind, presumably to calm markets. Against-the-wind and with-the-wind indicators are calculated based on 1 day, 1 week, 2 week and 4 week moving averages and a specification similar to Eqn. (2.2) is used to test if their correlation with volatility is asymmetric. Results show that almost all the gamma coefficients are insignificant, implying that against-the-wind and with-the-wind interventions have similar effects on exchange rate volatility[22].

[21] In later sections, the same specification is used to test if other characteristics of interventions have asymmetric effects on volatility.

[22] Due to constraints of space the results are not presented here.

2.4.3 Quantity

We now turn to investigating the effect of the size of an intervention on exchange rate volatility. A priori if we believe that central banks intervene to calm markets then we would expect the size of the intervention and volatility to be negatively correlated. On the other hand, it would not be surprising to find that central bank interventions, which are typically small relative to the daily turnover in foreign exchange markets[23] do not affect volatility. Finally, some microstructure models (Kyle (1985)) predict a positive relationship between intervention quantity and volatility since the central bank's (informed trader) demand is expected to move price (the exchange rate). So, what does the data tell us about the relationship between intervention quantity and volatility? Is this relationship linear or non-linear? To this end I regress the four volatility measures on indicators for intervention, quantity and squared intervention quantity. When there is an intervention, the quantity indicator variable is equal to the absolute amount of the intervention, and is zero otherwise. A squared quantity indicator is constructed along similar lines. The regression results presented in Table 2.6 show that for the absolute return based volatility measures intervention quantity has a lagged negative effect on volatility which would lend support to the idea that central banks intervene to calm markets. On the other hand, for the realised volatility based on squared returns there is no effect at all while for the squared return measure the lagged effect is positive. If we believed that interventions are informative trades then, we would expect an increase in volatility as the mar-

[23]In April 1998 the daily turnover in traditional foreign exchange instruments (spot, forwards and swaps) was $1.5 billion and in OTC foreign exchange derivatives it was $97 billion. Even though the turnover declined between 1998 and 2001, it was $1.2 billion in traditional foreign exchange instruments and $67 billion in OTC foreign exchange derivatives. Approximately 5% of the global transactions in the forex market are accounted for by trading in CHF-USD. This makes it the fourth most traded currency pair. Source: Pasquariello (forthcoming) and the BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity (1999).

ket absorbs this new information. However, if we consider the realised volatility measure, we find a small, negative effect. So again, the effect of the size of an intervention on volatility depends on how volatility is defined. Looking at the coefficients on squared quantity we see that only a few are significant (at lead 8, contemporaneously and then at lags 5, 6) and these are very small[24] indicating that the size effect might be non-linear but that this non-linearity is small[25].

I analyse the volatility and intervention quantity relationship further by estimating the effect of small, average and large quantity interventions on volatility[26]. Results in Table 2.7 indicate that as we move from small to large interventions the positive coefficients on interventions decrease and the negative coefficients increase. This means that larger interventions tend to increase volatility more than small interventions which is counter intuitive. One possible explanation could be that the market interprets larger intervention quantities as signals that the central bank trying to push the exchange rate unsuccessfully, and this negative signal leads to higher volatility.

2.4.4 Frequency

Frequency is the next characteristic of intervention we turn to. How is volatility affected by a continued presence of the central bank in the market relative to a one-off trade? The regression results in Table 2.8 indicate that the frequency effect differs across the different volatility measures. The sum of the significant

[24]This might be explained by the much larger scale of squared quantity relative to the volatility measures.

[25]Payne and Vitale (2003) find that the size effect on the level of the exchange rate is non-linear but that this non-linearity is not economically significant.

[26]Small interventions are defined as sales or purchases of up to 5 million US dollars, Average interventions as between 5 and 10 million US dollars and Large interventions are those that are larger than 10 million US dollars. With this classification there are 27 small, 26 average and 5 large interventions.

coefficients is small and positive indicating that more frequent interventions increase volatility. However, given that the coefficients are very small this could also be interpreted as the frequency of intervention actually having no relationship with volatility i.e. that the regression has estimated a significant coefficient of zero. Alternatively, it could be caused by the fact that the scale of the volatility measures is much smaller than that of the frequency variable and hence the estimated coefficient is small but non-zero. Finally, this might be the result of some kind of threshold effect i.e. if the central bank is in the market for long, this could be interpreted positively by the market to mean that the central bank is determined to achieve its goal or it could be interpreted negatively, sending a signal that the central bank is in a losing battle. To test this I estimate the effect of low, average and high frequency interventions using the following specification[27].

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \, I_{t+i} + \sum_{j=-8}^{8} \gamma_j \, LF_{t+j} + \sum_{k=-8}^{8} \delta_k \, AF_{t+k} + \sum_{l=-8}^{8} \phi_l \, HF_{t+l} + ... \\ \theta_1 \, vol_{t-1} + \theta_2 \, vol_{t-2} + \varepsilon_t \tag{2.3}$$

The results in Table 2.9 indicate that low frequency interventions have virtually no effect on volatility while average and high frequency interventions have a small, significant and positive effect on volatility. This result would support the view that markets interpret the continued presence of the central bank in the market as the central bank fighting a losing battle and this increases volatility.

[27]For a given 15 minute interval, the indicator for Low frequency interventions takes value 1 when there are between 1 and 6 interventions (44 data points), the Average frequency indicator takes the value 1 when there are between 7 and 12 interventions (12 data points), and the Large frequency indicator is 1 when the SNB intervenes between 13 and 18 times (2 data points).

2.4.5 Quantity and Frequency

We are now interested in the combined effect of the size and the frequency of interventions. From figures 2.3c and 2.3d we can see that the SNB's preferred strategy for intervention has been frequent interventions of small quantities. In the last two sections we saw that large size and high frequency intervention episodes increase volatility. Practically, we are asking do 5 interventions of US dollars 10 million each have the same effect on volatility as one intervention of US dollars 50 million? The results of regressing the volatility measure on intervention quantity, intervention frequency and a quantity-frequency interaction term are in Table 2.10. The sum of the significant quantity coefficients is positive for all except the absolute return measure confirming again that the larger the intervention, the higher the volatility. Almost all the frequency coefficients are insignificant[28]. The few quantity-frequency interaction coefficients that are significant sum to give a small positive effect for the squared return measure and the absolute return measure. This means that for a given intervention quantity, the higher the frequency of intervention, the higher the volatility. For both the realised volatility measures the sum of the significant coefficients is negative indicating that for a given intervention quantity or intervention frequency, the higher the other characteristic the lower the volatility. Thus the SNB's intervention strategy of small but frequent interventions would be supported by these results only if based on the realised volatility measures.

[28] A possible explanation for this might be the possibility that size and frequency are highly correlated and hence are capturing the same effect.

2.4.6 Time of Intervention

Central banks intervene at their own discretion. figure 2.3e shows that the maximum number of SNB interventions occur at 9am and 2pm GMT. Since the majority of the SNB's interventions were joint with either the Fed or the Buba or both[29], it is possible that the SNB timed its interventions to coincide with the opening of the London market and/or the New York market. The interesting question then is, do interventions at different times of the day have different effects on volatility? I test this by splitting the sample of interventions into two sets, those at 9am (London open) and those at 2pm (New York open). The results of regressing exchange rate volatility on these two variables plus a dummy variable to control for joint interventions are in Table 2.11. As before the effect of the timing of the intervention varies with the volatility measure. For the two realised volatility measures 9am interventions reduce volatility while for the other two measures the significant coefficients have an overall positive effect increasing volatility. 2pm interventions decrease volatility for both the squared return measures but increase volatility for both the absolute return measures.

A possible explanation for the positive coefficients is that at opening times there is increased uncertainty in the market and hence increased volatility. Alternatively, it could also be that the FFF seasonal has failed to capture the opening time volatility well enough.

Additionally, interventions were combined into morning and afternoon interventions[30] and their effect on volatility was assessed in a regression similar to Eqn. (2.2). The results[31] show that morning and afternoon interventions have a

[29]Table 2.3 gives the number of interventions joint with the Fed only, the Buba only and joint with both the Fed and the Buba.

[30]Morning interventions include those from 7am to 10am and afternoon interventions include interventions from 1pm to 4pm.

[31]Available on request

similar effect on volatility since nearly all the gamma coefficients are insignificant.

2.4.7 All Characteristics

In an effort to assess the combined effect of these different characteristics the volatility measures were regressed on the dummy variables for intervention, intervention quantity, frequency, a quantity-frequency interaction term, 9am interventions, 2pm interventions, interventions joint with the Fed and interventions joint with the Bundesbank. Again the results, presented in Table 2.12, depend on the choice of volatility measure but the measures are most responsive to interventions that are joint with the Fed, 2pm interventions and the size of the intervention. Counter intuitively, interventions that are joint with the Fed increase volatility for all measures except the squared return measure for which it decreases volatility. For the squared return and absolute return measures interventions that are joint with the Buba, 9am and 2pm interventions and the quantity-frequency interaction term all increase volatility but the size of the intervention and the frequency of the intervention decreases volatility. For the two realised volatility measures interventions that are joint with the Buba, the size and the frequency of the intervention all increase volatility while 2pm interventions and the quantity-frequency interaction term both decrease volatility and 9am interventions have no effect on volatility. So if the SNB used the realised volatility measures we would expect to see them intervening in small quantities frequently or in one shot with a large quantity and they would time the intervention at 2pm GMT. If you used the other two measures, the same strategy would end up increasing exchange rate volatility.

2.4.8 Reuters Reports

Since the data on Reuters reports starts in Sept 1989, only a sub-sample of the interventions data is used to match the Reuters reports data. During the period Sept 1989 to Aug 1995 the SNB bought US dollars on 11 occasions (over 6 different days) and sold US dollars on 47 occasions (over 27 different days)[32].

Regressing the volatility measures on a dummy variable for Reuters reports shows that the news reports have no overall effect on volatility. But splitting into reports of buy interventions and those of sell interventions reveals that reports of buys are mostly insignificant while reports of sell interventions have a negative effect on volatility, mostly anticipated but also with lag for the two realised volatility measures (Table 2.13)[33]. In efficient foreign exchange markets new information should be absorbed into price immediately which makes it puzzling to observe lagged effects of the news on volatility. One possible explanation for observing lagged news effect only for the realised volatility measures is that by construction they have a lagged structure. An alternative view would be that market participants are slow to interpret this new information and so volatility effects are observed with a lag. On the other hand the anticipation effect might be indicative of information leakage before the report is released[34]. These regressions give the impression that reports of buy interventions have a dissimilar impact than reports of sell interventions. However, testing this explicitly indicates that reports of buys and reports of sells do not have a dissimilar relationship with volatility[35].

[32]See Table 2.1.

[33]Only the table with results for the reports of sell interventions is presented here. The results for reports of buy interventions are available on request.

[34]The effects of the timeliness of the news (comparing the timing of the report to the time of the intervention) are investigated further in the next sub-section.

[35]Results are available on request

2.4.9 SNB Interventions and Reuters Reports

Finally, it is interesting to study whether, and how, markets reacts to actual interventions and news about the interventions. Intuitively, if a Reuters report was released before the intervention and if markets were efficient we would expect the intervention to have no impact on volatility since it does not convey new information. If the report is released after the intervention, then it could still have some effect on volatility since some market participants may still be unaware of the intervention. The strength of this effect will depend partly on how soon after the intervention the report is released. So it is interesting to examine the effect of Reuters reports on volatility in the presence of the actual intervention. I regress the volatility series on two dummy variables, one for the actual SNB interventions and the other for Reuters reports.

The results in Table 2.14 indicate that in the presence of the actual interventions, Reuters reports have almost no effect on volatility. For the squared return and both absolute return measures, Reuters reports have a small negative impact on volatility in contrast to the positive effect of the actual interventions. To understand this further I split these regressions into buy interventions and buy reports and sell interventions and sell reports. Looking at Table 2.15 we can see that this result is driven entirely by sell side interventions and reports. Reuters reports of buy interventions have an insignificant impact on volatility in the presence of the actual buy interventions while Reuters reports of sell interventions have a significant, anticipated and lagged, negative impact on volatility.

2.5 Conclusions

This research has conducted an event study using the CHF-USD exchange rate and SNB interventions to study the relationship between the volatility of the exchange rate and the various characteristics of interventions. Additionally, using Reuters reports, it studies the impact of the news of these interventions on volatility. The data set contains information on the size, direction, frequency and the exact time of the intervention making it unique in many ways. The analysis was conducted using four different measures of volatility - absolute returns, squared returns, one hour realised volatility based on absolute returns and one hour realised volatility based on squared returns. The results vary depending on which measure is used but there are some general conclusions that can be drawn. With this rich data set it has been possible to identify that interventions decrease volatility contemporaneously but this effect is reversed in the two hours afterward. Further, the direction of the intervention does not seem to affect volatility. Buy and sell interventions have similar effects on volatility and the same is true for against-the-wind and with-the-wind interventions.

The analysis also identifies a lagged negative effect of intervention quantity for the absolute return based volatility measures which would support the idea that large interventions calm markets. On the other hand, for realised volatility based on squared returns there is no effect at all while for the squared return measure the lagged effect is positive. There is weak evidence of non-linearity in the size effect. Further analysis of the volatility and intervention quantity relationship finds that as we move from small to large interventions, the larger interventions tend to increase volatility more than small interventions which is counter intuitive. This could be explained by the market interpreting larger intervention quantities

as the central bank trying to push the exchange rate unsuccessfully, and this negative signal leads to higher volatility.

The frequency of interventions has a small but positive impact on volatility, and this is underscored when the analysis is done by splitting the sample into low, average and high frequency interventions. While small frequency interventions have no effect on volatility, average and high frequency interventions continue to have a significant positive effect.

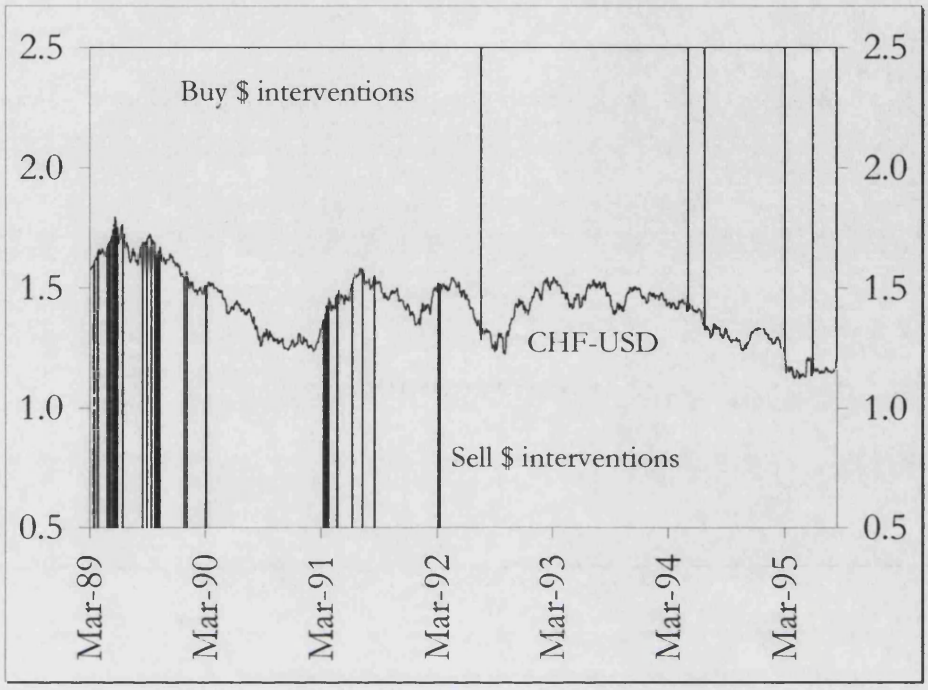
The interaction between intervention quantity and intervention frequency results in a small positive effect on volatility for the squared return measure and the absolute return measure. This means that for a given intervention quantity, the higher the frequency of intervention, the higher the volatility. For both the realised volatility measures this effect is negative indicating that for a given intervention quantity or intervention frequency, the higher the other characteristic the lower the volatility. So results based on the realised volatility measures would lend support to the SNB's intervention strategy of small but frequent interventions.

As before the effect of the timing of the intervention varies with the volatility measure. After controlling for joint interventions with the Fed and the Buba, results show that for the two realised volatility measures 9am interventions reduce volatility while for the other two measures the significant coefficients have an overall positive effect increasing volatility. On the other hand, 2pm interventions decrease volatility for both the squared return measures but increase volatility for both the absolute return measures.

Overall, Reuters reports of interventions do not appear to affect exchange rate volatility. This result appears to be driven by reports of buy interventions since reports of sell interventions have a lagged negative impact on volatility.

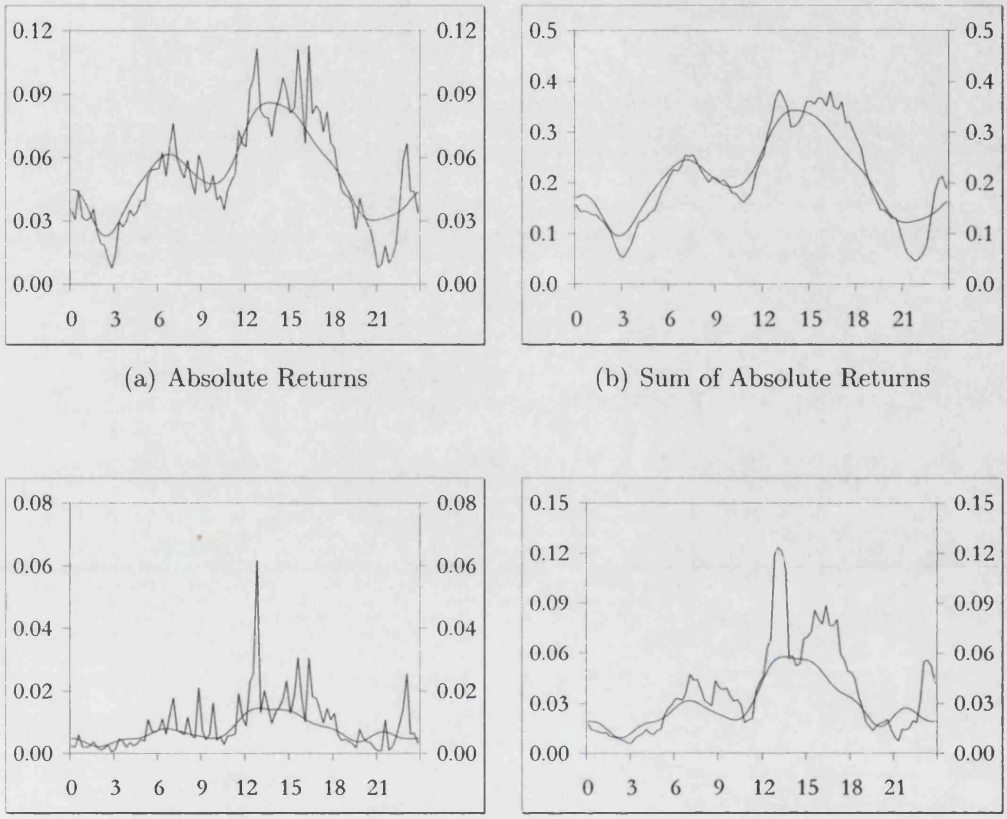
However, explicit testing of the difference of these impacts indicates that they are not dissimilar. Further, tests of the impact of Reuters reports in the presence of actual interventions find that Reuters reports have a small but significant and lagged negative effect on volatility for the squared return measure and both the absolute return measures. This overall effect is driven entirely by reports of sell interventions since reports of buy interventions are insignificant in the presence of buy intervention itself.

Figure 2.1: Swiss franc - U.S. dollar Exchange Rate and SNB Interventions



Notes: The data cover the period from March 1989 to Aug 1995. The currency is defined as the number of foreign currency per dollars and is the daily mid price at noon.

Figure 2.2: Intraday Seasonality and the Flexible Fourier Transform



(a) Absolute Returns

(b) Sum of Absolute Returns

(c) Squared Returns

(d) Sum of Squared Returns

Notes: The data cover the ten year period from 07 Oct 1986 to 15 Aug 1995 and are sampled at 15-minute frequency. The currency is defined as the number of foreign currency per dollars. For each of the four different measures of volatility, the figures plot the average intra-daily pattern of volatility (jagged line) and the Flexible Fourier Form seasonal (smooth line) over a 24-hour period. Volatility is defined as the absolute return, where returns are calculated as 100 times the log difference of the mid quote. The mid quote is calculated as the average of the bid and ask quotes.

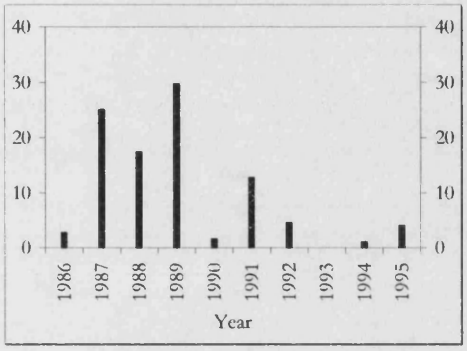
Table 2.1: SNB Interventions

	Number of interventions	Number of intervention days
Oct 86 - Aug 95		
Total	171	97
Buy	70	33
Sell	101	64
Mar 89 - Aug 95		
Total	58	33
Buy	11	6
Sell	47	27

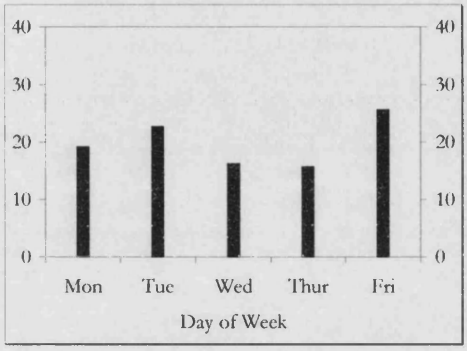
Table 2.2: Intervention Direction

	Moving Average			
	Daily	1 Week	2 Week	4 Week
Oct 86 - Aug 95				
Against-the-wind	86	143	145	146
With-the-wind	85	28	26	25
Mar 89 - Aug 95				
Against-the-wind	18	41	41	39
With-the-wind	40	17	17	19

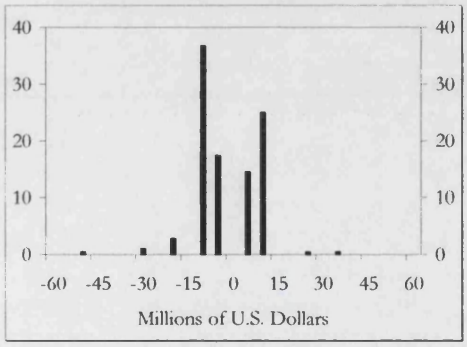
Figure 2.3: Characterising SNB Interventions



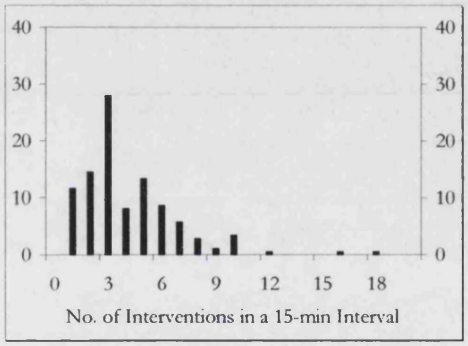
(a) By Year



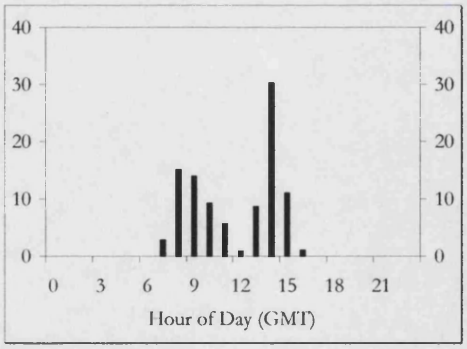
(b) By Day of Week



(c) By Intervention Quantity



(d) By Intervention Frequency



(e) By Time of Day

Notes: The data cover the ten year period from 07 Oct 1986 to 15 Aug 1995.

Table 2.3: Reuters Reports

	Buy	Sell
SNB Interventions	11	47
Reuters Reports		
Total	16	19
of which Joint	4	2
of which Joint with Fed and Buba	1	1
of which Joint with Fed only	2	0
of which Joint with Buba only	1	1
Missed	...	28
False	5	...

Table 2.4: Effect of Interventions on Volatility

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \, I_{t+i} + \theta_1 \, vol_{t-1} + \theta_2 \, vol_{t-2} + \varepsilon_t$$

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0012**	0.0029**	0.0010**	0.0026**
β_{-8}	-0.0058	-0.0087	-0.0015	-0.0017
β_{-7}	0.0022	0.0042	0.0016	0.0069
β_{-6}	-0.0013	-0.0098	-0.0029	-0.0087
β_{-5}	-0.0039	0.0015	-0.0040*	-0.0045
β_{-4}	0.0042	0.0063	0.0045	0.0073
β_{-3}	-0.0020	0.0052	-0.0020	0.0032
β_{-2}	-0.0021	0.0046	-0.0013	0.0053
β_{-1}	-0.0016	-0.0106	-0.0013	-0.0028
β_0	-0.0091*	-0.0208*	-0.0012	0.0017
β_1	-0.0034	-0.0163	-0.0012	-0.0037
β_2	0.0048	0.0156	-0.0004	-0.0041
β_3	0.0267**	0.0287*	0.0017	0.0071
β_4	-0.0362	-0.0056	0.0130**	0.0329**
β_5	0.0112	0.0280*	0.0093*	0.0305**
β_6	0.0292**	0.0269*	-0.0034	-0.0051
β_7	-0.0255	-0.0123	-0.0174*	-0.0053
β_8	0.0721*	0.0695**	0.0674*	0.0607**
θ_1	1.0368**	1.0460**	0.1738**	0.2373**
θ_2	-0.2466**	-0.2057**	0.0819*	0.1349**
Adj R^2	0.7172	0.7697	0.0590	0.1059
$Q(2)$	242.51**	195.39**	13.31**	12.65**
$F-test$	2624.7**	3458.4**	65.88**	123.52**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. I_{t+i} is the intervention indicator which is 1 whenever the SNB intervenes (whether to buy or sell) and 0 otherwise. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Table 2.5: Effect of Direction of Interventions on Volatility - Buy versus Sell Interventions

$$vol_t = \alpha + \sum_{j=-8}^{8} \beta_j \ (B_{t+j} + S_{t+j}) + \sum_{k=-8}^{8} \gamma_k \ S_{t+k} + ...$$
$$\theta_1 \ vol_{t-1} + \theta_2 \ vol_{t-2} + \varepsilon_t$$

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0012**	0.0028**	0.0010**	0.0026**
γ_{-8}	0.0005	-0.0046	0.0035	0.0077
γ_{-7}	0.0109	0.0051	0.0061	-0.0078
γ_{-6}	-0.0012	0.0030	0.0055	0.0141
γ_{-5}	0.0034	-0.0075	-0.0034	-0.0189
γ_{-4}	0.0023	0.0036	0.0058	0.0163
γ_{-3}	0.0045	0.0000	-0.0018	-0.0117
γ_{-2}	0.0053	0.0027	0.0081	0.0116
γ_{-1}	-0.0136	-0.0195	-0.0037	-0.0098
γ_0	-0.0062	-0.0134	0.0030	0.0090
γ_1	0.0132	0.0188	-0.0082	-0.0143
γ_2	0.0127	0.0242	0.0045	0.0076
γ_3	-0.0381	-0.0235	0.0152	0.0160
γ_4	0.1100*	0.0851	0.0157	0.0339
γ_5	-0.0162	-0.0172	-0.0183*	-0.0286
γ_6	-0.0574*	-0.0384	0.0041	-0.0024
γ_7	0.0650	0.0628*	0.0482*	0.0465*
γ_8	-0.1317	-0.0893	-0.1251	-0.0698
θ_1	1.0382**	1.0468**	0.1736**	0.2381**
θ_2	-0.2478**	-0.2060**	0.0836*	0.1352**
Adj R^2	0.7218	0.7706	0.0719	0.1084
$Q(2)$	251.06**	197.21**	13.17**	12.59**
$F-test$	1381.1**	1787.9**	42.26**	65.70**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. B_{t+j} (S_{t+j}) is the buy (sell) intervention indicator which is 1 whenever the SNB buys (sells) US dollars and 0 otherwise. As noted in the main text, the coefficients of interest are the gammas. A non-zero γ_k coefficient implies that the two independent variables have different relationships with volatility. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Table 2.6: Effect of Intervention Quantity on Volatility

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \, I_{t+i} + \sum_{j=-8}^{8} \gamma_j \, |Q_{t+j}| + \sum_{k=-8}^{8} \delta_k \, Q^2_{t+k} + \ldots$$
$$\theta_1 \, vol_{t-1} + \theta_2 \, vol_{t-2} + \varepsilon_t$$

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0012**	0.0029**	0.0010**	0.0026**
β_{-8}	-0.0052	-0.0009	0.0064	0.0331*
β_{-7}	0.0038	-0.0057	0.0055	0.0095
β_{-6}	-0.0026	-0.0141	-0.0112**	-0.0323*
β_{-5}	-0.0061	0.0056	-0.0083	-0.0176
β_{-4}	0.0067	0.0053	0.0127	0.0318
β_{-3}	-0.0049	0.0158	-0.0041	0.0066
β_{-2}	0.0000	-0.0097	-0.0039	-0.0089
β_{-1}	-0.0093	-0.0357	-0.0084	-0.0277
β_0	0.0014	0.0276	0.0062	0.0337
β_1	0.0140	0.0018	-0.0034	-0.0238
β_2	-0.0210	-0.0104	-0.0052	0.0038
β_3	0.0191	0.0283	0.0006	0.0153
β_4	-0.0683	-0.0791	-0.0006	0.0059
β_5	-0.0236	-0.0102	-0.0202	-0.0174
β_6	0.0848*	0.0920*	0.0077	0.0029
β_7	-0.0639	-0.0692	-0.0156	-0.0159
β_8	0.1278	0.1425	0.1039	0.1229
γ_{-8}	-0.0006	-0.0028	-0.0013	-0.0056**
γ_{-7}	-0.0003	0.0015	-0.0006	-0.0004
γ_{-6}	0.0003	0.0006	0.0012*	0.0034
γ_{-5}	-0.0001	-0.0018	0.0003	0.0006
γ_{-4}	0.0000	0.0012	-0.0009	-0.0027
γ_{-3}	0.0001	-0.0027	0.0002	-0.0010
γ_{-2}	-0.0003	0.0026	0.0003	0.0022
γ_{-1}	0.0016	0.0048	0.0010	0.0035
γ_0	-0.0018	-0.0075*	-0.0011	-0.0048*
γ_1	-0.0027	-0.0028	0.0005	0.0038
γ_2	0.0041	0.0042	0.0005	-0.0016
γ_3	0.0008	-0.0007	-0.0004	-0.0027

Table 2.6: Contd.

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
γ_4	0.0037	0.0092	0.0021	0.0040
γ_5	0.0051	0.0063	0.0045*	0.0076*
γ_6	-0.0086	-0.0114*	-0.0025	-0.0027
γ_7	0.0051	0.0075	-0.0007	0.0006
γ_8	-0.0068	-0.0094	-0.0042	-0.0079
δ_{-8}	0.0000	0.0001**	0.0000*	0.0002**
δ_{-7}	0.0000	-0.0001	0.0000	0.0000
δ_{-6}	0.0000	0.0000	0.0000*	-0.0001
δ_{-5}	0.0000	0.0001	0.0000	0.0001
δ_{-4}	0.0000	-0.0001	0.0000	0.0000
δ_{-3}	0.0000	0.0001	0.0000	0.0000
δ_{-2}	0.0000	-0.0001	0.0000	0.0000
δ_{-1}	-0.0001*	-0.0002*	0.0000	-0.0001
δ_0	0.0001*	0.0002**	0.0000	0.0001*
δ_1	0.0001	0.0001	0.0000	-0.0001**
δ_2	-0.0001*	-0.0001	0.0000	0.0001
δ_3	0.0000	0.0001	0.0000	0.0001*
δ_4	0.0000	-0.0001	-0.0001	-0.0001
δ_5	-0.0001	-0.0002	-0.0001**	-0.0002**
δ_6	0.0002*	0.0004**	0.0001*	0.0002
δ_7	-0.0001	-0.0001	0.0000	0.0000
δ_8	0.0001	0.0001	0.0000	0.0001
θ_1	1.0371**	1.0474**	0.1736**	0.2378**
θ_2	-0.2468**	-0.2068**	0.0829*	0.1364**
Adj R^2	0.7176	0.7705	0.0600	0.1092
$Q(2)$	244.00**	197.88**	13.27**	12.18**
$F-test$	911.03**	1203.0**	23.86**	44.93**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. I_{t+i} is the intervention indicator which is 1 whenever the SNB intervenes (whether to buy or sell) and 0 otherwise. $|Q_{t+j}|$ is the absolute magnitude of US dollars bought or sold by the SNB and Q^2_{t+k} is the squared quantity. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Table 2.7: Effect of Intervention Quantity on Volatility: Small, Average and Large Quantity Interventions

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \, I_{t+i} + \sum_{j=-8}^{8} \gamma_j \, SQ_{t+j} + \sum_{k=-8}^{8} \delta_k \, AQ_{t+k} + \ldots$$
$$\sum_{l=-8}^{8} \phi_l \, LQ_{t+l} + \theta_1 \, vol_{t-1} + \theta_2 \, vol_{t-2} + \varepsilon_t$$

	Volatility Measure (sum of all coefficients)			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0012**	0.0029**	0.0010**	0.0026**
β	-0.0487	-0.1574	-0.0550	-0.2100
γ	0.0186	0.0468	0.0211	0.0620
δ	0.0113	0.0261	0.0121	0.0332
ϕ	0.0052	0.0156	0.0047	0.0157
θ_1	1.0368**	1.0468**	0.1735**	0.2375**
θ_2	-0.2464**	-0.2061**	0.0823*	0.1365**
Adj R^2	0.7177	0.7707	0.0600	0.1096
$Q(2)$	243.47**	198.12**	13.28**	12.32**
$F-test$	687.11**	908.25**	18.24**	34.25**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. The table shows the sum of all coefficients. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. SQ_{t+j} is an indicator for small magnitude interventions which are defined as sales or purchases of up to 5 million US dollars, AQ_{t+k} is an indicator for interventions between 5 and 10 million US dollars and LQ_{t+l} is an indicator for interventions that are larger than 10 million US dollars. With this classification there are 27 small, 26 average and 5 large interventions. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Table 2.8: Effect of Intervention Frequency on Volatility

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \, I_{t+i} + \sum_{j=-8}^{8} \gamma_j \, F_{t+j} + \theta_1 \, vol_{t-1} + \theta_2 \, vol_{t-2} + \varepsilon_t$$

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0012**	0.0028**	0.0010**	0.0026**
β_{-8}	0.0047	0.0229	0.0002	0.0073
β_{-7}	-0.0053	-0.0077	-0.0028	0.0019
β_{-6}	-0.0079*	-0.0331*	-0.0026	-0.0069
β_{-5}	-0.0041	-0.0044	-0.0030	-0.0048
β_{-4}	-0.0069	-0.0187	-0.0092*	-0.0291**
β_{-3}	-0.0034	0.0092	-0.0033	-0.0018
β_{-2}	0.0038	0.0267	0.0006	0.0179
β_{-1}	0.0002	0.0028	-0.0015	0.0004
β_0	0.0022	-0.0025	-0.0030	-0.0021
β_1	-0.0197**	-0.0502**	-0.0032	-0.0125
β_2	-0.0265**	-0.0407**	-0.0096*	-0.0189
β_3	0.0124	0.0001	-0.0114	-0.0210
β_4	-0.0275	-0.0075	-0.0147	-0.0194
β_5	0.0176	0.0354	0.0159*	0.0358*
β_6	0.0352*	0.0519**	0.0163	0.0258
β_7	-0.0501*	-0.0440*	-0.0203	-0.0094
β_8	0.0509	0.0342	0.0268	0.0120
γ_{-8}	-0.0024*	-0.0074**	-0.0003	-0.0019
γ_{-7}	0.0017	0.0025	0.0012	0.0013
γ_{-6}	0.0016	0.0056*	0.0000	-0.0005
γ_{-5}	0.0000	0.0014	-0.0004	-0.0002
γ_{-4}	0.0027	0.0061*	0.0032*	0.0087**
γ_{-3}	0.0007	-0.0003	0.0005	0.0017
γ_{-2}	-0.0012	-0.0050	-0.0003	-0.0028
γ_{-1}	-0.0005	-0.0032	0.0001	-0.0007
γ_0	-0.0030	-0.0049	0.0004	0.0009
γ_1	0.0036*	0.0076*	0.0003	0.0019
γ_2	0.0078**	0.0139**	0.0021	0.0034
γ_3	0.0039	0.0074*	0.0032	0.0067*
γ_4	-0.0020	0.0007	0.0069**	0.0130**

Table 2.8: Contd.

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
γ_5	-0.0017	-0.0018	-0.0012	-0.0006
γ_6	-0.0016	-0.0061	-0.0050**	-0.0078**
γ_7	0.0060	0.0074	0.0004	0.0005
γ_8	0.0054	0.0090	0.0101	0.0122*
θ_1	1.0356**	1.0442**	0.1720**	0.2350**
θ_2	-0.2461**	-0.2045**	0.0828*	0.1355**
Adj R^2	0.7177	0.7706	0.0628	0.1106
$Q(2)$	245.39**	198.82**	13.28**	12.27**
$F-test$	1353.8**	1787.7**	36.71**	67.21**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. I_{t+i} is the intervention indicator which is 1 whenever the SNB intervenes (whether to buy or sell) and 0 otherwise. F_{t+j} is a dummy variable for the frequency of the intervention. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Table 2.9: Effect of Intervention Frequency on Volatility: Low, Average and High Frequency Interventions

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \, I_{t+i} + \sum_{j=-8}^{8} \gamma_j \, LF_{t+j} + \sum_{k=-8}^{8} \delta_k \, AF_{t+k} + \ldots$$
$$\sum_{l=-8}^{8} \phi_l \, HF_{t+l} + \theta_1 \, vol_{t-1} + \theta_2 \, vol_{t-2} + \varepsilon_t$$

	Volatility Measure (sum of all coefficients)			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0012**	0.0028**	0.0010**	0.0026**
β	-0.0761	-0.0460	-0.0689	-0.0588
γ	0.0397	0.0401	0.0366	0.0470
δ	0.0231	0.0340	0.0255	0.0424
ϕ	0.0171	0.0264	0.0160	0.0287
θ_1	1.0362**	1.0434**	0.1712**	0.2343**
θ_2	-0.2466**	-0.2035**	0.0821*	0.1343**
Adj R^2	0.7204	0.7718	0.0676	0.1128
$Q(2)$	242.26**	192.22**	13.25	12.27**
$F-test$	696.45**	913.54**	20.58**	35.34**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. The table shows the sum of all coefficients. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. I_{t+i} is the intervention indicator which is 1 whenever the SNB intervenes (whether to buy or sell) and 0 otherwise. LF_{t+j} is an indicator for low frequency interventions (between 1 and 6 times in 15 minutes), AF_{t+k} is an indicator for intervention frequency between 7 and 12 times in 15 minutes and HF_{t+l} is an indicator for frequency of interventions larger than 13. With this classification there are 44 low, 12 average and 2 high frequency interventions. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Table 2.10: Effect of Intervention Quantity and Frequency on Volatility

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \, I_{t+i} + \sum_{j=-8}^{8} \gamma_j \, Q_{t+j} + \sum_{k=-8}^{8} \delta_k \, F_{t+k} + ...$$
$$\sum_{l=-8}^{8} \phi_l \, Q_{t+l} * F_{t+l} + \theta_1 \, vol_{t-1} + \theta_2 \, vol_{t-2} + \varepsilon_t$$

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0012**	0.0028**	0.0010**	0.0026**
β_{-8}	0.0058	0.0078	0.0002	-0.0029
β_{-7}	-0.0039	0.0033	-0.0021	-0.0035
β_{-6}	-0.0012	-0.0056	-0.0016	-0.0007
β_{-5}	-0.0133	-0.0302	-0.0103	-0.0225
β_{-4}	-0.0103	-0.0143	-0.0124	-0.0193
β_{-3}	-0.0118	-0.0336	-0.0055	-0.0148
β_{-2}	-0.0309**	-0.0381	-0.0100	-0.0085
β_{-1}	0.0186	0.0522	-0.0066	-0.0086
β_0	-0.0078	-0.0147	-0.0103	-0.0162
β_1	-0.0094	-0.0084	0.0073	0.0272
β_2	0.0110	0.0111	0.0176*	0.0291
β_3	-0.0075	-0.0470	-0.0276*	-0.0647*
β_4	-0.0228	-0.0157	-0.0044	-0.0082
β_5	0.0241	0.0460	0.0144	0.0235
β_6	0.0416	0.0481	0.0050	0.0112
β_7	-0.0930	-0.0835	-0.0143	-0.0038
β_8	0.0773	0.0627	0.0288	0.0288
γ_{-8}	-0.0001	0.0013	-0.0001	0.0007
γ_{-7}	-0.0003	-0.0008	0.0000	0.0006
γ_{-6}	-0.0002	-0.0018	0.0001	-0.0001
γ_{-5}	0.0005	0.0018	0.0004	0.0012
γ_{-4}	0.0004	0.0000	0.0004	-0.0009
γ_{-3}	0.0010	0.0043*	0.0004	0.0016
γ_{-2}	0.0029**	0.0054**	0.0009	0.0023
γ_{-1}	-0.0014*	-0.0040	0.0005	0.0010
γ_0	0.0005	0.0000	0.0006	0.0010

Table 2.10: Contd.

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
γ_1	-0.0009	-0.0036*	-0.0009**	-0.0035**
γ_2	-0.0032	-0.0046	-0.0024**	-0.0043*
γ_3	0.0018	0.0046**	0.0013	0.0038*
γ_4	0.0003	0.0018	-0.0004	-0.0001
γ_5	-0.0006	-0.0010	0.0003	0.0013
γ_6	-0.0002	0.0013	0.0012	0.0018
γ_7	0.0037	0.0035	-0.0006	-0.0008
γ_8	-0.0026	-0.0024	-0.0005	-0.0017
δ_{-8}	-0.0046	-0.0099	-0.0005	-0.0004
δ_{-7}	0.0020	0.0014	0.0018	0.0045
δ_{-6}	0.0003	-0.0024	-0.0003	-0.0014
δ_{-5}	0.0002	0.0024	-0.0008	-0.0028
δ_{-4}	0.0051	0.0103	0.0057	0.0109
δ_{-3}	0.0012	0.0049	0.0008	0.0035
δ_{-2}	0.0086**	0.0148*	0.0020	0.0046
δ_{-1}	-0.0036	-0.0121*	0.0011	-0.0005
δ_0	-0.0004	-0.0009	0.0029	0.0054
δ_1	0.0012	-0.0027	-0.0009	-0.0037
δ_2	-0.0020	0.0012	-0.0063*	-0.0109*
δ_3	0.0070	0.0167*	0.0049	0.0120
δ_4	-0.0102	-0.0091	0.0036	0.0087
δ_5	-0.0044	-0.0025	-0.0009	0.0054
δ_6	-0.0020	-0.0102	-0.0049	-0.0108
δ_7	0.0134	0.0120	-0.0027	-0.0066
δ_8	0.0090	0.0126	0.0173	0.0171
ϕ_{-8}	0.0002	0.0003	0.0000	-0.0001
ϕ_{-7}	0.0000	0.0000	-0.0001	-0.0004
ϕ_{-6}	0.0000	0.0006	0.0000	0.0000
ϕ_{-5}	0.0001	0.0001	0.0001	0.0005
ϕ_{-4}	-0.0003	-0.0006	-0.0003	-0.0003
ϕ_{-3}	-0.0001	-0.0005	-0.0001	-0.0003
ϕ_{-2}	-0.0009**	-0.0018**	-0.0002	-0.0007
ϕ_{-1}	0.0002	0.0007	-0.0001	0.0000
ϕ_0	-0.0001	-0.0001	-0.0002	-0.0003
ϕ_1	0.0002	0.0009	0.0001	0.0004

Table 2.10: Contd.

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
ϕ_2	0.0009	0.0011	0.0008**	0.0014**
ϕ_3	-0.0003	-0.0009*	-0.0001	-0.0004
ϕ_4	0.0007	0.0008	0.0002	0.0002
ϕ_5	0.0002	0.0000	-0.0001	-0.0007
ϕ_6	-0.0001	0.0002	0.0000	0.0003
ϕ_7	-0.0006	-0.0003	0.0003	0.0008
ϕ_8	-0.0004	-0.0005	-0.0007	-0.0006
θ_1	1.0350**	1.0446**	0.1714**	0.2354**
θ_2	-0.2453**	-0.2045**	0.0836*	0.1367**
Adj R^2	0.7181	0.7711	0.0635	0.1128
$Q(2)$	243.79**	197.86**	13.27**	12.21**
$F-test$	688.48**	910.10**	19.32**	35.32**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. I_{t+i} is the intervention indicator which is 1 whenever the SNB intervenes (whether to buy or sell) and 0 otherwise. Q_{t+j} is the absolute magnitude of US dollars bought or sold by the SNB, F_{t+k} is a dummy variable for the frequency of the intervention and $Q_{t+l} * F_{t+l}$ is a dummy variable for the quantity-frequency interaction. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Table 2.11: Effect of Time of Interventions on Volatility: 9am versus 2pm

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \; 9am_{t+i} + \sum_{j=-8}^{8} \gamma_j \; 2pm_{t+j} + ... \sum_{k=-8}^{8} \delta_k \; J_{t+k} + \theta_1 \; vol_{t-1} + \theta_2 \; vol_{t-2} + \varepsilon_t$$

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0014**	0.0032**	0.0011**	0.0029**
β_{-8}	-0.0119**	-0.0186	-0.0117**	-0.0177
β_{-7}	0.0017	-0.0002	0.0069	0.0211
β_{-6}	-0.0081**	-0.0267*	-0.0069**	-0.0214**
β_{-5}	0.0018	0.0126	-0.0026	-0.0064
β_{-4}	-0.0075	-0.0258	-0.0020	-0.0051
β_{-3}	0.0082	0.0263	0.0046	0.0208
β_{-2}	0.0007	0.0023	0.0011	0.0056
β_{-1}	-0.0028	-0.0182	-0.0027	-0.0138
β_0	-0.0080	-0.0127	0.0071	0.0282*
β_1	0.0048	0.0035	-0.0037	-0.0064
β_2	0.0079	0.0257	0.0024	0.0061
β_3	0.0132	0.0336	0.0061	0.0172
β_4	0.0156	0.0595	0.0237**	0.0631**
β_5	0.0059	0.0142	0.0010	0.0182
β_6	0.0023	0.0154	0.0030	0.0116
β_7	-0.0137	-0.0133	-0.0012	0.0057
β_8	0.0230	0.0307	0.0127	0.0198
γ_{-8}	-0.0069	-0.0130	0.0018	0.0017
γ_{-7}	0.0023	0.0022	0.0040	0.0133
γ_{-6}	0.0012	-0.0096	-0.0028	-0.0069
γ_{-5}	-0.0071	-0.0211	-0.0083**	-0.0251**
γ_{-4}	0.0096	0.0156	0.0108	0.0169
γ_{-3}	0.0009	0.0082	0.0027	0.0106
γ_{-2}	0.0054	0.0293*	-0.0013	0.0095
γ_{-1}	0.0000	-0.0027	0.0007	0.0064
γ_0	-0.0085	-0.0069	0.0015	0.0084
γ_1	-0.0003	-0.0055	0.0021	0.0105
γ_2	-0.0082	-0.0183	-0.0086	-0.0204

Table 2.11: Contd.

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
γ_3	0.0373	0.0441*	0.0003	0.0090
γ_4	-0.0513	-0.0312	0.0137	0.0196
γ_5	0.0160	0.0230	0.0070	0.0279
γ_6	0.0456**	0.0526**	-0.0007	0.0091
γ_7	-0.0724*	-0.0508	-0.0294*	-0.0202
γ_8	0.0829	0.0726	0.0819	0.0753*
δ_{-8}	-0.0023	-0.0016	0.0008	0.0017
δ_{-7}	0.0221	0.0294	0.0165	0.0293
δ_{-6}	-0.0074	-0.0025	-0.0038	-0.0020
δ_{-5}	-0.0036	-0.0199	-0.0041	-0.0155
δ_{-4}	0.0007	-0.0244	0.0026	0.0045
δ_{-3}	-0.0201	-0.0188	-0.0079	-0.0059
δ_{-2}	0.0161	0.0223	0.0022	-0.0068
δ_{-1}	-0.0067	-0.0092	-0.0023	0.0024
δ_0	0.0240	0.0587*	0.0049	0.0390
δ_1	-0.0641	-0.0292	0.0135	0.0247
δ_2	0.0344	0.0276	0.0004	-0.0012
δ_3	0.0582	0.0511	0.0073	0.0289
δ_4	-0.0549	-0.0891	-0.0024	-0.0078
δ_5	0.1573	0.1201	0.1140	0.0820
δ_6	-0.0557	-0.0391	-0.0087	-0.0191
δ_7	0.0348	0.0622*	-0.0076	0.0093
δ_8	0.1056	0.1413*	0.0795	0.1171*
θ_1	1.0448**	1.0507**	0.1786**	0.2406**
θ_2	-0.2549**	-0.2101**	0.0763	0.1317**
Adj R^2	0.7186	0.7702	0.0566	0.1049
$Q(2)$	233.27**	190.34**	14.31**	12.96**
$F-test$	915.70**	1200.9**	22.50**	42.98**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. $9am_{t+i}$ is a dummy variable for interventions occurring at 9am, $2pm_{t+j}$ is a dummy variable for interventions occurring at 2pm and J_{t+k} is a dummy variable that controls for interventions that were joint with either the Fed or the Buba or both. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Table 2.12: Effect of Different Intervention Characteristics on Volatility

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \, I_{t+i} + \sum_{j=-8}^{8} \gamma_j \, Q_{t+j} + \sum_{k=-8}^{8} \delta_k \, F_{t+k} + \sum_{l=-8}^{8} \eta_l \, Q_{t+l} * F_{t+l} + \ldots$$
$$\sum_{m=-8}^{8} \kappa_m \, 9am_{t+m} + \sum_{n=-8}^{8} \lambda_n \, 2pm_{t+n} + \sum_{p=-8}^{8} \mu_p \, Fed_{t+p} + \ldots$$
$$\sum_{q=-8}^{8} \phi_q \, Buba_{t+q} + \theta_1 \, vol_{t-1} + \theta_2 \, vol_{t-2} + \varepsilon_t$$

	Volatility Measure (sum of all coefficients)			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0012**	0.0028**	0.0010**	0.0026**
β	-0.0040	-0.0470	-0.0155	-0.0636
γ	0.0001	0.0045	-0.0003	0.0033
δ	0.0176	0.0249	0.0199	0.0326
η	0.0001	0.0004	-0.0001	0.0001
κ	-0.0356	0.0173	-0.0237	0.0532
λ	-0.0185	-0.0190	0.0179	0.0461
μ	0.7966	0.5604	0.6868	0.5474
ϕ	0.3147	0.3539	0.2707	0.2824
θ_1	1.0367**	1.0423**	0.1697*	0.2334**
θ_2	-0.2474**	-0.2020**	0.0848*	0.1366**
Adj R^2	0.7312	0.7744	0.1018	0.1234
$Q(2)$	250.38**	195.56**	13.17**	12.49**
$F-test$	370.72**	467.63**	16.41**	20.15**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. The table shows the sum of all coefficients. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. I_{t+i} is the intervention indicator which is 1 whenever the SNB intervenes (whether to buy or sell) and 0 otherwise. Q_{t+j} is the absolute magnitude of US dollars bought or sold by the SNB, F_{t+k} is a dummy variable for the frequency of the intervention, $Q_{t+l} * F_{t+l}$ is a dummy variable for the quantity-frequency interaction, $9am_{t+i}$ is a dummy variable for interventions occurring at 9am, $2pm_{t+j}$ is a dummy variable for interventions occurring at 2pm, Fed_{t+p} is a dummy variable that controls for interventions that were joint with the Fed and $Buba_{t+q}$ is a dummy variable that controls for interventions that were joint with the Bundesbank. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Table 2.13: Effect of Reuters Reports of Sell Interventions on Volatility

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \, RS_{t+i} + \theta_1 \, vol_{t-1} + \theta_2 \, vol_{t-2} + \varepsilon_t$$

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0001	0.0003	0.0001	0.0002
β_{-8}	-0.0060**	-0.0150	-0.0066**	-0.0187*
β_{-7}	-0.0045	-0.0085	-0.0026	-0.0048
β_{-6}	-0.0044	-0.0057	-0.0031	-0.0054
β_{-5}	-0.0060	-0.0217	-0.0055*	-0.0179
β_{-4}	-0.0096	-0.0442*	-0.0051*	-0.0151
β_{-3}	-0.0071	-0.0162	-0.0025	-0.0109
β_{-2}	0.0054	0.0019	-0.0025	-0.0155
β_{-1}	-0.0040	0.0025	-0.0014	-0.0049
β_0	0.0083	0.0455*	0.0060	0.0321
β_1	0.0093	0.0047	0.0063	0.0117
β_2	-0.0077	-0.0056	-0.0048	-0.0052
β_3	0.0054	-0.0043	0.0043	-0.0026
β_4	-0.0090**	-0.0360*	-0.0033	-0.0178
β_5	-0.0003	0.0115	-0.0041	0.0000
β_6	-0.0074	-0.0257	0.0015	-0.0094
β_7	0.0075	0.0115	-0.0011	-0.0007
β_8	0.0079	0.0124	0.0064	0.0171
θ_1	1.0666**	1.0539**	0.2037**	0.2148**
θ_2	-0.2702**	-0.2297**	0.0591**	0.0931**
Adj R^2	0.7266	0.7485	0.0501	0.0642
$Q(2)$	230.49**	189.22**	14.68**	15.39**
$F-test$	2563.1**	3420.4**	46.75**	110.98**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. RS_{t+i} is a dummy variable which is 1 whenever there is a Reuters report that the SNB sold US dollars and 0 otherwise. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Table 2.14: Effect of SNB Interventions and Reuters Reports on Volatility

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \; I_{t+i} + \sum_{j=-8}^{8} \gamma_j \; RR_{t+j} + \theta_1 \; vol_{t-1} + \theta_2 \; vol_{t-2} + \varepsilon_t$$

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0001	0.0001	0.0001	0.0001
β_{-8}	-0.0019	0.0000	-0.0015	-0.0009
β_{-7}	0.0053	0.0025	0.0084	0.0143
β_{-6}	0.0034	0.0061	-0.0010	-0.0024
β_{-5}	-0.0040	0.0076	-0.0042	0.0008
β_{-4}	-0.0002	-0.0080	0.0020	0.0047
β_{-3}	0.0060	0.0275*	0.0031	0.0185
β_{-2}	-0.0042	-0.0090	-0.0028	-0.0019
β_{-1}	-0.0061	-0.0184	0.0010	0.0013
β_0	-0.0073	-0.0037	0.0030	0.0188
β_1	0.0073	-0.0003	-0.0029	-0.0071
β_2	0.0103	0.0335	0.0050	0.0167
β_3	0.0503**	0.0735**	0.0150*	0.0383**
β_4	-0.0606	-0.0164	0.0229**	0.0526**
β_5	0.0132	0.0328	0.0007	0.0280*
β_6	0.0497*	0.0520**	-0.0023	0.0085
β_7	-0.0511	-0.0228	-0.0237	-0.0083
β_8	0.1189*	0.1221*	0.1124*	0.1102*
γ_{-8}	0.0135	0.0189	0.0079	0.0075
γ_{-7}	-0.0121	-0.0135	0.0040	0.0085
γ_{-6}	0.0003	-0.0103	-0.0047	-0.0125
γ_{-5}	-0.0086	-0.0354*	-0.0090*	-0.0243*
γ_{-4}	-0.0026	-0.0249	-0.0093	-0.0250
γ_{-3}	-0.0018	-0.0068	0.0119	0.0054
γ_{-2}	-0.0019	-0.0045	-0.0040	-0.0123
γ_{-1}	0.0032	0.0192	-0.0018	0.0060
γ_0	0.0086	0.0163	-0.0087	-0.0009
γ_1	-0.0285	-0.0206	0.0163	0.0191
γ_2	0.0200	0.0136	-0.0002	-0.0028
γ_3	0.0177	-0.0050	-0.0029	-0.0136

Table 2.14: Contd.

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
γ_4	-0.0419	-0.0592	-0.0132*	-0.0204
γ_5	0.0863	0.0671	0.0539	0.0385
γ_6	-0.0477	-0.0446	-0.0143	-0.0212
γ_7	0.0163	0.0202	-0.0029	0.0046
γ_8	0.0511	0.0622	0.0363	0.0476
θ_1	1.0677**	1.0535**	0.2033**	0.2137**
θ_2	-0.2724**	-0.2303**	0.0583**	0.0921**
Adj R^2	0.7281	0.7489	0.0547	0.0661
$Q(2)$	238.74**	192.43**	13.27**	12.59**
$F-test$	1367.1**	1788.1**	36.64**	65.18**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. I_{t+i} is the intervention indicator which is 1 whenever the SNB intervenes (whether to buy or sell) and 0 otherwise and RR_{t+j} is a dummy variable indicating when there is a Reuters report of an SNB intervention. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Table 2.15: Effect of Sell Interventions and Sell Reports on Volatility

$$vol_t = \alpha + \sum_{i=-8}^{8} \beta_i \; IS_{t+i} + \sum_{j=-8}^{8} \gamma_j \; RS_{t+j} + \theta_1 \; vol_{t-1} + \theta_2 \; vol_{t-2} + \varepsilon_t$$

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
α	0.0001	0.0002	0.0001	0.0002
β_{-8}	-0.0015	0.0007	-0.0010	0.0002
β_{-7}	0.0115	0.0089	0.0109	0.0157
β_{-6}	0.0011	-0.0021	0.0006	-0.0017
β_{-5}	0.0003	0.0170	-0.0027	0.0001
β_{-4}	-0.0015	-0.0159	0.0036	0.0057
β_{-3}	0.0070	0.0295*	0.0004	0.0132
β_{-2}	-0.0049	-0.0092	0.0006	0.0051
β_{-1}	-0.0061	-0.0233	-0.0023	-0.0105
β_0	-0.0089	-0.0097	0.0053	0.0277*
β_1	0.0029	-0.0093	-0.0064	-0.0155
β_2	0.0136	0.0461*	0.0090	0.0225
β_3	0.0280**	0.0591**	0.0125*	0.0313*
β_4	0.0083	0.0471	0.0280**	0.0708**
β_5	0.0156*	0.0440**	0.0060	0.0354**
β_6	0.0146*	0.0341	0.0071	0.0122
β_7	-0.0096	-0.0060	-0.0047	0.0027
β_8	0.0360*	0.0541*	0.0289	0.0484*
γ_{-8}	-0.0063**	-0.0171*	-0.0072**	-0.0233*
γ_{-7}	-0.0084	-0.0182	-0.0034	-0.0082
γ_{-6}	-0.0076*	-0.0138	-0.0072*	-0.0155
γ_{-5}	-0.0115*	-0.0349*	-0.0103**	-0.0307**
γ_{-4}	-0.0107	-0.0494*	-0.0094**	-0.0276*
γ_{-3}	-0.0084	-0.0190	-0.0025	-0.0141
γ_{-2}	0.0009	-0.0120	-0.0055	-0.0253
γ_{-1}	-0.0089	-0.0068	-0.0054	-0.0147
γ_0	0.0010	0.0265	-0.0018	0.0132
γ_1	0.0060	-0.0054	0.0030	-0.0004
γ_2	-0.0096	-0.0120	-0.0079	-0.0143
γ_3	0.0008	-0.0182	0.0014	-0.0140

Table 2.15: Contd.

	Volatility Measure			
	Realised Volatility		Squared	Absolute
	Squared	Absolute	Return	Return
γ_4	-0.0176**	-0.0533**	-0.0088	-0.0294*
γ_5	-0.0051	-0.0037	-0.0096	-0.0146
γ_6	-0.0160**	-0.0445**	-0.0053	-0.0262
γ_7	0.0054	0.0029	-0.0040	-0.0094
γ_8	0.0048	0.0031	0.0047	0.0105
θ_1	1.0664**	1.0533**	0.2035**	0.2141**
θ_2	-0.2703**	-0.2296**	0.0589**	0.0926**
Adj R^2	0.7267	0.7486	0.0506	0.0651
$Q(2)$	231.33**	191.30**	15.66**	14.33**
$F-test$	1319.9**	1766.4**	25.10**	60.20**

Notes: The coefficient estimates are based on OLS regressions using Newey-West standard errors to correct for serial correlation and heteroskedasticity. A * (**) indicates significance at the 5% (1%) level. vol_t is the volatility measure. IS_{t+i} is the intervention indicator which is 1 whenever the SNB sells US dollars and 0 otherwise and RS_{t+j} is a dummy variable which is 1 whenever there is a Reuters report that the SNB sold US dollars and 0 otherwise. $Q(2)$ is the second order Box-Ljung statistic for serial correlation.

Chapter 3

What Defines "News" in Foreign Exchange Markets? [1]

3.1 Introduction

This paper examines intra-day foreign exchange market reactions to a wide array of "news" reported in the financial press. A number of previous studies have shown that in order to find significant reactions in the foreign exchange market to the macroeconomic variables that theory suggests should matter, one needs to measure the precise impact of macro surprises at the intra-day level. While these studies provide evidence that macro news influences both returns and volatility, because these announcements occur very infrequently (typically once a month or quarter) they cannot go far in explaining the bulk of foreign exchange rate movements. In this paper, we ask whether a much broader definition of "news" influences currency values and ought to be included in our models of exchange rate determination. Using Reuters' time-stamped newswire reports, we include

[1] This chapter is based on joint work with Prof. Kathryn M.E. Dominguez.

all news stories that provide information relevant to foreign exchange markets. The stories are then classified by information source (policymaker or market participant), geographic region (Euro zone, Japan, U.S. or U.K.) and substance (both actual events and rumours involving fundamentals and non-fundamentals). Our "news" data include the scheduled macro announcements that have been used in previous studies to allow us to compare the effects of our broader definition of news against these more "traditional" variables. The intra-day foreign exchange data used in this study are transactions prices and quote spreads in the USD-EUR and USD-GBP market from the Reuters D2000-2 electronic trading system. The data do not include information on traded quantities, but they do indicate whether trades were initiated by a buyer or seller, allowing us to measure order flow as well as returns and volatility. We use a 20 minute sampling frequency for each exchange rate and we measure order flow as the cumulative number of buyer initiated trades minus the cumulative number of seller initiated trades over the same 20 minutes.

These data allow us to test a number of interesting hypotheses. First, we test whether non-scheduled "news" of different sorts has similar impact effects on returns and volatility as compared to (the already heavily studied) scheduled macro announcements. Theory suggests that ambiguous information may lead to stronger differences of opinion about the implications of the information (and, in turn, larger increases in volatility). In our application, we can distinguish between scheduled (and presumably better-understood) macro announcements and more ambiguous news (for example, market rumours of impending interest rate changes). Second, we test whether news that is typically not considered "fundamental" in the context of standard models of exchange rate determination (for example, news related to technical analysis), helps to explain exchange rate

movements. Third, we examine whether any of the price discovery process in reaction to news occurs via order flow. Previous studies have found evidence that a substantial proportion of the market reaction to macro-announcements occurs via order flow. By examining how a broader set of news events influences order flow - we can begin to better understand how this measure relates to price and volatility movements in the foreign exchange markets.

The paper is organized as follows. Section 2 reviews the links between macroeconomic fundamentals and exchange rates in standard models, the lack of empirical support for these links, and alternative modeling strategies that may improve our understanding of what drives exchange rate movements. Section 3 describes the exchange rate and order flow data from Reuters D2000-2 used in our empirical analysis. Section 4 provides results of our event study analysis of the influence of our broader definition of news on exchange rate returns and volatility. Section 5 introduces our order flow information and examines its role in explaining exchange rate movements. Section 6 examines the influence of news on returns and order flow simultaneously in the context of a VAR analysis. Section 7 concludes.

3.2 News and Exchange Rates

The asset approach to exchange rate determination suggests that exchange rates are forward looking asset prices that react to changes in the market's expectation of future fundamentals. Empirical tests of the asset approach examine in various ways whether changes in the macroeconomic variables that are considered fundamentals explain exchange rate movements[2]. These tests generally find that macroeconomic variables, which tend to have fairly stable time series properties,

[2]Examples of "fundamentals" include: income (or output) differentials, money differentials, interest rate differentials, inflation differentials and the trade balance.

can explain little of the (sometimes dramatic) variation in exchange rate movements. This line of research is best summarized by a series of papers by Meese and Rogoff (1983a,b) which find that forecasts of exchange rates based on a random walk model of exchange rate determination do better than forecasts that are based on macro-economic models[3].

In the wake of the Meese and Rogoff papers[4], one branch of empirical research has focused on the possibility that their result was more a function of estimation imprecision than an indictment of the asset approach[5]. If the window of time around the shock to fundamentals is too wide, other news hitting the market will confound the econometrician's ability to precisely estimate the effects of the change in fundamentals on exchange rates. One solution is to use intra-daily exchange rate data that will allow a narrow enough window around the time of macro announcements to be able to set up a natural experiment. A number of papers, including Andersen, Bollerslev, Diebold, and Vega (2003), find that when a narrow window is used, they are able to find a strong relationship between certain macro-surprises and exchange rate returns[6]. An alternative approach is

[3]Engel and West (2005) provide an explanation for the Meese-Rogoff result based on the present value relationship that follows from the asset approach. They show that if the discount factor is near one, exchange rates will be largely driven by expected fundamentals far out into the future, which will be dominated by their random walk component. Other studies that re-examine the Meese-Rogoff result for long-horizon forecasts include Mark (1995), Kilian (1999), Kilian and Taylor (2003).

[4]A number of researchers have re-investigated the original Meese and Rogoff (1983a,b) result and have generally found it to be robust. See, for example, Flood and Rose (1995), Cheung, Chinn, and Pascual (2004).

[5]An alternative approach assumes that the underlying reason for the Meese-Rogoff result is that the foreign exchange market is either not efficient, or that market participants are not rational. The fact that many foreign exchange traders follow technical trading rules that are unrelated to the types of variables found in standard exchange rate determination models provides suggestive evidence that this approach may have some merit. See Osler (2003) for an example of this approach.

[6]The enormous literature measuring the effects of macro news on intra-daily exchange rates includes Hakkio and Pearce (1985), Ito and Roley (1987), Ederington and Lee (1995), de Gennaro and Shrieves (1997), Almeida, Goodhart, and Payne (1998), Andersen and Bollerslev (1998), Melvin and Yin (2000), Faust, Rogers, Wang, and Wright (2003), Love and Payne

taken by Fair (2003) who identifies large intra-day changes in exchange rates (and stock and bond prices) over the period 1982 through 1999 and then looks for "news" that hit markets around the large changes to connect exchange rates movements to changes in macro fundamentals.

This paper takes the results in Andersen, Bollerslev, Diebold, and Vega (2003) as a benchmark, and asks three important follow-on questions. First, are the traditional sets of macro surprises that most of the literature considers the only sorts of news that can explain exchange rate movements? We examine the intra-daily influence of a broad set of news reports, including variables which are not typically considered "fundamentals" in the context of standard models of exchange rate determination, and ask whether they too help explain exchange rate movements[7]. If we find that non-fundamental variables matter, the "positive" results that many researchers have found for the influence of macro announcements on exchange rates at intra-daily frequencies may need to be re-interpreted. If all sorts of news influence exchange rates, the "narrow window" explanation for why low frequency empirical tests of standard models are inappropriate, is no longer sufficient. Or, put another way, we are back again to the Meese-Rogoff result that it is not macro-fundamentals that best predict exchange rate behaviour. Second, we ask whether using a broader definition of news, we are able to explain a significant portion of the overall variation of exchange rate movements. Macro-announcements occur relatively infrequently, so that even if they explain 100% of the short-term movements in exchange rates, this translates into explaining

(2003), Love (2004), Chaboud, Chernenko, Howorka, Iyer, Liu, and Wright (2004), Bauwens, Omrane, and Giot (2005).

[7]A number of papers have considered the influence of central bank interventions and official policy statements on exchange rates. These papers include: Dominguez (1998, 2003b, forthcoming), Cai, Cheung, Lee, and Melvin (2001), Evans and Lyons (2003), Fatum and Hutchinson (2003), Fratzscher (2004), Panthaki (2005), Sager and Taylor (2004), Ehrmann and Fratzscher (2005), Jansen and de Haan (1987).

less than 1% of overall exchange rate movements. The third question we consider is whether "news" not only impacts exchange rates directly, but also influences exchange rates via order flow (signed trade volume). Like non-fundamental news, order flow plays no role in standard models of exchange rate determination, so a finding that order flow matters will provide evidence in favor of a different modeling strategy for exchange rate determination (at least for very short term movements)[8].

There are a number of reasons for questioning whether macro announcements are the best real-time source of information on fundamentals. First, macro announcements are retrospective, in the sense that they provide information about past changes in variables. Second, announcements are often revised substantially so that the first (or preliminary) report is not necessarily a good indication of the true (or final) report. When macro announcements are used in empirical studies they are generally measured relative to market expectations. Money Market Services International's median survey responses are used to calculate the "surprise" component, based on the assumption that market participants (and survey participants) are rational and the foreign exchange market is efficient, so that only unexpected news matters. There are a number of reasons to be skeptical that the median survey response accurately reflects market expectations[9]. So that both the announcements and the proxy used to measure the expectation of the announcements may be noisy indicators of actual macro surprises[10].

[8]Evans and Lyons (2002) is one of the first studies that found a link between order flow and exchange rate movements. We will be examining these same links though with a very different data set and time period.

[9]For example, the median survey participant may not be representative of "market" opinion, or survey participants may have strategic reasons not to reveal their true expectation.

[10]Chaboud, Chernenko, Howorka, Iyer, Liu, and Wright (2004), Laakkonen (2004) find that even if there is no macro surprise (so that the expectation exactly matches the announcement) volatility (and trading volume) tends to rise after the release of the (unsurprising) announcement. These results could either be interpreted as suggesting our measure of macro surprise is

In practice, dealers in the foreign exchange market receive information from numerous different sources, including their own customers, electronic brokerage systems, squawk boxes, and newswire services. Newswire services report the macro announcements described previously along with various other sorts of news which sometimes are also directly related to macro fundamentals. One of the major distinctions that can be made between macro announcements and other news is that the announcements are typically made on a schedule, so that market participants can plan their reactions in advance (depending on realizations). Non-scheduled news is by its nature less likely to be anticipated by the market. It may also be the case that market participants are less able to quickly interpret the implications of non-scheduled news for exchange rates, potentially leading to more heterogeneity in their responses to the news[11].

Whether news is scheduled or non-scheduled its influence on exchange rates may be related to the state of the market at the time of the news arrival[12]. News that arrives during periods of high uncertainty may have different effects on the exchange rate, than news that arrives in calmer periods[13]. It may also be the case that the frequency of news arrival itself will influence the relative importance of

flawed, or that market reactions to news do not conform to our standard models.

[11]Of course, an increase in market heterogeneity may also occur in reaction to scheduled announcements. Kondor (2005) shows that if traders display confirmatory bias, the release of public information may increase divergence in opinion. The main insight is that sometimes (public) information implies something different when it is coupled with different (private) pieces of existing information. Bacchetta and van Wincoop (2006) also model the influence of higher-order expectations in reaction to news.

[12]For example, Dominguez (2003b) shows that the influence of central bank interventions on exchange rate returns depends on the intra-day timing of intervention operations (whether they occur during heavy trading volume, or are closely timed to scheduled macro announcements) as well as whether the operations are coordinated with another central bank.

[13]Andersen, Bollerslev, Diebold, and Vega (2003) find evidence that "bad" news in good times (economic expansions) have greater impacts than good news in good times, suggesting that good news in good times confirms beliefs but bad news in good times comes as more of a surprise. Our short sample period will not allow us to test this hypothesis directly, though in future work we intend to test whether "confirming" versus "surprising" news have different effects.

individual news releases[14].

In this paper we allow for the possibility that exchange rates react to a wide spectrum of "news", including, but not exclusively, macro announcements. We also allow for the possibility that information on the "state of the market" will influence the way that news influences exchange rates. Finally, we allow for the possibility that the trading process itself serves to convey information to the market via order flow.

One way to think about why order flow might matter is suggested in the Kyle (1985) model which focuses on the strategic aspects of informed trading in a market microstructure model. Informed traders in Kyle's model can be thought of as information monopolists who act to exploit this advantage by maximizing the value of private information. In the model, Kyle introduces the concept of a price impact coefficient which reflects how much the market adjusts prices to reflect the information content of trades. The model suggests that since the more liquid a market, the less individual trades will impact price, informed traders will prefer to "hide" their private information by trading during periods of high liquidity. In this context private information will eventually become known (and be reflected in price) but the process of information revelation takes place gradually via order flow. Standard exchange rate models give no role to private information (or order flow) because the assumption is that the sorts of information that matter, macro fundamentals, are common knowledge and are incorporated into price instantaneously.

An alternative view is that individual traders are not "informed" in the sense that they have a better understanding of future market movements than other

[14]A dramatic example of this occurred during the period in late 1995 when the US government was shut down and macro announcements went unreported. During this period traders apparently reacted to "news" (such as the shoe manufacturer's monthly sales survey) which in normal periods have little influence.

traders, but that their own trading motives (based on real trade, profit repatriation, speculation, portfolio rebalancing) may be correlated with other traders, eventually leading to aggregate changes in fundamentals. In this context, dealers who have information about order flow may learn about fundamentals before they are officially announced. Evans and Lyons (2004) test this proposition using a data set that allows them to disaggregate order flow among various end-user segments (non-financial corporations, investors, leveraged traders); they find evidence that order flow information forecasts macro fundamentals.

We are not able to directly measure the "private" information available to individual dealers, but we have collected a relatively rich measure of public (time-stamped) news from Reuters's newswire reports[15] as well as the order flow information available from Reuters D2000-2. We use these two sources of "common knowledge" news, as well as the macro announcements typically used in the literature, to test some intra-daily implications of standard exchange rate models.

Tables 3.1 through 3.3 provide information about: (1) the scheduled macro news announcements from the UK, the US, and the Euro-zone, (2) the broad categories of non-scheduled fundamental news, and (3) the broad categories of non-scheduled non-fundamental news that we include in our empirical analysis. Our news variables were created using a search criteria which retrieved newswire articles under the broad subject areas of "money", "foreign exchange" and "economics" over the period 15 November 1999 through 18 January 2000. We excluded all re-published news, recurring price and market data, articles covering obituaries, sports, calendars of events, letters, diaries, weather, cooking and personal announcements. We then coded and grouped[16] news articles according to

[15]These data are from the Factiva database and, unfortunately, do not include the headline news that run over the Reuters and Bloomberg ticker second by second, but they include the major economic news events that occur over a given day.

[16]In theory each "news" report may have a different one-time influence on exchange rates.

source (policymaker or market participant), geographic region (Euro-zone, U.S. or Japan) and substance (related to fundamentals or non-fundamentals). On average there were 4 news items per day so that approximately 5% of our 72 20-minute return intervals per day include a news report. Approximately 65% of these news reports were categorized as related to 'fundamentals', while 35% were coded as non-fundamental news.

News that we code as "non-scheduled non-fundamental" largely falls into six main sub-categories. The first four categories: the options market, technical analysis, market characteristics and market sentiment, are all related specifically to the foreign exchange market, and are often based on interviews with or quotes from market participants who trade based on "technical" rather than "fundamental" information[17]. Our non-fundamental news also includes news related to the private sector (often focused on restructuring, and mergers and acquisitions), and politics. While it is possible that some of this news is indirectly related to fundamentals (when firms restructure they may improve profitability, and, in turn this may lead to higher country-level growth) our sense is that these sorts of news reports do not fit the traditional definition of "fundamentals". It is also likely that there is more heterogeneity in market participant's interpretations of the importance of this sort of news relative to, for example, scheduled macro announcements. In any case, given that a significant portion of newswire reports fall into this category of non-scheduled non-fundamental news, it seems worth examining whether their influence on exchange rates differs from fundamentals

We group similar news items together in order to examine whether certain "types" of news have a systematic influence on exchange rate behaviour.

[17]For example here are some quotes from market participants: "Price action today was dictated by technical factors, options related factors"; "Dealers said the euro would likely struggle to break key technical levels near $1.0350"; "Analysts said only a breach of key chart resistance located around $1.03 could give an incentive to market bulls for betting on the euro"; "Liquidity is still pretty poor... but it is a market that is moving as more people get sucked in, so inevitably momentum can build up and we can get a reasonably sharp move".

related news.

3.3 Exchange Market Data

Our intra-day exchange rate and order flow data cover a two-month period, from 15 Nov 1999 through 18 Jan 2000 for the USD-EUR and USD-GBP[18]. The data are from the brokered segment of the inter-dealer exchange rate market as captured by the Reuters D2000-2 electronic trading system[19]. Electronic brokers were first introduced in 1992 and since that time their market share has increased rapidly. In the early 1990s the inter-dealer market was split evenly between direct and voice-broker trading but by the late 1990s the two top electronic brokerage systems, Reuters and EBS, made up over 50 percent of the market.

Inter-dealer brokering systems provide prices that are advertised to all member dealers (though the identity of the quoting dealer is only available once the quote is hit). Dealers can submit a buy or sell quote or "hit" a quote of another dealer. Only the highest bid and lowest ask (the touch) are shown on the Reuters screen[20]. The quantity available at each (best) bid and ask is also shown (which may involve more than one bank), and when a bid or ask is hit the quantities available at that price are adjusted if they dip below $10 million. When multiple banks have

[18]EBS, the other major electronic brokerage system, has a much larger share of total trading in the USD-EUR market potentially leading the Reuters data for the USD-EUR to be less representative. Reuters USD-EUR order flow data, in particular, may not well capture average trading behaviour in that market outside of European hours. Reuters dominates EBS in the USD-GBP market.

[19]See Rime (2003) for a detailed description of electronic trading systems and Lyons (2001), chapter 3 for a full description of the three basic types of trades in the foreign exchange market. Direct inter-dealer trading was traditionally the most liquid part of the foreign exchange market - it typically is used for large size trades (above $10 million) and spreads are typically only one to two basis points. Brokered inter-dealer trades are a growing segment of the market, and typically involve slightly higher spreads of 2-3 basis points (especially for trades below $10 million). Customer-dealer trades involve 3-7 basis point spreads for "good" customers.

[20]Limit orders with prices below the best bid or above the best offer are not observable on Reuters D2000-2 but are shown on Minex.

entered the same bid or ask price, and the price is hit, offers are met on a first come basis (meaning that the dealer who first input the price gets the deal first and if more quantity is needed, the dealer that next submitted the same price fills the order, and so on). All transactions are made at either the posted bid or ask[21]. Figure 3.1 shows bid and ask quotes for the USD-EUR and USD-GBP rates over our sample period along with the quote mid-point It is worth noting that the USD-GBP rate was relatively stable over this sample period, with a fluctuation range of between 1.59 and 1.65. The USD-EUR rate was roughly twice as variable, with trades ranging from 0.99 to 1.16.

While dealers in individual banks will know their own customer order flow - they do not have access to information on customer orders of other banks. One of the reasons that inter-dealer brokerage systems have become so popular is that they provide an important source of real time information on both market quotes and overall market order flow. The Reuters D2000-2 system classifies transactions as buyer-initiated or seller-initiated, providing dealers with a real time proxy of signed trading volume[22]. We measure order flow in this study as the difference between the number of buyer-initiated trades and seller-initiated trades in each 20-minute interval. Figure 3.2 shows the number of buy and sell orders separately as well as our measure of order flow for the USD-EUR and USD-GBP rates.

The intra-day price series used in this study incorporates information from both transactions prices (actual trades) and (tradeable) bid and ask quotes submitted by dealers (but not hit)[23]. We use tradeable quotes in addition to actual

[21]One advantage of the (shrinking) voice-brokered market is that it allows for some communication between dealers and brokers which allows for negotiation over price.

[22]The dealer posting the quote is considered the non-initiating side. Reuters does not provide information on the size of each trade.

[23]Tradeable quotes differ from indicative quotes, which have been used in a number of previous studies, in that they provide "firm" prices. Indicative quotes provide market information for non-dealers.

transactions prices to create a 20-minute price series for each of our two exchange rates that spans the period over which we have "news" data[24]. We measure exchange rate returns, Δs_{t_i}, as the log difference in 20-minute (midpoint) prices and exchange rate volatility, V_{t_i}, as the absolute value of the 20-minute returns. Figure 3.3 shows USD-EUR and USD-GBP returns and volatility over our sample period. The volatility series displays the strong seasonal pattern that is typically found in intra-day exchange rate volatility data which, in turn, largely reflects the opening and closing of the three main trading markets in Tokyo, Europe and New York. We de-seasonalize the volatility series using the Andersen and Bollerslev (1997b,a, 1998) flexible fourier form (FFF) regression method which involves decomposing the demeaned i-minute exchange rate returns, into a daily volatility factor, a periodic component for the i^{th} intraday interval and an i.i.d. mean zero unit variance innovation term all divided by the square root of the number of uncorrelated intraday return components[25]. Figure 3.4 shows the average absolute USD-EUR and USD-GBP return in each 20-minute interval over the 24-hour GMT time scale along side the estimated FFF seasonal. Figure 3.5 shows average daily USD-EUR and USD-GBP returns, order flow and news arrival also over the 24-hour GMT time scale. It is worth noting that news arrival is fairly evenly spread over the day, while order flow for the USD-EUR market is relatively light outside of European trading hours, presumably reflecting that EBS holds a dominant share of trading volume in that market. There is little evidence of a within day trend in average returns for either exchange rate.

[24]There are a periods of low liquidity on Reuters D2000-2 due to technical problems (the feed failing), holidays, and during Asian trading hours. Some studies simply drop these time periods from the sample. Our approach is to interpolate a 20 minute time series (using a piecewise cubic Hermite interpolating function which preserves the monotonicity and shape of the data) from all available quotes in order to fully span our "news" data set. Reuters does not include weekend data so any news that arrives over a weekend is moved to the first 20-minute interval on the nearest Monday.

[25]See Dominguez (forthcoming) for a detailed description of how this was implemented.

Table 3.4 provides descriptive statistics for our 20-minute USD-EUR and USD-GBP exchange rates, returns[26] and volatility, order flow and order flow volatility, and transaction frequency (measured as the number of transactions in a given 20-minute interval). The USD-EUR exchange rate returns series only display first-order autocorrelation, suggesting that future exchange rate changes cannot be predicted from past changes beyond a 20 minute horizon. There is no evidence of autocorrelation for the USD-GBP returns. Intra-day return volatility and transaction frequency for both currencies shows evidence of strong and persistent autocorrelation. While buy and sell orders are highly autocorrelated, order-flow (buy orders minus sell orders) does not display significant autocorrelation for either currency.

Table 3.5 presents contemporaneous correlations among our key variables: exchange rate returns and volatility, order flow and order flow volatility as well as a measure of news arrival (measured as the number of news articles in a given 20-minute interval) and trading frequency[27]. The correlations indicate that there exists a strong contemporaneous association between exchange rate returns and order flow and order flow volatility and transaction frequency for both currencies. For the USD-GBP rate the correlations between exchange rate volatility, order flow volatility, and transaction frequency are also high. Beyond these contemporaneous correlations, we might expect longer-lived correlation between news and the other variables if traders have different views of the implications (and information content) of the news.

[26]We compute returns (approximately) as the percentage change in the exchange rate multiplied by 100, so the units can be thought of as basis points.

[27]Evans and Lyons (2003) document strong contemporaneous correlation between news arrival, transaction frequency and order flow volatility. Melvin and Yin (2000) find a positive correlation between trading frequency (using indicative quotes) and the rate of flow of public information.

3.4 Effects of Different Categories of News on Returns and Volatility

The standard approach in the empirical exchange rate literature is to run the following sort of "event study" style regression[28] of the conditional mean of i-minute exchange rate returns, Δs_{t_i}, on j leads[29] and lags of each of the k "news" announcements and g lags of past returns (to account for the autocorrelation we found in table 3.5); that is:

$$\Delta s_{t_i} = \alpha_0 + \sum_k \sum_j \alpha^k_{1,j} N^k_{t_{i-j}} + \sum_g \alpha_{2,g} \Delta s_{t_{i-g}} + \epsilon_{t_i} \tag{3.1}$$

where Δs_{t_i} denotes the change in the natural log of the i-minute (spot market) exchange rate on day t and N denotes the (time-stamped to the nearest i-minute) "news"[30]. We use the Schwarz (1978) criteria to fix the lag length on returns and the lead/lag length on "news", and we correct for heteroskedasticity and serial correlation in the error term using the Newey and West (1987) approach. Using this general regression specification it is possible to test for the impact and intra-day effects of news on exchange rate returns by examining whether the N^ks are individually and jointly statistically significant. The $\alpha^k_{1,j}$s in this context measure the typical effect of the k^{th} news announcement at time j (on day t) on exchange

[28] An alternative approach based on state dependent heteroscedasticity is used by Rigobon and Sack (2004), Evans and Lyons (2003).

[29] We include leads in order to take into account the possibility that the time-stamp on our "news" lags the actual timing of when market participants first learn about the news. We find evidence of significant lead effects for many of our variables for up to two hours prior to the Reuters' time-stamp.

[30] The Reuters news variables are (0,1) dummy variables. The macro surprises are measured as the difference between the specific announcement and the ex-ante expectation of the announcement (based on the median response to a survey conducted by Money Market Services International) divided by the sample standard deviation of each announcement (this serves to normalize the surprises so that comparisons of the relative size of coefficients is feasible).

rate returns in the same (narrow) 20-minute window. It is worth noting that in order to be able to interpret the $\alpha_{1,j}^k$s in this way we need to assume that the variables in the regression can be viewed as fixed over the 20-minute period (which is less likely to be realistic for low-frequency data windows). It is also the case that the $\alpha_{1,j}^k$s will measure the linear combination of exchange rate return effects associated with the market's assessment of both the "news" *and* how the news will influence the economy[31].

Our "news" variable includes three distinct categories of news: (1) scheduled macro surprises, (2) non-scheduled but fundamentals-driven news, and (3) non-scheduled non-fundamental based news. Within categories (2) and (3) news was further broken down by source (policy-maker or market participant), geographic region (Euro-zone, Japan, US or UK), substance (subcategories of fundamentals and non-fundamentals) and expected direction of influence (whether the news is expected to appreciate or depreciate the exchange rate)[32]. Category (2) and (3) news are in binary dummy variable form which is likely to downward bias our results if these sorts of news are sometimes anticipated by the market.

Table 3.6 presents results of our regression of USD-EUR and USD-GBP returns on various categories of "news". The first and third columns in table 3.6 present the results of our benchmark regression which include only the macro surprises as "news" for the USD-EUR (first column) and USD-GBP (third column). As has been found in previous studies, the macro surprises significantly influence both USD-EUR and USD-GBP returns, though the relatively low re-

[31]For a nice discussion of the underlying assumptions in this sort of event study analysis see Faust, Rogers, Wang, and Wright (2003) pages 6-9.

[32]We attempted to group news into variables in such a way as to insure that we would not be combining news that would be expected to lead to opposite effects on exchange rates. The coefficients on these disaggregated news variables are then aggregated into broader groupings of variables (monetary fundamentals, fiscal fundamentals, growth and unemployment, options market, technical analysis, private sector) in order to keep our tables readable. Regression results with the disaggregated news categories are available upon request.

gression goodness-of-fit (especially for the USD-GBP) suggests that macro surprises account for a small fraction of the overall variability of returns[33]. The second and fourth columns in table 3.6 present results of regressions that include our broader definition of news. These columns include, along with the macro surprises, non-scheduled news reports that are related to fundamentals and news that is not related to fundamentals. In the usd-euro regressions Euro-zone macro surprises are only statistically significant when other "news" is not included (first column). For the USD-GBP regressions both UK and Euro-zone macro surprises matter, even when other "news" is included (third and fourth column). US macro surprises did not enter significantly in any of the regressions.

Looking first at the influence of non-scheduled fundamentals, we find that a number of these "news" reports matter in terms of statistical significance. The first variable that shows up significant in the USD-EUR regression is contemporaneous "Euro-zone monetary fundamentals" with a coefficient of -0.02, which can be interpreted as indicating that these news reports (which tended to mention Euro-zone interest rates or inflation) led to a 2 basis point appreciation of the dollar relative to the euro. It is interesting to note that reports of Japanese interventions (which were aimed at weakening the yen over this time period)[34] led to a contemporaneous 3.8 basis point appreciation of the dollar relative to the euro and a similar size influence on the dollar relative to the pound (though in

[33]The macro surprises are disaggregated by region (so that all U.S. surprises are included as one variable). As robustness checks we also included disaggregated macro surprises (by type and region, e.g. US PPI, etc) as well as aggregating the surprises (all US, UK and European surprises included as one variable). Results were qualitatively similar across the three levels of aggregation. The non-reported results (disaggregated by type and region, and fully aggregated) are available upon request.

[34]The Japanese government intervened on 4 occasions during our sample period, all of these were dollar strengthening operations. A number of unrequited interventions (interventions that the market expected but did not occur) also influenced returns over this period. See Dominguez and Panthaki (2006) for a more detailed examination of the influence of actual and unrequited interventions.

the 20 minutes prior to the Reuters time-stamp). Focusing next on the influence of non-fundamentals related news, we find evidence that reports connected to all our included categories (option market, technical analysis, sentiment, private sector and politics) enter significantly. Moreover, the coefficient estimates on non-fundamental news are similar in size to those found for fundamentals-related news. We also find strong evidence of both lead (especially for the USD-GBP)[35] and lag effects on the non-scheduled news variables, suggesting both that some traders learn of the news before our Reuters' time-stamp and that market reaction to "news" is often not instantaneous.

The results in table 3.6 indicate that both scheduled macro surprises and non-scheduled fundamental and non-fundamental news influences returns. In order to further examine how information is processed by the market under different market conditions, we test for two types of interaction effects. First, we ask whether news is more (or less) likely to influence returns during periods when lots of other news is hitting the market. We create an indicator variable that takes on the value 1 during 20-minute intervals when the number of news reports exceeds the sample average by two standard deviations and run the following regression:

$$\Delta s_{t_i} = \alpha_0 + \sum_k \sum_j \alpha^k_{1,j} N^k_{t_i-j} + \sum_k \sum_j \alpha^k_{1,j} N^k_{t_i-j} * HN_{t_i-j} + \sum_g \alpha_{2,g} \Delta s_{t_i-g} + \epsilon_{t_i} \tag{3.2}$$

where Δs_{t_i} denotes the change in the natural log of the i-minute (spot market) exchange rate on day t, N denotes the (time-stamped to the nearest i-minute) "news" and HN is the indicator variable for periods with high news arrival. The

[35] One explanation for why lead effects are more important for the USD-GBP market is that the source of our data, Reuters, is the dominant player (in terms of market share) in this currency market.

first two columns of table 3.7 suggest that for both USD-EUR and USD-GBP returns "news" often had a larger impact on returns when it arrived during heavy news periods. Our results are even more dramatic when we test whether news has a stronger impact during periods of high market uncertainty (proxied by high volatility). We create an indicator variable that takes on the value 1 during 20-minute intervals when volatility (measured as the absolute value of returns) exceeds the sample average by two standard deviations and then run the regression:

$$\Delta s_{t_i} = \alpha_0 + \sum_k \sum_j \alpha^k_{1,j} N^k_{t_i-j} + \sum_k \sum_j \alpha^k_{1,j} N^k_{t_i-j} * HV_{t_i-j} + \sum_g \alpha_{2,g} \Delta s_{t_i-g} + \epsilon_{t_i} \quad (3.3)$$

where Δs_{t_i} denotes the change in the natural log of the i-minute (spot market) exchange rate on day t, N denotes the (time-stamped to the nearest i-minute) "news" and HV is the indicator variable for periods with high volatility. The second two columns in table 8 present regression results that show that during periods when the market is most uncertain "news" (of all types) had a significantly larger influence on returns than was the case when news arrived during normal periods.

The regression results presented in tables 3.6 and 3.7 indicate that "news" both narrowly defined as macro surprises, and more broadly defined, has an influence on intra-daily exchange rate returns. However, the relatively low regression goodness-of-fit suggests that even our broader measure of news does not go very far in explaining overall exchange rate movements. It is possible that our binary coding of news is partly to blame for our inability to explain a larger fraction of exchange rate variation. It may be that while we are not able to "sign" exchange rate movements using such a crude indicator of information flow, our

"news" variables will be more successful at explaining exchange rate volatility. It may also be that news (however measured) does not impact price directly, but that its influence is mediated through order flow. We investigate both these possibilities in the next two sets of regressions.

In order to examine whether our broader definition of news helps to explain the absolute value of exchange rate returns, we regress de-seasonalized intra-day volatility, $V^s_{t_i}$, on the same set of explanatory "news" variables:

$$V^s_{t_i} = \lambda_0 + \sum_k \sum_j \lambda^k_{1,j} N^k_{t_i - j} + \sum_g \lambda_{2,g} V_{t_i - g} + \eta_{t_i} \tag{3.4}$$

Andersen and Bollerslev (1998) find that three factors influence intra-daily exchange rate volatility: calendar effects and volatility dependencies (both of which are captured in the FFF seasonal) and macro surprises, with macro surprises providing the least explanatory power. We examine the influence of our broader definition of news on de-seasonalized[36] volatility and allow for a longer lag structure to test whether the effects of non-scheduled news reports are longer-lived. We use the Schwarz (1978) criteria to fix the leads and lags in the regression specification and correct for potential heteroskedasticity and serial correlation in the error term using the Newey and West (1987) approach.

Table 3.8 presents our volatility regression results using the same column format as we did in table 3.6. The first thing to note about these results, is that many more of our fundamental-related news reports, and especially our non-fundamentals related news reports, have a statistically significant effect on de-seasonalized volatility[37]. This provides suggestive evidence that non-scheduled

[36]It could be that the intra-day seasonal is explained by news arrival. We test for this possibility by including our news variables directly in the FFF regression and find no evidence of correlation between the daily seasonal and our news variables.

[37]It is also worth noting that the regression goodness-of-fit is dramatically higher, due in part

news, perhaps because it is more ambiguous, leads to stronger differences in opinions about the implications of the information. None of the macro surprises are significant in the USD-EUR regressions, while US macro surprises enter with a high degree of statistical significance in the USD-GBP regressions both when entered alone and when included with the other "news" variables.

3.5 What Does Order Flow Reveal?

In standard models of exchange rate behaviour when "positive" news arrives for a currency, demand for that currency rises, causing the relative value (the price) of the currency to rise. In these models there is no reason for order flow to rise in reaction to news because price is assumed to instantaneously reflect the news. Trading volume may rise in reaction to news, but as long as the new price is efficient, there is no reason for these trades to be biased in favor of purchases or sales. So that in standard models the arrival of "news" should increase volume, but be orthogonal to changes in order flow[38].

We use transaction frequency, TF, as a proxy for volume, and first test whether the arrival of "news" in our sample is positively related to transaction frequency.

$$TF_{t_i} = \gamma_0 + \sum_k \sum_j \gamma_{1,j}^k N_{t_i-j}^k + \sum_g \gamma_{2,g} TF_{t_i-g} + \nu_{t_i} \tag{3.5}$$

We find strong evidence of a positive association between "news" and transac-

to the strong AR component of volatility.

[38]One view of the relationship between order flow and prices is that it is only a temporary phenomenon. Order flow in this context reflects trader "digestion effects" in reaction to news, so that once the news is fully "digested", any order flow induced price effects will revert back. Work by Evans and Lyons (2002), Danielsson, Payne, and Luo (2002), however, shows that order flow continues to explain changes in foreign exchange returns well after 24 hours, suggesting either that digestion is very slow, or more likely, that the influence of order flow on prices is not temporary.

tion frequency. Interestingly, macro surprises were sometimes associated with a decrease in transactions, while all other "news" (and especially non-fundamental news) generally were positively associated with transaction frequency. In the USD-EUR regression macro surprises had no influence on transaction frequency, but other news, and again especially non-fundamentals related news, led to increases in transaction frequency.

Under what circumstance might "news" cause a change not just in volume, but in order flow? One reason that price might not immediately (or fully) react is if the "news" either is not common knowledge, or if different market participants interpret the news differently. In this case, order flow might convey this information to the market (rather than price). Further, if underlying demand for currencies is driven not by news per se, but by changes in risk aversion or hedging technologies, again it might be order flow that will convey this information to the market[39].

A simple linear regression specification that relates foreign exchange returns to order flow is:

$$\Delta s_{t_i} = \beta_0 + \sum_j \beta_{1,j} OF_{t_{i-j}} + \sum_g \beta_{2,g} \Delta s_{t_{i-g}} + \mu_{t_i} \tag{3.6}$$

Table 3.9 presents results for a regression of USD-EUR and USD-GBP returns on contemporaneous and lagged order flow. The first thing to note in the table is that our measure of regression goodness-of-fit is now markedly higher. Our estimates suggest that order flow explains over 25% of the variation in 20-minute USD-GBP returns and almost 40% in the USD-EUR market[40]. These results

[39]Recent papers that have studied the link between "news" and order flow are Love (2004), Love and Payne (2003), Melvin and Yin (2000), Evans and Lyons (2003, 2004, 2005). Breedon and Vitale (2004) examine the connection between order flow and liquidity risk.

[40]Danielsson, Payne, and Luo (2002) compare the for this sort of regression over multiple

are strongly suggestive that order flow belongs in our empirical models of exchange rate determination. Indeed, Danielsson, Payne, and Luo (2002), Evans and Lyons (forthcoming) perform Meese-Rogoff style RMSE comparisons to examine whether forecasting out-of-sample exchange rate returns with order flow outperforms the random walk model (using future realized values of order flow) and find strong evidence in favor of the order-flow model[41].

Our results so far suggest that news, broadly defined, influences exchange rate returns and volatility, and that order flow influences returns. The next question to ask is what drives order flow? Previous studies have found a link between macro surprises and order flow, which runs counter to standard models that would suggest that common knowledge news, such as macro surprises, should be instantly incorporated in price. We test whether this result also holds for our data sample, and whether our broader definition of news is also linked to order flow, OF.

$$OF_{t_i} = \gamma_0 + \sum_k \sum_j \gamma_{1,j}^k N_{t_{i-j}}^k + \sum_g \gamma_{2,g} OF_{t_{i-g}} + \nu_{t_i} \tag{3.7}$$

Table 3.10 presents results for the regression of USD-EUR and USD-GBP order flow on various categories of news. The first and third columns provide results for our benchmark specification which only includes the macro surprises. European macro surprises are highly statistically significant for USD-EUR order flow but none of the macro surprises are significant in the USD-GBP order flow regression. The results in the second and fourth columns indicate that many of the non-

sampling frequencies (from 5 minutes to one week) and find that for the USD-EUR rate the percent variation is fairly stable (around 40%) over all frequencies.

[41]However, when Danielsson, Payne, and Luo (2002) only use order flow information available at the forecast date, the RMSE of the order flow forecast model falls below the RMSE for the random walk model. Using disaggregated order flow information over a longer horizon (10 days or longer) Evans and Lyons (forthcoming) find that the forecasting ability of their order flow model is significantly better than the random walk model.

scheduled fundamental and non-fundamental related news enter significantly for both currencies. However, "news" explains a relatively small fraction of the overall variation in order flow. Our regression goodness-of-fit measure never rises above 0.05 for either currency, indicating that our measure of order flow is largely not being driven by our measures of "news"[42]. However, if we allow for interaction effects as we did previously in our returns regression, we find stronger evidence of a relationship between "news" and order flow. This is particularly true when we interact "news" with "high volatility" periods, where the regression goodness-of-fit rises to 0.14 for USD-EUR order flow and 0.13 for USD-GBP order flow.

3.6 VAR Analysis

In the previous section we analyzed the relationships between returns (or volatility), order flow and various categories of news using single equation methods. It is probably more appropriate, however, to think of these variables as part of an interrelated economic system. News hits the market and influences trader expectations, which in turn impacts prices (and returns), volume, and order flow[43]. It is also clear that order flow (imbalances in buy and sell orders) influence returns.

[42]This result is at odds with results in Evans and Lyons (2004) which find a strong connection between disaggregated order flow and news. It is possible that the difference in results is due to the fact that our order flow information is only reflecting inter-dealer trades.

[43]In standard macro models "news" should only influence prices and volume, not order flow. However, our single equation results strongly suggest that the influence of news is, at least in part, mediated through order flow, as well as directly affecting prices. Previous work by Evans and Lyons (2003) has attempted to disentangle the effects of news on prices and order flow by assuming that (common-knowledge) news is orthogonal to (dispersed information) order flow. Our approach is to assume that news influences both prices and order flow and focus more on the total influence of news - rather than attempting to disentangle its separate effects.

This suggests the following two-equation system:

$$\Delta s_{t_i} = \alpha_0 + \sum_k \sum_j \alpha_{1,j}^k N_{t_{i-j}}^k + \sum_g \alpha_{2,g} \Delta s_{t_{i-g}} + \sum_m \alpha_{3,m} OF_{t_{i-m}} + \epsilon_{t_i} \quad (3.8)$$

$$OF_{t_i} = \beta_0 + \sum_k \sum_j \beta_{1,j}^k N_{t_{i-j}}^k + \sum_g \beta_{2,g} \Delta s_{t_{i-g}} + \sum_m \beta_{3,m} OF_{t_{i-m}} + \nu_{t_i}, \quad (3.9)$$

Our identifying assumption is that order flow does not depend on contemporaneous returns, so that $\beta_{2,0} = 0$. This assumption is not innocuous. If returns are mean-reverting, feedback trading would be profitable and would in turn lead returns to influence order flow.

VAR regression results[44] indicate that order flow enters with a very high degree of statistical significance in the returns regression, as was true in our single equation estimates. An increase in USD-EUR order flow (an increase in net purchases of euros) leads on average to an increase in the USD-EUR rate (an euro appreciation relative to the dollar) of 0.4 basis points. Similarly, in the USD-GBP market an increase in net purchases of pounds leads, on average, to a 0.3 basis point appreciation of the pound relative to the dollar. While it is clear that most of the explanatory power in the returns regression is coming from order flow, "news" and especially non-scheduled "news", continues to also matter. Or, put another way, the inclusion of order flow does not wipe out the influence of "news". Likewise, all three types of "news" enter significantly in the order flow equations. Figures 3.6 and 3.7 present examples of the intra-day impulse responses of returns and order flow to "news".

[44] See tables A.1 and A.2 in Appendix A.

3.7 Conclusions

In this paper we examine the role of news in exchange rate determination. Previous studies have found that scheduled macro announcements, when measured in surprise form, help to explain intra-daily exchange rate behaviour. These results, in turn, have breathed new life into the post Meese-Rogoff empirical exchange rate literature. We measure news much more broadly, and include both fundamentals-related and non-fundamentals-related news reports to examine whether it is macro announcements, or simply intra-daily data (and a more "narrow window"), that accounts for these positive results. Overall, our results do not suggest that our broader definition of news provides a vast improvement over the macro surprises in explaining exchange rate behaviour, giving yet more credence to the importance of macro variables in standard models. We do, however, find that non-scheduled news, and intriguingly, non-scheduled non-fundamentals-related news has a statistically significant influence on both intra-day exchange rate returns and volatility. Further, we find that news has its largest impact during periods of higher than normal news arrival and higher market uncertainty.

We also examine the role of order flow in exchange rate determination. In standard models there is no reason for order flow to rise in reaction to news because price is assumed to instantaneously adjust. Trading volume may rise in reaction to news, but as long as the new price is efficient, there is no reason for trades to be biased in favor of purchases or sales. We find that order flow explains a large fraction of the variation in both USD-EUR and USD-GBP exchange rate returns, suggesting that prices are, at the very least, slow to adjust. At the same time, we find that our measure of "news" explains a relatively small fraction of the total variation in order flow. Overall, our results indicate that along with

the standard fundamentals, both non-fundamentals-related news and order flow matter, suggesting that future models of exchange rate determination ought to include all three types of explanatory variables.

Table 3.1: Summary Statistics of Macro News Announcements, 15 Nov 1999 - 18 Jan 2000

Announcement	Reported as	Local time
UK Announcements (total = 16)		
RPIX	Y/Y % change	08:30 GMT
Retail Sales	M/M % change	08:30 GMT
Global trade	GBP (billion)	08:30 GMT
Provisional M4	M/M % change	08:30 GMT
PPI	M/M % change NSA	08:30 GMT
Industrial Production	M/M % change	08:30 GMT
Unemployment	thousands	08:30 GMT
Current Account	GBP (billion)	08:30 GMT
US Announcements (total = 18)		
PPI	M/M % change	08:30 ET
CPI	M/M % change	08:30 ET
Industrial Production	M/M % change	09:15 ET
Monthly M3	change USD (billion)	16:30 ET
Goods & Services Trade Balance	USD (billion)	08:30 ET
Civilian Unemployment Rate	percent	08:30 ET
Nonfarm Payrolls	thousands	08:30 ET
Retail Sales	M/M % change	08:30 ET
Euro Area Announcements (total = 12)		
PPI	M/M % change	11:00 GMT
Harmonised CPI	M/M % change	11:00 GMT
Ind Production	3M/3M % change	11:00 GMT
M3	Y/Y % change	09:00 GMT
Trade ex-EMU prel. EUR	EUR (billion)	11:00 GMT
Unemployment rate	percent	11:00 GMT

Notes: M/M% change refers to month-on-month percentage change. 3M/3M% change is three month-on-three month percentage change. Y/Y% change is year-on-year percentage change. NSA refers to non-seasonally adjusted.

Table 3.2: Broad Categories of Non-Scheduled Fundamental-Related News

Monetary Fundamentals	Fiscal Fundamentals	Growth and Unemployment	Exchange Rate Policy Fundamentals
Inflation factor	Trade (surplus/deficit)	Growth news (positive/negative)	No exchange rate target
Inflation (rise/fall)	Fiscal position (good/bad)	Unemployment (good/bad)	Exchange rate target
Interest rates (rise/fall)			Intervention
Bias (loosening/tightening)		Real effective exchange rate	Intervention (potential weapon)
		Housing (strong/weak)	Joint Intervention
			No intervention
			Strong dollar policy
		Differences b/w Economies	
		Growth gap (increase/decrease)	
		B/w Europe-US	
		B/w Europe-Japan	

Table 3.3: Broad Categories of Non-Scheduled Non-Fundamental-Related News

Options Market	Technical Analysis	Market Characteristics	Market Sentiment	Private Sector	Politics
Options market (support no support)	Technical factors (good/bad)	Year end	Europe (positive/ negative)	Restructuring news (good/bad)	Political uncertainty
Demand for barrier options (up/down)	Technical magnetism of parity	Month end	US (positive/ negative)	Government intervention in corporate sector	Political news (good/bad)
Market for current current contracts (liquid/thin)	Window dressing	Y2K		Holzman	
Trading (at/below) par	Exposure driven trading	Thin/concentrated markets			
	Lack of momentum	Risks from large orders		M&A	
	Institutional selling	Aggressive selling (curbed)		Mannesman-Orange	
		Stop-loss selling/ orders executed		Vodafone-Mannesman	
		Investors/traders cut losses		Coca-Cola-Orangina	
		Long positions (opened/closed)		Novartis-AstraZeneca	
		Trading (choppy, lively, jittery)		Banking M&A	
		Exchange rate volatility (up/down)		Attempts to block M&A	
		Spreads (wider/ narrower)		Speculation about flows due to M&A	
				Deals (more,large)	

Table 3.4: Summary Statistics for USD-EUR and USD-GBP Quotes, Returns, Volatility, Order Flow and Transactions, 15 Nov 1999 - 18 Jan 2000

	Mid Quote	Return	Volatility	Order Flow	Order Flow Volatility	Transaction Frequency
a. USD-EUR						
Mean	1.02	0.11	4.18	-0.08	0.82	21.38
Variance	0.01	9.02	7.99	10.52	1.45	44.42
Skewness	5.05	0.39	5.00	0.15	2.16	3.53
Kurtosis	123.43	33.73	42.58	20.41	9.21	27.16
Autocorrelation						
lag 1	0.80	0.25	0.54	0.03	0.85	0.82
lag 5	0.76	0.09	0.27	-0.01	0.60	0.53
lag 10	0.73	0.02	0.13	-0.01	0.36	0.29
lag 20	0.70	0.00	0.09	-0.02	0.00	-0.03
b. USD-GBP						
Mean	1.62	-0.03	2.69	0.79	0.94	24.22
Variance	0.01	4.77	3.94	8.45	1.14	39.22
Skewness	0.33	-0.27	2.84	0.67	1.48	2.64
Kurtosis	2.37	11.54	14.04	13.77	5.36	13.23
Autocorrelation						
lag 1	1.00	-0.11	0.37	0.04	0.81	0.80
lag 5	0.99	-0.02	0.25	-0.02	0.61	0.54
lag 10	0.98	0.02	0.17	0.05	0.42	0.33
lag 20	0.96	-0.05	0.05	0.00	0.15	0.06

Notes: The data are sampled at 20-minute frequency. Both currencies are defined as the number of dollars per foreign currency (euro and sterling, respectively). The mid quote is calculated as the average of the bid and ask quotes. Returns are defined as 100 times the log difference of the mid quote. Volatility is defined as the absolute return. Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR and sterling for USD-GBP). In each 20-minute period, order flow volatility is the standard deviation of order flow, transaction price refers to the last transaction price and transaction frequency is the number of actual trades in a that 20-minute period.

Table 3.5: Contemporaneous Correlations Between Returns, Volatility, Order Flow, Transactions and Reuters News, 15 Nov 1999 - 18 Jan 2000

	Return	Volatility	Order Flow	Order Flow Volatility	Transaction Frequency	Reuters News Arrival
a. USD-EUR						
Return	1	...	...	...	...	...
Volatility	0.083	1	...	...	...	...
Order Flow	0.487	-0.010	1	...	...	...
Order Flow Volatility	-0.030	0.352	-0.016	1	...	...
Transaction Frequency	-0.007	0.350	0.015	0.955	1	...
Reuters News	0.012	0.020	0.012	0.042	0.041	1
b. USD-GBP						
Return	1	...	...	...	...	...
Volatility	-0.072	1	...	...	...	...
Order Flow	0.502	0.068	1	...	...	...
Order Flow Volatility	-0.002	0.577	0.114	1	...	...
Transaction Frequency	-0.003	0.574	0.104	0.930	1	...
Reuters News	-0.012	0.006	-0.030	0.039	0.037	1

Notes: The data are sampled at 20-minute frequency. Both currencies are defined as the number of dollars per foreign currency (euro and sterling, respectively). Returns are defined as 100 times the log difference of the mid quote where the mid quote is calculated as the average of the bid and ask quotes. Volatility is defined as the absolute return. Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR and sterling for USD-GBP). In each 20-minute period, order flow volatility is the standard deviation of order flow, transaction price refers to the last transaction price and transaction frequency is the number of actual trades in a that 20-minute period. Reuters News Arrival refers to an indicator variable for measures the number of news articles in each 20 minute period.

Table 3.6: The Influence of "News" on USD-EUR and USD-GBP Returns

Independent Variables	USD-EUR		USD-GBP	
	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News
Non-News				
Constant	0.0018	0.0010	-0.0003	-0.0001
Dependent Variable				
lag 1	0.2693***	0.2562***	-0.1159***	-0.1365***
lag 2	0.1813***	0.1673**	0.0000	-0.0170
Macro Surprises				
UK	-0.0169	-0.0178	0.0292*	0.0331**
US	-0.0507	-0.0513	-0.0283	-0.0296
Euro-zone	-0.0329***	0.0019	-0.0441***	-0.0222**
Fundamentals				
Monetary				
Euro-zone leads 2-6		0.0060		-0.0016
Euro-zone lead 1		-0.0049		-0.0093
Euro-zone lag 0		-0.0221*		-0.0084
Euro-zone lag 1		0.0056		0.0063
Euro-zone lags 2-6		-0.0035		0.0029
US leads 2-6		-0.0111*		-0.0037
US lead 1		-0.0046		0.0021
US lag 0		0.0099		0.0125*
US lag 1		-0.0060		-0.0003
US lags 2-6		0.0040		-0.0025
Other Asset Markets				
Euro-zone leads 2-6		0.0020		-0.0057
Euro-zone lead 1		0.0201		0.0203**
Euro-zone lag 0		0.0085		-0.0012
Euro-zone lag 1		-0.0256		-0.0051
Euro-zone lags 2-6		0.0005		-0.0013
US leads 2-6		0.0014		-0.0041
US lead 1		0.0021		-0.0037
US lag 0		-0.0128		-0.0116*
US lag 1		-0.0004		0.0028
US lags 2-6		-0.0050		-0.0002
Japan leads 2-6		0.0139		0.0084
Japan lead 1		0.0332		-0.0048
Japan lag 0		0.0118		0.0005

Table 3.6: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News
Japan lag 1		0.0505		0.0031
Japan lags 2-6		0.0257		0.0036
Fiscal				
Euro-zone leads 2-6		0.0011		0.0007
Euro-zone lead 1		-0.0158		-0.0105
Euro-zone lag 0		-0.0154		-0.0039
Euro-zone lag 1		-0.0098		-0.0100
Euro-zone lags 2-6		-0.0024		-0.0025
US leads 2-6		-0.0108		-0.0005
US lead 1		0.0000		0.0241*
US lag 0		-0.0403*		-0.0123
US lag 1		0.0216		0.0121
US lags 2-6		-0.0203		-0.0240**
Exchange Rate Policy				
Euro-zone leads 2-6		-0.0004		0.0001
Euro-zone lead 1		0.0037		-0.0034
Euro-zone lag 0		0.0025		-0.0044
Euro-zone lag 1		0.0121		-0.0022
Euro-zone lags 2-6		0.0026		0.0033
US leads 2-6		0.0486		0.0234**
US lead 1		-0.0733		0.0036
US lag 0		0.0441		0.0038
US lag 1		-0.0455		-0.0288
US lags 2-6		0.0011		-0.0067
Japan leads 2-6		-0.0037		0.0037
Japan lead 1		0.0111		-0.0023
Japan lag 0		0.0385**		0.0043
Japan lag 1		-0.0253*		-0.0130*
Japan lags 2-6		0.0168		0.0029
Actual Intervention				
Japan leads 2-6		-0.0019		-0.0125**
Japan lead 1		0.0522		0.0384**
Japan lag 0		-0.0479**		0.0084
Japan lag 1		0.0171		0.0038
Japan lags 2-6		-0.0044		-0.0042

Table 3.6: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News
Other Macro				
Euro-zone leads 2-6		-0.0068		-0.0007
Euro-zone lead 1		0.0092		0.0044
Euro-zone lag 0		0.0129		0.0114
Euro-zone lag 1		0.0124		0.0134*
Euro-zone lags 2-6		-0.0026		0.0033
US leads 2-6		-0.0021		-0.0018
US lead 1		-0.0098		0.0046
US lag 0		-0.0008		-0.0007
US lag 1		-0.0246**		-0.0039
US lags 2-6		-0.0012		-0.0033
Japan leads 2-6		0.0045		0.0099
Japan lead 1		-0.0663		-0.0374
Japan lag 0		0.0188		-0.0156
Japan lag 1		-0.0713**		-0.0287*
Japan lags 2-6		0.0040		0.0029
Non-Fundamentals				
Options Market				
leads 2-6		-0.0006		-0.0058*
lead 1		0.0090		0.0027
lag 0		-0.0003		-0.0030
lag 1		-0.0240**		-0.0035
lags 2-6		0.0051		0.0112**
Technical Analysis				
leads 2-6		0.0134		0.0042
lead 1		0.0040		-0.0085
lag 0		-0.0116		-0.0155*
lag 1		-0.0039		-0.0019
lags 2-6		-0.0048		-0.0014
Sentiment				
Euro-zone leads 2-6		0.0022		-0.0032
Euro-zone lead 1		-0.0042		0.0061
Euro-zone lag 0		0.0135		0.0006
Euro-zone lag 1		0.0048		0.0038
Euro-zone lags 2-6		0.0102		0.0233***

Table 3.6: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News
US leads 2-6		0.0360		0.0455***
US lead 1		0.0088		0.0555***
US lag 0		-0.0370		-0.0132
US lag 1		-0.0330***		0.0026
US lags 2-6		0.0160		-0.0091
Private Sector				
leads 2-6		-0.0002		0.0020
lead 1		-0.0104		-0.0058
lag 0		-0.0044		-0.0026
lag 1		0.0112		0.0032
lags 2-6		-0.0020		-0.0058***
Politics				
leads 2-6		0.0123		0.0092
lead 1		-0.0118		0.0266*
lag 0		-0.0439*		-0.0101
lag 1		0.0145		-0.0063
lags 2-6		0.0037		0.0037
Adj R^2	0.1360	0.1168	0.0140	0.027
$F-test$	119.10***	4.81***	11.95***	1.81***

Notes: Returns and order flow are calculated at 20 minute frequency. Returns are defined as 100 times the log difference of the mid quote. The mid quote is calculated as the average of the bid and ask quotes. Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR and sterling for USD-GBP). *, ** and *** represent significance at 10, 5 and 1 percent respectively.

Table 3.7: The Influence of "News" on USD-EUR and USD-GBP Returns in "High News Arrival" and "High Volatility" Periods

Independent	"High News Arrival"		"High Volatility"	
Variables	USD-EUR	USD-GBP	USD-EUR	USD-GBP
Non-News				
Constant	0.0010	-0.0002	-0.0001	-0.0003
Dependent Variable				
lag 1	0.2557***	-0.1359***	0.1592**	-0.1196***
lag 2	0.1716**	-0.0186	0.1055*	-0.0111
Macro Surprises				
UK	-0.0201	0.0331**	-0.0086	0.0336**
US	-0.0508	-0.0293	-0.0498	-0.0296
Euro-zone	0.0102	-0.0165	-0.0002	-0.0226**
Fundamentals				
Monetary				
Euro-zone leads 2-6	0.0063	-0.0023	0.0036	-0.0002
Euro-zone lead 1	-0.0096	-0.0120	-0.0163	-0.0027
Euro-zone lag 0	-0.0263*	-0.0036	-0.0183*	-0.0054
Euro-zone lag 1	-0.0022	0.0070	0.0014	-0.0075
Euro-zone lags 2-6	0.0012	0.0042	-0.0031	0.0053*
US leads 2-6	-0.0100	-0.0036	-0.0087**	-0.0036
US leads lead 1	-0.0025	0.0025	0.0000	-0.0078
US leads lag 0	0.0170	0.0045	0.0086	0.0048
US lag 1	-0.0071	-0.0008	-0.0063	0.0103**
US lags 2-6	0.0032	-0.0024	0.0050*	-0.0015
Other Asset Markets				
Euro-zone leads 2-6	-0.0028	-0.0069	0.0008	-0.0023
Euro-zone lead 1	0.0221	0.0211**	0.0240*	0.0216***
Euro-zone lag 0	-0.0139	0.0059	0.0138	0.0096
Euro-zone lag 1	-0.0347	-0.0172	-0.0163	-0.0082
Euro-zone lags 2-6	0.0030	-0.0015	-0.0016	0.0016
US leads 2-6	-0.0001	-0.0055	0.0008	-0.0022
US lead 1	0.0073	-0.0032	-0.0053	0.0028
US lag 0	-0.0166	-0.0054	-0.0129	-0.0058
US lag 1	-0.0021	0.0039	0.0103	-0.0027
US lags 2-6	-0.0070	-0.0010	-0.0016	0.0018
Japan leads 2-6	0.0094	0.0115**	0.0137	0.0071
Japan lead 1	0.0248	-0.0070	0.0076	-0.0001
Japan lag 0	0.0487	0.0004	-0.0177	-0.0103

Table 3.7: Contd.

Independent Variables	"High News Arrival"		"High Volatility"	
	USD-EUR	USD-GBP	USD-EUR	USD-GBP
Japan lag 1	0.0697*	0.0072	0.0088	0.0032
Japan lags 2-6	0.0271	0.0025	-0.0007	0.0093
Fiscal				
Euro-zone leads 2-6	-0.0010	-0.0012	0.0030	-0.0007
Euro-zone lead 1	-0.0167	-0.0099	-0.0197	-0.0152**
Euro-zone lag 0	0.0379	0.0005	-0.0123	-0.0084
Euro-zone lag 1	0.0091	0.0042	-0.0026	-0.0060
Euro-zone lags 2-6	-0.0038	-0.0020	0.0071	-0.0012
US leads 2-6	-0.0080	0.0019	-0.0184*	0.0031
US lead 1	-0.0023	0.0237	0.0048	0.0091
US lag 0	-0.0544	-0.0187	-0.0308	0.0084
US lag 1	-0.0002	0.0025	0.0435**	0.0146
US lags 2-6	-0.0166	-0.0222**	-0.0224*	-0.0267***
Exchange Rate Policy				
Euro-zone leads 2-6	-0.0004	0.0015	0.0002	-0.0006
Euro-zone lead 1	0.0079	-0.0019	0.0051	0.0028
Euro-zone lag 0	0.0045	-0.0037	0.0000	-0.0011
Euro-zone lag 1	0.0191	-0.0004	0.0008	-0.0003
Euro-zone lags 2-6	0.0013	0.0025	0.0019	0.0016
US leads 2-6	0.0354	0.0196**	...	0.0141*
US lead 1	-0.0806	0.0053	-0.0586	-0.0012
US lag 0	0.0194	-0.0193	0.0493	0.0121
US lag 1	-0.0513	-0.0259	-0.0503**	-0.0433***
US lags 2-6	0.0184	0.0051	-0.0096	-0.0165
Japan leads 2-6	0.0006	0.0007	0.0005	0.0020
Japan lead 1	0.0089	-0.0026	0.0088	-0.0048
Japan lag 0	0.0350**	-0.0077	0.0151	0.0029
Japan lag 1	-0.0253*	-0.0128*	-0.0126	-0.0124*
Japan lags 2-6	0.0149	0.0033	-0.0069	0.0016
Actual Intervention				
Japan leads 2-6	-0.0050	-0.0121**	0.0060	-0.0069**
Japan lead 1	0.0540	0.0385*	0.0303**	0.0160**
Japan lag 0	-0.0642*	0.0105	-0.0347*	0.0057
Japan lag 1	0.0128	0.0029	0.0042	0.0055
Japan lags 2-6	-0.0033	-0.0013	-0.0009	-0.0064**
Other Macro				
Euro-zone leads 2-6	-0.0068	-0.0001	-0.0071*	0.0018

Table 3.7: Contd.

Independent Variables	"High News Arrival"		"High Volatility"	
	USD-EUR	USD-GBP	USD-EUR	USD-GBP
Euro-zone lead 1	0.0038	0.0035	0.0071	0.0046
Euro-zone lag 0	0.0126	0.0144**	0.0094	0.0082
Euro-zone lag 1	0.0191	0.0118	0.0137	0.0133**
Euro-zone lags 2-6	-0.0018	0.0028	-0.0022	0.0030
US leads 2-6	-0.0017	-0.0030	-0.0024	-0.0005
US lead 1	-0.0135	0.0041	-0.0061	-0.0019
US lag 0	-0.0022	-0.0007	0.0015	-0.0031
US lag 1	-0.0311**	-0.0051	-0.0107	-0.0042
US lags 2-6	0.0008	-0.0024	-0.0009	-0.0036*
Japan leads 2-6	0.0024	0.0052	0.0078	-0.0002
Japan lead 1	-0.0645	-0.0374	-0.0459	-0.0010
Japan lag 0	-0.0566	-0.0879***	0.0281	-0.0120
Japan lag 1	-0.0603	-0.0303**	-0.0466	-0.0249
Japan lags 2-6	-0.0086	-0.0024	0.0039	0.0025
Non-Fundamentals				
Options Market				
leads 2-6	-0.0010	-0.0052*	0.0013	-0.0052*
leads lead 1	0.0094	0.0058	0.0166**	0.0003
leads lag 0	0.0077	0.0017	0.0050	-0.0029
lag 1	-0.0421***	-0.0029	-0.0192*	-0.0031
lags 2-6	0.0081	0.0142***	0.0069*	-0.0008
Technical Analysis				
leads 2-6	0.0140	0.0030	0.0026	0.0036
lead 1	-0.0008	-0.0094	0.0012	0.0056
lag 0	-0.0124	-0.0007	-0.0054	-0.0061
lag 1	-0.0027	-0.0010	-0.0026	-0.0082
lags 2-6	-0.0030	-0.0014	0.0019	0.0019
Sentiment				
Euro-zone leads 2-6	0.0115	-0.0020	0.0025	-0.0058
Euro-zone lead 1	0.0008	0.0062	0.0110	0.0063
Euro-zone lag 0	0.0245	-0.0150	0.0240	0.0149
Euro-zone lag 1	-0.0012	0.0101	0.0128	0.0127
Euro-zone lags 2-6	0.0086	0.0258***	0.0119	0.0009
US leads 2-6	0.0398	0.0500***	0.0340**	0.0267***
US lead 1	-0.2127	-0.1420*	0.0315	0.0428***
US lag 0	-0.8874*	-1.0732***	-0.0419*	0.0005
US lag 1	-0.0337***	0.0029	-0.0474***	-0.0035

Table 3.7: Contd.

Independent Variables	"High News Arrival" USD-EUR	"High News Arrival" USD-GBP	"High Volatility" USD-EUR	"High Volatility" USD-GBP
US lags 2-6	0.0159	-0.0082	0.0017	-0.0004
Private Sector				
leads 2-6	0.0019	0.0035	0.0006	0.0005
lead 1	-0.0104	-0.0057	-0.0095	-0.0157***
lag 0	-0.0042	-0.0077*	-0.0051	-0.0083**
lag 1	0.0136	0.0070	0.0059	0.0046
lags 2-6	-0.0051	-0.0053**	0.0003	-0.0056***
Politics				
leads 2-6	0.0038	0.0084	0.0223*	0.0057
lead 1	-0.0134	0.0281*	-0.0123	0.0402***
lag 0	-0.0676**	-0.0204	-0.0538**	-0.0019
lag 1	0.0111	-0.0121	0.0054	-0.0120
lags 2-6	0.0098	0.0032	-0.0052	0.0052
Interaction Terms				
Monetary Fundamentals				
US leads 2-6	-0.0079	0.0090	0.9797***	-0.2664
US lags 2-6	0.0116	-0.0027	-0.1100***	0.0085
Other Asset Markets				
Japan leads 2-6	-0.0525	-0.1767***	0.2342***	-0.4710
Japan lag 1	-0.8273***	-0.7267***	0.3322***	...
Fiscal Fundamentals				
US lags 2-6	-0.0639	-0.0105	-0.5274*	0.3910***
Exchange Rate Policy - Actual Intervention				
Japan lead 1	...	0.0458**	0.5289***	0.3010***
Other Macro Fundamentals				
Euro-zone leads 2-6	0.0280	0.0117	0.4087***	0.0441
Non-Fundamentals				
Options Market				
lags 2-6	0.0227	-0.0591**	0.4547	0.0779*
Adj R^2	0.1150	0.0293	0.2833	0.1716
$F-test$	3.44***	1.57***	9.83***	5.32***

Notes: Returns are calculated at 20 minute frequency and are defined as 100 times the log difference of the mid quote where the mid quote is calculated as the average of the bid and ask quotes. *, ** and *** represent significance at 10, 5 and 1 percent respectively.

Table 3.8: The Influence of "News" on USD-EUR and USD-GBP Volatility

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News
Non-News				
Constant	-0.0035*	-0.0042**	-0.0033***	-0.0042***
Dependent Variable				
lag 1	0.4674***	0.4604***	0.2181***	0.2023***
lag 2	0.0903*	0.0877*	0.1308***	0.1219***
lag 3	0.0971***	0.0958***	0.0486**	0.0421*
lag 4	0.0586**	0.0552**	0.0943***	0.0943***
lag 5	0.0011	0.0018	0.0518*	0.0477*
lag 6	0.0240	0.0258	0.0528*	0.0525*
Macro Surprises				
UK	-0.0295	-0.0312	-0.0123	-0.0105
US	-0.0143	-0.0150	-0.0376***	-0.0379***
Euro-zone	-0.0017	-0.0028	0.0049	0.0054
Fundamentals				
Monetary				
Euro-zone leads 2-6		0.0000		-0.0020
Euro-zone lead 1		-0.0069		0.0006
Euro-zone lag		-0.0105		-0.0005
Euro-zone lag 1		-0.0023		-0.0002
Euro-zone lags 2-6		-0.0053		-0.0036
US leads 2-6		-0.0049		-0.0005
US lead 1		0.0005		-0.0093
US lag 0		0.0066		-0.0023
US lag 1		0.0034		0.0010
US lags 2-6		0.0000		0.0039*
Other Asset Markets				
Euro-zone leads 2-6		-0.0055		0.0067*
Euro-zone lead 1		0.0180		-0.0034
Euro-zone lag 0		-0.0029		-0.0086
Euro-zone lag 1		0.0131		0.0068
Euro-zone lags 2-6		0.0002		0.0031
US leads 2-6		0.0001		0.0003
US lead 1		0.0077		0.0092
US lag 0		0.0125		0.0026
US lag 1		-0.0064		0.0108**

Table 3.8: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News
US lags 2-6		-0.0031		-0.0014
Japan leads 2-6		0.0001		-0.0115***
Japan lead 1		0.0095		-0.0016
Japan lag 0		0.0085		0.0029
Japan lag 1		0.0234		-0.0130*
Japan lags 2-6		0.0169		-0.006
Fiscal				
Euro-zone leads 2-6		-0.0063		-0.0105**
Euro-zone lead 1		-0.0157		-0.0048
Euro-zone lag 0		-0.0008		-0.0049
Euro-zone lag 1		-0.0365***		-0.0089
Euro-zone lags 2-6		-0.0149		-0.0110**
US leads 2-6		0.0076		0.0086
US lead 1		-0.0442**		-0.0196**
US lag 0		-0.0004		0.0254*
US lag 1		-0.0207		-0.0125
US lags 2-6		-0.0037		0.0010
Exchange Rate Policy				
Euro-zone leads 2-6		-0.0019		-0.0021
Euro-zone lead 1		0.0100		0.0017
Euro-zone lag 0		0.0044		-0.0021
Euro-zone lag 1		0.0121		0.0042
Euro-zone lags 2-6		0.0042		0.0056***
US leads 2-6		0.0138		-0.0133*
US lead 1		-0.0156		-0.0042
US lag 0		-0.0050		-0.0113
US lag 1		-0.0147		-0.0209
US lag 2-6		-0.0073		0.0011
Japan leads 2-6		0.0020		0.0013
Japan lead 1		0.0026		0.0071
Japan lag 0		0.0149		0.0007
Japan lag 1		-0.0146		-0.0081**
Japan lags 2-6		0.0122		-0.0044**
Actual Intervention				
Japan leads 2-6		-0.0088		0.0067
Japan lead 1		0.0118		0.0093
Japan lag 0		0.0165		-0.0039

Table 3.8: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News
Japan lag 1		0.0044		-0.0010
Japan lags 2-6		-0.0108		-0.0001
Other Macro				
Euro-zone leads 2-6		-0.0001		0.0012
Euro-zone lead 1		-0.0092		-0.0073
Euro-zone lag 0		-0.0118**		0.0005
Euro-zone lag 1		0.0101		-0.0017
Euro-zone lags 2-6		0.0009		-0.0009
US leads 2-6		0.0046		0.0027
US lead 1		-0.0191*		-0.0011
US lag 0		-0.0006		0.0020
US lag 1		-0.0159**		-0.0059
US lags 2-6		-0.0021		-0.0045**
Japan leads 2-6		-0.0047		0.0007
Japan lead 1		0.0369		0.0211
Japan lag 0		0.0126		-0.0134
Japan lag 1		-0.0155		0.0073
Japan lags 2-6		-0.0030		0.0038
Non-Fundamentals				
Options Market				
leads 2-6		-0.0017		-0.0058*
lead 1		-0.0013		-0.0070*
lag 0		0.0106**		-0.0065
lag 1		0.0106*		-0.0061**
lags 2-6		-0.0020		0.0032
Technical Analysis				
leads 2-6		0.0112		0.0040*
lead 1		-0.0063		0.0161
lag 0		-0.0147*		0.0033
lag 1		-0.0101		-0.0005
lags 2-6		0.0016		-0.0026
Sentiment				
Euro-zone leads 2-6		-0.0027		-0.0047
Euro-zone lead 1		-0.0162		-0.0240**
Euro-zone lag 0		-0.0119		-0.0107

Table 3.8: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News
Euro-zone lag 1		-0.0082		0.0048
Euro-zone lags 2-6		0.0058		0.0065
US leads 2-6		0.0336*		0.0102*
US lead 1		-0.0674***		-0.0105
US lag 0		-0.0451**		-0.0487***
US lag 1		0.0221**		-0.0138**
US lags 2-6		0.0048		0.0132*
Private Sector				
leads 2-6		0.0013		-0.0029**
lead 1		-0.0027		0.0057**
lag 0		-0.0003		0.0053*
lag 1		-0.0057		-0.0034
lags 2-6	-0.0004		0.0015	
Politics				
leads 2-6		-0.0133		-0.0074
lead 1		-0.0042		-0.0042
lag 0		0.0237		-0.0199**
lag 1		-0.0095		0.0038
lags 2-6		0.0033		-0.0042
Adj R^2	0.3628	0.3853	0.1503	0.154
$F-test$	235.78***	16.78***	67.93***	6.11***

Notes: Volatility is calculated at 20 minute frequency and is defined as the absolute return where returns are calculated as 100 times the log difference of the mid quote. The mid quote is calculated as the average of the bid and ask quotes. *, ** and *** represent significance at 10, 5 and 1 percent respectively.

Table 3.9: The Influence of Order Flow on USD-EUR and USD-GBP Returns

Independent	USD-EUR	USD-GBP
Variables	Return on order flow	Return on order flow
Non-News		
Constant	...	-0.0022***
Dependent Variable		
lag 1	0.3765***	...
lag 2	0.1422***	...
Order Flow		
lag 0	0.0041***	0.0028***
lag1	-0.0019***	-0.0003*
lags 2-6	...	...
Adj R^2	0.3895	0.2601
$F-test$	479.52***	267.07***

Notes: Returns and order flow are calculated at 20 minute frequency. Returns are defined as 100 times the log difference of the mid quote .The mid quote is calculated as the average of the bid and ask quotes. Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR and sterling for USD-GBP). *, ** and *** represent significance at 10, 5 and 1 percent respectively.

Table 3.10: The Influence of "News" on USD-EUR and USD-GBP Order Flow

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News
Non-News				
Constant	-0.0916	-0.0720	0.7134***	0.6438***
Dependent Variable				
lag 1	0.0276	0.0068	0.0375	0.0239
lag 2	0.0064	-0.0140	0.0612**	0.0414
Macro Surprises				
UK	5.0043	5.7282	5.5390	5.9551
US	-5.2395	-4.7519	-3.1900	-3.0639
Euro-zone	-14.3592***	-8.1623***	2.4857	6.2941
Monetary				
Euro-zone leads 2-6		-1.0664		0.6128
Euro-zone lead 1		-4.6384**		-3.0961***
Euro-zone lag 0		-0.2166		0.5266
Euro-zone lag 1		-0.5150		-3.8553***
Euro-zone lags 2-6		-2.0149*		-1.4698*
US leads 2-6		0.1683		-0.1976
US lead 1		0.4166		0.8880
US lag 0		-0.8355		0.0358
US lag 1		-0.8338		1.1835
US lags 2-6		1.1211**		0.2023
Other Asset Markets				
Euro-zone leads 2-6		0.7458		-1.4982**
Euro-zone lead 1		8.5026***		0.6791
Euro-zone lag 0		2.5776		-2.3840
Euro-zone lag 1		-2.2379		0.3759
Euro-zone lags 2-6		-2.6458*		0.5862
US leads 2-6		-0.9672		-0.0193
US lead 1		0.7701		2.0473**
US lag 0		-0.3633		0.1308
US lag 1		0.9499		0.2826
US lags 2-6		-0.8867		-0.5952
Japan leads 2-6		-0.0483		0.7684
Japan lead 1		-8.4890***		-1.8291
Japan lag 0		-1.6512		1.2118
Japan lag 1		3.4236		-1.6684

Table 3.10: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News
Japan lags 2-6		3.1405		-0.7835
Fiscal				
Euro-zone leads 2-6		0.4517		-0.3809
Euro-zone lead 1		-6.1345*		-1.3813
Euro-zone lag 0		-1.6459		2.8255
Euro-zone lag 1		-2.2238		-2.5632
Euro-zone lags 2-6		1.1478		-1.0193
US leads 2-6		-3.6302*		-1.0672
US lead 1		5.0921		1.0908
US lag 0		-5.7113		-1.5695
US lag 1		3.6271		6.5694**
US lags 2-6		-4.2852		-1.6651
Exchange Rate Policy				
Euro-zone leads 2-6		0.7444		-0.3120
Euro-zone lead 1		2.2783*		1.3134*
Euro-zone lag 0		-0.2348		-2.1597**
Euro-zone lag 1		0.3445		0.8507
Euro-zone lags 2-6		0.3848		1.0142**
US leads 2-6		1.2634		5.1489***
US lead 1		-14.8325		-2.7571
US lag 0		10.5302		2.5919
US lag 1		-5.9310		-4.2393
US lags 2-6		-6.6751*		-4.1263**
Japan leads 2-6		0.6125		0.4493
Japan lead 1		-1.5933		0.2873
Japan lag 0		1.4530		0.1225
Japan lag 1		-1.7703		-0.5979
Japan lags 2-6		-0.6091		-0.8216*
Actual Intervention		-2.0098		-0.7482
Japan leads 2-6				
Japan lead 1		7.4541		2.2856
Japan lag 0		1.2634		-0.1558
Japan lag 1		1.2091		-0.6040
Japan lags		1.3187		-0.4869

Table 3.10: Contd.

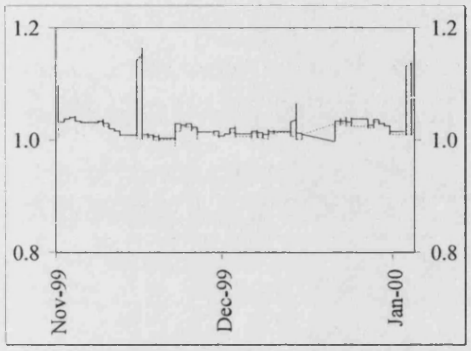
Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News
Other Macro				
Euro-zone leads 2-6		0.3565		0.2400
Euro-zone lead 1		1.1168		0.1463
Euro-zone lag 0		0.4636		0.4353
Euro-zone lag 1		3.3291		2.3196*
Euro-zone lags 2-6		0.9315		0.6359
US leads 2-6		-1.4502		0.1066
US lead 1		-1.7229		-0.7207
US lag 0		-1.2686		0.2478
US lag 1		-1.4547		-0.2004
US lags 2-6		-0.4525		-0.2859
Japan leads 2-6		0.0938		1.4134
Japan lead 1		-5.5085		-1.0686
Japan lag 0		-0.8941		-0.5508
Japan lag 1		-10.8177		-6.4707
Japan lags 2-6		-3.2868		2.2332
Non-Fundamentals				
Options Market				
leads 2-6		-2.0105		-0.0058*
lead 1		3.6767**		1.0264
lag 0		2.1123		0.0083
lag 1		-1.1373		-2.0049
lags 2-6		1.8932*		0.2565
Technical Analysis				
leads 2-6		-0.5391		0.1745
lead 1		0.5049		0.0781
lag 0		-1.2501		-1.2757
lag 1		1.5795		-0.2632
lags 2-6		-1.1253*		0.3740
Sentiment				
Euro-zone leads 2-6		1.9762		0.0214
Euro-zone lead 1		3.7804		1.8435
Euro-zone lag 0		5.1912		3.2942
Euro-zone lag 1		-2.1566		2.0271
Euro-zone lags 2-6		4.4319**		2.6850

Table 3.10: Contd.

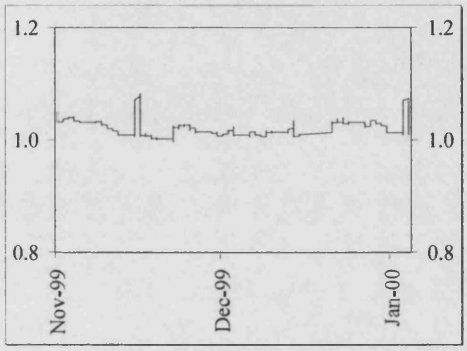
Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News
US leads 2-6		8.2922***		2.3937
US lead 1		18.1050***		3.4189
US lag 0		-1.8335		-2.4227
US lag 1		13.0734***		0.4593
US lags 2-6		0.1711		3.0685*
Private Sector				
leads 2-6		-0.4838		0.3700
leads 1		-2.7635		-1.0075
lag 0		-1.1951		0.1768
lag 1		1.0433		0.3638
lags 2-6		0.2696		-0.7336*
Politics				
leads 2-6		3.3832*		-0.1477
leads 1		-1.1338		-0.3227
lag 0		0.9213		-2.1606
lag 1		-5.8603**		-4.2438*
lags 2-6		-1.6658		-0.4108
Adj R^2	0.0020	0.0203	0.0048	0.012
$F-test$	2.76***	1.61***	4.90**	1.38**

Notes: Order flow is calculated at 20 minute frequency. It is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR and sterling for USD-GBP). *, ** and *** represent significance at 10, 5 and 1 percent respectively.

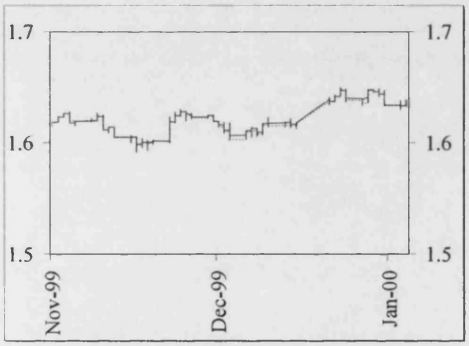
Figure 3.1: Reuters D2000-2 Bid, Ask and Mid Quotes, 15 Nov 1999 - 18 Jan 2000



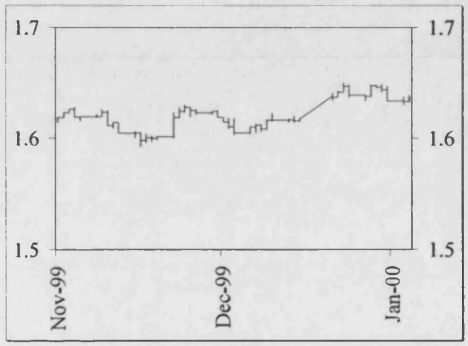
(a) USD-EUR Bid & Ask Quotes



(b) USD-EUR Mid Quote



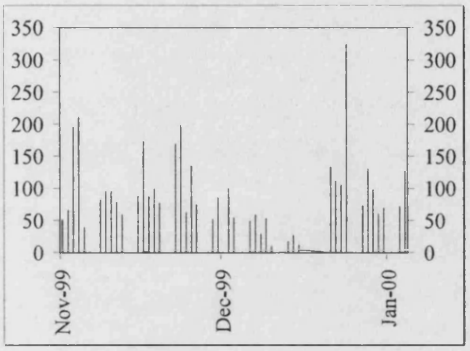
(c) USD-GBP Bid & Ask Quotes



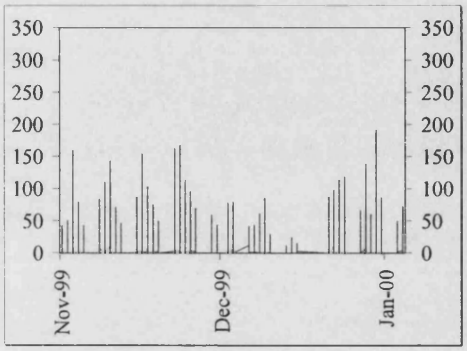
(d) USD-GBP Mid Quote

Notes: Both currencies are defined as the number of dollars per foreign currency (euro and sterling, respectively). The mid quote is calculated as the average of the bid and ask quotes.

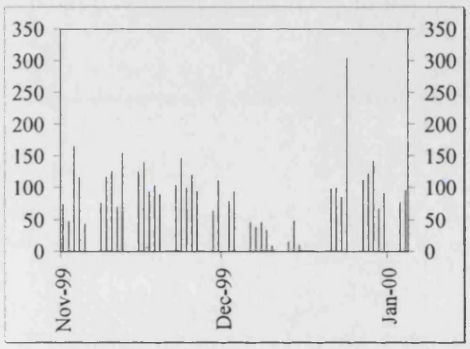
Figure 3.2: Total Buys, Total Sells and Order Flow, 15 Nov 1999 - 18 Jan 2000



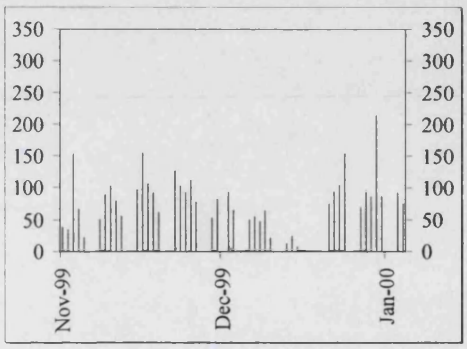
(a) USD-EUR Total Buy



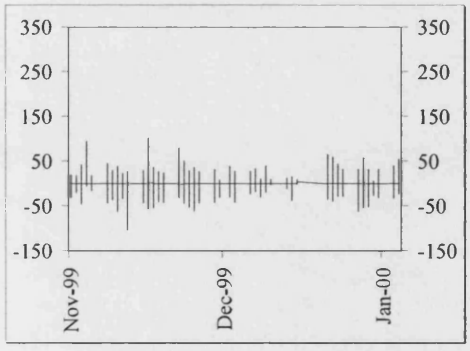
(b) USD-GBP Total Buy



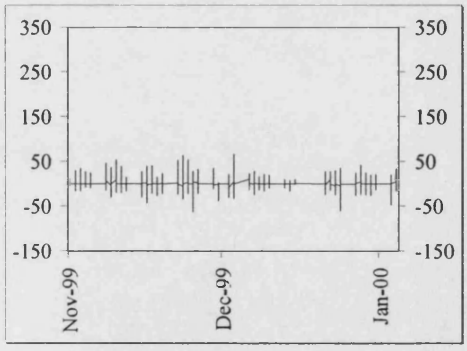
(c) USD-EUR Total Sell



(d) USD-GBP Total Sell



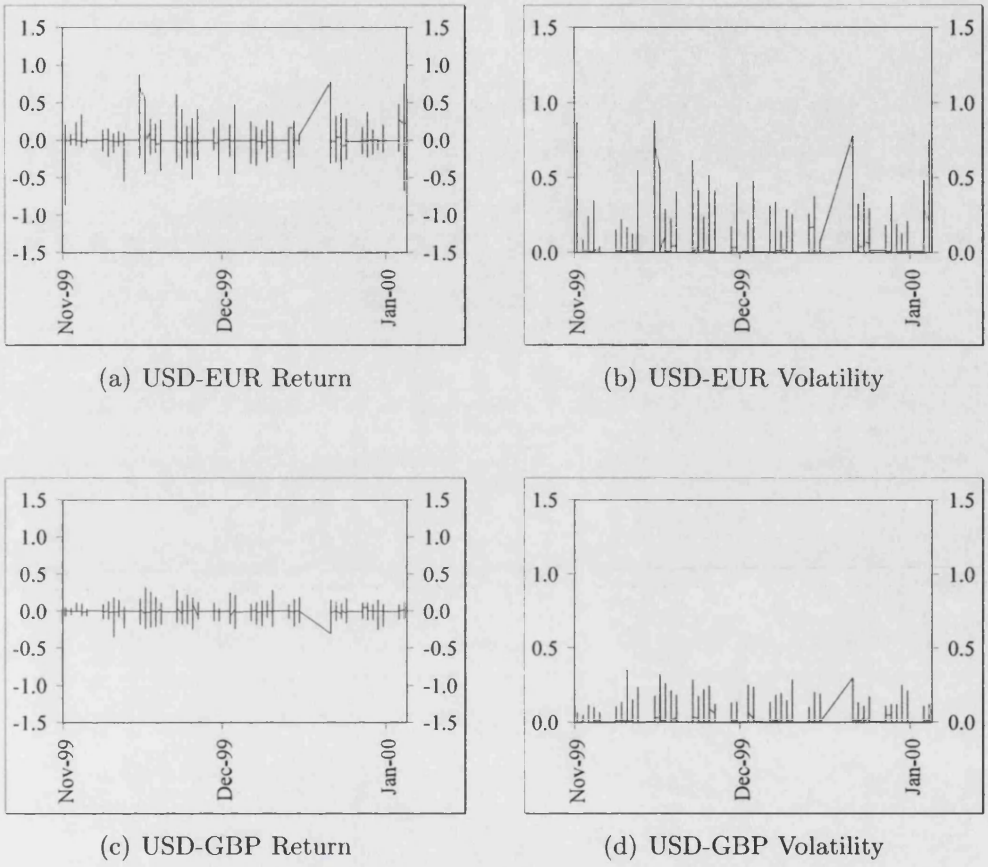
(e) USD-EUR Order Flow



(f) USD-GBP Order Flow

Notes: Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR and sterling for USD-GBP).

Figure 3.3: Exchange Rate Returns and Volatility, 15 Nov 1999 - 18 Jan 2000



(a) USD-EUR Return

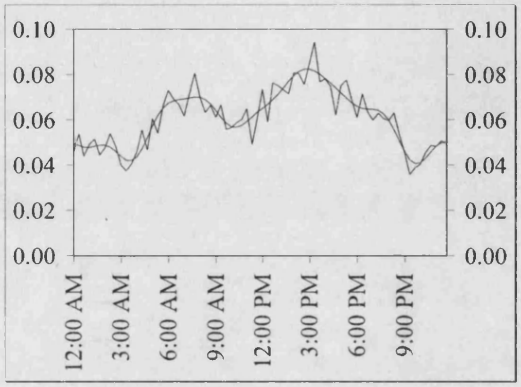
(b) USD-EUR Volatility

(c) USD-GBP Return

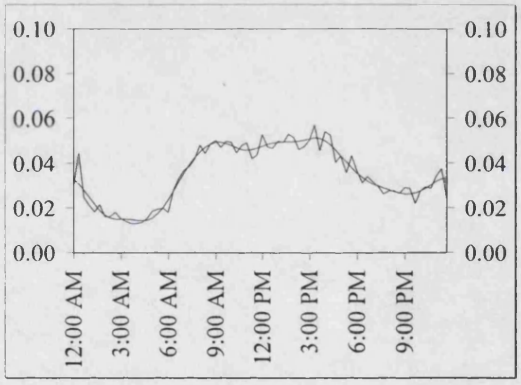
(d) USD-GBP Volatility

Notes: The data are sampled at 20-minute frequency. Both currencies are defined as the number of dollars per foreign currency (euro and sterling, respectively). Returns are defined as 100 times the log difference of the mid quote where the mid quote is calculated as the average of the bid and ask quotes. Volatility is defined as the absolute return.

Figure 3.4: Average Daily Volatility and the FFF Seasonal (in basis points), 15 Nov 1999 - 18 Jan 2000



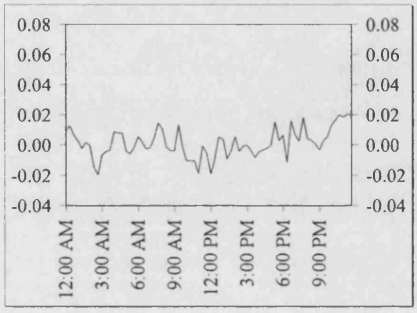
(a) USD-EUR



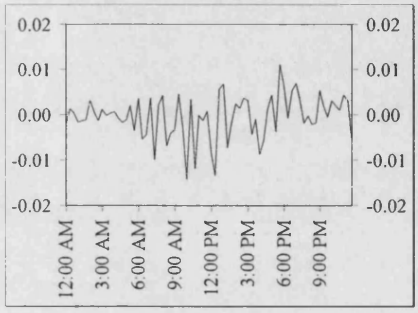
(b) USD-GBP

Notes: The data are sampled at 20-minute frequency. Both currencies are defined as the number of dollars per foreign currency (euro and sterling, respectively). The figures plot the average intra-daily pattern of volatility (jagged line) and the Flexible Fourier Form seasonal (smooth line) over a 24-hour period. Volatility is defined as the absolute return, where returns are calculated as 100 times the log difference of the mid quote. The mid quote is calculated as the average of the bid and ask quotes.

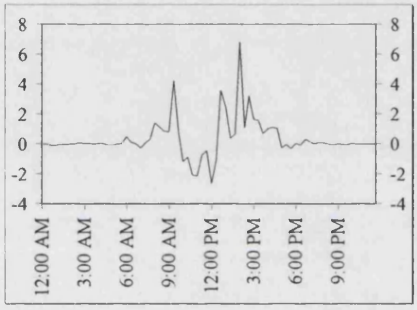
Figure 3.5: Average Daily USD-GBP Returns, Order Flow and News Arrival, 15 Nov 1999 - 18 Jan 2000



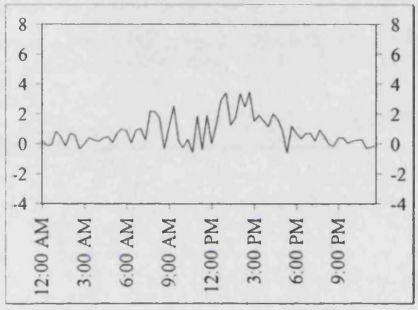
(a) USD-EUR Average Return



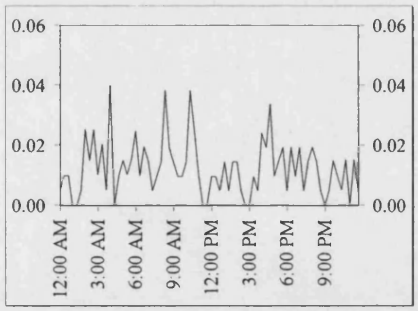
(b) USD-GBP Average Return



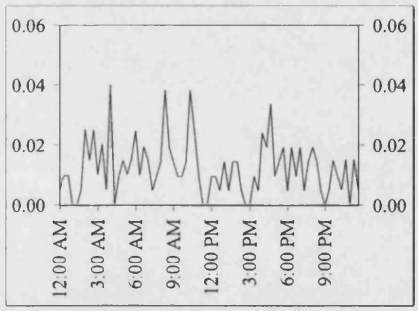
(c) USD-EUR Average Order Flow



(d) USD-GBP Average Order Flow



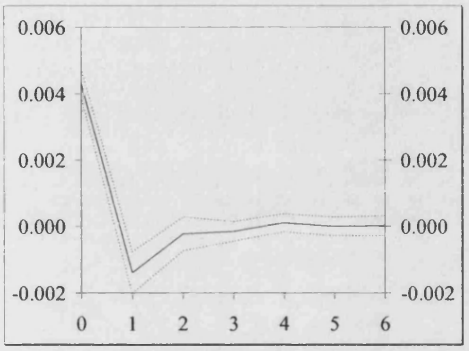
(e) USD-EUR Average News Arrival



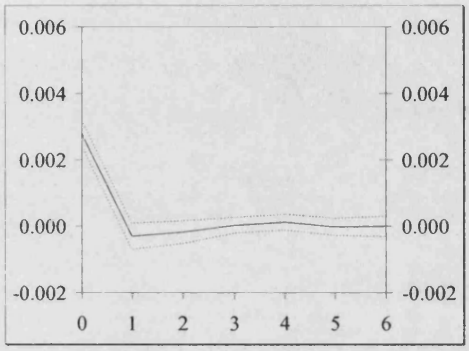
(f) USD-GBP Average News Arrival

Notes: The data are sampled at 20-minute frequency. Both currencies are defined as the number of dollars per foreign currency (euro and sterling, respectively). The figures plot the average intra-daily pattern of returns, order flow and news arrival over a 24-hour period. Returns are calculated as 100 times the log difference of the mid quote where the mid quote is calculated as the average of the bid and ask quotes. Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR and sterling for USD-GBP). News Arrival is an indicator variable for the number of Reuters news articles in each 20 minute period.

Figure 3.6: Intra-day Effects of Order Flow and News on USD-EUR and USD-GBP Returns

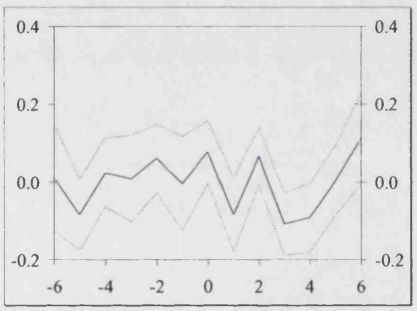


(a) USD-EUR

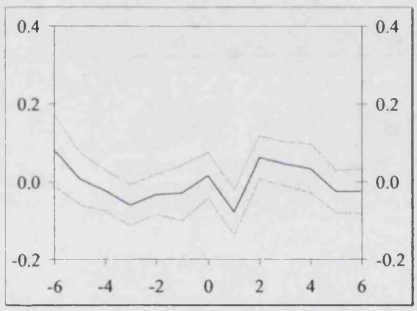


(b) USD-GBP

Order Flow

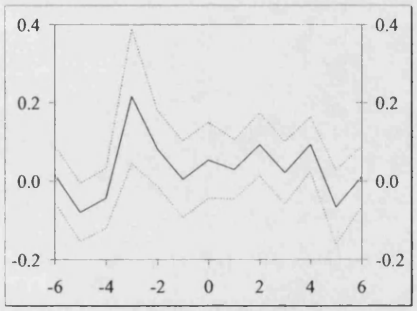


(c) USD-EUR

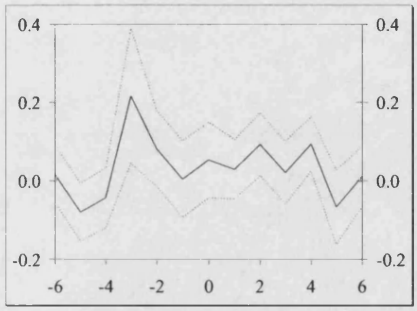


(d) USD-GBP

Fundamentals: US Unemployment Good News



(e) USD-EUR

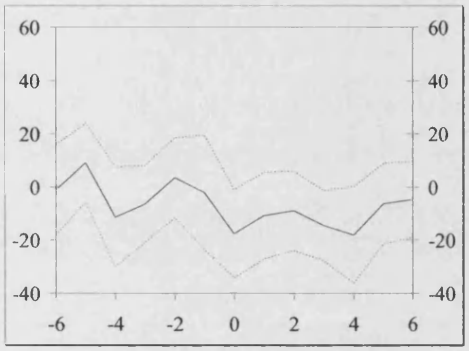


(f) USD-GBP

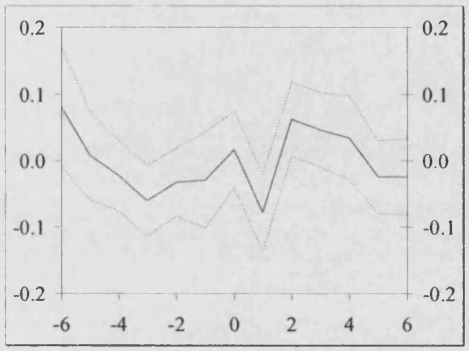
Non-Fundamentals: Technical Factor Good News

Notes: These figures show the cumulative effects on returns of order flow two hours after and "news" two hours before and after the time of the Reuters report (time 0). The dashed lines show the 95% confidence interval.

Figure 3.7: Intra-day Effects of News on USD-EUR and USD-GBP Order Flow

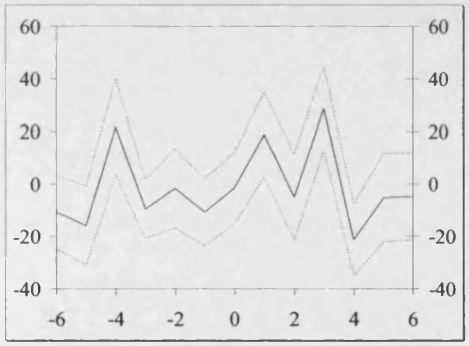


(a) USD-EUR

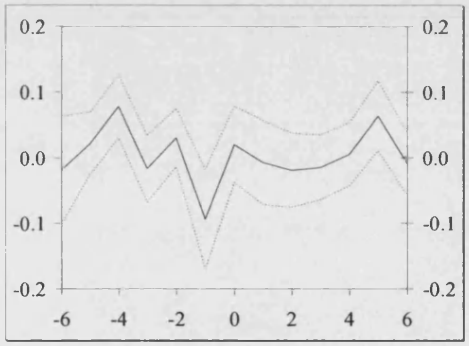


(b) USD-GBP

Fundamentals: US Unemployment Good News



(c) USD-EUR



(d) USD-GBP

Non-Fundamentals: Technical Factor Good News

Notes: These figures show the cumulative effects on order flow of "news" two hours before and after the time of the Reuters report(time 0). The dashed lines show the 95% confidence interval.

Chapter 4

Unrequited Interventions [1]

4.1 Introduction

This chapter examines intra-day foreign exchange market reactions to news of actual and unrequited interventions reported in the financial press. Intervention operations are used by many governments to manage their exchange rates. Research has found that these operations can, under certain circumstances, effectively influence the level and volatility of exchange rates[2]. One of the more

[1]This chapter is based on joint work with Prof. Kathryn M.E. Dominguez.

[2]A number of recent papers have examined the influence of intervention operations on daily exchange rate returns and volatility and generally find evidence that interventions influence returns and increase volatility. Dominguez and Frankel (1993a,b), Dominguez (2003a), Humpage (1999), Fatum and Hutchinson (2003, 2006), de Grauwe and Grimaldi (2003), Ito (2003) find that interventions influence daily returns. Bonser-Neal and Tanner (1996), Dominguez (1998), Galati, Melick, and Micu (forthcoming), Frenkel, Pierdzioch, and Stadtmann (2005) find that interventions lead to increases in implied volatilities measured using options data. Chaboud and LeBaron (1999) find a positive correlation between daily (futures) trading volume and Fed interventions. Dominguez (1998) using a GARCH model, Beine, Benassy-Quere, and Lecourt (2002) using a FIGARCH model, and Beine and Laurent (2003) using a model that allows for a time-varying jump probability associated with interventions, all find evidence that interventions tend to increase exchange rate volatility. Dominguez (forthcoming) and Beine, Laurent, and Palm (2003) examine the effects of G3 interventions on daily realized volatility using an ARFIMA model. A few papers find evidence that situation-specific interventions lead to decreases in volatility. For example, Beine, Laurent, and Lecourt (2003) allow for a regime-dependent specification using a Markov switching model and find that when the market is highly volatile concerted interventions decrease volatility. Dominguez (1998) and Taylor (2004)

puzzling aspects of intervention policy is the fact that some governments keep their intervention operations secret, even ex post[3]. The financial press often reports over the wire services when a central bank is intervening, though governments rarely officially confirm their presence in the market. Because there is often uncertainty in the market about whether a given government is intervening, there are inevitably circumstances when the financial press reports interventions that have not occurred. There are also frequently reports of what we term, unrequited interventions, interventions that the market expects but do not occur. In this chapter we examine the effects of various types of intervention news (reported actual interventions, falsely reported interventions, oral interventions and unrequited interventions) on exchange rate behaviour.

A number of previous studies have shown that in order to find significant reactions in the foreign exchange market to the news, one needs to measure the precise impact of the news at the intra-day level[4]. Using Reuters' time-stamped newswire reports we are able to match the timing of intervention news to movements in intra-day exchange rates. We also include scheduled macro announcement news reports which have been used in previous studies to allow us to compare the effects of intervention news against these more "traditional" variables.

The intra-day foreign exchange data used in this study are transactions prices

find that interventions in the mid-1980s reduced exchange rate volatility.

[3]Dominguez and Frankel (1993b) discuss the possible reasons that central banks might want to keep their intervention operations secret (the so-called stealth operations). Neely (2000) notes that central banks are moving increasingly toward electronic trading methods, which suggests that they are less interested in keeping operations secret. On this topic also see: Vitale (1999), Bhattacharya and Weller (1997), Chiu (2003), Beine, Janssen, and Lecourt (2004), Beine and Bernal (forthcoming). Although the Japanese government generally does not provide contemporaneous information about their intervention operations, the Ministry of Finance publishes lagged daily intervention data (lagged one month) on their website: http://www.mof.go.jp/english/e1c021.htm.

[4]See Dominguez and Panthaki (2006) for a more detailed discussion of the intra-day influence of news on exchange rates.

and quote spreads in three dollar currency markets: USD-EUR, USD-GBP and YEN-USD available from the Reuters D2000-2 electronic trading system over the period from December 1999 through July 2000. The data do not include information on traded quantities, but they do indicate whether trades were initiated by a buyer or seller, allowing us to measure order flow as well as returns and volatility. We use a 20 minute sampling frequency and measure order flow as the cumulative number of buyer initiated trades minus the cumulative number of seller initiated trades over the same 20 minutes.

The intra-day intervention news and exchange rate data allow us to test whether interventions have similar impact effects on returns and volatility as compared to (the already heavily studied) scheduled macro announcements. The fact that information regarding interventions most often comes from unofficial sources suggests that there are likely to be differences of opinion among market participants about the implications of the information. In our application, we can distinguish between scheduled (and presumably better-understood) macro announcements and more ambiguous intervention news. We also measure what proportion of the price discovery process in reaction to intervention news occurs via order flow. Previous studies have found evidence that a substantial proportion of the market reaction to macro-announcements occurs via order flow. By examining how intervention news events influence order flow - we can begin to better understand how this measure relates to price and volatility movements in the foreign exchange markets.

The chapter is organized as follows. Section 2 reviews the links between intervention operations and exchange rates in standard models. Section 3 describes the exchange rate and order flow data from Reuters D2000-2 used in our empirical analysis. Section 4 provides results of our event study analysis of the

influence of intervention news and macro surprises on exchange rate returns and volatility. Section 5 introduces our order flow information and examines its role in explaining exchange rate movements. Section 6 concludes.

4.2 Intervention News and Exchange Rates

Theory suggests that foreign exchange market interventions that are sterilized[5] may influence exchange rates through two potential channels: portfolio balance and "information/signaling". In portfolio-balance models of exchange rate determination, investors diversify their holdings among domestic and foreign assets as a function of expected returns and the variance of returns. Foreign and domestic assets are assumed to be outside assets (so that Ricardian equivalence does not hold) and imperfect substitutes (so that uncovered interest parity does not hold). Portfolio balance theory predicts that the change in the relative supply of foreign and domestic assets that occurs with a sterilized intervention will require a change in expected relative returns. For example, after a sterilized home-currency supporting intervention, investors will require a higher expected return on foreign assets to hold willingly the larger outstanding stock, leading to a depreciation of the foreign currency relative to the home currency. In the portfolio balance model, traders do not need to observe the intervention operation in order for it to be effective. However, only actual intervention operations, which change the composition of domestic relative to foreign assets in trader's portfolios, can in-

[5]Sterilized interventions are a combination of two transactions. The central bank conducts a non-sterilized intervention, for example, by purchasing (or selling) foreign-currency denominated bonds and increasing (decreasing) the home monetary base. The central bank then sterilizes the operation by selling (or purchasing) a corresponding quantity of home-currency denominated bonds in order to reverse the effects on the monetary base. Countries that adhere to monetary targets are generally assumed to engage chiefly in sterilized intervention operations. In practice the U.S. and the ECB claim to routinely sterilize their operations.

fluence exchange rates via this channel. Consequently, unrequited interventions (as well as false reports of interventions and oral interventions) should have no influence on exchange rates via the portfolio balance channel.

The second channel whereby intervention operations may influence exchange rates is the information or signaling channel. Intervention operations may provide investors with "information" about the Central Bank's (or Government's) view of the appropriate exchange rate[6]. Intervention operations may also provide a "signal" of future policy intentions (for example, future monetary policy). Moreover, the intervention operation may itself "buy credibility" for future policy intentions. As long as the information signaled through intervention policy is relevant and credible, it can potentially influence the exchange rate[7]. Only those intervention operations that are observed by the market can serve to influence exchange rates via the signaling channel so that non-reported or secret interventions (if they are truly secret) are unlikely to serve as signals[8].

When traders first learn of an intervention operation over the newswires, they may not know whether the information is substantiated or not. It is therefore possible for all intervention news (whether actual, false or unrequited) to have a short-term impact on exchange rates via the signaling channel. As soon as traders learn that intervention news is false or unrequited then we might expect returns and volatility to revert to their original levels. Alternatively, it may be that in periods when interventions are expected (even if they do not occur) that unrequited interventions reported over the newswires serve to coordinate the

[6]It is also possible for governments to communicate this information directly to the market. See, for example, Fratzscher (2004), Jansen and de Haan (1987), Sager and Taylor (2004).

[7]See Mussa (1981), Dominguez (1992b), Vitale (2003), Sarno and Taylor (2001), D'Souza (2002), Taylor (2005) for further discussion of the intervention-signaling hypothesis.

[8]Naranjo and Nimalendran (2000) hypothesize that non-secret interventions create significant adverse selection problems for dealers. They find evidence in daily data that dealers increase exchange rate spreads around interventions and suggest that in doing so they protect themselves against the greater informational asymmetry around interventions.

markets' view of exchange rate movements[9].

We use time-stamped Reuters's newswire reports[10] to measure intervention news. Our search criteria retrieved newswire articles under the joint subject area of "foreign exchange" and "intervention". We then coded and grouped[11] news articles according to geographic region (Euro-zone, U.K., U.S. or Japan) and type of intervention (threat, rumour, oral, unrequited, actual and joint). Table 4.1 provides a breakdown of the intervention news categories that appeared in newswire reports over the period under study. In the table we distinguish between cases where there was a 'Threat' or 'No Threat' of intervention from the policymaker. Further distinctions were made between interventions that were 'Reported' or 'Not Reported' in the news (panel a), and interventions that were 'Expected' or 'Not Expected' by the market (panel b). There were 172 'Threats'[12], which we define as news that a central bank intervened, threatened to intervene, or made a statement that was intended to influence the home currency (termed oral interventions). There were 48 'No Threat' interventions[13] which we define as news

[9]Montgomery and Popper (2001) suggest that actual central bank intervention may also serve to aggregate and disseminate traders' information and thereby serve an informational sharing role for a heterogeneously informed market.

[10]These data are from the Factiva database and, unfortunately, do not include the headline news that run over the Reuters ticker second by second, but they include the major economic news events that occur over a given day.

[11]In theory each "news" report may have a different one-time influence on exchange rates. We group similar news items together in order to examine whether certain "types" of intervention news have a systematic influence on exchange rate behaviour.

[12]09 May 2000: "The beleaguered euro got a boost overnight when French Finance Minister Laurent Fabius reminded markets that currency market intervention was a weapon in Europe's arsenal and the currency should rise in the coming weeks"; 14 Mar 2000: "Japanese Finance Minister Kiichi Miyazawa said Japan would act in response to rapid moves in the foreign exchange market".

[13]17 February 2000: "ECB President Wim Duisenberg was reported on February 10 as saying the ECB could not and should not do anything directly to influence the euro's exchange rate but said he would not fundamentally rule out intervention. Asked whether there was a floor set at which the ECB would defend the euro at all costs, Duisenberg said, If there were such a limit, I wouldn't tell you. But there isn't one. But we know how limited the effect of such intervention is. If we take such a step in coordination with the United States and Japan, then that would be a possibility. But we see no reason for it at present, he said; 06 March

that a central bank did not intend to intervene (including orally). The 'Intervention Detected'[14] category refers to cases where the central bank intervened and it was reported in the news. The one 'False Intervention'[15] refers to an occasion when the market incorrectly thought the ECB was intervening. The largest category of intervention news in the table is 'Unrequited Intervention'[16] which is defined as a report that the market expected an intervention that did not occur.

The euro officially came into existence in January 1999, and a year later there was broad concern in Europe that the euro had dipped below parity against the dollar. The majority of the unrequited intervention news reports in our data over this period were associated with the absence of ECB operations to support the euro against the dollar. An example of the sort of news reports involving the ECB in this period includes: "[ECB President Wim Duisenberg] poured cold water on speculation that euro zone central banks had been covertly propping up the currency... Such talk has swirled around the foreign exchanges for the past week as a steady stream of orders to buy the single currency from such quarters,

2000: "Bundesbank's Welteke quoted by magazine as saying he was convinced euro has upward potential due to internal strength. - Welteke also says doesn't believe short-term measures can stabilise euro's exchange rate".

[14]16 Mar 2000: "The Bank of Japan has intervened at least 16 times in foreign exchanges since June, 1999, most recently on Wednesday, in an attempt to fight the market forces which have driven the Japanese currency higher"

[15]4 May 2000: "Traders contacted by Reuters said it was unclear whether these orders were executed for commercial purposes or whether they were intended to signal official intervention in support of the battered euro"; 11 May 2000: "Duisenberg contradicted himself over how sensitive the ECB actually was to the threat of inflation being imported by the euro's protracted fall, and poured cold water on speculation that euro zone central banks had been covertly propping up the currency"; 11 May 2000: " Traders had already become more inclined to sell the euro after Duisenberg denied that any of the recent purchases of the euros by European central banks had been covert intervention.".

[16]28 February 2000: "The issue now is what are the Europeans going to do about it. Just to say it's got the potential to appreciate would not be enough - they've been saying that since we were at $1.10"; 05 May 2000: "The market is sick of words, we need action."; 05 May 2000: "The authorities have to show their hand. They have to stand up and be seen. I think the market will take their lead," Soros said in London on Thursday"; 11 May 2000: "Actions speak louder than words, and it is all very well saying that you want the currency to be higher but people are actually waiting to see intervention, said Paul Coughlin, chief trader at American Express Bank in London".

ostensibly for commercial reasons, has kept traders on their toes"(May 11, 2000 at 10:57am). It was not until September 2000 (beyond our sample period) that the ECB actually intervened (in coordination with a number of other central banks including the Fed, the BOJ and the BOE).

The Japanese government, in contrast to the Europeans, sought a depreciation of the yen relative to the dollar in this time period. Figure 4.1, which shows the YEN-USD exchange rate and BOJ interventions from 1990 though 2002, puts Japanese exchange rate objectives into context. After a number of years of yen depreciation relative to the dollar, the yen began to strengthen in August 1998 (on the heels of a number of interventions in support of the yen by the BOJ and the Fed[17]) with a precipitous rise in the value of the yen relative to the dollar starting in July 1999 through early 2000. The BOJ intervened to weaken the yen by selling yen and purchasing dollars on 17 days over the period January 1999 (with the YEN-USD rate at 108) through April 2000 (with the YEN-USD rate at 104). Our eight-month sample period (circled on Figure 4.1) includes the last 5 of these 17 intervention days. Table 4.2 shows the dollar amounts purchased by the Bank of Japan on each of these days[18]. Reuters reports over this period suggest that both the market and the Japanese government considered the YEN-USD "100" mark as a critical value not to be crossed (which indeed did not happen).

[17]Ito (2003) provides a chronological description of Japanese foreign exchange intervention over the period 1991 through 2004. He notes that Japanese intervention strategy changed dramatically in 1995 under Eisuke Sakakibara, the Director General of the International Bureau, toward larger sized interventions on fewer occasions. Sakakibara retired in July 1999 but his successor, Mr. Kuroda, who was in charge of Japanese intervention policy during our sample period, followed a similar intervention philosophy of infrequent, large and unpredictable operations. Also see Chaboud and Humpage (2005), Kim (forthcoming), Fatum and Hutchinson (2006), Frenkel, Pierdzioch, and Stadtmann (2005) for further analysis of Japanese interventions over this time period.

[18]Newswire reports reveal that the BOJ intervened on multiple occasions on each "intervention day". The Fed, Bundesbank, and ECB also generally follow a strategy of intervening on multiple occasions over the course of a given intervention day. See Dominguez (2003b) for more discussion of intra-day intervention operation strategies.

The first BOJ intervention in our sample occurred on December 24, 1999, a day when our Reuters electronic brokerage data (and the Reuters news data) suggests there was extremely little trading in advance of the Christmas holiday. The second intervention, on January 4, 2000, also occurred during a period of extremely light trading volume. The YEN-USD rate rebounded from the critical "100" level after these interventions for a few weeks and then as the yen began to depreciate in early March, the BOJ again intervened on March 8th, 15th and April 3rd. The YEN-USD rate rebounded over the next few months and it was not until after a year's hiatus that the BOJ again began to purchase dollars in September 2001 through June 2002. Along with the actual BOJ interventions that took place during this time, there were numerous unrequited intervention news reports of additional Japanese operations (which did not occur) to weaken the yen.

During our sample period the Bank of England (BOE) did not engage in any intervention operations and the there were no rumours of BOE interventions or reports of unrequited interventions in the USD-GBP market. We include the USD-GBP in our analysis in large part because the source of our exchange rate data, the Reuters D2000-2 electronic brokerage trading system, is most dominate in this market. Triangular arbitrage suggests that news that influences other dollar cross-rates is also likely to influence the USD-GBP rate, and for this reason we include it in our study.

The empirical approach we take in this chapter is based on the assumption that exchange rates are forward looking asset prices that react to changes in the market's expectation of future fundamentals. We further assume that "future fundamentals" may include both standard variables from international macro models (for example, money and income differentials) as well as variables such as

actual and unrequited interventions that may provide information about future fundamentals. We use intra-daily exchange rate data to allow a narrow enough window around the times of news announcements to be able to precisely estimate the exchange rate reactions in the spirit of Andersen, Bollerslev, Diebold, and Vega (2003)[19].

We examine the intra-daily influence of intervention news on exchange rate movements[20]. We also consider whether intervention news not only impacts exchange rates directly, but also influences exchange rates via order flow (signed trade volume). Like unrequited interventions, order flow plays no role in standard models of exchange rate determination, so a finding that order flow matters will provide evidence in favor of a different modelling strategy for exchange rate determination (at least for very short term movements)[21].

The information that market participants in foreign exchange markets receive can be broadly categorized into two categories: "scheduled" and "non-scheduled". Official macro data are typically announced by the relevant government agency on a pre-arranged schedule, so that market participants can plan in advance their reactions to this information. Table 4.3 describes the scheduled macro news

[19]The enormous literature measuring the effects of macro news on intra-daily exchange rates includes Hakkio and Pearce (1985), Ito and Roley (1987), Ederington and Lee (1995), de Gennaro and Shrieves (1997), Almeida, Goodhart, and Payne (1998), Andersen and Bollerslev (1998), Melvin and Yin (2000), Faust, Rogers, Wang, and Wright (2003), Love and Payne (2003), Love (2004), Chaboud, Chernenko, Howorka, Iyer, Liu, and Wright (2004), Bauwens, Omrane, and Giot (2005), Ehrmann and Fratzscher (2005).

[20]Bauwens, Omrane, and Giot (2005) examine the influence of news, including rumours of intervention, on euro-usd volatility over a six month period in 2001. They find that the most significant pre-announcement increase in volatility is related to rumours of central bank interventions. They also find that once a rumour is refuted, volatility stabilizes or drops. Other intra-day studies of the effects of (actual) intervention operations include: Goodhart and Hesse (1993), Peiers (1997), Chang and Taylor (1998), Beattie and Fillion (1999), Fischer and Zurlinden (1999), Neely (2002), Payne and Vitale (2003), Breedon and Vitale (2004), Panthaki (2005), Pasquariello (2004, forthcoming), Dominguez (2003b, forthcoming).

[21]Evans and Lyons (2002) is one of the first studies that found a link between order flow and exchange rate movements. We will be examining these same links though with a very different data set and time period.

announcements from the UK, the US, the Euro-area and Japan that are included in our "macro surprise" variables. Non-scheduled news is by its nature less likely to be anticipated by the market. It is also likely that market participants are less able to quickly interpret the implications of non-scheduled news, which would include all our categories of intervention news, for exchange rates, potentially leading to more heterogeneity in their responses to the news[22]. Further, regardless of whether news is scheduled or not, its influence on exchange rates may be related to the state of the market at the time of the news arrival[23]. News that arrives during periods of high uncertainty may have different effects on the exchange rate, than news that arrives in calmer periods[24].

4.3 Exchange Market Data

[25]Our intra-day exchange rate and order flow data cover an eight-month period, from December 1999 through July 2000 for the USD-GBP, the USD-EUR and

[22]Of course, an increase in market heterogeneity may also occur in reaction to scheduled announcements. Kondor (2005) shows that if traders display confirmatory bias, the release of public information may increase divergence in opinion. The main insight is that sometimes (public) information implies something different when it is coupled with different (private) pieces of existing information. Bacchetta and van Wincoop (2006) also model the influence of higher-order expectations in reaction to news.

[23]For example, Dominguez (2003b) shows that the influence of central bank interventions on exchange rate returns depends on the intra-day timing of intervention operations (whether they occur during heavy trading volume, or are closely timed to scheduled macro announcements) as well as whether the operations are coordinated with another central bank. Dominguez and Panthaki (2006) find that "news" has its greatest influence on intra-day exchange rate returns during periods of high market uncertainty (proxied by high volatility as measured by the absolute value of returns).

[24]Andersen, Bollerslev, Diebold, and Vega (2003) find evidence that "bad" news in good times (economic expansions) have greater impacts than good news in good times, suggesting that good news in good times confirms beliefs but bad news in good times comes as more of a surprise. Our short sample period will not allow us to test this hypothesis directly, though in future work we intend to test whether "confirming" versus "surprising" news about interventions has different effects.

[25]This section draws heavily from Dominguez and Panthaki (2006)

the YEN-USD[26]. The data are from the brokered segment of the inter-dealer exchange rate market as captured by the Reuters D2000-2 electronic trading system[27]. Electronic brokers were first introduced in 1992 and since that time their market share has increased rapidly. In the early 1990s the inter-dealer market was split evenly between direct and voice-broker trading but by the late 1990s (the sample period used in this study) the two top electronic brokerage systems, Reuters and EBS, made up over 50 percent of the market.

Inter-dealer brokering systems provide prices that are advertised to all member dealers (though the identity of the quoting dealer is only available once the quote is hit). Dealers can submit a buy or sell quote or "hit" a quote of another dealer. Only the highest bid and lowest ask (the touch) are shown on the Reuters screen[28]. The quantity available at each (best) bid and ask is also shown (which may involve more than one bank), and when a bid or ask is hit the quantities available at that price are adjusted if they dip below $10 million. When multiple banks have entered the same bid or ask price, and the price is hit, offers are met on a first come basis (meaning that the dealer who first input the price gets the deal first and if more quantity is needed, the dealer that next submitted the same price fills the order, and so on). All transactions are made at either the posted bid or ask[29]. Figure 4.2 shows bid and ask quotes for the USD-EUR, USD-GBP, and

[26]The exchange rate data are available from Reuters. The other major electronic brokerage system, EBS has a much larger share of total trading in the USD-EUR and YEN-USD markets potentially leading the Reuters data to be less representative. Reuters order flow data, in particular, may not well capture average trading behaviour in these markets.

[27]See Rime (2003) for a detailed description of electronic trading systems and Lyons (2001) for a full description of the three basic types of trades in the foreign exchange market. Direct inter-dealer trading was traditionally the most liquid part of the foreign exchange market - it typically is used for large size trades (above $ 10 million) and spreads are typically only one to two basis points. Brokered inter-dealer trades are a growing segment of the market, and typically involve slightly higher spreads of 2-3 basis points (especially for trades below $ 10 million). Customer-dealer trades involve 3-7 basis point spreads for "good" customers.

[28]Limit orders with prices below the best bid or above the best offer are not observable on Reuters D2000-2 but are shown on Minex.

[29]One advantage of the (shrinking) voice-brokered market is that they allow for some com-

YEN-USD rates over our sample period along with the quote mid-point. The relative depth of the Reuters D2000 USD-GBP market is apparent in Figure 4.2 based on the narrow spreads between bid and ask quotes. Spreads in the USD-EUR and YEN-USD quotes are sometimes quite wide due to the relative lack of liquidity in these markets on the Reuters system.

While dealers in individual banks will know their own customer order flow - they do not have access to information on customer orders of other banks. One of the reasons that inter-dealer brokerage systems have become so popular is that they provide an important source of real time information on both market quotes and overall market order flow. The Reuters D2000-2 system classifies transactions as buyer-initiated or seller-initiated, providing dealers with a real time proxy of signed trading volume[30]. We measure order flow in this study as the difference between the number of buyer-initiated trades and seller-initiated trades in each 20-minute interval. Figure 4.3 shows the number of buy and sell orders separately as well as our measure of order flow for the three exchange rates. It is worth noting that the relative number of transactions in the YEN-USD Reuters D2000-2 system is significantly lower than for either the USD-EUR or USD-GBP (the vertical axis on each of the figures is the same to highlight comparisons across the currencies). The low volume of transactions reported for the YEN-USD market is reflective of the fact that the competitor brokerage system, EBS, is dominant in this market.

The intra-day price series used in this study incorporates information from both transactions prices (actual trades) and (tradeable) bid and ask quotes submitted by dealers (but not hit)[31]. We use tradeable quotes in addition to actual

munication between dealers and brokers which allows for negotiation over price.

[30]The dealer posting the quote is considered the non-initiating side. Reuters does not provide information on the size of each trade.

[31]Tradeable quotes differ from indicative quotes, which have been used in a number of pre-

transactions prices to create a 20-minute price series for the USD-EUR, USD-GBP and YEN-USD rates that spans the period over which we have intervention news data[32]. We measure exchange rate returns, Δs_{ti}, as the log difference in 20-minute (midpoint) prices and exchange rate volatility V_{ti} as the absolute value of the 20-minute returns. Figure 4.4 shows USD-EUR, USD-GBP and YEN-USD returns and volatility over our sample period. The vertical axis on each of the figures is again the same to highlight comparisons across the currencies. It is worth noting that the range of USD-GBP returns (and volatility) is significantly lower than it is for USD-EUR and YEN-USD returns and volatility during the early part of the sample. It is only in late June and July 2000 that USD-GBP returns and volatility rise. Figure 4.5 shows average daily USD-EUR, USD-GBP and YEN-USD returns, order flow and news arrival (measured as the number of news articles in a given 20-min interval) over the 24-hour GMT time scale. It is worth noting that both news arrival and order flow are fairly evenly spread over the day, and there is little evidence of trend in average returns.

Figure 4.6 shows the average absolute return in each 20-minute interval over the 24-hour GMT time scale for each of the exchange rates[33]. The data confirm the seasonal pattern that is typically found in intra-day exchange rate volatility data which, in turn, largely reflects the opening and closing of the three main trading markets in Tokyo, Europe and New York. In order to take the opening and closings of markets into account we de-seasonalize the volatility series using

vious studies, in that they provide "firm" prices. Indicative quotes provide market information for non-dealers.

[32]There are a periods of low liquidity on Reuters D2000-2 due to technical problems (the feed failing), holidays, and during Asian trading hours. Some studies simply drop these time periods from the sample. Our approach is to interpolate a 20 minute time series (using a linear interpolation method) from all available quotes in order to fully span our "news" data set. Reuters does not include weekend data so any news that arrives over a weekend is moved to the first 20-minute interval on the nearest Monday.

[33]Note that in Figure 4.6 the x-axis for the three currencies starts at midnight, which is approximately 12am GMT for USD-EUR and USD-GBP, and 3pm GMT for YEN-USD.

the Andersen and Bollerslev (1997b,a, 1998) flexible fourier form (FFF) regression method which involves decomposing the demeaned i-minute exchange rate returns, into a daily volatility factor, a periodic component for the ith intraday interval and an i.i.d. mean zero unit variance innovation term all divided by the square root of the number of uncorrelated intraday return components[34]. This estimated FFF seasonal is shown (together with the average daily volatility) in Figure 4.6.

Table 4.4 provides descriptive statistics for our 20-minute exchange rates, returns[35] and volatility as well as order flow, order flow volatility and transaction frequency (measured as the number of transactions in a given 20-min interval). The three exchange rate returns series display little autocorrelation, suggesting that future exchange rate changes cannot be predicted from past changes. Intraday return volatility, order flow volatility, and transaction frequency for all three currencies shows evidence of strong and persistent autocorrelation. While buy and sell orders are highly autocorrelated, net order-flow (buy orders minus sell orders) does not display significant autocorrelation. As we saw visually in Figure 4.4 USD-GBP returns are significantly less variable than are USD-EUR or YEN-USD returns over this time period. And, as we saw visually in Figure 4.3, YEN-USD transaction frequency is significantly lower (at 3 transactions every 20 minutes) than is transaction frequency for USD-EUR or USD-GBP (which have closer to 30 transactions every 20 minutes).

Table 4.5 presents contemporaneous correlations among our key variables: exchange rate returns, exchange rate volatility, order flow, order flow volatility, trading frequency and news arrival[36]. The correlations for all three currencies in-

[34]See Dominguez (forthcoming) for a detailed description of how this was implemented.

[35]We compute returns (approximately) as the percentage change in the exchange rate multiplied by 100, so the units can be thought of as basis points.

[36]Evans and Lyons (2003) document strong contemporaneous correlation between news ar-

dicate that there exists a strong contemporaneous association between exchange rate returns and order flow, as well as between exchange rate volatility, order flow volatility and transaction frequency. The correlation between returns and order flow is highest for USD-EUR (at 0.51) and lowest for YEN-USD (at 0.224). Beyond these contemporaneous correlations, we might expect longer-lived correlation between intervention news and the other variables if traders have different views of the implications (and information content) of the news.

4.4 Effects of Intervention News on Returns and Volatility

The standard approach in the empirical exchange rate literature is to run the following sort of "event study" style regression[37] of the conditional mean of i-minute exchange rate returns, Δs_{ti}, on actual interventions, on j leads[38] and lags of each of the k "news" announcements, and on g lags of past returns (to account for any autocorrelation); that is:

$$\Delta s_{t_i} = \alpha_0 + \alpha_1 I_{t_i} + \sum_k \sum_j \alpha^k_{2,j} N^k_{t_{i-j}} + \sum_g \alpha_{3,g} \Delta s_{t_{i-g}} + \epsilon_{t_i} \qquad (4.1)$$

where Δs_{t_i} denotes the change in the natural log of the i-minute (spot market) exchange rate on day t_2, I_{ti} denotes actual interventions (which are included

rival, transaction frequency and order flow volatility. Melvin and Yin (2000) find a positive correlation between trading frequency (using indicative quotes) and the rate of flow of public information.

[37] An alternative approach based on state dependent heteroscedasticity is used by Rigobon and Sack (2004) and Evans and Lyons (2003).

[38] We include leads in order to take into account the possibility that the time-stamp on our news lags the actual timing of when market participants first learn about the news. We find some evidence of lead effects for our intervention news variables for up to 1 hour prior to the Reuters' time stamp.

as (0,1) dummy variables starting from the time the news of the intervention operation appears in Reuters through the end of day t[39]), and N denotes the (time-stamped to the nearest i-minute) intervention news and macro surprises[40]. We use the Schwarz (1978) criteria to fix the lag length on returns and the lead/lag length on News, and we correct for heteroskedasticity and serial correlation in the error term using the Newey and West (1987) approach. Using this general regression specification it is possible to test for the impact and intra-day effects of different kinds of intervention news and macro surprises on exchange rate returns by examining whether the N^ks are individually and jointly statistically significant. The $\alpha^k_{2,j}$s in this context measure the typical effect of the k^{th} news announcement at time i (on day t) on exchange rate returns in the same (narrow) i-minute window. It is worth noting that in order to be able to interpret the $\alpha^k_{2,j}$s in this way we need to assume that the variables in the regression can be viewed as fixed over the i-minute period (which is less likely to be realistic for low-frequency data windows). It is also the case that the $\alpha^k_{2,j}$s will measure the linear combination of exchange rate return effects associated with the market's assessment of both the news and how the news will influence the economy[41].

Our "news" variable includes three distinct categories of news: (1) macro surprises, (2) news about intervention policy from both policy-makers and the market and (3) news about unrequited interventions (interventions that the market expected but did not occur). Macro surprises are aggregated across each coun-

[39]We also tried a specification where the actual Japanese intervention dummy variable was included only through the end of Asia trading hours. These regression results are qualitatively similar to those presented in the tables and are available upon request.

[40]The intervention news variables are (0,1) dummy variables. Macro surprises are measured as the difference between the specific announcement and the ex-ante expectation of the announcement (based on the median response to a survey conducted by Money Market Services International) divided by the sample standard deviation of each announcement (this serves to normalize the surprises so that comparisons of the relative size of coefficients is feasible).

[41]For a nice discussion of the underlying assumptions in this sort of event study analysis see Faust, Rogers, Wang, and Wright (2003) pages 6-9.

try so that UK, US, Euro-area and Japanese surprises are included separately[42]. Within category (2) news was further broken down by type of intervention news (positive or negative) and for categories (2) and (3) by geographic region (Euro-zone, Japan, UK or Joint) and expected direction of influence (whether the news is expected to appreciate or depreciate the exchange rate)[43]. Category (2) and (3) news is in binary dummy variable form which is likely to downward bias our results if these sorts of news are sometimes anticipated by the market.

Table 4.6 presents results of our regression of intra-day (20-minute) USD-EUR, USD-GBP, and YEN-USD returns on actual intervention and the three categories of "news". Only coefficients that are statistically significant are included in the table. The first, third and fifth columns in Table 4.6 present the results of our benchmark regression, which include the actual Japanese interventions and the macro surprises as "news", for each exchange rate. Actual (Japanese) interventions do not significantly influence returns in these benchmark specifications and only Japanese macro surprises significantly influence USD-EUR returns. Further, the relatively low regression goodness-of-fit for these benchmark regressions suggests that actual interventions and macro surprises account for a small fraction of the overall variability of returns for all three exchange rates. The second, fourth and sixth columns in Table 4.6 include our intervention news variables. The coefficient values and statistical (in)significance of the macro surprises remain qualitatively unchanged with the inclusion of intervention news. The coefficient on actual Japanese interventions is now significant in the YEN-USD regression,

[42]As robustness checks we also included disaggregated macro surprises (by type and region). Results were qualitatively similar whether surprises are included in aggregated or disaggregated form.

[43]We attempted to group news into variables in such a way as to insure that we would not be combining news that would be expected to lead to opposite effects on exchange rates. The coefficients on these disaggregated news variables are then aggregated into broader groupings of variables in order to keep our tables readable. Regression results with the disaggregated news categories are available upon request.

suggesting that these interventions led to a depreciation of the yen relative to the dollar (which was the objective of the Japanese government in this period). Many of our intervention news categories are statistically significant contemporaneously and in leads and lags across all three exchange rates. Interestingly, reports of intervention, denials of interventions, and unrequited interventions all seem to have qualitatively similar influence on returns. For example, news that the ECB would not intervene generally led to a 1 basis point depreciation of the euro, pound and yen relative to the dollar. ECB denials of euro intervention led initially to a 5 to 7 basis point appreciation of the euro (based on the lead and contemporaneous coefficients), but eventually to a 13 basis point depreciation of the euro (based on the lag coefficients) relative to the dollar. Likewise, unrequited ECB interventions generally led to 1 to 3 basis point depreciation of the euro relative to the dollar. Recall that, had the ECB intervened (which they did not) in this sample period, their objective would have been to appreciate, not depreciate, the euro.

The regression results presented in Table 4.6 indicate that actual interventions, denials of interventions, and unrequited interventions all had an influence on intra-daily exchange rate returns. However, the relatively low regression goodness-of-fit (for all specifications across all three exchange rates) suggests that intervention news does not go very far in explaining overall exchange rate movements. It is possible that our binary coding of intervention news is partly to blame for our inability to explain a larger fraction of exchange rate variation. It may be that our intervention variables will be more successful at explaining exchange rates during periods when the market is more uncertain, or that interventions influence volatility more than returns. It may also be that interventions (however measured) do not impact price directly, but that their influence is me-

diated through order flow. We investigate these possibilities in the next three sets of regressions.

In order to examine how intervention information influences traders under different market conditions, we test for two types of interaction effects. First, we ask whether intervention news is more (or less) likely to influence returns during periods of high market uncertainty (proxied by high volatility). We create an indicator variable that takes on the value 1 during 20-minute intervals when volatility (measured as the absolute value of returns) exceeds the sample average by two standard deviations. The first three columns in Table 4.7 present regression results that show that during periods when the market is most uncertain intervention news (of all types) had a significantly larger influence on returns than was the case when news arrived during normal periods (the second page of Table 4.7 presents the coefficients on the intervention news variables interacted with the "high volatility" indicator variable). Second, we examine if intervention is more (or less) effective when lots of other news is hitting the market. We create an indicator variable that takes on the value 1 during 20-minute intervals when the number of news reports exceeds the sample average by two standard deviations[44]. The last three columns of Table 4.7 (again the second page of Table 4.7 presents the intervention news variables interacted with the "high news arrival" indicator variable) suggest that intervention news often had a larger impact on returns when it arrived during heavy news periods. These results suggest that intervention news is more likely to influence trader behaviour during specific market conditions, especially during times of high uncertainty. However, the regression goodness-of-fit measures remain relatively low indicating that intervention news explains a small fraction of overall variability of returns.

[44]The "news report" variable is based on a broad interpretation of foreign exchange market news. For more information about this variable see Dominguez and Panthaki (2006).

In order to examine whether intervention news helps to explain the absolute value of exchange rate returns, we regress de-seasonalized[45] intra-day volatility, $V_{t_i}^s$, on the same set of explanatory variables:

$$V_{t_i}^s = \lambda_0 + \lambda_1 I_{t_i} + \sum_k \sum_j \lambda_{2,j}^k N_{t_i-j}^k + \sum_g \lambda_{3,g} V_{t_i-g}^s + \eta_{t_i} \tag{4.2}$$

Andersen and Bollerslev (1998) find that three factors influence intra-daily exchange rate volatility: calendar effects and volatility dependencies (both of which are captured in the FFF seasonal) and macro surprises, with macro surprises providing the least explanatory power. We examine the influence of intervention news on volatility and allow for a longer lag structure to test whether the effects of these (non-scheduled) news reports are longer-lived. We use the Schwarz (1978) criteria to fix the leads and lags in the regression specification and correct for potential heteroskedasticity and serial correlation in the error term using the Newey and West (1987) approach.

Table 4.8 presents our volatility regression results using the same column format as we did in Table 4.6. We again find that only Japanese macro surprises enter significantly in the USD-EUR regression, providing suggestive evidence that scheduled news, perhaps because it is less ambiguous, has extremely short-lived (less than 20 minutes) influence on volatility. Actual Japanese interventions now only significantly influence USD-GBP volatility. As we found in Table 4.6 all the different types of intervention news significantly influence volatility across all three currencies[46]. Statements from the Japanese government that it did

[45]It could be that the intra-day seasonal is explained by news arrival. We test for this possibility by including our intervention news variables and macro surprises directly in the FFF regression and find no evidence of correlation between the daily seasonal and our news variables.

[46]It is also worth noting that the regression goodness-of-fit is dramatically higher, due in part to the strong AR component of volatility.

not intend to intervene generally led to reductions in YEN-USD and USD-GBP volatility, but led to increases in USD-EUR volatility. Unrequited interventions, on the other hand, seem to have generally led to reductions in volatility for all three currencies. One way to interpret this result is that market expectations of interventions (even if they do not occur) provide a calming influence on the market.

4.5 Does Intervention News Influence Order Flow?

In standard models of exchange rate behaviour when "positive" news arrives for a currency, demand for that currency rises, causing the relative value (the price) of the currency to rise. In these models there is no reason for order flow to rise in reaction to news because price is assumed to instantaneously reflect the news. Trading volume may rise in reaction to news, but as long as the new price is efficient, there is no reason for these trades to be biased in favor of purchases or sales. So that in standard models the arrival of "news" should be orthogonal to changes in order flow[47].

We use transaction frequency, TF, as a proxy for volume, and first test whether the arrival of intervention news in our sample is positively related to transaction frequency.

$$TF_{t_i} = \gamma_0 + \gamma_1 I_{t_i} + \sum_k \sum_j \gamma_{2,j}^k N_{t_i-j}^k + \sum_g \gamma_{3,g} TF_{t_i-g} + \nu_{t_i} \qquad (4.3)$$

[47]One view of the relationship between order flow and prices is that it is only a temporary phenomenon. Order flow in this context reflects trader "digestion effects" in reaction to news, so that once the news is fully "digested", any order flow induced price effects will revert back. Work by Evans and Lyons (2002), Danielsson, Payne, and Luo (2002), however, shows that order flow continues to explain changes in foreign exchange returns well after 24 hours, suggesting either that digestion is very slow, or more likely, that the influence of order flow on prices is not temporary.

Table 4.9 presents the results of this regression. We find strong evidence of a relationship between intervention news (but not actual Japanese interventions or macro surprises) and transaction frequency. This suggests that when traders learn of interventions news (regardless of whether the news indicates that an intervention is likely or not) this influences their decision about whether to trade or not. In some cases the coefficient sign on intervention news is negative suggesting transaction frequency fell in reaction to the news, though the signs on intervention news do not indicate any discernible patterns among the different sorts of news. While our measures of regression goodness-of-fit in Table 4.9 are quite high, this is largely due to the strong autoregressive nature of transaction frequency (as documented in Table 4.4).

Under what circumstance might intervention news cause a change not just in volume, but in order flow? One reason that price might not immediately (or fully) react is if the intervention news either is not common knowledge, or if different market participants interpret the news differently. Unrequited intervention operations are likely to be good examples of news that evoke heterogeneous reactions. In this case, order flow might convey this information to the market (rather than price). Further, if underlying demand for currencies is driven not by news per se, but by changes in risk aversion or hedging technologies, again it might be order flow that will convey this information to the market[48].

A simple linear regression specification that relates foreign exchange returns

[48]Four recent papers that have studied the link between "news" and order flow include: Love (2004), Love and Payne (2003), Melvin and Yin (2000), Evans and Lyons (2003), Dominguez and Panthaki (2006). Breedon and Vitale (2004) find that the strong contemporaneous correlation between order flow and exchange rates is mostly due to liquidity (and not information) effects.

to order flow is:

$$\Delta s_{t_i} = \beta_0 + \sum_j \beta_{1,j} OF_{t_{i-j}} + \sum_g \beta_{2,g} \Delta s_{t_{i-g}} + \mu_{t_i} \tag{4.4}$$

Table 4.10 presents results for a regression of returns on contemporaneous and lagged order flow (OF)[49]. The first thing to note in the table is that our measure of regression goodness-of-fit differs significantly across the three currencies. Our estimates suggest that order flow explains over 14% of the variation in 20-minute USD-GBP returns, 6% of YEN-USD returns, and only 2.8% of USD-EUR returns. These differences are likely due in large part to the fact that the Reuters D2000 system dominates in the sterling market but only captures a small fraction of trades in either the euro or yen markets. The coefficient on contemporaneous order flow is positively associated with returns for all three currencies, suggesting that the influence of news is not fully captured in price changes and that order flow may play a role in the price discovery process.

Our results so far suggest that intervention news influences exchange rate returns, volatility, and transaction frequency and that order flow influences returns. The next question to ask is what drives order flow? Previous studies have found a link between macro surprises and order flow, which runs counter to standard models that would suggest that common knowledge news, such as macro surprises, should be instantly incorporated in price. We test whether this result also holds for our data sample, and whether intervention news is also linked to order

[49]In future work we will also test for interaction effects between order flow and market conditions to see whether order flow is more (or less) important in the price discovery process when volatility (or news arrival frequency) is higher (or lower) than usual.

flow, OF.

$$OF_{t_i} = \gamma_0 + \gamma_1 I_{t_i} + \sum_k \sum_j \gamma_{2,j}^k N_{t_i-j}^k + \sum_g \gamma_{3,g} OF_{t_i-g} + \nu_{t_i} \tag{4.5}$$

Table 4.11 presents results for the regression of order flow on actual Japanese interventions, macro surprises, intervention news, and past order flow. The first, third and fifth columns provide results for our benchmark specification which only includes the actual Japanese interventions and macro surprises. While none of the macro surprises are statistically significant, actual Japanese interventions enter statistically significantly in both the USD-EUR and YEN-USD specifications. The results in the second, fourth and sixth columns indicate that actual interventions and all the different categories of intervention news significantly influence order flow. However, the regression goodness of fit never rises above 0.04 suggesting that order flow is largely not being driven by these variables[50]. The coefficient signs on intervention news generally suggest that actual and threatened interventions by the Japanese government led buy orders for dollars to rise relative to sell orders. Likewise, unrequited interventions by the BOJ led to a relative increase in dollar buy orders. A comparison of coefficient magnitudes across the different rows in Table 4.11 suggest that actual interventions had almost twice as large an influence on order flow as did unrequited interventions.

4.6 Conclusions

This chapter examined whether actual and unrequited intervention news influences exchange rates. Previous studies have found that surprises in scheduled

[50]This result is at odds with results in Evans and Lyons (2004) which find a strong connection between disaggregated order flow and news. It is possible that the difference in results is due to the fact that our order flow information is only reflecting inter-dealer trades.

macro announcements help to explain intra-daily exchange rate behaviour. Likewise, official interventions by governments in the foreign exchange market have been found to influence intra-day (and daily) returns and volatility. Results in this chapter indicate that unrequited intervention news (and even news of "no intervention") has a statistically significant influence on both exchange rate returns and volatility, suggesting that the expectation of intervention, even when governments do not intervene, can affect currency values. These results provide strong evidence in favor of the hypothesis that interventions influence exchange rates via the information or signaling channel.

We also examine the role of order flow in exchange rate determination. In standard models there is no reason for order flow to rise in reaction to news because price is assumed to instantaneously adjust. We find evidence that order flow has some explanatory power suggesting that prices are, at the very least, slow to adjust. At the same time, we find that actual interventions and our various categories of intervention news explain a very small fraction of the variation in order flow. Overall, our results indicate that along with actual interventions, other kinds of intervention news (including denials of intervention and unrequited interventions) and order flow matter. We do not find evidence that macro surprises have much influence on returns, volatility or order flow over our sample period. These results suggest that future models of exchange rate determination ought include a broader conception of price relevant "news".

Table 4.1: Broad Categories of Intervention News

(a) Interventions and News

	News	
Policymaker	Reported	Not Reported
Threat of Actual or Oral Intervention[51]	Intervention detected[52]	Intervention missed
Threat of No Actual or Oral Intervention[53]	False intervention[54]	

(b) Interventions and Market Expectations

	Market	
Policymaker	Expected	Not Expected
Threat of Actual or Oral Intervention[51]		Surprise intervention
Threat of No Actual or Oral Intervention[53]	Unrequited intervention[55]	

Notes: The data cover the eight month period from 01 Dec 1999 to 24 July 2000. The majority of unrequited interventions are for the ECB, since during this period of time the market constantly expected them to step in and shore up the euro but they did not. Both the ECB and the BOJ made numerous oral interventions, the former repeatedly stating that they would not intervene while the latter consistently assuring markets that the BOJ stood ready to step in if necessary.

[51] 38 for the Euro-zone, 134 for Japan out of which there were 4 actual Japanese interventions, 6 for Joint which includes G7.

[52] There were 4 actual interventions conducted by the Bank of Japan and all four were reported by Reuters.

[53] 26 for the Euro-zone, 1 for Japan, 1 for UK and 20 for Joint (which includes G7).

[54] There was one false intervention, when the market thought the ECB and other European banks might be intervening but this was denied by the ECB.

[55] 215 are unrequited actual interventions (Euro-zone: 76, Japan: 91, Joint: 48) and 77 are unrequited oral interventions (Euro-zone: 8, Joint: 69).

Table 4.2: Actual Japanese Interventions

Date	BOJ Intervention (in billions of yen)	Operation Details
24 December 1999	370.4	Purchase usd
4 January 2000	575.3	Purchase usd
8 March 2000	222.1	Purchase usd and euro[56]
15 March 2000	846.8	Purchase usd
3 April 2000	1385.4	Purchase usd

Notes: Daily Japanese intervention data are available at: http://www.mof.go.jp/english/feio/e034_133.htm

[56]The Bank of Japan purchased 150.1 billion usd and 72 billion euro.

Table 4.3: Summary Statistics of Macro News Announcements, 01 Dec 1999 - 24 July 2000

Announcement	Reported as	Local time
UK Announcements (total = 80)		
RPIX	Y/Y % change	08:30 GMT
Retail Sales	M/M % change	08:30 GMT
Global trade	GBP (billion)	08:30 GMT
Provisional M4	M/M % change	08:30 GMT
PPI	M/M % change NSA	08:30 GMT
Industrial Production	M/M % change	08:30 GMT
Unemployment	thousands	08:30 GMT
Current Account	GBP (billion)	08:30 GMT
US Announcements (total = 80)		
PPI	M/M % change	08:30 ET
CPI	M/M % change	08:30 ET
Industrial Production	M/M % change	09:15 ET
Monthly M3	change USD (billion)	16:30 ET
Goods & Services Trade Balance	USD (billion)	08:30 ET
Civilian Unemployment Rate	percent	08:30 ET
Nonfarm Payrolls	thousands	08:30 ET
Retail Sales	M/M % change	08:30 ET
Euro Area Announcements (total = 58)		
PPI	M/M % change	11:00 GMT
Harmonised CPI	M/M % change	11:00 GMT
Ind Production	3M/3M % change	11:00 GMT
M3	Y/Y % change	09:00 GMT
Trade ex-EMU prel. EUR	EUR (billion)	11:00 GMT
Unemployment rate	percent	11:00 GMT
Japanese Announcements (total = 122)		
Current Account	YEN (billions)	18:50 GMT
Adjusted Merchandise Trade Balance	YEN (billions)	18:50 GMT
CPI	M/M % change	18:00 GMT
CPI Tokyo	M/M % change	15:00 GMT
Crude Oil Imports	Y/Y % change	23:30 GMT
Domestic Wholesale Price Index		18:50 GMT
GDP	Q/Q % change	18:50 GMT

Table 4.3: Contd.

Announcement	Reported as	Local time
Housing Starts	Y/Y % change	23:00 GMT
Job-to-Applicant Ratio		18:00 GMT
Large Scale Retail Sales	Y/Y % change	18:50 GMT
Machine Orders	M/M % change	0:00 GMT
Merchandise Trade Balance Total	YEN (billions)	18:50 GMT
Money Supply	Y/Y % change	18:50 GMT
Preliminary Industrial Production	M/M % change	18:50 GMT
Tankan Survey Manufacturing		18:50 GMT
Tertiary Industry Index	M/M % change	18:50 GMT
Unemployment Rate	percent	18:00 GMT
Vehicle Sales	Y/Y % change	0:00 GMT
Workers' Household Spending	Y/Y % change	17:00 GMT

Notes: M/M% change refers to month-on-month percentage change. 3M/3M% change is three month-on-three month percentage change. Y/Y% change is year-on-year percentage change. NSA refers to non-seasonally adjusted. 22 GMT is 7am in Japan.

Table 4.4: Summary Statistics for USD-EUR, USD-GBP and YEN-USD Quotes, Returns, Volatility, Order Flow and Transactions, 01 Dec 1999 - 24 July 2000

	Mid Quote	Return	Volatility	Order Flow	Order Flow Volatility	Transaction Frequency
a. USD-EUR						
Mean	0.97	0.00	5.55	0.27	1.14	30.36
Variance	0.04	9.99	8.30	13.04	1.73	52.13
Skewness	0.10	-0.13	2.93	0.53	2.04	2.30
Kurtosis	2.87	12.07	14.56	17.62	11.62	11.27
Autocorrelation						
lag 1	0.99	0.13	0.47	0.04	0.86	0.85
lag 5	0.98	0.05	0.30	0.02	0.61	0.56
lag 10	0.98	0.01	0.19	-0.01	0.38	0.32
lag 20	0.97	-0.02	0.06	0.00	-0.03	-0.04
b. USD-GBP						
Mean	1.57	-0.03	2.06	0.42	1.07	28.02
Variance	0.05	2.88	2.01	7.88	1.17	41.51
Skewness	-0.32	0.00	1.40	0.38	1.39	2.24
Kurtosis	1.83	5.01	7.92	11.40	5.09	9.37
Autocorrelation						
lag 1	1.00	0.01	0.36	0.04	0.80	0.79
lag 5	1.00	0.02	0.26	0.02	0.56	0.49
lag 10	1.00	0.00	0.19	0.00	0.35	0.27
lag 20	1.00	0.01	0.12	0.00	0.00	-0.11
c. YEN-USD						
Mean	106.29	0.01	7.01	0.06	0.26	2.83
Variance	2.28	14.06	12.19	2.98	0.36	4.96
Skewness	-0.19	0.17	4.23	0.18	1.91	3.30
Kurtosis	3.15	21.82	26.83	20.46	8.45	20.50

Table 4.4: Contd.

	Mid Quote	Return	Volatility	Order Flow	Order Flow Volatility	Transaction Frequency
Autocorrelation						
lag 1	0.98	0.07	0.49	0.15	0.66	0.66
lag 5	0.95	0.04	0.17	0.04	0.47	0.43
lag 10	0.93	0.03	0.11	0.02	0.32	0.27
lag 20	0.91	0.01	0.04	-0.01	0.11	0.11

Notes: The data are sampled at 20-minute frequency. Currencies are defined as the number of dollars per foreign currency for the euro and sterling, and number of foreign currency per dollar for the yen. The mid quote is calculated as the average of the bid and ask quotes. Returns are defined as 100 times the log difference of the mid quote. Volatility is defined as the absolute return. Order flow is the net of the total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR, sterling for USD-GBP and dollar for YEN-USD). In each 20-minute period, order flow volatility is the standard deviation of order flow, transaction price refers to the last transaction price and transaction frequency is the number of actual trades in a that 20-minute period.

Table 4.5: Contemporaneous Correlations Between Returns, Volatility, Order Flow, Transactions and Reuters News, 01 Dec 1999 - 24 July 2000

	Return	Volatility	Order Flow	Order Flow Volatility	Transaction Frequency	Reuters News Arrival
a. USD-EUR						
Return	1	...	...	...	...	...
Volatility	-0.011	1	...	...	...	...
Order Flow	0.511	0.011	1	...	...	...
Order Flow Volatility	-0.023	0.318	0.022	1	...	...
Transaction Frequency	-0.015	0.333	0.055	0.956	1	...
Reuters News	0.006	0.019	0.000	-0.008	-0.007	1
b. USD-GBP						
Return	1	...	...	...	...	...
Volatility	-0.032	1	...	...	...	...
Order Flow	0.375	0.013	1	...	...	...
Order Flow Volatility	-0.024	0.450	0.036	1	...	...
Transaction Frequency	-0.020	0.403	0.036	0.925	1	...
Reuters News	-0.002	-0.010	-0.004	-0.023	-0.022	1

Table 4.5: Contd.

	Return	Volatility	Order Flow	Order Flow Volatility	Transaction Frequency	Reuters News Arrival
c. YEN-USD						
Return	1	...	...	...	...	...
Volatility	0.014	1	...	...	...	...
Order Flow	0.224	0.016	1	...	...	...
Order Flow Volatility	0.010	0.226	0.036	1	...	...
Transaction Frequency	0.007	0.203	0.028	0.922	1	...
Reuters News	-0.003	-0.008	-0.020	0.003	-0.001	1

Notes: The data are sampled at 20-minute frequency. Currencies are defined as the number of dollars per foreign currency for the euro and sterling, and number of foreign currency per dollar for the yen. Returns are defined as 100 times the log difference of the mid quote where the mid quote is calculated as the average of the bid and ask quotes. Volatility is defined as the absolute return. Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR, sterling for USD-GBP and dollar for YEN-USD). In each 20-minute period, order flow volatility is the standard deviation of order flow, transaction price refers to the last transaction price and transaction frequency is the number of actual trades in a that 20-minute period. Reuters News Arrival refers to an indicator variable for measures the number of news articles in each 20 minute period.

Table 4.6: The Influence of "News" on USD-EUR, USD-GBP and YEN-USD Returns

	USD-EUR		USD-GBP		YEN-USD	
Independent Variables	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News
Non-News						
Constant	-0.0001	-0.0004	-0.0004	-0.0004	0.0004	0.0009
Japanese Intervention	0.0040	0.0043	0.0011	0.0010	-0.0085	-0.0173**
Dependent Variable						
lag 1	0.1204***	0.1117***	0.0083	0.0063	0.0628	0.0579
lag 2	0.1013***	0.0946***	0.0120	0.0103	0.1218***	0.1174***
Macro Surprises						
UK	0.0083	0.0071	0.0013	0.0005	0.0005	0.0000
US	-0.0116	-0.0113	0.0025	0.0026	-0.0068	-0.0067
Euro-zone	0.0181	0.0161	0.0026	0.0022	-0.0162	-0.0178
Japan	0.0240**	0.0234**	0.0036	0.0031	-0.0055	-0.0050
Policymaker News						
Euro-zone Policy Statement						
lead 2-6	...	0.0033	...	0.0014	...	0.0002
lead 1	...	-0.0129	...	0.0010	...	0.0220
lag 0	...	0.0249	...	-0.0016	...	0.0521
lag 1	...	0.0078	...	0.0044	...	0.0192
lag 2-6	...	0.0058	...	-0.0014	...	0.0036

Table 4.6: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Euro-zone Intervention						
lead 2-6	...	0.0061	...	0.0001	...	0.0075
lead 1	...	0.0074	...	-0.0070*	...	-0.0206
lag 0	...	-0.0058	...	0.0066	...	0.0048
lag 1	...	0.0527***	...	-0.0027	...	0.0143
lags 2-6	...	0.0022	...	0.0060**	...	-0.0020
Euro-zone No Intervention						
leads 2-6	...	-0.0155*	...	-0.0043*	...	0.0135
lead 1	...	0.0076	...	-0.0023	...	0.0269*
lag 0	...	-0.0126	...	-0.0083*	...	-0.0180
lag 1	...	-0.0452*	...	-0.0057	...	-0.0237
lags 2-6	...	-0.0024	...	-0.0024	...	0.0089
Japan Policy Statement						
leads 2o6	...	-0.0566	...	-0.0033	...	0.0097
lead 1	...	-0.0984*	...	-0.0014	...	0.0316
lag 0	...	-0.1018*	...	-0.0112	...	0.0302
lag 1	...	0.0447	...	-0.0057	...	-0.0259
lag 2to6	...	0.0001	...	0.0034	...	0.0187
Japan Intervention						
leada 2-6	...	0.0075	...	-0.0003	...	0.0064
lead 1	...	0.0007	...	0.0039	...	0.0187
lag 0	...	-0.0027	...	0.0044*	...	0.0033
lag 1	...	0.0019	...	-0.0011	...	0.0080
lags 2-6	...	-0.0047	...	-0.0005	...	0.0037

Table 4.6: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Japan No Intervention						
leads 2-6	...	-0.0344***	...	0.0017	...	0.0163**
lead 1	...	-0.0818***	...	-0.0131***	...	0.0227
lag 0	...	-0.1751***	...	0.0043	...	-0.0117
lag 1	...	-0.1587***	...	-0.0546***	...	0.0290*
lags 2-6	...	-0.1454***	...	0.0080**	...	0.0221***
UK Policy Statement						
leads 2-6	...	-0.0086***	...	0.0047	...	-0.0366***
lead 1	...	-0.0350***	...	0.0037***	...	-0.0350***
lag 0	...	-0.0323***	...	0.0291***	...	-0.0183***
lag 1	...	-0.0300***	...	-0.0124***	...	0.0005
lags 2-6	...	0.0031	...	0.0021	...	0.0080
UK Intervention						
leads 2-6	...	0.0104	...	-0.0052	...	0.0174**
lead 1	...	-0.0412	...	-0.0313**	...	-0.0575*
lag 0	...	-0.0089	...	0.0081**	...	0.0989***
lag 1	...	0.0511	...	-0.0260*	...	-0.0560*
lags 2-6	...	0.0291	...	-0.0058	...	-0.0302**
UK No Intervention						
leads 2-6	...	-0.0607	...	...	...	-0.1040***
lead 1	...	-0.1367***	...	...	...	0.0048
lag 0	...	0.0151***	...	...	...	-0.1682***
lag 1	...	-0.1055***	...	...	...	-0.1132***
lags 2-6	...	0.0162	...	...	...	-0.0059

Table 4.6: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Joint Intervention						
leads 2-6	...	0.0015	...	0.0031	...	-0.0017
lead 1	...	-0.0151	...	-0.0133*	...	-0.0064
lag 0	...	-0.0073	...	0.0077	...	0.0050
lag 1	...	-0.0069	...	-0.0124	...	0.0122
lags 2-6	...	0.0816*	...	0.0082*	...	0.0797
Joint No Intervention						
leads 2-6	...	-0.0062	...	0.0024	...	-0.0135
lead 1	...	-0.0114	...	0.0035	...	-0.0061
lag 0	...	-0.0225	...	-0.0005	...	-0.0245
lag 1	...	0.0041	...	-0.0017	...	0.0199
lags 2-6	...	-0.0014	...	0.0032	...	-0.0134
Markets' Expectations News						
Euro-zone Intervention Rumour						
leads 2-6	...	-0.0094	...	-0.0028	...	-0.0354
lead 1	...	0.0254	...	-0.0022	...	0.0697*
lag 0	...	-0.0440	...	-0.0156	...	0.0096
lag 1	...	0.0180	...	-0.0224	...	-0.0123
lags 2-6	...	0.0327	...	0.0083	...	0.0208
Euro-zone Intervention Not Expected						
leads 2-6	...	-0.0122	...	0.0091**	...	0.0058
lead 1	...	0.0076	...	-0.0037	...	-0.0207
lag 0	...	-0.0337*	...	0.0099	...	-0.0684***
lag 1	...	-0.0142	...	-0.0131	...	-0.0007
lags 2-6	...	-0.0111	...	0.0043	...	-0.0107

Table 4.6: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Japan Intervention Rumour						
leads 2-6	...	0.0087	...	-0.0125**	...	-0.0962
lead 1	...	0.0152	...	0.0379***	...	-0.1883**
lag 0	...	0.1357**	...	0.0247	...	-0.0980
lag 1	...	-0.0343	...	0.0114	...	-0.1078
lags 2-6	...	-0.0107	...	-0.0079	...	-0.0145
Joint Intervention Rumour						
leads 2-6	...	0.0094	...	-0.0033	...	0.0121
lead 1	...	-0.0008	...	0.0067	...	-0.0013
lag 0	...	0.0781*	...	0.0169**	...	0.0213
lag 1	...	-0.0126	...	-0.0026	...	0.0518
lags 2-6	...	0.0047	...	-0.0018	...	0.0116
Joint Intervention Not Expected						
leads 2-6	...	-0.0304	...	-0.0012	...	0.0291
lead 1	...	-0.0031	...	0.0115	...	-0.0540
lag 0	...	-0.0274	...	-0.0188***	...	-0.0031
lag 1	...	0.0514*	...	0.0173	...	0.0488
lags 2-6	...	-0.0735**	...	-0.0038	...	0.0031
Policymaker and Market News						
ECB Denies Euro Intervention						
leads 2-6	...	-0.0083	...	...	...	0.0398
lead 1	...	0.0596*	...	...	...	-0.0584*
lag 0	...	0.0712**	...	...	...	-0.2236***
lag 1	...	-0.1363***	...	...	...	-0.3227***
lags 2-6	...	0.0151	...	...	...	-0.0319

Table 4.6: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Market Detects Japan Intervention						
leads 2-6	...	-0.0061	...	-0.0003	...	0.0060
lead 1	...	0.0027	...	0.0102	...	-0.0361
lag 0	...	-0.0174	...	-0.0186***	...	0.0335
lag 1	...	0.0236	...	0.0014	...	0.0077
lags 2-6	...	-0.0027	...	-0.0006	...	-0.0010
Unrequited Interventions News						
Euro-zone Actual Intervention						
leads 2-6	...	0.0059	...	0.0007	...	-0.0026
lead 1	...	-0.0037	...	0.0025	...	-0.0117
lag 0	...	0.0147	...	-0.0007	...	0.0077
lag 1	...	-0.0115	...	0.0106**	...	0.0067
lags 2-6	...	-0.0061	...	-0.0055***	...	-0.0039
Euro-zone Oral Intervention						
leads 2-6	...	0.0207*	...	-0.0026	...	0.0313**
lead 1	...	-0.0332	...	-0.0138**	...	0.0159
lag 0	...	-0.0033	...	-0.0013	...	0.0078
lag 1	...	-0.0278	...	-0.0088	...	0.0076
lags 2-6	...	-0.0143	...	-0.0062	...	-0.0018
Japan Actual Intervention						
leads 2-6	...	0.0011	...	0.0011	...	-0.0030
lead 1	...	0.0166	...	0.0015	...	-0.0132
lag 0	...	0.0111	...	-0.0031	...	0.0254*
lag 1	...	0.0062	...	-0.0007	...	-0.0153
lags 2-6	...	0.0000	...	-0.0005	...	-0.0070

Table 4.6: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Joint Actual Intervention						
leads 2-6	...	-0.0118	...	0.0028	...	-0.0081
lead 1	...	0.0006	...	-0.0045	...	-0.0115
lag 0	...	-0.0265	...	-0.0069	...	0.0013
lag 1	...	0.0086	...	0.0046	...	-0.0157
lags 2-6	...	0.0020	...	0.0023	...	-0.0026
Joint Oral Intervention						
leads 2-6	...	0.0037	...	-0.0004	...	-0.0182**
lead 1	...	0.0028	...	0.0012	...	-0.0043
lag 0	...	-0.0098	...	-0.0024	...	-0.0199*
lag 1	...	0.0014	...	0.0033	...	-0.0204**
lags 2-6	...	0.0089	...	-0.0001	...	-0.0135
Adj R^2	0.0279	0.0319	-0.0003	-0.0007	0.0195	0.0181
$F-test$	59.99***	4.35***	0.7106	0.9404***	41.45***	2.85***

Notes: Returns and order flow are calculated at 20 minute frequency. Returns are defined as 100 times the log difference of the mid quote. The mid quote is calculated as the average of the bid and ask quotes. Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR, sterling for USD-GBP and US dollar for YEN-USD). *, ** and *** represent significance at 10, 5 and 1 percent respectively and "..." indicates that the coefficient is insignificant.

Table 4.7: The Influence of"News" on USD-EUR, USD-GBP and YEN-USD Returns in "High Volatility" and "High News Arrival" Periods

Independent	"High Volatility"			"High News Arrival"		
Variables	USD-EUR	USD-GBP	YEN-USD	USD-EUR	USD-GBP	YEN-USD
Non-News						
Constant	-0.0009	-0.0004	0.0012	-0.0005	-0.0004	0.0010
Japanese Intervention	0.0039	0.0001	-0.0141*	0.0038	0.0013	-0.0179**
Dependent Variable						
lag 1	0.0734***	0.0109	0.0490	0.1054***	0.0096	0.0556
lag 2	0.0729***	0.0091	0.1083***	0.0879***	0.0090	0.1168***
Macro Surprises						
UK	0.0067	0.0017	0.0020	0.0067	0.0010	0.0003
US	-0.0103	0.0024	0.0088	-0.0107	0.0026	-0.0065
Euro-zone	-0.0006	0.0013	-0.0162	0.0148	0.0026	-0.0166
Japan	0.0227**	0.0031	-0.0052	0.0231**	0.0031	-0.0044
Policymakers News						
Euro-zone Policy Statement						
leads 2-6	-0.0058	0.0035*	-0.0110	0.0057	0.0011	-0.0016
lead 1	-0.0006	-0.0041	0.0139	-0.0118	-0.0015	0.0211
lag 0	0.0260	0.0035	0.0309	0.0383*	-0.0024	0.0591*
lag 1	0.0087	0.0055	0.0230	0.0129	0.0032	0.0196
lags 2-6	0.0111	-0.0003	-0.0082	0.0057	0.0004	0.0056

Table 4.7: Contd.

Independent	"High Volatility"			"High News Arrival"		
Variables	USD-EUR	USD-GBP	YEN-USD	USD-EUR	USD-GBP	YEN-USD
Euro-zone Intervention						
leads 2-6	0.0030	-0.0007	-0.0007	0.0063	0.0001	0.0103
lead 1	-0.0027	-0.0043	0.0048	0.0029	-0.0045	-0.0146
lag 0	-0.0223*	0.0085*	-0.0094	-0.0050	0.0066	-0.0024
lag 1	0.0161	0.0022	-0.0120	0.0506***	0.0015	0.0220
lags 2-6	0.0031	0.0062***	0.0003	0.0039	0.0049*	-0.0092
Euro-zone No Intervention						
leads 2-6	0.0001	-0.0057***	-0.0033	-0.0204**	-0.0058**	0.0154
lead 1	0.0030	-0.0035	0.0145	0.0108	0.0018	0.0133
lag 0	0.0066	-0.0098**	-0.0058	-0.0387	-0.0104*	-0.0247
lag 1	-0.0196	-0.0100**	-0.0115	-0.0425*	-0.0086	-0.0322*
lags 2-6	-0.0126**	-0.0017	0.0046	-0.0066	-0.0032	0.0166**
Japan Policy Statement						
leads 2-6	0.0139	0.0014	0.0069	-0.0515	-0.0026	0.0259*
lead 1	-0.0328	-0.0047	0.0278	-0.1013*	-0.0014	0.0301
lag 0	-0.0410**	-0.0038	0.0141	-0.0708***	-0.0117	0.0093
lag 1	-0.0034	-0.0065	-0.0392	0.0424	-0.0064	-0.0275
lags 2-6	-0.0026	0.0042	0.0180*	0.0002	0.0033	0.0114
Japan Intervention						
leads 2-6	0.0005	0.0002	0.0026	0.0073	-0.0005	0.0067
lead 1	-0.0010	0.0042	0.0092	0.0019	0.0035	0.0192
lag 0	0.0071	0.0036	0.0051	0.0004	0.0059*	0.0156
lag 1	-0.0018	-0.0004	0.0017	0.0054	-0.0003	0.0078
lags 2-6	-0.0040	-0.0009	-0.0034	-0.0040	0.0001	0.0065

Table 4.7: Contd.

Independent	"High Volatility"			"High News Arrival"		
Variables	USD-EUR	USD-GBP	YEN-USD	USD-EUR	USD-GBP	YEN-USD
Japan No Intervention						
leads 2-6	-0.0322***	0.0030	0.0156***	-0.0290**	0.0143*	0.0192**
lead 1	-0.0680***	-0.0128***	0.0266**	-0.0889***	-0.0136***	0.0230
lag 0	-0.1684***	0.0037	0.0070	-0.1700***	0.0105**	0.0115
lag 1	-0.1704***	-0.0548***	0.0233*	-0.1505***	-0.0555***	0.0230
lags 2-6	-0.1572***	0.0066*	0.0228***	-0.1496***	0.0083**	0.0218***
UK Policy Statement						
leads 2-6	-0.0085***	0.0047	-0.0370***	-0.0086***	0.0047	-0.0367***
lead 1	-0.0354***	0.0039***	-0.0359***	-0.0350***	0.0038***	-0.0353***
lag 0	-0.0336***	0.0290***	-0.0201***	-0.0325***	0.0290***	-0.0185***
lag 1	-0.0319***	-0.0125***	-0.0004	-0.0304***	-0.0125***	0.0004
lags 2-6	0.0037	0.0021	0.0082	0.0032	0.0021	0.0080
UK Intervention						
leads 2-6	0.0171	-0.0117***	0.0168***	0.0113	-0.0056	0.0196**
lead 1	-0.0373	-0.0288***	-0.0746***	-0.0459***	-0.0291*	-0.1236***
lag 0	-0.0135	0.0076**	0.1383***	0.0624***	0.0238***	0.0001
lag 1	0.0664**	-0.0253*	-0.0962***	0.0912*	-0.0216	0.0093
lags 2-6	-0.0220***	-0.0060	0.0170	0.0273	-0.0061	-0.0333**
UK No Intervention						
leads 2-6	0.0075		0.1121***	-0.0619		-0.1043***
lead 1	-0.1331***		0.0016	-0.1356***		0.0049
lag 0	0.0106***		-0.1672***	0.0144***		-0.1682***
lag 1	-0.1077***		-0.1152***	-0.1062***		-0.1136***
lags 2-6	0.0145		-0.0075	0.0159		-0.0061

Table 4.7: Contd.

Independent	"High Volatility"			"High News Arrival"		
Variables	USD-EUR	USD-GBP	YEN-USD	USD-EUR	USD-GBP	YEN-USD
Joint Intervention						
leads 2-6	-0.0083	-0.0051	0.0148	-0.0130	0.0012	0.0020
lead 1	-0.0030	-0.0138*	-0.0111	-0.0007	-0.0143*	-0.0157
lag 0	0.0036	0.0089	-0.0066	-0.0221	0.0123	-0.0098
lag 1	-0.0061	-0.0092	0.0062	0.0092	-0.0115	0.0019
lags 2-6	0.0368	0.0005	0.0026	0.0694*	0.0121**	0.0838
Joint No Intervention						
leads 2-6	-0.0144**	0.0020	0.0109	-0.0022	0.0019	-0.0137
lead 1	0.0096	0.0040	-0.0088	-0.0086	0.0061	-0.0077
lag 0	-0.0065	-0.0028	-0.0296*	-0.0154	-0.0067	-0.0364
lag 1	-0.0024	-0.0047	-0.0124	0.0171	0.0024	0.0200
lags 2-6	0.0117	0.0034	-0.0106	-0.0069	0.0020	-0.0165
Markets' Expectations News						
Euro-zone Intervention Rumour						
leads 2-6	0.0064	-0.0022	-0.0276	-0.0062	-0.0038	-0.0370
lead 1	-0.0497*	-0.0053	0.0565	0.0208	-0.0099	0.0423
lag 0	-0.0279	-0.0026	0.0517*	-0.0353	-0.0177	0.0342
lag 1	-0.0253	-0.0198	-0.0294	0.0200	-0.0331**	-0.0287
lags 2-6	-0.0080	0.0043	0.0092	0.0440*	0.0057	-0.0079
Euro-zone Intervention Not Expected						
leads 2-6	0.0051	0.0129***	0.0156	-0.0167	0.0079	0.0003
lead 1	0.0056	-0.0015	-0.0233	0.0020	-0.0045	-0.0099
lag 0	-0.0341*	0.0088	-0.0503**	-0.0501**	0.0096	-0.0567**
lag 1	0.0012	-0.0104	-0.0070	-0.0158	-0.0048	0.0008
lags 2-6	-0.0141**	0.0045	-0.0034	-0.0126	0.0036	-0.0067

Table 4.7: Contd.

Independent	"High Volatility"			"High News Arrival"		
Variables	USD-EUR	USD-GBP	YEN-USD	USD-EUR	USD-GBP	YEN-USD
Japan Intervention Rumour						
leads 2-6	-0.0092	-0.0113	-0.0498*	0.0124	-0.0164**	-0.1084*
lead 1	0.0235	0.0286**	-0.1370	0.0102	0.0387***	-0.1893**
lag 0	0.0666***	0.0213	0.0602	0.1201*	0.0252	-0.0859
lag 1	-0.0138	0.0108	-0.0393	-0.0131	0.0110	-0.1141
lags 2-o6	-0.0071	-0.0112	0.0001	-0.0114	-0.0050	-0.0098
Joint Intervention Rumour						
leads 2-6	-0.0076	-0.0012	-0.0073	0.0069	-0.0030	0.0181
lead 1	-0.0358	0.0047	0.0035	-0.0222	0.0064	0.0031
lag 0	-0.0040	0.0181**	0.0251	0.0656	0.0221***	0.0557**
lag 1	-0.0444*	-0.0062	0.0432	-0.0254	-0.0054	0.0625*
lags 2-6	-0.0100	-0.0016	0.0145	-0.0045	-0.0041	0.0111
Joint Intervention Not Expected						
leads 2-6	0.0076	0.0097*	-0.0024	-0.0330	-0.0005	0.0303
lead 1	0.0240	0.0118	-0.0736	0.0053	0.0143	-0.0829
lag 0	0.0067	-0.0192***	-0.0206	-0.0063	-0.0217***	0.0019
lag 1	0.0707***	0.0056	0.0229	0.0688***	0.0198	0.0354
lags 2-6	-0.0448***	-0.0067	0.0243	-0.0619**	-0.0050	0.0005
Policymaker and Market News						
ECB Denies Euro Intervention						
leads 2-6	0.0080		-0.0060	-0.0093		0.0238
lead 1	0.0746**		-0.0755***	0.1224***		-0.0786
lag 0	0.1041***		-0.0130	0.1087**		-0.2348***
lag 1	-0.1172***		-0.0834***	-0.1374***		-0.3098***
lags 2-6	0.0149		-0.0055	0.0043		0.0140

Table 4.7: Contd.

Independent	"High Volatility"			"High News Arrival"		
Variables	USD-EUR	USD-GBP	YEN-USD	USD-EUR	USD-GBP	YEN-USD
Market Detects Japan Intervention						
leads 2-6	-0.0064	-0.0002	0.0008	-0.0064	-0.0008	0.0088
lead 1	0.0124	0.0040	-0.0367	0.0066	0.0137*	-0.0575**
lag 0	-0.0156*	-0.0177***	0.0260	-0.0209	-0.0178***	0.0348
lag 1	-0.0014	0.0016	0.0054	0.0290	0.0022	0.0053
lags 2-6	0.0007	0.0006	-0.0017	-0.0061	-0.0021	0.0039
Unrequited Interventions News						
Euro-zone Actual Intervention						
leads 2-6	-0.0021	-0.0012	-0.0013	0.0050	0.0010	-0.0012
lead 1	0.0013	0.0035	-0.0061	0.0012	0.0041	-0.0108
lag 0	0.0083	-0.0013	-0.0092	0.0193	0.0003	-0.0059
lag 1	-0.0086	0.0091**	0.0121	-0.0129	0.0115**	0.0069
lags 2-6	0.0035	-0.0037**	-0.0040	-0.0059	-0.0052***	-0.0045
Euro-zone Oral Intervention						
leads 2-6	0.0149	-0.0020	0.0282*	0.0189	-0.0022	0.0358**
lead 1	0.0063	-0.0133**	0.0243	-0.0177	-0.0137**	-0.0058
lag 0	-0.0012	-0.0056	-0.0008	-0.0088	-0.0083	0.0051
lag1	-0.0129	-0.0093	-0.0069	-0.0171	-0.0068	-0.0060
lags 2-6	0.0019	-0.0087**	0.0113	-0.0204	-0.0049	0.0141
Japan Actual Intervention						
leads 2-6	0.0014	-0.0004	0.0012	-0.0015	0.0006	-0.0059
lead 1	0.0020	0.0006	-0.0107	0.0192*	0.0013	-0.0134
lag 0	-0.0006	-0.0020	0.0139	0.0100	-0.0047	0.0208
lag 1	0.0087	-0.0001	-0.0024	-0.0044	-0.0005	-0.0121
lags 2-6	0.0007	0.0011	-0.0033	0.0015	-0.0013	-0.0083

Table 4.7: Contd.

Independent	"High Volatility"			"High News Arrival"		
Variables	USD-EUR	USD-GBP	YEN-USD	USD-EUR	USD-GBP	YEN-USD
Joint Actual Intervention						
leads 2-6	0.0102	0.0020	-0.0076	-0.0099	0.0030	-0.0095
lead 1	0.0146	-0.0037	-0.0132	0.0081	-0.0050	-0.0105
lag 0	0.0065	-0.0071*	-0.0015	-0.0103	-0.0114***	-0.0216
lag 1	0.0330***	0.0060	-0.0265*	0.0115	0.0046	-0.0194
lags 2-6	0.0063	0.0009	-0.0088	0.0084	0.0028	-0.0049
Joint Oral Intervention						
leads 2-6	0.0019	-0.0011	-0.0003	0.0068	-0.0003	-0.0204**
lead 1	0.0030	0.0020	0.0033	-0.0022	0.0017	0.0009
lag 0	-0.0034	-0.0031	-0.0107	-0.0087	-0.0055*	-0.0184**
lag 1	0.0049	0.0033	-0.0069	-0.0060	0.0026	-0.0162*
lags 2-6	0.0068	0.0008	-0.0060	0.0115*	0.0001	-0.0128
Interaction Terms						
Policymakers News						
Euro-zone Policy Statement						
leads 2-6	0.0460	-0.0257	-0.0152	-0.0508	0.0120	0.0598*
lag 0		-0.0692***	0.5920***			
Euro-zone Intervention						
lag 0	0.6590***	-0.0752***	0.3748			
lags 2-6	0.0341	0.0355***	-0.1882	0.0131	0.0084	0.0369
Euro-zone No Intervention						
leads 2-6	-0.4246***	-0.0126	0.4780	0.0183	0.0009	-0.0043
lag 0	-0.0913			-0.0094	-0.0745***	0.2252*
lag 1	-0.5365***	0.0633***		0.0093	-0.0026	0.1644*
lags 2-6	0.1675	-0.0226	-0.2045	0.0474*	-0.0009	-0.0434

Table 4.7: Contd.

Independent	"High Volatility"			"High News Arrival"		
Variables	USD-EUR	USD-GBP	YEN-USD	USD-EUR	USD-GBP	YEN-USD
Japan Policy Statement						
leads 2-6	-0.7931**	-0.0771***	-0.1839	-0.0024	-0.0051	-0.1548*
lag 0	-1.2279***	0.1557**				
lags 2-6		-0.0205	-0.4013*	0.0384	0.0042	0.0506
Japan Intervention						
lag 0	-0.1864	0.0660**	-0.2116			
Japan No Intervention						
leads 2-6				-0.0323	-0.0370***	-0.0358
UK Intervention						
lead 1		0.0099		-0.0240	-0.0171	0.2562***
lags 2-6	0.4954***	0.0496***	-0.2391	-0.2354***	-0.0207	
UK No Intervention						
leads 2-6	-0.3665***		-0.5452***			
Joint No Intervention						
leads 2-6	0.1629	0.0040	-0.5760***	-0.0507	0.0108	0.0286
lag 1		0.0711***	0.5392*	-0.2478***	-0.0614***	-0.0011
Markets' Expectations News						
Euro-zone Intervention Rumour						
lead 1	-0.2329			-0.0285	0.0348*	0.3240***
lags 2-6	0.3090	0.2225***	-0.0665	-0.0694	0.0228	0.1981
Euro-zone Intervention Not Expected						
leads 2-6	-0.1810	-0.0839		0.0622	0.0042	-0.0726*
lags 2-6	-0.2306***	0.0475		0.0222	0.0015	-0.0163

Table 4.7: Contd.

Independent	"High Volatility"			"High News Arrival"		
Variables	USD-EUR	USD-GBP	YEN-USD	USD-EUR	USD-GBP	YEN-USD
Japan Intervention Rumour						
leads 2-6			0.2751	-0.0324	0.0282**	0.0306
lag 0	-0.0165		-0.7890**			
Joint Intervention Rumour						
lag 0	0.8920*		2.1248***			
lag 1	0.0701			-0.3106**	0.0908***	0.0672
Joint Intervention Not Expected						
leads 2-6	-0.7495***	-0.0934***				
lag 1		0.0618***				
lags 2-6	0.0485	0.0083	-0.3099**	-0.1239	-0.0301	
Policymaker and Market News						
ECB Denies Euro Intervention						
leads 2-6				-0.1407		0.2355*
lag 0			-0.8464***			
lags 2-6				0.0416		-0.1821**
Market Detects Japan Intervention						
lead 1		0.0414	0.2157	-0.0108	-0.0238	0.1713**
lag 0			0.9206**			
lag 1	0.7832***		0.2937	-0.0123	0.0004	0.0157
lags 2-6	-0.3726***	-0.0127	-0.1390	0.0167*	0.0078**	-0.0209
Unrequited Interventions News						
Euro-zone Actual Intervention						
lags 2-6	-0.0942	-0.0734***	0.0323	-0.0148	-0.0035	0.0145
Joint Actual Intervention						
lag 1	-0.1910			0.0228	0.0399***	0.0209

Table 4.7: Contd.

Independent	"High Volatility"			"High News Arrival"		
Variables	USD-EUR	USD-GBP	YEN-USD	USD-EUR	USD-GBP	YEN-USD
Joint Oral Intervention						
leads 2-6	-0.0237	0.0128	-0.0358	-0.0657	0.0058	0.0721***
lag 0	-0.2838	-0.2899***	-1.4061***			
lag 1	0.1844	0.1784***	0.4144***	0.3584***	-0.0105	-0.1439*
lags 2-6	0.0865	-0.0360***	0.2534	-0.0317	0.0032	-0.0147
Adj R^2	0.0364	0.0217	0.0623	-0.0007	-0.0011	0.0171
$F-test$	8.99***	2.41***	5.48***	3.5159***	0.9387	2.16***

Notes: Returns are calculated at 20 minute frequency and are defined as 100 times the log difference of the mid quote where the mid quote is calculated as the average of the bid and ask quotes. *, ** and *** represent significance at 10, 5 and 1 percent respectively and "..." indicates that the coefficient is insignificant.

Table 4.8: The Influence of "News" on USD-EUR, USD-GBP and YEN-USD Volatility

	USD-EUR		USD-GBP		YEN-USD	
Independent Variables	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News
Non-News						
Constant	-0.0001	-0.0005	-0.0001	0.0000	-0.0002	-0.0002
Japanese Intervention	-0.0012	0.0014	0.0017	0.0029*	-0.0001	0.0028
Dependent Variable						
lag 1	0.3195***	0.3129***	0.2208***	0.2181***	0.4385***	0.4338***
lag 2	0.1237***	0.1193***	0.1336***	0.1315***	0.0323	0.0300
lag 3	0.1037***	0.1015***	0.0945***	0.0934***	0.0594***	0.0574***
lag 4	0.0794***	0.0792***	0.0869***	0.0883***	0.0275*	0.0298*
lag 5	0.0466***	0.0479***	0.0811***	0.0832***	0.0206	0.0214*
lag 6	0.0468***	0.0500***	0.0654***	0.0665***	0.0456***	0.0468***
Macro Surprises						
UK	-0.0078	-0.0070	0.0011	0.0009	-0.0036	-0.0041
US	0.0079	0.0080	-0.0027	-0.0024	0.0168	0.0176
Euro-zone	0.0042	0.0029	-0.0040	-0.0034	-0.0047	-0.0058
Japan	0.0167*	0.0168**	0.0018	0.0017	0.0030	0.0029
Policymakers News						
Euro-zone Policy Statement						
leads 2-6	...	-0.0102	...	-0.0013	...	0.0275
lead 1	...	0.0043	...	0.0066	...	-0.0264
lag 0	...	-0.0035	...	-0.0025	...	0.0073
lag 1	...	-0.0178	...	-0.0037*	...	-0.0280
lags 2-6	...	0.0049	...	0.0038**	...	-0.0076

Table 4.8: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Euro-zone Intervention						
leads 2-6	...	0.0051	...	0.0001	...	0.0105
lead 1	...	-0.0150	...	-0.0055**	...	-0.0309
lag 0	...	-0.0043	...	0.0029	...	0.0045
lag 1	...	0.0238*	...	-0.0002	...	0.0001
lags 2-6	...	-0.0095**	...	-0.0005	...	-0.0056
Euro-zone No Intervention						
leads 2-6	...	-0.0022	...	-0.0008	...	-0.0090
lead 1	...	-0.0115	...	-0.0026	...	-0.0033
lag 0	...	-0.0069	...	-0.0045	...	0.0021
lag 1	...	-0.0048	...	-0.0015	...	-0.0023
lags 2-6	...	0.0012	...	0.0016	...	-0.0071
Japan Policy Statement						
leads 2-6	...	0.0140	...	0.0033	...	-0.0122
lead 1	...	0.0243	...	-0.0080**	...	0.0235
lag 0	...	-0.0007	...	0.0098*	...	-0.0469**
lag 1	...	-0.0418	...	-0.0110***	...	-0.0066
lags 2-6	...	-0.0245	...	0.0000	...	-0.0013
Japan Intervention						
leads 2-6	...	-0.0020	...	0.0002	...	-0.0062**
lead 1	...	-0.0188***	...	-0.0001	...	0.0016
lag 0	...	0.0061	...	-0.0020	...	-0.0084
lag 1	...	-0.0023	...	0.0011	...	0.0108
lags 2-6	...	-0.0009	...	-0.0012	...	-0.0003

Table 4.8: Contd.

Independent Variables	USD-EUR		USD-GBP		YEN-USD	
	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News
Japan No Intervention						
leads 2-6	...	0.0200**	...	-0.0090***	...	-0.0241***
lead 1	...	0.0137	...	-0.0084***	...	-0.0181
lag 0	...	0.1217***	...	-0.0149***	...	-0.0281***
lag 1	...	0.0793***	...	0.0468***	...	-0.0217**
lags 2-6	...	0.0599***	...	-0.0087***	...	-0.0130***
UK Policy Statement						
leads 2-6	...	-0.0059***	...	-0.0004	...	0.0190**
lead 1	...	0.0211***	...	-0.0180***	...	-0.0519***
lag 0	...	0.0121***	...	0.0124***	...	-0.0202***
lag 1	...	0.0068***	...	-0.0046***	...	-0.0498***
lags 2-6	...	0.0074	...	0.0009	...	0.0431**
UK Intervention						
leads 2-6	...	0.0130*	...	0.0096***	...	0.0054
lead 1	...	-0.0291***	...	0.0003	...	0.0203*
lag 0	...	0.0013	...	-0.0024	...	-0.0088
lag 1	...	0.0123	...	-0.0096	...	-0.0495***
lags 2-6	...	0.0346	...	0.0089**	...	0.0405***
UK No Intervention						
leads 2-6	...	0.0559*	...	...	...	0.1079***
lead 1	...	0.0466***	...	...	...	-0.0972***
lag 0	...	-0.1052***	...	...	...	0.0532***
lag 1	...	0.0634***	...	...	...	-0.0170**
lags 2-6	...	-0.0107	...	...	...	-0.0174

Table 4.8: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Joint Intervention						
leads 2-6	...	0.0102	...	-0.0044	...	-0.0056
lead 1	...	0.0133	...	-0.0010	...	-0.0158
lag 0	...	0.0033	...	-0.0064	...	-0.0148
lag 1	...	0.0201	...	-0.0004	...	-0.0328*
lags 2-6	...	0.0086	...	0.0104	...	0.0638
Joint No Intervention						
leads 2-6	...	-0.0058	...	0.0026	...	0.0145
lead 1	...	0.0218	...	0.0024	...	-0.0089
lag 0	...	-0.0071	...	0.0043	...	-0.0074
lag 1	...	0.0099	...	0.0015	...	-0.0018
lags 2-6	...	0.0040	...	-0.0007	...	-0.0150*
Markets' Expectations News						
Euro-zone Intervention Rumour						
leads 2-6	...	0.0012	...	0.0001	...	-0.0046
lead 1	...	0.0645**	...	-0.0044	...	0.0066
lag 0	...	-0.0329	...	0.0083	...	-0.0226
lag 1	...	0.0176	...	-0.0051	...	0.0234
lags 2-6	...	0.0327	...	0.0027	...	0.0718**
Euro-zone Intervention Not Expected						
leads 2-6	...	0.0095	...	0.0000	...	-0.0048
lead 1	...	-0.0170	...	0.0050	...	0.0031
lag 0	...	-0.0166	...	-0.0076*	...	-0.0083
lag 1	...	0.0137	...	-0.0016	...	0.0295
lags 2-6	...	-0.0062	...	0.0010	...	-0.0166*

Table 4.8: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Japan Intervention Rumour						
leads 2-6	...	-0.0025	...	0.0023	...	0.0548
lead 1	...	-0.0110	...	0.0204*	...	0.1116**
lag 0	...	0.0441	...	0.0023	...	0.0344
lag 1	...	-0.0475	...	0.0135*	...	0.0126
lags 2-6	...	-0.0026	...	-0.0021	...	0.0149
Joint Intervention Rumour						
leads 2-6	...	-0.0283*	...	-0.0005	...	0.0125
lead 1	...	-0.0068	...	-0.0032	...	0.0099
lag 0	...	-0.0075	...	-0.0038	...	-0.0249
lag 1	...	-0.0002	...	0.0068	...	0.0344
lags 2-6	...	0.0281*	...	0.0009	...	-0.0151
Joint Intervention Not Expected						
leads 2-6	...	-0.0214	...	0.0008	...	-0.0443***
lead 1	...	-0.0217	...	0.0080*	...	0.0676
lag 0	...	-0.0168	...	-0.0029	...	-0.0308
lag 1	...	0.0081	...	0.0002	...	-0.0070
lags 2-6	...	-0.0017	...	-0.0011	...	0.0182
Policymaker and Market News						
ECB Denies Euro Intervention						
leads 2-6	...	-0.0240	...	...	...	-0.1171***
lead 1	...	-0.0118	...	...	...	-0.0176
lag 0	...	0.0270	...	...	...	0.2109***
lag 1	...	0.0037	...	...	...	0.2011***
lags 2-6	...	0.0222	...	...	...	0.0248*

Table 4.8: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Market Detects Japan Intervention						
leads 2-6	...	0.0018	...	-0.0009	...	-0.0006
lead 1	...	0.0038	...	0.0070*	...	0.0146
lag 0	...	-0.0241***	...	-0.0018	...	0.0002
lag 1	...	0.0154	...	-0.0064***	...	-0.0110
lags 2-6	...	-0.0014	...	-0.0012	...	-0.0023
Unrequited Interventions News						
Euro-zone Actual Intervention						
leads 2-6	...	0.0018	...	0.0007	...	-0.0026
lead 1	...	-0.0088	...	0.0004	...	0.0114
lag 0	...	0.0104	...	-0.0005	...	0.0010
lag 1	...	-0.0066	...	0.0043*	...	-0.0231***
lags 2-6	...	0.0038	...	-0.0003	...	0.0022
Euro-zone Oral Intervention						
leads 2-6	...	-0.0074	...	-0.0018	...	-0.0112
lead 1	...	-0.0289*	...	-0.0006	...	0.0140
lag 0	...	0.0200	...	-0.0069*	...	-0.0204*
lag 1	...	-0.0258	...	0.0027	...	-0.0319**
lags 2-6	...	-0.0176	...	-0.0020	...	-0.0043
Japan Actual Intervention						
leads 2-6	...	0.0008	...	-0.0013	...	0.0066
lead 1	...	0.0131*	...	0.0021	...	-0.0095
lag 0	...	0.0023	...	-0.0002	...	0.0115
lag 1	...	0.0099	...	-0.0002	...	0.0044
lags 2-6	...	-0.0009	...	0.0008	...	-0.0056

Table 4.8: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Joint Actual Intervention						
leads 2-6	...	0.0089	...	-0.0027*	...	-0.0069
lead 1	...	-0.0033	...	-0.0011	...	-0.0042
lag 0	...	0.0060	...	0.0008	...	0.0047
lag 1	...	0.0030	...	-0.0035	...	-0.0169*
lags 2-6	...	-0.0152**	...	0.0000	...	0.0000
Joint Oral Intervention						
leads 2-6	...	0.0176***	...	0.0005	...	0.0065
lead 1	...	0.0023	...	-0.0009	...	-0.0094
lag 0	...	0.0076	...	0.0016	...	0.0079
lag 1	...	-0.0057	...	-0.0015	...	-0.0075
lags 2-6	...	-0.0030	...	-0.0010	...	0.0109
Adj R^2	0.2900	0.2911	0.2134	0.2133	0.2542	0.2548
$F-test$	503.15***	41.37***	291.44***	26.25***	414.39***	34.17***

Notes: Volatility is calculated at 20 minute frequency and is defined as the absolute return where returns are calculated as 100 times the log difference of the mid quote. The mid quote is calculated as the average of the bid and ask quotes. *, ** and *** represent significance at 10, 5 and 1 percent respectively and "..." indicates that the coefficient is insignificant.

Table 4.9: The Influence of "News" on USD-EUR, USD-GBP and YEN-USD Transaction Frequency

	USD-EUR		USD-GBP		YEN-USD	
Independent Variables	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News
Non-News						
Constant	-0.1191	-0.1669	-0.1348	-0.0463	0.0254	0.0237
Japanese Intervention	0.1111	1.4011	0.2837	2.2116	-0.1479	-0.0967
Dependent Variable						
lag 1	0.7757***	0.7700***	0.6105***	0.6056***	0.4561***	0.4529***
lag 2	0.0427	0.0435	0.1427***	0.1406***	0.1610***	0.1638***
lag 3	0.0516**	0.0535**	0.1141***	0.1150***	0.0807***	0.0778***
lag 4	0.0286	0.0302	0.0026	0.0041	0.0472***	0.0464***
lag 5	0.0006	0.0022	-0.0092	-0.0079	0.0411**	0.0433**
lag 6	-0.0200	-0.0228	-0.0104	-0.0104	0.0190	0.0184
Macro Surprises						
UK	-0.7110	-0.4008	-1.8893	-1.8783	0.6009	0.6338
US	-3.2545	-3.1218	-8.3139	-7.6455	-0.1151	-0.0838
Euro-zone	5.0453	4.4099	2.9518	4.0523	0.1497	0.1080
Japan	1.2370	1.2266	3.3537	3.3480	0.0493	0.0598
Policymakers News						
Euro-zone Policy Statement						
leads 2-6	...	-1.0823	...	-3.5747**	...	0.9078**
lead 1	...	-3.8739	...	1.4189	...	-1.0977
lag 0	...	1.0178	...	-2.4579	...	-1.2081
lag 1	...	-2.8044	...	5.5219	...	-0.2763
lags 2-6	...	5.9955	...	1.1216	...	0.5240

Table 4.9: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Euro-zone Intervention						
leads 2-6	...	0.5831	...	2.4328	...	0.1188
lead 1	...	-5.5056	...	-0.1535	...	-0.7075
lag 0	...	-2.0409	...	0.6084	...	-0.4569
lag 1	...	2.0008	...	-1.4992	...	1.2223
lags 2-6	...	-2.7741	...	-2.8091	...	-0.1643
Euro-zone No Intervention						
leads 2-6	...	-2.6902	...	-2.4982	...	-0.1493
lead 1	...	1.7784	...	-1.1041	...	-0.2471
lag 0	...	-2.4048	...	-1.2829	...	0.0895
lag 1	...	0.3803	...	-2.4438	...	-0.0165
lags 2-6	...	0.3336	...	0.6201	...	0.1139
Japan Policy Statement						
leads 2-6	...	-9.8919	...	2.5937	...	0.1264
lead 1	...	-1.9381	...	-11.8245***	...	-0.8506
lag 0	...	7.7966	...	-2.2490	...	-1.2707***
lag 1	...	-5.9042	...	-4.0775**	...	-1.3386***
lags 2-6	...	-0.2155	...	-0.0261	...	-0.0308
Japan Intervention						
leads 2-6	...	-0.1411	...	-1.0660	...	-0.0261
lead 1	...	-2.7364	...	1.4473	...	0.3461
lag 0	...	-2.3994	...	-2.4012*	...	-0.1276
lag 1	...	-1.9540	...	-0.9994	...	0.1948
lags 2-6	...	0.4534	...	-1.1900	...	-0.0935

Table 4.9: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Japan No Intervention						
leads 2-6	...	-0.0824	...	-3.8608***	...	-0.6175***
lead 1	...	-0.8786	...	-2.9270	...	-0.2838
lag 0	...	-4.9613*	...	-5.4316**	...	-0.0030
lag 1	...	-1.2251	...	5.5040*	...	-0.5991
lags 2-6	...	-1.2942	...	-5.1247***	...	0.9473**
UK Policy Statement						
leads 2-6	...	0.0753	...	5.7916*	...	1.1470***
lead 1	...	-1.9180***	...	-24.0771***	...	-5.4239***
lag 0	...	-1.3735***	...	-10.4315***	...	1.2127***
lag 1	...	-1.4509***	...	-6.4750***	...	-0.6482***
lags 2-6	...	0.2833	...	2.1236***	...	0.0696
UK Intervention						
leads 2-6	...	2.1577	...	5.9899	...	-0.3962*
lead 1	...	-12.4467**	...	-18.1542*	...	1.6275**
lag 0	...	-0.4054	...	0.2144	...	-3.0208***
lag 1	...	12.2095	...	9.1821***	...	0.3601
lags 2-6	...	19.7575	...	22.9598**	...	0.7077*
UK No Intervention						
leads 2-6	...	16.1599	...	...	...	7.7523***
lead 1	...	59.1926***	...	...	...	-15.5949***
lag 0	...	-34.1638***	...	...	...	0.3743
lag 1	...	16.5015***	...	...	...	3.7740***
lags 2-6	...	4.6558	...	...	...	1.0486

Table 4.9: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Joint Intervention						
leads 2-6	...	-8.1347***	...	-2.1731	...	0.1036
lead 1	...	-2.4003	...	-6.6085	...	0.7630
lag 0	...	-4.7618	...	-1.1574	...	-0.1263
lag 1	...	2.8660	...	1.0669	...	-0.3590
lags 2-6	...	-7.5746**	...	-2.9022	...	0.2961
Joint No Intervention						
leads 2-6	...	1.5683	...	0.3500	...	0.5197
lead 1	...	0.7957	...	8.5668*	...	-1.3226**
lag 0	...	-2.9739	...	5.7461	...	0.5940
lag 1	...	-2.4368	...	3.1022	...	-1.3561
lags 2-6	...	0.0877	...	-1.3477	...	-0.6475***
Markets' Expectations News						
Euro-zone Intervention Rumour						
leads 2-6	...	3.0919	...	-7.0001	...	1.0068
lead 1	...	2.2644	...	-11.9918	...	0.6641
lag 0	...	-14.9089**	...	7.3302	...	-0.7211
lag 1	...	-11.0659	...	20.9957*	...	-1.6429
lags 2-6	...	20.6951**	...	13.6894	...	0.8342
Euro-zone Intervention Not Expected						
leads 2-6	...	6.3587	...	1.5525	...	0.0359
lead 1	...	-10.8800	...	-5.6801	...	-1.7589*
lag 0	...	-10.3835*	...	-7.1485	...	1.6553
lag 1	...	0.1824	...	-2.4088	...	-0.5777
lags 2-6	...	-2.8829	...	0.2545	...	-0.7046*

Table 4.9: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Japan Intervention Rumour						
leads 2-6	...	-33.5305	...	11.1123	...	1.1799
lead 1	...	-5.4654	...	-13.5491*	...	-2.0552
lag 0	...	-12.4225	...	-13.7972**	...	-0.7157
lag 1	...	-5.9700	...	-1.7792	...	-2.0647**
lags 2-6	...	-4.1077	...	-5.1590	...	0.4320
Joint Intervention Rumour						
leads 2-6	...	-2.7537	...	0.8994	...	0.2306
lead 1	...	1.9300	...	-2.9782	...	1.9195
lag 0	...	-3.1121	...	-4.3300	...	-0.7594
lag 1	...	8.5803	...	8.0125	...	-1.1988
lags 2-6	...	-0.8401	...	-1.8870	...	-0.4259
Joint Intervention Not Expected						
leads 2-6	...	0.8656	...	-2.2587	...	-1.6031***
lead 1	...	-4.3529	...	18.4291*	...	5.4832*
lag 0	...	14.4336	...	-5.4565	...	1.6213
lag 1	...	-6.0109	...	12.6291*	...	1.6776
lags 2-6	...	5.4311	...	10.4574	...	0.7324
Policymaker and Market News						
ECB Denies Euro Intervention						
leads 2-6	...	-5.1443	...	...	...	-2.6839**
lead 1	...	6.0032	...	...	...	-1.4297
lag 0	...	-25.5413***	...	...	...	9.6255***
lag 1	...	-4.8274	...	...	...	-1.6589*
lags 2-6	...	10.0206*	...	...	...	1.6004

Table 4.9: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Market Detects Japan Intervention						
leads 2-6	...	-1.2566	...	-1.5004	...	-0.0438
lead 1	...	0.6017	...	-4.2591**	...	-0.4087
lag 0	...	0.7568	...	-2.0461*	...	-0.3876
lag 1	...	1.1870	...	-2.3036	...	-0.1975
lags 2-6	...	-1.4051	...	-0.6249	...	0.1616
Unrequited Interventions News						
Euro-zone Actual Intervention						
leads 2-6	...	1.7551	...	1.0524	...	0.0287
lead 1	...	1.0349	...	4.9853	...	0.3895
lag 0	...	7.9300**	...	-2.8856	...	0.7296
lag 1	...	4.4938	...	-0.0094	...	-0.3628
lags 2-6	...	-0.1858	...	0.0000	...	0.0075
Euro-zone Oral Intervention						
leads 2-6	...	-1.8132	...	-3.0198*	...	-0.3193
lead 1	...	-6.0245	...	-0.0842	...	0.4627
lag 0	...	-0.7910	...	0.0349	...	0.1940
lag 1	...	4.7574	...	-8.8983*	...	-1.0147
lags 2-6	...	-5.1974	...	-1.6680	...	-0.4344
Japan Actual Intervention						
leads 2-6	...	-0.4777	...	-0.2984	...	0.0010
lead 1	...	4.7189	...	0.6937	...	-0.3291
lag 0	...	2.8580	...	2.6335	...	-0.2412
lag 1	...	0.7294	...	1.9979	...	0.4409
lags 2-6	...	0.2977	...	-0.1580	...	-0.0063

Table 4.9: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Joint Actual Intervention						
leads 2-6	...	-0.6855	...	-0.0271	...	-0.4368**
lead 1	...	0.0774	...	-0.5229	...	-0.2539
lag 0	...	1.6138	...	1.9670	...	0.1465
lag 1	...	-3.7833*	...	-4.8069	...	0.5747
lags 2-6	...	-0.1704	...	1.0529	...	-0.0252
Joint Oral Intervention						
leads 2-6	...	1.4115	...	0.0753	...	0.2731
lead 1	...	-2.1958	...	-1.7508	...	-1.0830***
lag 0	...	0.2604	...	-0.3129	...	0.4856
lag 1	...	-4.5715**	...	-3.8372**	...	-0.3765
lags 2-6	...	1.1432	...	0.2452	...	0.0927
Adj R^2	0.7444	0.0000	0.6534	0.6527	0.4815	0.0000
$F-test$	3580.2***	287.68***	2019.2***	175.88***	1127.3***	91.77***

Notes: Transaction frequency is calculated as the number of transactions in any given 20 minute period. *, ** and *** represent significance at 10, 5 and 1 percent respectively and "..." indicates that the coefficient is insignificant.

Table 4.10: The Influence of Order Flow on USD-EUR, USD-GBP and YEN-USD Returns

	Return on Order Flow		
Independent Variables	USD-EUR	USD-GBP	YEN-USD
Non-News			
Constant	-0.0007	-0.0008***	-0.0004
Lagged Dependent Variable			
lag 1	0.1675***	0.0219	0.0569
lag 2	0.1092***	0.0279**	0.1166***
Order Flow			
lag 0	0.0039***	0.0014***	0.0104***
lag1	-0.0010***	-0.0002***	-0.0008
lags 2-6	0.0000	0.0000	-0.0003**
Adj R^2	0.0279	0.1429	0.0677
$F-test$	1309.9***	447.60***	221.48***

Notes: Returns and order flow are calculated at 20 minute frequency. Returns are defined as 100 times the log difference of the mid quote. The mid quote is calculated as the average of the bid and ask quotes. Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR, sterling for USD-GBP and US dollar for YEN-USD). *, ** and *** represent significance at 10, 5 and 1 percent respectively.

Table 4.11: The Influence of "News" on USD-EUR, USD-GBP and YEN-USD Order Flow

Independent Variables	USD-EUR		USD-GBP		YEN-USD	
	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News
Non-News						
Constant	0.2080*	0.2235*	0.3731***	0.4199***	0.0630**	0.0952***
Japanese Intervention	1.6459**	2.0492**	0.7717	1.1083*	-0.3475***	-0.3851***
Dependent Variable						
lag 1	0.0394**	0.0372**	0.0409**	0.0375**	0.1443***	0.1398***
lag 2	-0.0207	-0.0243	0.0080	0.0039	0.0444**	0.0435**
Macro Surprises						
UK	3.0878	2.9353	2.8361	2.6467	-0.6851	-0.7558
US	-0.3649	-0.2769	1.7786	1.7572	-0.3065	-0.3002
Euro-zone	2.1182	1.8108	-0.8635	-1.2158	-0.5097	-0.5574
Japan	-0.6084	-0.7647	1.1375	0.9545	0.0033	-0.0266
Policymakers News						
Euro-zone Policy Statement						
leads 2-6	...	0.2426	...	0.8825	...	0.2407
lead 1	...	0.0935	...	-0.0843	...	0.5711
lag 0	...	5.6901**	...	-0.7996	...	-0.9097
lag 1	...	0.4000	...	1.3558	...	0.6017
lags 2-6	...	-0.6265	...	-0.0357	...	-0.7437*
Euro-zone Intervention						
leads 2-6	...	0.9496	...	-0.4779	...	-0.0160
lead 1	...	2.0617	...	-2.1921	...	-0.3057
lag 0	...	-3.2170	...	-0.0664	...	-0.0374
lag 1	...	4.8435**	...	-3.3023**	...	0.3898
lags 2-6	...	1.0745	...	1.2720	...	0.5332**

Table 4.11: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Euro-zone No Intervention						
leads 2-6	...	-1.5923	...	-0.3487	...	0.2904
lead 1	...	-0.8517	...	-1.1820	...	-0.7690
lag 0	...	0.8086	...	0.6501	...	0.2747
lag 1	...	-1.8882	...	0.7387	...	-0.4789
lags 2-6	...	-1.5967	...	-1.2097*	...	0.0707
Japan Policy Statement						
leads 2-6	...	2.2553	...	0.7651	...	-0.2557
lead 1	...	-2.3174	...	2.2733	...	-0.3551
lag 0	...	-6.2474	...	-0.3496	...	-0.2199
lag 1	...	1.7836	...	-0.7399	...	-0.4314
lags 2-6	...	-1.3052	...	-0.2940	...	0.2550
Japan Intervention						
leads 2-6	...	0.0478	...	-0.0872	...	-0.0344
lead 1	...	-0.7477	...	-0.1227	...	0.2077
lag 0	...	1.3768	...	0.7259	...	0.2058
lag 1	...	0.2616	...	-0.9076	...	0.4525*
lags 2-6	...	-0.4249	...	-0.6331**	...	-0.1367
Japan No Intervention						
leads 2-6	...	-0.1969	...	1.8581**	...	0.0401
lead 1	...	-5.4053***	...	-0.4401	...	-0.3494
lag 0	...	-0.4208	...	-0.9131	...	0.0613
lag 1	...	0.5683	...	-13.3560***	...	0.2706
lags 2-6	...	0.0951	...	0.5585	...	0.4769*

Table 4.11: Contd.

Independent Variables	USD-EUR		USD-GBP		YEN-USD	
	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News
UK Policy Statement						
leads 2-6	...	0.3714**	...	-2.6370**	...	-2.2069***
lead 1	...	-0.2607**	...	4.1237***	...	0.6722***
lag 0	...	-0.1992	...	0.4884*	...	-3.9647***
lag 1	...	-0.2235*	...	2.5270***	...	-2.5359***
lags 2-6	...	-1.0212*	...	1.8993**	...	-0.3932
UK Intervention						
leads 2-6	...	-0.5071	...	-3.3257***	...	0.8210***
lead 1	...	4.6147	...	-5.5302	...	1.6616**
lag 0	...	-12.4332	...	5.7917	...	-0.7453
lag 1	...	10.3757	...	-11.7637	...	2.2342**
lags 2-6	...	5.2592	...	-0.9037	...	-1.1879**
UK No Intervention						
leads 2-6	...	-22.3954**	...	...	...	-2.7476**
lead 1	...	-38.6217***	...	...	...	-1.2196***
lag 0	...	11.4225***	...	...	...	-4.1294***
lag 1	...	-27.5438***	...	...	...	-2.4924***
lags 2-6	...	4.1392	...	...	...	-3.4954**
Joint Intervention						
leads 2-6	...	-0.5599	...	0.4197	...	0.3466
lead 1	...	0.9095	...	1.5596	...	-0.7916
lag 0	...	0.0134	...	0.7063	...	1.1777
lag 1	...	-2.4532	...	3.2671	...	-0.0959
lags 2-6	...	-0.5542	...	-0.8474	...	0.5245

Table 4.11: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Joint No Intervention						
leads 2-6	...	-1.0040	...	1.4740	...	0.0048
lead 1	...	2.1191	...	-2.2228	...	-0.1883
lag 0	...	-2.2471	...	1.9865	...	-1.1493
lag 1	...	1.4976	...	-1.5539	...	-0.5847*
lags 2-6	...	0.3612	...	2.2740***	...	-0.0838
Markets' Expectations News						
Euro-zone Intervention Rumour						
leads 2-6	...	1.2052	...	-1.2717	...	0.1124
lead 1	...	3.3579	...	1.1801	...	1.1792
lag 0	...	-12.9361*	...	3.9654	...	3.6847**
lag 1	...	-3.5211	...	-1.5121	...	-0.1748
lags 2-6	...	7.9182**	...	1.0447	...	0.3852
Euro-zone Intervention Not Expected						
leads 2-6	...	-3.3163*	...	0.6598	...	0.1163
lead 1	...	1.6053	...	-3.1539	...	-0.7862
lag 0	...	-4.5707	...	1.8284	...	-1.8090**
lag 1	...	1.9184	...	-7.7603**	...	-0.1629
lags 2-6	...	0.5770	...	2.0654*	...	0.0393
Japan Intervention Rumour						
leads 2-6	...	-0.0990	...	1.9614	...	0.4158
lead 1	...	-1.4992	...	13.1025*	...	-0.3570
lag 0	...	2.7281	...	10.4908**	...	0.0872
lag 1	...	-1.9650	...	-2.0319	...	0.3600
lags 2-6	...	0.6277	...	1.8386	...	-0.9601**

Table 4.11: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Joint Intervention Rumour						
leads 2-6	...	0.4839	...	-2.0999	...	0.3357
lead 1	...	0.7862	...	1.2380	...	0.8790
lag 0	...	3.5766	...	3.6004	...	-1.5897
lag 1	...	-6.5737	...	2.5833	...	-0.8238
lags 2-6	...	-1.2034	...	1.0242	...	-0.9270***
Joint Intervention Not Expected						
leads 2-6	...	-6.8488	...	0.4649	...	-0.6168
lead 1	...	-3.7064	...	-1.8376	...	-2.7690
lag 0	...	-9.5704	...	-2.6581	...	2.5971
lag 1	...	8.8355**	...	1.3359	...	2.5695
lags 2-6	...	-3.6728	...	3.1124*	...	-0.7601
Policymaker and Market News						
ECB Denies Euro Intervention						
leads 2-6	...	-3.3153	...	...	...	-0.9361
lead 1	...	16.9509***	...	...	...	-0.1789
lag 0	...	-1.5291	...	...	...	-7.0859*
lag 1	...	-9.5598*	...	...	...	-3.0197**
lags 2-6	...	0.6507	...	...	...	-1.7189**
Market Detects Japan Intervention						
leads 2-6	...	-0.6607	...	-0.0018	...	-0.0976
lead 1	...	0.4429	...	0.7762	...	-0.5286*
lag 0	...	-1.4686*	...	-1.4194*	...	0.3591
lag 1	...	-1.6056	...	0.4822	...	0.0141
lags 2-6	...	-0.7906	...	-0.1216	...	0.0114

Table 4.11: Contd.

Independent Variables	USD-EUR Benchmark	USD-EUR Benchmark + Reuters News	USD-GBP Benchmark	USD-GBP Benchmark + Reuters News	YEN-USD Benchmark	YEN-USD Benchmark + Reuters News
Unrequited Interventions News						
Euro-zone Actual Intervention						
leads 2-6	...	0.6585	...	0.4050	...	-0.3107*
lead 1	...	-0.2408	...	0.1546	...	0.3588
lag 0	...	3.3120	...	-1.6748	...	-0.4065
lag 1	...	-1.0034	...	1.5304	...	0.2120
lags 2-6	...	-1.2116	...	-1.1465	...	-0.3368
Euro-zone Oral Intervention						
leads 2-6	...	2.3432	...	0.7649	...	0.3613
lead 1	...	-4.8194	...	0.4384	...	1.5196
lag 0	...	-2.8450	...	0.8576	...	0.7968
lag 1	...	-0.8370	...	3.3824	...	0.3776
lags 2-6	...	-3.4705*	...	-0.2042	...	0.2204
Japan Actual Intervention						
leads 2-6	...	-0.3527	...	-0.4489	...	-0.2061*
lead 1	...	2.9203*	...	-0.0385	...	-0.1983
lag 0	...	0.6967	...	-1.8323*	...	-0.0199
lag 1	...	-0.4155	...	0.6857	...	-0.2292
lags 2-6	...	-0.0636	...	0.4792	...	0.1099
Joint Actual Intervention						
leads 2-6	...	-0.0959	...	1.0503*	...	-0.0721
lead 1	...	-2.4456	...	-1.3736	...	-0.2883
lag 0	...	-1.5986	...	-1.3222	...	0.6100
lag 1	...	3.7832**	...	0.0354	...	0.6241*
lags 2-6	...	-0.0117	...	0.0536	...	0.2473*

Table 4.11: Contd.

Independent Variables	USD-EUR		USD-GBP		YEN-USD	
	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News	Benchmark	Benchmark + Reuters News
Joint Actual Intervention						
leads 2-6	...	0.4744	...	-0.2017	...	0.0434
lead 1	...	-0.1610	...	-0.4029	...	-0.0313
lag 0	...	-0.3285	...	-0.5013	...	-0.4511
lag 1	...	0.7773	...	-0.1139	...	-0.2455
lags 2-6	...	0.9341	...	-0.4104	...	0.1266
Adj R^2	0.0023	0.0022	0.0023	0.0027	0.0252	0.0271
$F-test$	5.91**	1.23*	5.36**	1.27**	53.34***	3.8***

Notes: Order flow is calculated at 20 minute frequency. It is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR, sterling for USD-GBP and US dollar for YEN-USD). *, ** and *** represent significance at 10, 5 and 1 percent respectively and "..." indicates that the coefficient is insignificant. For each regressor the sum of leads 2-6, lead 1, lag 0, lag 1 and the sum of lags 2-6 were included in the regression.

Figure 4.1: Japanese Interventions and the YEN-USD Exchange Rate, 1990-2002

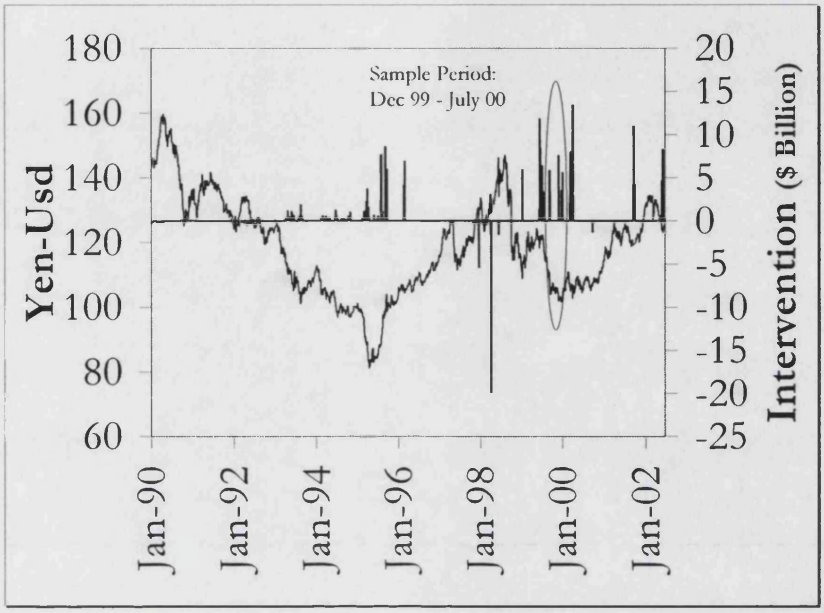
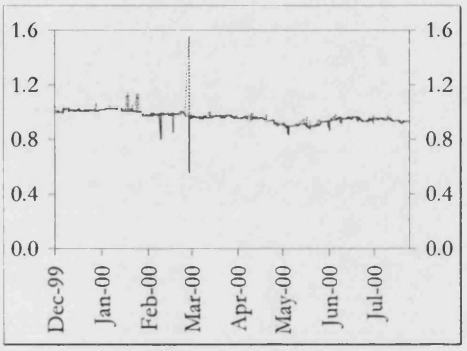
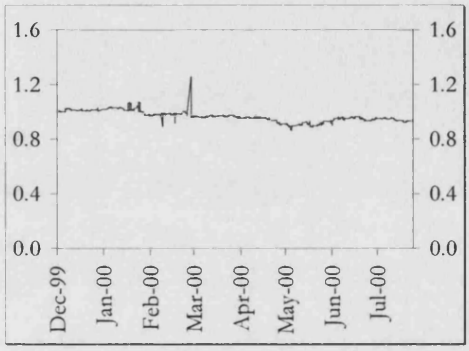


Figure 4.2: Reuters D2000-2 Bid, Ask and Mid Quotes, 01 Dec 1999 - 24 July 2000

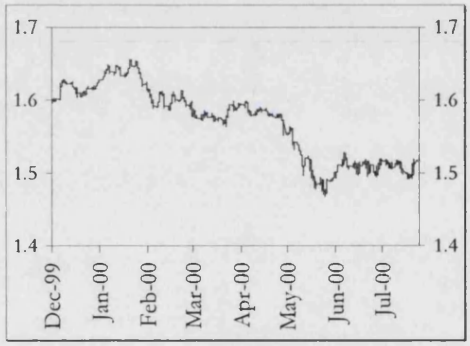


(a) USD-EUR Bid & Ask Quotes

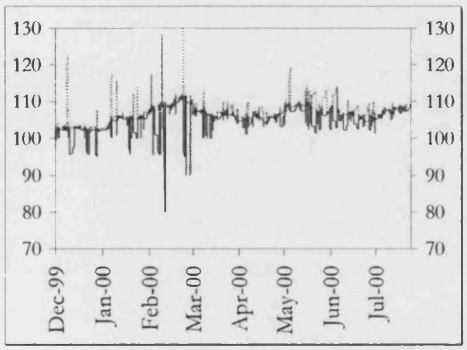


(b) USD-EUR Mid Quote

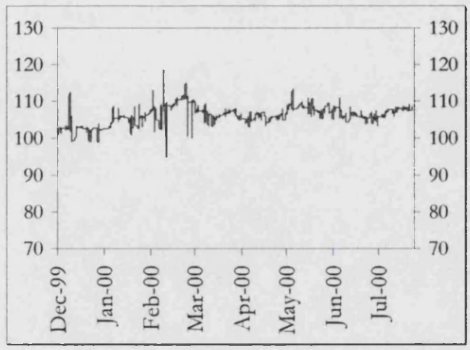
(c) USD-GBP Bid & Ask Quotes



(d) USD-GBP Mid Quote



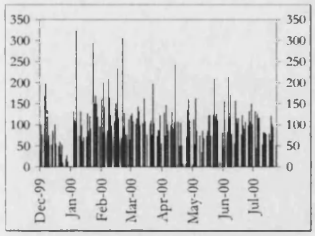
(e) YEN-USD Bid & Ask Quotes



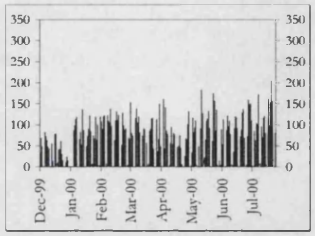
(f) YEN-USD Mid Quote

Notes: Currencies are defined as the number of dollars per foreign currency for the euro and sterling, and number of foreign currency per dollar for the yen. The mid quote is calculated as the average of the bid and ask quotes.

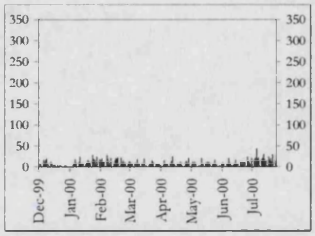
Figure 4.3: Total Buys, Total Sells and Order Flow, 01 Dec 1999 - 24 July 2000



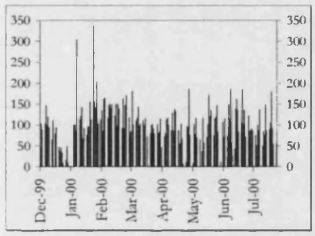
(a) USD-EUR Total Buy



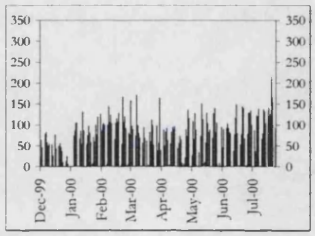
(b) USD-GBP Total Buy



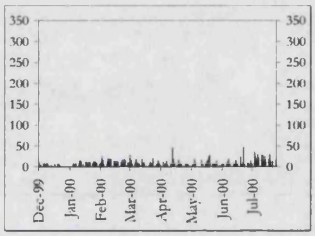
(c) YEN-USD Total Buy



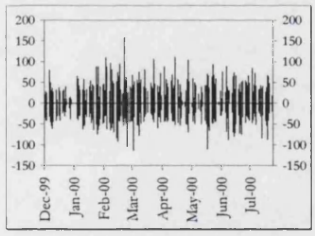
(d) USD-EUR Total Sell



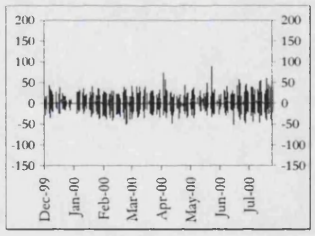
(e) USD-GBP Total Sell



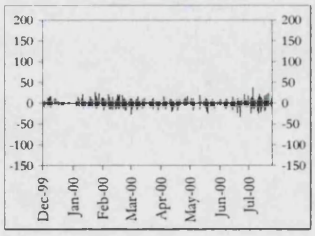
(f) YEN-USD Total Sell



(g) USD-EUR Order Flow



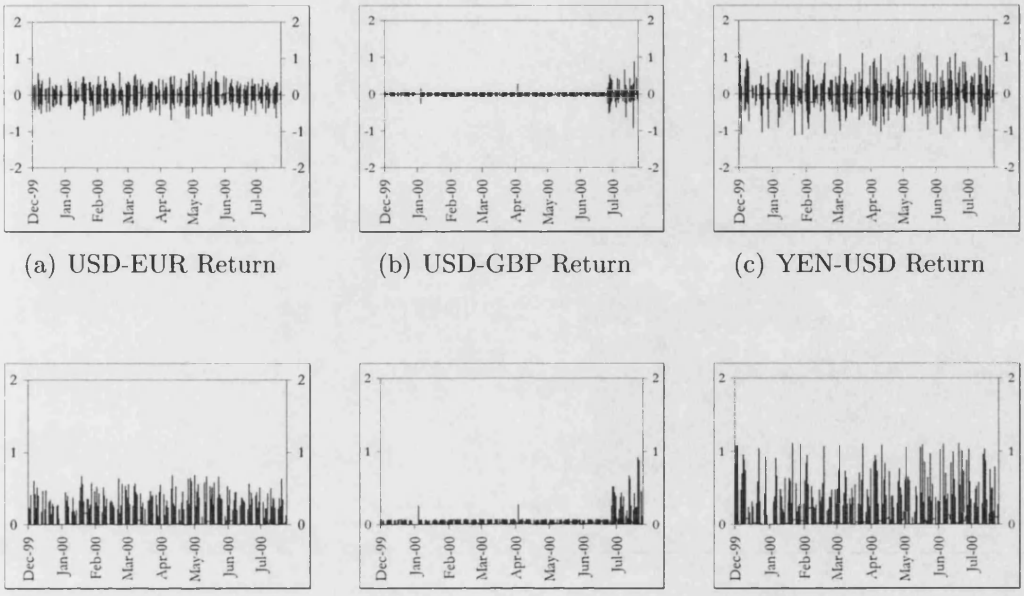
(h) USD-GBP Order Flow



(i) YEN-USD Order Flow

Notes: Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR, sterling for USD-GBP and dollar for YEN-USD).

Figure 4.4: Exchange Rate Returns and Volatility, 01 Dec 1999 - 24 July 2000

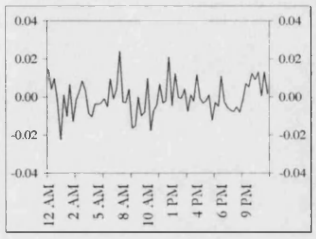


(a) USD-EUR Return (b) USD-GBP Return (c) YEN-USD Return

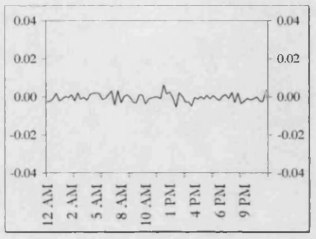
(d) USD-EUR Volatility (e) USD-GBP Volatility (f) YEN-USD Volatility

Notes: The data are sampled at 20-minute frequency. Currencies are defined as the number of dollars per foreign currency for the euro and sterling, and number of foreign currency per dollar for the yen. Returns are defined as 100 times the log difference of the mid quote where the mid quote is calculated as the average of the bid and ask quotes. Volatility is defined as the absolute return.

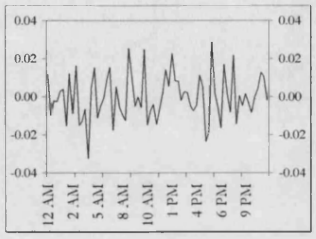
Figure 4.5: Average Daily USD-GBP Returns, Order Flow and News Arrival, 01 Dec 1999 - 24 July 2000



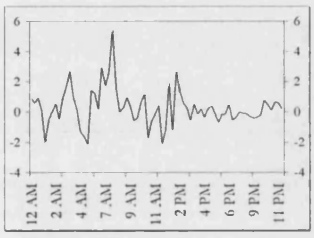
(a) USD-EUR Average Return



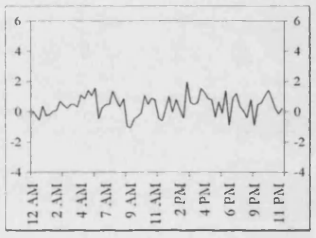
(b) USD-GBP Average Return



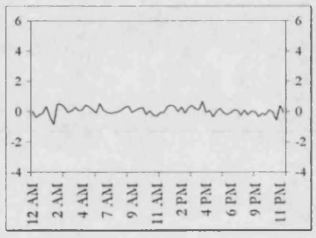
(c) YEN-USD Average Return



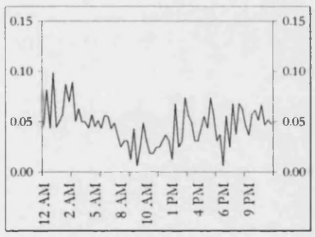
(d) USD-EUR Average Order Flow



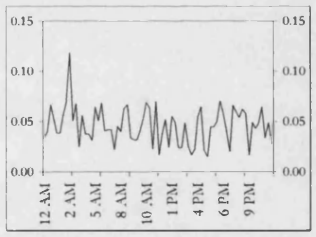
(e) USD-GBP Average Order Flow



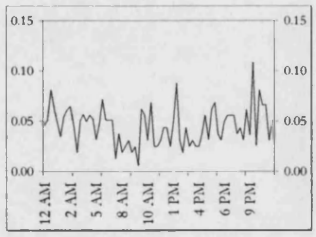
(f) YEN-USD Average Order Flow



(g) USD-EUR Average News Arrival



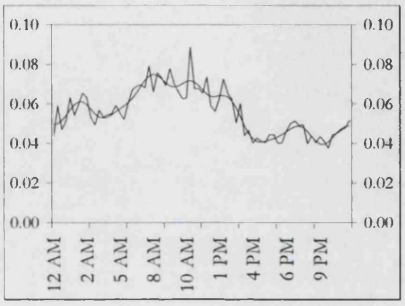
(h) USD-GBP Average News Arrival



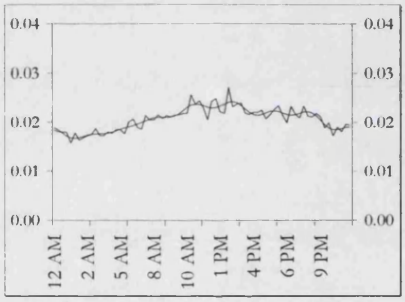
(i) YEN-USD Average News Arrival

Notes: The data are sampled at 20-minute frequency. Currencies are defined as the number of dollars per foreign currency for the euro and sterling, and number of foreign currency per dollar for the yen. The figures plot the average intra-daily pattern of returns, order flow and news arrival over a 24-hour period. Returns are calculated as 100 times the log difference of the mid quote where the mid quote is calculated as the average of the bid and ask quotes. Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR and sterling for USD-GBP). News Arrival is an indicator variable for the number of Reuters news articles in each 20 minute period.

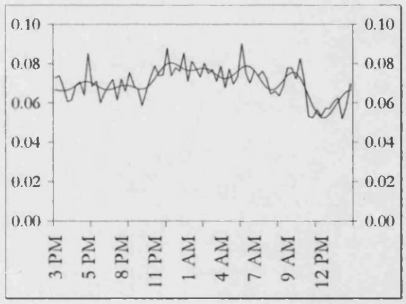
Figure 4.6: Average Daily Volatility and the FFF Seasonal (in basis points), 01 Dec 1999 - 24 July 2000



(a) USD-EUR



(b) USD-GBP



(c) YEN-USD

Notes: The data are sampled at 20-minute frequency. Currencies are defined as the number of dollars per foreign currency for the euro and sterling, and number of foreign currency per dollar for the yen. The figures plot the average intra-daily pattern of volatility (jagged line) and the Flexible Fourier Form seasonal (smooth line) over a 24-hour period. Volatility is defined as the absolute return, where returns are calculated as 100 times the log difference of the mid quote. The mid quote is calculated as the average of the bid and ask quotes.

Chapter 5

Conclusion

This thesis contributes to and extends the literature by analysing the effect of different types of information on order flow, high frequency exchange rate returns and volatility.

The first chapter conducted an event study using the CHF-USD exchange rate and SNB interventions to study the relationship between various characteristics of interventions and the volatility of the exchange rate. Additionally, using Reuters reports, it studies the impact of the news of these interventions on volatility. The data set contains information on the size, direction, frequency and timing of the intervention, making it unique in many ways. The analysis was conducted using four different measures of volatility - absolute returns, squared returns, one hour realised volatility based on absolute returns and one hour realised volatility based on squared returns. The results vary depending on which measure is used but there are some general conclusions that can be drawn. With this rich data set it has been possible to identify that interventions decrease volatility contemporaneously but this effect is reversed in the two hours afterward, a result that is in line with previous empirical work in the area. Further, the direction of the inter-

vention does not seem to affect volatility. Buy and sell interventions have similar effects on volatility and the same is true for against-the-wind and with-the-wind interventions.

Additionally, a lagged size effect of intervention is identified, but whether this effect is positive or negative depends on the volatility measure used. It is positive for both the absolute return based volatility measures, which would support the idea that large interventions calm markets. On the other hand, for realised volatility based on squared returns there is no effect at all while for the squared return measure the effect is positive. Further analysis of the volatility and intervention size relationship finds that as we move from small to large interventions, the larger interventions tend to increase volatility relative to small interventions which is counter intuitive. A possible explanation for this could be that the market interprets larger intervention quantities as indication that the central bank is trying to push the exchange rate unsuccessfully, and this negative signal leads to higher volatility.

The frequency of interventions has a small but positive impact on volatility, underscored further when the analysis is done by splitting the sample into low, average and high frequency interventions. The interaction between intervention size and intervention frequency results in a small positive effect on volatility for the squared return measure and the absolute return measure. This implies that for a given intervention size, the higher the frequency of intervention, the higher the volatility. For both the realised volatility measures this effect is negative indicating that for a given intervention size or intervention frequency, the higher the other characteristic the lower the volatility. Therefore the SNB's intervention strategy of small but frequent interventions would be supported by the results that are based on the realised volatility measures.

The effect of the timing of the intervention varies with the volatility measure, but clearly is a significant component of the central bank's intervention strategy. After controlling for joint interventions with the Fed and the Buba, I find that for the two realised volatility measures 9am interventions reduce volatility while for the other two measures the significant coefficients have an overall positive effect increasing volatility. 2pm interventions decrease volatility for both the squared return measures but increase volatility for both the absolute return measures.

Overall, Reuters reports of interventions do not appear to affect exchange rate volatility. This result appears to be driven by reports of buy interventions since reports of sell interventions have a lagged negative impact on volatility. However, explicit testing of the difference of these impacts indicates that they are insignificant. Further, testing the impact of Reuters reports in the presence of actual interventions I find that Reuters reports have a small but significant and lagged negative effect on volatility for the squared return measure and both the absolute return measures. This overall effect is driven entirely by reports of sell interventions since reports of buy interventions are insignificant in the presence of buy intervention itself.

In the second chapter we examined the role of news in exchange rate determination using Reuters' newswire reports and high frequency data on the USD-EUR and USD-GBP exchange rates from the Reuters' D2000-2 electronic trading system. Previous studies have found that surprises in scheduled macro announcements help to explain intra-daily exchange rate behavior. We measure news much more broadly, including both fundamentals-related and non-fundamentals-related time-stamped Reuters news reports to examine whether it is macro announcements, or simply intra-daily data (and a more "narrow window"), that accounts for these positive results. Overall, our results do not suggest that our broader

definition of news provides a vast improvement over the macro surprises in explaining exchange rate behavior, giving yet more credence to the importance of macro variables in standard models. We do, however, find that non-scheduled news, and intriguingly, non-scheduled non-fundamentals-related news has a statistically significant influence on both intra-day exchange rate returns and volatility. Further, we find that news has its largest impact during periods of higher than normal news arrival and higher market uncertainty.

We also examine the role of order flow in exchange rate determination. In standard models there is no reason for order flow to rise in reaction to news because price is assumed to instantaneously adjust. Trading volume may rise in reaction to news, but as long as the new price is efficient, there is no reason for trades to be biased in favor of purchases or sales. We find that order flow explains a large fraction of the variation in both USD-EUR and USD-GBP exchange rate returns, suggesting that prices are, at the very least, slow to adjust. At the same time, we find that our measure of "news" explains a relatively small fraction of the total variation in order flow. Overall, our results indicate that along with the standard fundamentals, both non-fundamentals-related news and order flow matter, suggesting that future models of exchange rate determination ought to include all three types of explanatory variables.

The last chapter analysed whether actual and unrequited intervention news influences exchange rates. Previous studies have found that official interventions by governments in the foreign exchange market influence intra-day (and daily) returns and volatility. Results in this paper indicate that unrequited intervention news (and even news of "no intervention") has a statistically significant influence on both exchange rate returns and volatility, suggesting that the expectation of intervention, even when governments do not intervene, can affect currency values.

These results provide strong evidence in favor of the hypothesis that interventions influence exchange rates via the information or signaling channel.

Further, we find evidence that order flow has some explanatory power for exchange rate returns. However, at the same time, we find that actual interventions and our various categories of intervention news explain a very small fraction of the variation in order flow. Overall, our results indicate that along with actual interventions, other kinds of intervention news (including denials of intervention and unrequited interventions) and order flow matter. We do not find evidence that macro surprises have much influence on returns, volatility or order flow over our sample period.

The results from these studies suggest that future models of exchange rate determination ought to include a broader conception of price relevant "news", while giving yet more credence to the importance of macro variables in these models.

Appendix A

Table A.1: The Influence of "News" on USD-EUR Returns and Order Flow: A VAR Model

Independent	Benchmark		Benchmark +Reuters News	
Variables	Return	Order Flow	Return	Order Flow
Non-News				
Constant	0.0017	-0.0962	0.0010	-0.0743
Return				
lag 1	0.3582***	1.3101	0.3459***	1.1430
lag 2	0.1788***		0.1643**	
Order Flow				
lag 0	0.0041***		0.0042***	
lag 1	-0.0019***	0.0221	-0.0018***	0.0020
lag 2	-0.0006**	0.0068	-0.0005*	-0.0136
Macro Surprises				
UK	-0.0101	5.0274	-0.0147	5.7477
US	-0.0277	-5.2604	-0.0294	-4.7663
Euro-zone	0.0338*	-14.3703***	0.0395	-8.1814***
Fundamentals				
Monetary				
Euro-zone leads 2-6			0.0084	-1.0791
Euro-zone lead 1			0.0129	-4.6559**
Euro-zone lag 0			-0.0305***	-0.2344
Euro-zone lag 1			0.0059	-0.4899
Euro-zone lags 2-6			0.0024	-2.0145*
US leads 2-6			-0.0102*	0.1796
US lead 1			-0.0044	0.4414
US lag 0			0.0160**	-0.8204
US lag 1			-0.0036	-0.8439
US lags 2-6			0.0008	1.1213**
Other Asset Markets				
Euro-zone leads 2-6			0.0023	0.7519
Euro-zone lead 1			-0.0160	8.4874***
Euro-zone lag 0			0.0104	2.5912
Euro-zone lag 1			-0.0086	-2.2406
Euro-zone lags 2-6			0.0072	-2.6507*
US leads 2-6			0.0037	-0.9658
US lead 1			-0.0049	0.7425
US lag 0			-0.0125	-0.3583

Table A.1: Contd.

Independent	Benchmark		Benchmark +Reuters News	
Variables	Return	Order Flow	Return	Order Flow
US lag 1			-0.0045	0.9636
US lags 2-6			-0.0015	-0.8800
Japan leads 2-6			0.0095	-0.0814
Japan lead 1			0.0689**	-8.5058***
Japan lag 0			0.0004	-1.7482
Japan lag 1			0.0249	3.3829
Japan lags 2-6			0.0144	3.0938
Fiscal				
Euro-zone leads 2-6			-0.0025	0.4461
Euro-zone lead 1			0.0113	-6.1151*
Euro-zone lag 0			-0.0177	-1.6637
Euro-zone lag 1			-0.0040	-2.2044
Euro-zone lags 2-6			-0.0073	1.1606
US leads 2-6			0.0039	-3.6388*
US lead 1			-0.0326	5.0813
US lag 0			-0.0126	-5.6661
US lag 1			0.0034	3.6566
US lags 2-6			-0.0058	-4.2576
Exchange Rate Policy				
Euro-zone leads 2-6			-0.0016	0.7563
Euro-zone lead 1			-0.0045	2.2718*
Euro-zone lag 0			0.0085	-0.2313
Euro-zone lag 1			0.0105	0.3313
Euro-zone lags 2-6			0.0015	0.3730
US leads 2-6			0.0290	1.2358
US lead 1			-0.0130	-14.9526
US lag 0			-0.0214	10.4919
US lag 1			-0.0157	-5.9246
US lags 2-6			0.0200	-6.7035*
Japan leads 2-6			-0.0049	0.6127
Japan lead 1			0.0219	-1.5432
Japan lag 0			0.0293*	1.4404
Japan lag 1			-0.0190	-1.8030
Japan lags 2-6			0.0166	-0.6215

Table A.1: Contd.

Independent	Benchmark		Benchmark +Reuters News	
Variables	Return	Order Flow	Return	Order Flow
Actual Intervention				
Japan leads 2-6			0.0030	-2.0271
Japan lead 1			0.0119	7.4136
Japan lag 0			-0.0475**	1.2369
Japan lag 1			0.0212	1.2510
Japan lags 2-6			-0.0065	1.3283
Other Macro				
Euro-zone leads 2-6			-0.0070*	0.3599
Euro-zone lead 1			0.0057	1.1424
Euro-zone lag 0			0.0123	0.4687
Euro-zone lag 1			-0.0013	3.3193
Euro-zone lags 2-6			-0.0029	0.9345
US leads 2-6			0.0006	-1.4605
US lead 1			-0.0054	-1.7089
US lag 0			0.0006	-1.2609
US lag 1			-0.0202**	-1.4458
US lags 2-6			-0.0008	-0.4373
Japan leads 2-6			0.0050	0.0990
Japan lead 1			-0.0301	-5.5000
Japan lag 0			0.0227	-0.8689
Japan lag 1			-0.0313	-10.8247
Japan lags 2-6			0.0065	-3.2790
Non-Fundamentals				
Options Market				
leads 2-6			0.0055	-2.0109*
lead 1			-0.0118**	3.6691**
lag 0			-0.0057	2.1169
lag 1			-0.0130*	-1.1340
lags 2-6			0.0016	1.9008*
Technical Analysis				
leads 2-6			0.0112	-0.5570
lead 1			0.0008	0.4721
lag 0			-0.0058	-1.2684
lag 1			-0.0118	1.5752
lags 2-6			-0.0022	-1.1207*

Table A.1: Contd.

Independent	Benchmark		Benchmark +Reuters News	
Variables	Return	Order Flow	Return	Order Flow
Sentiment				
Euro-zone leads 2-6			-0.0012	1.9952
Euro-zone lead 1			-0.0192	3.7682
Euro-zone lag 0			-0.0012	5.2044
Euro-zone lag 1			0.0245	-2.1541
Euro-zone lags 2-6			-0.0039	4.4245**
US leads 2-6			0.0087	8.2858***
US lead 1			-0.0380**	18.0051***
US lag 0			0.0108	-1.8307
US lag 1			-0.0743***	13.0514***
US lags 2-6			0.0072	0.1633
Private Sector				
leads 2-6			0.0004	-0.4880
lead 1			-0.0006	-2.7580
lag 0			-0.0036	-1.1938
lag 1			0.0044	1.0452
lags 2-6			-0.0025	0.2699
Politics				
leads 2-6			0.0077	3.3985*
lead 1			-0.0060	-1.1605
lag 0			-0.0499**	0.9199
lag 1			0.0433	-5.8070**
lags 2-6			0.0060	-1.6747
Adj R^2	0.3926	0.0018	0.3785	0.0200
$F-test$	278.03***	9.27***	18.04***	1.59***

Notes: Returns and order flow are calculated at 20 minute frequency. Returns are defined as 100 times the log difference of the mid quote .The mid quote is calculated as the average of the bid and ask quotes. Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (euro for USD-EUR). *, ** and *** represent significance at 10, 5 and 1 percent respectively.

Table A.2: The Influence of "News" on USD-GBP Returns and Order Flow: A VAR Model

Independent	Benchmark		Benchmark +Reuters News	
Variables	Return	Order Flow	Return	Order Flow
Non-News				
Constant	-0.0020***	0.6698***	-0.0017**	0.6051***
Return				
lag 1	-0.0506	-20.0019***	-0.0706**	-20.8298***
lag 2	0.0380		0.0222	
Order Flow				
lag 0	0.0028***		0.0028***	
lag 1	-0.0003*	0.0946**	-0.0003	0.0838*
lag 2	-0.0002	0.0515*	-0.0002	0.0313
Macro Surprises				
UK	0.0168*	4.6876	0.0195*	5.1041
US	-0.0184	-3.1246	-0.0201	-2.9920
Euro-zone	-0.0515***	2.0898	-0.0395***	5.7900
Monetary				
Euro-zone leads 2-6			-0.0034	0.6135
Euro-zone lead 1			-0.0003	-3.1164***
Euro-zone lag 0			-0.0098	0.4872
Euro-zone lag 1			0.0179*	-4.0717***
Euro-zone lags 2-6			0.0062	-1.2827
US leads 2-6			-0.0030	-0.2047
US lead 1			-0.0005	0.8677
US lag 0			0.0125**	0.0279
US lag 1			-0.0045	1.4418*
US lags 2-6			-0.0029	0.1465
Other Asset Markets				
Euro-zone leads 2-6			-0.0020	-1.4182**
Euro-zone lead 1			0.0194**	0.2162
Euro-zone lag 0			0.0050	-1.9617
Euro-zone lag 1			-0.0072	0.4866
Euro-zone lags 2-6			-0.0028	0.5554
US leads 2-6			-0.0037	-0.0836
US lead 1			-0.0089	1.8597*
US lag 0			-0.0108*	-0.1105
US lag 1			0.0031	0.1144

Table A.2: Contd.

Independent	Benchmark		Benchmark +Reuters News	
Variables	Return	Order Flow	Return	Order Flow
US lags 2-6			0.0015	-0.5809
Japan leads 2-6			0.0066	0.6622
Japan lead 1			-0.0007	-1.3717
Japan lag 0			-0.0038	1.2016
Japan lag 1			0.0081	-1.7746
Japan lags 2-6			0.0053	-0.6891
Fiscal				
Euro-zone leads 2-6			0.0020	-0.4322
Euro-zone lead 1			-0.0076	-1.0020
Euro-zone lag 0			-0.0122	2.6589
Euro-zone lag 1			-0.0016	-2.8042
Euro-zone lags 2-6			0.0008	-1.1038
US leads 2-6			0.0018	-0.9108
US lead 1			0.0208*	0.8346
US lag 0			-0.0086	-1.1735
US lag 1			-0.0064	6.3639**
US lags 2-6			-0.0184**	-1.8804
Exchange Rate Policy				
Euro-zone leads 2-6			0.0008	-0.2765
Euro-zone lead 1			-0.0069*	1.2496*
Euro-zone lag 0			0.0023	-2.2964**
Euro-zone lag 1			-0.0047	0.9328
Euro-zone lags 2-6			0.0005	0.9969**
US leads 2-6			0.0091	5.1061***
US lead 1			0.0106	-2.5427
US lag 0			-0.0053	2.9542
US lag 1			-0.0170	-4.2673
US lags 2-6			0.0040	-3.9449**
Japan leads 2-6			0.0022	0.4737
Japan lead 1			-0.0029	0.2613
Japan lag 0			0.0041	0.1106
Japan lag 1			-0.0116*	-0.4721
Japan lags 2-6			0.0049**	-0.7589*
Actual Intervention				
Japan leads 2-6			-0.0092**	-1.0261*

Table A.2: Contd.

Independent	Benchmark		Benchmark +Reuters News	
Variables	Return	Order Flow	Return	Order Flow
Japan lead 1			0.0322**	2.5535
Japan lag 0			0.0062	0.5593
Japan lag 1			0.0037	-0.5178
Japan lags 2-6			-0.0029	-0.4907
Other Macro				
Euro-zone leads 2-6			-0.0010	0.1616
Euro-zone lead 1			0.0038	0.2698
Euro-zone lag 0			0.0100*	0.4621
Euro-zone lag 1			0.0063	2.4618**
Euro-zone lags 2-6			0.0013	0.6684
US leads 2-6			-0.0018	0.0531
US lead 1			0.0068*	-0.7845
US lag 0			-0.0017	0.4053
US lag 1			-0.0034	-0.2447
US lags 2-6			-0.0024	-0.3051
Japan leads 2-6			0.005	1.6024
Japan lead 1			-0.0348**	-0.8739
Japan lag 0			-0.0124	-1.2328
Japan lag 1			-0.0085	-6.7247
Japan lags 2-6			-0.0020	1.9949
Non-Fundamentals				
Options Market				
leads 2-6			-0.0002	-2.0209***
lead 1			-0.0013	1.2625*
lag 0			-0.0034	0.0442
lag 1			0.0022	-2.0562
lags 2-6			0.0095**	0.4567
Technical Analysis				
leads 2-6			0.0037	0.1490
lead 1			-0.0086	0.1370
lag 0			-0.0114	-1.4763
lag 1			-0.0001	-0.4729
lags 2-6			-0.0020	0.3156

Table A.2: Contd.

Independent	Benchmark		Benchmark +Reuters News	
Variables	Return	Order Flow	Return	Order Flow
Sentiment				
Euro-zone leads 2-6			-0.0030	-0.0295
Euro-zone lead 1			0.0009	2.0491
Euro-zone lag 0			-0.0089	3.3249
Euro-zone lag 1			-0.0013	1.8110
Euro-zone lags 2-6			0.0145*	3.0085
US leads 2-6			0.0367***	2.8369*
US lead 1			0.0397**	5.1246*
US lag 0			-0.0115	-1.7072
US lag 1			0.0005	0.5496
US lags 2-6			-0.0161*	2.7729
Private Sector				
leads 2-6			0.0010	0.3894
lead 1			-0.0032	-0.9397
lag 0			-0.0031	0.1356
lag 1			0.0024	0.2909
lags 2-6			-0.0037**	-0.7539*
Politics				
leads 2-6			0.0085	0.0708
lead 1			0.0279**	-0.4620
lag 0			-0.0057	-1.5963
lag 1			0.0052	-4.3907*
lags 2-6			0.0044	-0.3170
Adj R^2	0.2628	0.0139	0.268	0.022
$F-test$	155.12***	9.72***	11.36***	1.66***

Notes: Returns and order flow are calculated at 20 minute frequency. Returns are defined as 100 times the log difference of the mid quote .The mid quote is calculated as the average of the bid and ask quotes. Order flow is the net of total buys and total sells, where a buy (sell) refers to a trade in which the initiator is a purchaser (seller) of the denominator currency (sterling for USD-GBP). *, ** and *** represent significance at 10, 5 and 1 percent respectively.

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