Economic News, Price Discovery and Liquidity in the Foreign Exchange Market

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Abstract

This paper studies the impact of trading and market liquidity on exchange rates surrounding the release of macroeconomic news. Our results show a significant increase in the informational role of trading and a significant reduction in market liquidity following macroeconomic announcements. The findings suggest that releases of public information increase the level of information asymmetry and discourage the participation of discretionary liquidity traders in the foreign exchange market. The results highlight the importance of price discovery in understanding the behavior of exchange rates and market liquidity.

1 Introduction

Market liquidity and trading activity are key features of financial markets, and are important for asset and derivative pricing, financial stability, risk management, asset allocation and central bank policy.[1] Better knowledge of the factors that influence market liquidity and trading activity can improve financial market organization and development, financial regulation and investment management.[2] Macroeconomic news announcements not only are frequent occurrences of information arrival about the state of the economy but also one of the factors affecting market liquidity, thus macroeconomic news announcements are vigilantly monitored by market practitioners, consumers, economists, business corporations and the financial press. Understanding the effect of macroeconomic news on asset prices also improves the efficiency of resource allocation, the effectiveness of central bank's policies and the efficacy of risk management.[3] Evans and Lyons (2002, 2005, 2008) highlight the importance of studying trading activities and market liquidity in the FX market during macroeconomic announcements.

Despite their importance, no empirical study of trading costs and liquidity surrounding news announcements have been carried out in the foreign exchange (FX) market. This is probably due to the unavailability of reliable intraday data, which are needed for the construction of liquidity measures from the limit order book. Thus very little is known about market liquidity and the price impact of trades surrounding news announcements. In particular, some basic questions remain unanswered:

- What is the adverse selection compensation demanded by liquidity providers during public news arrival in the FX inter-dealer market?[4]
- How do information releases and uncertainty affect market liquidity in FX inter-dealer market?
- Are news announcements preceded or followed by information asymmetry?

[1] Some recent representative articles looking at various aspects and the importance of liquidity are Amihud, Mendleson, Pedersen (2005), Chordia, Roll and Subrahmanyam (2001), Evans and Lyon (2002), O'Hara (2004) and Pastor and Stambaugh (2003).

[2] See Hasbrouck and Seppi (2001), Chordia, Roll and Subrahmanyam (2000) and Coughenour and Saad (2004).

[3] See Rigobon and Sacks (2004), Bernanke (2004) and Kodres and Pritsker (2002).

[4] The adverse selection compensation stems from the risk faced by the uninformed liquidity providers of trading against informed traders.

These questions have a direct impact on our understanding of price discovery and how information flows into the foreign exchange market. They will also be of interest to investors and international business corporations developing trading strategies and to central banks attempting to understand the transmission of news across financial markets. In addition, answering the above questions could shed light on how market liquidity in the FX market might affect financial stability through the lens of microstructure.

This paper addresses these questions by investigating the direct and indirect impacts of different categories of macroeconomic news on exchange rates and the level of market liquidity on announcement days versus non-announcement days in the FX market. We employ two years of tick-by-tick data (obtained on special demand from Reuters D-3000 system) for three major currency pairs. The informational role of trading is measured by using a structural model to infer the asymmetric information component of the effective bid–ask spread. The approach, a generalized version of Huang and Stoll (1997) (HS), allows for the informational role of trading to vary with the characteristics of different announcements. The study of market liquidity is based on measures taken from the reconstructed limit order book for the three currency pairs.

When some market participants have private information about the value of an asset, their trades reveal that information to the market. This concept was first introduced by Glosten and Milgrom (1985) and Kyle (1985). In the FX market, Lyons (1995) and Cao, Evans, and Lyons (2006) suggest that customers' order flows signal the future evolution of the exchange rate, and those dealers that observe a larger portion of customer trades will be better informed than those with fewer customer contacts.[5] Better informed dealers can then exploit their informational advantage through trading on the inter-dealer market. Studies of Lyons (1995), Bjønnes and Rime (2005) and Bjønnes, Osler, and Rime (2007) document the presence of adverse selection in the FX interdealer market. However, these authors do not study the presence of adverse selection surrounding macroeconomic announcements and they use a data sample of just 5 trading days. Moreover, they use proprietary customer data, which are not available publicly, instead of interdealer data. The use of a longer interdealer dataset allows us to carry out a more detailed event study of trading transaction costs under conditions of information uncertainty.

[5] Order flow is the signed transaction volume.

Market microstructure models, e.g. Admati and Pfleiderer (1988) and Foster and Viswanathan (1990), predict that liquidity will fall in the presence of information uncertainty and adverse selection. They suggest that some liquidity traders are strategic in choosing when to execute their trades within a given time period. These discretionary liquidity traders choose not to participate during periods surrounding scheduled public news announcements, because the information uncertainty and the higher probability of trading against more informed traders. Notwithstanding its importance, this hypothesis has not been explored in the FX market. Recently, Ito and Hashimoto (2006), Chaboud *et al.* (2007) and Gau (2005) examine intraday patterns of volume, spread and volatility in the FX market. However, these authors do not have appropriate data with which to construct the limit order book and directly analyze the behavior of liquidity. Danielson and Payne (2002) attempt to reconstruct the limit orderbook from October 6 to October 10, 1997 for the DM/USD with an ad-hoc procedure employing indicative quotes with no guarantee of a sensible output. Their data are used by Carlson and Lo (2006) who examine the effect of one surprise announcement by the Bundesbank on DM/USD. However, this study uses a very short sample of interdealer data from the early phase of the electronic FX market (before 2000) and major developments in the electronic market have since taken place. Satisfactory answers and conclusions to any hypothesis and analysis most likely depend on a sample period long enough, and a dataset reliable enough, to test the hypothesis. With a rich and reliable dataset, we extend the current literature by studying the effect of scheduled UK, US and EMU macroeconomic announcements on the dynamics of market liquidity for three major currency pairs

The results from our empirical analysis suggest that adverse selection costs (and the informational role of trades) increase after macroeconomic announcements, indicating that the release of public information raises both the degree of information asymmetry and the dispersion of beliefs in the FX market. The increased informational role of trading is consistent with the interpretation that some market participants have an informational advantage, such as being able to observe more informative order flows (i.e. Lyons, 1995; Cao, Evans, and Lyons, 2006) or being more skilled at information processing when determining how macroeconomic news influence exchange rates (Kim and Verrecchia, 1994, 1997).

Consistent with no information leakage prior to macroeconomic announcements, we find that adverse selection costs before macroeconomic announcements are similar to those on non-announcement days.[6] However, as competitive informed traders trade very aggressively, information asymmetry and dispersion of beliefs dissipate quite quickly following announcements, resulting in a semi strong-form efficient FX market. The observation of a rapid decrease in the impact of trades after an announcement is congruent with Holden and Subrahmanyam (1992), who show that competition among multiple informed traders leads to prices that incorporate private information quickly. Consistent with existing market microstructure theory, our study also finds that the price impact of trades increases and liquidity decreases after macroeconomic announcements. The widest quoted spreads and the highest of sensitivity to trades is found to be within a minute of announcements. The increase in spreads is as large as 27%, while the sensitivity increases by as much as 49%.

Taken together, the results highlight the importance of price discovery in the FX market and support the existing literature that trades reveal fundamental information about the exchange rates. Macroeconomic announcements affect exchange rates in two stages. The first stage is through an immediate directional price impact of prices. It stems from the general market consensus about whether the news is “good” or “bad”. This is consistent with the intraday analysis of Andersen *et al.* (2003). However, due to diverse opinions about the severity of the news, participants enter into the process of price discovery through trades until a new price level is agreed by all participants. The level of diversity in opinions and information asymmetry are linked to order flow, as the dispersion of beliefs is reduced over time as more information is revealed through trades. In the second stage the information advantage of some market participants is revealed to the market through trading. The results are congruent with those of Love and Payne (2008) and Evans and Lyons (2008) where it is suggested that news can affect currency prices not only directly but also indirectly via order flow. As a consequence of the price discovery process, the increased sensitivity to order flow causes strategic liquidity traders to avoid trading during periods of information uncertainty. In conclusion, this study further cements the fact that market participants actively study trading to help determine the effect of new economic information on exchange rates.

[6] There should not be any leak regarding the scheduled announcements as reporters enter a lock-up room at least 30 minutes before an announcement. They will receive the report and begin typing their stories into their computers. They are however disconnected from the internet until one minute before the announcement. At that time, the reporters press their "reconnect" buttons and wait for a countdown. At precisely the time of the scheduled announcements the reporters are connected and are able to transmit their stories.

The remainder of the paper is organized as follows: Section 2 describes the transaction and quote data from Reuters D3000 electronic platform and the macroeconomic announcement data. Section 3 follows with a description of the model and the methodology of measuring the direct and indirect impacts of macroeconomic announcements on transaction prices. Section 4 presents the empirical results, and Section 5 concludes.

2 Data and Preliminaries

2.1 Data Sources

The FX market is the largest financial market globally with an estimated daily turnover of about 3.2 trillion US dollar (USD) (Bank for International Settlement, BIS, 2007).[7] Electronic broker trading platforms have been the preferred means of settling trades in recent years with over 60 percent of the turnover in major currency pairs being settled through two major FX electronic trading platforms namely, Reuters and Electronic Brokerage System (EBS) (Galati and Melvin, 2004). Reuters, whose Dealing 2000 products were virtually unchallenged in the foreign exchange interbank market until EBS was formed, announced the launch of its upgraded Dealing 3000 system in January 2000. The new product was formed partly in response to competition from EBS and partly in response to customer demand.[8] Data from these two platforms have been previously used by several researchers, i.e. Evans (2002), Payne (2003), Danielson and Payne (2002), etc.

While most previous research used data during the early rise of the electronic platform before the 2000, this paper uses tick by tick data from Reuters trading system Dealing 3000 for three currency pair of US dollar-euro (dollars per euro), US dollar-UK sterling (dollars per pound) and UK-euro sterling (pounds per euro) (hereafter USD/EUR, USD/GBP, and GBP/EUR respectively), for the sample period from January 2, 2003 to December 30, 2004. All weekends and holidays are excluded. The Bank for International Settlement (BIS, 2004) estimates that trades in these currencies constitute up to 60 percent of the FX spot transactions, 53 percent of which are interdealer trades which indicates that our data represent a substantial part of the FX market.

[7] For a detailed description of the structure of the FX market and electronic trading platforms, see Lyons (2001) and Rime (2003).

[8] The previous system comprised Dealing 2000-1, a "conversational" service, which Reuters claims is used for around half the world's foreign exchange trading, and Dealing 2000-2, an anonymous electronic price matching service. Under the new system, these will correspond to Dealing 3000 Direct (the conversational system) and Dealing 3000 Spot Matching.

The data analyzed consist of continuously recorded transaction and quotation between 07:00-17:00 GMT. The advantage of this dataset is the availability of volume in all quotes as well as all trades and hidden orders, which allows one to reconstruct the full limit orderbook, without making any assumption. For each quote, the dataset reports the currency pair, unique order identifier, quoted price, order quantity, hidden quantity (D3000 function), quantity traded, order type, transaction identifier of order entered and removed, status of market order, entry type of orders, removal reason, time of orders entered and removed. The time stamp of the data has an accuracy of one-thousandth of a second. This extremely detailed dataset facilitates a clear and easy reconstruction of the limit order book. To reconstruct the limit order book, We start at the beginning of the trading day tracking all types of orders submitted throughout the day and updating the order book accordingly. Thus all entries, removals, amendments and trade executions are accounted for when the book is updated. The exchange rate returns, Δp_t, is calculated as the log difference in prices.

The data on macroeconomic announcement shocks covers the EMU, UK and US markets. We have data on the announcement value and the median of the expectations of market participants. The data is provided from Money Market Survey (MMS) carried out by InformaGM. Market participants' expectations on macroeconomic news are collected weekly and processed on the Thursday prior to the announcement week. Announcement surprises are measured as the realized announced value minus the median of the survey value. As in previous literature that uses such announcement surprise variables, We standardize surprises to facilitate comparison across announcements. The surprise of announcement type k on day τ is defined as,

$$N_{k\tau} = \frac{A_{k\tau} - F_{k\tau}}{\sigma_k}, \tag{1}$$

where $A_{k\tau}$ and $F_{k\tau}$ are the actual announcement value and median forecast respectively and σ_k is the standard deviation of $(A_{k\tau} - F_{k\tau})$. Announcement day in this paper means days with either EMU, UK or US news announcements. There is a total of 102 non-announcement days in the sample.

2.2 Summary Statistics

Summary statistics for transaction data are reported in Panel A of Table 6. The panel reports information on the standard deviation of transaction prices changes (in pips), average trade duration (in seconds), the average of transaction size (in millions of base currency), the average numbers of trade on both the macroeconomic announcement and non-announcement days and the total number of transaction across the sample.[9]

The standard deviation of the tick-by-tick log price changes for the three currency pairs, USD/EUR, USD/GBP and GBP/EUR, are 1.1, 0.73 and 0.83 pips respectively. The average trade duration and total number of trades reflects that the USD/GBP is the most heavily traded currency pair among the three pairs on the Reuters platform. The average daily number of trades during macroeconomic announcement days is also found to be significantly larger than those on non-announcement days for all currency pairs, as market participants respond to the information inflow and rebalance their portfolios.

Figure 1 plots numbers of trades in each hour of the day in the USD/EUR, USD/GBP and GBP/EUR currency pairs. It indicates that the most active trading hours are between 7:00 and 17:00 GMT and there are substantially more trades on days with macroeconomic announcement than on non-announcement days. The increase in trading activity also coincides with the time of macroeconomic announcements in Europe, UK and US; the expiration time for most foreign currency options; WM/Reuters spot foreign exchange fixing at 16:00 London time (WM Company, 2004).[10] The 'M' shaped pattern of trades is notable in each market. In the half-hour before announcements, trading intensity is lower than usual but it increases in the 30 minutes immediately following the release of news. Since the intraday pattern indicates that majority of the trading activities occur between 7:00 to 17:00 GMT, trades and quotes outside these hours are excluded from the subsequent analysis.

Figure 2 plots trading volume in each 30 minutes of the day in the USD/EUR, USD/GBP and GBP/EUR. The trading volume spikes at 8:30 and 9:30 GMT when the London market opens and when UK and EMU macroeconomic announcements are released. There is very little differences between the trading volume on an announcement and non-announcement day during the European trading hours except for GBP/EUR. In fact, average trading volume is heavier on non-announcement

[9] A pip, which stands for "price interest point", represents the smallest fluctuation in the price of a currency. Depending on the context, normally one basis point 0.0001 in the case of EUR/USD and GBD/USD. GBP/EUR is displayed in a slightly different way from most other currency pairs in that although one pip is worth 0.0001, the rate is often displayed to five decimal places. The fifth decimal place can only be 0 or 5 and is used to display half pips.

[10] London uses GMT in the winter and British Summer time (BST) in the summer.

days during the European trading hours (8:00 - 12:00 GMT). This observation appears to be consistent with the suggestion of Admati and Pfleiderer (1988) that discretionary liquidity traders might time their trades to minimize the cost of transaction. Discretionary liquidity traders (DLTs) who receive exogenous trade demands prior to announcements will postpone trading until the announcement is made and the information asymmetry is resolved. The lower transaction cost (observed bid-ask spread) during the European trading hours on non-announcement days seem to encourage discretionary liquidity trading which explain the higher level of trading volume.

Average trading volume on announcement days is substantially higher that those on non-announcement days for USD/EUR and USD/GBP at about 12:30 and 13:30 GMT and the announcements of important US macroeconomic data releases. The increase in trading volume during those hours coincide with the arrival of information which suggest the presence of information asymmetry. Kim and Verrecchia (1991) and He and Wang (1995) have shown that abnormal trading occurs and trading volume increases only if there is some type of asymmetry among investors either in their risk aversion or private information. The patterns in trading and volume is similar to the findings of Ito and Hashimoto (2006) and Chaboud *et al.* (2007).

Rather than focus on the levels of volume and volatility as in previous work, this paper investigates how they interrelate by studying the market liquidity and the sensitivity of prices to signed order flow surrounding macroeconomic news releases. Figure 6 provides a preliminary illustration. The exchange rate is expressed as the domestic value of one unit of foreign currency where the US dollar is the domestic currency. The chart plots the sequence of transaction prices for USD/EUR from 13:25 to 14:00 GMT on January 10, 2003, a day on which the non-farm payroll employment number was announced at 13:30 GMT. There is an unexpected deviation in the non-farm payroll employment number of 125,000 from the market expectation, and everyone agrees that it is bad news and that USD should depreciate against the euro. This general consensus about the news is reflected by the instant shift of the exchange rate from 1.0498 to about 1.0545, the direct effect of macroeconomic announcements. The initial price response is followed by increased volatility and trading intensity. Due to diverse opinions on what the exact value for the depreciation of the USD should be, market participants enter into a process of price discovery through trades until a new price level is agreed by the all participants. The level of diversity in opinions and information asymmetry are linked to order flow as all private information must be revealed through the trades of the participants with informational and technical advantage to profit. Transaction prices are also much more sensitive to a sequence of buys or sells, which suggests that market participants may be watching order flow to help interpret the news. This channel of information flow contributes to the indirect impact of macroeconomic news announcements. The next section describes the methodology used to quantify the sensitivity of transaction prices to order flow.

3 Methodology and Model

We measure the informational role of trading by isolating the component of effective bid-ask spreads that is related to information asymmetry. The approach is based on the price formation model of Huang and Stoll (1997). The HS model is an improvement of Stoll (1989) which examines the serial correlation in trade flows to determine components of the bid-ask spread. The model assumes that quote adjustments that do not reverse indicate adjustments made for informational reasons. Therefore, using a transaction approach, HS are able to determine the order processing, inventory and adverse selection components of the spread. It differs from earlier models in that it is a trade indicator model that uses transactions level data and takes into account the effect of price changes on a transaction-by-transaction basis. The HS model attributes transaction price changes to public news and microstructure effects. The choice of using trade direction over trade size to capture informational trade is not unreasonable especially when only the direction of the trade can be observed by dealers in the FX market. Bjønnes and Rime (2005) find strong evidence that trade direction is more informative than trade size in the FX interdealer market. The idea of HS is formalized below where the price set by the uninformed Dealer i (P_{it}) is linearly related to his conditional expectation (μ_{it}) about the true value V_t at the beginning of the period:

$$P_{it} = \mu_{it} + \frac{spread}{2} D_t + \eta_t \tag{2}$$

The D_t term is a direction dummy that takes the value 1 if Dealer i sells (trades at the ask) and -1 if Dealer i buys (trades at the bid). $\frac{spread}{2}$ is the half spread (constant) and η_t is error due to discreteness. The expectation μ_{it} is modelled according to

$$\mu_{it} = \mu_{it-1} + \alpha \frac{spread}{2} D_{t-1} + \varepsilon_{it}, \tag{3}$$

where α is the percentage of the half-spread attributed to updating beliefs conditioned on a signal in the direction of previous trade D_{t-1}, and ε_t is the serially uncorrelated public information shock. This equation can be thought as the explicit modeling of informed dealer's demand and the Bayesian expectation formation in a structural Madhavan and Smidt (1991) model. Equation 2 and 3 give us the basic regression model in HS:

$$\begin{aligned} \Delta P_{it} &= \frac{spread}{2}(D_t - D_{t-1}) + \alpha \frac{spread}{2} D_{t-1} + \varepsilon_{it} + \eta_t - \eta_{t-1}. && (4) \\ &= \frac{spread}{2}(D_t - D_{t-1}) + \alpha \frac{spread}{2} D_{t-1} + \varepsilon_{it} + \Delta \eta_t. && (5) \end{aligned}$$

$(1 - \alpha)$ is the portion of the half spread that is not due to asymmetric information and can be treated as order processing costs, such as labor and equipment costs, and rents. We have assumed the absence of inventory cost in our setting based on the findings of Bjønnes and Rime (2005). They suggest that dealers do not tend to quote shade most of the time, i.e. use favorable price quote to induce purchases and sales of their unbalanced inventories in FX market, but transfer their inventory risk by selling their excess inventories to other dealers in the interdealer market resulting in a game of 'hot-potato trading'. Their empirical findings support the exclusion of inventory cost in the decomposition of the bid-ask spread. Moreover, the isolation of the inventory effect might not be a serious concern especially with the availability of many hedging instruments and the highly liquid futures and options markets.

Since the P_{it} is driven by some public signal U_t, order flow plus some order processing cost, the expectation error ε_{it} must stem from dealer i's error in predicting public signal at $t-1$. If one considers the exchange rate as the present value of future fundamentals:

$$S_t = (1 - b) \sum_{i=0}^{\infty} b^i E_t f_{t+i} \tag{6}$$

where S_t is the log nominal exchange rate, and f_t is the current log macro fundamentals. This equation nests many macro exchange rate models. The precise definition of fundamentals and the specific form of the parameter b depends on the macro model in question. One can iterate the present value model above to yield:

$$\triangle S_{t+1} = \frac{1-b}{b}\left(S_t - E_t f_t\right) + \omega_{t+1} \tag{7}$$

$$\omega_{t+1} = (1-b)\sum_{i=0}^{\infty} b^i \left(E_{t+1} - E_t\right) f_{t+i+1}. \tag{8}$$

Meese and Rogoff (1983) highlight the difficulties in forecasting future spot rate changes with fundamentals found in macro models. Engel and West (2005) show that forecasting with fundamentals is hard if the fundamentals are non-stationary processes and the value of b implied by macro model is close to unity. Evans and Lyons (2005) suggest to focus on the ω_{t+1} term, namely exchange rate dynamics that come from expectation surprises. If one assumes that the exchange rate is driven by the present value of expected future fundamentals, then exchange rate dynamics are also driven by the expectation shock of these macro fundamentals.

Two recent studies carried out in this spirit are Andersen, Bollerslev, Diebold and Vega (2003) and Faust, Rogers, Wang and Wright (2003), who look at various currencies vis-à-vis the US dollar for the period 1992 till 1998 and 1987 till 2002, respectively. Using five-minute and twenty-minute intervals, they find that various US macro news significantly affect exchange rates.

In view of the significance of announcement shocks in Andersen, Bollerslev, Diebold and Vega (2003), our proxy for ε_{it} is

$$\sum_{k=1}^{K} N_{k\tau} = \sum_{k=1}^{K} \frac{A_{k\tau} - F_{k\tau}}{\sigma_k}$$

from the MMS data, where $N_{k\tau}$ is the surprise of macro announcement type k on day τ , $A_{k\tau}$ and $F_{k\tau}$ are the actual value and forecast, and σ_k is the standard deviation of $(A_{k\tau} - F_{k\tau})$. Thus

$$\Delta P_t = \frac{spread}{2}\left(D_t - D_{t-1}\right) + \alpha\frac{spread}{2}D_{t-1} + \sum_{k=1}^{K}\gamma_k N_{k\tau} + \Delta\eta_t, \tag{9}$$

where γ_k measures the sensitivity to expectation shocks of macroeconomic announcement type k. The above estimable equation has important implications in currency price determination literature as it provides a theoretical model with a direct and a indirect information impact on exchange rate, bridging the gap between classical and market microstructure FX theory.

4 Empirical Results

4.1 Trade Impact Surrounding Macroeconomic Announcements

If information is impounded into the financial market directly and indirectly, one would find significant explanatory power of macroeconomic shocks on the conditional mean adjustment of the exchange rate, where positive news on an economy is associated with a higher demand for the currency of the economy. One would also find an increased adverse selection cost as private information is gradually revealed by trades to uninformed market participants. Market microstructure theory suggests that the informational role of trading will increase in the presence of traders with private information and market participants with more superior information processing skills. We examine these hypotheses by allowing the microstructure parameters in equation (9) to vary before and after announcements of US, EMU and UK macroeconomic news as follows:

$$\begin{aligned}
\Delta P_t \;=\;& I_{N,t}\frac{spread}{2}D_t + I_{N,t-1}\left(\alpha-1\right)\frac{spread}{2}D_{t-1} \\
&+I_{B,t}\frac{spread}{2}D_t + I_{B,t-1}\left(\alpha-1\right)\frac{spread}{2}D_{t-1} \qquad (10)\\
&+I_{A,t}\frac{spread}{2}D_t + I_{A,t-1}\left(\alpha-1\right)\frac{spread}{2}D_{t-1} + \sum_{k=1}^{K}\gamma_k N_{k\tau(US)} + e_t \qquad (11)
\end{aligned}$$

where $I_{N,t}=1$ if the transaction at time t takes place on a day without an economic announcement, 0 otherwise. Similarly, the dummy variables $I_{B,t}$ and $I_{A,t}$ designate trades in the half-hour before and after announcements. $\sum_{k=1}^{K} N_{k\tau(US)}$ are the macroeconomic announcement shocks for the US. Since the characteristics of the price discovery and order processing cost might be different for different geographical origins, We will also investigate the nature of price impact of trades across EMU and UK announcement through by replacing $\sum_{k=1}^{K}\gamma_k N_{k\tau(US)}$ with $\sum_{k=1}^{K} N_{k\tau(UK)}$ and $\sum_{k=1}^{K} N_{k\tau(EMU)}$ respectively.[11]

The model is estimated using the generalized method of moments (GMM, Hansen (1982)). In particular, We follow Ferson and Forester (1994) and use the iterative GMM (IGMM) with a Newey-West correction for autocorrelation and heteroskedasticity.[12] Such an estimator is efficient and has

[11] As the announcements may not be released precisely at the predetermined time of release, I account for the time non-synchronicity to ensure the price change spans the release by omitting five trades prior and after the announcement time unless the trades occur 2 minutes before and after the announcement time as in Green (2004). The results are not sensitive to changes in the procedure.

[12] I choose GMM because (i) it does not require the usual normality assumption, and (ii) standard errors can be adjusted to take account of both heteroscedasticity and serial correlation. In all of the regressions, the set of instruments

smaller bias than the commonly used two-step GMM estimator. Statistical differences of the impact of trades on non-announcement days, before announcements and after announcements are measured using likelihood ratio tests that compare the restricted and unrestricted GMM criterion function (Davidson and MacKinnon, 1993).

4.2 Results

The results are shown in Tables 2-4. The estimates and t-statistics computed using the Newey-West estimator of the covariance matrix show that all the microstructure parameters are significantly different from zero, with p-values less than 0.001.

In Table 2, the adverse selection component α, which measures the information role of trading, for GBP/EUR exhibits significant presence of information asymmetry especially after US and UK macroeconomic announcements. There is an increase of about 25%, 36% and 18% in the adverse selection component 5 minutes after the UK and the 13:30 GMT and the 15:00 GMT US announcements respectively. The adverse selection component reverts back to the level on non-announcement days about 15 minutes after the UK announcement but remain about 13% above those on non-announcement days 30 minutes after the 13:30 GMT US announcements. In Table 3, the adverse selection component α for USD/EUR exhibits significant presence of information asymmetry for all three categories of macroeconomic announcements. There is an increase of about 20%, 30%, 44% and 25% in the adverse selection component 5 minutes after the EMU, UK and the 13:30 GMT and the 15:00 GMT US announcements respectively. The adverse selection component revert back to the level on non-announcement days about 15 minutes after the UK, EMU and the 15:00 GMT US announcements but remain about 20% above those on non-announcement days 30 minutes after the 13:30 GMT US announcements. In Table 4, the adverse selection components α for USD/GBP are found to have increased significantly after the US and UK news announcements. There is an increase of about 13%, 16% and 10% in the adverse selection component 5 minutes after the UK and the 13:30 GMT and the 15:00 GMT US announcements respectively. The adverse selection component reverts back to the level on non-announcement days about 5 minutes after the UK and the 15:00 GMT US announcements but remain about 12% above those on non-announcement days 30 minutes

equals the set of regressors. Five lags are used to construct the Newey-West estimate of the covariance matrix. Including more lags does not alter the significance of the results.

after the 13:30 GMT US announcements.

The χ^2 statistic for the likelihood ratio test of the restriction $\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ are presented in Table 5. The statistics for GBP/EUR has a p-value less than 0.0001 for ± 5 minutes for UK announcements and ± 30 minutes, ± 15 minutes, ± 5 minutes for US announcements at both 13:30 and 15:00 GMT. While there is a lack of evidence of an increased impact of trades on GBP/EUR after EMU news. The χ^2 statistic the statistics for USD/EUR has a p-value less than 0.0001 for ± 5 minutes for UK and EMU announcements and ± 30 minutes, ± 15 minutes, ± 5 minutes for US announcements at both 13:30 and 15:00 GMT. The χ^2 statistic for USD/GBP has a p-value less than 0.0001 for ± 5 minutes for UK announcements and US announcements at 15:00 GMT and ± 30 minutes, ± 15 minutes, ± 5 minutes for US announcements at 13:30 GMT.

The results support the hypothesis that adverse selection costs increase after scheduled announcements. Order flow contains relatively little information before the release of economic news and more information than usual afterwards. The reduced information content of trading prior to the announcement suggests that the information is not leaked in the half-hour before the release. The increased information content of trading following the announcement suggests that public information releases raise the level of information heterogeneity in the foreign exchange market. However, the information asymmetry decreases over time, as private information is revealed to the market through trades. The decrease in the impact of trade with time after an announcement is consistent with Holden and Subrahmanyam (1992) where it is shown that competition among multiple informed traders leads to a quick incorporation of private information into prices.

Table 6 reports the coefficient γ_k for the sensitivity of prices to the surprise component of schedule economic announcements and their expected sign on exchange rate. In general, an improvement of procyclical US indicators has negative impact on prices, i.e. increases in non-farm payroll employment lead to decreases in USD/EUR and USD/GBP. While procyclical base country indicators has positive impact on prices, i.e. increases in UK retail sales increases USD/GBP. The price impact varies considerably across announcements with non-farm payroll employment having the largest effect on all three currency pairs. As in Andersen *et al.* (2003), US indicators like non-farm payroll, durable goods order, GDP advance, consumer confidence, construction spending and housing starts have statistically significant effects on the three currency pairs. UK indicators like manufacturing wages, retail sales, trade balance, budget deficit, retail price index, consumer price index and producer price index statistically affect the three currency pairs. In sharp contrast to the large number of US and UK macroeconomic indicators whose news affect the three currency pairs, only the one EMU macroeconomic indicator has a significant effect (consumer price index).

It is interesting to note the heavier influence of US macro news over European news for the euro-linked currency pairs. As the world's largest economy, the United States is the leading export market for many foreign economies. It has a substantial effect on the global economy and thus the exchange rate of its major trading partners. This is consistent with other studies that have found US macro news to have a bigger impact than European news (for example, Andersen *et al.* 2003). Moreover, the more frequent releases of US macroeconomic news also serve as a good indicator for the euro-area economies and thus lessening the impact of EMU macro news announcements on exchange rates. The lack of impact of European news on the currency pairs might also be due to information leakage through the earlier individual announcements of its member states.

The results also support the hypothesis that macroeconomic news flows into the FX market in two stages. The immediate impact of macroeconomic announcements or the first state of public information flow is studied through a minute-by-minute examination of market behavior. The second stage is reflected through the indirect adjustment to the macroeconomic announcements through trades. The results confirm the findings of Evans and Lyons (2008) and Love and Payne (2008) that there is an direct and indirect impact of news in the FX market.

4.3 Robustness Checks

4.3.1 Vector Autoregressive Approach

Since there are many strong assumptions imposed on the proposed microstructure model, We conduct a robustness check using the Vector Auto-Regressive approach (VAR) pioneered by Hasbrouck (1991) which has been successfully applied by Payne (2003) in the FX market. This approach is not predicated on any particular microstructure model, thus making it very flexible and suitable as a tool for robustness test on my structural model. While the proposed model for price discovery focuses on the first moment of price changes, the VAR analysis focuses on how news is transmitted into prices via decomposition of the volatility. The VAR model's inferences about the information content of order flow is based on the identification of informed trading from the impulse responses of prices to order flow with order flow inducing a long-run response in price. Secondly, variance decompositions allow one to determine the proportion of all information that enters prices through order flow:

$$\begin{aligned} r_t &= \sum_{j=1}^{p} \vartheta_j r_{t-j} + \sum_{j=0}^{p} \beta_j x_{t-j} + \varphi_{1t} \\ x_t &= \sum_{j=1}^{p} \phi_j r_{t-j} + \sum_{j=1}^{p} \delta_j x_{t-j} + \varphi_{2t} \end{aligned} \tag{12}$$

where r_t and x_t denotes the percentage change in the spread midpoint and the incoming signed order respectively and t is the transaction-time observation counter. Identification requires restriction on the innovations:

$$\begin{aligned} E\left(\varphi_{1t}\right) &= E\left(\varphi_{2t}\right) = E\left(\varphi_{1t}\varphi_{2t}\right) = 0 \\ E\left(\varphi_{1t}\varphi_{1s}\right) &= E\left(\varphi_{2t}\varphi_{2s}\right) = E\left(\varphi_{1t}\varphi_{2s}\right) = 0 \ \forall t \neq s. \end{aligned}$$

The effect of order flow information can be retrieved by inverting the VAR representation into a Vector moving average model

$$\begin{pmatrix} r_t \\ x_t \end{pmatrix} = \left(\begin{array}{cc} f\left(L\right) & g\left(L\right) \\ h\left(L\right) & n\left(L\right) \end{array} \right) \begin{pmatrix} \varphi_{1t} \\ \varphi_{2t} \end{pmatrix}$$

where $f\left(L\right) = f_0 + f_1 L + f_2 L^2 \cdots + f_y L^y$. A variance decomposition for returns, based on Hasbrouck (1991) and Payne (2003). In doing so, one can write down the share of variance that is generated from order flow innovations.

Tables 7-9 report results from the variance decompositions for the three currency pairs. Most of the results from the variance decomposition corroborate those found in our structural model. We find that variances of price changes attributed to order flow increase especially after the UK and US announcements.

There is an increase for price variance of GBP/EUR attributed to order flow from 28% for non-announcement days to 37.4% for trades that occur five minutes after UK announcements. The level of information asymmetry after US macro announcements can be seen by the substantially higher variance contribution of order flow for GBP/EUR. The results for USD/EUR also support the role of trade impact after announcements observed in our structural model except a minor decrease in the variance contribution of order flow 15 minutes after the US 15:00 GMT announcements.

The robustness test using variance decomposition of price changes support most of the results derived from the HS model. As a comparison to the Love and Payne (2008), our variance contributions from order flow are lower than those reported in their exercise. A likely explanation is the increased trading activities in the electronic platform and trading environment after year 2000 as well as differences between the data used and the sample period of the data.

4.3.2 Effective Spread and Model Spread

The second robustness check to evaluate the model performance is to compare the model spread against the quoted spread.[13] Glosten and Milgrom (1985) were the first to show formally that, with informed trading, a bid-ask spread would exist even if there were no order processing and inventory costs. Thus, one expects to see a widening of spreads in the presence of asymmetric information in the financial market. A good bid-ask model will have an estimated effective spread that is close to the quoted spread during the period of interest.

Tables 7-9 report the model spread and the average of the quoted spread. The model spread are inferred from transaction prices changes and not from the best bid-ask quotes. Thus, the implied model spread are not constrained to be equal to the quoted spread. The average quoted spread is found to be consistent with the implied spread in widening after macroeconomic announcements signaling the increase of adverse selection costs. The quoted spread for USD/GBP 15 minutes after UK announcements decreases back to the level of non-announcement days. This is consistent with the result from our structural model. Moreover, the quoted spread decreases over time after an announcements in contrast to the results found by the variance decomposition analysis for USD/EUR fifteen minutes after US 15:00 GMT announcements. However, the model implied spread is found to be smaller than the quoted spread indicating a downward bias exhibit by most bid-ask models.

4.3.3 Trade Intensity and Informed Traders

The next robustness test uses trade duration or intensity as a proxy measure for asymmetric information. Economic considerations in Glosten and Milgrom (1985), Diamond and Verrecchia (1987) and Easley and O'Hara (1992) suggest that durations are indicative of informed trading. In particular, when even the existence of information event is uncertain, Easley and O'Hara (1992) demonstrate

[13] Quoted spread is the difference between the best bid and ask prices quoted in the market.

that the lack of trade provides a signal to market participants that there is no information. Shorter duration between consecutive trades is associated with a higher level of informed trading. Dufour and Engle (2000) highlight the crucial role of duration empirically in assessing the price impact of a trade. In particular, the price impact of a trade tends to increase as the time duration between two trades decreases, suggesting that increased trading activity would be associated with a higher level of information asymmetry. These allow one to hypothesize that in the event of uncertainty and the presence of asymmetric information, the trade intensity in the market increases. We will use a simple measure of trade intensity across the sample of interest, using a homogeneous Poisson process. The trade intensity across the samples can be easily calculated by taking the number of trades divided by the time horizon of the sample.

$$Trade\ intensity_i = \left(\frac{1}{M_s} \sum_{x_1=1}^{M_s} \frac{1}{M_d} \sum_{x_2=1}^{M_d} (t_{i+1,d} - t_{i,d}) \right)^{-1}$$

where $\frac{1}{M_d} \sum_{x_2=1}^{M_d} (t_{i+1,d} - t_{i,d})$ is the average duration after an announcements. M_d and M_s are the number of trades after the announcement and the number of announcement days across data sample respectively. In another words, we average the trade durations 30 minutes after each announcement. The average duration across each announcement is then average across M_s announcement in the whole sample. The average trade intensity is measured for 5, 15 and 30 minutes before and after announcements as well as on non-announcement days.

This alternative measure of asymmetric information is based on the frequency measure of trades rather than the price measure. Higher frequency of trades is often associated with the presence of information asymmetry. The average trade intensity is found mostly to be higher after all announcements. This could be due to portfolio rebalancing, "hot potato passing" by dealers due to inventory imbalance, as well as the presence of diverse information and interpretation of the news. We find substantially higher trade intensity for periods previously reported to exhibit information asymmetry. Although the substantial increase in the trade intensity is consistent with our findings about periods of information asymmetry, it is difficult to differentiate the components behind the increased in trading intensities. However, We have found that trade intensities decay with time after announcements indicating the reduction in information asymmetry as well as inventory management via inventory passing. In general, different measures of information asymmetry seems to suggest that the presence of information asymmetry macroeconomic announcements.

5 Liquidity and Macroeconomic Announcements

Macroeconomic announcements not only provide an opportunity to examine the effects of information heterogeneity around public news arrival, they also provide an interesting opportunity to examine the effects on market liquidity. Since the timing of macroeconomic announcements used in this paper is scheduled and they convey price-relevant information, strategic liquidity providers will anticipate a greater chance of trading with an informed trader surrounding the news event. The liquidity providers are at greater risk during this period and will protect themselves by widening spreads, increasing sensitivity to trade and lowering depths (Admati and Pfleiderer, 1988; Easley and O'Hara, 1992). Therefore, if informed traders are likely to have valuable private information after macroeconomic announcements as suggested by the previous sections, market liquidity is expected to be low succeeding these events. A liquid market is defined as one in which trades can be executed with no cost or very low transaction cost (O'Hara, 1995). Of the several dimensions of market liquidity, two of the most important are tightness and depth. Tightness is defined as a market's ability to match supply and demand at low cost (measured by bid-ask spreads). Market depth relates to the ability of a market to absorb large trade flows without a significant impact on prices. In this paper the quoted spread will be used as a measurement of tightness and Kyle's λ as a measurement of depth.[14] Previous empirical studies provide indirect evidence on the measurement of Kyle's λ, by analyzing the price movements following trades in a time-series context. Since we have reconstructed and can observe the order book, we can provide direct evidence on the features of the price schedule.[15]

[14] Kyle's λ measures the volume required to move price by one unit and is an inverse measure of liquidity. Kyle's λ is used as it is a more comprehensive and natural measurement of depth over the more commonly used quoted depth.

[15] The average measure of the slope of the demand and supply schedule is as follows. The volume is accumulated for both the demand and supply schedule. The local slope is calculated using the best and second best ask and bid price as well as their corresponding aggregated volume. The average of the bid and ask slope is taken giving a single slope measure. The single slope measure is then averaged across the period of interest.

$$Slope = \frac{1}{R}\sum_{\tau=1}^{R}\frac{1}{2}\left(\frac{Best_{1,\tau}^{Ask} - Best_{0,\tau}^{Ask}}{Vol_{1,\tau}^{Ask} - Vol_{0,\tau}^{Ask}} + \frac{Best_{0,\tau}^{Bid} - Best_{1,\tau}^{Bid}}{Vol_{1,\tau}^{Bid} - Vol_{0,\tau}^{Bid}}\right)$$

where $Best_{0,\tau}^{Ask}$, $Best_{0,\tau}^{Bid}$, $Best_{1,\tau}^{Ask}$, $Best_{1,\tau}^{Bid}$ are the best ask, best bid, second best ask and second best bid at time τ respectively with $Vol_{0,\tau}^{Ask}$, $Vol_{0,\tau}^{Bid}$, $Vol_{1,\tau}^{Ask}$, $Vol_{1,\tau}^{Bid}$ as the aggregated volume at each respective price level and R is the total number of order revisions over the period of interest.

Table 10 reports the preliminary statistics of various market liquidity in terms of bid-ask spread, quote arrivals and price impact of trade (slope of demand and supply schedule). On average a quote arrives every 1.05, 1.71 and 1.31 seconds for USD/EUR, USD/GBP and GBP/EUR respectively. This is much lower than quote arrival rate of 15-20 seconds reported by Engle and Russell (1998) and Bollerslev and Domowitz (1993). The increase in trading activities in the FX market is attributed to the recent propagation of electronic trading platforms which enabled large financial institutions to set up more comprehensive trading facilities for the increasing numbers of retail investors.

The average daily bid-ask spread is found 2.9, 2.5 and 1.2 pips for USD/EUR, USD/GBP and GBP/EUR respectively indicating that at first glance, D3000-2 is a very tight market. However, our recorded average bid-ask spread for USD/EUR is higher than those recorded in Ito and Hashimoto (2006) and Berger *et al.* (2008) who use EBS data but is similar to those recorded by Goodhart, Love, Payne and Rime (2002) who use Reuters D2000-2 data. The larger recorded spread for USD/EUR in Reuters data is congruent with the higher market share and trading activities of this currency pair on the EBS platform. The average bid-ask spread for USD/GBP is much lower than those recorded by Hau, Killeen and Moore (2002) who use Reuters indicative quote data. The lower spread for USD/GBP and GBP/EUR is indicative that Reuters still holds a commanding share of these two currency pair in the FX spot market.

The average daily slope of the demand and supply schedules increases on announcement days. The slopes increase from 107.6 to 126.8, 70.13 to 72.11 and 30.23 to 31.62 basis point per billion of currency trade from non-announcement to announcement days for USD/EUR, USD/GBP and GBP/EUR respectively. Evans and Lyons (2002) find the contemporaneous impact of order flow on price is about 60 basis points per $1 billion for DM/USD.[16] The increase in our ex-ante measurement of price impact of trade exhibits the increase in sensitivity to trade of the liquidity provider during periods of information uncertainty on announcement days.

Figures 4-6 show the intraday hourly patterns of quoted spreads and slopes of the average demand and supply schedules for the three currency pairs. There appear to be a systematic increase in both the slope and quoted spread on an announcement days over non-announcement days. The differences

[16] The estimated impact of trade is based on an average trade size in their sample of $3.9 million. (This average trade size is available despite individual trade sizes not being available.)

appear to more pronounce from 12:00 to 14:00 GMT around the 13:30 GMT US macroeconomic announcements. The spread and the slope increase as the market approaches the overnight period and the market liquidity decreases. Table 11 reports the p-values from the t-statistic comparing hour means of the quoted spread and the slope for announcement and non-announcement days assuming unequal variances. The results suggests that the hourly average quoted spread and slope are statistically different from each others on announcement and non-announcement days.

We further characterize the state of liquidity surrounding the news announcements through a ten minutes-by- ten minutes examination of the limit order book. Panel A of Table 12 and Table 13 present the quoted spread and slope for every ten-minutes from 09:00 to 10:00 GMT for the three currency pairs respectively. Panel B and C of Table 12 and Table 13 present the quoted spread and slope for every ten-minutes from 13:00 to 14:00 GMT and 14:30 to 15:30 GMT respectively. We find that the release of an announcement induces a widening of the quoted spread and a dramatic increase in the slope. The spread and the slope start to increase slightly before the announcements. The widest of the spread and the steepest of slope coincide with the minute of the announcement. The spread then narrows sharply and the slope as the news get digested by the market. The increase in spread and slope can go as high as 27% and 49% respectively during the uncertain periods of macroeconomic announcements. The wide bid-ask spread and high price impact of trade at announcement reflect the dealer reluctance to make markets at a time of sharp price changes.

These preliminary observations are consistent with Bjønnes, Osler and Rime (2007), Lyons (1995) and Bjønnes and Rime (2005) that information appears to be asymmetric in the FX interdealer market. We find that not only the adverse selection component of the bid-ask spread increases after macroeconomic announcements, but also market liquidity decreases as liquidity providers become more sensitive and less willing to trade.

6 Conclusion

This paper studies the influence of macroeconomic news releases on the informational role of trading and market liquidity in the foreign exchange interdealer market. We use a structural model to infer the component of effective spread related to information heterogeneity and study how the informational role of trade varies around US, EMU and UK macroeconomic news releases. Liquidity measures on the tightness and depth of the market derived from reliable limit order book are studied. Robustness checks confirm the usefulness of the model at capturing the informational role of trading.

We find that exchange rates exhibit increased sensitivity to trade following macroeconomic announcements, indicating that the release of public information raises the degree of information asymmetry and dispersion of beliefs in the FX market. However, information asymmetry returns near to the normal level within 30 minutes of the scheduled news releases. Consistent with no information leakage prior to macroeconomic announcements, adverse selection costs are found to be lower than usual before macroeconomic announcements. Market liquidity succeeding the macroeconomic announcements is found to be lower than usual as liquidity providers becomes wearier of trading against an informed dealer. In summary, our main conclusion is that specialists and other liquidity providers actively manage information asymmetry risk by adjusting both spreads and depths. Our results also confirm the hypothesis that news flow into the FX market through two channel suggested by Evans and Lyons (2008). In conclusion, this study further cements the fact that market participants actively study trading to help determine the effect of new economic information on exchange rates.

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Tables

Table 1: Preliminary data analysis

This table provides descriptive statistics on the standard deviation of transaction price changes (in pips), average trade duration (in seconds), average transaction size (in base currency), average daily number of trades for non-announcement and announcement days and the total number of trades for the USD/EUR, USD/GBP and GBP/EUR exchange rates. The sample period is from January 2, 2003 to December 30, 2004.

Variables	GBP/EUR	USD/EUR	USD/GBP
Std. dev of transaction price changes	0.83	1.10	0.73
Average trade duration	13.24	15.93	8.02
Average transaction size	1.56	1.31	1.42
Average daily number of trades (non-ann)	2741.15	2275.54	5011.47
Average daily number of trades (ann)	4002.66	3390.60	7174.97
Total number of trades	1452841	1193698	2407526

Table 2: GBP/EUR: The indirect effect of economic announcements and components of effective spread

The table reports IGMM estimates with Newey-West correction of the model fit to transaction price changes in equation (9) for the GBP/EUR exchange rate before and after economic announcements. Indicator variables are used to allow the model parameters to vary around EMU, UK and US macroeconomic announcement release times. The scheduled EMU and UK announcements are released at 9:30 and 10:00 GMT, respectively. The US announcements are categorized into groups with announcements occurring at 13:30 and 15:00 GMT. The No Ann column presents the results for the estimation of the model on days with no announcements of economic variables of any sort from EMU, UK and US. The Before column presents the results for before scheduled announcements and the After column presents the after scheduled announcements. $Half\ Spread$ and $\alpha \times Half\ Spread$ coeffients are presented in pips. $\alpha \times Half\ Spread$ is the proportion of the half spread contributed by adverse selection. Panels A, B and C present the results for thirty, fifteen and five minutes before or after announcements. ***, ** and * indicate significance at the one percent, five percent and ten percent levels, respectively. The sample period is from January 2, 2003 to December 30, 2004.

	UK			EMU			US (13:30)			US (15:00)		
	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After
Panel A: 30 minutes before and after the announcements												
$Half\ Spread$	0.44***	0.47***	0.47***	0.44***	0.47***	0.46***	0.45***	0.46***	0.51***	0.46***	0.46***	0.48***
$\alpha \times Half\ Spread$	0.17***	0.20***	0.20***	0.17***	0.20***	0.19***	0.17***	0.17***	0.22***	0.17***	0.18***	0.20***
$\%\ of\ Adverse\ Selection\ \alpha$	39	43	43	39	43	41	38	37	43	37	39	42
Obs	25045	21752	29315	24517	18843	15641	30467	16170	21359	30815	11536	15094
Panel B: 15 minutes before and after the announcements												
$Half\ Spread$	0.43***	0.47***	0.48***	0.45***	0.44***	0.47***	0.45***	0.46***	0.55***	0.47***	0.47***	0.51***
$\alpha \times Half\ Spread$	0.16***	0.18***	0.19***	0.17***	0.16***	0.17***	0.17***	0.17***	0.25***	0.17***	0.18***	0.21***
$\%\ of\ Adverse\ Selection\ \alpha$	37	38	40	38	36	36	38	37	46	36	38	41
Obs	12432	10564	19925	12292	7786	8528	14885	8379	12472	15155	5897	9003
Panel C: 5 minutes before and after the announcements												
$Half\ Spread$	0.43***	0.42***	0.52***	0.45***	0.42***	0.48***	0.44***	0.48***	0.62***	0.49***	0.49***	0.56***
$\alpha \times Half\ Spread$	0.17***	0.16***	0.26***	0.17***	0.15***	0.18***	0.17***	0.20***	0.33***	0.19***	0.20***	0.26***
$\%\ of\ Adverse\ Selection\ \alpha$	40	38	50	38	36	38	39	42	53	39	41	46
Obs	4021	3453	6646	2648	2648	2332	4996	2793	4021	5831	2241	2657

Table 3: USD/EUR: The indirect effect of economic announcements and components of effective spread

The table reports IGMM estimates with Newey-West correction of the model fit to transaction price changes in equation (9) for the USD/EUR exchange rate before and after economic announcements. Indicator variables are used to allow the model parameters to vary around EMU, UK and US macroeconomic announcement release times. The scheduled EMU and UK announcements are released at 9:30 and 10:00 GMT, respectively. The US announcements are categorized into groups with announcements occurring at 13:30 and 15:00 GMT. The No Ann column presents the results for the estimation of the model on days with no announcements of economic variables of any sort from EMU, UK and US. The Before column presents the results for before scheduled announcements and the After column presents the after scheduled announcements. $Half\ Spread$ and $\alpha \times Half\ Spread$ coeffients are presented in pips. $\alpha \times Half\ Spread$ is the proportion of the half spread contributed by adverse selection. Panels A, B and C present the results for thirty, fifteen and five minutes before or after announcements. ***, ** and * indicate significance at the one percent, five percent and ten percent levels, respectively. The sample period is from January 2, 2003 to December 30, 2004.

	UK			Euro-area			US (13:30)			US (15:30)		
	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After
Panel A: 30 minutes before and after the announcements												
$Half\ Spread$	0.85***	0.85***	0.89***	0.85***	0.86***	0.91***	1.00***	1.09***	1.32***	1.11***	1.11***	1.25***
$\alpha \times Half\ Spread$	0.34***	0.34***	0.35***	0.34***	0.35***	0.37***	0.44***	0.47***	0.70***	0.52***	0.51***	0.64***
% $Adverse\ Selection\ \alpha$	40	40	39	40	41	41	44	43	53	47	46	51
Obs	22238	22097	20350	21338	12987	13588	28468	11795	22681	21890	9076	13026
Panel B: 15 minutes before and after the announcements												
$Half\ Spread$	0.85***	0.84***	0.91***	0.85***	0.83***	0.90***	1.00***	1.15***	1.46***	1.13***	1.14***	1.28***
$\alpha \times Half\ Spread$	0.33***	0.32***	0.38***	0.35	0.34***	0.39***	0.44***	0.51***	0.79***	0.56***	0.56***	0.69***
% $Adverse\ Selection\ \alpha$	39	38	42	41	41	43	44	44	54	50	49	54
Obs	11019	10367	10689	11036	6482	7894	14197	6206	15905	11209	4686	8640
Panel C: 5 minutes before and after the announcements												
$Half\ Spread$	0.80***	0.74***	0.90***	0.86***	0.82***	0.98***	1.10***	1.17***	1.59***	1.10***	1.08***	1.40***
$\alpha \times Half\ Spread$	0.32***	0.32***	0.47***	0.34	0.32***	0.47***	0.47***	0.59***	1.01***	0.5.4***	0.55***	0.85***
% $Adverse\ Selection\ \alpha$	40	43	52	40	39	48	43	50	64	49	51	61
Obs	3580	3307	2889	3946	2135	2105	4523	2168	5209	2340	1539	2687

Table 4: USD/GBP: The indirect effect of economic announcements and components of effective spread

The table reports IGMM estimates with Newey-West correction of the model fit to transaction price changes in equation (9) for the USD/GBP exchange rate before and after economic announcements. Indicator variables are used to allow the model parameters to vary around EMU, UK and US macroeconomic announcement release times. The scheduled EMU and UK announcements are released at 9:30 and 10:00 GMT, respectively. The US announcements are categorized into groups with announcements occurring at 13:30 and 15:00 GMT. The No Ann column presents the results for the estimation of the model on days with no announcements of economic variables of any sort from EMU, UK and US. The Before column presents the results for before scheduled announcements and the After column presents the after scheduled announcements. $Half\ Spread$ and $\alpha \times Half\ Spread$ coeffients are presented in pips. $\alpha \times Half\ Spread$ is the proportion of the half spread contributed by adverse selection. Panels A, B and C present the results for thirty, fifteen and five minutes before or after announcements. ***, ** and * indicate significance at the one percent, five percent and ten percent levels, respectively. The sample period is from January 2, 2003 to December 30, 2004.

	UK			Euro-area			US (13:30)			US (15:00)		
	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After
Panel A: 30 minutes before and after the announcements												
Half Spread	0.98***	1.00***	0.99***	1.02***	1.02***	1.04***	0.99***	1.06***	1.17***	1.07***	1.06***	1.12***
$\alpha\times$ Half Spread	0.43***	0.44***	0.44***	0.45***	0.44***	0.47***	0.42***	0.46***	0.55***	0.45***	0.44***	0.46***
% $Adverse\ Selection\ \alpha$	44	44	44	44	43	45	42	43	47	42	42	41
Obs	39422	33343	45831	37882	27416	21306	51206	23419	47779	58024	19353	29526
Panel B: 15 minutes before and after the announcements												
$Half\ Spread$	0.97***	1.01***	0.98***	1.02***	0.96***	1.03***	0.99***	1.11***	1.23***	1.00***	1.10***	1.16***
$\alpha \times Half\ Spread$	0.42***	0.44***	0.43***	0.45***	0.44***	0.48***	0.42	0.49***	0.59***	0.42***	0.46***	0.49***
% $Adverse\ Selection\ \alpha$	43	44	44	44	46	47	42	44	48	42	42	42
Obs	19352	15387	31269	20040	10797	12088	25372	12623	30917	30746	10415	18513
Panel C: 5 minutes before and after the announcements												
$Half\ Spread$	0.96***	0.96***	1.06***	1.03***	0.91***	1.10***	1.01***	1.25***	1.41***	0.97***	1.06***	1.20***
$\alpha \times Half\ Spread$	0.43***	0.44***	0.54***	0.46***	0.41***	0.51***	0.44	0.58***	0.72***	0.41***	0.44***	0.55***
% $Adverse\ Selection\ \alpha$	45	46	51	45	45	46	44	46	51	42	42	46
Obs	6424	4975	10092	6916	4439	3320	8835	4439	10693	11390	4150	5873

Table 5: Likelihood ratio test on the significance of the indirect impact of news announcements on the exchange rate

This table reports the restrictions and χ^2 p-values for Likelihood Ratio tests that compare the restricted and unrestricted GMM criterion functions (see Davidson and Mackinnon, 1993). Subscript "N" refers to estimates on days with no announcements. Subscript "A" refers to estimates from trades after announcements. Subscript "B" refers to estimates from trades before announcements. Panels A, B and C present the results for GBP/EUR, USD/EUR and USD/GBP respectively. The sample period is from January 2, 2003 to December 30, 2004.

H_0	LR p-value
Panel A. GBP/EUR	
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 30 minutes US, 13:30 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 15 minutes US, 13:30 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 5 minutes US, 13:30 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 30 minutes US, 15:00 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 15 minutes US, 15:00 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 5 minutes US, 15:00 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 5 minutes UK, 9:30 GMT)	0.000
Panel B. USD/EUR	
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 30 minutes US 13:30 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 15 minutes US 13:30 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 5 minutes US 13:30 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 30 minutes US 15:00 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 15 minutes US 15:00 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 5 minutes US 15:00 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$, ($\pm$ 5 minutes EMU 10:00 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$, ($\pm$ 15 minutes UK 9:30 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$, ($\pm$ 5 minutes UK 9:30 GMT)	0.000
Panel C. USD/GBP	
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 30 minutes US 13:30 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 15 minutes US 13:30 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 5 minutes US 13:30 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 5 minutes US 15:00 GMT)	0.000
$\alpha_N = \alpha_A$, $\alpha_B = \alpha_A$ ($\pm$ 5 minutes UK 9:30 GMT)	0.000

Table 6: EMU, UK, US news announcements direct impact exchange rates

This table reports the coefficients γ_k on the standardized surprise component of the announcements for the exchange rates. The standardized surprise component of the announcements is the difference between the actual value ($A_{k\tau}$) of the macroeconomic indicator minus the median forecast ($F_{k\tau}$), standardized by the standard deviation (σ_k) of the sample, $(A_{k\tau} - F_{k\tau})/\sigma_k$. Only variables significant at least at the ten percent level using heteroskedasticity- and autocorrelation-consistent standard errors are reported in order to conserve space. The Expected Sign column reports the expected sign of the news impact on the exchange rate. ***, ** and * indicate significance at the one percent, five percent and ten percent levels, respectively. Panels A, B and C present the results for GBP/EUR, USD/EUR and USD/GBP respectively. The sample period is from January 2, 2003 to December 30, 2004.

	UK	EMU	US (13:30)	US (15:00)	Exp. Sign
		Panel A. GBP/EUR			
Manufacturing wages	-1.0E-4**				-
Retail Sales (mom)	-3.1E-3***				-
Trade Balance	-3.2E-4***				-
Budget Deficit	1.7E-4***				+
Retail Price Index (mom)	-3.5E-4***				+/-
Producer Input Price Index (mom)	-1.7E-4**				+/-
GDP Final - US			-3.0E-5***		+/-
Housing Start - US			-5.0E-5*		+/-
Non-Farm Payroll Employment			-6.0E-4***		+/-
Consumer Confidence Index				-1.8E-4***	+/-
		Panel B. USD/EUR			
Retail Sales (mom)	6.7E-4***				+/-
Producer Input Price Index (mom)	8.7E-5**				+/-
Consumer Price Index		-1.5E-4***			+/-
GDP Advance			-2.8E-3***		-
Non-Farm Payroll Employment			-3.5E-3***		-
Consumer Confidence Index				-8.0E-4**	-
Construction Spending				-6.0E-5**	-
		Panel C. USD/GBP			
GDP Provisional (qoq)	5.3E-4***				+
Retail Sales (mom)	8.8E-3***				+
Trade Balance	7.7E-4***				+
Budget Deficit	-4.3E-4***				-
Retail Price Index (mom)	9.6E-4***				+/-
Producer Input Price Index (mom)	5.5E-4***				+/-
Durable Orders			-1.3E-3***		-
GDP Advance			-3.5E-3***		-
Non-Farm Payroll Employment			-3.4E-3***		-
Construction Spending				-8.0E-5***	-
Consumer Confidence Index				-7.6E-4**	-

Table 7: GBP/EUR: Robustness test

The table reports the results from variance-based, realized-based, liquidity-based and frequency-based robustness tests for the presence of information asymmetry for GBP/EUR. Variance decomposition presents the impact of a trade on the price change in percentage. The reported bid-ask spread is the quoted mean best bid-ask spread, presented in pips. The reported slope is the average measure of the slope of the demand and supply schedule for each currency pair, presented in basis point per billion base currency. The reported trade intensity is presented in number of trades per second. Robustness tests are carried out on non-announcement days and scheduled announcement days around EMU, UK and US macroeconomic announcement release time. The scheduled EMU and UK announcements are release at 9:30 and 10:00 GMT respectively. The US announcements are categorized into groups with announcements at 13:30 and 15:00 GMT. The No Ann. column presents the results on days with no announcements of economic variables of any sort from EMU, UK, and US. The Before column presents the results before scheduled announcements for the four categories of announcements. The After column presents the results for after scheduled announcements. Panels A, B and C present the results for thirty, fifteen and five minutes before or after announcements. The sample period is January 2, 2003 to December 30, 2004.

	UK			EMU			US			US (15:30)		
	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After
Panel A. 30 minutes before and after the announcements												
Variance decomposition (%)	24.4	25.3	25.0	25.9	27.0	26.7	27.6	21.5	52.5	28.6	27.9	48.5
Quoted spread	1.14	1.20	1.13	1.16	1.14	1.17	1.16	1.22	1.42	1.22	1.22	1.29
Model spread	0.88	0.94	0.94	0.88	0.94	0.92	0.90	0.92	1.02	0.92	0.92	0.96
Slope	25	25	24	25	22	25	24	25	28	24	26	28
Trade intensity	0.65	0.75	0.89	0.63	0.80	0.79	0.91	0.90	1.27	0.95	0.92	1.11
Obs	4351	1449	1437	4351	1085	1043	4351	1017	923	4351	820	859
Panel B. 15 minutes before and after the announcements												
Variance decomposition (%)	25.9	23.6	26.3	30.4	22.9	30.0	27.2	30.2	55.8	31.5	20.6	52.6
Quoted spread	1.13	1.20	1.13	1.16	1.11	1.17	1.18	1.28	1.54	1.21	1.22	1.29
Model spread	0.86	0.94	0.96	0.90	0.88	0.94	0.90	0.92	1.10	0.94	0.94	1.02
Slope	25	26	24	25	23	25	25	26	31	27	24	28
Trade intensity	0.64	0.74	1.00	0.65	0.75	0.82	0.90	0.93	1.34	0.98	0.93	1.17
Obs	2165	688	716	2132	471	491	2337	489	425	2394	400	412
Panel C. 5 minutes before and after the announcements												
Variance decomposition (%)	28.0	26.0	37.4	33.6	27.3	30.8	27.9	27.8	72.0	34.7	30.0	56.8
Quoted spread	1.15	1.19	1.23	1.17	1.11	1.15	1.21	1.38	1.79	1.23	1.24	1.41
Model spread	0.86	0.84	1.04	0.9	0.84	0.96	0.88	0.96	1.24	0.98	0.98	1.12
Slope	25	25	28	24	22	25	24	29	35	27	24	29
Trade intensity	0.65	0.79	1.22	0.67	0.77	0.84	0.92	0.97	1.50	1.05	1.01	1.34
Obs	662	201	167	680	132	150	708	144	137	756	114	128

Table 8: USD/EUR: Robustness test

The table reports the results from variance-based, realized-based, liquidity-based and frequency-based robustness tests for the presence of information asymmetry for USD/EUR. Variance decomposition presents the impact of a trade on the price change in percentage. The reported bid-ask spread is the quoted mean best bid-ask spread, presented in pips. The reported slope is the average measure of the slope of the demand and supply schedule for each currency pair, presented in basis point per billion base currency. The reported trade intensity is presented in number of trades per second. Robustness tests are carried out on non-announcement days and scheduled announcement days around EMU, UK and US macroeconomic announcement release time. The scheduled EMU and UK announcements are release at 9:30 and 10:00 GMT respectively. The US announcements are categorized into groups with announcements at 13:30 and 15:00 GMT. The No Ann. column presents the results on days with no announcements of economic variables of any sort from EMU, UK, and US. The Before column presents the results before scheduled announcements for the four categories of announcements. The After column presents the results for after scheduled announcements. Panels A, B and C present the results for thirty, fifteen and five minutes before or after announcements. The sample period is January 2, 2003 to December 30, 2004.

	UK			EMU			US			US (15:30)		
USD/EUR	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After
Panel A. 30 minutes before and after the announcements												
Variance decomposition (%)	30.7	27.2	26.7	26.4	20.4	25.5	21.1	27.3	47.9	22.8	26.7	48.1
Quoted spread	2.06	2.03	2.06	2.11	2.08	2.12	2.26	2.39	2.80	2.77	2.58	2.68
Model spread	1.70	1.70	1.78	1.7	1.72	1.82	2.00	2.18	2.64	2.22	2.22	2.50
Slope	53	58	58	54	61	60	64	75	95	95	95	98
Trade intensity	0.78	0.92	0.87	0.79	0.85	0.99	1.33	1.14	2.07	1.23	1.28	1.69
Obs	4212	1548	1418	4064	1042	1029	4415	935	939	3974	764	808
Panel B. 15 minutes before and after the announcements												
Variance decomposition (%)	27.8	28.1	33.9	24.7	20.1	26.4	19.7	26.3	49.5	23.3	25.8	46.3
Quoted spread	2.06	2.04	2.30	2.11	2.07	2.19	2.25	2.55	3.11	2.52	2.62	3.11
Model spread	1.70	1.68	1.82	1.70	1.66	1.80	2.00	2.30	2.92	2.26	2.28	2.56
Slope	54	54	60	53	59	60	65	82	99	94	95	99
Trade intensity	0.77	0.88	0.90	0.81	0.85	1.05	1.33	1.23	2.30	1.25	1.33	1.85
Obs	2066	728	667	2014	490	447	2153	467	441	2003	378	400
Panel C. 5 minutes before and after the announcements												
Variance decomposition (%)	26.7	30.7	51.7	23.5	18.8	43.6	28.7	27.5	54.2	31.7	31.5	58.6
Quoted spread	2.06	2.06	2.24	2.12	2.16	2.20	2.35	3.09	3.86	2.80	2.57	3.12
Model spread	1.6	1.48	1.80	1.72	1.64	1.96	2.20	2.34	3.18	2.20	2.16	2.80
Slope	53	57	62	52	56	62	69	98	105	92	102	108
Trade intensity	0.77	0.86	0.97	0.85	0.87	1.1	1.39	1.28	2.72	1.35	1.33	2.24
Obs	617	201	178	642	141	149	664	128	141	644	111	127

Table 9: USD/GBP: Robustness test

The table reports the results from variance-based, realized-based, liquidity-based and frequency-based robustness tests for the presence of information asymmetry for USD/GBP. Variance decomposition presents the impact of a trade on the price change in percentage. The reported bid-ask spread is the quoted mean best bid-ask spread, presented in pips. The reported slope is the average measure of the slope of the demand and supply schedule for each currency pair, presented in basis point per billion base currency. The reported trade intensity is presented in number of trades per second. Robustness tests are carried out on non-announcement days and scheduled announcement days around EMU, UK and US macroeconomic announcement release time. The scheduled EMU and UK announcements are release at 9:30 and 10:00 GMT respectively. The US announcements are categorized into groups with announcements at 13:30 and 15:00 GMT. The No Ann. column presents the results on days with no announcements of economic variables of any sort from EMU, UK, and US. The Before column presents the results before scheduled announcements for the four categories of announcements. The After column presents the results for after scheduled announcements. Panels A, B and C present the results for thirty, fifteen and five minutes before or after announcements. The sample period is January 2, 2003 to December 30, 2004.

	UK			EMU			US			US (15:30)		
USD/GBP	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After	No Ann	Before	After
Panel A. 30 minutes before and after the announcements												
Variance decomposition	32.1	35.8	35.0	31.4	34.6	35.3	33.6	35.0	43.6	38.5	40.8	47.0
Effective spread - Mean	2.52	2.60	2.49	2.60	2.67	2.67	2.52	2.75	2.82	2.51	2.60	2.58
Model spread	1.96	2.00	1.98	2.04	2.04	2.08	1.98	2.12	2.34	2.14	2.12	2.24
Slope	63	65	61	66	67	70	61	66	68	60	64	58
Trade intensity (Trades/Sec)	0.53	0.54	0.67	0.52	0.58	0.52	0.77	0.55	1.06	0.82	0.69	1.00
Obs	4812	1595	1587	4694	1166	1128	5134	1065	972	5311	927	927
Panel B. 15 minutes before and after the announcements												
Variance decomposition	35.9%	31%	59.1%	28.6%	34.8%	36%	34.3%	31%	48%	41.4%	43.0%	52%
Effective spread	2.52	2.59	2.53	2.60	2.67	2.67	2.52	2.89	3.00	2.49	2.66	2.70
Model spread	1.94	2.02	1.96	2.04	1.92	2.06	1.98	2.22	2.46	2.00	2.20	2.32
Slope	64	65	63	65	66	70	63	70	72	59	65	61
Trade intensity	0.52	0.52	0.76	0.55	0.51	0.55	0.78	0.57	1.19	0.85	0.70	1.11
Obs	2353	748	756	2326	562	529	2515	522	455	2635	449	439
Panel C. 5 minutes before and after the announcements												
Variance decomposition	40%	40.2%	65.5%	30.8%	31.2%	35.6%	35.1%	37.1%	66.6%	39.0%	42.3%	69.1%
Effective spread	2.53	2.60	2.77	2.61	2.66	2.67	2.56	2.94	3.32	2.46	2.62	2.98
Model spread	1.92	1.92	2.12	2.06	1.82	2.20	2.02	2.50	2.82	1.94	2.12	2.40
Slope	64	62	63	66	67	70	63	85	121	59	64	69
Trade intensity	0.53	0.53	0.95	0.58	0.53	0.58	0.82	0.62	1.55	0.91	0.76	1.34
Obs	729	214	235	728	162	122	772	149	107	831	169	136

Table 10: Preliminary data analysis of liquidity

This table provides descriptive statistics on average inter-quote duration (in seconds), average quoted spread (in pips), average slope of the demand and supply schedule in basis points per billion of the base currency for non-announcement and announcement days and the average depth (in million of base currency) for the USD/EUR, USD/GBP and GBP/EUR exchange rates. The sample period is from January 2, 2003 to December 30, 2004.

Variables	GBP/EUR	USD/EUR	USD/GBP
Average inter-quote duration	1.31	1.05	1.71
Average bid-ask spread (non-ann)	1.2	2.9	2.5
Average bid-ask spread (ann)	1.3	4.1	2.7
Average slope of demand and supply schedules (non-ann)	30.23	107.6	70.13
Average slope of demand and supply schedules (ann)	31.62	126.8	72.11
Average depth	48.5	28.9	48.6

Table 11: Test of equality of spreads and slopes for announcement and non-announcement days

The table presents the p-values from the t-statistics comparing means of the quoted spread and the average slope of the demand and supply schedules for announcement and non-announcement days assuming unequal variances. All one-hour intervals between 07:00 and 17:00 GMT are examined. The sample period is from January 2, 2003 to December 30, 2004.

Hour	Quoted Spread			Average slope		
	GBP/EUR	*USD/EUR*	*USD/GBP*	*GBP/EUR*	*USD/EUR*	*USD/GBP*
07:00-08:00	0.28	0.001	0.001	0.49	0.001	0.001
08:00-09:00	0.001	0.001	0.001	0.001	0.001	0.001
09:00-10:00	0.001	0.001	0.08	0.001	0.001	0.001
10:00-11:00	0.14	0.001	0.01	0.001	0.001	0.32
11:00-12:00	0.02	0.001	0.001	0.001	0.001	0.001
12:00-13:00	0.001	0.001	0.001	0.001	0.001	0.001
13:00-14:00	0.001	0.001	0.001	0.001	0.001	0.001
14:00-15:00	0.001	0.001	0.001	0.001	0.001	0.001
15:00-16:00	0.001	0.001	0.001	0.001	0.001	0.001
16:00-17:00	0.001	0.001	0.001	0.001	0.001	0.001

Table 12: Dynamics of bid-ask spread by 10-minute intervals

Ten-minute averages of quoted bid-ask spread are reported and compared for announcement and non-announcement days for EUR/GBP, USD/EUR and USD/GBP. Announcement days are defined as those with EMU, UK and US macroeconomic announcements and the rest are non-announcement days. The scheduled EMU and UK announcements are released at 9:30 and 10:00 GMT respectively. The US announcements are categorized into groups with announcements at 13:30 and 15:00 GMT. The reported bid-ask spread is the quoted mean best bid-ask spread, presented in pips. All 10-minute intervals, 30 minutes before and after the time of the announcements are examined. The sample period is January 2, 2003 to December 30, 2004.

Panel A. Time	**9:00-9:10**	**9:10-9:20**	**9:20-9:30**	**9:30-9:40**	**9:40-9:50**	**9:50-10:00**
			EUR/GBP			
Non-announcement	1.13	1.13	1.16	1.12	1.14	1.15
Announcement	1.22	1.17	1.17	1.31	1.24	1.23
			USD/EUR			
Non-announcement	1.89	1.91	1.93	1.97	1.98	2.02
Announcement	2.07	2.05	2.04	2.10	2.16	2.25
			USD/GBP			
Non-announcement	2.48	2.46	2.41	2.46	2.43	2.44
Announcement	2.52	2.52	2.53	2.57	2.57	2.63
Panel B. Time	**13:00-13:10**	**13:10-13:20**	**13:20-13:30**	**13:30-13:40**	**13:40-13:50**	**13:50-14:00**
			EUR/GBP			
Non-announcement	1.27	1.21	1.26	1.26	1.29	1.27
Announcement	1.26	1.21	1.27	1.42	1.28	1.29
			USD/EUR			
Non-announcement	2.11	2.03	2.04	2.12	2.12	2.13
Announcement	2.32	2.33	2.41	2.71	2.48	2.46
			USD/GBP			
Non-announcement	2.41	2.35	2.34	2.40	2.33	2.32
Announcement	2.65	2.57	2.58	2.76	2.65	2.63
Panel C. Time	**14:30-14:40**	**14:40-14:50**	**14:50-15:00**	**15:00-15:10**	**15:10-15:20**	**15:20-15:30**
			EUR/GBP			
Non-announcement	1.13	1.13	1.26	1.15	1.15	1.18
Announcement	1.34	1.29	1.34	1.36	1.41	1.67
			USD/EUR			
Non-announcement	2.33	2.51	2.38	2.80	2.92	2.98
Announcement	2.78	3.04	3.17	3.65	3.94	4.41
			USD/GBP			
Non-announcement	2.48	2.46	2.40	2.42	2.46	2.49
Announcement	2.61	2.69	2.65	2.82	2.79	2.78

Table 13: Dynamics of slope of the demand and supply schedules by 10-minute intervals

Ten-minute averages of slopes of the demand and supply schedules are reported and compared for announcement and nonannouncement days for EUR/GBP, USD/EUR and USD/GBP. Announcement days are defined as those with EMU, UK and US macroeconomic announcements and the rest are non-announcement days. The scheduled EMU and UK announcements are released at 9:30 and 10:00 GMT respectively. The US announcements are categorized into groups with announcements at 13:30 and 15:00 GMT. The reported slope is the average measure of the slope of the demand and supply schedule for each currency pair, presented in basis point per billion base currency. All 10-minute intervals, 30 minutes before and after the time of the announcements are examined. The sample period is January 2, 2003 to December 30, 2004.

Panel A. Time	**9:00-9:10**	**9:10-9:20**	**9:20-9:30**	**9:30-9:40**	**9:40-9:50**	**9:50-10:00**
			EUR/GBP			
Non-announcement	26.3	26.2	25.9	26.8	26.2	27.0
Announcement	30.5	29.6	29.3	34.5	29.1	28.8
			USD/EUR			
Non-announcement	46.2	47.8	47.7	48.2	49.1	49.7
Announcement	56.6	53.5	55.0	72.0	55.4	63.4
			USD/GBP			
Non-announcement	62.2	60.4	62.0	59.7	59.9	62.3
Announcement	67.8	66.2	68.7	71.6	70.8	72.8
Panel B. Time	**13:00-13:10**	**13:10-13:20**	**13:20-13:30**	**13:30-13:40**	**13:40-13:50**	**13:50-14:00**
			EUR/GBP			
Non-announcement	25.3	28.8	27.6	28.7	28.8	28.8
Announcement	30.6	29.9	30.3	31.5	30.8	30.9
			USD/EUR			
Non-announcement	53.7	54.2	51.5	52.9	53.0	54.9
Announcement	70.2	66.3	70.5	77.0	75.3	73.2
			USD/GBP			
Non-announcement	61.8	59.0	61.3	60.9	60.7	59.2
Announcement	69.7	64.9	67.1	71.2	69.1	69.1
Panel C. Time	**14:30-14:40**	**14:40-14:50**	**14:50-15:00**	**15:00-15:10**	**15:10-15:20**	**15:20-15:30**
			EUR/GBP			
Non-announcement	30.1	31.1	31.2	33.6	34.6	35.7
Announcement	30.5	31.6	31.6	36.3	36.2	38.5
			USD/EUR			
Non-announcement	59.8	56.7	59.5	64.2	65.4	65.7
Announcement	86.7	94.4	99.2	127.0	144.5	167.0
			USD/GBP			
Non-announcement	62.2	61.4	62.0	61.8	61.2	61.1
Announcement	68.0	70.6	70.7	72.8	70.8	68.6

Figure 1: Intraday patterns of the number of trades for announcement and non-announcement days

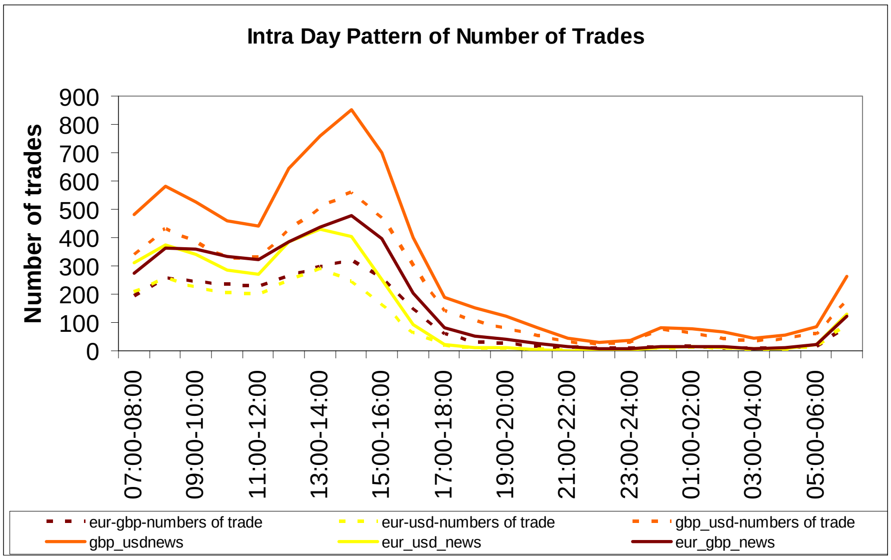

Figure 2: Intraday patterns of the trading volume for announcement and non-announcement days

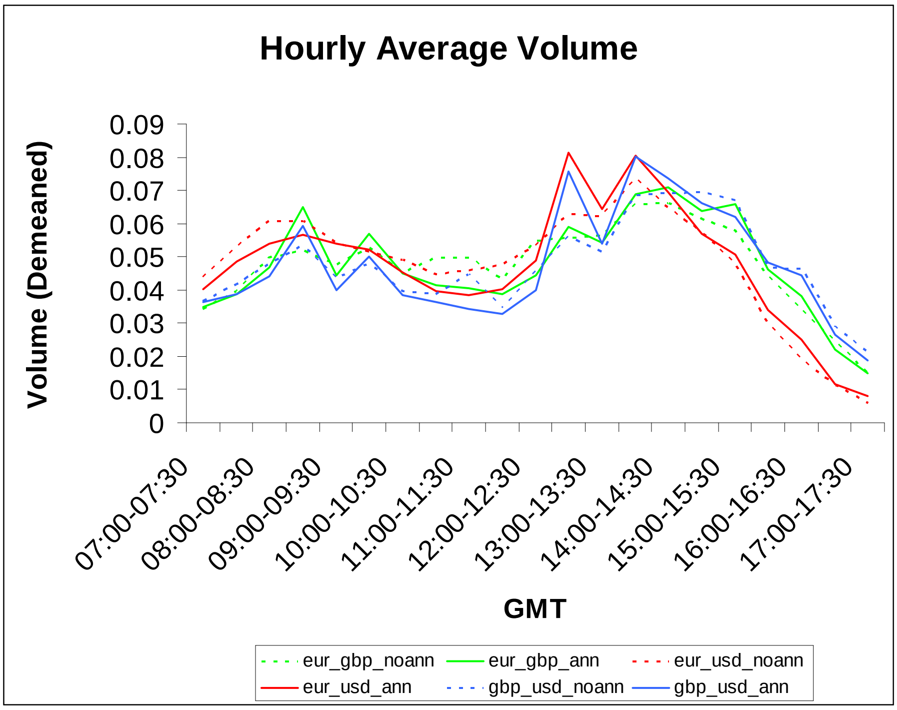

Figure 3: Sequences of exchange rate USD/EUR from 13:25-14:00 GMT on January 10, 2003, when the non-farm payroll employment number was announced at 13:30 GMT.

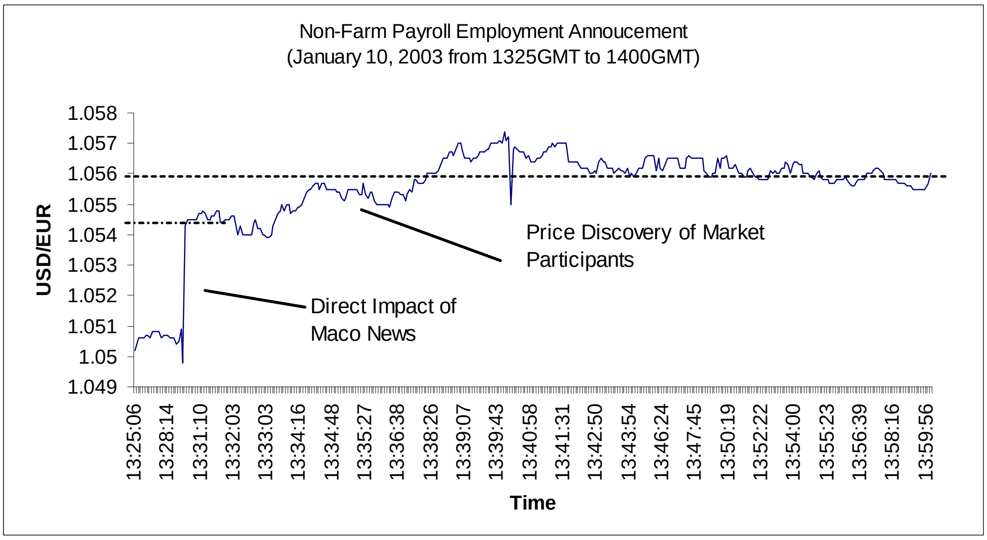

Figure 4: Hourly pattern of the bid-ask spread and the slope for GBP/EUR

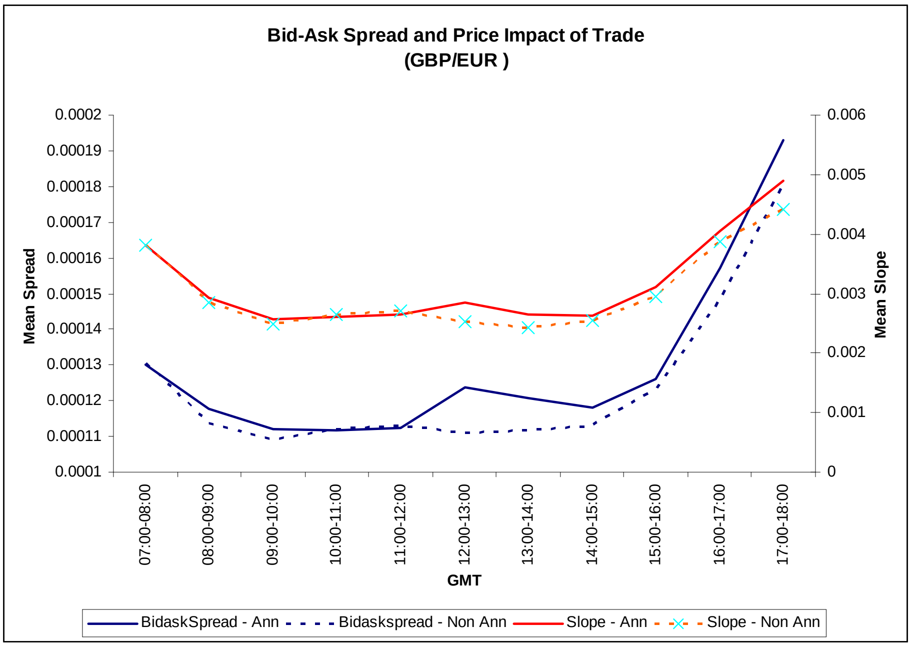

Figure 5: Hourly pattern of the bid-ask spread and the slope for USD/EUR

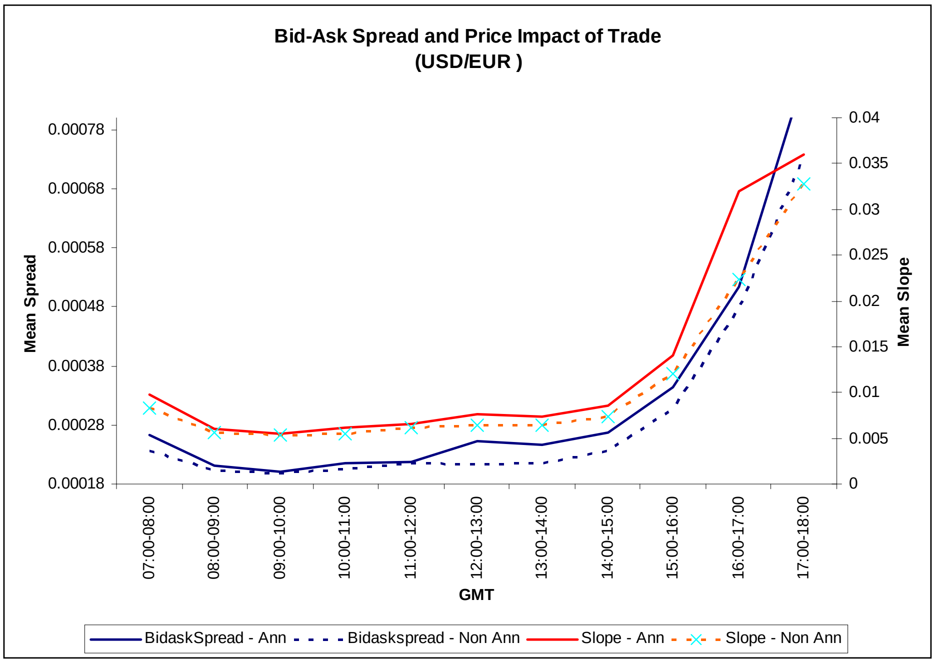

Figure 6: Hourly pattern of the bid-ask spread and the slope for USD/GBP